STORMWATER MANAGEMENT STRATEGY

Subdivision of
Lot 1 DP 1087105 & Lot 4 DP 1087106
Leo Drive, Narrawallee

Prepared for: Hazcorp Pty Ltd
C/- Peter Lean Pty. Ltd.
PO Box 252
CROYDON NSW 2132

Submitted by: J. Wyndham Prince Pty. Ltd.
77 Union Rd.
PENRITH NSW 2750
Telephone: (02) 4732 3366
Facsimile: (02) 4721 7638

DOCUMENT CONTROL SHEET

Issue	Amendment	Prepared by & Date	Checked by & Date	Approved by & Date
A	First Issue	PM (20-04-05)	PM (21-04-05)	PM (21-04-05)
B	Second Issue	ER (14-11-06)	PM (15-11-06)	PM (15-11-06)
C	Third Issue	ER (17-11-06)	PM (20-11-06)	PM (20-11-06)

CONTENTS

LIST OF TABLES

1 INTRODUCTION

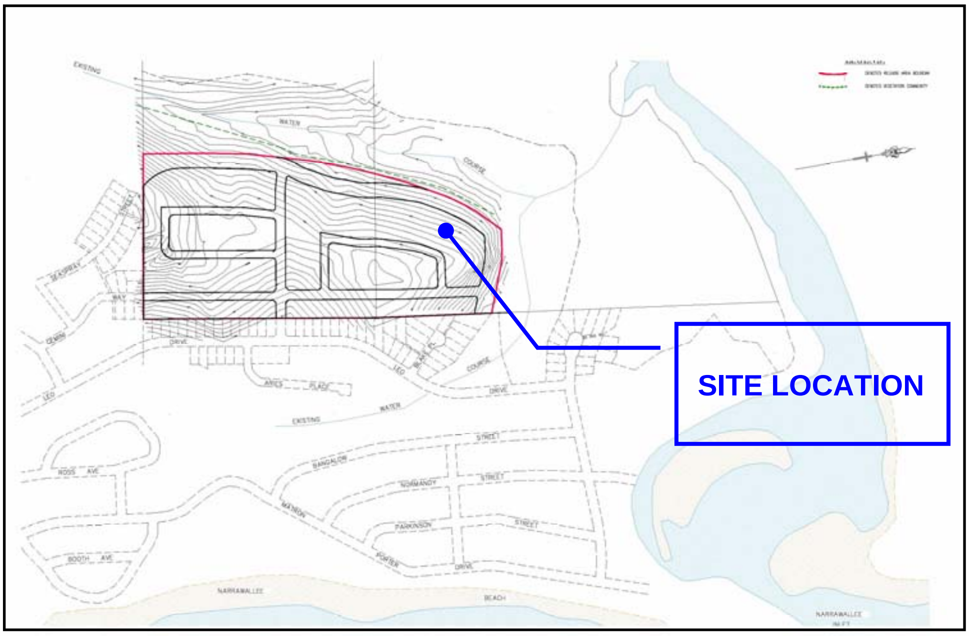
This report details the procedures used and presents the results of the various investigations undertaken in developing a Stormwater Management Strategy to integrate with and support the development planning process for the proposed subdivision of Lot 1 DP 1087105 and Lot 4 in DP 1087106 at Leo Drive, Narrawallee. The objectives of this investigation include (1) the identification of stormwater issues that need to be considered in the detailed planning, design and development of the Leo Drive, Narrawallee development, (2) the identification of appropriate options and locations for the control of the quantity and quality of stormwater leaving the site and (3) the identification of land areas required to implement the recommended options.

The investigation addresses engineering, environmental, social and economic considerations and places a strong focus on conserving and enhancing the bio-diversity, ecological health and positive water quality benefits within the existing riparian corridor to provide an integrated natural resource for the incoming residents.

2 THE EXISTING ENVIRONMENT

2.1 The Site

The site comprises Lot 1 DP 1087105 and Lot 4 DP 1087106 off Leo Drive, Narrawallee and is located within the Shoalhaven Local Government Area. Bordering the site are the properties fronting Leo Drive and Blake Place to the east, a dense bushland to the north and west and the properties fronting Seaspray Street and Gemini Way to the south. The location of the proposed Narrawallee development is shown in the figure below and more details of the said development can be found in Figure 1 of the Attachments.



2.2 Rainfall Data

2.2.1 Rainfall Data

Rainfall records for the Narrawallee / Milton area were obtained from the Bureau of Meteorology (BOM). The details of these rainfall data are shown in Table 2.1 below.

Table 2.1
Rainfall Records Used For Narrawallee Subdivision

Station	Location	Years of Record	Type of Data
68203	Sassafras (Ettrema)	1965-1972, 1974-1983	6 minute
69016	Milton Post Office	1876 - 2005	daily

2.2.2 Intensity-Frequency-Duration (I.F.D.)

Design rainfall Intensity-Frequency-Duration (I.F.D.) data for the site was obtained using the methods set out in Australian Rainfall and Runoff (AR&R 1987, Ref. 1). A summary of the rainfall intensities adopted in this study is given in Table 2.2. These values were used to determine the critical storm duration for each sub-catchment.

The models used to examine the performance of each catchment utilised temporal patterns for synthetic design storms as detailed in AR&R 1987.

Table 2.2
Narrawallee Rainfall Intensities

Storm Duration (min)	Rainfall Intensity (mm/hr)	
	5 year ARI	100 year ARI
5	175	288
10	137	230
15	117	200
20	103	179
25	93	163
30	85	151
45	69	125
60	59	107
90	47	86
120	39	72
180	31	57
270	24	44
360	20	37
540	15	29
720	13	24
1080	10	19
1440	8	16
2880	5	10

2.3 Existing Drainage System

Drainage of the site is dictated by its landform of which the main characteristic is a central ridge running through it from north to south. In consideration of natural drainage directions, the site can be subdivided into three subcatchments: northern, western and eastern. A description of each subcatchment is presented below. The lines and points of discharge for these three subcatchments at the perimeter of the site are shown in Figure 2 of the Attachments.

Northern Catchment. With an area of 3.5 Ha, this catchment occupies the north eastern corner of the site and drains north towards the eastern tributary of the unnamed watercourse.

Western Catchment. Having an area 10.3 Ha, this catchment is the largest of the three. It generally drains in a westward direction into the existing swamp forest and eventually into the unnamed watercourse that drains into Narrawallee Inlet.

Eastern (Leo Drive) Catchment. Covering an area of 8.2 Ha, this catchment drains in an easterly direction into the street drainage system which services Leo Drive. Stormwater from this existing system is discharged further to the existing swamp forest located on the eastern side of Aries Place.

2.4 The Proposed Development

The proposed residential development covers an area of approximately 22 Ha consisting of 168 residential and 3 public reserves including the associated road and drainage networks. The dwellings are to be built above the regional 100 year ARI flood level. The proposed development layout is indicated in Figure 2 of the Attachments.

3 DEVELOPMENT GUIDELINES

3.1 Council's Stormwater Requirements

Council's guidelines relating to water quantity and water quality management for land development are set out in the Shoalhaven City Council's Subdivision Code (DCP 100, Ref. 2).

The main objectives extracted from DCP 100 are as follows:

Stormwater Drainage

Major Systems

- *To provide a stormwater system which adequately protects the natural and built environment at the acceptable level of risk.*
- *To provide a major system which is economically maintainable, taking account life cycle costs.*
- *To control flooding and maintain road access in accordance with accepted levels of service.*
- *To minimise the risk of traffic accidents related to flooded roads in accordance with the accepted level of risk.*

Minor Systems

- *To consider damage by stormwater to property such as houses and gardens.*
- *To provide a minor system that takes account of the whole of life-cycle costs and minimise nuisance flooding.*
- *To reduce localised flooding to a level which adequately protects the community.*
- *To minimise the risk of traffic accidents by reducing the contributing factor of water on roads in a minor storm event.*

Stormwater Quality Management

- *To ensure that existing downstream systems are not adversely affected and ensure no net increase in pollution levels discharging from the development.*
- *The interception and treatment of pollutants through the use of appropriate water quality control measures prior to discharge to receiving waters, including wetlands, lakes and ponds.*
- *The drainage system optimises control of any accumulation of silts and controls blockages by debris of inlet structures and pipes.*
- *The design and construction of water quality control facilities will be undertaken to the requirements of Council and relevant authorities.*

Specific stormwater treatment objectives are set out in Chapter D5 of Shoalhaven City Council's Engineering Design Specifications (Ref. 3). Council's construction stage requirements are summarised as follows;

- *An Erosion and Sediment Management Plan is to be prepared and it is to comply with Council's Engineering Design Specification – Chapter D7 (Ref. 3) and NSW EPA guidelines (Ref. 5).*

3.2 Environment Protection Authority (EPA) Requirements

The EPA supports the principle of no net deterioration in water quality and recommends the following:

- *Incorporate best management practices to minimise impacts on water quality during construction and long term operation of the development.*
- *Produce an estimate of the expected pollutant loads from the site and identify and describe the likely environmental impact of these loads (changes in water quality).*
- *Water quality criteria need to be linked with existing Council catchment and stormwater management plans.*

Adequate sediment and nutrient controls should be implemented during and after development of the land in accordance with Council's requirements (Erosion and Sediment Control plans).

The EPA has set guidelines for stormwater quality from urban developments in their Managing Urban Stormwater: Council Handbook (Ref. 4). This document nominates quantitative post construction phase stormwater management objectives for the reduction of various pollutants for a range of new developments. The retention criteria for the site are listed in Table 3.1.

Table 3.1
EPA Requirements for Pollutant Reduction and Retention

Pollutant	EPA Requirement
Total Phosphorous	45% retention of average annual load
Total Nitrogen	45% retention of average annual load
Suspended Solids	80% retention of average annual load for particles 0.5 mm or less
Fine Particles	50% retention of average annual load for particles 0.1 mm or less
Litter	Retention of litter greater than 50 mm for flows up to 25% of the 1 year ARI peak flow
Coarse Sediment	Retention of sediment coarser than 0.125mm for flows up to 25% of the 1 year ARI peak flow
Oil and Grease	In areas with concentrated hydrocarbon deposition, no visible oils for flows up to 25% of the 1 year ARI peak flow

3.3 Director-General's Environmental Assessment Requirements

In accordance with Section 75F of the Environmental Planning and Assessment Act 1979, the Environmental Assessment must address the following key issues (related to the management of stormwater discharging from the site):

- *The provision of Infrastructure including the construction of a bio-swale….*
- *The preparation of a stormwater plan for the subdivision layout based upon best practice Water Sensitive Urban Design Principles. An operation and maintenance manual must accompany this and a copy provided to Council prior to the commencement of works on Stage 1.* (Refer to "Operation & Maintenance Manual prepared by Bio Engineered Solutions" – Ref. 5).
- *A water quality monitoring program is required and submitted for approval prior to the commencement of works on Stage 1.* (Refer to "Water Quality Monitoring Strategy prepared by Australian Wetlands" – Ref. 6).

3.4 ANZECC Water Quality Guidelines (2000)

The ANZECC Guidelines (Ref. 8) provide a range of default "trigger" values for certain pollutants as a starting point for the design of strategies to improve water quality.

- *The trigger values should be used where site data (i.e. biological effects) or local reference data is not available.*

- *The default trigger guidelines were derived from unmodified to slightly modified ecosystems supplied by state agencies and collected within five geographical regions in Australia and New Zealand.*

- *The default trigger values are defined using the 80^{th} and or 20^{th} percentile of the reference data.*

- *Default trigger values are used to assess risk of adverse effects due to nutrients, biodegradable organic matter and pH in various ecosystem types.*

- *The default ANZECC trigger guidelines may be too stringent for certain highly disturbed environments and a lower level of protection should be sought through reference site data, predictive modelling or professional judgement.*

- *The trigger values applicable to the Narrawallee site are as follows:*

Total Phosphorous	*0.025 mg/l*
Total Nitrogen	*0.35 mg/l*

3.5 Regional Flooding

No regional flooding information was available for the unnamed watercourse adjacent the Leo Drive Narrawallee development. We have however assessed peak 100 year ARI flood levels within this watercourse and included this information in Section 4.2.

3.6 Development Objectives

In accordance with the principles of Ecologically Sustainable Development (ESD), the proposed development area is to be designed, developed and maintained in accordance with the following drainage and flooding objectives.

- *Preserve the ecological integrity of the Fresh Treed Swampland (FTS) and Blackbutt Tall Forest (Dense understorey) (BTFD) west of the proposed development.*

- *Restrict development to above the 1% AEP flood level.*

- *Incorporate water sensitive urban design principles within the development.*

- *Ensure post-development water quality complies with Council's and EPA's requirements.*

- *Minimise land take consistent with the achievement of Council's and the EPA's technical and environmental objectives.*

- *Integrate open space with constructed water quality swales (bio-retention) to provide high amenity and maintain the natural character and ecology within the open space corridor.*

- *Provision of a sustainable aquatic environment that preserves the potential for creating habitat for locally indigenous flora and fauna.*

- *Minimise Council's maintenance requirements for open space, water quality swales and litter control structures.*

- *Enhance the biodiversity, ecological health and positive water quality benefits within the drainage corridor to provide an integrated natural resource for the incoming residents.*

4 HYDROLOGIC ANALYSIS AND FLOODING

The hydrologic analysis for this study was performed using the rainfall-runoff flood routing model called XP-RAFTS (Runoff and Flow Training Simulation with XP Graphical Interface, Refs. 9 & 10).

4.1 Sub-Catchments

Sub-catchment areas contributing to this drainage system, for both the pre-development and post-development scenarios, were established through site investigations, detail survey, examination of 1:4000 scale orthophoto maps and consideration of the development's concept Master plan. Catchment boundaries for the areas contributing to the drainage system are shown in Figure 2. We have conservatively ignored the impact of the proposed open space areas on the modelling results.

4.2 Calibration

It is normal practice for flood routing models such as RAFTS-XP to be calibrated with historical rainfall and stream flow data for the catchment being investigated in order to produce the most reliable results. The model parameter values are adjusted so that the model adequately reproduces observed hydrographs. As no streamflow records are available for this location, calibration was undertaken by comparing the results from a number of recognised flow estimation techniques and adjusting the RAFTS model to provide similar results. The two methods used to compare with RAFTS results are as follows:

Urban Rational Method. This method as outlined in Book 8 of AR&R 1987 (Ref. 1) has long been used in urban stormwater drainage design as a reliable estimate of peak flow rates.

Watershed Boundary Network Model (WBNM). This event based hydrologic and flood routing model was developed by Michael J. Boyd, David Pilgrim and Ian Cordery in 1979 and is recognised by AR&R (Ref 1).

Table 4.1
Summary of Peak 100 year ARI Flow Rates
Obtained by Various Estimation Methods

Node	Probabilistic Rational Method (m^3/s)	WBNM (m^3/s)	RAFTS Bx=1.0 (m^3/s)
West	6.75	4.45	6.42

The results presented in Table 4.1 show that the default RAFTS model (Storage Coefficient Multiplication Factor, Bx=1.0) produces peak flow estimates that are 5% lower than those estimated by the Probabilistic Rational Method (PRM) and 44%

higher than the estimates derived by the WBNM model. The Bx value adopted for the modelling was 1.0 (default) for two reasons. Firstly, this Bx produces flows that match closely with flows obtained by PRM. Secondly, these flows are more conservative estimates than the flows derived using the WBNM model. The Storage Non-linearity Exponent (n) was set at the default value of -0.285.

4.2.1 Initial / Continuing Loss Model

The XP-RAFTS models were formulated using a standard initial and continuing loss rate model. The values adopted were standard parameters for XP-RAFTS modelling as follows:

Initial loss	10.0 mm
Continuing loss	2.5 mm/hr

4.2.2 Model Parameters

As mentioned in Section 4.2, the Storage Coefficient Multiplication Factor (Bx) and Storage Non-linearity Exponent (n) were set to 1.0 and -0.285 respectively.

Table 4.2
XP-RAFTS Model Parameters

Parameter	Catchment Condition	Value
Pern (n)	Rural Conditions	0.070
	Urban Pervious	0.025
	Urban Impervious	0.015

4.3 Discharge Estimates

Discharge estimates were obtained for both the pre-development and post-development catchments for storms ranging from 5 years to 100 years ARI. A range of storm durations ranging from 10 minutes to 24 hours was used as model input to determine the critical storm duration for each sub-catchment.

XP-RAFTS modelling was performed to estimate peak discharges from the catchment for the following catchment conditions:

- Existing rural catchments.
- Site developed in accordance with the Current Master Plan configuration without detention storage provided. Refer to Figure 2 of the Attachments.

Table 4.3
Summary of Peak 5 year ARI Flow Rates

	Pre Development			Post Development			Ratio
Link Label	Max Inflow (m^3/s)	Storm Dur. (min)	Time To Peak (min)	Max Inflow (m^3/s)	Storm Dur. (min)	Time To Peak (min)	PostDev/ PreDev
1.00	0.42	120	41	0.69	25	15	1.63
2.00	0.15	120	41	0.25	25	15	1.72
3.00	1.00	120	49	2.34	25	15	2.35
East	1.48	120	45	3.28	25	15	2.22
4.00	0.64	120	44	1.53	25	15	2.39
5.01	0.76	120	44	1.36	25	15	1.80
5.02	0.54	120	44	1.09	25	15	2.02
5.03	0.37	120	41	0.48	25	15	1.30
5.04	0.42	120	41	0.52	25	15	1.22
5.05	0.47	120	41	0.48	25	15	1.02
5.06	0.34	120	41	0.44	25	15	1.26
5.07	0.27	25	17	0.40	25	14	1.46
West	3.15	120	41	4.76	25	15	1.51
Total	5.22	120	41	9.57	25	15	1.83

Table 4.4
Summary of Peak 100 year ARI Flow Rates

	Pre Development			Post Development			Ratio
Link Label	Max Inflow (m^3/s)	Storm Dur. (min)	Time To Peak (min)	Max Inflow (m^3/s)	Storm Dur. (min)	Time To Peak (min)	PostDev/ PreDev
1.00	0.83	90	31	1.16	90	30	1.40
2.00	0.28	90	31	0.42	90	30	1.49
3.00	2.27	120	45	4.62	90	30	2.03
East	3.29	120	41	6.20	90	30	1.89
4.00	1.35	120	41	2.70	90	30	2.01
5.01	1.60	120	41	2.37	90	30	1.48
5.02	1.15	120	41	1.93	90	30	1.67
5.03	0.74	90	31	0.80	90	30	1.07
5.04	0.84	90	31	0.86	90	30	1.02
5.05	0.93	90	31	0.80	90	30	0.86
5.06	0.68	90	31	0.72	90	30	1.06
5.07	0.51	90	30	0.66	90	29	1.29
West	6.42	90	31	8.13	90	30	1.27
Total	10.99	120	41	17.04	90	30	1.55

The 5 year and 100 yr ARI peak flows from the catchment for each of these conditions are presented in Tables 4.3 and 4.4 respectively. The location of the sub-catchments is indicated in Figure 2. The XP-RAFTS output for these conditions are also provided in Attachment A.

4.4 Basin Performance

The bio-retention swales located on the western fringe of the development are to incorporate a detention storage component that will reduce post development discharges to the Swamp Forest for all storms up to and including the 5 year ARI design event to pre-development levels. This will be discussed further in Section 6.1.

Each of the bio-retention swales/detention basins is to service their own sub-catchments independently, managing discharge for all storms up to and including the 100 year ARI design event and directing flows to the Swamp Forest to the west of the development by means of infiltration and the even distribution of overflows.

The performance of the detention storage component of these swales has been modelled using XP-RAFTS. As each of the combined water quality and quantity control storages is sized proportionately to the catchment it services (2.4% of catchment area), the modelling was undertaken for a typical sub-catchment (i.e. sub-catchment A) which is indicated in Figure 2.

The performance of the typical basin for the 5 ARI storm event is detailed in Table 4.5.

Table 4.5
Typical Detention Basin Performance

Peak Inflow (m^3/s)	Storm Dur. (min)	Time to Peak (min)	Peak Outflow (m^3/s)	Storm Duration (min)	Time to Peak (min)	Stage Used (m)	Storage Used (cu.m)
0.48	25	17	0.29	120	41	0.62	184.0

The storage provided to restrict peak 5 year post development discharges to pre-development levels equates to 240 m^3/Ha. The detention basin proposed to service each of the sub-catchments on the western side of the development will be sized to provide similar same storage rate.

4.5 Discussion of Modelling

Results obtained from the XP-RAFTS modelling showed that the incorporation of appropriately sized detention basins will ensure that post development discharges from the site are reduced to pre-development levels for storms up to and including the 5 year ARI design event. The impact of the proposed development is minimised by reducing the magnitude regular storm flows prior to discharging to the bushland located to the west of the site.

4.6 Unnamed Watercourse

The unnamed watercourse located on the western side of the development was assessed to determine approximate 100 yr ARI flood depths. Flood depths were determined in sufficient detail to demonstrate that the peak 100 year ARI flood level is significantly lower than the adjacent residential development. Flood flows were determined using the PRM in accordance with AR&R 1987 (Ref. 1). The site contour plan (2m contour interval) was used to determine a typical watercourse section adjacent the development. A simple Manning's calculation was undertaken to estimate the depth of flow at the typical section. The results are presented in Table 4.6

Table 4.6
Unnamed Watercourse
100 year ARI Flood Depths Adjacent to Leo Drive
Narrawallee Development

Catcment Area (ha)	100 Year ARI Flow (m^3/s)	Invert RL (m AHD)	Flood Level (m AHD)	Adjacent Minimum Lot Level (m AHD)	Freeboard (m)
90.00	36.0	7.00	7.79	11.00	3.22

5 WATER QUALITY

The water quality analysis for this study was undertaken using the water quality modelling software called MUSIC which is short for Model for Urban Stormwater Improvement Conceptualisation (Ref. 11). Developed by the CRC for Catchment Hydrology, MUSIC was released in July 2002 and has since undergone numerous improvements. The latest version of MUSIC (i.e. ver 3.01) is used in this study. The modelling software is now accepted as an industry standard among water quality modellers here in Australia and abroad.

As a water quality modelling software, MUSIC has features that can do the following:

- Modelling the potential nutrient reduction benefits of gross pollutant traps, constructed wetlands, grass swales, bio-retention swales and stormwater re-use as a treatment technique.

- Performance evaluation of treatment devices against required water quality objectives

The reason for doing the MUSIC modelling is twofold. First, is to determine whether the stormwater management strategy proposed for Narrawallee development will result in reductions in overall post–development pollutant loads and concentrations being discharged to the Swamp Forest, and the Narrawallee Inlet. Second, is to ensure that reductions in pollutant loads comply with the required standards.

5.1 Catchments

The MUSIC model was set up to represent a typical sub-catchment scale treatment configuration. Catchment A (Refer to Figure 2 - Node 5.03) was adopted as being representative in size and configuration. The catchment was determined to be 1.32 hectares in size and to have a fraction impervious of 50%. We have conservatively ignored the impact of the proposed open space areas on the modelling results.

The schematic diagram of the MUSIC model adopted for the proposed development is indicated in Attachment B.

5.2 Rainfall Data

MUSIC can take, as one its required inputs, rainfall data that can have any of the following time steps: 6 minutes, hourly, 6 hours and daily. Adopted for our modelling purposes is the 6-minute time data taken at Station 68203 Sassafras which is the closest station to the site. As indicated in Table 2.1, eighteen years of 6 minute pluviograph data was available. However, only the data for the year 1976 was used as input in the actual modelling. This year was identified to have average total rainfall and an above average number of rain days.

5.3 Pollutant Loading Rates

In the absence of site specific data, the streamflow and pollutant loading rates adopted for Leo Drive, Narrawallee are based on the default values built into the MUSIC model. The adopted loading rates are presented in Table 5.1.

Table 5.1
Annual Pollutant Loading Rates
Adopted in Water Quality Modelling

	Forest Source Node		Urban Source Node	
Pollutant	Base Flow (mg/L)	Storm Flow (mg/L)	Base Flow (mg/L)	Storm Flow (mg/L)
TSS	7.94	79.4	12.6	158
TP	0.0316	0.0794	0.151	0.355
TN	0.724	0.841	2.09	2.63

5.4 Treatment Device Performance

5.4.1 Litter and Sediment Control Structures

The sediment and nutrient removal performance of the proposed litter and sediment control structures was determined using the Gross Pollutant Trap treatment device built into the MUSIC model. Operation of the devices for removal of TSS, TP and TN was modelled using the built in transfer functions with performance data based on results obtained from monitoring of a CDS unit installed in Coburg in Melbourne. Refer to Appendix 3 of MUSIC User Manual (Ref. 11).

5.4.2 Bio-Retention Swales

The expected sediment and nutrient removal performance of the proposed Bio-Retention Swales was determined using the default equations and parameters provided in the MUSIC model. The water quality reduction mechanisms in MUSIC are based on an exponential decay equation referred to as the k – C* curve. (refer to Wong et al., Ref. 12). The performance parameters used in the MUSIC model are summarised in Table 5.2.

The Bio-Retention Swales will essentially function in the same manner as Sub-Surface Wetlands. While they will be located on grade adjacent to roadways, a series of baffles and choked outlets will ensure retention times sufficient for suitable treatment is attained. The design of the swales is based on the following assumptions:

1. The Bio-ribbon provided would have a surface area equal to 2.4 % of the catchment it services.

2. It is assumed that trash and gross sediments will be effectively removed prior to entering the Bio-Retention Swale.

Table 5.2
MUSIC Model Performance Parameters

Pollutant	Bio- Retention k (m/yr)	Bio- Retention C* (mg/L)
TSS	1000	12.000
TP	500	0.130
TN	50	1.300

5.5 Pollutant Load Estimates

Total annual pollutant load estimates were derived using MUSIC for the developed site incorporating the proposed water quality treatment system.

The estimated annual pollutant loads and concentrations are presented in Tables 5.3 and 5.4 respectively.

Table 5.3
Summary of Mean Annual Pollutant Loads and Reductions

Pollutants		Source	Discharge	Reduction
TSS	(kg/yr)	2850	351	87.7%
TP	(kg/yr)	5.95	2.32	56.7%
TN	(kg/yr)	41.60	18.00	46.6%
GP	(kg/yr)	228.00	0.00	100.0%

Table 5.4
Summary of Pollutant Concentrations
Discharging into Narrawallee Inlet

	TSS (mg/L)	TP (mg/L)	TN (mg/L)
Mean	3.61	0.045	0.472
Median	2.69	0.041	0.432
Maximum	106	0.342	2.260
Minimum	2.24	0.027	0.260
10 %ile	2.48	0.034	0.381
90 %ile	4.33	0.053	0.567

Details results from MUSIC for the 31 year period modelled (1970-2000) including cumulative frequency graphs of pollutant concentrations is provided in Attachment B.

5.6 Discussion of Modelling

A summary of the performance of the proposed water quality management strategy for Leo Drive, Narrawallee obtained using the MUSIC model and related industry target standards are included in Table 5.5.

Table 5.5
Comparison of Pollutant Concentrations to Target Levels

Pollutant	MUSIC Mean Pollutant Loading Rate-Urban Storm Conditions	MUSIC Median Discharge Concentration	ANZECC Trigger Values	MUSIC Reduction of Pollutant Loads	EPA Target Reductions
	(mg/l)	(mg/l)	(mg/l)	%	%
TSS	158	2.69	6.00	87.7	80
TP	0.355	0.041	0.025	56.7	45
TN	2.63	0.432	0.350	46.6	45

By comparing the achieved values versus the target values, the following conclusions can be drawn:

- The provision of the proposed water quality management system will ensure that Suspended Solids are reduced by 87.7 % which exceeds the target reduction of 80% nominated in the EPA guidelines. (Ref. 4)
- The incorporation of the proposed bio-retention swales will ensure that total reduction in post development nutrient discharges of a minimum of 46.6% will comply with the objective of 45% retention of the average annual nutrient load nominated by the EPA guidelines (Ref. 4).
- The median pollutant discharge concentrations from the development compare favourably with the target values for unmodified or slightly modified ecosystems nominated in the ANZECC guidelines (Ref. 8).

The above results are slightly conservative since the nutrient stripping potential of the riparian corridors downstream of the residential development and their naturally functioning watercourses has not been included in the calculations.

6 STORMWATER QUALITY/QUANTITY CONCEPT

The stormwater management strategy proposed for the Leo Drive, Narrawallee development has been developed in consideration of the separate issues affecting both the sloping portions in the western and eastern sides of the site.

6.1 Western Catchment

A critical consideration is the ongoing ecological sustainability of the existing Swamp Forest within the western edge of the site. To maintain stormwater quality to the required levels a "treatment train" approach is proposed where various types of pollutants are removed by a number of devices acting in series.

The water quality treatment train proposed for the portion of the site draining directly to the Swamp Forest includes the following devices:

- "Enviropod" (or equivalent) pit inserts which are to be provided in every inlet pit to remove trash, litter, vegetative matter, visible oils and greases and sediment from stormwater prior to discharge to the bio-retention swale.

- A Bio-retention swale which is to be constructed on the interface to the Swamp Forest to control nutrients and fine sediments, to act as a level spreader to evenly distribute flows, to encourage infiltration to groundwater and to provide buffer storage to mimic existing inundation patterns.

- The bio retention swale which incorporates a detention storage component that will reduce post development discharges to the Swamp Forest for all storms up to and including the 5 year ARI design event to pre-development levels.

The proposed system also provides the following additional benefits:

- Conservation of vegetation – the proposed water quality treatment devices has been kept clear of high value environmental areas, in particular the Swamp Forest. An appropriate vegetation management plan will be provided to ensure long term operation and maintenance of the devices.

- Amenity – opportunities exist for introducing amenity within and adjacent the treatment devices (boardwalks, pathways, education trails, interpretive/cultural signage, biological corridor).

- Design minimises land take consistent with management of flows and water quality.

- Maintenance costs to be kept to a minimum consistent with achievement of system performance and amenity considerations (water level control, maintenance access, litter pre-interception)

The concept balances the engineering principals of stormwater conveyance and treatment with the community's desire for resource conservation, habitat

conservation and the provision of quality recreation opportunities. The drainage concept is illustrated in Figure 2.

6.2 Eastern Catchment

The eastern sub-catchments will discharge into the existing infrastructure along the eastern boundary of the proposed sub-division (Refer to Figure 2).

"Enviropod" (or equivalent) pit inserts are also to be provided in every inlet pit within the eastern catchments to remove trash, litter, vegetative matter, visible oils and greases and sediment from stormwater prior to discharge to the downstream drainage system.

A detailed investigation of the existing infrastructure will be undertaken during the detailed design process for the development on the eastern side of the site in order to determine the capacities of the existing drainage infrastructure. Works such as augmenting parts of drainage systems, modification of drainage pits, installation of filters in kerb inlet pits, GPT etc. may be needed to be incorporated.

6.3 Litter and Sediment Control

Local drainage throughout the development should be filtered prior to discharge into the downstream drainage systems, Bio-Retention Swales and Swamp Forest.

It is proposed that Ingal Environmental Services "Enviropod" (or equivalent) pit inserts be used on every inlet pit to capture litter, coarse sediment and also fine sediments (down to 200 µm) prior to discharge to the downstream treatment devices. It is expected that the Leo Drive, Narrawallee development would require approximately 110 of these inserts. These devices are particularly effective in filtering litter and vegetative matter and up to 80% of the total sediment load from storm flows.

It is expected that this option would have similar capital and maintenance costs to the use of conventional litter control structures it would allow for reductions in the annual maintenance costs of the downstream devices while also significantly improving the overall performance of the system.

6.4 Bio-Retention Swale

Bio-Retention Swales have been located on the fringe of the Swamp Forest to facilitate the removal of suspended solids and nutrients from the urban catchment, to encourage groundwater recharge and to evenly distribute flows (level spreader) to the sensitive ecological communities downstream. Typical details of the bio retention swale and the pipe drainage system connection are provided on Figure 3.

The Bio-Retention Swales consist of a gravel filled trench located at the toe of the road batter. The surface of the Bio-Retention Swale is typically treated as a grassed swale. The Bio-Retention Swales are typically 0.8 metres deep. These systems would be designed to receive, convey and treat 1 year ARI flows from the upstream catchment. Treatment is attained by detention of flows and nutrient stripping by bio-films which establish on the surface of the gravel. A series of baffles and choked outlets are used to promote extended detention times within the trench. The bio-retention swale will incorporate a bio-filtration trench throughout the full length of the

swale. A series of weir structures at designated intervals and levels will create a series of small bio-retention storages serving the western sub-catchments of the proposed sub-division..

The bio-retention swale will have an extended detention zone of 300 mm depth which will service 1 year ARI flows from the urban development. Additional storage provided above the swale will act as a detention system to limit 5 year ARI flows discharging to the swamp forest to pre-development levels (refer to Section 4.4). The detention storage function will be achieved through a restricted outlet pipe which connects to a level spreader constructed on the western side of the swale. (Refer to Figure 3 for details).

The size of a typical bio-retention swale has been determined using MUSIC modelling (Refer to Section 5.4). The performance of the device is detailed in Section 5.5 of this report. The general features and configuration of the system is detailed in Table 6.1

Maintenance requirements for the Bio-Retention Swales would typically involve weed control, repair of erosion and structural damage and removal of localised sediment build-up. This would be undertaken on a quarterly basis on average. In addition, it is expected that the gravel within the trench may need to be removed and either washed or discarded and replaced at approximately 15 yearly intervals.

Table 6.1
Water Quality Treatment Systems General Features and Configuration

Storage	
Extended Detention Depth (m)	0.3
Surface Area (m)	311
Infiltration	
Filter Area (m²)	33.6
Filter Depth (m)	0.6
Filter Particle Effective Diameter (mm)	5
Saturated Hydraulic Conductivity (mm/hr)	100
Outlet	
Overflow Weir Width (m)	1.2

6.5 Construction Stage

Erosion and sediment control measures should be implemented during the construction phase in accordance with the requirements of Shoalhaven City Council and the guidelines set out by the NSW Department of Housing (the "Blue Book", Ref. 5).

The erosion and sediment controls will include the following measures:

- Construction of temporary diversion drains ("Blue Book" Standard Drawing SD 5-8) or provision of staked hay bales (SD 6-6) on the high side of the disturbed areas to direct upstream runoff around the area.

- The use of silt fencing (SD 6-7) on the downstream side of area of works to retain soil.

- Provision of a stabilised site access (SD 5-7) at appropriate points where construction vehicles will enter and leave the site to reduce the likelihood of vehicles tracking soil materials onto public roads.

- Topsoil stockpile (SD 4-1) located adjacent the areas of disturbance and to have an earth bank (SD 5-2) on the upslope side to divert runoff around the stockpile and a sediment fence (SD 6-7) located 1 to 2 metres down slope of the stockpile.

- Rock wrapped in geofabric or hay bales will be installed in or around respectively, any stormwater inlet pits receiving water from disturbed catchments

As the operation of the gravel bed based water quality treatment systems proposed is sensitive to the impact of sedimentation, these controls should generally be maintained until the majority of site building works are complete. Alternatively, a very high level of at source control on individual allotments during the building and site landscaping works which is regularly inspected by Council officers would be required.

6.6 Long Term Management

Regular maintenance of the stormwater quality treatment devices is required to control weeds, remove rubbish, and monitor plant establishment and health. Some sediment build-up is expected on the floor of the wetland basin and may require removal to maintain the high standard of stormwater treatment.

Proper management and maintenance of the water quality control systems will ensure long-term, functional stormwater treatment. A site-specific Operation and Maintenance (O & M) manual should be prepared for the system. The O & M manual should provide information on the Best Management Practices (BMP) for the long-term operation of the treatment devices. The manual should provide site-specific management procedures for:

- Maintenance of the ”Enviropods” including rubbish and sediment removal.

- Management of the bio-retention swales including plant monitoring, replanting guidelines, monitoring and replacement of the gravel media and general maintenance (i.e. weed control, sediment removal).

7 SUMMARY & CONCLUSION

J. Wyndham Prince Pty Ltd has prepared this Stormwater Management Strategy to integrate with the development planning process for the proposed Narrawallee Subdivision. The plan has been prepared to conform to statutory requirements and industry best practice for stormwater management in this catchment, encompassing the technical and environmental requirements of the Council and the EPA. Due to the proximity of the site to the coastline, the Stormwater Management Strategy also addresses the Coastal Protection requirements specified in State Environmental Planning Policy No.71. Sufficient detail is provided to integrate with and support the development planning process for the proposed subdivision.

Results of the water quality modelling for the proposed residential development indicate an increase in pollutant loadings if water quality controls are not implemented. EPA guidelines require 45% reduction in annual load of Nitrogen and Phosphorus and 80% retention of the annual load for suspended solids.

The most suitable stormwater management strategy JWP proposes for the Leo Drive, Narrawallee site is a combination of options including:

Litter & Sediment Control	"Enviropod" pit inserts are to be provided in every inlet pit throughout the catchment as they remove litter, vegetative matter and sediments prior to discharge to the downstream treatment devices.
Bio-Retention Swale	Servicing the western portion of the residential areas prior to drainage to the Swamp Forest. Located at the toe of the road batter. Functions to remove suspended solids and nutrients, to encourage groundwater recharge and to evenly distribute flows to these sensitive ecological communities.
Detention Storage	Servicing the western portion of the residential area the detention storages will be integrated with the bio-retention swales and will be sized to restrict post development discharges for storms up to the 5 year ARI design event to pre-development levels. This will minimise the impact of the proposed development by reducing the most regular storm flows prior to discharge to the bushland to the west of the site.

A general arrangement plan indicating proposed locations for the water quality and quantity treatments for the site is attached to this report. See Figure 2 of the Attachments.

The proposed stormwater management strategy provides a basis for the detailed design and development of the site to ensure that the following objectives for stormwater management and site discharge are achieved:

Environmental

Existing vegetation within and adjacent the Swamp Forest retained; retaining surface hydrology, groundwater hydrology, surface levels associated with the existing Swamp Forest; downstream discharge peaks and velocities limited to avoid scouring, siltation and flora and fauna impacts; water quality elements as proposed to remove gross pollutants from the urban catchments; stormwater quality treatment provided off-line to significantly enhance water quality and aquatic ecosystems.

Urban Amenity

Limits of flood 1% affectation can be defined and future development can conform with Council's requirements for freeboard and public safety; access to proposed bio-retention swales provided; existing aquatic ecosystems retained and protected and quality passive recreational amenity can be integrated with the concept for the incoming community.

Engineering Considerations

Proposed stormwater quality treatment devices designed to conform to Council's technical requirements for performance and maintenance; litter control structures proposed in the urban areas to conform to Council's performance and maintenance requirements and enhance downstream water quality.

Economics

The stormwater management concept is functional; will deliver more than the required technical and environmental performance; avoids environmental degradation and pressure on downstream and adjacent ecosystems; and provides for a 'soft' sustainable solution for management of stormwater at this location.

8 REFERENCES

1. INSTITUTION OF ENGINEERS, AUSTRALIA (1987). Australian Rainfall and Runoff. Institution of Engineers Australia.

2. SHOALHAVEN CITY COUNCIL (2001). Subdivision Code (Development Control Plan 100)

3. SHOALHAVEN CITY COUNCIL (1999). Engineering Design Specifications.

4. NSW ENVIRONMENT PROTECTION AUTHORITY (1997). Managing Urban Stormwater: Council Handbook (Draft).

5. NSW DEPARTMENT OF HOUSING (1998). Managing Urban Stormwater – Soils and Construction. 3rd Edition.

6. BIO ENGINEERED SOLUTIONS (2005). Operation and Maintenance Manual for the Enviropods, Basins and Bio-Retention Swales.

7. AUSTRALIAN WETLANDS (2005). Water Quality Monitoring Strategy.

8. AUSTRALIAN AND NEW ZEALAND ENVIRONMENT AND CONSERVATION COUNCIL (2000). National Water Quality Management Strategy. Volume 4. Australian and New Zealand Guidelines for Fresh and Marine Water Quality.

9. WILLING & PARTNERS PTY. LTD. (1994). Runoff Analysis & Flow Training Simulation. Detailed Documentation and User Manual. Version 4.0.

10. WILLING & PARTNERS PTY. LTD. (1996). Runoff Analysis & Flow Training Simulation. Addendum. Version 5.0.

11. CRC FOR CATCHMENT HYDROLOGY (2002). MUSIC Model for Urban Stormwater Improvement Conceptualisation. User Manual Version 1.00.

12. WONG, T.H.F., DUNCAN, H.P., FLETCHER, T.D & JENKINS G.A. (2001). A Unified Approach to Modelling Stormwater Treatment. Proceedings of the 2nd South Pacific Stormwater Conference, Auckland, New Zealand, 27-29 June 2001, pp 319-327.

9 FIGURES

FIGURES

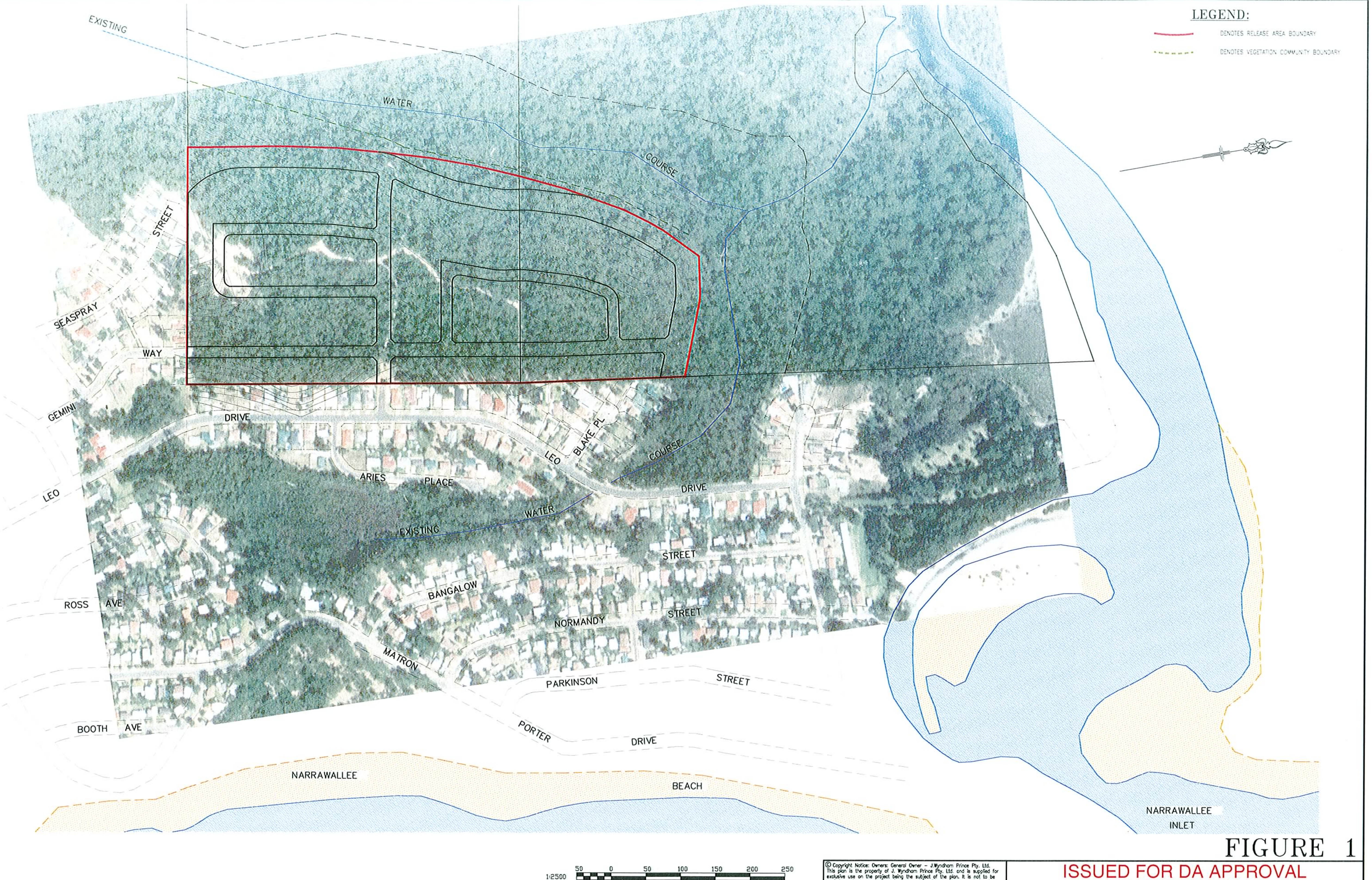


FIGURE 1

ISSUED FOR DA APPROVAL
NOT FOR CONSTRUCTION

SIGNED...DATE.......................

ISSUE	AMENDMENT	DATE
F		
E		
D		
C	TITLE BLOCK AMENDED	13/11/06
B	UPDATED ROAD LAYOUT	01/04/05
A	FIRST ISSUE	11/03/03

J. Wyndham Prince Pty. Ltd.
CONSULTING CIVIL ENGINEERS & PROJECT MANAGERS
A.B.N. 67002 318 621
P.O. BOX 4366
PENRITH WESTFIELD. 2750
DX 8032 PENRITH
EMAIL: jwp@jwprince.com.au
PH: (02) 4732 3366
FAX: (02) 4721 7638

DESIGNED J.C
DRAWN JC/JG
CHECKED PM

DATUM: A.H.D.
ORIGIN:

THIS DRAWING MUST NOT BE USED FOR CONSTRUCTION UNLESS SIGNED AS PART OF AN APPROVED CONSTRUCTION CERTIFICATE.

SCALES:
PLAN 1:2500

CLIENT:
HAZCORP PTY. LTD.
PETER LEAN PTY. LTD.

NARRAWALLEE SUBDIVISION
LEO DRIVE, NARRAWALLEE

SITE LAYOUT PLAN

PLAN No. 7109/P1 C
FILE No. 7109fig1
SHEET 1 OF 3 SHEETS

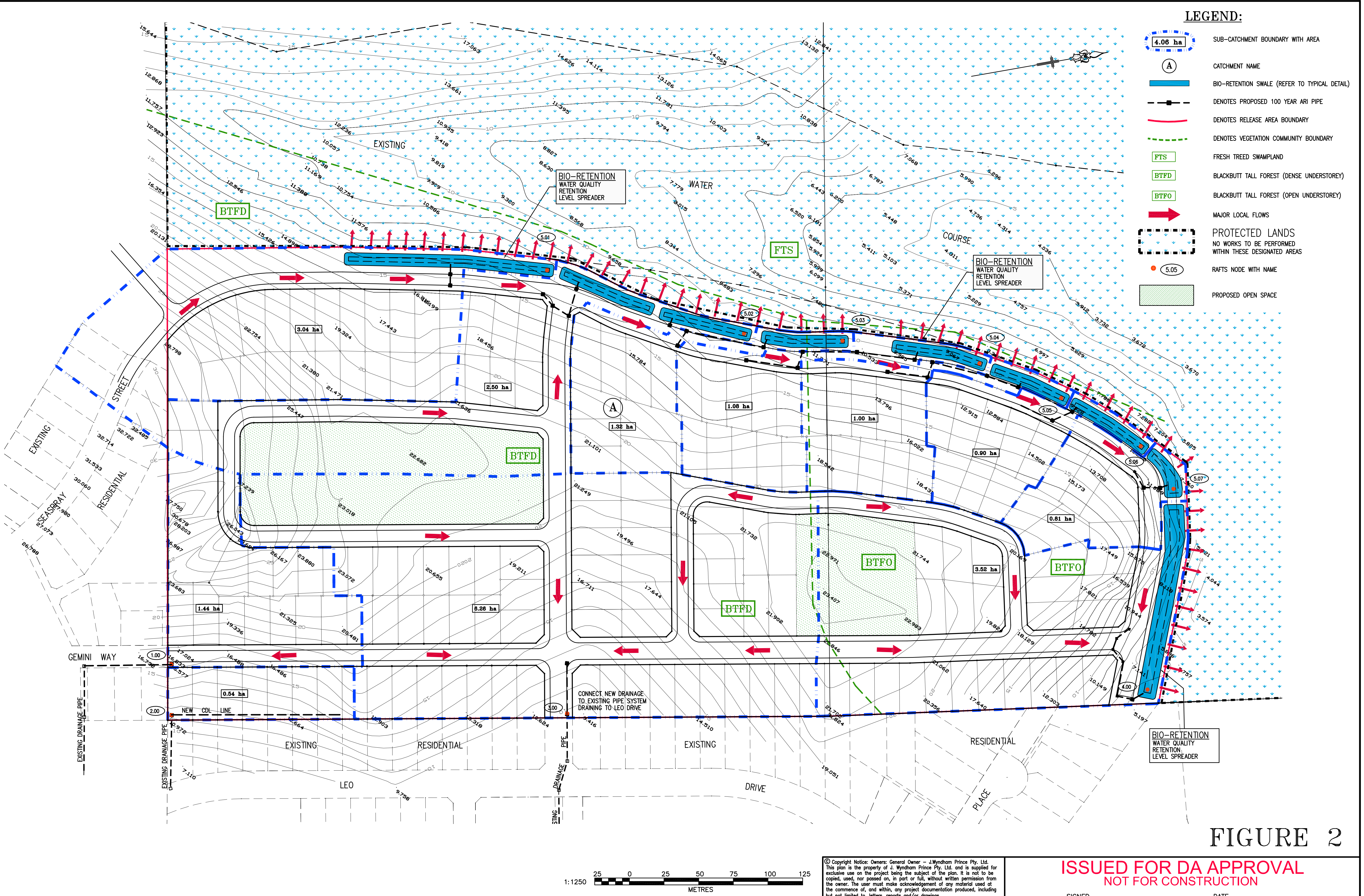


FIGURE 2

ISSUED FOR DA APPROVAL
NOT FOR CONSTRUCTION

SIGNED...DATE......................

ISSUE	AMENDMENT	DATE
F		
E		
D		
C	LOT LAYOUT AMENDED	13/11/06
B	LOT AND CATCHMENT LAYOUTS ALTERED	01/04/05
A	FIRST ISSUE	11/03/03

J. Wyndham Prince Pty. Ltd.
CONSULTING CIVIL ENGINEERS & PROJECT MANAGERS
A.B.N. 67002 318 621
P.O. BOX 4366
PENRITH WESTFIELD. 2750
DX 8032 PENRITH
EMAIL: jwp@jwprince.com.au
PH: (02) 4732 3366
FAX: (02) 4721 7638

DESIGNED J.C.
DRAWN JC/JG
CHECKED ER

DATUM: A.H.D.
ORIGIN:

SCALES:
PLAN 1:1250

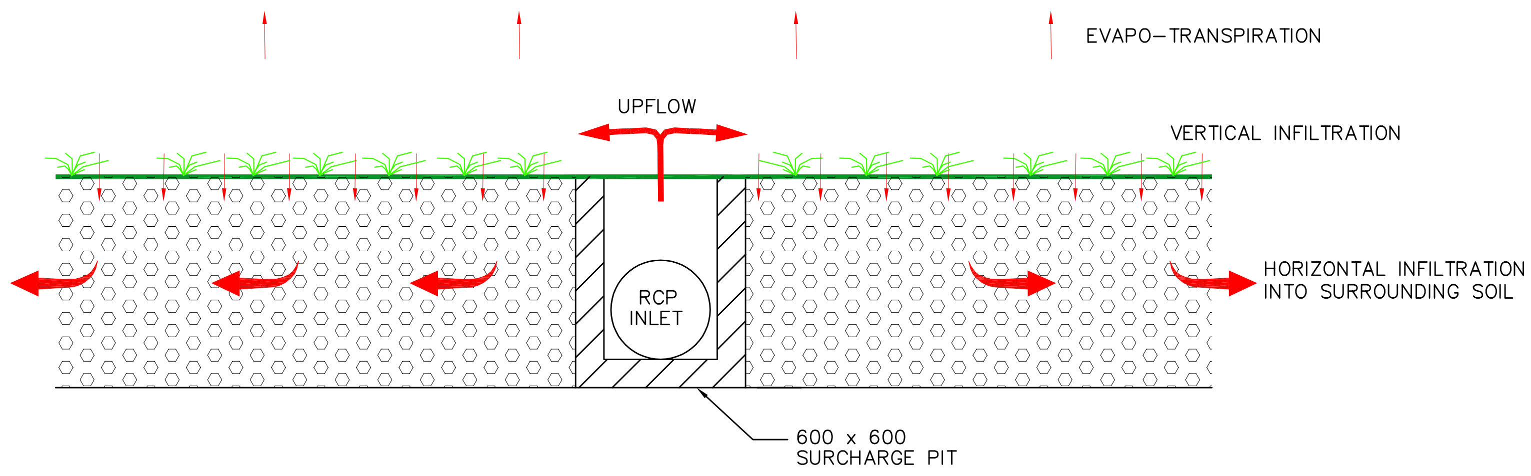
CLIENT:
HAZCORP PTY. LTD.
PETER LEAN PTY. LTD.

THIS DRAWING MUST NOT BE USED FOR CONSTRUCTION UNLESS SIGNED AS PART OF AN APPROVED CONSTRUCTION CERTIFICATE.

NARRAWALLEE SUBDIVISION
LEO DRIVE, NARRAWALLEE

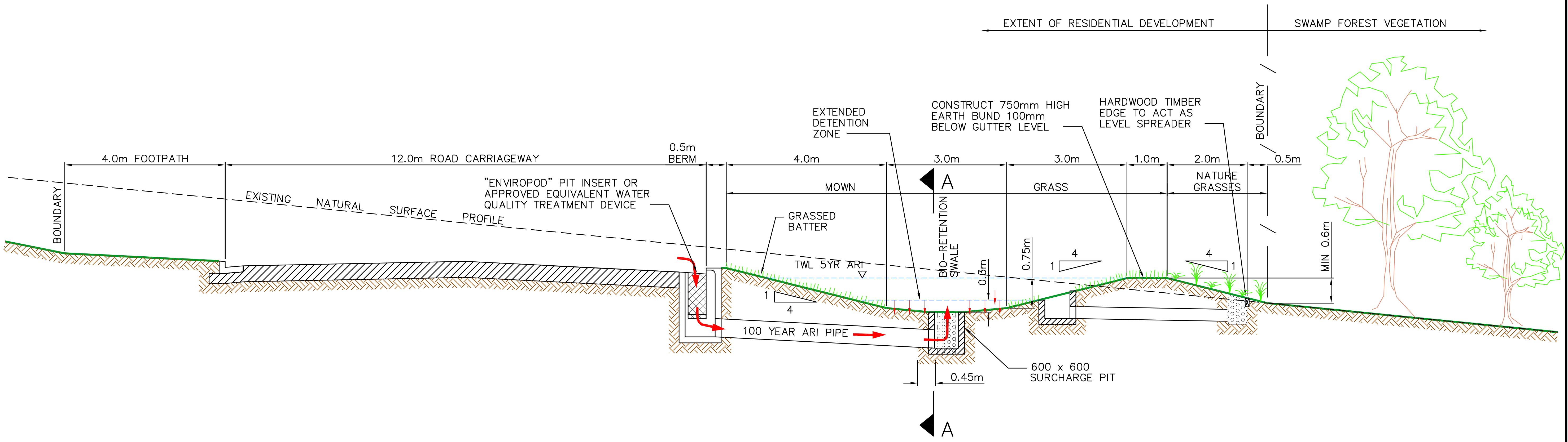
STORMWATER MANAGEMENT STRATEGY

PLAN No. 7109/P2 C
FILE No. 7109fig2
SHEET 2 OF 3 SHEETS



TYPICAL SECTION A — A THROUGH BIO RETENTION SWALE

NTS



TYPICAL BIO RETENTION SWALE ADJACENT TO PERIMETER ROAD

FIGURE 3

1:100 — 2 1 0 1 2 3 4 5 6 7 8 9 10 — METRES (FOR A3 PLOT)

ISSUED FOR DA APPROVAL

NOT FOR CONSTRUCTION

SIGNED..DATE.....................

ISSUE	AMENDMENT	DATE
F		
E		
D		
C		
B	TITLE BLOCK AMENDED	13/11/06
A	FIRST ISSUE	11/03/03

J. Wyndham Prince Pty. Ltd.

CONSULTING CIVIL ENGINEERS & PROJECT MANAGERS

A.B.N. 67002 318 621

P.O. BOX 4366 PENRITH WESTFIELD. 2750 — DX 8032 PENRITH — EMAIL: jwp@jwprince.com.au — PH: (02) 4732 3366 FAX: (02) 4721 7638

DESIGNED J.C. — DRAWN JC/JG — CHECKED ER

DATUM: A.H.D. — ORIGIN:

SCALES: 1:100 (AT A3)

CLIENT: HAZCORP PTY. LTD. PETER LEAN PTY. LTD.

THIS DRAWING MUST NOT BE USED FOR CONSTRUCTION UNLESS SIGNED AS PART OF AN APPROVED CONSTRUCTION CERTIFICATE.

NARRAWALLEE SUBDIVISION
LEO DRIVE, NARRAWALLEE

TYPICAL SECTION THROUGH BIO-RETENTION SWALE

PLAN No. 7109/P3 — B

FILE No. 7109fig3

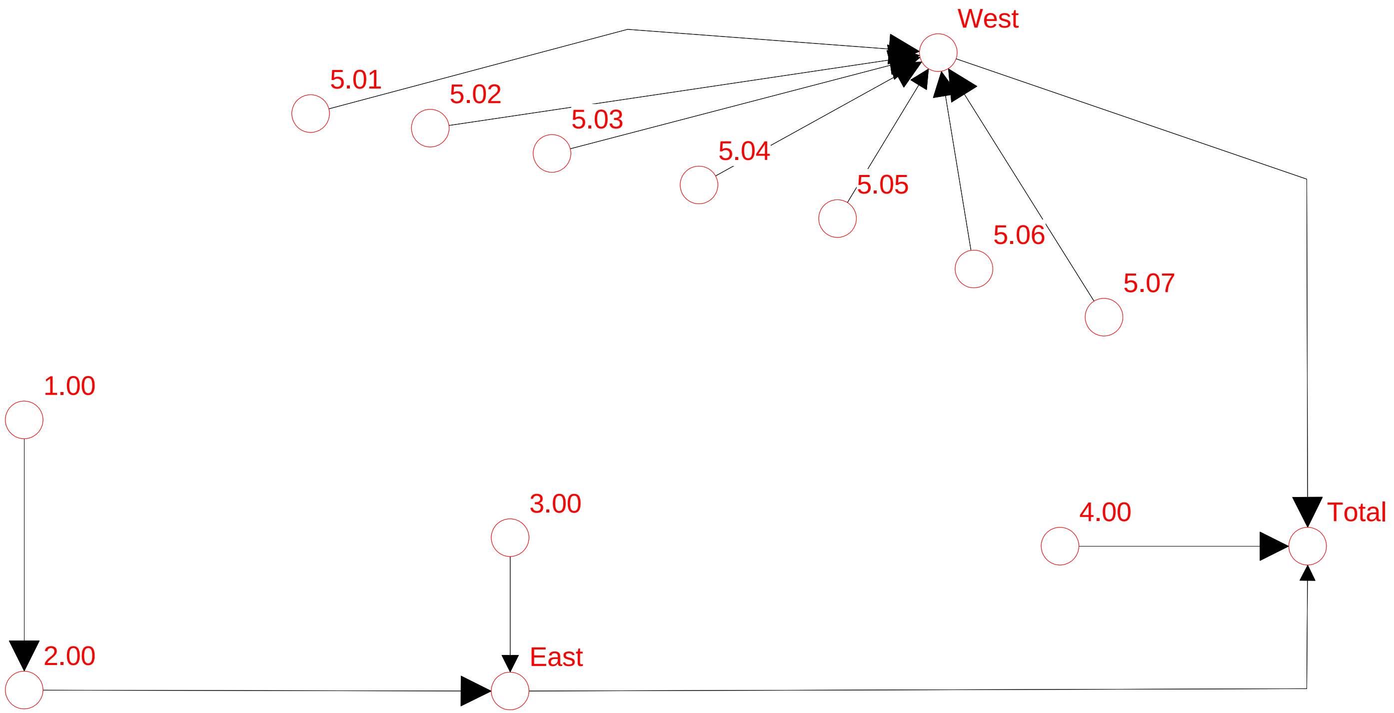
SHEET 3 OF 3 SHEETS

ATTACHMENT A

XP-RAFTS MODELLING RESULTS

Pre Development (100 Year_90 min)

Post Development (100 Year_90 min)


West
5.01
5.02
5.03
5.04
5.05
5.06
5.07
1.00
3.00
4.00
Total
2.00
East

Run started at: 21st April 2005 9:11:21

###
Narrawallee-Post Development

Results for period from 0: 0.0 1/ 1/1903
to 5: 0.0 1/ 1/1903
###

ROUTING INCREMENT (MINS) = 1.00
STORM DURATION (MINS) = 90.
RETURN PERIOD (YRS) = 100.
BX = 1.0000
TOTAL OF FIRST SUB-AREAS (ha) = 11.04
TOTAL OF SECOND SUB-AREAS (ha) = 11.04
TOTAL OF ALL SUB-AREAS (ha) = 22.08

SUMMARY OF CATCHMENT AND RAINFALL DATA

Link	Catch. Area		Slope		% Impervious		Pern		B		Link
Label	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	No.
	(ha)		(%)		(%)						
1.00	0.7200	0.7200	9.400	9.400	1.000	100.0	.025	.015	.0068	.0004	1.000
3.00	3.130	3.130	4.500	4.500	1.000	100.0	.025	.015	.0212	.0013	2.000
2.00	0.2650	0.2650	4.700	4.700	1.000	100.0	.025	.015	.0058	.0003	3.000
East	.00001	0.000	.0010	0.000	0.000	0.000	.025	0.00	.0021	0.000	1.001
4.00	1.760	1.760	6.800	6.800	1.000	100.0	.025	.015	.0128	.0008	4.000
5.01	1.520	1.520	7.500	7.500	1.000	100.0	.025	.015	.0113	.0007	5.000
5.02	1.250	1.250	6.000	6.000	1.000	100.0	.025	.015	.0114	.0007	6.000
5.03	0.5000	0.5000	7.500	7.500	1.000	100.0	.025	.015	.0063	.0004	7.000
5.04	0.5400	0.5400	8.300	8.300	1.000	100.0	.025	.015	.0063	.0004	8.000
5.06	0.4500	0.4500	8.300	8.300	1.000	100.0	.025	.015	.0057	.0003	9.000
5.07	0.4050	0.4050	11.00	11.00	1.000	100.0	.025	.015	.0047	.0003	10.00
5.05	0.5000	0.5000	8.300	8.300	1.000	100.0	.025	.015	.0060	.0004	11.00
West	.00001	0.000	1.000	0.000	1.000	0.000	.025	0.00	0.000	0.000	5.001
Total	.00001	0.000	1.000	0.000	1.000	0.000	.025	0.00	0.000	0.000	1.002

Link	Average	Init. Loss		Cont. Loss		Excess Rain		Peak	Time	Link
Label	Intensity	#1	#2	#1	#2	#1	#2	Inflow	to	Lag
	(mm/h)	(mm)		(mm/h)		(mm)		(m^3/s)	Peak	mins
1.00	85.901	10.00	1.000	2.500	0.000	115.43	127.85	1.161	30.00	0.000
3.00	85.901	10.00	1.000	2.500	0.000	115.43	127.85	4.619	30.00	0.000
2.00	85.901	10.00	1.000	2.500	0.000	115.43	127.85	0.4214	30.00	0.000
East	85.901	10.00	0.000	2.500	0.000	115.43	0.000	6.201	30.00	0.000
4.00	85.901	10.00	1.000	2.500	0.000	115.43	127.85	2.704	30.00	0.000
5.01	85.901	10.00	1.000	2.500	0.000	115.43	127.85	2.366	30.00	0.000
5.02	85.901	10.00	1.000	2.500	0.000	115.43	127.85	1.927	30.00	0.000
5.03	85.901	10.00	1.000	2.500	0.000	115.43	127.85	0.7958	30.00	0.000
5.04	85.901	10.00	1.000	2.500	0.000	115.43	127.85	0.8629	30.00	0.000
5.06	85.901	10.00	1.000	2.500	0.000	115.43	127.85	0.7212	30.00	0.000
5.07	85.901	10.00	1.000	2.500	0.000	115.43	127.85	0.6617	29.00	0.000
5.05	85.901	10.00	1.000	2.500	0.000	115.43	127.85	0.8005	30.00	0.000
West	85.901	10.00	0.000	2.500	0.000	115.43	0.000	8.134	30.00	0.000
Total	85.901	10.00	0.000	2.500	0.000	115.43	0.000	17.039	30.00	0.000

Run completed at: 21st April 2005 9:11:23

##
Narrawallee-Pre Development

Results for period from 0: 0.0 1/ 1/1903
to 5: 0.0 1/ 1/1903

##

ROUTING INCREMENT (MINS)	=	1.00
STORM DURATION (MINS)	=	90.
RETURN PERIOD (YRS)	=	100.
BX	=	1.0000
TOTAL OF FIRST SUB-AREAS (km2)	=	22.54
TOTAL OF SECOND SUB-AREAS (km2)	=	0.00
TOTAL OF ALL SUB-AREAS (km2)	=	22.54

SUMMARY OF CATCHMENT AND RAINFALL DATA

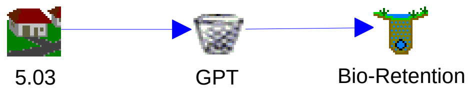
Link Label	Catch. Area #1 (ha)	Catch. Area #2	Slope #1 (%)	Slope #2	% Impervious #1 (%)	% Impervious #2	Pern #1	Pern #2	B #1	B #2	Link No.
1.00	1.430	0.000	9.400	0.000	1.000	0.000	.070	0.00	.0215	0.000	1.000
3.00	5.940	0.000	4.500	0.000	1.000	0.000	.070	0.00	.0652	0.000	2.000
2.00	0.5300	0.000	4.700	0.000	1.000	0.000	.070	0.00	.0181	0.000	3.000
East	.00001	0.000	1.000	0.000	1.000	0.000	.025	0.00	0.000	0.000	1.001
4.00	2.680	0.000	6.800	0.000	1.000	0.000	.070	0.00	.0351	0.000	4.000
5.01	3.160	0.000	7.500	0.000	1.000	0.000	.070	0.00	.0364	0.000	5.000
5.02	2.320	0.000	6.000	0.000	1.000	0.000	.070	0.00	.0346	0.000	6.000
5.03	1.320	0.000	7.500	0.000	1.000	0.000	.070	0.00	.0231	0.000	7.000
5.04	1.490	0.000	8.300	0.000	1.000	0.000	.070	0.00	.0234	0.000	8.000
5.05	1.670	0.000	8.300	0.000	1.000	0.000	.070	0.00	.0248	0.000	9.000
5.06	1.180	0.000	8.300	0.000	1.000	0.000	.070	0.00	.0207	0.000	10.00
5.07	0.8200	0.000	11.00	0.000	1.000	0.000	.070	0.00	.0149	0.000	11.00
West	.00001	0.000	4.500	0.000	1.000	0.000	.070	0.00	0.000	0.000	5.001
Total	.00001	0.000	1.000	0.000	1.000	0.000	.025	0.00	0.000	0.000	1.002

Link Label	Average Intensity (mm/h)	Init. Loss #1 (mm)	Init. Loss #2	Cont. Loss #1 (mm/h)	Cont. Loss #2	Excess Rain #1 (mm)	Excess Rain #2	Peak Inflow (m^3/s)	Time to Peak	Link Lag mins
1.00	85.901	10.00	0.000	2.500	0.000	115.43	0.000	0.8310	31.00	0.000
3.00	85.901	10.00	0.000	2.500	0.000	115.43	0.000	2.160	38.00	0.000
2.00	85.901	10.00	0.000	2.500	0.000	115.43	0.000	0.2816	31.00	0.000
East	85.901	10.00	0.000	2.500	0.000	115.43	0.000	3.143	31.00	0.000
4.00	85.901	10.00	0.000	2.500	0.000	115.43	0.000	1.331	31.00	0.000
5.01	85.901	10.00	0.000	2.500	0.000	115.43	0.000	1.579	31.00	0.000
5.02	85.901	10.00	0.000	2.500	0.000	115.43	0.000	1.127	31.00	0.000
5.03	85.901	10.00	0.000	2.500	0.000	115.43	0.000	0.7415	31.00	0.000
5.04	85.901	10.00	0.000	2.500	0.000	115.43	0.000	0.8425	31.00	0.000
5.05	85.901	10.00	0.000	2.500	0.000	115.43	0.000	0.9340	31.00	0.000
5.06	85.901	10.00	0.000	2.500	0.000	115.43	0.000	0.6831	31.00	0.000
5.07	85.901	10.00	0.000	2.500	0.000	115.43	0.000	0.5122	30.00	0.000
West	85.901	10.00	0.000	2.500	0.000	115.43	0.000	6.417	31.00	0.000
Total	85.901	10.00	0.000	2.500	0.000	115.43	0.000	10.892	31.00	0.000

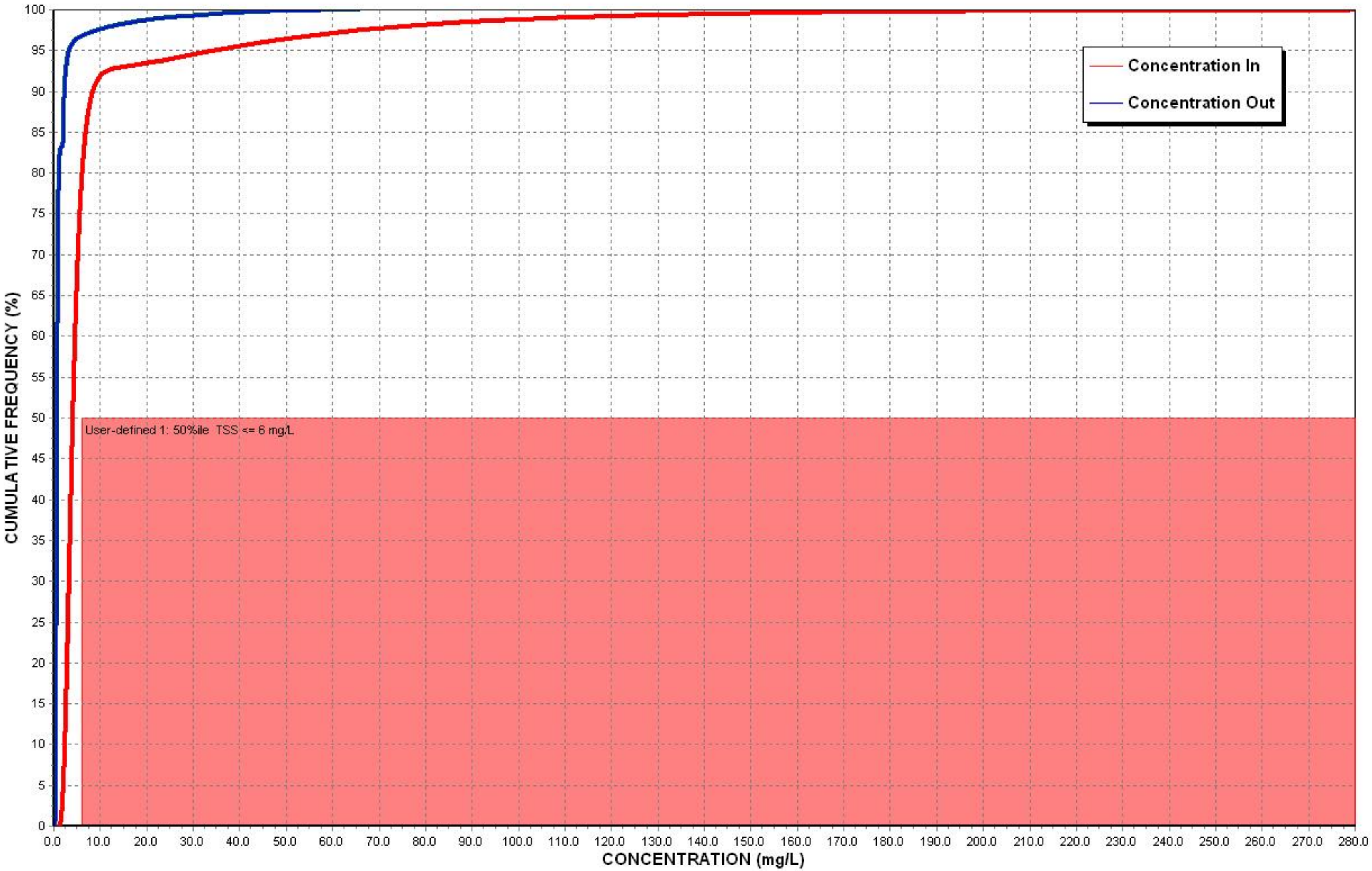
ATTACHMENT B

MUSIC MODELLING

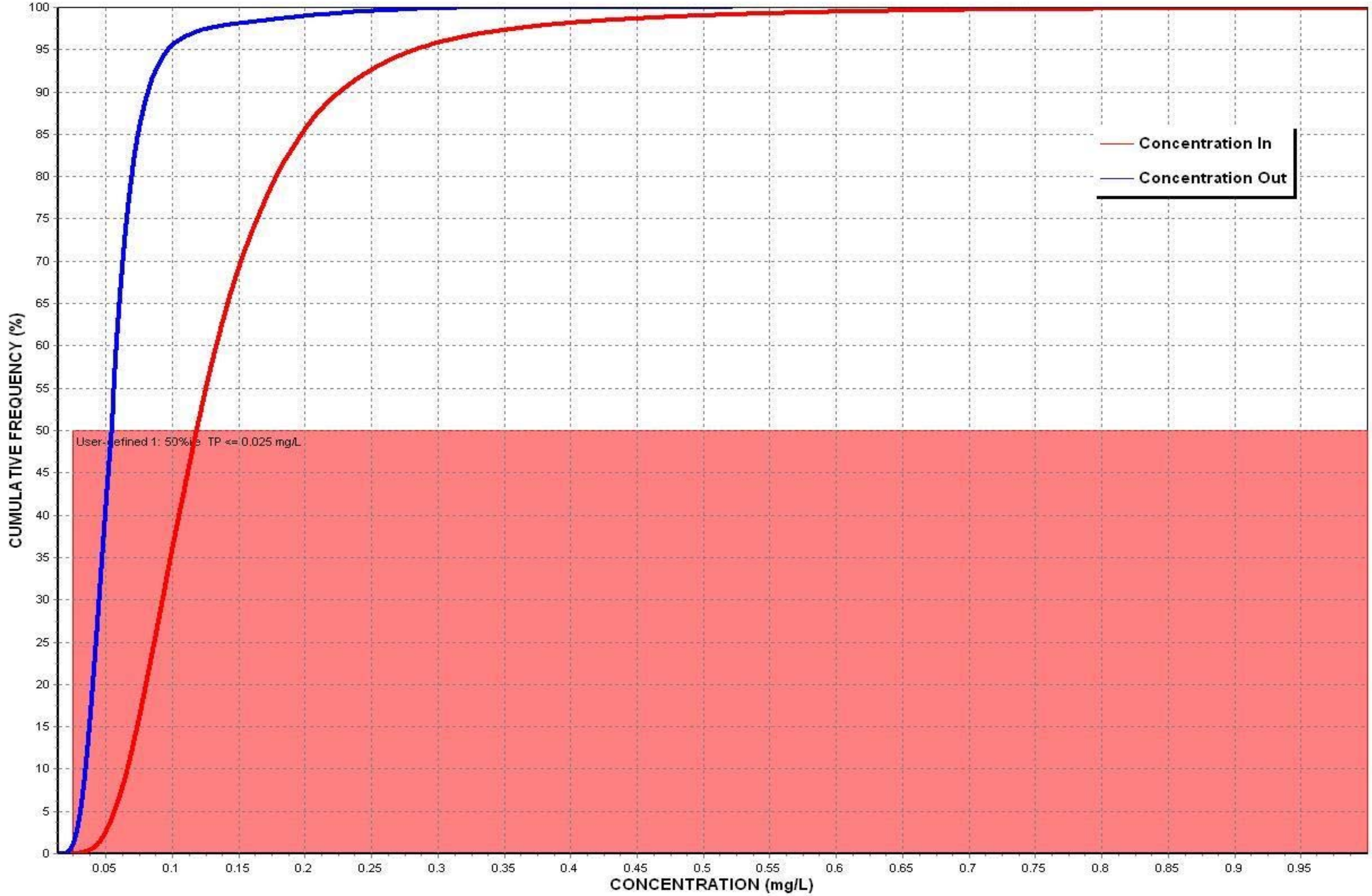
6 minute Rainfall (1976)

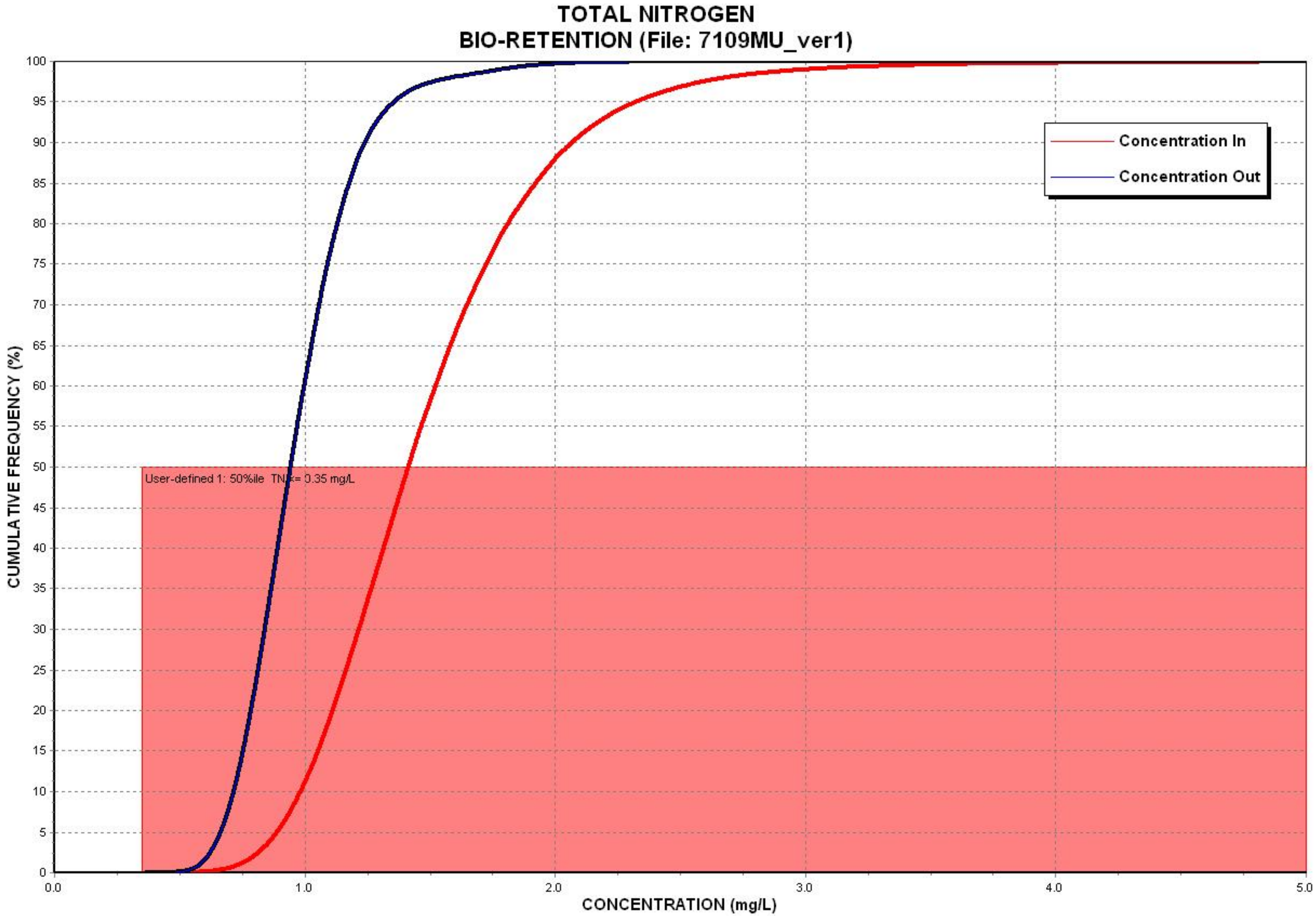

5.03
GPT
Bio-Retention

TOTAL SUSPENDED SOLIDS
BIO-RETENTION (File: 7109MU_ver1)



TOTAL PHOSPHORUS
BIO-RETENTION (File: 7109MU_ver1)




TOTAL NITROGEN
BIO-RETENTION (File: 7109MU_ver1)
CUMULATIVE FREQUENCY (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0.0
1.0
2.0
3.0
4.0
5.0
CONCENTRATION (mg/L)
Concentration In
Concentration Out
User-defined 1: 50%ile TN <= 0.35 mg/L