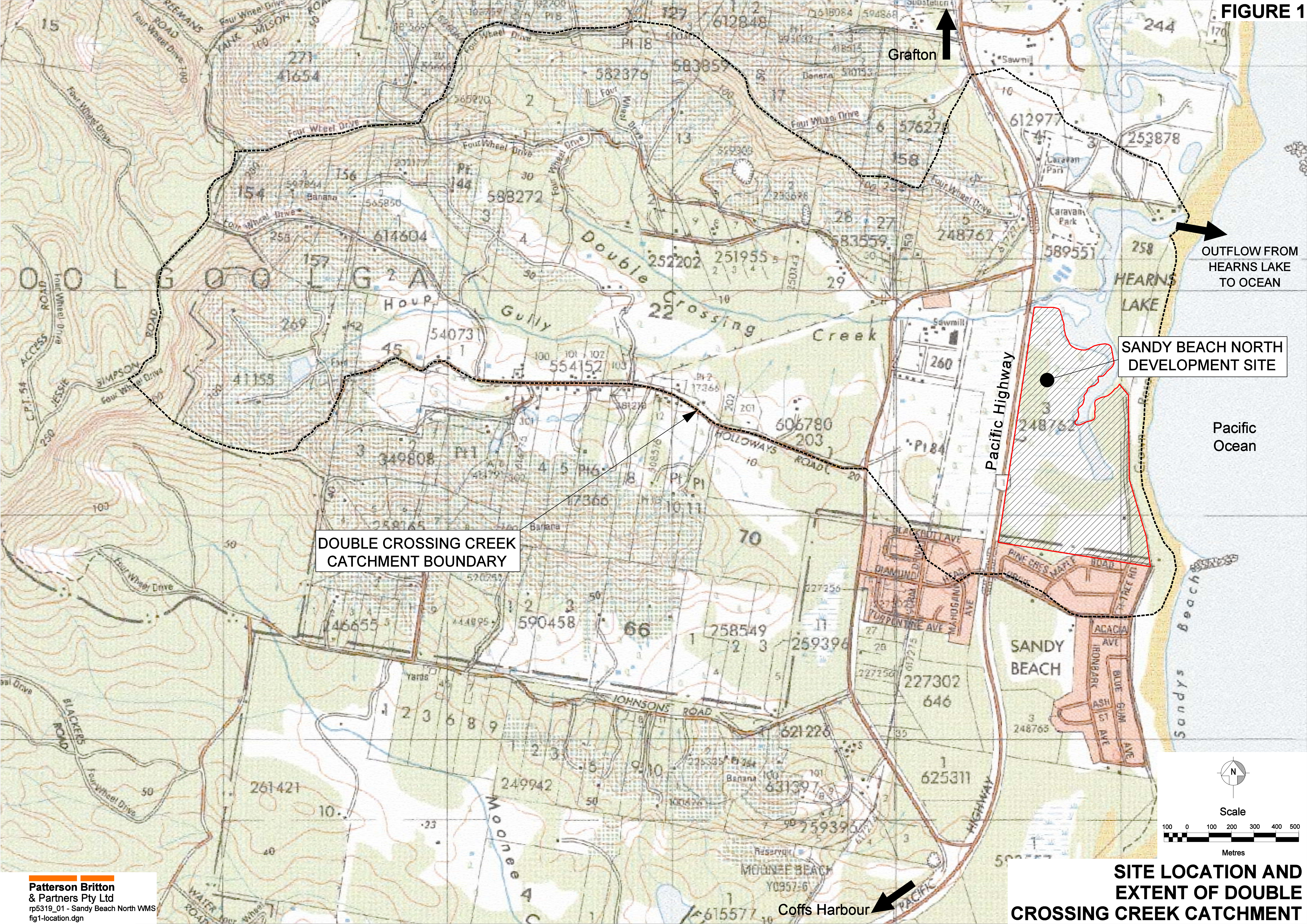

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fig1-location.dgn

SITE LOCATION AND EXTENT OF DOUBLE CROSSING CREEK CATCHMENT

FIGURE 2

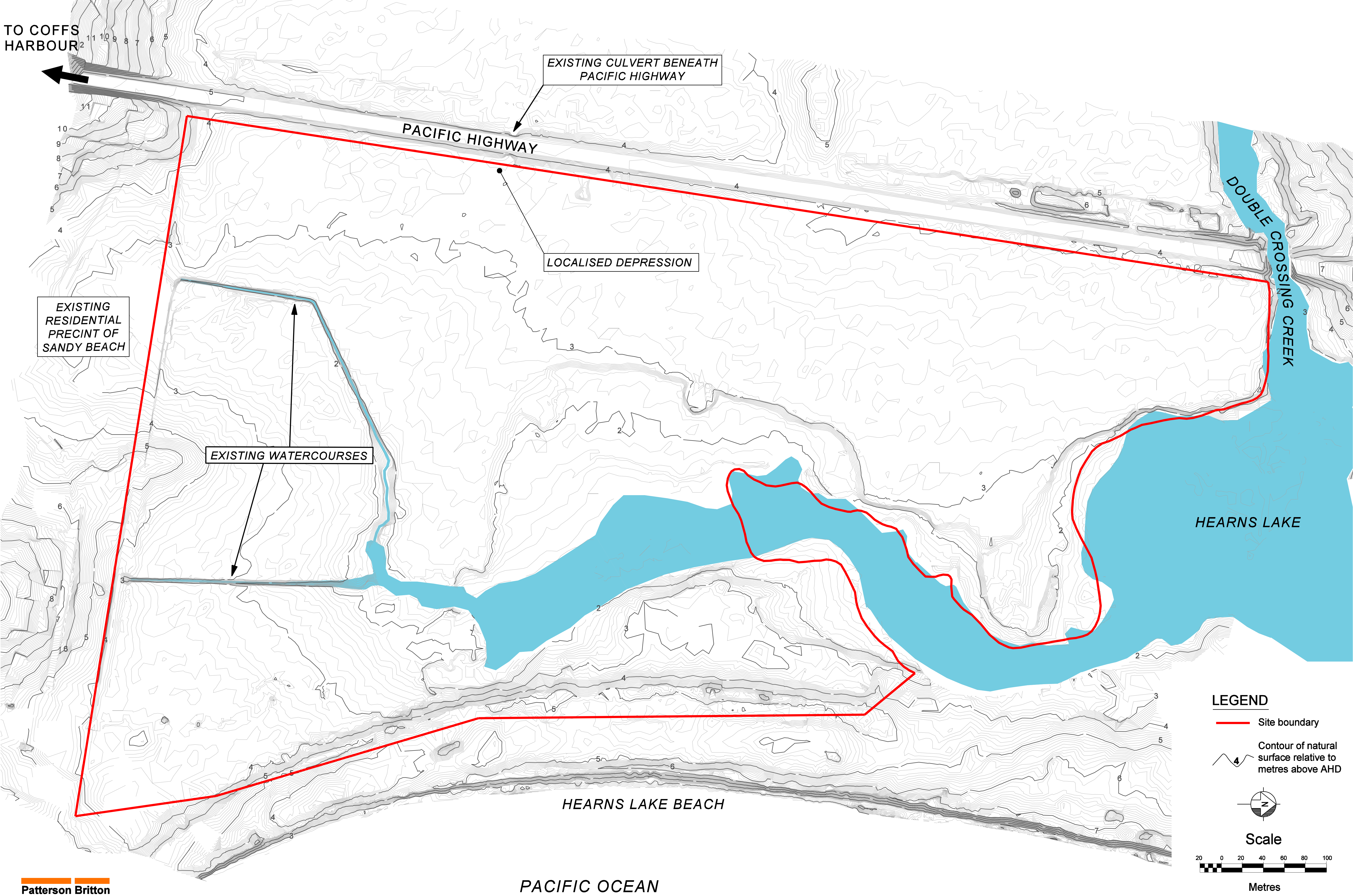

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fig2_topo.dgn

EXISTING SITE TOPOGRAPHY

FIGURE 3

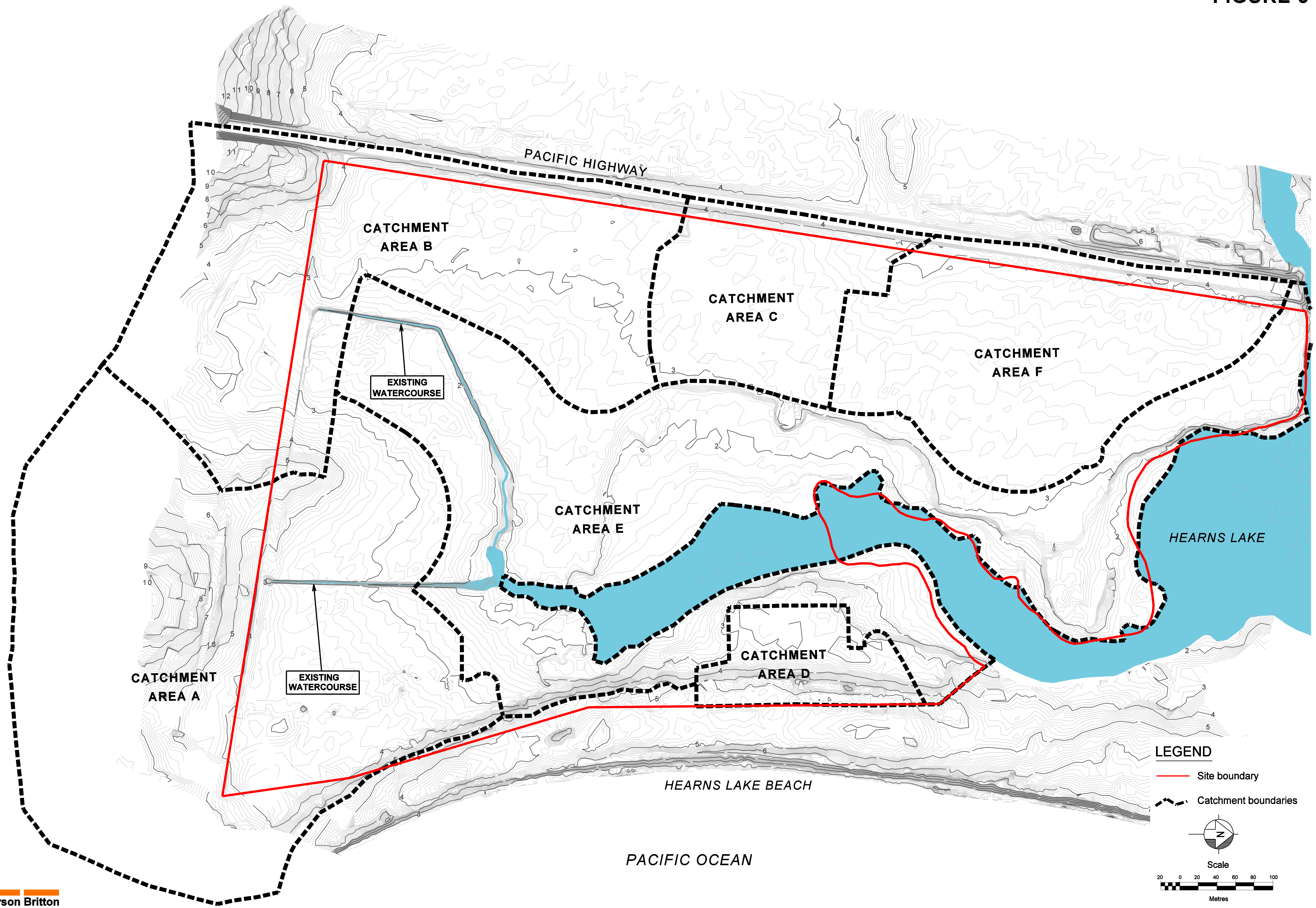

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fig3_cccatchments.dgn

ADOPTED DELINEATION OF CATCHMENT BOUNDARIES

FIGURE 4

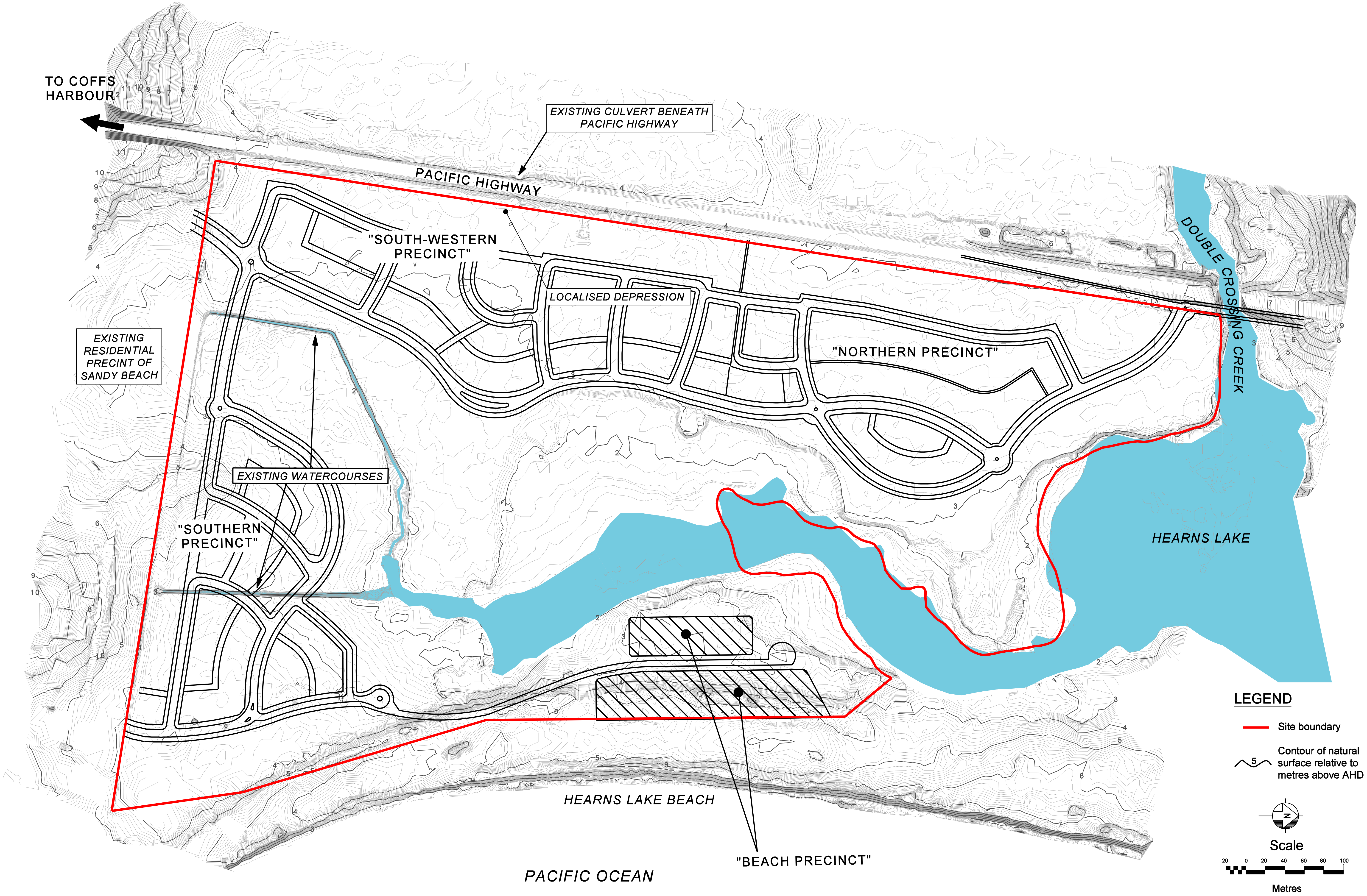

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fig4_cclayout.dgn

LAYOUT OF PROPOSED DEVELOPMENT

FIGURE 5

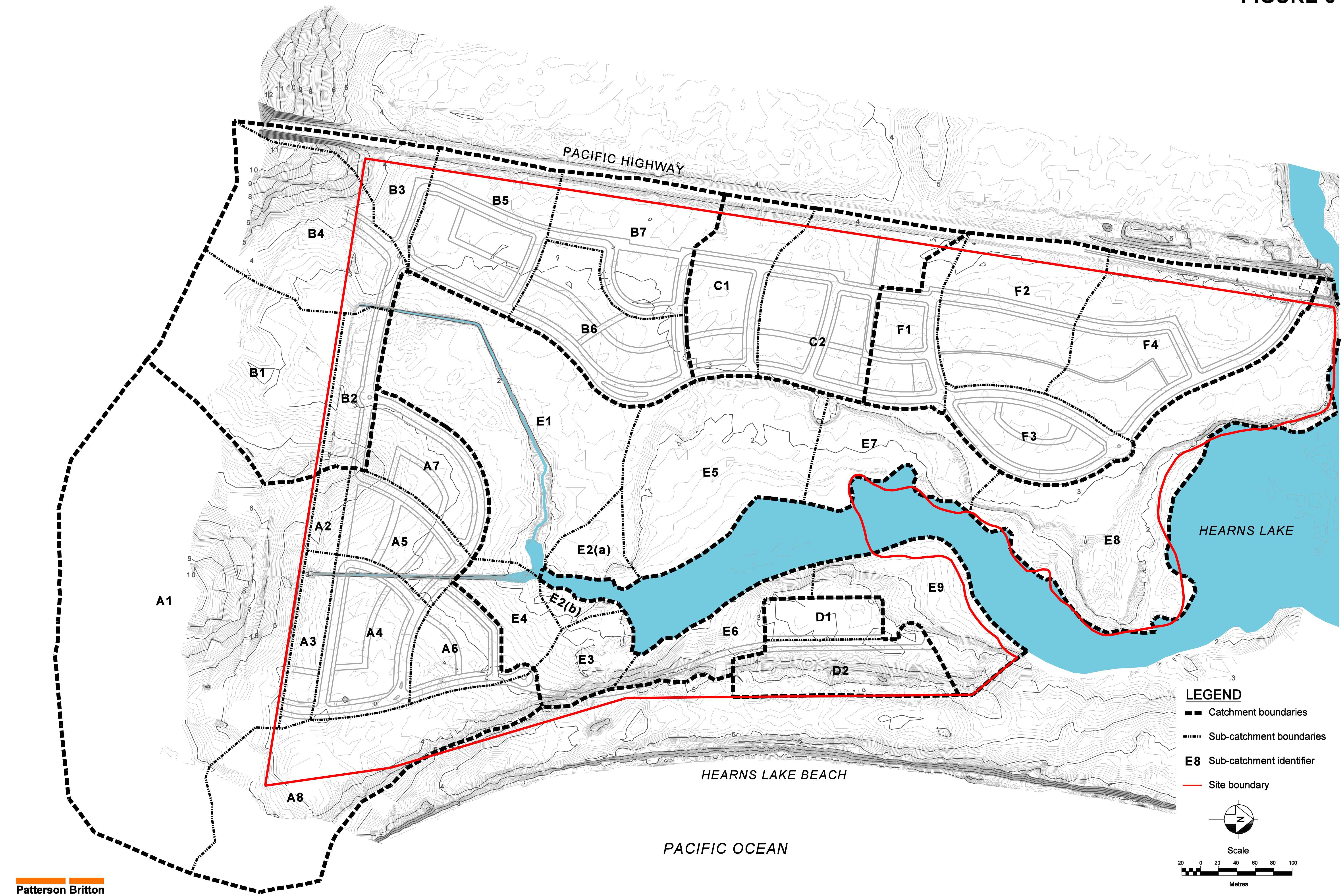

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fig5_ccsub-catchments_post.dgn

ADOPTED BREAKUP OF SITE CATCHMENTS FOR MUSIC MODELLING

FIGURE 6

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fig6_ccwms.dgn

CONCEPTUAL LAYOUT OF PROPOSED WATER MANAGEMENT STRUCTURES

SANDY SHORES DEVELOPMENT PTY LTD

SANDY BEACH NORTH RESIDENTIAL DEVELOPMENT

WATER MANAGEMENT STRATEGY

Issue No. 3
OCTOBER 2008

Patterson Britton
& Partners Pty Ltd
consulting engineers

SANDY SHORES DEVELOPMENT PTY LTD

SANDY BEACH NORTH RESIDENTIAL DEVELOPMENT

WATER MANAGEMENT STRATEGY

Issue No. 3
OCTOBER 2008

Document Amendment and Approval Record

Issue	Description of Amendment	Prepared by [date]	Verified by [date]	Approved by [date]
1	Draft Report - Issued for Client Review	MTG/SL/CRT (*6/05/05*)	CRT (*10/5/05*)	
2	Final Report	MTG/CRT (*26/10/05*)	CRT (*27/10/05*)	CRT (*31/10/05*)
3	Final Report – Revised Development Layout	SMD/CRT [*13/10/08*]		Chris Thomas [5/11/08] C.Thomas

Note: This document is preliminary unless it is approved by a principal of Patterson Britton & Partners.

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1 INTRODUCTION

Sandy Shores Development Pty Ltd (*Sandy Shores*) plans to develop a 49 hectare (*ha*) parcel of land near Sandy Beach on the North Coast of New South Wales. The site is located adjacent to the Pacific Highway about 20 kilometres north of Coffs Harbour. As shown in **Figure 1**, the site adjoins the southern shoreline of Hearns Lake and extends to the rear of the back beach dunes along Hearns Lake Beach.

Hearns Lake is an Intermittently Closed and Open Lake or Lagoon (*ICOLL*) which drains to the ocean at the northern end of Hearns Lake Beach. The lake has a surface area of about 15 hectares and is fed by catchment runoff that is discharged to the lake via Double Crossing Creek (*refer* **Figure 1**). The lake is usually closed to the ocean but opens following significant rainfall in the catchment.

Sandy Shores plans to develop the land and create up to 280 residential lots within an integrated landscape comprising a balanced mix of open space, leafy streetscapes and gardens, and set within a restored coastal landscape.

The proposed development will involve the construction of buildings and the formation of paved surfaces such as roads, footpaths and driveways. These components of the development will result in an increase in the proportion of the site that is covered by impervious surfaces. Accordingly, there will be an associated increase in the proportion of the rain that falls on the site that will not infiltrate the land surface. This rainfall excess will accumulate as runoff, and will be concentrated along existing or artificially created watercourses.

The proposed development also has the potential to alter the quality of runoff that will enter Hearns Lake. Pollutant loads from the site are likely to be increased by the accumulation of sediments and other materials from human activity on impervious surfaces throughout the development. During rainfall events, these contaminants can become entrained within runoff and can subsequently be transported downstream toward the receiving waters (*in this case, the lake*).

Sandy Shores recognises the inherent aesthetic and ecological value of Hearns Lake. The lake is considered to provide an excellent vista for the style of development that is proposed. Furthermore, the ecological and environmental value of the lake is considered to be appealing to the type of resident that the company would like to attract to the development. Therefore, in the interests of retaining this vista and ensuring that the proposed development provides an environmentally attractive setting, the company would like to ensure that the development incorporates best practice in the control and treatment of runoff that may discharge from the developed site to the lake.

In recognition of these issues, Bluegrass Nominees, acting on behalf of Sandy Shores, engaged Patterson Britton & Partners (*now WorleyParsons*) to prepare a Water Management Strategy for the proposed development and to ‘work up’ concept designs for structures required to control runoff and treat it before discharge to Hearns Lake.

This report documents the findings of investigations undertaken to assess the potential pollutant loading from the developed site, and mechanisms that could be implemented to mitigate any adverse impacts on lake water quality. The report addresses the following:

§ local catchment runoff patterns within the development site and the nature of small-scale drainage behaviour for both major and minor storm events;

§ the existing quality of runoff that would discharge from the site and enter Hearns Lake;

§ the quality of runoff that would conceivably be discharged from the developed site;

§ the proposed means by which the existing water quality will be maintained or improved following site development.

§ to document a Water Management Strategy for the proposed development such that the relevant criteria for post-development conditions are satisfied.

The report effectively serves as the Water Management Strategy for the site and has been prepared as supporting documentation for the Environmental Assessment Report being prepared by Planning Workshop Australia.

2 EXISTING SITE HYDROLOGY

2.1 SITE DESCRIPTION

The development site is located on the eastern side of the Pacific Highway about 3 kilometres south of the North Coast town of Woolgoolga (*refer* **Figure 1**). It is situated immediately north of the village of Sandy Beach and covers all of the land between the Pacific Highway and Hearns Lake Beach. As shown in **Figure 2**, the southern shoreline of Hearns Lake effectively forms the northern boundary of the site.

Hearns Lake is an Intermittently Closed and Open Lake or Lagoon (*ICOLL*) which drains to the ocean at the northern end of Hearns Lake Beach. The lake has a surface area of about 15 hectares and is fed by catchment runoff that is discharged to the lake via Double Crossing Creek (*refer* **Figure 1**). Double Crossing Creek drains a 526 ha catchment that extends to the west of the Pacific Highway and discharges into Hearns Lake immediately downstream of the Pacific Highway bridge crossing (*refer* **Figure 1**).

The development site has a total area of 49 ha. It's current zoning varies and includes areas zoned Residential 2A (*low density*), Residential 2E (*Residential Tourist*), 7A Environmental Protection Habitat and Catchments, and 7B Environmental Protection / Scenic Buffer.

The existing vegetation across the site varies from open pasture to more densely vegetated areas that flank the creek and lake shorelines. There is also a corridor of dense vegetation that extends along the rear of the back beach dunal system that adjoins Hearns Lake Beach.

A detailed survey of the site was undertaken by Asquith & de Witt Pty Ltd using photogrammetry. Contours of natural surface were developed from the data and are shown at 0.1 metre intervals in **Figure 2**.

The western portion of the site is characterised by a sparsely vegetated coastal plain. The land in this area has a typical grade of less than 1% and generally slopes from the Pacific Highway toward Hearns Lake.

The southern area of the site is steeper and grades in a northerly direction from a maximum elevation of 5.5 mAHD at the southern site boundary to the southern shoreline of the lake. This southern section of the site is drained by two existing watercourses that appear to be man-made earth lined channels (*refer* **Figure 2**). These channels carry runoff from the northern section of the existing residential precinct of Sandy Beach. The banks of both channels are densely vegetated, particularly in the vicinity of their point of discharge to Hearns Lake. The adjacent floodplain has scattered vegetation similar to that observed across the western portion of the site.

As shown in **Figure 2**, the eastern site boundary follows the alignment of the crest of the back beach dune of Hearns Lake Beach. This dunal ridge rises to a crest elevation of between 5 and 6 mAHD. The eastern section of the site between the eastern site boundary and the lake shoreline is typically covered by relatively dense vegetation, particularly along the dunal ridge.

This area of the site has typical grades of between 2% and 3% and directs runoff from the dunal ridge toward the shoreline of Hearns Lake.

A localised depression exists along the western boundary of the site at the location identified in **Figure 2**. It appears that this coincides with a low point in the Pacific Highway and is fed by runoff from both the highway and areas west of the highway. This runoff appears to be discharged to this depression via a culvert that extends across the highway at this location (*refer* **Figure 2**).

2.2 ASSESSMENT OF EXISTING SITE HYDROLOGY

In order to identify the nature and extent of water management systems that might be required for the developed site, it is necessary to firstly understand the existing site hydrology.

Accordingly, the catchment "draining through the site" was identified and subdivided according to the manner in which runoff would be transported to the shoreline of Hearns Lake.

The extent of the overall catchment that "drains through the site" is shown in **Figure 3**. This catchment extends to the south of the southern site boundary and into the existing residential precinct of Sandy Beach. The southern limit of this catchment was determined using contours available from 1:25000 series topographic mapping of the area.

The overall catchment that drains through the site was subdivided into six separate catchments as shown in **Figure 3**. The catchment subdivision was based on consideration of primary drainage flow paths and the projected extent of the development.

Catchments A and B extend beyond the southern site boundary and are effectively drained by the two watercourses identified in **Figure 3**. The downstream boundaries of these catchments were delineated based on the projected downstream limit of development and consideration of the potential location for runoff treatment structures. The downstream boundaries of Catchments C, D and F were also determined based on the projected downstream limit of development.

The area of the site which is not proposed to be developed is collectively referred to as Catchment E, and comprises those areas immediately adjacent to Hearns Lake.

2.2.1 Maximum Rate of Runoff for Existing Conditions

Analyses were undertaken using standard procedures outlined in *'Australian Rainfall and Runoff – A Guide to Flood Estimation'* (*ARR 1998*) to determine the peak rate of runoff from each of the catchments for a range of design storm events.

The design storm rainfall data was generated by applying the principles of rainfall intensity estimation described in Chapter 2 of ARR 1998. Intensity-frequency-duration data for Sandy Beach were developed using these procedures and are enclosed in **Appendix A**.

Runoff coefficients were derived from probabilistic procedures outlined in ARR 1998 for eastern New South Wales. Runoff coefficients of 1.00 and 0.79 were determined for impervious and pervious ground covers, respectively.

The adopted catchment parameters for existing conditions are listed in **Table 1**. 100 year rainfall intensities were based on storm durations corresponding to the time of concentration established for each catchment using procedures outlined for the Probabilistic Rational Method.

Pervious and impervious proportions of each catchment were determined from site inspection and aerial photograph analysis. Existing 'greenfield' areas of the site were considered to be 100% pervious and existing residential areas within Sandy Beach were assumed to comprise land surfaces that are on average, 25% pervious.

Table 1 PRE-DEVELOPMENT CATCHMENT PARAMETERS

CATCHMENT	AREA (*ha*)			TIME OF CONCENTRATION (*minutes*)	100 YEAR ARI RAINFALL INTENSITY (*mm/hr*)
	Impervious	Pervious	TOTAL		
A	7.96	12.24	20.20	24.8	158
B	5.75	7.72	13.47	21.3	168
C	0	4.21	4.21	13.7	204
D	0	1.95	1.95	10.2	228
F	0	8.36	8.36	17.8	182

Peak 100 year recurrence storm discharges were then determined for each catchment using the data listed in **Table 1** and by applying the Probabilistic Rational Method. **Table 2** lists the predicted peak 100 year recurrence storm discharge for each catchment under existing conditions. A detailed summary of the Rational Method calculations is included within **Appendix B** (*refer* **Table B1**).

Table 2 ESTIMATED PEAK 100 YEAR RECURRENCE STORM DISCHARGES FOR EXISTING CATCHMENT CONDITIONS

CATCHMENT	PEAK DISCHARGE (m^3/s)
A	7.7
B	5.5
C	1.9
D	1.0
F	3.3

2.2.2 Total Volume of Runoff for Existing Conditions

The hydrology of the site is also defined by the manner in which runoff would be distributed through the site and into Hearns Lake. This is significant in terms of maintaining the local water table and has implications for pollutant management. Therefore, a water balance model was developed to assist in understanding the hydrology of the site for wet, dry and average dry weather conditions.

The water balance model was developed using the Model for Urban Stormwater Improvement Conceptualisation (*also known as MUSIC*). MUSIC has been developed by the CRC for Catchment Hydrology and can be used to simulate both the quality of runoff from a catchment and the effects of a wide range of treatment facilities on runoff water quality. The software also incorporates a water balance capability, and thereby provides a tool suitable for the overall assessment of runoff for average conditions.

For the pre-development scenario, the water balance model was developed based on the extent of imperviousness listed in **Table 1**. Default soil parameters specified in the User Manual (*2003*) were adopted along with meteorological data for the Coffs Harbour area. Recorded rainfall data from Rainfall Station No 59040 (*referred to as Coffs Harbour MO*) and monthly average potential evapo-transpiration rates for Coffs Harbour, were used to define the meteorological conditions over the duration of the analysis.

Water balance simulations were undertaken over a period of three (*3*) years between 1999 and 2001 using a 6 minute time step. This period was selected based on an analysis of the rainfall record which showed that it was representative of a wide range of rainfall conditions.

For example, the average annual rainfall for Coffs Harbour as reported by the Bureau of Meteorology is 1687 mm. In 2001, the total rainfall recorded at the gauge was approximately equivalent to this average value. In contrast, the annual rainfall recorded for 1999 was 2459 mm and for 2000 was 1288 mm. Hence, 1999 was considered to be representative of high rainfall year and 2000 to be representative of low rainfall conditions.

Accordingly, the water balance model was applied to determine the total volume of runoff from the undeveloped site to Hearns Lake over this three year simulation period.

The water balance model established that the total annual volume of runoff from the site in “average” conditions is 593 ML. The total annual volume of runoff from the site in typically “wet” conditions was determined to be 1010 ML, and the total annual volume under typical “dry” conditions is estimated to be 424 ML.

The water balance model established that the total volume of runoff from the site for the three year simulation period is 678 ML/year.

2.3 EXISTING POLLUTANT LOAD

As outlined above, MUSIC has primarily been developed to assess the quality of runoff from a catchment. Accordingly, the water balance model was extended to assess the quality of runoff from the site under "pre-development" conditions.

The site is currently used to graze cattle. Agricultural land uses involve the use fertilisers and the production of animal waste, which can result in nutrient enriched runoff. In order to simulate the transport of nutrients from this type of land use, the default properties of an 'agricultural' pollutant source node were adopted within the MUSIC model for each of the catchments that drain through the site.

Those sections of Catchments A and B (*refer* **Figure 3**) that extend into the urbanised area of Sandy Beach, drain stormwater runoff via two existing channels that cross the site from south to north, and ultimately discharge into the southern end of Hearns Lake. It was therefore necessary to include these areas as contributing to the overall pollutant load from the site in the pre-development modelling scenario.

These areas were modelled as 'urbanised' pollutant source nodes. These 'urbanised' pollutant source nodes were assumed to be 100% impervious in order to simulate the worst case scenario in terms of the quality of the runoff for the purposes of the model. Details of the adopted Structure of the MUSIC model are provided in **Appendix C** (*refer to* **Table C1**).

The MUSIC model was used to determine mean annual loads of sediment and nutrients received by Hearns Lake over an average year and over typical "wet" and "dry" years. The results of the analysis are listed in **Table 3**. As a comparison, the average annual pollutant load over the 3 years from 1999 to 2001 is also provided.

Table 3 EXISTING MEAN ANNUAL POLLUTANT LOADS

POLLUTANT	MEAN ANNUAL LOAD (*kg/yr*)			
	Average Year (*2001*)	Typical "Wet" Year (*1999*)	Typical "Dry" Year (*2000*)	Over 3 Years from 1999 to 2001
Total Suspended Solids	108×10^3	175×10^3	61×10^3	114×10^3
Total Phosphorus	252	420	146	278
Total Nitrogen	2190	3230	1140	2000

The pollutant loads in **Table 3** represent the estimated amount of nutrients and suspended solids that would enter Hearns Lake from the existing site, including the additional nutrients and suspended solids that would be entrained into runoff distributed through the site from the urban areas of Sandy Beach.

It is considered that as a minimum, these loads would need to be maintained under post-development conditions.

3 DESIGN CRITERIA

3.1 GENERIC DESIGN CRITERIA

Typically, the following generic design criteria apply to developments that involve substantial changes in land use:

- stormwater runoff from the developed site should be controlled so that the potential for erosion is minimised and so that pre-development discharges at the site boundaries are maintained; and,
- stormwater runoff from the developed site should be treated so that gross pollutants and suspended solids are trapped, and so that there is potential for chemical pollutants such as nutrients to be removed from the system to the extent that nutrient levels in the receiving waters are maintained at pre-development levels.

In some circumstances, more detailed design criteria are specified, including the specification of a percent reduction in the anticipated nutrient and turbidity load that could be exported from the developed site.

CHCC does not stipulate specific reduction criteria for pollutant export from a development site. As runoff from the developed site will eventually discharge to Hearns Lake, it is considered appropriate that measures be implemented on-site to ensure that the nutrient and turbidity levels in runoff from the site is maintained at acceptable levels.

Similarly, CHCC does not specify criteria defining the allowable peak discharge from a developed site. It is therefore considered appropriate to ensure that post-development discharges at the site boundaries are maintained at pre-development levels.

To address these criteria, an assessment of both stormwater quantity and stormwater quality was undertaken for the developed site. This assessment was based on methodologies considered suitable for the conceptual design of a stormwater management system for the development. In this regard, it is recognised that more rigorous analysis may be required at the detail design stage. However, it is considered that if a more rigorous analysis is required it would serve to optimise the mechanisms proposed to attenuate / control runoff and reduce pollutant export loads.

3.2 ADOPTED STORMWATER MANAGEMENT DESIGN CRITERIA

3.2.1 Stormwater Quantity

It was determined that runoff from the site should be managed by developing a stormwater system that addressed the principles of the major / minor concept outlined in *'Australian Rainfall & Runoff – A Guide to Flood Estimation'* (*1998*).

Accordingly, the design for this system is to employ current 'best practice', ensuring the sustainable management of stormwater runoff by incorporating provisions for the harvesting of rainfall for water re-use/recycling and the treatment of residual runoff prior to any discharge to Hearns Lake.

The minor system typically comprises the gutter and pipe network which is designed to carry runoff during minor storms. It discharges runoff to the receiving waters, or to the major system.

The major system typically comprises overland flowpaths that have the capacity to carry runoff in excess of that able to be carried by the minor system. It also incorporates flood storages and channel works. The major system effectively forms the trunk drainage system and discharges runoff in major storms to the receiving waters.

It is proposed that the minor system, comprising pipes and pits, be designed with sufficient capacity to safely carry the 5 year recurrence flow. The major system is to carry flows up to the 100 year recurrence event, and have the capacity to safely distribute runoff during events rarer than the 100 year recurrence storm.

Therefore, peak 100 year recurrence flows will be used to conceptually size storage structures proposed for the site and bio-retention systems such as swales, that might be used within the developed site to ‘polish’ runoff before discharge to Hearns Lake.

3.2.2 Stormwater Quality Assessment

A major influence on the design for the proposed development is the need to take advantage of the inherent aesthetic and ecological value of Hearns Lake. The lake is considered to provide an excellent vista for the style of development that is proposed. Furthermore, the ecological and environmental value of the lake is considered to be appealing to the type of resident to which the development will be targeted.

Therefore, in the interests of retaining this vista and ensuring that the development provides an environmentally attractive setting, the stormwater drainage system is to be designed to ensure that post development nutrient and suspended sediment loads are less than pre-development estimates.

The average annual pollutant load exported in runoff from the existing site has been determined using the MUSIC model developed and discussed in **Section 2.3**. This software has been formulated using the most recent research and field data for runoff pollutant export. The results of the modelling quantify the mass of total suspended solids, total phosphorous and total nitrogen that is typically delivered to the lake with runoff, under existing conditions.

The potential quality of runoff from the site will be assessed under post-development conditions. The results of this assessment will be used to size the treatment measures required to ensure runoff to Hearns Lake carries reduced nutrient and sediment loads.

Accordingly, it will be necessary to design any flood storages recommended as part of the water quantity assessment, so that they also provide water quality benefits. Therefore, rather than providing detention basins along the alignment of watercourses, a series of water quality control ponds (*WQCPs*), will be designed to incorporate a flood storage component. WQCPs can be designed to achieve both nutrient reduction and flood storage, as well as serving as attractive water features within an urban development.

These structures will be sized for water quality management by simulating the pollutant loads in runoff under post development conditions using the MUSIC model established to define existing conditions. The model will be adjusted to reflect the urbanisation proposed in the development layout. This will provide a measure of post-development pollutant loadings with no treatment measures in place.

The MUSIC model will then be modified to incorporate potential elements of the Water Management Strategy, such as bio-retention swales and water quality control ponds. Simulations will be undertaken for a period of several years to determine the extent to which the measures proposed as part of the Water Management Strategy would reduce post development pollutant loadings under dry, wet and average dry weather conditions.

Using the results of this analysis, the Water Management Strategy will be modified as required, to achieve the necessary reductions in post-development runoff pollutant loading.

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4 POTENTIAL IMPACT OF PROPOSED DEVELOPMENT ON SITE HYDROLOGY

4.1 DESCRIPTION OF PROPOSED DEVELOPMENT

The layout of the proposed residential development is shown in **Figure 4**. The development will comprise up to 280 residential lots within an integrated landscape comprising a balanced mix of open space and leafy streetscapes and gardens, within a coastal setting. Lots have been distributed across the site area and are serviced by an internal road network. Access to the development is provided from the Pacific Highway and two (*2*) existing streets within the existing residential precinct of Sandy Beach.

As shown in **Figure 4**, the lots within the development are concentrated along the western and southern site boundaries. A small number of lots is also proposed within the "Beach Precinct" which is located along the eastern site boundary and at the rear of Hearns Lake Beach.

All lots and roadways are set back at least 70 metres from the shoreline of Hearns Lake and Double Crossing Creek. Provision has also been made to retain flowpaths along the two existing watercourses that run in a northerly direction from the southern site boundary and which drain runoff from the existing Sandy Beach residential area to Hearns Lake.

4.2 ASSESSMENT OF POTENTIAL IMPACTS OF THE PROPOSED DEVELOPMENT ON HYDROLOGIC REGIME

4.2.1 Potential to Increase Peak Rates of Runoff

A hydrologic analysis was undertaken to assess the potential impact of the development on the rate of runoff from the site. This involved subdividing the primary site catchments shown in **Figure 3**, into smaller sub catchments according to the likely distribution of runoff following site development. Sub catchment break-up also considered the proposed land use; for example, whether the land is to be developed for buildings and roadways or retained as open space. The adopted break-up is shown in **Figure 5**.

The Rational Method was then applied to quantify peak discharges from each sub catchment based on the available rainfall intensity data and the projected increase in imperviousness associated with the proposed development.

Runoff coefficients and rainfall intensities outlined in **Section 2.2** for the pre-development scenario were applied for the analysis of the post-development scenario. Impervious and pervious areas were determined for each of the sub catchments based on the subdivision layout provided in the Concept Plan and shown in **Figure 4**. Sub catchments in which roads and buildings are proposed were assumed to be 75% impervious. Areas of remaining open space were assumed to be 100% pervious.

A summary of catchment parameters adopted for the analysis is provided in **Table 4**.

Table 4 PRE-DEVELOPMENT AND POST-DEVELOPMENT CATCHMENT PARAMETERS

CATCHMENT	AREA (*ha*)				
	PRE-DEVELOPMENT		POST-DEVELOPMENT		TOTAL
	Impervious	Pervious	Impervious	Pervious	
A	7.96	12.24	14.93	5.27	20.20
B	5.75	7.72	9.87	3.60	13.47
C	0	4.21	3.16	1.05	4.21
D	0	1.95	1.46	0.49	1.95
F	0	8.36	5.94	2.42	8.36

The Rational Method was employed to determine peak post development discharges from each catchment in the design 100 year recurrence storm, assuming no on-site detention or attenuation of runoff. The results of the analysis are presented in **Table 5**. This includes a comparison of peak discharges determined for each of the primary site catchments, under both pre and post-development conditions.

Table 5 PRE-DEVELOPMENT AND POST-DEVELOPMENT CATCHMENT PEAK DISCHARGES

CATCHMENT	PEAK DISCHARGE (*m³/s*)		INCREASE IN PEAK DISCHARGE DUE TO DEVELOPMENT (%)
	Pre-development	Post-development without Attenuation	
A	7.74	8.38	8
B	5.54	5.94	7
C	1.88	2.26	20
D	0.98	1.17	19
F	3.34	3.97	19

The results of the analysis indicate that the development will result in increases of up to 20% in the peak rate of post development runoff. Accordingly, it is considered appropriate to incorporate on-site storages within the development site in an endeavour to reduce peak post development discharges to pre-development levels. This will have the added benefit of increasing the residence time of runoff in smaller events, thereby increasing the potential for runoff in average dry weather flow conditions to be polished before discharge to Hearns Lake.

4.2.2 Potential for Increases in Total Volume of Runoff

The impervious surfaces associated with the proposed development also have the potential to increase the total volume of runoff that will enter Hearns Lake. The development will result in less infiltration and less interception by vegetation. This will increase the total volume of runoff exported from the site.

The water balance model that was developed for existing conditions using the MUSIC software was modified to reflect the change in imperviousness associated with the proposed development of the site. The modified water balance model was then applied to determine the total volume of runoff from the developed site to Hearns Lake over the same three year simulation period outlined in **Section 2.2.2**.

The analysis confirmed that the proposed development would result in a 31% increase in the total annual volume of runoff discharged to Hearns Lake from the site and existing urban areas of Sandy Beach. The water balance model established that the total volume of runoff from the developed site for the three year simulation period would be on average, 887 ML/year. In contrast, under existing conditions, the total annual volume was estimated to be 678 ML.

However, provided this runoff is suitably treated, this is considered to be a benefit as it will improve the potential for “re-charge” of Hearns Lake under average dry weather conditions. Hence, it will reduce the frequency of lower than average water levels in the lake.

4.2.3 Potential for Increases in Pollutant Loading to Hearns Lake

The MUSIC model was also used to simulate runoff water quality for post-development conditions without the inclusion of any treatment mechanisms. This involved modifying the model to reflect the changed land use. Existing ‘agricultural’ pollutant source nodes were converted to ‘urban’ pollutant source nodes and percentage impervious areas were modified according to the data presented in **Table 4** and **Appendix C** (*refer* **Table C2**).

In order to represent the worst case scenario for the overall pollutant load being discharged from the site, developed areas were assumed to be 100% impervious. Open space areas were considered to be fully pervious as per existing conditions (*e.g., those areas within Catchment E in* **Figure 5**).

The mean annual pollutant loads predicted to be generated under post-development conditions (*without treatment*) are listed in **Table 6**.

The model results indicate that the urbanisation of the site without inclusion of runoff water quality treatment mechanisms, would increase the pollutant loads received by Hearns Lake. In particular, it is predicted that on average, there could be an 81% increase in Total Suspended Solids (TSS) discharged to the lake annually (*for dry weather conditions as shown in* **Table 6**). For an average year, and assuming no treatment systems are implemented, the urbanisation associated with the proposed development would result in a 50% increase in TSS and a 40% increase in nutrient concentrations within runoff distributed annually to Hearns Lake.

Table 6 POST-DEVELOPMENT MEAN ANNUAL POLLUTANT LOADS

POLLUTANT	"WET" YEAR (*1999*)		"DRY" YEAR (*2000*)		AVERAGE YEAR (*2001*)	
	Load (*kg/yr*)	% Increase	Load (*kg/yr*)	% Increase	Load (*kg/yr*)	% Increase
Total Suspended Solids	220×10^3	26	111×10^3	81	162×10^3	50
Total Phosphorus	491	17	235	61	347	38
Total Nitrogen	3810	18	1660	46	2290	5

Increases of this magnitude are not consistent with the design criteria outlined in **Section 3**, and indicate that treatment measures are required to attenuate runoff and allow the 'settling out' of entrained sediment.

5 STRATEGY FOR SITE WATER MANAGEMENT

5.1 PROPOSED CONCEPT FOR STORMWATER MANAGEMENT

The results of the analyses discussed in **Sections 3** and **4** indicate that there is a need to attenuate runoff from the site during major storm events and to provide treatment systems to 'polish' runoff in average dry weather flow conditions prior to discharge to Hearns Lake.

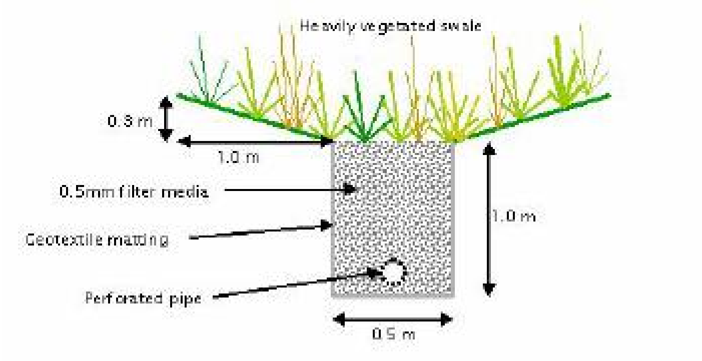
Accordingly, the increased peak discharges and increased pollutant loadings from the development site will by mitigated by the construction of a combination of water quality control ponds that will intercept site runoff and treat it prior to discharge to the lake. Runoff from areas upstream of the water quality control ponds will be collected within a series of bio-retention swales that will direct flows toward the WQCPs. The combined system of bio-retention swales and WQCPs will serve to 'polish' runoff before discharge to Hearns Lake. The WQCPs will also be designed to incorporate a flood storage capacity.

5.1.1 Bio-retention Systems

General Description of Bio-Retention System

Bio-retention systems provide both stormwater treatment and conveyance functions. Typically a bio-retention system is installed in the base of a swale that is designed to convey runoff following minor storm events. The swale component of the system provides pre-treatment of stormwater to remove coarse particulates and associated contaminants, while the bio-retention system removes finer particulates and associated contaminants.

A cross-section of a typical bio-retention system is shown below. Typically these systems should be installed along swales with slopes of between 1 and 4%. In steeper areas, check dams or drop structures are required to reduce flow velocities and foster increased residence times for runoff.



CROSS-SECTION OF A TYPICAL BIO-RETENTION SYSTEM

Treatment Processes

The capacity of bio-retention systems to treat stormwater is documented in a report prepared by the Institution of Engineers' National Committee on Water Engineering which is titled, *'Australian Runoff Quality'* (*2006*). The primary treatment processes are described as follows:

- Runoff is filtered through a fine media layer as it percolates downwards. It is then collected via a perforated pipe and discharged either directly or via conventional stormwater pipes. The hydraulic conductivity of the filter media is significantly higher than the surrounding soils such that the flow path of infiltrated stormwater is well defined and minimal exfiltration from the trench to the surrounding soils occurs.

  Treatment can be enhanced with bio-retention systems by creating ponding over the filter media. This increases the amount of time that runoff can infiltrate and also increases the volume of runoff that is treated.

- Vegetation is a crucial component of bio-retention systems.

  Above-ground vegetation acts to retard and distribute flows and to prevent scouring of the swale. Under these circumstances the vegetation is also helpful for trapping suspended sediments.

  Below ground, the vegetation in bio-retention systems has a number of functions. Firstly, filtered waters must pass through the root zone of the plants which is a highly biologically active area. As water passes through the root zone materials carried by the water can be either physically trapped by the high surface area of the media or can be actively taken up by plant roots and associated bacteria and fungi. Secondly between flow events plant growth plays an important role in maintaining the structure and hydraulic conductivity of the media.

Water Quality Treatment Performance

There are relatively few studies indicating the performance of bio-retention systems applied for the treatment of stormwater runoff. Based on studies undertaken by Davis et al (*2001*) and Lloyd et al (*2002*), the following approximated reductions in total phosphorous, total nitrogen and suspended solids can be achieved:

- Total Suspended Solids ==> 73-90% reduction;
- Total Phosphorous ==> 77-86% reduction; and,
- Total Nitrogen ==> 70-75% reduction.

Design Characteristics

The design of bio-retention systems are governed by a combination of site constraints and design parameters. The design parameters that govern the physical shape of bio-retention systems have been sourced from the National Committee on Water Engineering document titled, *'Australian Runoff Quality'*. The relevant design parameters are:

- Longitudinal slope of bio-retention swales should be a maximum of 4%
- Side slopes of bio-retention swales should be a maximum of 1(V):3(H)

- Swales should be designed to safely carry a minimum flow corresponding to the 2 year recurrence storm discharge and such that inundation of adjacent lots does not occur in events of this magnitude
- Subsoil drainage capacity must exceed the saturated infiltration capacity of the filter media (*both inlet and flow capacity*)
- The swales should be designed to cater for scour potential arising from flows generated in storms up to and including the 100 year recurrence event.

The site constraints that restrict the application of the proposed bio-retention systems include the maximum available area and slope resulting from the natural topography.

5.1.2 Water Quality Control Ponds

A ‘constructed wetland’ is a purpose built structure that performs the desired physical, chemical and biological processes and functions of natural wetlands to achieve improved water quality.

As water flows through a ‘constructed wetland’, it slows down and many of the suspended solids become trapped by the aquatic vegetation and settle out. Other pollutants are transformed to less soluble forms which are taken up by plants or may become inactive. Wetland plants also provide the ideal conditions for many microorganisms, which through a series of complex processes, transform and remove pollutants from the water (*DLWC, 1998*).

A constructed wetland may be constructed for a number of reasons such as water quality control, hydraulic modification (*flood storage*), aesthetics, habitat and rehabilitation. A water quality control pond (*WQCP*) is a constructed wetland built for the purposes of managing the quality of urban stormwater runoff.

5.2 PROPOSED WATER MANAGEMENT STRATEGY

The proposed Water Management Strategy for the development is broadly presented in **Figure 6**. It incorporates nearly 4 kilometres of bio-retention swales and three WQCPs that are strategically located to intercept runoff before discharge to Hearns Lake.

The siting for the WQCPs has also considered the alignment of existing watercourses and the topography of individual site catchments, so that the lengths of bund walls will be kept to a minimum. Where possible, the ponds have been located to maximise their visual and aesthetic value.

WQCPs 1 and 2 are proposed to be ‘on-line’ structures that will be installed along the alignment of the two existing watercourses that drain the southern section of the site. WQCP #3 is located in the North-western Precinct and will service the northern section of the development adjacent to the Pacific Highway.

The Water Management Strategy for the development site comprises the following components:

- § The installation of rainwater tanks within each dwelling for water re-use.
- § The provision of overland flow paths via bio-retention swales capable of safely carrying site runoff up to the peak discharge predicted in the design 100 year recurrence storm. The subdivision has been designed to include laneways that will allow rear access to individual lots, thereby ensuring the proposed bio-retention swales provide continuous linkages for runoff that will not be interrupted by driveway accesses.
- § Design of the WQCPs to take full advantage of available space and so that the potential to treat runoff and reduce pollutant loadings in average dry weather conditions is maximised.

5.3 EFFECTIVENESS OF PROPOSED WATER MANAGEMENT SYSTEM

5.3.1 Provision for Water Quantity Control

Management of Peak Flows

The proposed WQCPs will all have a permanent pool above which a transient extended detention storage volume is provided. The extended detention component of the ponds has been sized to ensure that the peak post-development 100 year recurrence storm discharge from all catchments is attenuated to match the peak pre-development discharge.

The WQCPs have been conceptually designed to ensure peak 100 year recurrence discharges match the corresponding peak pre-development discharges listed in **Table 2**. For example, WQCP #1 has been designed to ensure a peak post development 100 year recurrence discharge of 7.7 m^3/s.

Post-development inflow hydrographs were determined using the Rational Method and considering various storm durations. The volume of storage required was measured as the difference between the inflow and outflow hydrographs. The rainfall duration causing the largest storage volume required was considered to be the critical storm duration. The minimum extended detention volume required and the corresponding critical storm duration for each WQCP are listed in **Table 7**. Spreadsheets used to calculate the pond volumes are enclosed within **Appendix D**.

Table 7 MINIMUM EXTENDED DETENTION VOLUMES REQUIRED FOR WATER QUALITY CONTROL PONDS

WQCP	FEEDING CATCHMENT	EXTENDED DETENTION VOLUME (m^3)	CRITICAL STORM DURATION (*minutes*)
1	A	967	25
2	B	648	25
3	F	862	25

The estimation pond storage volume is considered to be conservative as no provision has been made to account for the attenuation offered by the proposed bio-retention swales. Bio-retention swales distributed throughout the proposed development site will provide additional runoff storage volumes and will thus reduce peak flows in a similar manner to the WQCPs. For example, if the full capacity of all swales was utilized, the potential storage volume would equate to over 4000 m^3.

The attenuation volume offered by the proposed bio-retention swales within Catchments C and D provide significantly more volume than the combined storage requirement for those catchments.

Management of Overland Flow

As discussed in **Section 3.2.1**, the conveyance of stormwater from the site will be provided by the minor and major systems. In this case the minor system comprises the gutter and pipe network which collects and conveys low flows to the major system. Formation of the minor system will be considered at the detail design stage. At this stage it has been assumed that low flows are appropriately conveyed to the corresponding components of the major system. During high flows the capacity of the minor system is exceeded and overland flow paths will direct runoff to the major system. It has been assumed, in such cases, that overland flow paths can be appropriately provided.

The major system comprises the bio-retention swale network and adjoining WQCP's and conveys low and high flows to the receiving waters. As outlined previously, the conceptual layout of the major system is presented in **Figure 6**.

Components within the major system have been designed to cater for the 100 year recurrence design storm. Details pertaining to the capacities of the WQCPs have been outlined above. The bio-retention swales have been designed using the MUSIC model to contain and convey runoff generated under post-development conditions during the 100 year design storm.

Flows have been estimated based on the perceived contribution from sub catchments that will drain to each segment of bio-retention swale in the post-development scenario. It has been assumed that 25% of runoff from the existing urban development to the south, will be collected along the adjacent boundary swales. The remaining 75 percent is assumed to discharge directly into the existing watercourses by way of an outfall pipe located adjacent to the boundary.

A range of different bio-retention swale geometries have been considered for the conveyance of flows throughout the site. In each case, consideration has also been given to the type of ground cover. All bio-retention swales have been assumed to have a 1% longitudinal grade which roughly correlates to existing grades across the development. Details of the sizing and flow assessment for the bio-retention swales are enclosed within **Appendix E**.

In most cases a bio-retention swale with a surface width of 2.5 metres and a depth of 0.3 metres will be adequate. In some circumstances, such as where the bio-retention swales are in series, the downstream swale segments will require surface widths of 5 to 6 metres and depth of up to 0.7 metres. All swales will "fit into" the space requirements imposed by the road network and subdivision layout presented in the Concept Plan.

All bio-retention swales were analysed to assess the potential for scour during a 100 year recurrence design storm event. A velocity of 1.6 m/s was determined to be the maximum acceptable velocity through each swale to ensure that there was no risk of scour. The analysis showed that swale velocities were less than the maximum allowable value of 1.6 m/s at all points along all bio-retention swales.

Post-Development Runoff Volumes

The MUSIC water balance model was revisited to incorporate the three proposed WQCPs and the bio-retention swales, and applied to establish the likely total volume of runoff that would be distributed to Hearns Lake. The analysis assumed no seepage loss from the WQCPs or bio-retention swales, and that there was an evaporative loss of 100% of potential evapo-transpiration (*PET*).

The results of the analysis show that under post-development conditions and with the proposed Water Management Strategy in place, that the total volume of runoff that would be discharged to Hearns Lake annually would be about 864 ML. This is similar to the total volume predicted for post-development conditions <u>without</u> the proposed water management measures in place.

Hence, the proposed water management measures do not have any significant effect on the annual water balance for the site.

Notwithstanding, the post development conditions (*with or without WQCPs and bio-retention swales*) will increase the annual volume of runoff to Hearns Lake by about 27%. However, this is considered to be a benefit as it will improve the potential for "re-charge" of Hearns Lake under average dry weather conditions.

In order to further understand the water balance, the MUSIC model was used to assess the potential for the WQCPs to "dry out". Separate analyses were undertaken for each of the three WQCPs for wet, dry and average dry weather conditions. Each model was applied to assess the variation in total volume (*and therefore water level*) within each of the ponds over the three year simulation period documented in **Section 2.2.2**.

It was initially assumed that the base of each pond would be constructed from insitu materials (*i.e., sand*). The results of this analysis indicated that the water balance for each pond would be sensitive to seepage losses and the ponds could potentially 'dry out' as a result of seepage. Therefore, it is recommended that the ponds be constructed with an impermeable liner. If an impermeable or clay liner is employed, a permeability co-efficient of 0.36 mm/hr (*limit between heavy – medium clay*) and an evaporation rate of 125% of PET can be assumed. The results of the analysis undertaken using these parameters are presented in **Table 8**.

The results indicate that over the 3 year simulation period comprising a combination of dry, wet, and average rainfall conditions, that the ponds will not fall below a minimum depth of 1 metre.

Table 8 WATER BALANCE FOR WATER QUALITY CONTROL PONDS

WQCP	PERMEABILITY CO-EFFICIENT (*mm/hr*)	PERMANENT VOLUME (*m³*)	VOLUME LOSS (*m³*)	DEPTH REDUCTION (*m*)	FINAL VOLUME (*m³*)
1	0.36	3150	945	0.45	2205
2	0.36	2100	630	0.45	1470
3	0.36	2550	765	0.45	1785

5.3.2 Provision for Water Quality Control

The three proposed WQCPs were sized to ensure that the level of total suspended solids and nutrients in Hearns Lake will not be increased as a result of the proposed development.

Procedures for the sizing of WQCPs are outlined in the Department of Land & Water Conservation's *'Constructed Wetlands Manual'* (*1998*). These procedures involve the application of several different sizing methods in sequence. These methods, in order of application, are:

§ the 'Percentage Catchment Area Method';

§ the 'Generic Curve Method'; and,

§ the 'Detailed Wetland Zone Sizing Method'.

The sequence of application of the various methods is employed to increase the level of refinement to the design of a particular WQCP. The first two of these methods were applied to develop and confirm the initial concept for the ponds proposed for the Sandy Beach North development. A discussion of the manner in which each of the sizing methods has been applied to conceptually design the WQCPs is presented in the following sections.

Percentage Catchment Area Method

The 'Percentage Catchment Area Method' suggests that the surface area of an urban stormwater wetland should be at least 2% of the catchment area that drains into the wetland. This figure has been based on statistical analysis of wetland systems in the United States.

Typically, a more rigorous analysis is required to design a WQCP, often including the need to assess pollutant export loads and runoff retention times. However, this "rule of thumb" provides a mechanism to determine an indicative estimate of the size of the WQCP that will be required for the site.

Figure 6 shows the extent of the catchment areas draining to each WQCP. Details of the calculations undertaken for the initial sizing of the ponds using this method are enclosed in **Appendix F**. A summary of the results showing the initial proposed surface areas is presented in **Table 9**.

Table 9 INDICATIVE WQCP SIZING BASED ON PERCENTAGE CATCHMENT AREA

POND	TOTAL CATCHMENT AREA (m^2)	SURFACE AREA OF POND (m^2)
WQCP #1	202,000	4000
WQCP #2	134,700	2700
WQCP #3	83,600	1700

Generic Curve Method

The 'Generic Curve Method' provides a more rigorous assessment of the water quality enhancement capacity. It is based on a number of empirically derived curves and equations that have been developed using performance data from wetland systems in Sydney, Canberra and Adelaide. This method was applied to determine the extent to which the proposed WQCP would "remove" pollutants from runoff entering the pond.

In the absence of site specific criteria, it is customary to design WQCPs so that they achieve a 50% removal of dissolved phosphorus carried by runoff entering them. This will typically achieve a hydraulic residence time for nutrients such as phosphorus of about 15 days (*assuming average dry weather flow conditions*).

In this instance, it was necessary to ensure that the concentrations of pollutants in post-development discharges were no greater than the existing. This meant that the WQCPs needed to achieve a 50% removal of total suspended solids, 38% removal of dissolved phosphorous and 5% removal of dissolved nitrogen.

Therefore, the sizing of the ponds was refined using the generic curve method and based on achieving a reduction of 38% in dissolved phosphorous and 50% removal of suspended solids (*refer* **Appendix F**). **Table 10** summarises the pond sizes calculated using the generic curve method. In all instances, pond sizes shown will achieve a hydraulic residence time of approximately 2.5 days.

Table 10 INDICATIVE POND DIMENSIONS BASED ON GENERIC CURVE METHOD

POND	POND VOLUME (m^3)	POND DEPTH (m)	SURFACE AREA (m^2)
WQCP#1	1634	0.78	2095
WQCP#2	1090	0.78	1397
WQCP#3	676	0.78	867

The pond dimensions shown in **Table 10**, were then modified according to constraints imposed by the development layout, site topography and the requirements for attenuation of stormwater runoff. **Table 11** summarises the adopted sizing for the three water quality control ponds.

Table 11 ADOPTED WATER QUALITY CONTROL POND CHARACTERISTICS

POND	SURFACE AREA (m^2)	EXTENDED DETENTION DEPTH (m)	DEPTH (m)	PERMANENT POOL VOLUME (m^3)	EXTENDED DETENTION VOLUME (m^3)
WQCP#1	2100	0.5	1.5	3150	1000
WQCP#2	1400	0.5	1.5	2100	700
WQCP#3	1700	0.5	1.5	2550	850

Bio-retention Swale Design

As outlined previously, it is proposed that the bio-retention swales be sited along road verges where there are no driveways proposed and in areas of open space. The proposed alignments for the bio-retention swales are shown in **Figure 6**.

The length and flow direction of each bio-retention swale was determined based on the layout of the roads and driveways and the site topography. The width and depth of each swale was determined by reference to the water quantity assessment described in **Section 5.3.1** of this report and the width constraints of each road verge.

The key features for the majority of the proposed bio-retention swales are as follows:

§ Base (*filter*) width of 1.5 metres

§ Top width of 2.5 to 5.0 metres

§ Maximum swale depth of 0.3 metres (*i.e.* side slopes of 1(V):3(H))

§ Average depth of bio-retention filter of 1 metre

§ Longitudinal slope of 1.0%.

As shown in **Figure 6**, the design for the bio-retention swales system has been developed so that all sub catchment areas drain to a bio-retention swale prior to flows being directed to one of the three water quality control ponds. Only sub catchments C1, C2, D1 and D2, (*refer* **Appendix E**) do not drain to a WQCP.

5.4 PERFORMANCE OF STORMWATER TREATMENT SYSTEM

The components of the proposed Water Management Strategy for the development (*i.e., the WQCPs and the Bio-Retention Swales*) were then assessed within the MUSIC model to determine their performance in terms of polishing runoff from the development site.

The MUSIC model was modified to incorporate the range of treatment measures as specific "treatment nodes". The dimensions and structure sizes presented in **Table 11** for the three WQCPs were adopted and incorporated into the parameters details within the model for each of the corresponding treatment nodes. Default filter properties for sandy loam soil were adopted for each bio-retention swale. This involved the adoption of filter particle diameters of 0.45 mm and a saturated hydraulic conductivity of 180 mm/hr for soils along the alignment of the bio-retention swales.

The modified MUSIC model was then used to simulate runoff processes and determine the overall effectiveness of the proposed Water Management Strategy, measured in terms of post development pollutant load to Hearns Lake.

Table 12 provides a summary of the mean annual pollutant loads for the post-development scenario with the treatment measures incorporated into the model. The MUSIC model structure and the associated model results are enclosed within **Appendix C** (*refer* **Table C3)**.

Table 12 MEAN ANNUAL POLLUTANT LOADS FOR POST-DEVELOPMENT CONDITIONS AND WITH TREATMENT SYSTEMS IN PLACE

POLLUTANT	MEAN ANNUAL LOAD (*kg/yr*)			% REDUCTION	
	Existing Conditions	Post-Development	Post-development PLUS Treatments	Relative to Existing Conditions	Relative to Non-Treatment Scenario
Total Suspended Solids	114×10^3	164×10^3	45×10^3	60	72
Total Phosphorus	278	356	169	39	53
Total Nitrogen	2000	2560	1540	23	40

As shown by the numbers presented in **Table 12**, the proposed combination of WQCPs and bio-retention swales will result in a significant decrease in the overall pollutant loads distributed to Hearns Lake. The predicted reductions in all pollutants are at or near the pollutant reduction criteria recommended in Department of Environment and Conservation guidelines (*EPA, 1997*). These guidelines recommend the following reductions in pollutant loads:

§ 80% reduction in TSS;

§ 45% reduction in TP; and,

§ 45% reduction in TN.

It should be noted that these percentage reductions are considered to be highly conservative.

6 CONCLUSIONS

The Sandy Beach North development will satisfy the principles of Ecologically Sustainable Development (*ESD*) by incorporating the latest techniques in Water Sensitive Urban Design (*WSUD*). This will be achieved by the sustainable management of stormwater runoff incorporating the components of the Water Management Strategy outlined in this report. These components include the harvesting of rainfall for water re-use / recycling and the treatment of residual runoff prior to any discharge to Hearns Lake.

The Water Management Strategy includes three water quality control ponds (*WQCPs*) which are to be strategically sited at the locations identified in **Figure 6**. The WQCPS have been sited as shown to minimise the extent of earthworks that will be required, while at the same time maximising the opportunity for runoff residence times and runoff treatment.

The WQCPS will be "fed" by runoff carried by a series of bio-retention swales that will typically be located along roadway verges and within open space areas (*refer* **Figure 6**). The combined length of the bio-retention swales is approximately four kilometres. The swale component of the system provides pre-treatment of stormwater to remove coarse particulates and associated contaminants, while the bio-retention system removes finer particulates and associated contaminants.

Water quality modelling undertaken using the MUSIC software indicates that the proposed combination of bio-retention swales and WQCPs will ensure the following reduction in the mean annual pollutant loads from the developed site:

§ Total Suspended Solids ==> 72% reduction

§ Total Phosphorous ==> 53% reduction

§ Total Nitrogen ==> 40% reduction

These reductions are at or near pollutant upper bound reduction criteria recommended for nutrient and suspended solids reductions for urban development (*refer EPA 1997*).

The components of the proposed Water Management Strategy will also result in a net reduction in the total load of nutrients and suspended solids estimated to be currently discharged to the lake from the site (*refer* **Table 12**).

Therefore, it is considered that the proposed system of bio-retention swales and WQCPs, combined with the harvesting of rainwater from the rooves of dwellings, will suitably treat stormwater from the developed site, and will in fact, improve the quality of runoff currently discharged to Hearns Lake.

The proposed WQCPs have also been designed to incorporate a flood storage component. The storage volume has been sized to ensure that the peak 100 year recurrence post-development discharge from all catchment areas within the site will be retained at pre-development levels.

The WQCPs have also been designed to ensure that they do not dry out during periods of low rainfall. The MUSIC model was used to complete a water balance for each of the ponds and the developed site as a whole. The results of the analysis show that even under low rainfall conditions extending for up to a year, the depth of all of the ponds will be maintained at or above two-thirds of the nominal permanent pond water depth; i.e., a minimum depth of 1 metre will be retained. This will be achieved by providing an impermeable clay liner across the full area of the bed of each of the WQCPs.

The water balance analysis also established that under post development conditions, there will be a 31% increase in the annual volume of runoff discharged from the site to Hearns Lake. This is considered to be a benefit as it will improve the potential for “re-charge” of Hearns Lake under average dry weather conditions.

Therefore, it is considered that the inclusion of the proposed bio-retention systems, water quality control ponds and associated water sensitive urban design features, will suitably treat and polish runoff from the developed site, and ensure that runoff discharged to Hearns Lake is of a quality that will not adversely impact on the lake hydrology and associated ecosystems.

7 REFERENCES

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APPENDIX A

INTENSITY-FREQUENCY-DURATION DATA
FOR SANDY BEACH

IFD ANALYSIS BASED ON AUSTRALIAN RAINFALL & RUNOFF 1987

Site Location: Hearns Lake

Geographical factor for 6 min 2 yr storm = 4.375
Geographical factor for 6 min 50 yr storm = 16.6
Skewness = 0.04

2 Year ARI:
1 hour intensity = 46 mm/hr
12 hour intensity = 9.55 mm/hr
72 hour intensity = 3.26 mm/hr

50 Year ARI:
1 hour intensity = 90 mm/hr
12 hour intensity = 19.4 mm/hr
72 hour intensity = 7.75 mm/hr

IFD Table for Various ARIs and Duration

Duration	1 yr (*mm/hr*)	2 yr (*mm/hr*)	5 yr (*mm/hr*)	10 yr (*mm/hr*)	20 yr (*mm/hr*)	50 yr (*mm/hr*)	100 yr (*mm/hr*)
5 mins	115	146	181	201	228	264	290
6	108	137	170	189	215	249	274
10	88	112	141	157	179	207	229
15	74	94	119	133	151	176	195
20	64	82	104	116	133	155	172
30	52	67	85	96	110	129	143
45	41.9	53.9	69.1	78	90	105	117
1 hour	35.6	45.9	59.1	67	77	91	101
1.5	27.7	35.7	46.2	52	60	71	79
2	23.1	29.8	38.6	43.8	51	60	67
3	17.8	23.0	29.9	34.0	39.3	46	52
4.5	13.7	17.8	23.1	26.3	30.5	36.0	40.2
6	11.4	14.8	19.3	21.9	25.4	30.1	33.6
9	8.82	11.4	14.9	17.0	19.8	23.4	26.2
12	7.34	9.52	12.5	14.2	16.5	19.6	21.9
18	5.81	7.57	10.05	11.6	13.5	16.1	18.1
24	4.92	6.43	8.62	9.96	11.7	14.0	15.8
30	4.30	5.65	7.63	8.85	10.42	12.5	14.2
36	3.85	5.07	6.89	8.02	9.47	11.4	13.0
48	3.22	4.25	5.84	6.83	8.10	9.84	11.20
72	2.45	3.25	4.54	5.36	6.40	7.83	8.96

APPENDIX B

RATIONAL METHOD CALCULATIONS
FOR PRE AND POST DEVELOPMENT

TABLE B1: Rational Method Calculations for 100 Year ARI event under Existing Conditions

Time of concentration	$t_c = 0.76A^{0.38}$

$^{10}I_1$ *(mm/hr)*	67

Catchment Area A

Area A	Area *(ha)*	t_c^ *(mins)*	f	C'_{10}	C_{10}	F_{100}#	C_{100}	CA	^{100}I *(mm/hr)*	Q_{100} *(m^3/s)*
Impervious	7.965	24.8	1	0.66	0.90	1.2	1.00	7.9654	158	3.496
Pervious	12.235	24.8	0	0.66	0.66	1.2	0.79	9.6693	158	4.244
TOTAL	20.20									7.741

Catchment Area B

Area B	Area *(ha)*	t_c^ *(mins)*	f	C'_{10}	C_{10}	F_{100}#	C_{100}	CA	^{100}I *(mm/hr)*	Q_{100} *(m^3/s)*
Impervious	5.753	21.3	1	0.66	0.90	1.2	1.00	5.7530	168	2.689
Pervious	7.717	21.3	0	0.66	0.66	1.2	0.79	6.0989	168	2.851
TOTAL	13.47									5.540

Catchment Area C

Area C	Area *(ha)*	t_c^ *(mins)*	f	C'_{10}	C_{10}	F_{100}#	C_{100}	CA	^{100}I *(mm/hr)*	Q_{100} *(m^3/s)*
Impervious	0	13.7	1	0.66	0.90	1.2	1.00	0.0000	204	0.000
Pervious	4.21	13.7	0	0.66	0.66	1.2	0.79	3.3272	204	1.882
TOTAL	4.21									1.882

Catchment Area D

Area D	Area *(ha)*	t_c^ *(mins)*	f	C'_{10}	C_{10}	F_{100}#	C_{100}	CA	^{100}I *(mm/hr)*	Q_{100} *(m^3/s)*
Impervious	0	10.2	1	0.66	0.90	1.2	1.00	0.0000	228	0.000
Pervious	1.950	10.2	0	0.66	0.66	1.2	0.79	1.5411	228	0.976
TOTAL	1.950									0.976

Catchment Area F

Area F	Area *(ha)*	t_c^ *(mins)*	f	C'_{10}	C_{10}	F_{100}#	C_{100}	CA	^{100}I *(mm/hr)*	Q_{100} *(m^3/s)*
Impervious	0	17.8	1	0.66	0.90	1.2	1.00	0.0000	182	0.000
Pervious	8.360	17.8	0	0.66	0.66	1.2	0.79	6.6071	182	3.341
TOTAL	8.360									3.341

TABLE B2: Rational Method Calculations for 100 Year ARI event under Post-development Conditions

Time of concentration	$t_c = 0.76A^{0.38}$

$^{10}I_1$ *(mm/hr)*	67

Catchment A

A1	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	7.965	24.8	1	0.66	0.90	1.2	1.00	7.9650	158	3.496
Pervious	2.655	24.8	0	0.66	0.66	1.2	0.79	2.0983	158	0.921
TOTAL	10.620									4.417

A2	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	0.225	24.8	1	0.66	0.90	1.2	1.00	0.2250	158	0.099
Pervious	0.075	24.8	0	0.66	0.66	1.2	0.79	0.0593	158	0.026
TOTAL	0.300									0.125

A3	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	0.480	24.8	1	0.66	0.90	1.2	1.00	0.4800	158	0.211
Pervious	0.160	24.8	0	0.66	0.66	1.2	0.79	0.1265	158	0.056
TOTAL	0.640									0.266

A4	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	1.185	24.8	1	0.66	0.90	1.2	1.00	1.1850	158	0.520
Pervious	0.395	24.8	0	0.66	0.66	1.2	0.79	0.3122	158	0.137
TOTAL	1.580									0.657

A5	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	0.653	24.8	1	0.66	0.90	1.2	1.00	0.6525	158	0.286
Pervious	0.508	24.8	0	0.66	0.66	1.2	0.79	0.4011	158	0.176
TOTAL	1.160									0.462

A6	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	0.698	24.8	1	0.66	0.90	1.2	1.00	0.6975	158	0.306
Pervious	0.233	24.8	0	0.66	0.66	1.2	0.79	0.1837	158	0.081
TOTAL	0.930									0.387

A7	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	0.930	24.8	1	0.66	0.90	1.2	1.00	0.9300	158	0.408
Pervious	0.310	24.8	0	0.66	0.66	1.2	0.79	0.2450	158	0.108
TOTAL	1.240									0.516

A8	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	2.798	24.8	1	0.66	0.90	1.2	1.00	2.7975	158	1.228
Pervious	0.933	24.8	0	0.66	0.66	1.2	0.79	0.7370	158	0.324
TOTAL	3.730									1.551

TOTAL	20.20									8.382

Catchment B

B1	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	2.310	21.3	1	0.66	0.90	1.2	1.00	2.3100	168	1.080
Pervious	0.770	21.3	0	0.66	0.66	1.2	0.79	0.6085	168	0.284
TOTAL	3.080									1.364

B2	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	0.630	21.3	1	0.66	0.90	1.2	1.00	0.6300	168	0.294
Pervious	0.210	21.3	0	0.66	0.66	1.2	0.79	0.1660	168	0.078
TOTAL	0.840									0.372

B3	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	0.470	21.3	1	0.66	0.90	1.2	1.00	0.4700	168	0.220
Pervious	0.470	21.3	0	0.66	0.66	1.2	0.79	0.3715	168	0.174
TOTAL	0.940									0.393

B4	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	2.078	21.3	1	0.66	0.90	1.2	1.00	2.0775	168	0.971
Pervious	0.693	21.3	0	0.66	0.66	1.2	0.79	0.5473	168	0.256
TOTAL	2.770									1.227

B5	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	1.545	21.3	1	0.66	0.90	1.2	1.00	1.5450	168	0.722
Pervious	0.515	21.3	0	0.66	0.66	1.2	0.79	0.4070	168	0.190
TOTAL	2.060									0.912

B6	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	1.380	21.3	1	0.66	0.90	1.2	1.00	1.3800	168	0.645
Pervious	0.460	21.3	0	0.66	0.66	1.2	0.79	0.3635	168	0.170
TOTAL	1.840									0.815

B7	Area (ha)	t_c ^ (mins)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (mm/hr)	Q_{100} (m^3/s)
Impervious	1.455	21.3	1	0.66	0.90	1.2	1.00	1.4550	168	0.680
Pervious	0.485	21.3	0	0.66	0.66	1.2	0.79	0.3833	168	0.179
TOTAL	1.940									0.859

TOTAL	13.470	5.943

Catchment C

C1	Area (ha)	t_c ^ (mins)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (mm/hr)	Q_{100} (m^3/s)
Impervious	1.215	13.7	1	0.66	0.90	1.2	1.00	1.2150	204	0.687
Pervious	0.405	13.7	0	0.66	0.66	1.2	0.79	0.3201	204	0.181
TOTAL	1.620									0.868

C2	Area (ha)	t_c ^ (mins)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (mm/hr)	Q_{100} (m^3/s)
Impervious	1.943	13.7	1	0.66	0.90	1.2	1.00	1.9425	204	1.099
Pervious	0.648	13.7	0	0.66	0.66	1.2	0.79	0.5117	204	0.289
TOTAL	2.590									1.388

TOTAL	4.210	2.256

Catchment D

D1	Area (ha)	t_c ^ (mins)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (mm/hr)	Q_{100} (m^3/s)
Impervious	0.550	10.2	1	0.66	0.90	1.2	1.00	0.5498	228	0.348
Pervious	0.183	10.2	0	0.66	0.66	1.2	0.79	0.1448	228	0.092
TOTAL	0.733									0.440

D2	Area (ha)	t_c ^ (mins)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (mm/hr)	Q_{100} (m^3/s)
Impervious	0.914	10.2	1	0.66	0.90	1.2	1.00	0.9143	228	0.579
Pervious	0.305	10.2	0	0.66	0.66	1.2	0.79	0.2409	228	0.153
TOTAL	1.219									0.732

TOTAL	1.952	1.172

Catchment F

F1	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	0.500	17.8	1	0.66	0.90	1.2	1.00	0.4995	182	0.253
Pervious	0.611	17.8	0	0.66	0.66	1.2	0.79	0.4825	182	0.244
TOTAL	1.110									0.497

F2	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	1.800	17.8	1	0.66	0.90	1.2	1.00	1.8000	182	0.910
Pervious	0.600	17.8	0	0.66	0.66	1.2	0.79	0.4742	182	0.240
TOTAL	2.400									1.150

F3	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	1.095	17.8	1	0.66	0.90	1.2	1.00	1.0950	182	0.554
Pervious	0.365	17.8	0	0.66	0.66	1.2	0.79	0.2885	182	0.146
TOTAL	1.460									0.700

F4	Area (*ha*)	t_c ^ (*mins*)	f	C'_{10}	C_{10}	F_{100} #	C_{100}	CA	^{100}I (*mm/hr*)	Q_{100} (m^3/s)
Impervious	2.543	17.8	1	0.66	0.90	1.2	1.00	2.5425	182	1.286
Pervious	0.848	17.8	0	0.66	0.66	1.2	0.79	0.6698	182	0.339
TOTAL	3.390									1.624

TOTAL	8.360	3.971

APPENDIX C
MUSIC MODELLING RESULTS

Source nodes									
Location	Catchment A1	Rest of Catchment A	Catchment B1	Rest of Catchment B	Catchment B4	Catchment C	Catchment D	Catchment E	Catchment F
ID	2	3	4	5	6	7	8	9	10
Node Type	UrbanSourceNode	AgriculturalSourceNode	UrbanSourceNode	AgriculturalSourceNode	UrbanSourceNode	AgriculturalSourceNode	AgriculturalSourceNode	AgriculturalSourceNode	AgriculturalSourceNode
Total Area (ha)	10.62	6.94	3.08	9.65	3.16	4.66	1.86	16.85	7
Area Impervious (ha)	10.62	0	3.08	0	2.3779	0	0	0	0
Area Pervious (ha)	0	6.94	0	9.65	0.7821	4.66	1.86	16.85	7
Field Capacity (mm)	80	80	80	80	80	80	80	80	80
Pervious Area Infiltration Capacity coefficient - a	200	200	200	200	200	200	200	200	200
Pervious Area Infiltration Capacity exponent - b	1	1	1	1	1	1	1	1	1
Impervious Area Rainfall Threshold (mm/day)	1	1	1	1	1	1	1	1	1
Pervious Area Soil Storage Capacity (mm)	120	120	120	120	120	120	120	120	120
Pervious Area Soil Initial Storage (% of Capacity)	30	30	30	30	30	30	30	30	30
Groundwater Initial Depth (mm)	10	10	10	10	10	10	10	10	10
Groundwater Daily Recharge Rate (%)	25	25	25	25	25	25	25	25	25
Groundwater Daily Baseflow Rate (%)	5	5	5	5	5	5	5	5	5
Groundwater Daily Deep Seepage Rate (%)	0	0	0	0	0	0	0	0	0
Stormflow Total Suspended Solids Mean (log mg/L)	2.2	2.3	2.2	2.3	2.2	2.3	2.3	2.3	2.3
Stormflow Total Suspended Solids Standard Deviation (log mg/L)	0.32	0.31	0.32	0.31	0.32	0.31	0.31	0.31	0.31
Stormflow Total Suspended Solids Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Stormflow Total Suspended Solids Serial Correlation	0	0	0	0	0	0	0	0	0
Stormflow Total Phosphorus Mean (log mg/L)	-0.45	-0.27	-0.45	-0.27	-0.45	-0.27	-0.27	-0.27	-0.27
Stormflow Total Phosphorus Standard Deviation (log mg/L)	0.25	0.3	0.25	0.3	0.25	0.3	0.3	0.3	0.3
Stormflow Total Phosphorus Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Stormflow Total Phosphorus Serial Correlation	0	0	0	0	0	0	0	0	0
Stormflow Total Nitrogen Mean (log mg/L)	0.42	0.59	0.42	0.59	0.42	0.59	0.59	0.59	0.59
Stormflow Total Nitrogen Standard Deviation (log mg/L)	0.19	0.26	0.19	0.26	0.19	0.26	0.26	0.26	0.26
Stormflow Total Nitrogen Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Stormflow Total Nitrogen Serial Correlation	0	0	0	0	0	0	0	0	0
Baseflow Total Suspended Solids Mean (log mg/L)	1.1	1.4	1.1	1.4	1.1	1.4	1.4	1.4	1.4
Baseflow Total Suspended Solids Standard Deviation (log mg/L)	0.17	0.13	0.17	0.13	0.17	0.13	0.13	0.13	0.13
Baseflow Total Suspended Solids Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Baseflow Total Suspended Solids Serial Correlation	0	0	0	0	0	0	0	0	0
Baseflow Total Phosphorus Mean (log mg/L)	-0.82	-0.88	-0.82	-0.88	-0.82	-0.88	-0.88	-0.88	-0.88
Baseflow Total Phosphorus Standard Deviation (log mg/L)	0.19	0.13	0.19	0.13	0.19	0.13	0.13	0.13	0.13
Baseflow Total Phosphorus Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Baseflow Total Phosphorus Serial Correlation	0	0	0	0	0	0	0	0	0
Baseflow Total Nitrogen Mean (log mg/L)	0.32	0.074	0.32	0.074	0.32	0.074	0.074	0.074	0.074
Baseflow Total Nitrogen Standard Deviation (log mg/L)	0.12	0.13	0.12	0.13	0.12	0.13	0.13	0.13	0.13
Baseflow Total Nitrogen Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Baseflow Total Nitrogen Serial Correlation	0	0	0	0	0	0	0	0	0
OUT - Mean Annual Flow (ML/yr)	179	59.2	51.9	82.3	46.7	39.8	15.9	144	59.7
OUT - TSS Mean Annual Load (kg/yr)	3.71E+04	7.97E+03	1.08E+04	1.18E+04	9.02E+03	5.75E+03	2.39E+03	2.06E+04	8.74E+03
OUT - TP Mean Annual Load (kg/yr)	75.6	24.2	21.9	34.5	18.5	16.5	6.82	59.9	25.6
OUT - TN Mean Annual Load (kg/yr)	512	178	151	244	133	113	47.9	428	182
OUT - Gross Pollutant Mean Annual Load (kg/yr)	4.11E+03	0	1.19E+03	0	1.08E+03	0	0	0	0
No Imported Data Source nodes									
No USTM treatment nodes									
No Generic treatment nodes									
Other nodes									
Location	Hearns Lake								
ID	1								
Node Type	ReceivingNode								
IN - Mean Annual Flow (ML/yr)	678								
IN - TSS Mean Annual Load (kg/yr)	1.14E+05								
IN - TP Mean Annual Load (kg/yr)	283								
IN - TN Mean Annual Load (kg/yr)	1.99E+03								
IN - Gross Pollutant Mean Annual Load (kg/yr)	6.39E+03								
OUT - Mean Annual Flow (ML/yr)	0								
OUT - TSS Mean Annual Load (kg/yr)	0								
OUT - TP Mean Annual Load (kg/yr)	0								
OUT - TN Mean Annual Load (kg/yr)	0								
OUT - Gross Pollutant Mean Annual Load (kg/yr)	0								
Links									
Location	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link
Source node ID	2	3	4	6	5	7	9	8	10
Target node ID	1	1	1	1	1	1	1	1	1
Muskingum-Cunge Routing	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed
Muskingum K									
Muskingum theta									
IN - Mean Annual Flow (ML/yr)	179	59.2	51.9	46.7	82.3	39.8	144	15.9	59.7
IN - TSS Mean Annual Load (kg/yr)	3.71E+04	7.97E+03	1.08E+04	9.02E+03	1.18E+04	5.75E+03	2.06E+04	2.39E+03	8.74E+03
IN - TP Mean Annual Load (kg/yr)	75.6	24.2	21.9	18.5	34.5	16.5	59.9	6.82	25.6
IN - TN Mean Annual Load (kg/yr)	512	178	151	133	244	113	428	47.9	182
IN - Gross Pollutant Mean Annual Load (kg/yr)	4.11E+03	0	1.19E+03	1.08E+03	0	0	0	0	0
OUT - Mean Annual Flow (ML/yr)	179	59.2	51.9	46.7	82.3	39.8	144	15.9	59.7
OUT - TSS Mean Annual Load (kg/yr)	3.71E+04	7.97E+03	1.08E+04	9.02E+03	1.18E+04	5.75E+03	2.06E+04	2.39E+03	8.74E+03
OUT - TP Mean Annual Load (kg/yr)	75.6	24.2	21.9	18.5	34.5	16.5	59.9	6.82	25.6
OUT - TN Mean Annual Load (kg/yr)	512	178	151	133	244	113	428	47.9	182
OUT - Gross Pollutant Mean Annual Load (kg/yr)	4.11E+03	0	1.19E+03	1.08E+03	0	0	0	0	0

Source nodes																
Location	Catch A1	Catch A2	Catch A3	Catch A4	Catch A8	Catch A6	Catch A5	Catch A7	Catch B1	Catch B2	Catch B3	Catch B4	Catch B5	Catch B6	Catch B7	Catch C1
ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Node Type	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	AgriculturalSourceN	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode
Total Area (ha)	10.62	0.3	0.64	1.58	3.373	0.93	1.16	1.24	3.08	0.84	0.94	2.77	2.06	1.84	1.94	1.62
Area Impervious (ha)	7.985494737	0.225578947	0.4784	1.58	2.523240702	0.93	1.16	1.24	2.3177	0.650226316	0.465835965	2.084425	1.541024561	1.84	1.45015	1.218126316
Area Pervious (ha)	2.634505263	0.074421053	0.1616	0	0.849759298	0	0	0	0.7623	0.189773684	0.474164035	0.685575	0.518975439	0	0.48985	0.401873684
Field Capacity (mm)	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Pervious Area Infiltration Capacity coefficient - a	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Pervious Area Infiltration Capacity exponent - b	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Impervious Area Rainfall Threshold (mm/day)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pervious Area Soil Storage Capacity (mm)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
Pervious Area Soil Initial Storage (% of Capacity)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Groundwater Initial Depth (mm)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Groundwater Daily Recharge Rate (%)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Groundwater Daily Baseflow Rate (%)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Groundwater Daily Deep Seepage Rate (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stormflow Total Suspended Solids Mean (log mg/L)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.3	2.2	2.2	2.2	2.2	2.2
Stormflow Total Suspended Solids Standard Deviation (log mg/L)	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.31	0.32	0.32	0.32	0.32	0.32
Stormflow Total Suspended Solids Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Stormflow Total Suspended Solids Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stormflow Total Phosphorus Mean (log mg/L)	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.27	-0.45	-0.45	-0.45	-0.45	-0.45
Stormflow Total Phosphorus Standard Deviation (log mg/L)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.3	0.25	0.25	0.25	0.25	0.25
Stormflow Total Phosphorus Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Stormflow Total Phosphorus Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stormflow Total Nitrogen Mean (log mg/L)	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.59	0.42	0.42	0.42	0.42	0.42
Stormflow Total Nitrogen Standard Deviation (log mg/L)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.26	0.19	0.19	0.19	0.19	0.19
Stormflow Total Nitrogen Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Stormflow Total Nitrogen Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseflow Total Suspended Solids Mean (log mg/L)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.4	1.1	1.1	1.1	1.1	1.1
Baseflow Total Suspended Solids Standard Deviation (log mg/L)	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.13	0.17	0.17	0.17	0.17	0.17
Baseflow Total Suspended Solids Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Baseflow Total Suspended Solids Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseflow Total Phosphorus Mean (log mg/L)	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.88	-0.82	-0.82	-0.82	-0.82	-0.82
Baseflow Total Phosphorus Standard Deviation (log mg/L)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.13	0.19	0.19	0.19	0.19	0.19
Baseflow Total Phosphorus Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Baseflow Total Phosphorus Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseflow Total Nitrogen Mean (log mg/L)	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.074	0.32	0.32	0.32	0.32	0.32
Baseflow Total Nitrogen Standard Deviation (log mg/L)	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.12	0.12	0.12	0.12	0.12
Baseflow Total Nitrogen Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Baseflow Total Nitrogen Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OUT - Mean Annual Flow (ML/yr)	157	4.43	9.46	26.6	49.9	15.7	19.6	20.9	45.5	12.6	11.9	40.9	30.4	31	28.7	23.9
OUT - TSS Mean Annual Load (kg/yr)	2.98E+04	870	1.81E+03	5.55E+03	9.67E+03	3.27E+03	4.07E+03	4.33E+03	8.49E+03	2.48E+03	2.61E+03	7.80E+03	6.05E+03	6.38E+03	5.53E+03	4.73E+03
OUT - TP Mean Annual Load (kg/yr)	61.5	1.78	3.77	11.2	20	6.61	8.29	8.69	17.9	5.13	7.1	16.3	12.4	12.9	11.5	9.63
OUT - TN Mean Annual Load (kg/yr)	451	12.5	26.6	77.5	140	45.2	56.7	60.8	130	36.6	48.9	117	86.4	89.3	80.9	67.1
OUT - Gross Pollutant Mean Annual Load (kg/yr)	3.64E+03	103	219	612	1.15E+03	360	449	480	1.05E+03	291	264	948	705	712	664	555
No Imported Data Source nodes																
No USTM treatment nodes																
No Generic treatment nodes																
Other nodes																
Location	Hearns Lake															
ID	20															
Node Type	ReceivingNode															
IN - Mean Annual Flow (ML/yr)	887															
IN - TSS Mean Annual Load (kg/yr)	1.64E+05															
IN - TP Mean Annual Load (kg/yr)	356															
IN - TN Mean Annual Load (kg/yr)	2.56E+03															
IN - Gross Pollutant Mean Annual Load (kg/yr)	1.67E+04															
OUT - Mean Annual Flow (ML/yr)	0															
OUT - TSS Mean Annual Load (kg/yr)	0															
OUT - TP Mean Annual Load (kg/yr)	0															
OUT - TN Mean Annual Load (kg/yr)	0															
OUT - Gross Pollutant Mean Annual Load (kg/yr)	0															
Links																
Location	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link
Source node ID	24	21	22	23	25	26	27	29	28	15	14	16	17	30	31	32
Target node ID	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Muskingum-Cunge Routing	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed
Muskingum K																
Muskingum theta																
IN - Mean Annual Flow (ML/yr)	28.2	6.3	6.49	8.52	13.8	39.4	14.7	6.56	40.2	28.7	31	23.9	38.3	18.7	35.5	24.6
IN - TSS Mean Annual Load (kg/yr)	4.07E+03	889	999	1.23E+03	1.94E+03	5.56E+03	2.07E+03	751	4.50E+03	5.53E+03	6.38E+03	4.73E+03	7.44E+03	3.84E+03	6.81E+03	5.28E+03
IN - TP Mean Annual Load (kg/yr)	11.8	2.63	2.8	3.45	5.7	16	5.96	1.94	11.9	11.5	12.9	9.63	15.7	7.79	14	10.4
IN - TN Mean Annual Load (kg/yr)	84.8	19	18.8	25.4	40.6	124	43.2	16.8	102	80.9	89.3	67.1	108	54.3	100	72.3
IN - Gross Pollutant Mean Annual Load (kg/yr)	0	0	0	0	0	0	0	0	0	664	712	555	887	430	822	565
OUT - Mean Annual Flow (ML/yr)	28.2	6.3	6.49	8.52	13.8	39.4	14.7	6.56	40.2	28.7	31	23.9	38.3	18.7	35.5	24.6
OUT - TSS Mean Annual Load (kg/yr)	4.07E+03	889	999	1.23E+03	1.94E+03	5.56E+03	2.07E+03	751	4.50E+03	5.53E+03	6.38E+03	4.73E+03	7.44E+03	3.84E+03	6.81E+03	5.28E+03
OUT - TP Mean Annual Load (kg/yr)	11.8	2.63	2.8	3.45	5.7	16	5.96	1.94	11.9	11.5	12.9	9.63	15.7	7.79	14	10.4
OUT - TN Mean Annual Load (kg/yr)	84.8	19	18.8	25.4	40.6	124	43.2	16.8	102	80.9	89.3	67.1	108	54.3	100	72.3
OUT - Gross Pollutant Mean Annual Load (kg/yr)	0	0	0	0	0	0	0	0	0	664	712	555	887	430	822	565

Catch C2	Catch D1	Catch D2	Catch E2	Catch E3	Catch E6	Catch E5	Catch E7	Catch E8	Catch E9	E1	E4	F1	F2	F3	F4	F
17	18	19	21	22	23	24	25	26	27	28	29	30	31	32	33	34
UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	AgriculturalSourceN	AgriculturalSourceN	AgriculturalSourceN	AgriculturalSourceN	AgriculturalSourceN	AgriculturalSourceN	AgriculturalSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode
2.59	0.73	1.13	0.738	0.76	0.999	3.304	1.612	4.62	1.72	4.715	0.769	1.11	2.4	1.46	3.39	7
1.947498246	0.545675	0.849680702	0	0	0	0	0	0	0	0	0	1.11	1.806	1.46	2.550975	5.577587719
0.642501754	0.184325	0.280319298	0.738	0.76	0.999	3.304	1.612	4.62	1.72	4.715	0.769	0	0.594	0	0.839025	1.422412281
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2
0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-0.45	-0.45	-0.45	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45
0.25	0.25	0.25	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.42	0.42	0.42	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.42	0.42	0.42	0.42	0.42	0.42	0.42
0.19	0.19	0.19	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1	1.1	1.1	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.1	1.1	1.1	1.1	1.1	1.1	1.1
0.17	0.17	0.17	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-0.82	-0.82	-0.82	-0.88	-0.88	-0.88	-0.88	-0.88	-0.88	-0.88	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82
0.19	0.19	0.19	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.32	0.32	0.32	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.32	0.32	0.32	0.32	0.32	0.32	0.32
0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
38.3	10.8	16.7	6.3	6.49	8.52	28.2	13.8	39.4	14.7	40.2	6.56	18.7	35.5	24.6	50.1	106
7.44E+03	2.14E+03	3.28E+03	889	999	1.23E+03	4.07E+03	1.94E+03	5.56E+03	2.07E+03	4.50E+03	751	3.84E+03	6.81E+03	5.28E+03	9.94E+03	2.12E+04
15.7	4.39	6.78	2.63	2.8	3.45	11.8	5.7	16	5.96	11.9	1.94	7.79	14	10.4	20.3	43.7
108	30.7	47.6	19	18.8	25.4	84.8	40.6	124	43.2	102	16.8	54.3	100	72.3	142	304
887	250	387	0	0	0	0	0	0	0	0	0	430	822	565	1.16E+03	2.47E+03
Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link
33	13	12	11	10	9	5	6	19	18	2	1	3	7	4	8	34
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	24
Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed
50.1	30.4	40.9	11.9	12.6	45.5	49.9	15.7	16.7	10.8	4.43	157	9.46	19.6	26.6	20.9	106
9.94E+03	6.05E+03	7.80E+03	2.61E+03	2.48E+03	8.49E+03	9.67E+03	3.27E+03	3.28E+03	2.14E+03	870	2.98E+04	1.81E+03	4.07E+03	5.55E+03	4.33E+03	2.12E+04
20.3	12.4	16.3	7.1	5.13	17.9	20	6.61	6.78	4.39	1.78	61.5	3.77	8.29	11.2	8.69	43.7
142	86.4	117	48.9	36.6	130	140	45.2	47.6	30.7	12.5	451	26.6	56.7	77.5	60.8	304
1.16E+03	705	948	264	291	1.05E+03	1.15E+03	360	387	250	103	3.64E+03	219	449	612	480	2.47E+03
50.1	30.4	40.9	11.9	12.6	45.5	49.9	15.7	16.7	10.8	4.43	157	9.46	19.6	26.6	20.9	106
9.94E+03	6.05E+03	7.80E+03	2.61E+03	2.48E+03	8.49E+03	9.67E+03	3.27E+03	3.28E+03	2.14E+03	870	2.98E+04	1.81E+03	4.07E+03	5.55E+03	4.33E+03	2.12E+04
20.3	12.4	16.3	7.1	5.13	17.9	20	6.61	6.78	4.39	1.78	61.5	3.77	8.29	11.2	8.69	43.7
142	86.4	117	48.9	36.6	130	140	45.2	47.6	30.7	12.5	451	26.6	56.7	77.5	60.8	304
1.16E+03	705	948	264	291	1.05E+03	1.15E+03	360	387	250	103	3.64E+03	219	449	612	480	2.47E+03

Source nodes															
Location	Catch A1	Catch A2	Catch A3	Catch A4	Catch A8	Catch A6	Catch A5	Catch A7	Catch B1	Catch B2	Catch B3	Catch B4	Catch B5	Catch B6	Catch B7
ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Node Type	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	AgriculturalSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode
Total Area (ha)	10.62	0.3	0.64	1.58	3.373	0.93	1.16	1.24	3.08	0.84	0.94	2.77	2.06	1.84	1.94
Area Impervious (ha)	7.985494737	0.225578947	0.4784	1.58	2.523240702	0.93	1.16	1.24	2.3177	0.650226316	0.465835965	2.084425	1.541024561	1.84	1.45015
Area Pervious (ha)	2.634505263	0.074421053	0.1616	0	0.849759298	0	0	0	0.7623	0.189773684	0.474164035	0.685575	0.518975439	0	0.48985
Field Capacity (mm)	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Pervious Area Infiltration Capacity coefficient - a	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Pervious Area Infiltration Capacity exponent - b	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Impervious Area Rainfall Threshold (mm/day)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pervious Area Soil Storage Capacity (mm)	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
Pervious Area Soil Initial Storage (% of Capacity)	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Groundwater Initial Depth (mm)	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Groundwater Daily Recharge Rate (%)	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Groundwater Daily Baseflow Rate (%)	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Groundwater Daily Deep Seepage Rate (%)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stormflow Total Suspended Solids Mean (log mg/L)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.3	2.2	2.2	2.2	2.2
Stormflow Total Suspended Solids Standard Deviation (log mg/L)	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.31	0.32	0.32	0.32	0.32
Stormflow Total Suspended Solids Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Stormflow Total Suspended Solids Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stormflow Total Phosphorus Mean (log mg/L)	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45	-0.27	-0.45	-0.45	-0.45	-0.45
Stormflow Total Phosphorus Standard Deviation (log mg/L)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.3	0.25	0.25	0.25	0.25
Stormflow Total Phosphorus Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Stormflow Total Phosphorus Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stormflow Total Nitrogen Mean (log mg/L)	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.59	0.42	0.42	0.42	0.42
Stormflow Total Nitrogen Standard Deviation (log mg/L)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.26	0.19	0.19	0.19	0.19
Stormflow Total Nitrogen Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Stormflow Total Nitrogen Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseflow Total Suspended Solids Mean (log mg/L)	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.4	1.1	1.1	1.1	1.1
Baseflow Total Suspended Solids Standard Deviation (log mg/L)	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.17	0.13	0.17	0.17	0.17	0.17
Baseflow Total Suspended Solids Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Baseflow Total Suspended Solids Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseflow Total Phosphorus Mean (log mg/L)	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82	-0.88	-0.82	-0.82	-0.82	-0.82
Baseflow Total Phosphorus Standard Deviation (log mg/L)	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.13	0.19	0.19	0.19	0.19
Baseflow Total Phosphorus Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Baseflow Total Phosphorus Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Baseflow Total Nitrogen Mean (log mg/L)	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.074	0.32	0.32	0.32	0.32
Baseflow Total Nitrogen Standard Deviation (log mg/L)	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.13	0.12	0.12	0.12	0.12
Baseflow Total Nitrogen Estimation Method	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
Baseflow Total Nitrogen Serial Correlation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
OUT - Mean Annual Flow (ML/yr)	157	4.43	9.46	26.6	49.9	15.7	19.6	20.9	45.5	12.6	11.9	40.9	30.4	31	28.7
OUT - TSS Mean Annual Load (kg/yr)	3.05E+04	846	1.86E+03	5.57E+03	9.74E+03	3.19E+03	4.04E+03	4.36E+03	8.97E+03	2.38E+03	2.63E+03	7.87E+03	5.83E+03	6.51E+03	5.68E+03
OUT - TP Mean Annual Load (kg/yr)	62.7	1.77	3.79	11.2	19.9	6.49	8.17	8.67	18.5	5	7.05	16.1	12	13.2	11.7
OUT - TN Mean Annual Load (kg/yr)	450	12.7	26.7	78	142	45.7	56.9	60.6	129	35.6	49.7	117	87.1	89.4	80.9
OUT - Gross Pollutant Mean Annual Load (kg/yr)	3.64E+03	103	219	612	1.15E+03	360	449	480	1.05E+03	2.91E+02	264	948	7.05E+02	712	664

No Imported Data Source nodes

USTM treatment nodes															
Location	WQCP #1	WQCP #2	WQCP #3	396m	160m	356m	160m	291m	259m	200m	124m	66m	175m	190m	85m
ID	28	29	32	37	38	39	40	41	42	43	44	45	46	47	48
Node Type	PondNode	PondNode	PondNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode
Lo-flow bypass rate (cum/sec)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hi-flow bypass rate (cum/sec)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Inlet pond volume	0	0	0												
Area (sqm)	2100	1400	1700	1215	800	1780	400	727.5	1295	1000	620	165	437.5	950	212.5
Extended detention depth (m)	0.5	0.5	0.5	0.3	0.7	0.53	0.3	0.3	0.3	0.3	0.7	0.3	0.3	0.7	0.3
Permanent pool volume (cum)	3150	2100	2550												
Proportion vegetated	0.1	0.1	0.1												
Equivalent pipe diameter (mm)	300	300	300												
Overflow weir width (m)	5	5	5	3.9	5	5	3.3	3.3	5	5	5	3.3	3.3	5	3.3
Notional Detention Time (hrs)	1.97	1.31	1.59												
Orifice discharge coefficient	0.6	0.6	0.6												
Weir coefficient	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
Number of CSTR cells	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3
Total Suspended Solids k (m/yr)	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Total Suspended Solids C* (mg/L)	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
Total Suspended Solids C** (mg/L)	12	12	12												
Total Phosphorus k (m/yr)	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Total Phosphorus C* (mg/L)	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Total Phosphorus C** (mg/L)	0.13	0.13	0.13												
Total Nitrogen k (m/yr)	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Total Nitrogen C* (mg/L)	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Total Nitrogen C** (mg/L)	1.3	1.3	1.3												
Threshold hydraulic loading for C** (m/yr)	3500	3500	3500												
Extraction for Re-use	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off	Off
Annual Re-use Demand - scaled by daily PET (ML)															
Constant Daily Re-use Demand (kL)															
User-defined Annual Re-use Demand (ML)															
Percentage of User-defined Annual Re-use Demand Jan															
Percentage of User-defined Annual Re-use Demand Feb															
Percentage of User-defined Annual Re-use Demand Mar															
Percentage of User-defined Annual Re-use Demand Apr															
Percentage of User-defined Annual Re-use Demand May															
Percentage of User-defined Annual Re-use Demand Jun															
Percentage of User-defined Annual Re-use Demand Jul															
Percentage of User-defined Annual Re-use Demand Aug															
Percentage of User-defined Annual Re-use Demand Sep															
Percentage of User-defined Annual Re-use Demand Oct															
Percentage of User-defined Annual Re-use Demand Nov															
Percentage of User-defined Annual Re-use Demand Dec															
Filter area (sqm)				729	480	1068	240	436.5	777	600	372	99	262.5	570	127.5
Filter depth (m)				1	1	1	1	1	1	1	1	1	1	1	1
Filter median particle diameter (mm)				0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Saturated hydraulic conductivity (mm/hr)				180	180	180	180	180	180	180	180	180	180	180	180
Voids ratio				0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Length (m)															
Bed slope															
Base Width (m)															
Top width (m)															
Vegetation height (m)															
Proportion of upstream impervious area treated															
Seepage Rate (mm/hr)	0.36	0.36	0.36	0	0	0	0	0	0	0	0	0	0	0	0
Evap Loss as proportion of PET	1.25	1.25	1.25												
Depth in metres below the drain pipe				0	0	0	0	0	0	0	0	0	0	0	0
IN - Mean Annual Flow (ML/yr)	304	201	129	54.2	78.9	50.1	23.9	38.3	28.7	31	90.3	11.9	12.6	45.5	4.43
IN - TSS Mean Annual Load (kg/yr)	1.39E+04	1.13E+04	1.78E+03	1.07E+04	6.33E+03	9.71E+03	4.72E+03	7.36E+03	5.68E+03	6.51E+03	6.68E+03	2.63E+03	2.38E+03	8.97E+03	8.46E+02
IN - TP Mean Annual Load (kg/yr)	42.7	32.7	10.7	21.9	16.7	20.2	9.71	15	11.7	13.2	18.1	7.05	5	18.5	1.77
IN - TN Mean Annual Load (kg/yr)	451	330	153	155	152	142	67.8	111	80.9	89.4	167	49.7	35.6	129	12.7
IN - Gross Pollutant Mean Annual Load (kg/yr)	0	9.48E+02	0	1.25E+03	565	1.16E+03	555	887	664	712	705	264	291	1.05E+03	1.03E+02
OUT - Mean Annual Flow (ML/yr)	294	195	121	54.3	78.9	50.2	24	38.3	28.8	31.1	90.3	11.9	12.6	45.6	4.45
OUT - TSS Mean Annual Load (kg/yr)	1.16E+04	7.62E+03	1.95E+03	1.24E+03	1.22E+03	5.56E+02	844	1.14E+03	354	4.96E+02	1.89E+03	576	183	8.25E+02	5.06E+01
OUT - TP Mean Annual Load (kg/yr)	48.3	32.2	14.9	6.4	5.85	4.83	3.31	4.74	2.82	3.2	7.82	2.58	1.29	4.94	0.422
OUT - TN Mean Annual Load (kg/yr)	458	321	156	81.2	83.6	69.5	37.6	60.5	39.5	40.4	101	27.9	17.6	66.3	6.12
OUT - Gross Pollutant Mean Annual Load (kg/yr)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

APPENDIX C3: POST-DEVELOPMENT + TREATMENT MUSIC MODEL DATA

No Generic treatment nodes															
Other nodes															
Location	Hearns Lake														
ID	20														
Node Type	ReceivingNode														
IN - Mean Annual Flow (ML/yr)	864														
IN - TSS Mean Annual Load (kg/yr)	4.61E+04														
IN - TP Mean Annual Load (kg/yr)	169														
IN - TN Mean Annual Load (kg/yr)	1.54E+03														
IN - Gross Pollutant Mean Annual Load (kg/yr)	0														
OUT - Mean Annual Flow (ML/yr)	0														
OUT - TSS Mean Annual Load (kg/yr)	0														
OUT - TP Mean Annual Load (kg/yr)	0														
OUT - TN Mean Annual Load (kg/yr)	0														
OUT - Gross Pollutant Mean Annual Load (kg/yr)	0														
Links															
Location	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link
Source node ID	28	29	24	21	22	23	25	26	27	31	30	32	33	34	35
Target node ID	20	20	20	20	20	20	20	20	20	20	20	20	37	37	38
Muskingum-Cunge Routing	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed
Muskingum K															
Muskingum theta															
IN - Mean Annual Flow (ML/yr)	294	195	28.2	6.3	6.49	8.52	13.8	39.4	14.7	6.56	40.2	121	18.7	35.5	24.6
IN - TSS Mean Annual Load (kg/yr)	1.16E+04	7.62E+03	3.96E+03	9.63E+02	9.40E+02	1.23E+03	2.03E+03	5.72E+03	2.19E+03	7.29E+02	4.81E+03	1.95E+03	3.84E+03	6.90E+03	5.09E+03
IN - TP Mean Annual Load (kg/yr)	48.3	32.2	11.3	2.65	2.69	3.59	5.86	16.2	6.25	1.95	12.2	14.9	7.78	14.2	10.3
IN - TN Mean Annual Load (kg/yr)	458	321	85.3	18.6	19	25.1	42.2	115	45.3	16.9	103	156	54.5	100	70.9
IN - Gross Pollutant Mean Annual Load (kg/yr)	0	0.00E+00	0	0	0	0	0	0	0	0	0	0	430	822	565
OUT - Mean Annual Flow (ML/yr)	294	195	28.2	6.3	6.49	8.52	13.8	39.4	14.7	6.56	40.2	121	18.7	35.5	24.6
OUT - TSS Mean Annual Load (kg/yr)	1.16E+04	7.62E+03	3.96E+03	9.63E+02	9.40E+02	1.23E+03	2.03E+03	5.72E+03	2.19E+03	7.29E+02	4.81E+03	1.95E+03	3.84E+03	6.90E+03	5.09E+03
OUT - TP Mean Annual Load (kg/yr)	48.3	32.2	11.3	2.65	2.69	3.59	5.86	16.2	6.25	1.95	12.2	14.9	7.78	14.2	10.3
OUT - TN Mean Annual Load (kg/yr)	458	321	85.3	18.6	19	25.1	42.2	115	45.3	16.9	103	156	54.5	100	70.9
OUT - Gross Pollutant Mean Annual Load (kg/yr)	0	0.00E+00	0	0	0	0	0	0	0	0	0	0	430	822	565
Links	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link
Location	10	46	9	47	2	1	3	49	48	50	7	51	4	52	8
Source node ID	46	29	47	29	48	49	49	50	50	28	51	28	52	28	53
Target node ID	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed
Muskingum-Cunge Routing															
Muskingum K															
Muskingum theta	12.6	12.6	45.5	45.6	4.43	157	9.46	166	4.45	171	19.6	19.6	26.6	26.7	20.9
IN - Mean Annual Flow (ML/yr)	2.38E+03	183	8.97E+03	825	8.46E+02	3.05E+04	1.86E+03	1.55E+04	5.06E+01	1.00E+04	4.04E+03	6.78E+02	5.57E+03	1.45E+03	4.36E+03
IN - TSS Mean Annual Load (kg/yr)	5	1.29	18.5	4.94	1.77	62.7	3.79	39.5	0.422	27.7	8.17	2.67	11.2	4.56	8.67
IN - TP Mean Annual Load (kg/yr)	35.6	17.6	129	66.3	12.7	450	26.7	354	6.12	274	56.9	29.7	78	45.3	60.6
IN - TN Mean Annual Load (kg/yr)	291	0	1.05E+03	0	103	3.64E+03	219	0	0	0	449	0	6.12E+02	0	480
IN - Gross Pollutant Mean Annual Load (kg/yr)	12.6	12.6	45.5	45.6	4.43	157	9.46	166	4.45	171	19.6	19.6	26.6	26.7	20.9
OUT - Mean Annual Flow (ML/yr)	2.38E+03	183	8.97E+03	825	8.46E+02	3.05E+04	1.86E+03	1.55E+04	5.06E+01	1.00E+04	4.04E+03	6.78E+02	5.57E+03	1.45E+03	4.36E+03
OUT - TSS Mean Annual Load (kg/yr)	5	1.29	18.5	4.94	1.77	62.7	3.79	39.5	0.422	27.7	8.17	2.67	11.2	4.56	8.67
OUT - TP Mean Annual Load (kg/yr)	35.6	17.6	129	66.3	12.7	450	26.7	354	6.12	274	56.9	29.7	78	45.3	60.6
OUT - TN Mean Annual Load (kg/yr)	291	0	1.05E+03	0	103	3.64E+03	219	0	0	0	449	0	6.12E+02	0	480
OUT - Gross Pollutant Mean Annual Load (kg/yr)															

Catch C1	Catch C2	Catch D1	Catch D2	Catch E2	Catch E3	Catch E6	Catch E5	Catch E7	Catch E8	Catch E9	E1	E4	F1	F2	F3	F4
16	17	18	19	21	22	23	24	25	26	27	30	31	33	34	35	36
UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	AgriculturalSourceNode	AgriculturalSourceNode	AgriculturalSourceNode	AgriculturalSourceNode	AgriculturalSourceNode	AgriculturalSourceNode	AgriculturalSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode	UrbanSourceNode
1.62	2.59	0.73	1.13	0.738	0.76	0.999	3.304	1.612	4.62	1.72	4.715	0.769	1.11	2.4	1.46	3.39
1.218126316	1.947498246	0.545675	0.849680702	0	0	0	0	0	0	0	0	0	1.11	1.806	1.46	2.550975
0.401873684	0.642501754	0.184325	0.280319298	0.738	0.76	0.999	3.304	1.612	4.62	1.72	4.715	0.769	0	0.594	0	0.839025
80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2.2	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.2	2.2	2.2	2.2	2.2	2.2
0.32	0.32	0.32	0.32	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.32	0.32	0.32	0.32	0.32	0.32
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-0.45	-0.45	-0.45	-0.45	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.27	-0.45	-0.45	-0.45	-0.45	-0.45	-0.45
0.25	0.25	0.25	0.25	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.25	0.25	0.25	0.25	0.25	0.25
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.42	0.42	0.42	0.42	0.59	0.59	0.59	0.59	0.59	0.59	0.59	0.42	0.42	0.42	0.42	0.42	0.42
0.19	0.19	0.19	0.19	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.19	0.19	0.19	0.19	0.19	0.19
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.1	1.1	1.1	1.1	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.1	1.1	1.1	1.1	1.1	1.1
0.17	0.17	0.17	0.17	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.17	0.17	0.17	0.17	0.17	0.17
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
-0.82	-0.82	-0.82	-0.82	-0.88	-0.88	-0.88	-0.88	-0.88	-0.88	-0.88	-0.82	-0.82	-0.82	-0.82	-0.82	-0.82
0.19	0.19	0.19	0.19	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.19	0.19	0.19	0.19	0.19	0.19
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0.32	0.32	0.32	0.32	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.32	0.32	0.32	0.32	0.32	0.32
0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12
Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic	Stochastic
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
23.9	38.3	10.8	16.7	6.3	6.49	8.52	28.2	13.8	39.4	14.7	40.2	6.56	18.7	35.5	24.6	50.1
4.72E+03	7.36E+03	2.07E+03	3.26E+03	9.63E+02	9.40E+02	1.23E+03	3.96E+03	2.03E+03	5.72E+03	2.19E+03	4.81E+03	7.29E+02	3.84E+03	6.90E+03	5.09E+03	9.71E+03
9.71	15	4.3	6.7	2.65	2.69	3.59	11.3	5.86	16.2	6.25	12.2	1.95	7.78	14.2	10.3	20.2
67.8	111	30.5	48.3	18.6	19	25.1	85.3	42.2	115	45.3	103	16.9	54.5	100	70.9	142
555	887	250	3.87E+02	0	0	0	0	0	0	0	0	0	430	822	565	1.16E+03

140m	96m	130m	115m	200m	180m	110m	330m	159m
49	50	51	52	53	54	55	56	57
BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode	BioRetentionNode
0	0	0	0	0	0	0	0	0
100	100	100	100	100	100	100	100	100
700	595.2	325	287.5	500	900	550	1950	397.5
0.3	0.7	0.3	0.3	0.3	0.3	0.7	0.3	0.3
5	6.2	3.3	3.3	3.3	5	5	5	5
1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7	1.7
3	3	3	3	3	3	3	3	3
1000	1000	1000	1000	1000	1000	1000	1000	1000
12	12	12	12	12	12	12	12	12
500	500	500	500	500	500	500	500	500
0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
50	50	50	50	50	50	50	50	50
1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Off	Off	Off	Off	Off	Off	Off	Off	Off
420	288	195	172.5	300	540	330	990	238.5
1	1	1	1	1	1	1	1	1
0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
180	180	180	180	180	180	180	180	180
0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
166	171	19.6	26.6	20.9	49.9	65.6	16.7	10.8
3.24E+04	1.55E+04	4.04E+03	5.57E+03	4.36E+03	9.74E+03	4.67E+03	3.26E+03	2.07E+03
66.5	40	8.17	11.2	8.67	19.9	12.9	6.7	4.3
477	360	56.9	78	60.6	142	124	48.3	30.5
3.85E+03	0	449	612	480	1.15E+03	360	387	250
166	171	19.6	26.7	20.9	49.9	65.6	16.8	10.8
1.55E+04	1.00E+04	678	1.45E+03	506	1.48E+03	1.27E+03	179	1.58E+02
39.5	27.7	2.67	4.56	2.4	6.43	5.31	1.6	1.1
354	274	29.7	45.3	28.9	78	72.5	22.8	15
0	0	0	0	0	0	0	0	0

Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link
37	36	38	39	16	17	40	41	15	14	13	43	42	44	12	11	45
38	39	32	32	40	41	20	20	42	43	44	44	44	29	29	45	29
Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed
54.3	50.1	78.9	50.2	23.9	38.3	24	38.3	28.7	31	30.4	31.1	28.8	90.3	40.9	11.9	11.9
1.24E+03	9.71E+03	1.22E+03	5.56E+02	4.72E+03	7.36E+03	8.44E+02	1.14E+03	5.68E+03	6.51E+03	5.83E+03	4.96E+02	3.54E+02	1.89E+03	7.87E+03	2.63E+03	5.76E+02
6.4	20.2	5.85	4.83	9.71	15	3.31	4.74	11.7	13.2	12	3.2	2.82	7.82	16.1	7.05	2.58
81.2	142	83.6	69.5	67.8	111	37.6	60.5	80.9	89.4	87.1	40.4	39.5	101	117	49.7	27.9
0	1.16E+03	0	0	555	887	0	0.00E+00	664	712	705	0	0	0	948	264	0
54.3	50.1	78.9	50.2	23.9	38.3	24	38.3	28.7	31	30.4	31.1	28.8	90.3	40.9	11.9	11.9
1.24E+03	9.71E+03	1.22E+03	5.56E+02	4.72E+03	7.36E+03	8.44E+02	1.14E+03	5.68E+03	6.51E+03	5.83E+03	4.96E+02	3.54E+02	1.89E+03	7.87E+03	2.63E+03	5.76E+02
6.4	20.2	5.85	4.83	9.71	15	3.31	4.74	11.7	13.2	12	3.2	2.82	7.82	16.1	7.05	2.58
81.2	142	83.6	69.5	67.8	111	37.6	60.5	80.9	89.4	87.1	40.4	39.5	101	117	49.7	27.9
0	1.16E+03	0	0	555	887	0	0.00E+00	664	712	705	0	0	0	948	264	0
Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link	Drainage Link								
53	5	6	54	55	19	56	18	57								
28	54	55	55	28	56	20	57	20								
Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed	Not Routed								
20.9	49.9	15.7	49.9	65.6	16.7	16.8	10.8	10.8								
5.06E+02	9.74E+03	3.19E+03	1.48E+03	1.27E+03	3.26E+03	179	2.07E+03	158								
2.4	19.9	6.49	6.43	5.31	6.7	1.6	4.3	1.1								
28.9	142	45.7	78	72.5	48.3	22.8	30.5	15								
0	1.15E+03	360	0	0	387	0	250	0								
20.9	49.9	15.7	49.9	65.6	16.7	16.8	10.8	10.8								
5.06E+02	9.74E+03	3.19E+03	1.48E+03	1.27E+03	3.26E+03	179	2.07E+03	158								
2.4	19.9	6.49	6.43	5.31	6.7	1.6	4.3	1.1								
28.9	142	45.7	78	72.5	48.3	22.8	30.5	15								
0	1.15E+03	360	0	0	387	0	250	0								

APPENDIX D

WQCP STORAGE VOLUME CALCULATIONS

APPENDIX D1: WQCP 1 Calculations for Attenuation Storage Volume Required

Rainfall Event Duration-Intensity

Event ARI (yrs)	100
Duration (min.)	Intensity (mm/hr)
10	229
20	172
30	143
60	101
120	67
180	52
360	33.6

Catchment Parameters

	C	A (m2)
Impervious	1.00	149,330
Pervious	0.79	52,680
	0.95	202,010

T_c (min.)	24.80

Max. Allowable Outflow

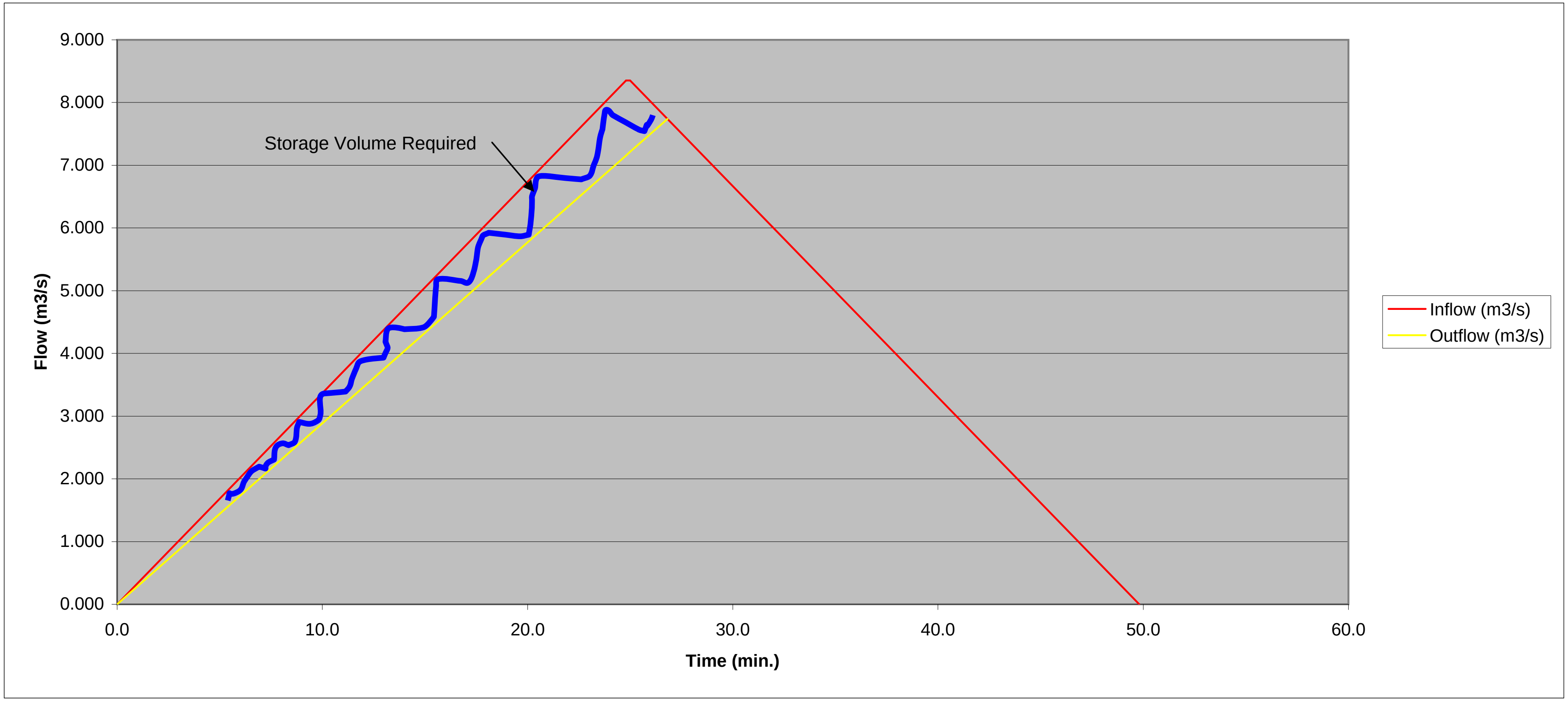
Peak (m3/s)	7.74

Storage Volume Required

Duration (min.)	Intensity (mm/hr)	Peak Inflow (m3/s) - Q=CiA			Volume (m3) *	
		Impervious	Pervious	Total		
10	229.0	9.499	2.647	12.146	NA	
15	200.5	8.317	2.318	10.635	NA	
20	172.0	7.135	1.988	9.123	NA	
25	157.5	6.533	1.821	8.354	967	Critical
30	143.0	5.932	1.653	7.585	NA	
35	136.0	5.641	1.572	7.214	NA	
40	129.0	5.351	1.491	6.842	NA	
45	122.0	5.061	1.410	6.471	NA	
50	115.0	4.770	1.329	6.100	NA	
55	108.0	4.480	1.249	5.728	NA	
60	101.0	4.190	1.168	5.357	NA	
70	95.3	3.954	1.102	5.057	NA	
80	89.7	3.719	1.037	4.756	NA	
90	84.0	3.484	0.971	4.455	NA	
100	78.3	3.249	0.906	4.155	NA	
110	72.7	3.014	0.840	3.854	NA	
120	67.0	2.779	0.775	3.554	NA	
130	64.5	2.675	0.746	3.421	NA	
140	62.0	2.572	0.717	3.289	NA	
150	59.5	2.468	0.688	3.156	NA	
160	57.0	2.364	0.659	3.023	NA	
170	54.5	2.261	0.630	2.891	NA	
180	52.0	2.157	0.601	2.758	NA	
200	50.0	2.072	0.578	2.650	NA	
220	47.9	1.987	0.554	2.541	NA	
240	45.9	1.903	0.530	2.433	NA	
260	43.8	1.818	0.507	2.324	NA	
280	41.8	1.733	0.483	2.216	NA	
300	39.7	1.648	0.459	2.107	NA	
320	37.7	1.563	0.436	1.999	NA	
340	35.6	1.479	0.412	1.891	NA	
360	33.6	1.394	0.388	1.782	NA	

* Critical duration chosen for corresponding maximum storage volume required. Note that duration must be >= to Tc to ensure all catchment area is contributing runoff to peak inflow and peak inflow must be >= to peak outflow, otherwise volume given as NA.

WQCP 1 Hydrograph Plot of Attenuation Storage Volume Required



Critical Event Duration (min.)	25
T_c (min.)	24.8
Peak Inflow (m3/s)	8.354
Peak Outflow (m3/s)	7.74

Graph Coordinates

Time (min.)	Inflow (m3/s)	Outflow (m3/s)
0.0	0.000	0.000
24.8	8.354	7.156
25.0	8.354	7.214
26.8	7.740	7.740
49.8	0.000	

APPENDIX D2: WQCP 2 Calculations for Attenuation Storage Volume Required

Rainfall Event Duration-Intensity

Event ARI (yrs)	100
Duration (min.)	Intensity (mm/hr)
10	229
20	172
30	143
60	101
120	67
180	52
360	33.6

Catchment Parameters

	C	A (m2)
Impervious	1.00	98,675
Pervious	0.79	36,025
	0.94	134,700

T_c (min.)	21.30

Max. Allowable Outflow

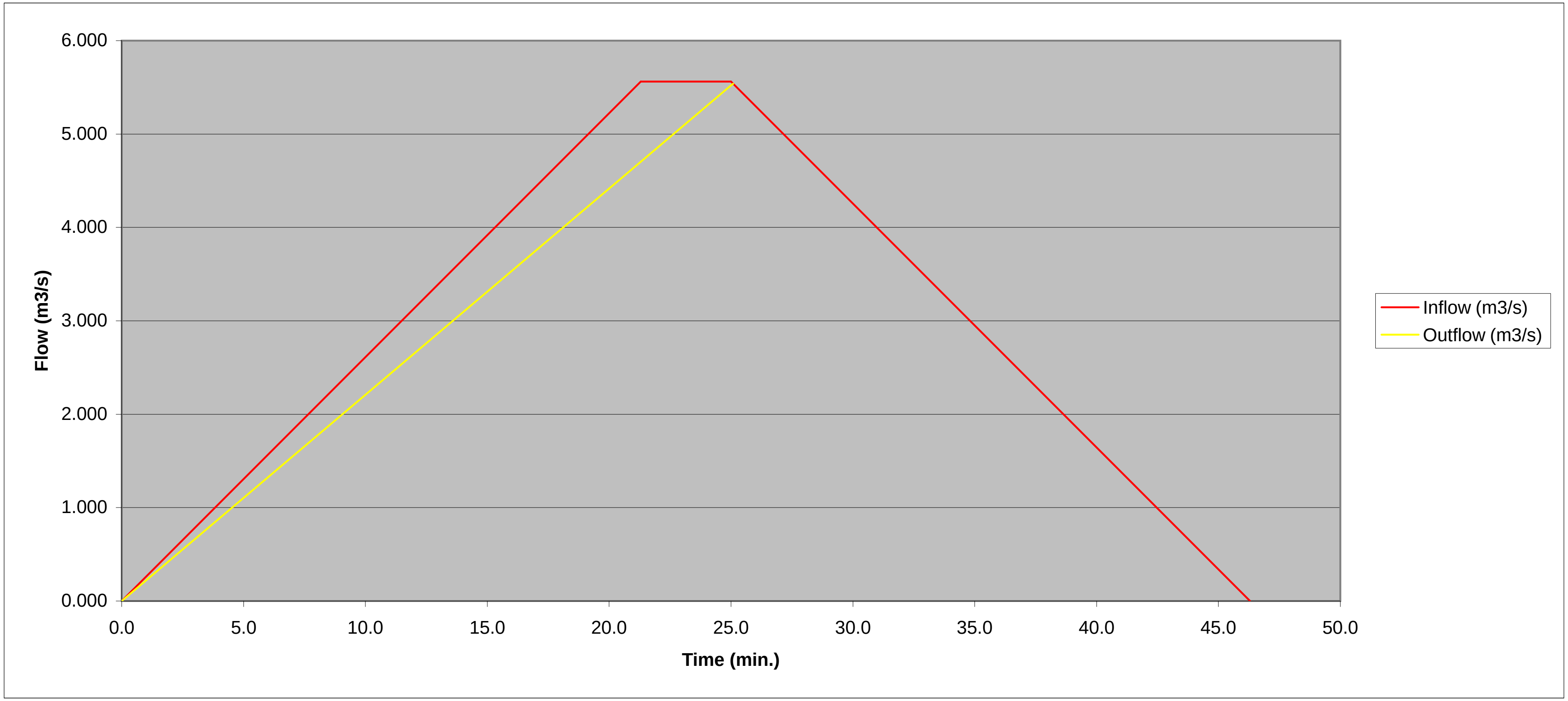
Peak (m3/s)	5.54

Storage Volume Required

Duration (min.)	Intensity (mm/hr)	Inflow (m3/s) - Q=CiA			Volume (m3) *	
		Impervious	Pervious	Total		
10	229.0	6.277	1.810	8.087	NA	
15	200.5	5.496	1.585	7.081	NA	
20	172.0	4.714	1.360	6.074	NA	
25	157.5	4.317	1.245	5.562	648	Critical
30	143.0	3.920	1.130	5.050	NA	
35	136.0	3.728	1.075	4.803	NA	
40	129.0	3.536	1.020	4.556	NA	
45	122.0	3.344	0.964	4.308	NA	
50	115.0	3.152	0.909	4.061	NA	
55	108.0	2.960	0.854	3.814	NA	
60	101.0	2.768	0.798	3.567	NA	
70	95.3	2.613	0.754	3.367	NA	
80	89.7	2.458	0.709	3.167	NA	
90	84.0	2.302	0.664	2.966	NA	
100	78.3	2.147	0.619	2.766	NA	
110	72.7	1.992	0.574	2.566	NA	
120	67.0	1.836	0.530	2.366	NA	
130	64.5	1.768	0.510	2.278	NA	
140	62.0	1.699	0.490	2.190	NA	
150	59.5	1.631	0.470	2.101	NA	
160	57.0	1.562	0.451	2.013	NA	
170	54.5	1.494	0.431	1.925	NA	
180	52.0	1.425	0.411	1.836	NA	
200	50.0	1.369	0.395	1.764	NA	
220	47.9	1.313	0.379	1.692	NA	
240	45.9	1.257	0.363	1.620	NA	
260	43.8	1.201	0.346	1.548	NA	
280	41.8	1.145	0.330	1.475	NA	
300	39.7	1.089	0.314	1.403	NA	
320	37.7	1.033	0.298	1.331	NA	
340	35.6	0.977	0.282	1.259	NA	
360	33.6	0.921	0.266	1.187	NA	

* Critical duration chosen for corresponding maximum storage volume required. Note that duration must be >= to Tc to ensure all catchment area is contributing runoff to peak inflow and peak inflow must be >= to peak outflow, otherwise volume given as NA.

WQCP 2 Hydrograph Plot of Attenuation Storage Volume Required



Specify Event Duration (min.)	25
T_c (min.)	21.3
Peak Inflow (m3/s)	5.562
Peak Outflow (m3/s)	5.54

Graph Coordinates

Time (min.)	Inflow (m3/s)	Outflow (m3/s)
0.0	0.000	0.000
21.3	5.562	4.704
25.0	5.562	5.521
25.1	5.540	5.540
46.3	0.000	

APPENDIX D3: WQCP 3 Calculations for Attenuation Storage Volume Required

Rainfall Event Duration-Intensity

Event ARI (yrs)	100
Duration (min.)	Intensity (mm/hr)
10	229
20	172
30	143
60	101
120	67
180	52
360	33.6

Catchment Parameters

	C	A (m2)
Impervious	1.00	59,370
Pervious	0.79	24,230
	0.94	83,600

T_c (min.)	17.80

Max. Allowable Outflow

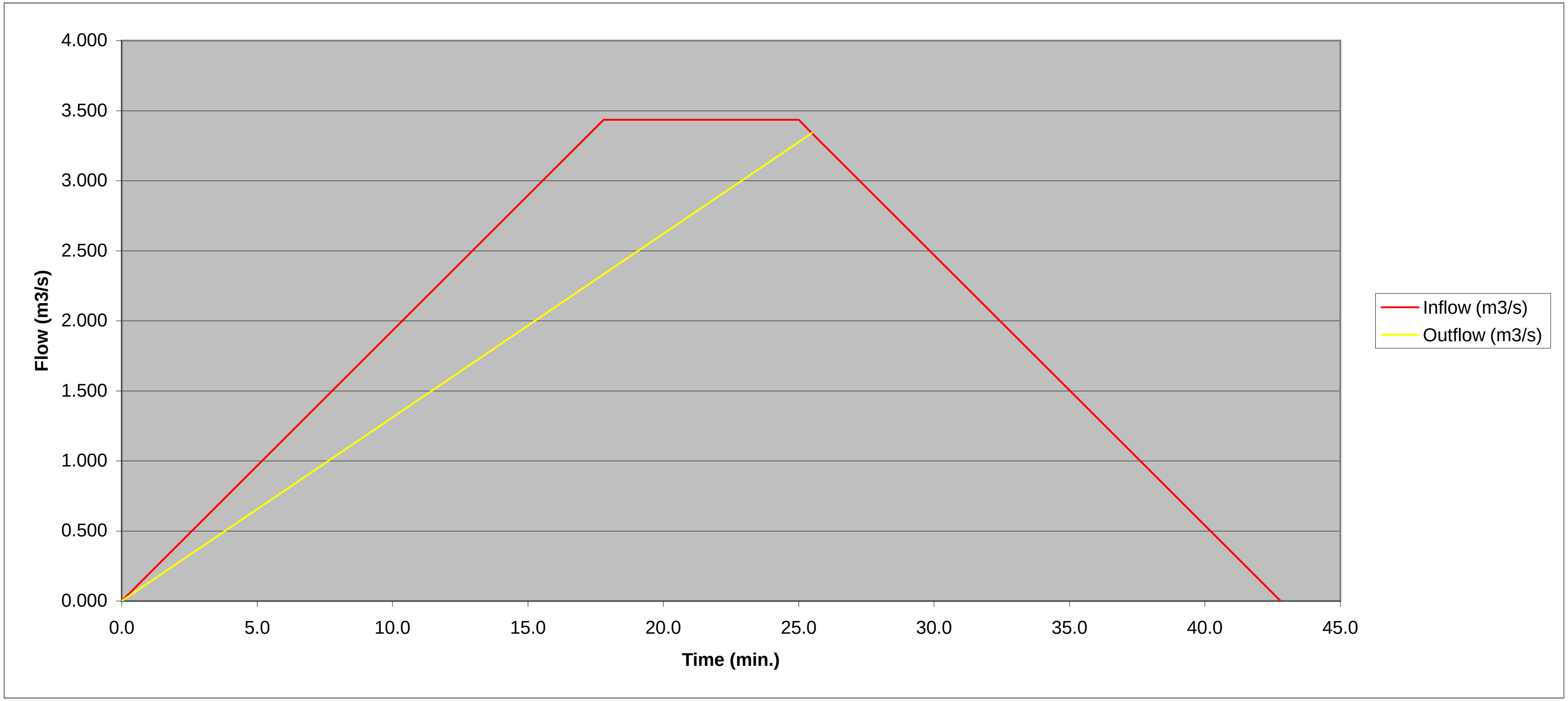
Peak (m3/s)	3.341

Storage Volume Required

Duration (min.)	Intensity (mm/hr)	Inflow (m3/s) - Q=CiA			Volume (m3) *	
		Impervious	Pervious	Total		
10	229.0	3.777	1.218	4.994	NA	
15	200.5	3.307	1.066	4.373	NA	
20	172.0	2.837	0.915	3.751	713	
25	157.5	2.597	0.837	3.435	862	Critical
30	143.0	2.358	0.760	3.119	NA	
35	136.0	2.243	0.723	2.966	NA	
40	129.0	2.127	0.686	2.813	NA	
45	122.0	2.012	0.649	2.661	NA	
50	115.0	1.897	0.611	2.508	NA	
55	108.0	1.781	0.574	2.355	NA	
60	101.0	1.666	0.537	2.203	NA	
70	95.3	1.572	0.507	2.079	NA	
80	89.7	1.479	0.477	1.956	NA	
90	84.0	1.385	0.447	1.832	NA	
100	78.3	1.292	0.417	1.708	NA	
110	72.7	1.198	0.386	1.585	NA	
120	67.0	1.105	0.356	1.461	NA	
130	64.5	1.064	0.343	1.407	NA	
140	62.0	1.022	0.330	1.352	NA	
150	59.5	0.981	0.316	1.298	NA	
160	57.0	0.940	0.303	1.243	NA	
170	54.5	0.899	0.290	1.189	NA	
180	52.0	0.858	0.276	1.134	NA	
200	50.0	0.824	0.266	1.089	NA	
220	47.9	0.790	0.255	1.045	NA	
240	45.9	0.756	0.244	1.000	NA	
260	43.8	0.723	0.233	0.956	NA	
280	41.8	0.689	0.222	0.911	NA	
300	39.7	0.655	0.211	0.867	NA	
320	37.7	0.622	0.200	0.822	NA	
340	35.6	0.588	0.190	0.777	NA	
360	33.6	0.554	0.179	0.733	NA	

* Critical duration chosen for corresponding maximum storage volume required. Note that duration must be >= to Tc to ensure all catchment area is contributing runoff to peak inflow and peak inflow must be >= to peak outflow, otherwise volume given as NA.

WQCP 3 Hydrograph Plot of Attenuation Storage Volume Required



Specify Event Duration (min.)	25
T_c (min.)	17.8
Peak Inflow (m3/s)	3.435
Peak Outflow (m3/s)	3.341

Graph Coordinates

Time (min.)	Inflow (m3/s)	Outflow (m3/s)
0.0	0.000	0.000
17.8	3.435	2.333
25.0	3.435	3.277
25.5	3.341	3.341
42.8	0.000	

APPENDIX E

BIO-RETENTION SWALE DESIGN CALCULATIONS

APPENDIX E1: Check on Bioretention Swale Capacities and Corresponding Full Capacity Storage Volumes

WSUD	Swale ID	Check on Swale Capacities						Swale Geometric Dimensions and Full Capacity Storage Volumes							
		Contributing Sub-catchments	100yr ARI Peak Flow (m3/s)	Cover Type	Size	Capacity (m3/s)	Is Capacity > Peak Flow?	Length (m)	Surface Width (m)	Extended Detention Depth (m)	Filter Width (m)	Surface Area (m2)	Filter Area (m2)	Storage Volume (m3)	**Sub-total Storage Volume (m3)**
Swale to WQCP 1	BS1	A3 + 0.2*A1	1.179	Grass	Large	1.310	yes	140	5.0	0.3	3.0	700	420	168	
	BS2	A2 + 0.1*A1	0.581	Grass	Standard	0.630	yes	85	2.5	0.3	1.5	213	128	51	
	BS3	A1 + A2+ A3	4.932	Grass	Easement	4.790	yes*	96	6.2	0.7	3.0	595	288	309	
	BS4	A4	0.674	Grass	Standard	0.630	yes*	115	2.5	0.3	1.5	288	173	69	
	BS5	A8	1.592	Grass	Large	1.310	yes*	180	5.0	0.3	3.0	900	540	216	
	BS6	A6 + A8	1.989	Grass	Easement	3.260	yes	110	5.0	0.7	3.0	550	330	308	
	BS7	A5	0.475	Grass	Standard	0.630	yes	130	2.5	0.3	1.5	325	195	78	
	BS8	A7	0.529	Grass	Standard	0.630	yes	200	2.5	0.3	1.5	500	300	120	1319
Swale to WQCP 2	BS9	0.5*B2	0.187	Grass	Standard	0.630	yes	70	2.5	0.3	1.5	175	105	42	
	BS10	B1 + 0.5*B4	1.989	Vegetation	Easement	2.540	yes	190	5.0	0.7	3.0	950	570	532	
	BS11	0.5*B2	0.187	Grass	Standard	0.630	yes	105	2.5	0.3	1.5	263	158	63	
	BS12	B3	0.395	Grass	Standard	0.630	yes	66	2.5	0.3	1.5	165	99	40	
	BS13	B5 + B6 + B7	2.600	Grass	Easement	3.260	yes	124	5.0	0.7	3.0	620	372	347	
	BS14	B7	0.864	Grass	Large	1.310	yes	74	5.0	0.3	3.0	370	222	89	
	BS15	B7	0.864	Grass	Large	1.310	yes	185	5.0	0.3	3.0	925	555	222	
	BS16	B6	0.819	Grass	Large	1.310	yes	200	5.0	0.3	3.0	1000	600	240	1575
Swale	BS17	0.5*C1	0.427	Grass	Standard	0.630	yes	108	2.5	0.3	1.5	270	162	65	
	BS18	0.5*C1	0.427	Grass	Standard	0.630	yes	52	2.5	0.3	1.5	130	78	31	
	BS19	0.25*C2	0.341	Grass	Standard	0.630	yes	96	2.5	0.3	1.5	240	144	58	
	BS20	0.25*C2	0.341	Grass	Standard	0.630	yes	50	2.5	0.3	1.5	125	75	30	
	BS21	0.25*C2	0.341	Grass	Standard	0.630	yes	95	2.5	0.3	1.5	238	143	57	
	BS22	0.25*C2	0.341	Grass	Standard	0.630	yes	50	2.5	0.3	1.5	125	75	30	271
Swale to WQCP 3	BS23	0.5*F1	0.128	Grass	Standard	0.630	yes	70	2.5	0.3	1.5	175	105	42	
	BS24	0.5*F1 + F2	1.442	Grass	Large	1.310	yes*	90	5.0	0.3	3.0	450	270	108	
	BS25	0.5*F2	0.593	Grass	Standard	0.630	yes	100	2.5	0.3	1.5	250	150	60	
	BS26	F1 + F2 + 0.6*F3	2.130	Grass	Easement	3.260	yes	160	5.0	0.7	3.0	800	480	448	
	BS27	0.4*F4	0.670	Grass	Standard	0.630	yes*	90	2.5	0.3	1.5	225	135	54	
	BS28	0.4*F3 + F4	1.963	Grass	Easement	3.260	yes	47	5.0	0.7	3.0	235	141	132	
	BS29	0.6*F4	1.005	Grass	Large	1.310	yes	219	5.0	0.3	3.0	1095	657	263	
	BS30	0.5*F2	0.593	Grass	Standard	0.630	yes	136	2.5	0.3	1.5	340	204	82	1188
Swale	BS31	D2	0.734	Vegetation	Large	1.020	yes	45	5.0	0.3	3.0	225	135	54	
	BS32	D2	0.734	Vegetation	Large	1.020	yes	40	5.0	0.3	3.0	200	120	48	
	BS33	D1	0.442	Vegetation	Standard	0.490	yes	115	2.5	0.3	3.0	288	345	95	
	BS34	D1	0.442	Vegetation	Standard	0.490	yes	44	2.5	0.3	1.5	110	66	26	
	BS35	D2	0.734	Vegetation	Large	1.020	yes	245	5.0	0.3	1.5	1225	368	239	462

* The capacity of the swale is only marginally less than the estimated peak flow and therefore is accepted.

APPENDIX E2: Rational Method Generation of Post-development Sub-catchment Flows

Rational Formula; $q_p = CiA$

Runoff Coefficient

	Impervious	Pervious
C	1.00	0.79

Rainfall Intensity (based on catchment T_c)

i (mm/hr)	
A	162.12
B	169.15
C	200.18
D	228.86
F	187.64

Sub-catchment Area & Corresponding Peak Flow

Catchment	Area (ha)			Peak Flow (m3/s)		
	Impervious	Pervious	Total	Impervious	Pervious	Total
A1	7.964	2.655	10.619	3.587	0.945	4.531
A2	0.225	0.075	0.300	0.101	0.027	0.128
A3	0.480	0.160	0.640	0.216	0.057	0.273
A4	1.185	0.395	1.580	0.534	0.141	0.674
A5	0.653	0.508	1.161	0.294	0.181	0.475
A6	0.698	0.233	0.931	0.314	0.083	0.397
A7	0.930	0.310	1.240	0.419	0.110	0.529
A8	2.798	0.933	3.731	1.260	0.332	1.592
			20.202			8.600
B1	2.311	0.770	3.081	1.086	0.286	1.372
B2	0.63	0.21	0.840	0.296	0.078	0.374
B3	0.47	0.47	0.940	0.221	0.175	0.395
B4	2.078	0.693	2.771	0.976	0.257	1.234
B5	1.545	0.515	2.060	0.726	0.191	0.917
B6	1.38	0.46	1.840	0.648	0.171	0.819
B7	1.455	0.485	1.940	0.684	0.180	0.864
			13.472			5.975
C1	1.215	0.405	1.620	0.676	0.178	0.854
C2	1.943	0.648	2.591	1.080	0.285	1.365
			4.211			2.219
D1	0.55	0.183	0.733	0.350	0.092	0.442
D2	0.914	0.305	1.219	0.581	0.153	0.734
			1.952			1.176
F1	0.5	0.611	1.111	0.261	0.252	0.512
F2	1.8	0.6	2.400	0.938	0.247	1.185
F3	1.095	0.365	1.460	0.571	0.150	0.721
F4	2.543	0.848	3.391	1.325	0.349	1.675
			8.362			4.094

APPENDIX F

WATER QUALITY CONTROL POND SIZING

SUB-CATCHMENT PARAMETERS

SUB-CATCHMENT CALCULATIONS

Refer to 'music_catchmentsdgn'.

ID	Land Use	Total Development Area (ha)	Area to WQCP (ha)	Area to WQCP (m2)	Yield
A	Medium density residential	20.200	20.2	202000	75
B		13.470	13.47	134,700	75
C		4.657	0.00	0	75
D		1.864	0.00	0	75
F		8.360	8.36	83,600	75
E	Agricultural	19.237	0.00	0	10

FEASABILITY OF WQCP'S AT THE SITE

PERCENTAGE CATCHMENT AREA METHOD

Refer to 'Constructed Wetlands Manual - Volume 2' Section 16.3.2.1

The feasability of incorporating WQCP's within the development site can be prelimarily assessed using *Equation 16-2* of the *'Constructed Wetlands Manual - Volume 2'* .

Wetland Area / Total Catchment Area x 100 > 2%

Sub-catchment ID	Area (m^2)	Required Surface Area of Wetland (m^2)	Preliminary dimensions			Land Available
WQCP 1	202,000	4040	37	x	110	yes
WQCP 2	134,700	2694	30	x	90	yes
WQCP 3	83,600	1672	23.6	x	71	yes

ANALYSIS OF SUB-CATCHMENT RUNOFF VOLUMES

CATCHMENT RUNOFF CALCULATIONS

Refer to 'Constructed Wetlands Manual - Volume 2' , Dialogue Box 16-1

Mean Annual Rainfall (mm) = 1687

Mean annual rainfall is derived from the daily rainfall records for the Coffs Harbour MO rainfall station (No. 59039) for the period 1970-2002.

Yield Factor (impervious surfaces) = 75

Yield factors are for impervious surfaces in cases where mean annual rainfall is > 1100mm. Values have been derived from *Table 10-5* in the *'Constructed Wetlands Manual - Volume 1'* . A yield factor of 70 is the lower range value for impervious surfaces however this is still considered conservative as there are is a component of pervious surfaces within each sub-catchment.

Sub-catchment ID	Land Use	Area (ha)	Yield	Runoff (m^3/day)
WQCP 1	Medium density residential	20.2	70	654
WQCP 2		13.47	70	436
WQCP 3		8.36	70	270

ID	WSUD	Sub-Catchment Area (ha)	Yield	Runoff (m^3/day)
A1	swale to WQCP 1	10.620	70	344
A2		0.300	70	10
A3		0.640	70	21
A4		1.580	70	51
A5		1.160	70	38
A6		0.930	70	30
A7		1.240	70	40
A8		3.730	70	121
B1	swale to WQCP 2	3.080	70	100
B2		0.840	70	27
B3		0.940	70	30
B4		2.770	70	90
B5		2.060	70	67
B6		1.840	70	60
B7		1.940	70	63
F1	swale to WQCP 3	1.110	70	36
F2		2.400	70	78
F3		1.460	70	47
F4		3.390	70	110

ANALYSIS OF WQCP VOLUMES

GENERIC CURVE METHOD

Refer to 'Constructed Wetlands Manual - Volume 2' Section 16.3.2.2

Coffs Harbour City Council has no specific guidelines for pollutant removal from new residential sub-divisions. However, as runoff will eventually runoff into Hearns Lake, measures should be implemented to ensure that nutrient and turbidity levels are maintained at acceptable levels. The design criteria applied is therefore based on the existing condition.

The design criteria applied below assumes 30% removal of TP. Based on this criteria, the pollutant removal curve in Figure 16-13 of the 'Constructed Wetlands Manual - Volume 2', can be used to determine the hydraulic residence time.

Hydraulic Residence time, HRT (days) = 2.5

The results derived are based on the pollutant removal curves shown at left taken from the 'Constructed Wetlands Manual'.

Sub-catchment ID	Runoff (m^3/day)	Volume (m^3)	Predicted % Reduction in Pollutant Concentration		
			TP	TN	TSS
WQCP 1	654	1634	> 30%	~26%	~38%
WQCP 2	436	1090	> 30%	~26%	~38%
WQCP 3	270	676	> 30%	~26%	~38%

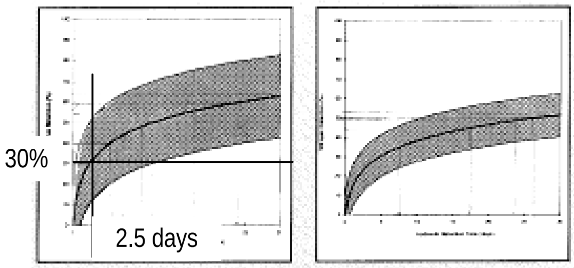
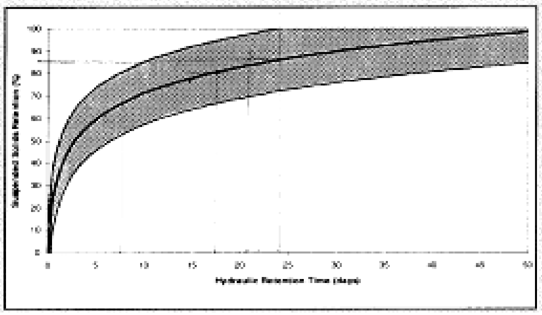


Figure 16-15 Sediment removal - generic curve.



ANALYSIS OF AVERAGE DEPTH OF WQCP'S

GENERIC CURVE METHOD

Refer to 'Constructed Wetlands Manual - Volume 2' Section 16.3.1.2

In the absence of data (ratio particulate P to dissolved P), the *'Constructed Wetlands Manual - Volume 2'* recommends applying a volume ratio of 2:1. *Figure 16-8* from the *'Constructed Wetlands Manual - Volume 2'* can then be used to calculate the average depth.

Average depth based on Fig *16-8* (m) = 0.78

MODIFIED MEAN ANNUAL RUNOFF METHOD

Refer to 'Constructed Wetlands Manual - Volume 2' Section 16.3.1.2

Based on *Figure 16-6* of the *'Constructed Wetlands Manual - Volume 2')* a ratio of open water to reed beds of 1:4 is considered optimal in terms of habitat diversity and water quality. Using this value and *Figure 16-9* from the *'Constructed Wetlands Manual - Volume 2'* the average depth can then be calculated.

Average depth based on Fig *16-9* (m) = 0.62

To be conservative the higher value of 0.78 metres has been adopted.

ANALYSIS OF WQCP SURFACE AREA

GENERIC CURVE METHOD

Refer to 'Constructed Wetlands Manual - Volume 2' Section 16.3.2.2

Using the volume and average depth determined previously and applying *Equation 16-4* of the *'Constructed Wetlands Manual - Volume 2'* the surface area of the WQCP can be calculated.

$$\text{Wetland Area } (m^2) = \text{Wetland Volume } (m^3) / d_{AV} \text{ (m)}$$

Sub-catchment ID	Volume (m^3)	Average Depth (m)	Surface Area (m^2)	Potential Dimensions		
WQCP 1	1634	0.78	2095	26	x	79
WQCP 2	1090	0.78	1397	22	x	65
WQCP 3	676	0.78	867	17.0	x	51