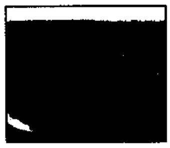
STORMWATER MANAGEMENT PLAN
SECTOR 5, WARRIEWOOD



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STORMWATER MASTERPLAN SECTOR 5, WARRIEWOOD

FOR JUBILEE DEVELOPMENTS

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LIST OF ABBREVIATIONS

AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
DCP	Development Control Plan
EMC	Event Mean Concentration
FPL	Flood Planning Level
ha	Hectare (Area = 10,000m^2)
LGA	Local Government Area
m^3/s	Cubic meters per second
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCP	Reinforced Concrete Pipe
RCBC	Reinforced Concrete Box Culvert
SMP	Stormwater Management Plan

STORMWATER MASTERPLAN
SECTOR 5, WARRIEWOOD

1 INTRODUCTION

Brown Consulting (NSW) Pty Ltd has been commissioned to provide a stormwater management plan for a application for rezoning at Sector 5 Warriewood Valley in the Pittwater local government area. This report and its associated drawings provide concept detail as to the stormwater management for the proposed residential development.

The following drawings in **Appendix A** should be read in conjunction with this stormwater management plan:

- D01 Existing Survey and Flood Extents
- D02 Stormwater Drainage Concept Plan
- D03 Biofiltration Basin A1 Plan and Section
- D04 Biofiltration Basin A2 Plan and Section
- D05 Biofiltration Basin B Plan and Section
- D06 Overland Flowpath Long Section – Sector 5
- D07 Narrabeen Creek Design Plan & HEC-RAS Cross Sections
- D08 Narrabeen Creek Existing & Design Long Section
- D09 Narrabeen Creek Design Cross Sections – Sheet 1
- D10 Narrabeen Creek Design Cross Sections – Sheet 2
- D11 Narrabeen Creek Design Cross Sections – Sheet 3
- D12 Design Creek Details and pipe long section

1.1 SITE LOCATION & DESCRIPTION

The site is located in the upper reaches of Narrabeen Creek, with the proposed development located to the south of Narrabeen Creek, which flows in an easterly direction. The site currently contains glasshouses and is predominantly cleared. Most riparian vegetation on Sector 5 is predominantly weed species and significant incision (up to 2 m depth) of the creek channel has occurred in places as a result of channel instability. In its existing condition, this section of Narrabeen Creek is considered a Class 3 fish habitat "Minimal Fish Habitat', although with riparian restoration would be considered a Class 2 habitat "Moderate Fish Habitat".

A steep bushland catchment of 4.12 ha to the South of the site drains through the site in a northerly direction. Drainage from this catchment is currently conveyed through the site by a series of small earth drains and pipe culverts, and in places the drainage line would only exist as sheet overland flow. This drainage discharges into Narrabeen Creek near the creek crossing with Jubilee Avenue.

The ephemeral drainage line passing through Sector 5 is considered a Class 4 fish habitat "Unlikely Fish Habitat" by the NSW Department of Primary Industry (Fisheries) due to the ephemeral nature of this drainage line, lack of vegetation, significant modification of the drainage line, lack of connectivity to Narrabeen Creek and the absence of any upstream or downstream significant aquatic habitat.

1.2 THE DEVELOPMENT PROPOSAL

The Rezoning application is for the construction of 68 residential dwellings in Sector 5 Warriewood Valley, as shown in **Drawing D02**. A total of 50 dwellings are proposed adjacent to Narrabeen Creek, denoted Site A in this study. A further 18 dwellings are proposed in the south-east corner of Sector 5, denoted Site B in this study.

The development of Sector 5 will utilise stormwater quality and quantity controls in accordance with industry 'best practice management', and more specifically to meet the objectives of Pittwater Council's *"Water Management Specification"*. This will include stormwater reuse for each dwelling in accordance with the NSW government's BASIX, in addition to utilising stormwater treatments such as biofiltration basins, swales and gross pollutant traps. The development will also provide on-site detention to maintain existing flow regimes and provide rehabilitation of Narrabeen Creek through Sectors 5 & 6.

2 BACKGROUND

2.1 WARRIEWOOD VALLEY STORMWATER MANAGEMENT SPECIFICATION

This study has been developed in accordance with Pittwater Councils (2001) Stormwater Management Specification for the Warriewood Valley Urban Release Area. The key issues outlined by this specification include:

Stormwater Quantity Management

- Developed hydrograph must be within ±10% of the pre-developed hydrograph,
- Peak flow from the sector to be within ±5% of the peak flow given in Appendix A of the specification.
- Developed peak flow to be no greater than pre-developed conditions,
- All OSD aboveground structures to be located above the 100 year ARI flood level,
- Stormwater reuse to be utilised for the development

Flooding

- Estimation of flood levels for pre and post development,
- Floor levels to be +500 mm above the 1% AEP flood,
- The 50% AEP flood to be conveyed within the creek banks,
- Walkways & cycleways to be above 20% AEP flood level,
- Water quality control devices to be above the 20% AEP flood level,
- Flood hazard and evacuation associated with the PMF to be considered if it flows through residential areas.

Stormwater Quality

- Load based modelling of pre and post development using a daily load model for 90^{th} 50^{th} and 10^{th} percentile rainfall years,
- Ensure post developed pollutant loads do not exceed existing loads,
- Concept design of stormwater treatment facilities,

Water Balance

- Water balance modelling for pre and post development,

Watercourse & Creekline Preservation

- Establish baseline conditions by survey every 25 m,
- 1% AEP flood to be conveyed in creekline for post-development conditions,
- Use of natural channels in the design sections of the creek,
- 50% AEP flood to be conveyed below bank-full levels,
- Stormwater discharges to be adequately stabilised,

2.2 NARRABEEN CREEK CORRIDOR THROUGH SECTOR 5

Narrabeen Creek is considerably degraded adjacent to Sector 5, showing signs of scour and containing many weed species in the riparian area. Proposed creek works will aid in stabilising the creek and provide a revegetated riparian corridor.

Drawing D10 and **Drawing D11** show the existing creek survey information in section and plan.

2.3 EXISTING HYDROLOGY

The hydrology of the proposed development area has been previously modelled by Lawson & Treloar Pty Ltd for Pittwater Council using the *XP-RAFTS* hydrological model. This model was a broad scale model covering most of the catchment of Narrabeen Creek, including the study area (Sector 5).

The existing peak flows at the upstream and downstream end of Sector 5 & 6 for various design floods as quoted in Councils DCP are shown in **Table 2.1**.

Table 2.1 Peak Flows Upstream & Downstream of Sectors 5 & 6

Sector 5	PMF	100 Y ARI	50 Y ARI	20 Y ARI	5 Y ARI	2 Y ARI
Upstream	62.8	14.1	11.5	8.6	4.2	1.3
Downstream	75.0	17.0	13.6	10.1	5.0	1.5

These flows relate to the runoff contributed from both Sectors 5 and 6.

A small ephemeral drainage line passes through the proposed subdivision. This drainage line has a catchment area of 4.12 ha upstream of the proposed subdivision. The catchment landuse is bushland and the average slope in this area is 15%.

The peak 100 year ARI flow from this catchment has been estimated using the RAFTS component of DRAINS as being 1.54 m^3/s. This flow was estimated using a Manning's roughness value of 0.06 (representing the bushland conditions) and the same initial and continuing losses as adopted in the RAFTS model developed for Narrabeen Creek by Lawson & Treloar Pty Ltd.

2.4 EXISTING FLOOD CONDITIONS IN NARRABEEN CREEK

Flood levels for existing conditions were established by Lawson & Treloar Pty Ltd (2001) for Pittwater Council from four cross sections through the site. The estimated 100 year ARI flood level varied from 20.77 to 19.79 m AHD through Sector 5. These flood levels were revised as part of this study using a more detailed survey through the site, which was taken at 25 m spacings along the creek and extended further onto the floodplain.

The HEC-RAS boundary condition adopted was the known surface water level downstream of the site as derived from the modelling undertaken by Lawson & Treloar Pty Ltd for each design flood (eg 17.92 m AHD for the 100 y ARI flood). The model was run in sub-critical mode.

Cardno Lawson Treloar reviewed the previous HEC-RAS modelling undertaken as part of the Brown Consulting (2004) *Concept Stormwater Management Plan* submitted for the Development Application at Sector 5 Warriewood Valley. In a fax dated 9 May 2005 to Pittwater Council, Cardno Lawson Treloar noted that the Manning's values adopted in the Brown Consulting HEC-RAS model were lower then values used in the Warriewood Valley Flood Study (April, 2006).

Brown Consulting revised the HEC-RAS model to include the mannings values suggested by Cardno Lawson Treloar (mannings n of 0.16). The model resulted in flood levels significantly above the levels presented in the Warriewood Valley Water Management Specification (2001) suggesting the mannings values were too high. A site visit further indicated that the mannings values suggested were too conservative. The HEC RAS model was further refined to adopt a channel mannings of 0.087 and overbank mannings value of 0.1. The flood level results match the levels presented in the Cardno Lawson Treloar (2004) study. **Table 2.2** presents the existing 100 year ARI flood levels taken from the HEC RAS model based on those mannings values.

It should be noted that the Cardno Lawson Treloar fax dated 9 May, 2005 suggested that the peak flows used on the upstream end for the 100 year ARI event appeared to be higher then those issued by Lawson & Treloar, however the 14.1 m^3/s flow was adopted from Table B1 of the Warriewood Valley Management Specification (2001) for Sectors 5 & 6. Therefore, those flows stated in the DCP were used.

Table 2.2 Existing 100 year ARI Flood Levels

Section	Q Total (m3/s)	Flood Level (m, AHD)	Channel Velocity (m/s)	Froude	Mannings LOB	Mannings Channel	Mannings ROB
11	14.1	21.23	1.29	0.38	0.1	0.087	0.1
10	14.1	20.98	1.25	0.4	0.1	0.087	0.1
9	14.1	20.77	1.04	0.28	0.1	0.087	0.1
8	14.1	20.60	1.07	0.30	0.1	0.087	0.1
7	14.1	20.39	1.26	0.34	0.1	0.087	0.1
6	14.1	20.13	1.43	0.42	0.1	0.087	0.1
5	14.1	20.03	0.93	0.24	0.1	0.087	0.1
4	14.1	19.89	0.95	0.26	0.1	0.087	0.1
3	14.1	19.78	0.9	0.25	0.1	0.087	0.1
2	14.1	19.34	1.90	0.59	0.1	0.087	0.1
1	17	18.95	1.53	0.47	0.1	0.087	0.1
0	Bridge at Jubilee Ave						

Drawing D01 shows the PMF, 20 and 100 year ARI flood extents through Sector 5. **Table 2.2** shows that the revised 100 year ARI flood level varies from approximately 21.23 to 19.95 m AHD through the site. All floods except the PMF are completely contained within the existing channel of Narrabeen Creek.

3 WATER BALANCE MODELLING - SECTOR 5

A daily water balance model was developed for pre and post development of the site using a spreadsheet model. This type of approach is recommended by the EPA (1997) for estimating daily runoff characteristics at the development application stage.

3.1 MODEL ASSUMPTIONS

This model used daily rainfall data from the Bureau of meteorology Station at Mona Vale to estimate daily runoff volumes. The period of record covered 31 years from January 1972 to the end of 2002. Evaporation data used were daily averages for each month.

Volumetric runoff coefficients (Cv) and initial rainfall loss used in the model for each landuse included:

	Cv	Loss
• Existing Site	15%	7 mm
• Roof Areas	100%	0 mm
• Road Reserve	85%	1 mm
• Lots	18%	2 mm

For developed conditions, the daily rainwater demand was assumed to be 360 L/d/dwelling if available (for irrigation, washing machines and toilet flushing) as recommended by Cardno Lawson Treloar . Total rainwater storage for each dwelling is 4,500 L and top-up from Sydney Water mains of up to 15% tank capacity was also included in the model.

3.2 WATER BALANCE SUMMARY

The water balance modelling estimated the following total rainfall depths for statistically representative rainfall years:

▪ 10th Percentile Rainfall Year	744 mm
▪ Average rainfall year	1,090 mm
▪ 90th Percentile rainfall year	1,537 mm

The water balance model results are shown in **Table 3.1**.

Table 3.1 **Water Balance Modelling Results**

	Pre-development Runoff (ML/y)		Post-Development Runoff with Stormwater Re-use (ML/y)		Stormwater Re-use (ML/y)	
Site	***A***	***B***	***A***	***B***	***A***	***B***
10th Percentile Rainfall Year	3.37	0.51	3.31	0.44	1.96	0.44
Average rainfall year	5.46	0.78	5.20	0.70	2.35	0.56
90th Percentile rainfall year	9.35	1.34	8.21	1.03	3.57	0.93

The model shows that development of Sector 5 would not increase runoff volumes from that of existing conditions. This has been achieved by incorporating a stormwater reuse component for each dwelling.

In attempt to minimise reductions of environmental flows to Narrabeen Creek, rainwater reuse has been limited to runoff from roof areas. Within the site all roads and lot areas bypass the rainwater tanks and continue to flow to Narrabeen Creek through the water quality treatment devices and on-site detention. However, the water balance suggests that the environmental flows to Narrabeen Creek will still be reduced with associated rainwater reuse.

Cardno Lawson Treloar facsimile to Pittwater Council (dated 9/5/05) stated that the water balance should demonstrate a balance in the pre and post development cases. However preliminary investigations suggest that in order to balance flow volumes off the site a significant reduction in stormwater reuse. Therefore, resulting in non compliance with BASIX potable water demand reductions.

It should be noted that the amount of re-use will always be limited if environmental flows are to be maintained, as optimum stormwater reuse can only occur if most of the runoff is utilised. Therefore to maintain stormwater storage for rainwater reuse (for irrigation, washing machines and toilet flushing) a certain trade off has to be made with slight reductions in developed stormwater runoff volumes.

Figure 2.1 shows the storage in the rainwater tanks associated with the stormwater demand for an average rainfall year on Site A. It can be seen that for approximately 70% of the year Sydney Water top up was required on Site A.

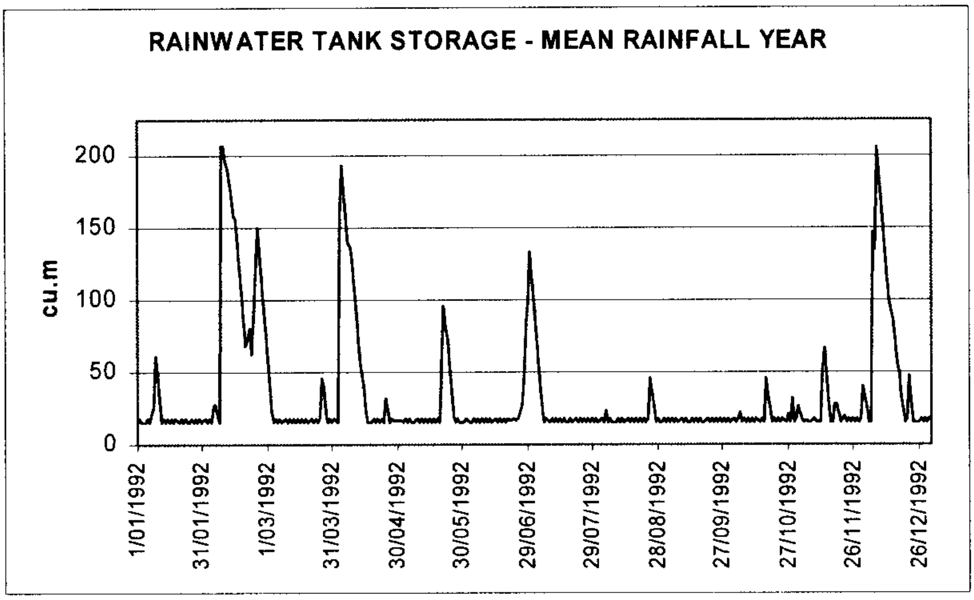

Figure 2.1 **Rainwater Tank Storage - Site A**

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4 STORMWATER DRAINAGE CONCEPT PLAN (SDCP)

A requirement of Pittwater Council is to provide a Stormwater Drainage Concept Plan (SDCP). This plan is shown in **Drawing D02**, which identifies:

- Location & size of SQIDS
- Location of diversion drains,
- Location and size of the OSD systems,
- 1% AEP and PMF extents - post development
- Creekline corridors - post development
- Piped drainage system
- Surface overland flowpaths

5 STORMWATER QUALITY MANAGEMENT

5.1 MODELLING METHODOLOGY

Water quality modelling of the proposed development has been undertaken using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software package developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH). MUSIC enables the user to model the transfer of pollutants through a catchment and provides an aid in determining the treatment strategy required to meet the water quality objectives applicable to the site. The critical pollutants to be modelled are Gross Pollutants, Total Nitrogen (TN), Total Phosphorous (TP) and Total Suspended Solids (TSS).

The generation, transfer and removal of these critical pollutants will be modelled through the treatment strategy employed. Only the critical pollutants will be further addressed in this report, however the treatment devices will provide mitigation of other pollutant loads, such as heavy metals, since they are predominantly associated with fine sediment. The Gross Pollutant Trap's (GPT's) will intercept pollutants such as litter, rubbish, leaves etc therefore minimising the runoff of oxygen demanding substances.

The event mean concentrations (EMC) used were taken from the Warriewood Valley Water Management Specification, as shown in Table 5.1.

Table 5.1 Pollutant EMC Values & Runoff Coefficients

Landuse	TSS (mg/L)	TP (mg/L)	TN (mg/L)
Urban	100	0.3	1.5
Rural Residential	35	0.1	1
Horticultural	45	0.2	2.5
Pasture	15	0.04	0.5
Forest/Native Vegetation	10	0.03	0.32

Source: Warriewood Valley Water Management Specifications (2001)

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5.2 MODELLING STORMWATER OF MANAGEMENT STRATEGIES

Pollutant export analysis has been undertaken for three scenarios using MUSIC. The three models are:

- Existing Scenario - Pre-developed site
- Developed Scenario - site developed as proposed, without any stormwater quality treatment; and
- Mitigated Scenario - site developed as proposed with stormwater quality treatment.

It should be noted that the updated version of the MUSIC program (v.3) was used for the modelling.

5.2.1 Source Nodes

For modelling with MUSIC, subject sites have to be classified into different land uses that are represented as source nodes. The source nodes that have been used in the modelling are Agriculture and Urban. Each are used for various land uses within the site for the existing and developed scenarios.

The two types of source nodes used in the MUSIC modelling have used the following total impervious percentages:

- Agriculture - An impervious percentage of 5% was used for the existing scenario and areas of open space
- Urban - An impervious percentage of 80% was used for roof, and access road areas and 50% for lots.

Soil properties, base and storm flow pollutant concentrations for each source node are set as defaults use by MUSIC for the two respective source node types. Stochastic generation estimation and serial autocorrelation set to zero has also been adopted.

5.2.2 Drainage Links

No routing has been adopted for all drainage links within each model. This assumption is due to the type of SQID's modelled and the limited overland flow lengths. It is believed this assumption will produce more conservative results.

5.3 RESULTS FOR THE EXISTING & DEVELOPED SCENARIO'S

Table 5.2 and 5.3 summarises the results of the existing and developed (without mitigation) scenario pollutants loads generated from the site.

Table 5.2 Existing pollutant Loads

Percentile Year	TSS Conc. (mg/L)	TP Conc. (mg/L)	TN Conc. (mg/L)
Site A			
10th	17.2	0.09	0.813
mean	26.9	0.14	1.28
90th	39	0.197	1.86
Mean Annual Loads (kg/Yr)	383	1.81	20.3
Site B			
10th	17.3	0.09	0.813
mean	26.9	0.14	1.28
90th	39.1	0.197	1.86
Mean Annual Loads (kg/Yr)	151	0.712	7.99

Table 5.3 Developed (no mitigation) pollutant Loads

Percentile Year	TSS Conc. (mg/L)	TP Conc. (mg/L)	TN Conc. (mg/L)
Site A			
10th	15.1	0.144	1.52
mean	21.8	0.162	1.81
90th	22.6	0.205	2.12
% increase	-19%	16%	41%
Mean Annual Loads (kg/Yr)	1830	5.76	32.3
Site B			
10th	12.6	0.112	1.50
mean	20.6	0.165	1.91
90th	23.2	0.236	2.38
% increase	-23%	18%	49%
Mean Annual Loads (kg/Yr)	726	2.28	12.7

The objective of the stormwater quality treatment strategy is to ensure no worsening of existing runoff quality conditions.

5.4 PROPOSED STORMWATER TREATMENT STRATEGY – SITE A

The water quality treatment for Site A will consist of:

- Stormwater re-use of dwelling roof runoff by utilising rainwater tanks,
- Gross pollutant traps to pre-treat road and lot drainage, and
- Two biofiltration basins which will receive flows from the gross pollutant traps.

The estimates of pollutant loads from Site A with stormwater treatment are shown in **Table 5.4**.

Table 5.4 Site A - Pollutant Loads with Stormwater Treatment

	TSS	TP	TN
Percentile Year	Conc. (mg/L)	Conc. (mg/L)	Conc. (mg/L)
10th	2.11	0.043	0.84
mean	4.10	0.054	0.97
90th	4.78	0.065	1.1
Mean Annual Loads (kg/Yr)	214	1.58	18.2
Existing Mean	26.9	0.14	1.28

5.4.1 Biofiltration Basin Concept Design

Biofiltration Basin Sizing

Filter Media depth	750 mm
Filter Media Surface Area	592 m^2 (Total)
Extended Detention Depth	300 mm
Total Basin Volume (not including OSD)	178 m^3 (Total) - Approx 2 Y ARI
Maximum Time to Drain Basin	24 hours

Filter Media Specification

Filter Media Type	Sandy Loam (0.45 mm)
Maximum Hydraulic Conductivity	180 mm/h
Sub-surface Drain Type	Ag Drain (min 0.5% grade) 100 & 150mm slotted pipe

Surface Treatment on Filter Media

Plants selected for use in biofiltration systems need to be able to tolerate periods of inundation, as these systems can be expected to have a proportion of the soil profile saturated for several days. The selection of a sandy loam soil with a hydraulic conductivity in the range of 40-180mm/h will normally ensure soils are not waterlogged, which has been accommodated in the concept design.

Plants with extensive fibrous root systems are generally preferred as they prevent the filter media from clogging. Plants with a spreading, rhizomatous or suckering habit are also preferred. The filter must be planted to ensure it does not clog, and a stone layer at the surface could be used if required, although no mulch should be placed on the filter.

Sub-surface Drainage

100 mm & 150mm Ag drain will be placed in a 150-200 mm thick fine gravel layer below a 100 mm thick sand transition layer located immediately below the filter media. The grading of the transition layer should be:

- 1.4 mm 100% passing
- 1.0 mm 80%
- 0.7 mm 44%
- 0.5 mm 8.4% passing

The maximum spacing of the Ag drain is to be maximum 2 m spacings centre to centre.

The proposed bio-filtration filter will incorporate a ***HPDE or Bentofix liner*** beneath the gravel layer to ensure no infiltration into the surrounding soil occurs.

5.5 PROPOSED STORMWATER TREATMENT STRATEGY – SITE B

The water quality treatment for Site B will consist of:

- Stormwater re-use from dwelling roof runoff using rainwater tanks,
- Gross pollutant trap to treat road and lot drainage, and
- Biofiltration basin which will receive flows from the gross pollutant trap.

The model estimates of pollutant loads from Site B on Sector 5 are shown in **Table 5.5**.

Table 5.5 Site B - Pollutant Loads with Treatment

Percentile Year	TSS Conc. (mg/L)	TP Conc. (mg/L)	TN Conc. (mg/L)
10th	0.478	0.022	0.66
mean	0.709	0.030	0.81
90th	0.779	0.040	0.98
Mean Annual Loads (kg/Yr)	50.8	0.448	6.15
Existing Mean	26.9	0.14	1.28

5.5.1 Concept Water Quality Treatment Device Sizing – Site B

Biofiltration Basin Sizing

Filter Media depth	750 mm
Filter Media Surface Area	230 m^2
Extended Detention Depth	300 mm
Total Basin Volume (not including OSD)	70 m^3 - Approx 2 Y ARI
Maximum Time to Drain Basin	24 hours

Filter Media Specification

Filter Media Type	Sandy Loam (0.45 mm)
Maximum Hydraulic Conductivity	180 mm/h
Sub-surface Drain Type	Ag Drain (min 0.5% grade)

Surface Treatment on Filter Media

As per Basin A, refer to Section 5.4.1.

Sub-surface Drainage

As per Basin A, refer to Section 5.4.1.

5.6 MAINTENANCE

The Gross pollutant traps shall be inspected every three months to establish the frequency of cleaning required. At a minimum the traps will require cleaning every six months.

The biofiltration basins will be self cleaning when planted appropriately and fitted with a back flush system (pipe riser). Maintenance will be limited to landscaping and weed control.

5.7 MOSQUITO RISK

Mosquitoes require still permeant water bodies to lay eggs. As the biofiltration basins do not hold water and will be self draining, the risk of mosquito breeding is considered minimal to none.

5.8 WATER QUALITY MONITORING

It is understood that wet and dry weather water quality monitoring for the Narrabeen Creek has been undertaken as part of the Sector 6 Development. This will need to be confirmed.

6 ONSITE DETENTION REQUIREMENTS - SECTOR 5

The Warriewood Valley Water Management Specification provides site storage requirements (SSR) and permissible site discharge (PSD) for Sector 5. These were estimated from the *RAFTS* modelling undertaken by Lawson & Treloar for Pittwater Council. These factors were determined as being:

- SSR for 1% AEP 1 hr Storm 368 m3/ha
-
- PSD for 1% AEP 1 hr Storm 0.331 m3/s
- PSD for 1% AEP 2 hr Storm 0.390 m3/s

The PSD and SSR were verified using the *RAFTS* hydrological component of the *DRAINS* model for catchment Site A and *ILSAX* hydrological component of the *DRAINS* B in Sector 5. This software has a more advanced detention basin modelling component than RAFTS that allows multiple orifices to be modelled and hydrographs examined. Initial and continuing losses adopted were those used in the Narrabeen Creek Flood Study by Lawson & Treloar Pty Ltd for Pittwater Council.

6.1 ONSITE DETENTION REQUIREMENTS - SITE A

The hydrological parameters adopted for the existing catchment conditions were the same as for the RAFTS modelling undertaken by Lawson & Treloar, being:

Existing Mannings 'n'	0.05
Developed Mannings 'n'	0.025
Slope	5%
Contributing catchment area	2.1 ha
Impervious percentage	50%

Exceptions from the parameters used in the existing *RAFTS* model were the catchment area modelled, where it is proposed to develop only 2.1 ha of Site A and hydrologically isolate the remaining upslope catchment area from the rest of the site, by diverting these flows directly to Narrabeen Creek through a swale.

The Site A basin outflow was adjusted to account for a 0.38ha catchment area by-passing the OSD basins. The bypass area include the road and lots along the eastern site A boundary and the upstream catchment overland flow path through the site.

The proposed OSD system for Site A is shown in **Drawing D03**. The OSD system will utilise 740 m^3 of storage located in two bio-filtration basins. The *DRAINS* modelling has estimated that the development of Site A would not increase the peak flow from that of existing conditions when using OSD, as shown in **Table 6.1**.

Table 6.1 Summary of Peak Flows - Site A

ARI Storm	Existing Conditions	PSD	Developed With OSD
5	0.362	0.362	0.360
20	0.555	0.555	0.554
100	0.769	0.769 (0.819*)	0.718

*PSD from the Warriewood Valley Urban Release Area Water Management Specification (2001)

Basin A1

The concept outlet arrangement from the Site A1 OSD outlet is:

- Low level orifice 170 mm at centre RL 21.09 m
- High level Orifice 230 mm at centre RL 21.12 m with inlet pit at RL 21.52
- Emergency overflow weir at RL 23.1 m
- 100 Year ARI top water level RL 23 m
- Outlet using a 375 mm RCP at IL 21 m

Basin A2

The concept outlet arrangement from the Site A2 OSD outlet is:

- Low level orifice 220 mm at centre RL 22.11m
- High level Orifice 270 mm at centre RL22.13 m with inlet pit at RL 22.54
- Emergency overflow weir at RL 24.1 m
- 100 Year ARI top water level RL 24 m
- Outlet using a 375 mm RCP at IL 22 m

The OSD system has been designed to ensure that there is no pronounced 'tail' of the hydrograph and that the times of peak and hydrograph shapes are similar (**Figure 6.1**). Furthermore, the system has been designed to account for the hydraulic grade line in the outlet pipe due to flooding in Narrabeen Creek.

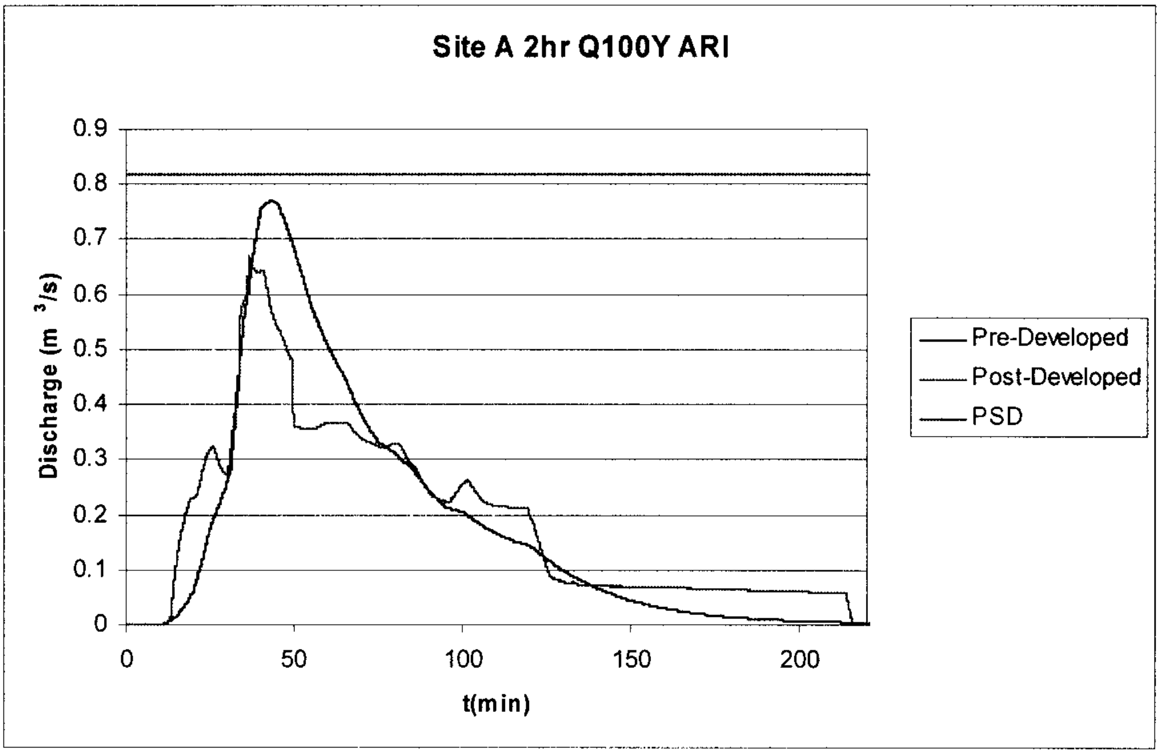


Figure 6.1
2 hour 100 year ARI Storm Hydrograph - Site A

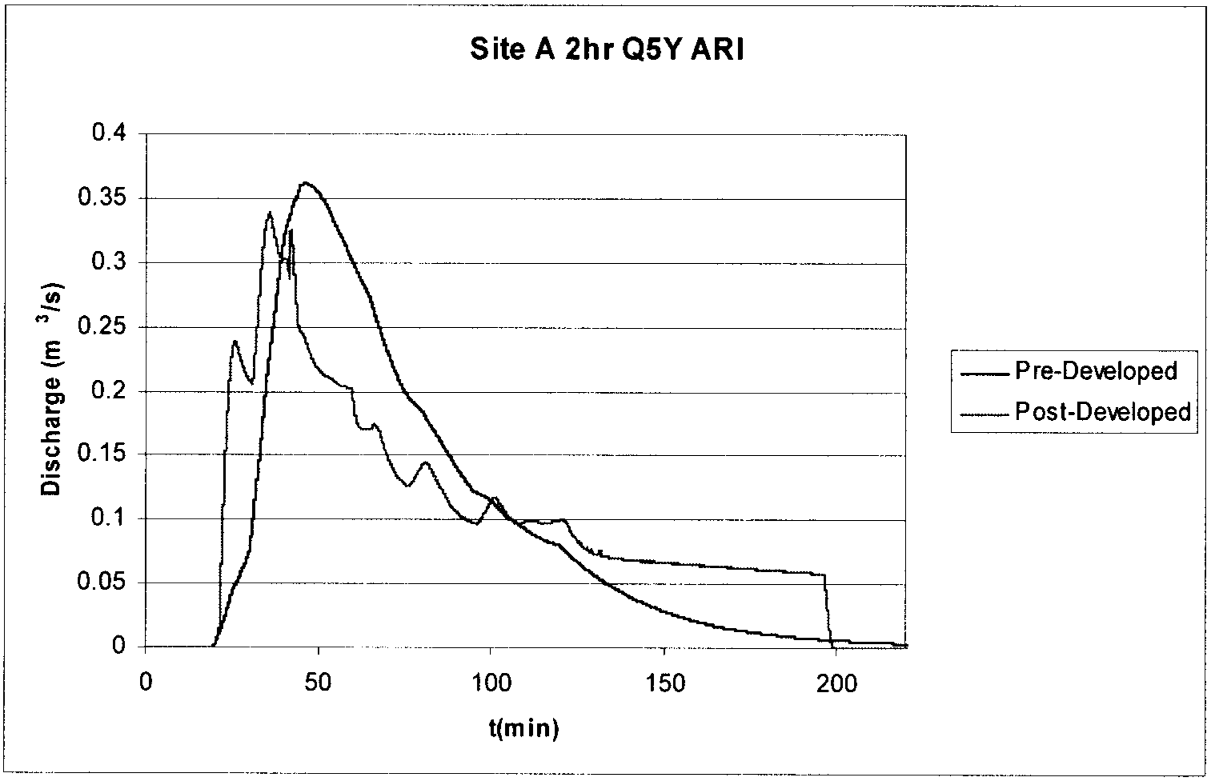


Figure 6.2
2 hour 5 year ARI Storm Hydrograph - Site A

6.1.1 Freeboard

Floor levels for properties adjacent to the OSD have been set at least 0.5m above the 1 in 100 year ARI flood level.

A 0.3m freeboard has been provided along the road to the East of OSD basin A1 to protect downstream properties. Discussions with Council suggest such a freeboard is sufficient as an emergency spillway has been provided discharging to Narrabeen Creek with ample capacity to cater for all flows off the site. The emergency spillway across the road has capacity in the order of $3m^3/s$ at a flow depth of 20mm.

6.2 ONSITE DETENTION REQUIREMENTS - SITE B

This catchment was modelled in *DRAINS* using the *ILSAX* hydrological component, as a smaller sub-catchment in the RAFTS component will alter the peak flows from the catchment.

The existing peak flows for each design storm were adopted as the PSD for the site, except for the 100 year ARI storm where the PSD given in the Warriewood Water Management Specification was used. The PSD and results are shown in **Table 6.2**.

The developed model parameters included;

Developed Mannings 'n'	0.02 (paved)
	0.035 (grassed)
Slope	5%
Contributing catchment area	0.827 ha
Impervious percentage	50%

Table 6.2 Summary of Peak Flows - Site B

ARI Storm	Existing Conditions	PSD	Developed With OSD
5	0.179	0.179	0.178
20	0.27	0.270	0.209
100	0.361	0.361 (PSD.0.274*)	0.267

*PSD from the Warriewood Valley Urban Release Area Water Management Specification (2001)

The proposed OSD system utilises a bio-filtration basin to provide storage of 240 m^3 as shown in **Drawing D05**.

Concept design details for the OSD on Site B are provided below:

- Low level orifice 285 mm at centre RL 20.54 m
- High level Orifice 190 mm at centre RL20.5 m with inlet pit at RL 21.8
- 100 Year ARI top water level RL 22.3m

The OSD system has been designed to ensure that there is no pronounced 'tail' on the falling limb of the hydrograph and that the times of peak and hydrograph shapes are similar (**Figure 6.3**). Furthermore, the system has been designed to account for the hydraulic grade line in the outlet pipe due to flooding in Narrabeen Creek.

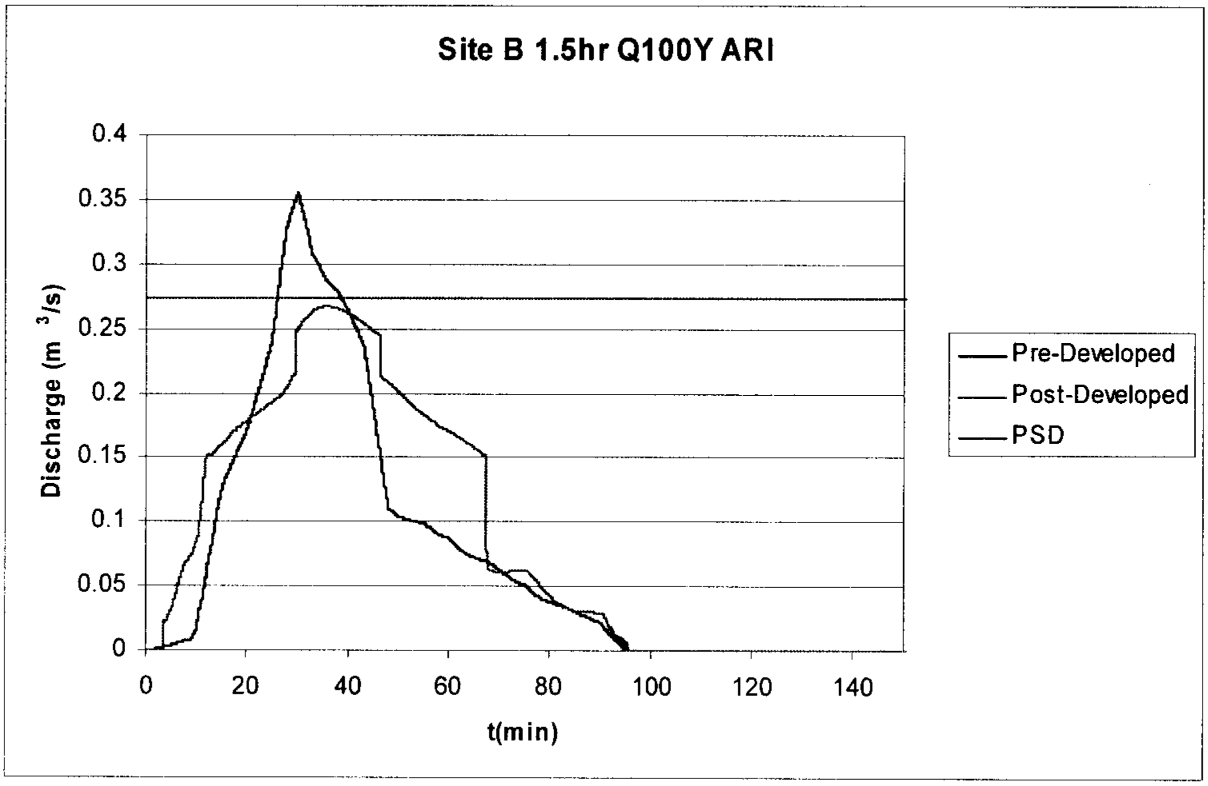


Figure 6.3
1.5 hour 100 year ARI Storm Hydrograph - Site B

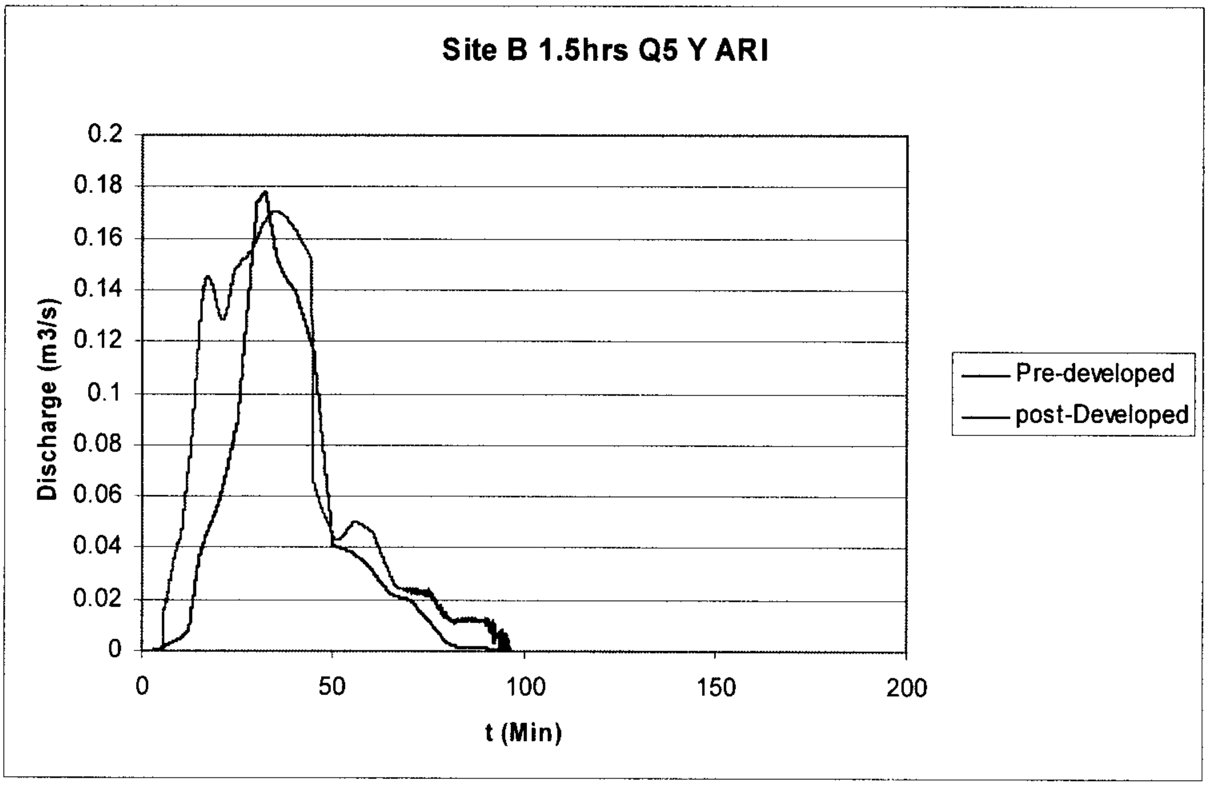


Figure 6.4
1.5 hour 5 year ARI Storm Hydrograph - Site B

6.2.1 Freeboard

Floor levels for properties adjacent to the OSD in site B have been set at least 0.5m above the 1 in 100 year ARI flood level.

A 0.5m embankment above the 100 year ARI top water level has been provided around the basin to protect any downstream properties. Furthermore a pit and pipe system downstream of the basin will be design to collect 100 year ARI storm event flows off the site in the event of a complete system failure.

7 WATERCOURSE RESTORATION & FLOOD PROTECTION

7.1 NARRABEEN CREEK

Narrabeen Creek will be rehabilitated by providing revegetation of the riparian zone along with earthworks to stabilise the existing creek and manage flooding. The existing creek channel will be stabilised by creating benching in accordance with natural channel design principles. Small natural sandstone retaining walls of 300 mm height will extend above the bank full flow section of the channel throughout some sections of the creek. The creek bank above these retaining wall sections is proposed to be battered at a 1 in 6 grade to other 300 mm high benches until the design or natural surface level is reached. Concept creek design sections are shown in **Drawings D07, D08, D09, D10, and D11**.

We have been advised that the section of Narrabeen Creek on Sector 6 will have straight 1 in 3 batters, which has been adopted for the hydraulic modelling. Therefore, flood levels through this section of Narrabeen Creek will need to be re-viewed in the context of proposed works on the other side of the creek that fronts Sector 6 for the detailed design. In either case, changes to the flood levels estimated in this study are expected to be minimal for the detailed design.

7.1.1 Estimate of Design Flood Levels – Narrabeen Creek

Flood levels in Narrabeen Creek adjacent to Sector 5 were estimated using HEC-RAS, the cross sectional geometry from the proposed creek design and the estimate of flows derived by Lawson & Treloar for Sectors 5 & 6. The hydraulic modelling results are given in **Table 7.1**.

Table 7.1 Hydraulic Modelling Results & the Flood Planning Level

Section	PMF (m, AHD)	100 y ARI (m, AHD)	100 y ARI Velocity (m/s)	20 y ARI (m, AHD)	2 y ARI (m, AHD)	Flood Planning Level * (m, AHD)
11	21.89	20.35	3.10	20.04	19.38	20.85
10	21.6	20.08	2.03	19.8	19.17	20.58
9	21.6	20.01	1.60	19.7	19.03	20.51
8	21.36	19.81	1.98	19.52	18.88	20.31
7	21.24	19.65	2.05	19.36	18.73	20.15
6	21.18	19.51	1.98	19.22	18.57	20.01
5	21.15	19.43	1.80	19.13	18.45	19.93
4	21	19.22	2.14	18.91	18.28	19.72
3	21.01	19.09	1.97	18.77	18.12	19.59
2	20.99	18.96	1.92	18.62	17.91	19.46
1	20.92	18.83	2.12	18.54	17.77	19.33
0	Bridge					

*Flood Planning Level = (Q100+500 mm for minimum floor level for adjacent buildings)

Mannings values adopted for the flood study for the design creek included:

- 0.1 for overbanks (representing dense planting within the riparian zone), and
- 0.045 for the rehabilitated creek bed (representing scattered vegetation with riffle/pool system).

Hydraulic controls included the road bridge immediately downstream of Sector 5.

Drawing D09 shows the design 100 year ARI flood levels along this section of creek. It can be seen that the design of the creek reduces flood levels from that of existing conditions as a consequence of increasing the conveyance capacity of Narrabeen Creek.

7.1.2 Mosquito Risk – Narrabeen Creek

Due to the ephemeral nature of the creek the risk of Mosquito breeding is considered minimal to none.

7.2 STORMWATER OUTLET CONCEPT DESIGN

A single stormwater outlet to Narrabeen Creek is proposed for the water quality/onsite detention system. This outlet will contain a 1,050 mm RCP discharging through a rock stacked headwall situated in the riparian zone. The DRAINS model has estimated the flow velocity in the pipe to be a maximum of 1.3 m/s. The outlet will remain above the Narrabeen Creek 100 year ARI flood level.

The outlet will incorporate a natural rip rap energy dissipater in accordance with a *Type A - Roads & Traffic Authority* dissipater to force a hydraulic jump and allow flow to return to sub-critical before entering the main creek channel. A total dissipater length of 10 m has been provided to prevent scour at the confluence of this outlet and Narrabeen Creek. The proposed creek design will require that this stormwater outlet be surrounded by a sandstone boulder retaining wall that will mesh with the proposed benched creek design.

7.3 OVERLAND FLOW PATH THROUGH SITE A

A minor overland flow path is proposed to pass through the site in Site A. An ephemeral landscaped corridor has been provided to pass overland flows from the upstream 4.12 ha catchment, in addition to conveying the flows from the 0.81 ha catchment upslope of Site B.

7.3.1 Estimated Flows

The 100 year ARI flow from the total 4.93 ha upstream catchment is estimated as being 1.91 m^3/s, of which 1.52 m^3/s upstream of catchment A and 0.389 m^3/s is diverted from the upslope catchment of Site B. A box culvert under the access road is proposed to convey the 1.52 m^3/s flows into the designated overland flow path through Site A. Two box culverts of 1800 mm width and 600 mm height will convey this flow without overtopping of the access road when 50% blocked. Their combined capacity without blockage is estimated at 2.84 m^3/s at a headwater depth of 0.6 m. With blockage the culvert capacity is estimated at 2.0 m^3/s at the same headwater depth, which exceeds the estimated 100 year ARI flow at this location.

The flow off the catchment upstream of site B is diverted to a pit in site A and piped to an outlet discharging into Narrabeen Creek. A 525mm diameter RCP has sufficient capacity to convey the flow.

7.3.2 Estimate of Design Flood Levels – Sector 5 overland Flow Path (Swale)

A HEC-RAS hydraulic model was used to estimate flood levels in the proposed overland flow path through Sector 5. A mannings value of 0.045 was adopted for the grass swale.

Drawings D06, cross sections of this overland flow path along with the 100 year ARI flood level. It can be seen that all adjacent dwellings are located a minimum of 500 mm above the 100 year ARI flood level. Furthermore, all dwellings fronting the access road have sufficient freeboard.

For storms greater than the 100 year ARI, or if significant blockage of the culvert occurred, the adjacent road would act as an overland flow path for those overflows allowing runoff to reach Narrabeen Creek. Dwellings adjacent to the road have sufficient freeboard provided.

Table 7.2 100 Year ARI flood Levels in the Overland Flow Path

Section	100 Y ARI Flood Level (m, AHD)	Energy Grade Elevation (m, AHD)	100 Y ARI Channel Velocity (m/s)	Flood Planning Level (m AHD)
A	28.56	28.72	1.75	29.06
B	27.7	27.74	0.98	28.2
C	27.2	27.36	1.75	27.7
D	26.15	26.23	1.52	25.65
E	25.25	25.45	1.74	25.75

A bund along the eastern side of the road will be constructed to provide freeboard for houses to the east of the swale.
The overland flow path will incorporate a natural rip rap energy dissipater to allow flow to return to sub-critical before entering the main creek channel.

8 RECOMMENDATIONS

The stormwater management plan for Sector 5 Warriewood Valley has been prepared in accordance with Pittwater Councils Water Management Specification. The stormwater components used in the development will meet five principle objectives being:

- Ensuring that peak flows are maintained at a rate not exceeding that of existing conditions, while maintaining a similar deign storm hydrograph,
- Improving water quality in discharge from the site so that it is no worse than that of existing conditions,
- Ensuring that the average annual flows from the site are no greater than that of existing conditions,
- Promoting WSUD in the design,
- Rehabilitating the creek corridor along Narrabeen Creek ensuring long term channel stability and promoting revegetated benched riparian zones.

9 REFERENCES

Duncan H.P. (1999). *"Urban Stormwater Quality: A Statistical Overview"*. CRC for Catchment Hydrology.

Institution of Engineers Australia (2004) Australian Runoff Quality - DRAFT.

Melbourne Water (2004). WSUD Engineering Procedures: Stormwater DRAFT.

NSW EPA (1997a). Managing Urban Stormwater: Council Handbook.

NSW EPA (1997b). Managing Urban Stormwater: Treatment Techniques.

Pittwater Council (2001). Warriewood Valley Urban Land Release Water Management Specification. Prepared by Lawson & Treloar Pty Ltd.

10 GLOSSARY OF TERMS

Australian Height Datum	National survey datum corresponding approximately to mean sea level.
Annual Exceedance Probability	The chance of a flood of a given size or larger occurring in any one year, generally expressed as percentage probability. For example, a 100 year ARI flood is a 1% AEP flood. An important implication is that when a 1% AEP flood occurs, there is still a 1% probability that it could occur the following year.
Average Recurrence Interval	Is the long term average number of years between the occurrence of a flood as big as, or larger than the selected flood event.
Catchment	The catchment at a particular point is the area of land which drains to that point.
Design floor level	The minimum (lowest) floor level specified for a building.
Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100 year or 1% probability flood). The design flood may comprise two or more single source dominated floods.
Development	Existing or proposed works which may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
Discharge	The rate of flow of water measured in terms of volume over time. It is not the velocity of flow which is a measure of how fast the water is moving rather than how much is moving. Discharge and flow are interchangeable.
Flood	Above average river or creek flows which overtop banks and inundate floodplains.
Flood awareness	An appreciation of the likely threats and consequences of flooding and an understanding of any flood warning and evacuation procedures. Communities with a high degree of flood awareness respond to flood warnings promptly and efficiently, greatly reducing the potential for damage and loss of life and limb. Communities with a low degree of flood awareness may not fully appreciate the importance of flood warnings and flood preparedness and consequently suffer greater personal and economic losses.
Flood behaviour	The pattern / characteristics / nature of a flood.
Flooding	The State Emergency Service uses the following definitions in flood warnings: *Minor flooding:* causes inconvenience such as closing of minor roads and the submergence of low level bridges *Moderate flooding:* low-lying areas inundated requiring removal of stock and/or evacuation of some houses. Main traffic bridges may be covered. *Major flooding:* extensive rural areas are flooded with properties, villages and towns isolated and/or appreciable urban areas are flooded.

Flood frequency analysis	An analysis of historical flood records to determine estimates of design flood flows.
Flood fringe	Land which may be affected by flooding but is not designated as a floodway or flood storage.
Flood hazard	The potential threat to property or persons due to flooding.
Flood level	The height or elevation of flood waters relative to a datum (typically the Australian Height Datum). Also referred to as "stage".
Flood liable land	Land inundated up to the probable maximum flood - flood prone land.
Floodplain	Land adjacent to a river or creek which is inundated by floods up to the probable maximum flood that is designated as flood prone land.
Flood Planning Levels	Are the combinations of flood levels and freeboards selected for planning purposes to account for uncertainty in the estimate of the flood level.
Flood proofing	Measures taken to improve or modify the design, construction and alteration of buildings to minimise or eliminate flood damages and threats to life and limb.
Floodplain Management	The coordinated management of activities which occur on flood liable land.
Floodplain Management Manual	A document by the NSW Government (2001) that provides a guideline for the management of flood liable land. This document describes the process of a floodplain risk management study.
Flood source	The source of the flood waters.
Floodplain Management Standard	A set of conditions and policies which define the benchmark from which floodplain management options are compared and assessed.
Flood standard	The flood selected for planning and floodplain management activities. The flood may be an historical or design flood. It should be based on an understanding of the flood behaviour and the associated flood hazard. It should also take into account social, economic and ecological considerations.
Flood storages	Floodplain areas which are important for the temporary storage of flood waters during a flood.
Floodways	Those areas of the floodplain where a significant discharge of flow occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if they are partially blocked, would cause significant redistribution of flood flows, or a significant increase in flood levels.
Freeboard	A factor of safety usually expressed as a height above the flood standard. Freeboard tends to compensate for the factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.
Historical flood	A flood which has actually occurred - Flood of Record.
Hydraulic	The term given to the study of water flow in rivers, estuaries with coastal systems.
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrology	The term given to the study of the rain-runoff process in catchments.

Management plan	A clear and concise document, normally containing diagrams and maps, describing a series of actions that will allow an area to be managed in a coordinated manner to achieve defined objectives.
Peak flood level, flow or velocity	The maximum flood level, flow or velocity occurring during a flood event.
Probable Maximum Flood	An extreme flood deemed to be the maximum flood likely to occur at a particular location.
Probable Maximum Precipitation	The greatest depth of rainfall for a given duration meteorologically possible over a particular location. Used to estimate the probable maximum flood.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Riparian Zone	Areas that are located adjacent to watercourses. Their definition is vague and can be characterised by landform, vegetation, legislation or their function.
Runoff	The amount of rainfall from a catchment which actually ends up as flowing water in the river of creek.
Stage	Equivalent to water level above a specific datum- see flood level.
Stage hydrograph	A graph of water level over time.
Velocity	The speed at which the flood waters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.

11 APPENDICIES

Appendix A	**Drawings**
Appendix B	**MUSIC Output**
Appendix C	**HEC RAS Results**
Appendix D	**DRAINS Output**
Appendix E	**Documentation Checklist**

APPENDIX A

Drawings

APPENDIX B

MUSIC Output

APPENDIX C

HEC RAS Results

APPENDIX D

DRAINS Output

BROWN

APPENDIX E

Documentation Checklist

MUSIC MODELLING RESULTS SUMMARY SITE A

Filename: G:\0004 - Macquarie\X04023.01 Warriewood Sector 5\Current\Engineering\MUSIC\[MUSIC output.xls]Site A
Date: 27/04/2006
By: TE

X04023.01.total.ms - **Existing Scenario Results** - Flow-Based Sub-Sample Statistics

Inflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	3.35E-04	5.20E-03	1.10E-04	0.563	1.61E-06	1.07E-05	4.17E-04
TSS Concentration (mg/L)	26.9	8.44	25.6	94.5	7.43	17.2	39
Log [TSS] (mg/L)	1.41	0.134	1.41	1.98	0.871	1.24	1.59
TP Concentration (mg/L)	0.14	4.25E-02	0.134	0.417	3.48E-02	9.04E-02	0.197
Log [TP] (mg/L)	-0.873	0.131	-0.872	-0.379	-1.46	-1.04	-0.705
TN Concentration (mg/L)	1.28	0.424	1.21	3.8	0.34	0.813	1.86
Log [TN] (mg/L)	8.53E-02	0.139	8.15E-02	0.58	-0.468	-9.00E-02	0.27
TSS Load (kg/6 Minutes)	4.40E-03	8.42E-02	9.92E-04	9.12	5.51E-06	8.96E-05	4.12E-03
TP Load (kg/6 Minutes)	2.07E-05	3.73E-04	5.21E-06	4.05E-02	3.55E-08	4.73E-07	2.15E-05
TN Load (kg/6 Minutes)	2.32E-04	4.68E-03	4.71E-05	0.507	3.00E-07	4.23E-06	1.95E-04
Gross Pollutant Load (kg/6 Minutes)	7.15E-04	1.01E-02	0	0.738	0	0	0

Mean Annual Loads	
Flow (ML/yr)	10.6
Total Suspended Solids (kg/yr)	385
Total Phosphorus (kg/yr)	1.81
Total Nitrogen (kg/yr)	20.3
Gross Pollutants (kg/yr)	62.6

X04023.01.total.ms - **Developed Scenario Results** - Flow-Based Sub-Sample Statistics

Inflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	6.51E-04	6.88E-03	4.86E-05	0.564	7.22E-07	4.72E-06	1.93E-04
TSS Concentration (mg/L)	21.8	16.7	18.1	99.4	10.2	15.1	22.6
Log [TSS] (mg/L)	1.29	0.165	1.26	2	1.01	1.18	1.35
TP Concentration (mg/L)	0.162	4.01E-02	0.154	0.362	7.82E-02	0.124	0.205
Log [TP] (mg/L)	-0.801	9.53E-02	-0.813	-0.442	-1.11	-0.907	-0.689
TN Concentration (mg/L)	1.81	0.234	1.79	3.15	1.04	1.52	2.12
Log [TN] (mg/L)	0.255	5.51E-02	0.254	0.498	1.83E-02	0.181	0.327
TSS Load (kg/6 Minutes)	2.09E-02	0.235	3.16E-04	18.5	2.86E-06	2.93E-05	1.29E-03
TP Load (kg/6 Minutes)	6.58E-05	7.19E-04	2.68E-06	5.77E-02	2.03E-08	2.49E-07	1.12E-05
TN Load (kg/6 Minutes)	3.69E-04	3.94E-03	3.19E-05	0.336	2.75E-07	2.99E-06	1.29E-04
Gross Pollutant Load (kg/6 Minutes)	5.52E-03	5.16E-02	0	3.5	0	0	0

Mean Annual Loads	
Flow (ML/yr)	20.5
Total Suspended Solids (kg/yr)	1.83E+03
Total Phosphorus (kg/yr)	5.76
Total Nitrogen (kg/yr)	32.3
Gross Pollutants (kg/yr)	484

X04023.01.total.ms - **Mitigated Scenario Results** - Flow-Based Sub-Sample Statistics

Inflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	6.32E-04	3.23E-03	5.34E-05	0.189	6.73E-07	5.50E-06	5.73E-04
TSS Concentration (mg/L)	4.1	4.82	3.46	77.4	0.847	2.11	4.78
Log [TSS] (mg/L)	0.538	0.206	0.539	1.89	-7.21E-02	0.325	0.679
TP Concentration (mg/L)	5.48E-02	1.56E-02	5.26E-02	0.248	2.46E-02	4.33E-02	6.50E-02
Log [TP] (mg/L)	-1.27	9.02E-02	-1.28	-0.606	-1.61	-1.36	-1.19
TN Concentration (mg/L)	0.974	1.03E-01	0.971	1.57	0.641	0.843	1.11
Log [TN] (mg/L)	-1.38E-02	4.61E-02	-1.29E-02	0.195	-0.193	-7.42E-02	4.41E-02
TSS Load (kg/6 Minutes)	2.45E-03	3.34E-02	6.85E-05	4.03	3.86E-07	6.57E-06	4.17E-04
TP Load (kg/6 Minutes)	1.80E-05	1.48E-04	1.04E-06	1.49E-02	8.82E-09	1.01E-07	1.03E-05
TN Load (kg/6 Minutes)	2.07E-04	1.25E-03	1.91E-05	0.105	1.63E-07	1.89E-06	1.92E-04
Gross Pollutant Load (kg/6 Minutes)	3.43E-04	3.19E-03	0	0.206	0	0	0

Mean Annual Loads	
Flow (ML/yr)	19.9
Total Suspended Solids (kg/yr)	214
Total Phosphorus (kg/yr)	1.58
Total Nitrogen (kg/yr)	18.2
Gross Pollutants (kg/yr)	30.1

SITE A DATA

PIT / NODE DETAILS

Name	Type	Family	Version 9 Size	Ponding Volume (cu.m)	Pressure Change Coeff. Ku	Surface Elev (m)	Max Pond Depth (m)	Base Inflow (cu.m/s)	Blocking Factor	x	y	Bolt-down lid
Creek	Node					18		0		915.241	-820.925	
N183	Node							0		151.088	-825.953	
N193	Node					22		0		393.308	-614.201	
N190	Node							0		259.249	-228.781	
N191	Node							0		417.683	-240.969	
N192	Node							0		591.35	-245.539	

DETENTION BASIN DETAILS

Name	Elev	Volume	Init Vol. (cu.m)	Outlet Type	K	Dia(mm)	Centre RL	Pit Family	Pit Type	x	y	HED
Basin A	21	1	0	Orifice		170	21			303.428	-413.112	No
	22	5										
	22.3	156										
	23	625										
Basin A2	22	1	0	Orifice		220	22			429.87	-414.636	No
	23	5										
	23.3	21.6										
	24	115										

SUB-CATCHMENT DETAILS

Name	Pit or Node	Total Area	impervious Area	Avg Slope(%)	Hydrological Model
Exist Site A	N183	2.1	5	5	RAFTS
Cat 1	N190	1.125	50	5	RAFTS
Cat 2	N191	0.586	50	5	RAFTS
Bypass	N192	0.389	50	5	RAFTS

PIPE DETAILS

Name	From	To	Length (m)	U/S IL (m)	D/S IL (m)	Slope (%)	Type	Dia (mm)	I.D. (mm)	Rough	Pipe Is	No. Pipes
Pipe56	Basin A	N193	30	21	20.7	1	Concrete, under roads	525	525	0.3	NewFixed	1
Pipe57	Basin A2	N193	65	22	21.7	0.46	Concrete, under roads	525	525	0.3	NewFixed	1

DETAILS of SERVICES CROSSING PIPES

Pipe	Chg (m)	Bottom Elev (m)	Height of Service (m)	Chg (m)	Bottom Elev (m)	Height of Service (m)	Chg (m)	Bottom Elev (m)	Height of Service (m)	etc
										etc

CHANNEL DETAILS

Name	From	To	Type	Length (m)	U/S IL (m)	D/S IL (m)	Slope (%)	Base Width (m)	L.B. Slope (1:?)	R.B. Slope (1:?)	Manning n	Depth (m)

OVERFLOW ROUTE DETAILS

Name	From	To	Travel Time (min)	Spill Level (m)	Crest Length (m)	Weir Coeff. C	Cross Section	Safe Depth Major Storms (m)	SafeDepth Minor Storms (m)	Safe DxV (sq.m/sec)	Bed Slope (%)	D/S Area Contributing %
OF181	N183	Creek	1				Pathway 4m wide	0.3	0.3	0.6	1	0
OF175	Basin A	N193	1	22.52			Overflow	0.3	0.3	0.6	1	0
OF179	N193	Creek	1				Pathway 4m wide	0.3	0.3	0.6	1	0
OF176	Basin A2	N193	1	23.54			Overflow	0.3	0.3	0.6	1	0
OF167	N190	Basin A	1				8m wide road	0.14	0.14	0.6	1	0
OF168	N191	Basin A2	1				8m wide road	0.14	0.14	0.6	1	0
OF169	N192	N193	1				8m wide road	0.14	0.14	0.6	1	0

SITE A Q100 Y ARI RESULTS

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint
N193	20.83		0				

SUB-CATCHMENT DETAILS

Name	Max Flow (cu.m/s)	Due to Storm
Exist Site A	0.734	AR&R 100 year, 1 hour storm, average 95 mm/h, Zone 1
Cat 1	0.816	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1
Cat 2	0.428	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1
Bypass	0.284	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm
Pipe56	0.081	1.9	21.134	20.834	AR&R 100 year, 2 hours storm, average 63 mm/h, Zone 1
Pipe57	0.132	1.5	22.222	21.922	AR&R 100 year, 2 hours storm, average 63 mm/h, Zone 1

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Chainage (m)	Max HGL (m)	Due to Storm

)VERFLOW ROUTE DETAILS

Name	Max Q U/S	Max Q D/S	Safe Q	Max D	Max DxV	Max Width	Max V	Due to Storm
OF181	0.734	0.734	1.931	0.167	0.26	4	1.56	AR&R 100 year, 1 hou
OF175	0.105	0.105	5.556	0.042	0.03	5.75	0.63	AR&R 100 year, 2 hou
OF179	0.715	0.715	1.931	0.166	0.26	4	1.55	AR&R 100 year, 1.5 hc
OF176	0.144	0.144	5.556	0.049	0.03	6.01	0.7	AR&R 100 year, 2 hou
OF167	0.816	0.816	0.251	0.207	0.35	4.17	1.68	AR&R 100 year, 1.5 hc
OF168	0.428	0.428	0.251	0.164	0.22	4	1.35	AR&R 100 year, 1.5 hc
OF169	0.284	0.284	0.251	0.146	0.17	3.96	1.17	AR&R 100 year, 1.5 hc

DETENTION BASIN DETAIL$

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level
Basin A	22.88	0	0.186	0.081	0.105
Basin A2	23.87	0	0.276	0.132	0.144

CONTINUITY CHECK for AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1

Node	Inflow (cu.m)	Outflow (cu.m)	Storage Change (cu.m)	Difference %
Creek	4483.97	4483.97	0	0
N183	2189.12	2189.12	0	0
Basin A	1152.86	1203.57	1.03	-4.5
N193	2295.9	2295.9	0	0
Basin A2	664.36	664.99	1.23	-0.3
N190	1152.87	1152.87	0	0
N191	664.77	664.77	0	0
N192	427.51	427.51	0	0

SITE B DATA

PIT / NODE DETAILS

Name	Type	Family	Version 9 Size	Ponding Volume (cu.m)	Pressure Change Coeff. Ku	Surface Elev (m)	Max Pond Depth (m)	Base Inflow (cu.m/s)	Blocking Factor	x	y	Bolt-down lid
N12	Node							0		1388.686	-68.221	
N314	Node					21		0		996.525	-904.456	
N330	Node							0		531.573	-124.932	
N340	Node							0		594.488	-525.435	
N341	Node							0		634.384	-789.368	
N367	Node					20		0		1149.975	-924.404	

DETENTION BASIN DETAILS

Name	Elev	Volume	Init Vol. (cu.m)	Outlet Type	K	Dia(mm)	Centre RL	Pit Family	Pit Type	x	y	HED
Basin263	20.4	1	0	Orifice		285	20.4			784.765	-850.748	No
	21.4	3										
	21.7	50										
	22	140										
	22.3	250										

SUB-CATCHMENT DETAILS

Name	Pit or Node	Total Area (ha)	Paved Area %	Grass Area %	Supp Area %	Paved Time (min)	Grass Time (min)	Supp Time (min)	Paved Length (m)	Grass Length (m)	Supp Length (m)	Paved Slope(%) %
Exist Cat1	N12	0.8265	5	95	0	1	10	2	120	120	120	18.5
CatA	N330	0.3245	50	50	0	2	5	0	70	70	70	5
CatB	N340	0.446	50	50	0	2	5	0	80	80	80	10
CatC	N341	0.056	10	90	0	2	5	0				

PIPE DETAILS

Name	From	To	Length (m)	U/S IL (m)	D/S IL (m)	Slope (%)	Type	Dia (mm)	I.D. (mm)	Rough	Pipe Is	No. Pipes
Pipe76	Basin263	N314	10	20.4	20.3	1	Concrete, not under roac	375	375	0.3	NewFixed	1

DETAILS of SERVICES CROSSING PIPES

Pipe	Chg (m)	Bottom Elev (m)	Height of Service (m)	Chg (m)	Bottom Elev (m)	Height of Service (m)	Chg (m)	Bottom Elev (m)	Height of Service (m)	etc
										etc

CHANNEL DETAILS

Name	From	To	Type	Length (m)	U/S IL (m)	D/S IL (m)	Slope (%)	Base Width (m)	L.B. Slope (1:?)	R.B. Slope (1:?)	Manning n	Depth (m)

OVERFLOW ROUTE DETAILS

Name	From	To	Travel Time (min)	Spill Level (m)	Crest Length (m)	Weir Coeff. C	Cross Section	Safe Depth Major Storms (m)	SafeDepth Minor Storms (m)	Safe DxV (sq.m/sec)	Bed Slope (%)	D/S Area Contributing %
OF6	N12	N367	0.1				Pathway 4m wide	0.3	0.3	0.6	3	0
OF302	Basin263	N314	1	21.8			8m wide road	0.14	0.14	0.6	1	0
OF330	N314	N367	1				Pathway 4m wide	0.3	0.3	0.6	1	0
OF300	N330	Basin263	0.2				8m wide road	0.14	0.14	0.6	1	0
OF304	N340	Basin263	0.2				Pathway 4m wide	0.3	0.3	0.6	1	0
OF305	N341	Basin263	0.2				8m wide road	0.14	0.14	0.6	1	0

SITE B Q100Y ARI RESULTS

PIT / NODE DETAILS

Name	Max HGL	Max Pond HGL	Max Surface Flow Arriving (cu.m/s)	Version 8 Max Pond Volume (cu.m)	Min Freeboard (m)	Overflow (cu.m/s)	Constraint
N314	20.59		0				

SUB-CATCHMENT DETAILS

Name	Max Flow Q (cu.m/s)		Paved Max Q (cu.m/s)	Grassed Max Q (cu.m/s)	Paved Tc (min)	Grassed Tc (min)	Supp. Tc (min)	)ue to Storm
Exist Cat1	0.361	0.027		0.339	5.41	17.24	6.41	r storm, average 95 mm/h, Zone 1
CatA	0.203	0.114		0.089	4.86	9	0	:es storm, average 144 mm/h, Zone
CatB	0.28	0.156		0.124	4.51	8.52	0	:es storm, average 144 mm/h, Zone
CatC	0.038	0.004		0.034	2	5	0	ırs storm, average 75 mm/h, Zone

PIPE DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Max U/S HGL (m)	Max D/S HGL (m)	Due to Storm
Pipe76	0.203	2.2	20.691	20.591	AR&R 100 year, 1.5 hours storm, average 75 mm/h, Zone 1

CHANNEL DETAILS

Name	Max Q (cu.m/s)	Max V (m/s)	Chainage (m)	Max HGL (m)	Due to Storm

)VERFLOW ROUTE DETAILS

Name	Max Q U/S	Max Q D/S	Safe Q	Max D	Max DxV	Max Width	Max V	Due to Storm
OF6	0.361	0.361	1.805	0.105	0.17	4	1.64	1 hour storm, average !
OF302	0.063	0.063	0.251	0.089	0.08	2.08	0.88	AR&R 100 year, 1.5 hc
OF330	0.265	0.265	1.931	0.113	0.12	4	1.06	AR&R 100 year, 1.5 hc
OF300	0.203	0.203	0.251	0.13	0.14	3.44	1.1	AR&R 100 year, 25 mi
OF304	0.28	0.28	1.931	0.115	0.12	4	1.08	AR&R 100 year, 25 mi
OF305	0.038	0.038	0.251	0.076	0.06	1.64	0.82	AR&R 100 year, 1.5 hc

DETENTION BASIN DETAILS

Name	Max WL	MaxVol	Max Q Total	Max Q Low Level	Max Q High Level
Basin263	22.07	167.2	0.265	0.203	0.063

AR&R 100 year, 1 hour storm, average 95 mm/h, Zone 1

Node	Inflow (cu.m)	Outflow (cu.m)	Storage Change (cu.m)	Difference %
N12	575.79	575.79	0	0
Basin263	667.53	667.04	1.07	-0.1
N314	667.04	667.04	0	0
N330	264.22	264.22	0	0
N340	363.22	363.22	0	0
N341	40.09	40.09	0	0
N367	1242.83	1242.83	0	0

DOCUMENTATION CHECKLIST - REZONING

(Detach and include with submissions)

Section	Item	Requirement	Check (√)
4.1	Water Cycle Assessment - Water Balance Modelling Pre & Post Development		✓
4.1.1	Stream Gauging, infiltration testing and use of local rainfall data for modelling	♦♦♦♦♦♦♦♦	–
4.2.1	Water Quality Monitoring Plan	♦♦♦♦♦♦♦♦	–
4.2.1	Water Quality Monitoring Sites Shown on Plan (at least three)	♦♦♦♦♦♦♦♦	–
4.2.1, 2, C	Water Quality Monitoring Data	♦♦♦♦♦♦♦♦	–
4.2.1, 2, C	Assessment and interpretation of water quality monitoring data	♦♦♦♦♦♦♦♦	–
4.2.1, 2, C	Assessment and interpretation of water quality monitoring data from SQID's		
4.3	Water Quality Management Assessment - Load Modelling Pre and Post Development		✓
4.3.1, 3	Justification of assumptions for Event Mean Concentrations	♦♦♦♦♦♦♦♦	✓
4.3.2	Identification of and details for Stormwater quality facilities		✓
4.3.2, 4.4.5	Mosquito Risk Assessment for both Watercourse and Water Quality/Quantity features		✓
4.3.6, 4.6.5	Inspection and Cleaning Reports for SQID's and OSD		
4.3.5	Environmental Management Plan (Soil and Water Aspects)		
4.3.4	Erosion and Sediment Control Plan		
4.3.6	Management Plan for Stormwater Quality Improvement Devices		
4.4.3, 4, 5	Existing and Proposed Creek Corridor in plan with cross/long sections with flood levels	□□□□□□□□□□□	✓
4.4.4	Proposed Creek Corridor Planting Schedule		–
4.4.5	Creek Corridor Vegetation Monitoring and Management Plan		
4.4.5	Vegetation and Creek Maintenance and Monitoring Reports		
4.5	Flood Analysis – existing and design conditions		✓
4.5.2	Compliance of structures and creek corridor with flood planning levels		✓
4.5.4	Details of Interim Flood Protection Works		✓
4.6.3	Design Storm Hydrological Modelling of Site - Pre and Post Development		✓
4.6.3	On-Site Detention Facilities		✓
4.6.4	Stormwater Retention Facilities		✓
4.7	Stormwater Concept Drainage Plan	□□□□□□□□□□□	✓

KEY:

	Preliminary Calculations/Assessment Required		*Work as Executed Plans*
□□□□□□□	*Concept Design Required*	♦♦♦♦♦♦	*Required/Reviewed/Updated*
+++++++	*Detailed Assessment/Calculations/Design*		*Not required*

Note 1 Even if the works are not to be constructed by the Applicant on the land to be transferred to Council under the Material Public Benefit Option in the Section 94 Plan, preliminary investigation for Rezoning and concept design at DA stage is required

~~*Completed by Principal Certifier:*~~

Name: ROBERT PETERSON NPER # 537342

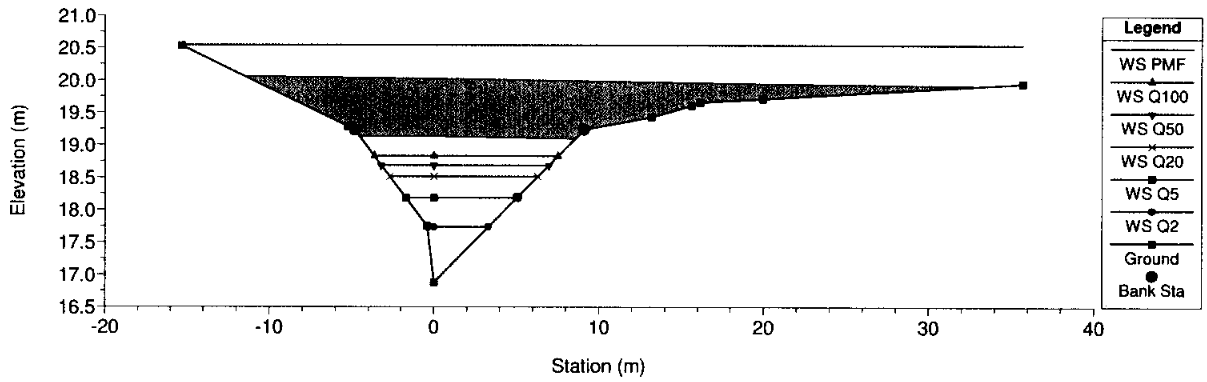
Title: MANAGER WATER + ENVIRONMENT

Organisation: BROWN CONSULTING

Signature: [signature]

Date: 29-6-2006

Sector5 Warriewood Plan: DESIGN
River = Sector5 Reach = 01 RS = 50 BR



Sector5 Warriewood Plan: DESIGN
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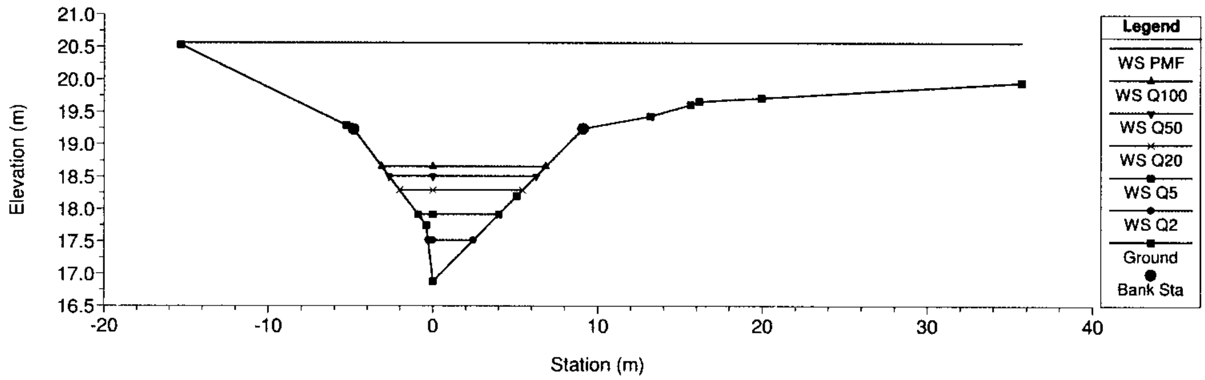

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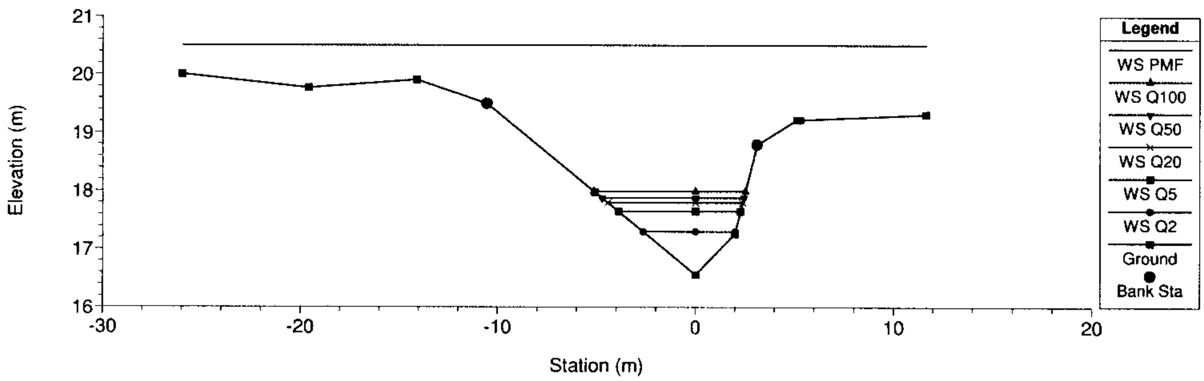
River = Sector5 Reach = 01 RS = 0



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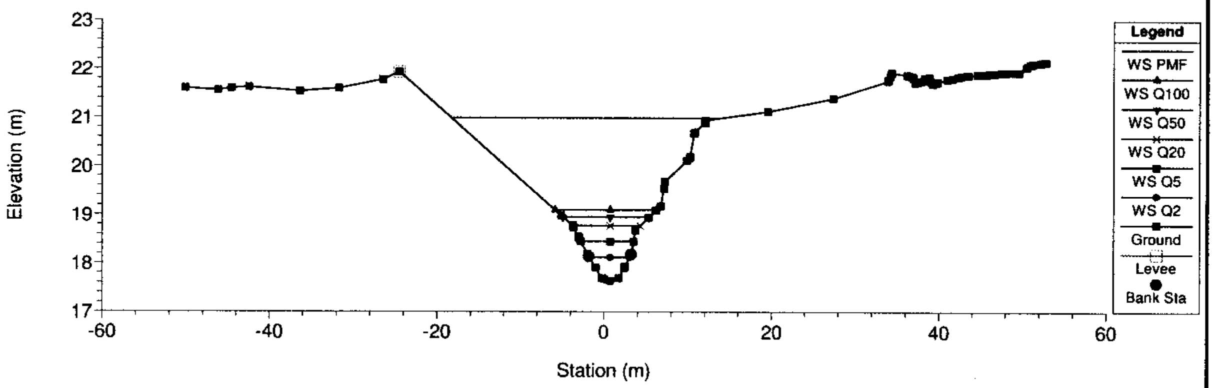
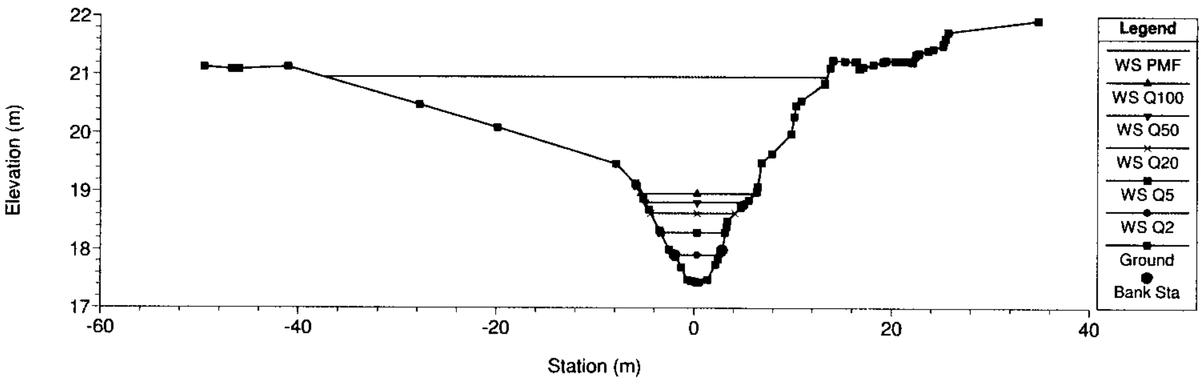


Sector5 Warriewood Plan: DESIGN
River = Sector5 Reach = 01 RS = 81



Sector5 Warriewood Plan: DESIGN
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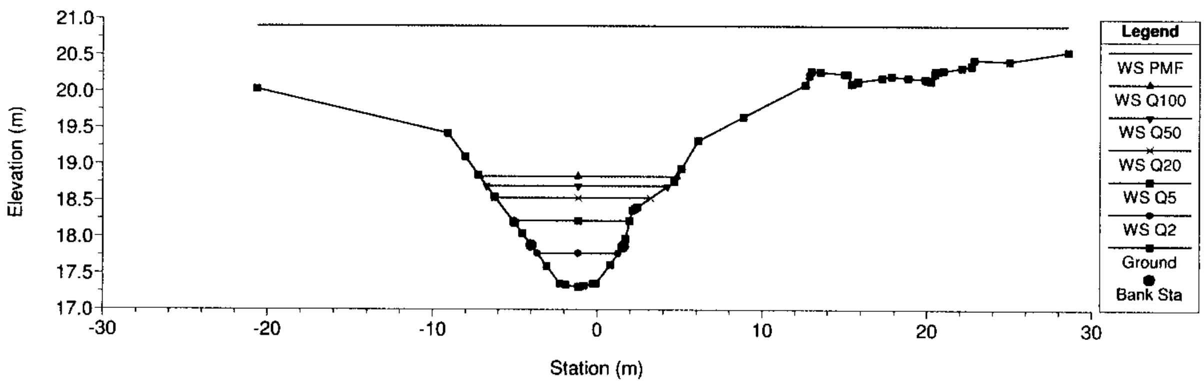
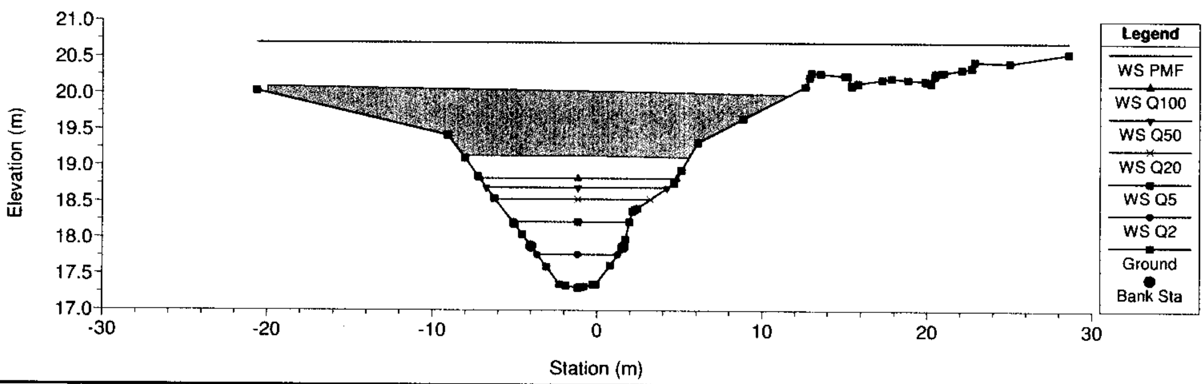


Sector5 Warriewood Plan: DESIGN
River = Sector5 Reach = 01 RS = 50 BR



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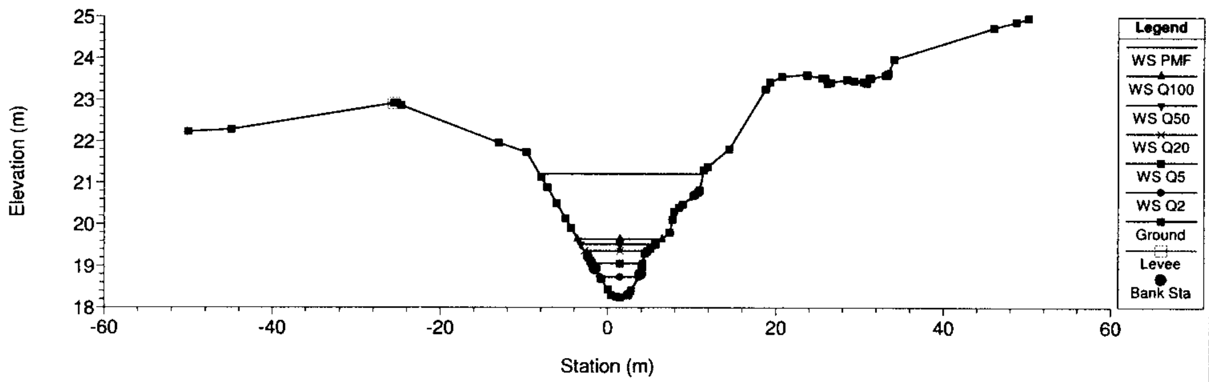

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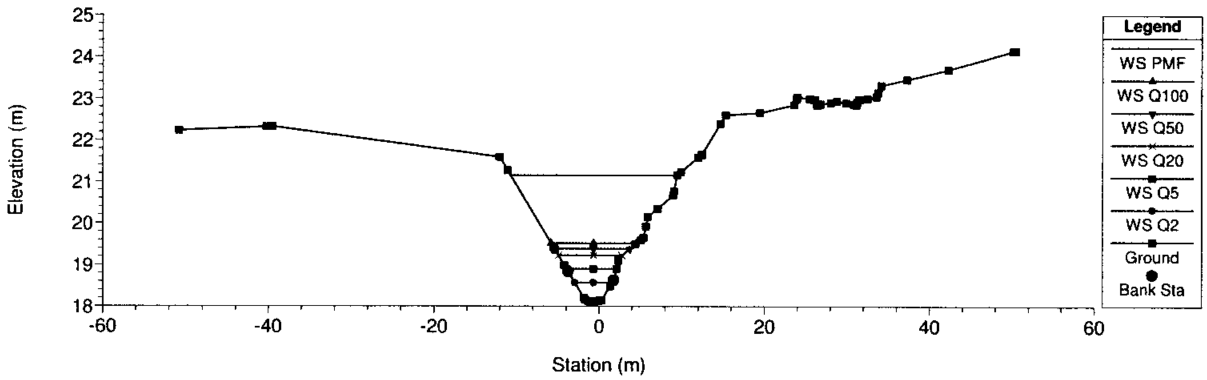
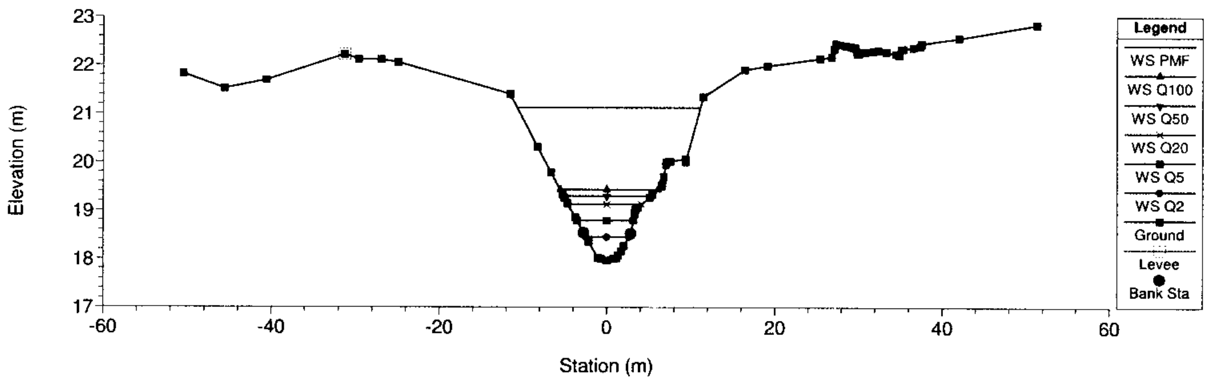
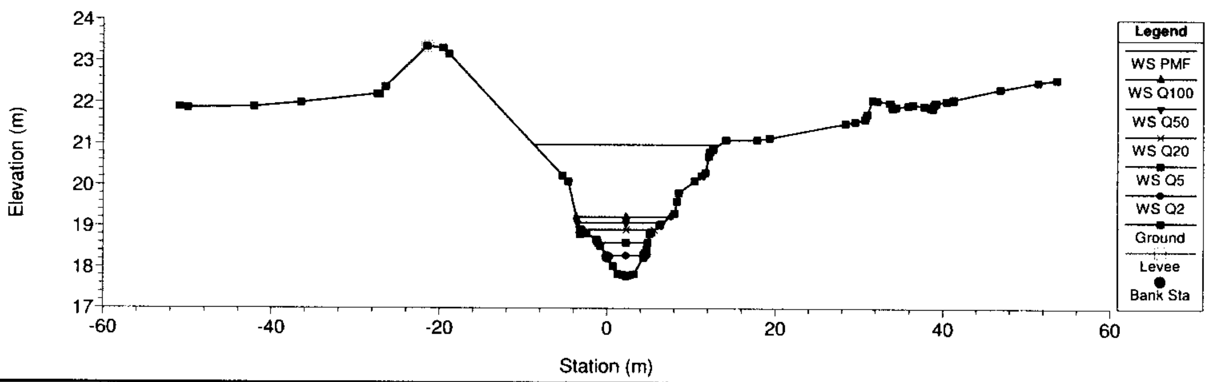
River = Sector5 Reach = 01 RS = 174

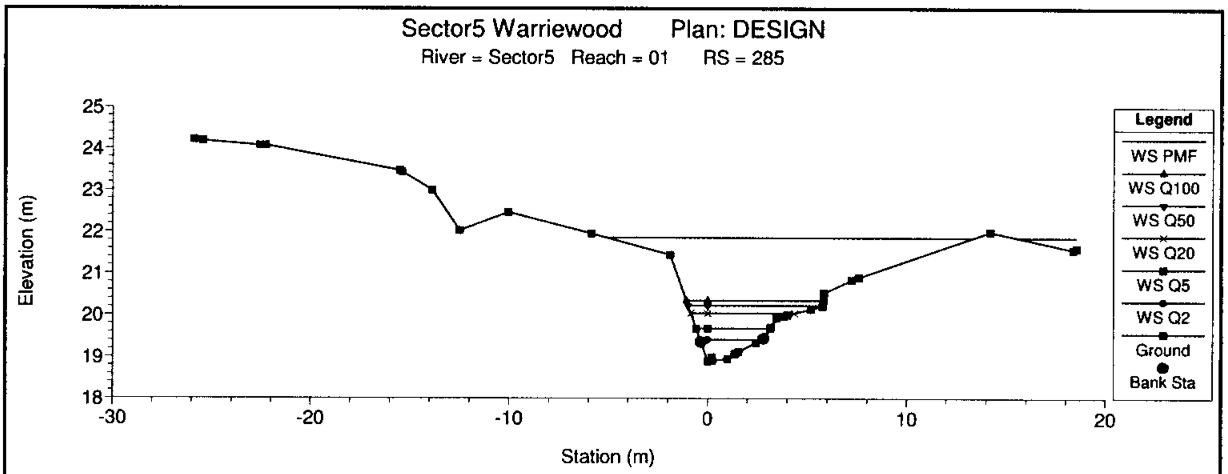


Sector5 Warriewood Plan: DESIGN
River = Sector5 Reach = 01 RS = 155



Sector5 Warriewood Plan: DESIGN
River = Sector5 Reach = 01 RS = 129




Sector5 Warriewood Plan: DESIGN
River = Sector5 Reach = 01 RS = 285
Elevation (m)
Station (m)
Legend
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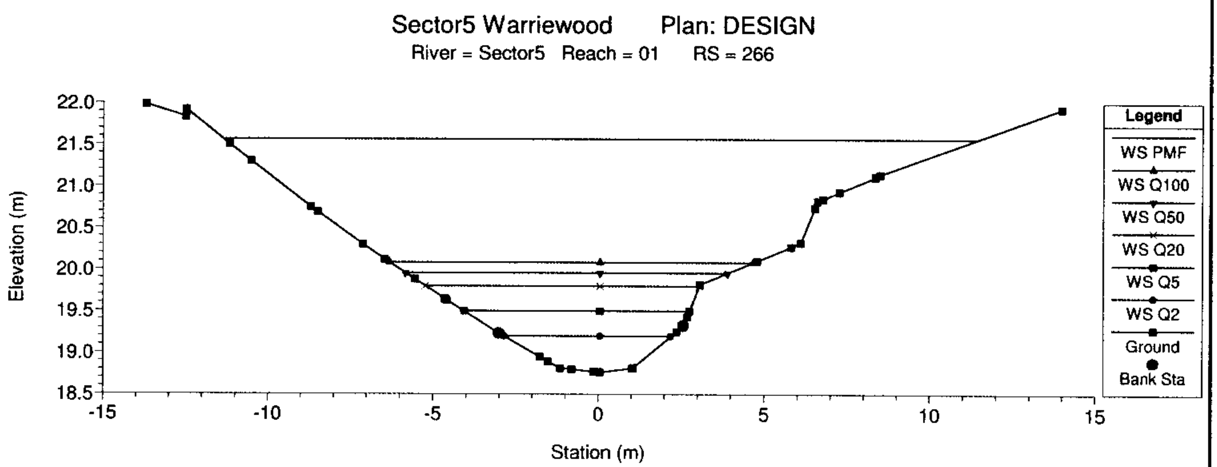
WS Q100
WS Q50
WS Q20
WS Q5
WS Q2
Ground
Bank Sta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River = Sector5 Reach = 01 RS = 266
Elevation (m)
Station (m)
Legend
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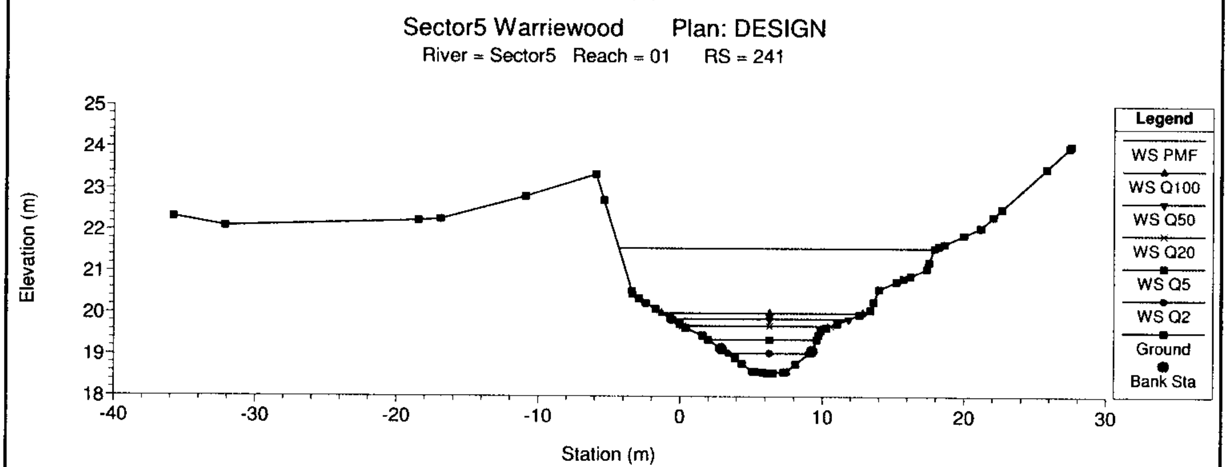
WS Q50
WS Q20
WS Q5
WS Q2
Ground
Bank Sta


Sector5 Warriewood Plan: DESIGN
River = Sector5 Reach = 01 RS = 241
Elevation (m)
Station (m)
Legend
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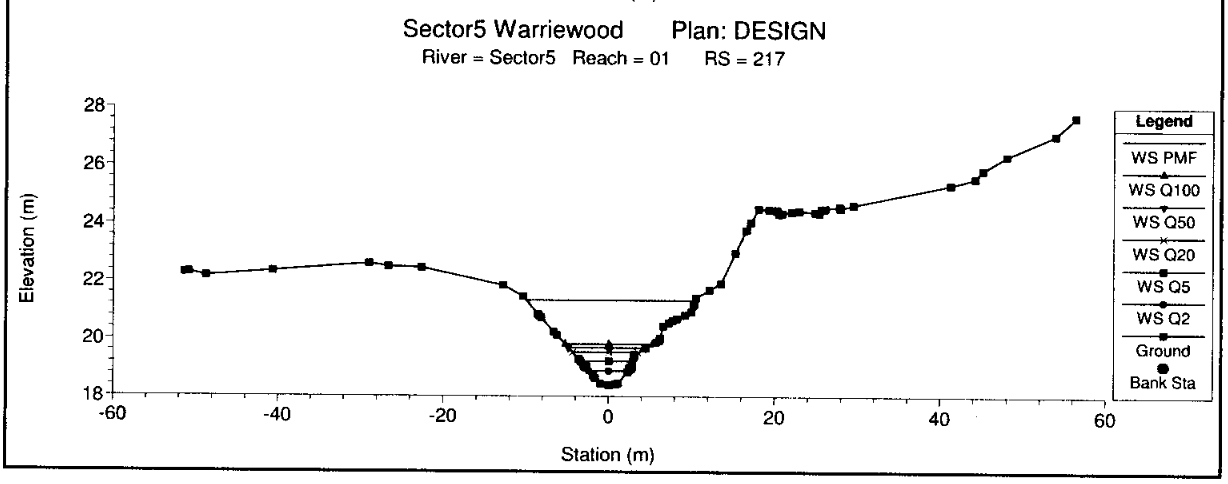
WS Q100
WS Q50
WS Q20
WS Q5
WS Q2
Ground
Bank Sta


Sector5 Warriewood Plan: DESIGN
River = Sector5 Reach = 01 RS = 217
Elevation (m)
Station (m)
Legend
WS PMF
WS Q100
WS Q50
WS Q20
WS Q5
WS Q2
Ground
Bank Sta

MUSIC MODELLING RESULTS SUMMARY SITE B

Filename: G:\0004 - Macquarie\X04023.01 Warriewood Sector 5\Current\Engineering\MUSIC\[MUSIC output.xls]Site B
Date: 27/04/2006
By: TE

B05192.total.ms - **Existing Scenario Results** - Flow-Based Sub-Sample Statistics

Inflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	1.32E-04	2.05E-03	4.33E-05	2.22E-01	6.39E-07	4.19E-06	1.64E-04
TSS Concentration (mg/L)	26.9	8.42	25.6	80	8.18	17.3	38.9
Log [TSS] (mg/L)	1.41E+00	1.34E-01	1.41E+00	1.9	0.913	1.24E+00	1.59
TP Concentration (mg/L)	0.14	4.23E-02	0.134	0.419	4.19E-02	9.02E-02	0.197
Log [TP] (mg/L)	-0.874	0.131	-0.873	-0.378	-1.38	-1.04	-0.705
TN Concentration (mg/L)	1.28	0.424	1.21	3.61	0.329	0.813	1.86E+00
Log [TN] (mg/L)	8.55E-02	0.139	8.13E-02	5.57E-01	-0.483	-9.00E-02	2.70E-01
TSS Load (kg/6 Minutes)	1.73E-03	3.31E-02	3.93E-04	3.59	2.45E-06	3.52E-05	1.62E-03
TP Load (kg/6 Minutes)	8.13E-06	1.47E-04	2.05E-06	1.59E-02	1.17E-08	1.85E-07	8.44E-06
TN Load (kg/6 Minutes)	9.13E-05	1.84E-03	1.85E-05	0.199	1.07E-07	1.67E-06	7.66E-05
Gross Pollutant Load (kg/6 Minutes)	2.81E-04	3.96E-03	0	0.29	0	0	0

Mean Annual Loads	
Flow (ML/yr)	4.16E+00
Total Suspended Solids (kg/yr)	151
Total Phosphorus (kg/yr)	0.712
Total Nitrogen (kg/yr)	7.99E+00
Gross Pollutants (kg/yr)	24.6

B05192.total.ms - **Developed Scenario Results** - Flow-Based Sub-Sample Statistics

Inflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	2.56E-04	2.71E-03	1.90E-05	0.222	2.78E-07	1.86E-06	7.55E-05
TSS Concentration (mg/L)	2.06E+01	1.72E+01	1.66E+01	99.6	7.53	1.26E+01	2.32E+01
Log [TSS] (mg/L)	1.25	0.185	1.22	2	0.877	1.1	1.37
TP Concentration (mg/L)	0.165	5.11E-02	0.154	0.524	6.04E-02	0.112	0.236
Log [TP] (mg/L)	-0.801	0.125	-0.813	-0.281	-1.22	-0.952	-6.27E-01
TN Concentration (mg/L)	1.91E+00	0.352	1.87E+00	4.09	0.934	1.50E+00	2.38E+00
Log [TN] (mg/L)	2.74E-01	7.84E-02	2.72E-01	0.612	-2.96E-02	1.77E-01	3.77E-01
TSS Load (kg/6 Minutes)	8.29E-03	9.39E-02	1.13E-04	7.49	7.86E-07	1.04E-05	4.76E-04
TP Load (kg/6 Minutes)	2.61E-05	2.86E-04	1.05E-06	2.30E-02	7.41E-09	9.57E-08	4.52E-06
TN Load (kg/6 Minutes)	1.45E-04	1.53E-03	1.31E-05	0.128	9.98E-08	1.21E-06	5.40E-05
Gross Pollutant Load (kg/6 Minutes)	2.23E-03	2.09E-02	0	1.42	0	0	0

Mean Annual Loads	
Flow (ML/yr)	8.09
Total Suspended Solids (kg/yr)	726
Total Phosphorus (kg/yr)	2.28
Total Nitrogen (kg/yr)	12.7
Gross Pollutants (kg/yr)	195

B05006.total.ms - **Mitigated Scenario Results** - Flow-Based Sub-Sample Statistics

Inflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	2.47E-04	1.66E-03	1.98E-05	0.133	2.50E-07	2.03E-06	2.11E-04
TSS Concentration (mg/L)	7.09E-01	1.03E+00	5.94E-01	60.9	0.302	4.78E-01	0.779
Log [TSS] (mg/L)	-0.198	0.156	-0.226	1.78	-0.52	-0.321	-1.09E-01
TP Concentration (mg/L)	3.02E-02	8.07E-03	2.88E-02	0.229	1.24E-02	2.22E-02	4.04E-02
Log [TP] (mg/L)	-1.53	1.02E-01	-1.54E+00	-0.641	-1.91	-1.65	-1.39E+00
TN Concentration (mg/L)	0.817	1.26E-01	8.06E-01	1.72	0.439	6.59E-01	9.84E-01
Log [TN] (mg/L)	-9.31E-02	6.63E-02	-9.35E-02	0.236	-0.358	-1.81E-01	-6.83E-03
TSS Load (kg/6 Minutes)	5.79E-04	2.52E-02	4.31E-06	2.86	3.26E-08	4.13E-07	5.50E-05
TP Load (kg/6 Minutes)	5.08E-06	1.02E-04	2.11E-07	1.09E-02	1.35E-09	2.01E-08	2.39E-06
TN Load (kg/6 Minutes)	7.02E-05	7.38E-04	5.94E-06	7.26E-02	4.11E-08	5.81E-07	5.98E-05
Gross Pollutant Load (kg/6 Minutes)	0	0	0	0	0	0	0

Mean Annual Loads	
Flow (ML/yr)	7.78E+00
Total Suspended Solids (kg/yr)	50.8
Total Phosphorus (kg/yr)	0.445
Total Nitrogen (kg/yr)	6.15E+00
Gross Pollutants (kg/yr)	0