MIRVAC

WARRIEWOOD VALLEY
SECTOR 3

Water Management Report
Rezoning Application Stage

Issue No. 2
AUGUST 2005

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1 INTRODUCTION

Sector 3 is part of the land included within the Warriewood Valley Urban Release Area, which has been identified for release for urban purposes by the Minister for Planning.

The sector has a total area of approximately 8.13 hectares, of which 6.07 hectares is proposed to be developed by Mirvac (*refer to* ***Drawing 5093-01*** *for catchment details*). The sector has frontages to Macpherson Street to the southwest, Brands Lane to the southeast and is bounded by the Narrabeen Creek to the northeast. A retirement village lies to the northwest.

Patterson Britton & Partners *(PBP)* has been engaged by Mirvac to prepare a Water Management Report relating to the impacts of the proposed development of Sector 3 on water management issues. These issues include long-term hydrologic assessment *(water balance)*, water quality assessment and management, flood attenuation, floodplain management and stormwater quantity management.

This current report is for the Rezoning Application stage and has been prepared for the portions of Sector 3 to be developed by Mirvac, which comprises 3 lots, including the Flower Power site. The remaining portion of Sector 3, which lies to the south east of Brands Lane has not been incorporated in this report (i.e. the ARV section of Sector 3).

The Water Management Report has been prepared in accordance with Pittwater Council's publication "*Warriewood Valley Urban Land Release – Water Management Specification*" *(February, 2001) (WMS)*.

A completed copy of the "*Documentation Checklist – Rezoning Application*", confirming that all tasks required by Council's WMS have been undertaken, is found at **Appendix A**.

1.1 CERTIFICATION

The contents of this report are certified by Michael Shaw, who is a registered NPER engineer with the Institution of Engineers, to comply with the requirements of Pittwater Council's Water Management Specification (*February 2001*).

2 EXECUTIVE SUMMARY

2.1 WATER MANAGEMENT APPROACH

Pittwater Council's Water Management Specification *(2001)* (*WMS*) requires that for the overall development:

- peak runoff flow rates do not exceed existing values;
- average annual runoff volume after development be reduced to approach the existing values; and
- average annual pollutant load in runoff after development does not exceed existing values.

In adherence to the above, PBP have incorporated the principles of Water Sensitive Urban Design (*WSUD*) and Ecologically Sustainable Development (*ESD*).

The development, therefore, has been designed with a water management strategy which incorporates stormwater detention *(to reduce localised peak runoff flow rates),* on-site retention, reuse and infiltration near the source *(to reduce runoff volumes)* and pollutant removal devices *(to reduce pollutant load).*

2.2 WATER CYCLE ASSESSMENT

Runoff volume control facilities proposed for implementation include rainwater storage tanks *(an average of* $2m^3$ *of storage proposed for each dwelling)*, underground detention tanks, permeable paving, bio-retention basins & associated infiltration trenches.

Runoff collected by the proposed rainwater tanks is proposed to be re-used internally for toilet flushing & laundry purposes and externally for garden irrigation and car washing. The proposed bio-retention basins and associated infiltration trenches will serve a three fold function of water quality control, stormwater detention and runoff volume control (*or stormwater retention*).

These facilities enable achievement of a post development volumetric surface runoff co-efficient that is lower than that under existing conditions.

2.3 WATER QUALITY ASSESSMENT

A water quality monitoring plan has been formulated in accordance with Council's Water Management Specification, to develop an understanding of the runoff water quality from the site in existing conditions and to measure the effectiveness of the stormwater quality treatment measures proposed to be implemented as part of the development.

2.4 WATER QUALITY MANAGEMENT

2.4.1 Construction Phase

During the construction phase, sediment and erosion control facilities will be designed and installed in accordance with the Council's specifications and the requirements of the publication *"Managing Urban Stormwater – Soils and Construction" (Dept. of Housing, 1998)*.

2.4.2 Post Development Phase

As required in Council's specification, the objective of the water quality management strategy is to ensure a *"no net increase"* in pollutant loads discharged from the developed site compared to existing conditions.

The principle water quality treatment devices *(eg. gross pollutant traps, permeable paving and bio-retention basins)* have been sized to achieve that objective as a minimum.

Long-term time series modelling of the performance of the proposed treatment train using MUSIC shows that in all cases *(dry, wet and average years)*, the proposed facilities would reduce pollutant loads below those which are predicted to be discharged from the site in existing conditions.

2.5 STORMWATER QUANTITY MANAGEMENT

2.5.1 Flow/Volume Management

The integrated strategy proposed for management of stormwater runoff quantity on the site is comprised of:

- source control which includes:
  - use of rainwater tanks (*2m^3/lot* ***(260 m^3)****, of which 25% is counted as effective OSD storage –* ***65 m^3***) to reduce runoff volume, maximise non-potable supply/re-use and minimise peak flows discharging from individual allotments;
  - minimising impervious surfaces (*limited to 50% site wide*) to maximise infiltration potential and reduce runoff volumes;
  - the use of landscaping which encourages the maximisation of infiltration.
- the conveyance system which includes:
  - road and accessway's (*effective detention storage volume =* ***73 m^3***) to reduce peak flow rates in events between the 20 year and 100 year average recurrence interval (ARI) events;
  - the proposed 20 year ARI piped drainage system (*effective detention storage volume =* ***66 m^3***) to reduce peak flow rates in events between the 20 year and 100 year ARI events;
- formal detention system:

- on-site detention tanks (10 m^3 each) (*effective detention storage volume =* ***250 m³***) for 25 lots fronting Macpherson Street.
- bio-retention basins (*effective detention storage volume =* ***1,782 m³***) to maximise the potential of infiltration and provide detention storage volume, which in turn will reduce peak flow rates and volumes for frequent events. This will directly reduce peak runoff rates for all storm events;

The total stormwater detention volume proposed for Sector 3 is **2,236 m^3**. Hence, a stormwater detention storage is proposed at the rate of **466 m^3/ha** *(based on a proposed road and lot area of 4.8 ha)*, to mitigate localised increases in peak flow rates exiting the site**.** The proposed storage rate exceeds the detention rate of **368 m^3/ha** required by Council in their WMS.

RAFTS modelling shows the proposed detention system mitigates total peak flow impacts for all storm events and durations.

2.5.2 Flood Management and Creekline Rehabilitation

Sector 3 is bordered by Narrabeen Creek to the northwest, which is the primary source of floodwaters at the site.

Flood levels for the 5, 20, 100 year ARI floods and Probable Maximum Flood (PMF) events under existing conditions are illustrated in **Drawing 5194-03**. These flood levels are likely to decrease under proposed conditions as the waterway area for flood conveyance in Narrabeen Creek is increased.

The proposed earthworks regrading will ensure that all habitable floors will be located at least 500mm above the 100 year ARI flood level and above the PMF level. The intention is to preclude any flooding notations on S194 certificates for the new allotments by filling on the site.

It is proposed that Narrabeen Creek be rehabilitated in accordance with Council's specification and to ensure no detrimental influence (*in terms of flood levels*) on the upstream creek design/areas.

2.6 STORMWATER DRAINAGE CONCEPT PLAN

The elements of the proposed Stormwater Drainage Concept Plan are presented in **Drawing 5194-02**.

A minor/major storm drainage philosophy has been adopted. All flows generated as runoff are proposed to be directed to retention infrastructure *(rainwater tanks and bio-retention basins)*. The proposed permeable paving will treat runoff from the road running alongside the creek.

All piped drainage infrastructure has been designed to convey the 20 year ARI flows generated on site. Flows in excess of the 20 year ARI up to the 100 year ARI event have been designed to be conveyed within the internal roadways.

Runoff water quality is proposed to be managed through a combination of treatment measures, with special emphasis on source control. The proposed stormwater treatment measures include rainwater tanks to capture roof runoff, permeable paving for creekline road runoff, gross pollutant traps (*3 month ARI treatment capacity*) and bio-retention basins to treat all runoff from the development.

It has been estimated that the anticipated pollutant loads discharging from the developed site will be lower than for the existing site conditions, making a substantial contribution to long-term improvements in receiving water quality. The total peak flow rates exiting the site following development will be less than for existing conditions. Similarly, the surface runoff volume after development will be less than for existing conditions. This represents a significant overall improvement on the current conditions and will contribute to improving water quality in the catchment.

3 EXISTING SITE CONDITIONS

3.1 EXISTING TOPOGRAPHY AND LANDUSE

Drawing 5194-01 illustrates the existing site topography, which generally slopes toward the west and south, following the alignment of Narrabeen Creek.

The site is made up of the Flower Power horticulture and garden supplies business, a number of glass houses and rural residences. The current land use is generally horticultural with a component of rural residential and a portion of urban (commercial).

3.2 EXISTING GEOTECHNICAL CONDITIONS / CONTAMINATION

According to reports by Douglas Partners signs of chemical contamination are not present at the site, but asbestos fibres were detected in a surface soil sample. It was recommended that asbestos be removed from the site.

Geotechnical conditions were noted to be highly variable, which would have implications for differential settlement. It is understood a strategy has been adopted to prepare the site to accommodate the variable conditions.

The potential for Acid Sulphate Soils was also noted and recommended for further investigation.

Refer to Douglas Partners' "Report on Preliminary Contamination Assessment" November 2004 and "Report on Preliminary Geotechnical Assessment" December 2004 for further details.

3.3 EXISTING CATCHMENTS

Catchment definition for the site is largely dependent on artificial surface features such as buildings and pavements. The catchments are detailed in **Drawing 5194-01**.

The site drains to Narrabeen Creek and ultimately to the Warriewood Wetlands.

3.4 HABITAT

A habitat assessment of Narrabeen Creek in the vicinity of the site was undertaken by Robyn Tuft & Associates and is included in **Appendix D**.

The assessment found that "Narrabeen Creek is accommodating a variety of different fauna, including some pollutant sensitive taxa".

4 PROPOSED CONDITIONS

The development proposal is shown in **Appendix I** and includes the provision of 130 new residential dwellings with associated roads, open space, retained bushland and water management infrastructure.

In accordance with Pittwater Council's "*Development Control Plan No. 29 – Warriewood Valley Urban Land Release*" *(July, 2001)* and "*Warriewood Valley Section 94 Contributions Plan*" *(October, 2001)* it is proposed that the development would be responsible for rehabilitation of half the width of Narrabeen Creek, which borders the site in the north east.

4.1 SITE CUT/FILL

It is proposed that fill works be undertaken across the site, to ensure that a development platform is created at least 0.5 m above the 100 year ARI flood level and above the PMF level. This will require filling in the order of 0.5m to 2.0m across the allotments and internal roads. In combination with the proposed filling, cut works will also be undertaken in the northwest of the site in formation of the new Narrabeen Creek cross section. Refer to **Drawing 5194-05** for preliminary fill levels.

5 WATER CYCLE ASSESSMENT

5.1 WATER CYCLE ASSESSMENT OVERVIEW

The inhouse water balance programme utilised in this assessment uses a dynamic analysis to represent the sites stormwater losses and gains over an historical rainfall period. The programme is a daily rainfall model, which accounts for all inputs and outputs within a closed system.

Inputs to the system include:

- rainfall; and
- potable water supply.

Outputs to the system include:

- interception;
- depression storage;
- soil moisture storage;
- infiltration;
- internal reuse;
- irrigation (*triggered only when it is determined to be required*); and
- evapotranspiration.

The water balance model offers the analysis of a combination of the following variable factors:

- impervious areas to rainwater tanks;
- impervious areas not to rainwater tanks;
- pervious areas to be irrigated;
- pervious areas not to be irrigated;
- forested areas;
- infiltration system areas (*ie bio-retention basins*); and
- wetland areas;
- rainwater collection tanks;
- internal reuse of collected rainwater; and
- irrigation of pervious areas with collected rainwater.

Refer to **Diagram 1** for a schematic of the PBP water balance model.

The assessment of the water cycle of Sector 3 has been carried out to ascertain the impact of proposed development on runoff volumes. The existing water cycle was used as a basis of comparison for two development scenarios. The first scenario explored the impact of development where minimal management practices were introduced. The second scenario compares existing conditions with the proposed development layout in which a suite of water management practices are proposed.

The water balance was simulated over a four year period (*1995 to 1998 inclusive*) to model an extensive range of possible localised conditions.

Details of the water cycle assessment are included in **Appendix B**. The following sections describe the analysis.

5.2 REVIEW OF WATER CYCLE AND PBP WATER BALANCE MODEL

During the initial stages of precipitation, a small proportion of rain falling upon impervious areas evaporates. Water stored in depressions following rainfall also evaporates. For the PBP water balance model, these two forms of rainfall loss have been combined as paved area depression storage.

During the course of precipitation, the canopy of trees and other vegetation intercepts some of the initial rainfall before it reaches the ground. This phenomenon is known as interception. When the interception capacity is exceeded, water will drip to the ground (*through fall*) and run down the tree trunks (*stem flow*). The water captured by the interception storage of the vegetation is evaporated. The amount of precipitation lost to interception can be significant. Fetter (*1994*) suggests dense forests can intercept 8% to 35% of annual precipitate while Kuczera (1996) suggests interception loss accounts for about 10% - 20% of above canopy rainfall of a eucalypt forest.

Rainfall that reaches the pervious areas from direct precipitate, through flow and stem flow can infiltrate into the soil. The amount of infiltration is dependent upon the type of soil, the degree of saturation (*antecedent moisture condition*) and the intensity of rainfall. When precipitation exceeds the infiltration capacity of the soil, puddles may form and runoff can occur. The amount of water trapped as puddles is termed depression storage.

Many models have been developed to determine the rate of infiltration of various soils. Generally however, these models provide infiltration capacities that vary hourly (*or more frequent*) as the moisture level of the soil increases. While these models provide an accurate representation of infiltration they are not applicable to daily rainfall records. Given daily precipitation records, it is not known whether any particular rainfall depth occurred during a single event lasting less than an hour or by several small events evenly spaced over a 24 hour period. Traditional models, while defining the amount of infiltration entering a soil column, do not differentiate between deep infiltration to groundwater and infiltration to the capillary or root zone. This has a large influence on determining the amount of irrigation required to sustain vegetation, and the amount of water available to recharge aquifers. For these reasons, a soil storage model was developed for the PBP daily water balance model to replace the traditional infiltration model.

The conceptual soil storage model, *(refer to* **Diagram 2***)*, refers more to the moisture content of the soil rather than any physical water elevation. At any time the "*moisture level*" of the soil is dependent upon four variables, precipitation, irrigation, evapotranspiration and deep infiltration. Both precipitation and irrigation will have the effect of increasing the moisture level, while deep infiltration and evapotranspiration will decrease the moisture level. As the moisture level decreases, a level will be reached where plants will begin to wilt. At this level, irrigation is necessary and will be applied until a satisfactory moisture level is restored. If however, precipitation and/or irrigation increase the moisture level to beyond that of the capillary zone, deep infiltration will occur and water will be lost to the aquifer. If precipitation and/or irrigation continues, the soil will become saturated and runoff will result.

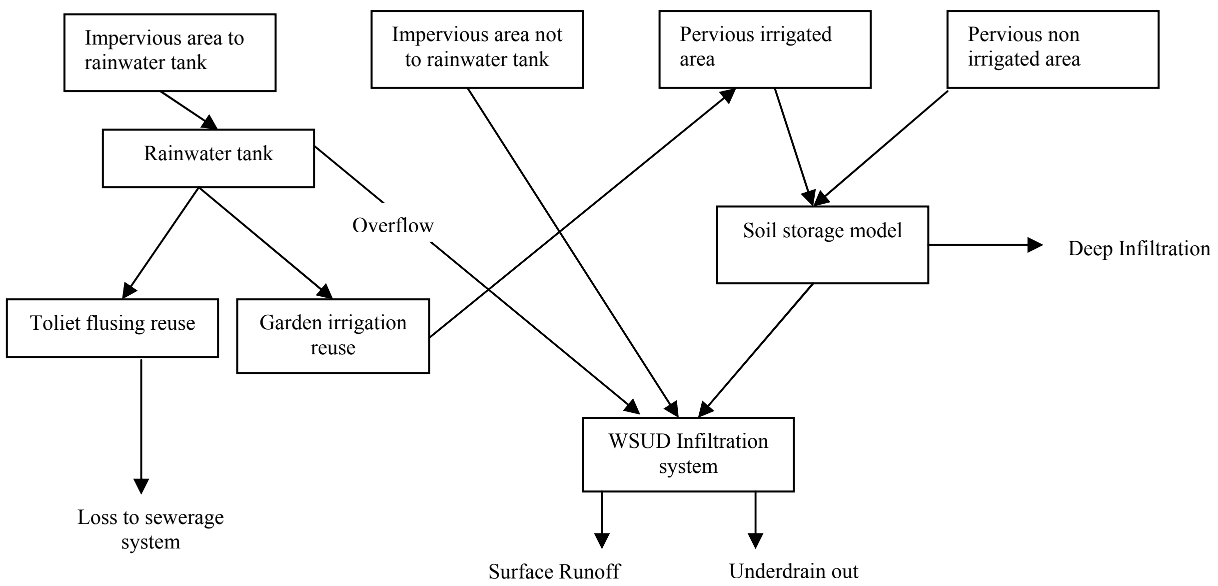

Diagram 1 – Water Balance Model Schematic

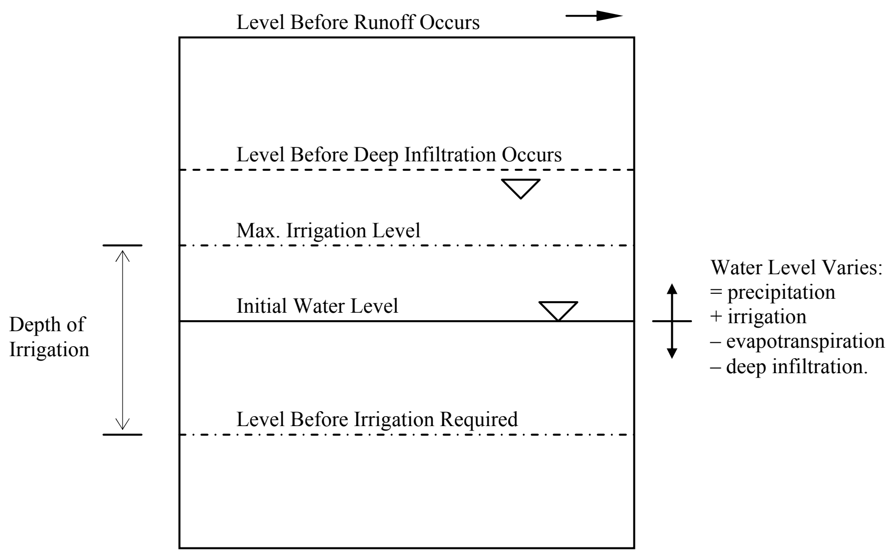

Diagram 2 – Soil Storage Model.

5.3 PHYSICAL CATCHMENT CHARACTERITICS

The portion of Sector 3 under consideration in this report has a total area of approximately 6.07 ha. Of this total area approximately 4.8 ha is proposed to be developed (*ie roads and lots*).

5.4 RAINFALL DATA

Daily rainfall data was compiled for the years 1995 to 1998. The data was obtained from the Bureau of Meteorology for the rainfall gauge closest to the site (Ingleside *66183).* The period from 1995 to 1998 was selected as it contains average, wet and dry years.

The average annual rainfall depth for the area between 1995 and 1998 was 1,463mm. The long term average for the region is approximately 1,230 mm/yr.

5.5 EVAPOTRANSPIRATION DATA

Monthly average point potential evapotranspiration values were obtained from the BOM publication titles "*Climatic Atlas of Australia – Evapotranspiration*" 2001 and converted to daily evaporation rates to be used in the evapotranspiration component of the water balance analysis.

5.6 WATER CYCLE FLOW GAUGING

No flow gauging has been undertaken to date for calibration of the water balance assessment.

The proportion of total runoff predicted in the PBP water cycle model is consistent with published data on gauged catchments. However the site varies from the general characteristics of Warriewood Valley in its land use and percentage impervious. Hence, the runoff generated is slightly higher than that generated in the hydrologic NAM model constructed for Council by Lawson and Treloar in the "*Integrated Water Management Strategy (IWMS) – Warriewood Valley*" *(November 1997)*.

5.7 SUMMARY OF MODEL INPUT PARAMETERS

Input data used for all scenarios is detailed in **Appendix B** and briefly summarised below:

General catchment area data for all scenarios was based on the physical catchment characteristics described in **Section 5.3:**

- Total catchment area = 6.07 ha;
- Developable area = 4.8 ha;
- 35% impervious area under existing conditions;
- 50% impervious area under post development conditions;
- Roof area only to rainwater tanks;
- The area to be irrigated under proposed conditions was 50% of the total pervious area; and
- The dedicated infiltration area is based on the total area of bio-retention basins.

The maximum daily interception storage for pervious area canopies was limited to 1.5 mm. Studies by Fetter (*1994*) suggests that dense forests can intercept 8 % to 35 % of annual precipitate, which for Sector 3 if fully forested could result in an average annual interception storage loss of between 98 mm and 431 mm or 0.27 mm and 1.2 mm per day (*average*). Hence, the adopted maximum storage rate of 1.5 mm is considered acceptable.

Depression storage was set at 1.5 mm for impervious areas, 0.5 mm for pervious areas and 1.0 mm for forested areas. These values are based on typical inputs utilised in models such as the ILSAX loss model to represent depression storage.

The adopted pervious soil moisture storage parameters are as follows:

- Maximum storage = 80 mm;
- Initial moisture storage = 70 mm;
- Storage before infiltration occurs = 60 mm;
- Deep infiltration rate = 17 mm/day[1] ;
- Storage before watering is required 5 mm; and
- Water until storage reaches 8 mm.

The maximum storage value is the typical depth at which all of the water cycle processes occur (*ie in the topsoil zone, where infiltration ,watering and evapotranspiration all interact*). The initial moisture storage level is representative of high antecedent moisture conditions and hence is conservative as infiltration cannot occur until there is a 60 mm depth deficit. Watering was selected to occur only in dry conditions when the storage levels fall to 5 mm depth and stops when a depth of 8 mm is reached (*considered conservative also*).

The total rainwater tank volume proposed is based on the average size tank (*ie 2* m^3) multiplied by the number of tanks proposed. It was assumed that this volume was 50% full at the start of the simulation. The equivalent tenement value is based on the number of lots proposed and the estimated daily potable water demand is based on the NSW Planning average usage rate for toilet flushing, washing machines and car washing.

5.8 DESCRIPTION OF STORMWATER RETENTION DEVICES

5.8.1 Bio-Retention Basins

For an illustration of the proposed bio-retention basin locations and configuration refer to **Drawing 5194-02**. A summary is also provided below.

A total length of 330 m bio-retention basins of 5.5 m base width are proposed in Sector 3. The typical basin section is shown on **Drawing 5194-02** and within the overall corridor on **Drawing 5194-07**. The minimum extended detention depth for the retention and infiltration system is 100 mm, while the maximum ponded water depth is 600 mm for

[1] 17 mm/day is based on infiltration testing results (Refer **Appendix C**).

stormwater detention purposes, with a maximum side slope of 1(v) in 3(h), i.e. small rainfall events will pond and infiltrate, while during larger rainfall events water will initially infiltrate the trenches before also spilling into a discharge control pit, which will employ an orifice outlet to detain peak flows.

Each basin consists of a low flow storage area underlain by topsoil, infiltration media and an underdrain system. Runoff from the roads, non-roofed areas and rainwater tank overflow drains to the basins. To promote detention, the surface of the basins will be densely planted in accordance with the landscape architects specifications and bunds will be incorporated at regular intervals.

The extent and type of planting proposed within the basins has been designed to discourage pedestrian and vehicular entry, mistreatment and misuse.

Runoff captured by the basins may pond on the surface and will infiltrate into the surface, through the drainage media at a rate of 100 mm/h to an underdrain system. A portion of the runoff will also infiltrate into the surrounding subsoils. Flows collected by the underdrain system will eventually discharge into the trunk drainage system. This underdrain system along with the highly permeable backfill and topsoil (*sandy loam*) utilised within the basin will prevent the area from being saturated or becoming "boggy" for extended periods during wet weather.

The free volume provided by the bio-retention basins will be at least 1782 m^3 (*ie the volume in the surface storage area and within the voids of the infiltration trench*).

The maximum longitudinal grade of the basins will not exceed 2%, with an average grade of approximately 1%.

The basin will be vegetated with turf, shrubs and trees (*refer to Landscape Architects Drawings for details*). This vegetation will assist in the retention of a minor proportion of the runoff volume by trapping/slowing flows.

These devices will serve a threefold function of stormwater retention, stormwater detention and reduction of stormwater pollution levels.

5.8.2 Rainwater Tanks

It is proposed that an average 2 m^3 (*2kL*) rainwater tank will be installed on all 130 lots within Sector 3. The size of tank may vary from lot to lot dependant on site area , however 260 m^3 of rainwater tank storage will be achieved in total.

Runoff collected in the proposed rainwater tanks (*average of 2kL/lot*) is proposed to be reused on each lot, both internally for toilet flushing and in washing machines and externally for irrigation and car washing purposes. Average water usage data published by NSW Planning and summarised in **Table 1** was utilised as input to the water balance model for internal reuse and for comparison of the rate of irrigation determined to be required over the 4 year period at Sector 3 (*ie derived by the water balance model*).

All roof area of the proposed development is to be directed to the rainwater tanks installed on each lot. This constitutes a total area of approximately 15,200 m^2 for Sector 3.

The proposed 2 m^3 volume rainwater tank is one component of a sector wide strategy to achieve the following objectives:

- Development of a sector based stormwater management system that incorporates water sensitive urban design;
- Ecologically sustainable development;
- Implementation of sufficient stormwater retention measures to ensure no adverse impact on runoff volumes (ie *achievement of the predevelopment runoff volume*), particularly with respect to frequent flows; and
- Reduction of potable water demand.

A summary of the proposed rainwater tank design is as follows:

- An average 2 m^3 volume rainwater tank designed to collect the majority of roof runoff and store it for irrigation, car washing, clothes washing machine and toilet flushing purposes only will be installed on each of the lots in Sector 3;
- The tank is to incorporate a first flush device, inspection/cleanout hatch and cleanout valve;
- The tank is to incorporate an outlet tap for connection to an irrigation system driven by the tank head;
- All tank overflow should be directed to the sites formal piped stormwater drainage systems (*ie overflow to the street drainage system*) to prevent nuisance flooding;
- All rainwater tanks should be installed and maintained so as to prevent cross connection with the potable water supply;
- A "*topping up*" device (*from the potable water supply*) shall be provided to supplement roof runoff from the rainwater tanks;
- A *"backflow prevention device"* shall be installed;
- All rainwater services shall be clearly labelled "*Non Potable Water*" with appropriate hazard identification;
- Pipework used for rainwater services shall be coloured purple in accordance with AS1345. All valves and apertures shall be clearly and permanently labelled with safety signs to comply with AS 1319; and
- Achievement of the pre development runoff volume objective for the whole of Sector 3 requires full utilisation of the entire 2 m^3 volume for re-use, hence no air pocket should be incorporated.

5.8.3 Permeable Paving

It is proposed to use of permeable paving for approximately one third of the total plan area of the creekline road. For an illustration of the proposed locations of permeable paving refer to **Drawing 5194-02**.

The permeable paving would be installed in sags along the road to capture and treat road runoff. The sags in the local road would promote shallow ponding of water above the paving to allow water to infiltrate through the paving. Once passing the paving, water would infiltrate to the surrounding soils and an underdrain system beneath the paving would collect any excess treated water and convey it to the bio-retention system.

Table 1 NSW Planning Average Water Use Rates (Single Dwelling)

Occupancy Rate = 3.06													
Internal	**End Use**	**Calculated Usage (L/person/day)**	**Proportion of total water use**	**Best Practise Feature**	**Reduction - where possible**	**Reduction (L/person/day)**	**Reduction as a percentage of total use**	**Score**	**Second Reduction Feature**	**Reduction - where possible**	**Reduction (L/person/day)**	**Reduction as a percentage of total use**	**Score**
a	Kitchen Sink	13.0	5.3%	Flow Regulator	50%	6.5	3%	**3**					
b	Bathroom Basin	7.6	3.1%	Flow Regulator	50%	3.8	2%	**2**					
c	Laundry Trough	8.7	3.5%	N/A	0%	0.0	0%	**0**					
d	Bath	9.7	3.9%	N/A	0%	0.0	0%	**0**					
e	Shower	61.7	25.0%	AAA-rated Showerhead	55%	33.9	14%	**14**					
f	Toilet	48.7	19.7%	6/3 L Dual Flush	67%	32.6	13%	**13**	Flush Arrestor	17%	8.3	3%	**3**
g	Washing Clothes	44.3	17.9%	AAA rating best practice front loading washing machine	63%	27.9	11%	**11**	AAA rating top loading washing machine	25%	11.1	4%	**4**
h	Washing Dishes	2.1	0.8%	Current AAA-rated dishwasher	64%	1.3	1%	**1**	1993-96 Model Dishwasher	42%	0.9	0%	**0**
	TOTAL INDOOR	195.7	79.2%										
External													
j	Garden Irrigation	46.8	18.9%	Controlled Irrigation System with Moisture Sensor	50%	23.4	9%	**9**	Tap Timer	20%	9.4	4%	**4**
k	Car Washing	1.5	0.6%	Bucket Washing	44%	0.7	0%	**0**					
l	Swimming Pool	3.1	1.3%	Pool Cover	50%	1.5	1%	**1**					
	TOTAL OUTDOOR	51.4	20.8%										

5.9 WATER CYCLE ASSESSMENT RESULTS

5.9.1 Existing Conditions

Details of the water cycle assessment inputs and results under existing conditions are included in **Appendix B1** and summarised below.

The results indicated that 43.0% of total rainfall was converted to surface runoff for existing conditions.

The total rainfall volume falling on the study area (*6.07 ha*) for the years of 1995 to 1998 was 355,156 m^3 (*ie. total for 4 years*).

The estimated total volume of surface runoff from impervious surfaces was 109,756 m^3.

The estimated total volume of pervious surface runoff was 53,173 m^3.

The estimated total volume of infiltration was 63,384 m^3.

The estimated total runoff as a percentage of total rainfall (*43%*) is similar to Cv values derived by the EPA for partially developed sites but slightly higher than the percentage calculated in the IWMS (*36%*) using the (*NAM*) model for the Warriewood Valley. This is to be expected given the relatively developed nature of the site in comparison to the remainder of the Warriewood Valley.

5.9.2 Post Development – No Water Management Practices

Details of the water cycle assessment inputs and results under post development conditions with no measures are included in **Appendix B2** and summarised below.

The results indicated that 53% of total rainfall was converted to runoff for the post development conditions without introduction of specific water volume reduction measures.

The total rainfall volume falling on the study area (*6.07 ha*) for the years of 1995 to 1998 was 355,156 m^3 (*ie. total for 4 years*).

The estimated total volume of surface runoff from impervious surfaces was 156,794 m^3.

The estimated total volume of pervious surface runoff was 76,124 m^3.

The estimated total volume of infiltration was 47,040 m^3.

As expected, there was an increase in runoff volume from impervious surfaces and a decrease in infiltration volume.

5.9.3 Post Development – Introduction of Water Management Practices

Details of the water cycle assessment inputs and results under post development conditions with measures (*including the 2 m^3 rainwater tank and other measures)* are included in **Appendix B3** and summarised below.

Water management practices proposed to reduce the increased runoff volume include:

- use of bio-retention basins/infiltration trenches;
- use of rainwater tanks (*average of 2 kL per lot*);
- use of permeable paving; and
- maximisation of the infiltration potential for all pervious areas on the site.

The results of the water balance indicated that 31.0% of total rainfall was converted to runoff for the post development conditions with the introduction of the above mentioned measures.

The total rainfall volume falling on the study area (*6.07 ha*) for the years of 1995 to 1998 was 355,156 m^3 (*ie. total for 4 years*).

In this period, a total volume of 83,692 m^3 flowed to the rainwater tanks from the roof areas of Sector 3. The reuse demand (*including irrigation*) was 30,281 m^3, however 11,655 m^3 of domestic water top up was required due to tank depletion at the time of need, leading to a total spillage or an overflow volume over the 4 years of 65,197 m^3. Hence, 62 % of the re-use demand was supplied by rainwater. The total number of times that domestic water top up was required was 300 (*out of 1460 days*). The change in storage volume from the initial storage level of the rainwater tanks (*ie starts at 50% full*) is -130 m^3 (*ie the tanks are empty at the end of the four year study period*). The difference in runoff co-efficient between the inlet and outlet of the rainwater tanks is 0.19.

The total runoff volume from all remaining impervious areas (*ie those areas not draining to the rainwater tanks such as roads, paved court yards, paths etc*) was 73,102 m^3.

The net flow volume generated by the "*pervious areas to be irrigated*" was 9,148 m^3, added to which was 15,277 m^3 required for irrigation, totalling 24,425 m^3. Of this total, 14,705 m^3 was infiltrated into the sub-soils of the pervious area and 10,285 m^3 runoff exited the area at the surface. The change in storage volume from the initial storage level of the soil moisture store for pervious areas (*ie starts at 88% full or at 70mm of the maximum 80mm depth*) is –565 m^3 (*ie down to 18 mm at the end of the four year study period*).

The net flow volume generated by the "*pervious areas not irrigated*" was 26,641 m^3. Of this total, 16,593 m^3 was infiltrated into the sub-soils of the pervious area and 10,783 m^3 runoff exited the area at the surface. The change in storage volume from the initial storage level of the soil moisture store for pervious areas (*ie starts at 88% full or at 70mm of the maximum 80mm depth*) is –735 m^3 (*ie down to 10 mm at the end of the four year study period*).

The net flow volume generated by the "*forested area*" was 22,562 m^3. Of this total, 13,681 m^3 was infiltrated into the sub-soils of the pervious area and 9529 m^3 runoff exited the area at the surface. The change in storage volume from the initial storage level of the soil moisture store for pervious areas (*ie starts at 88% full or at 70mm of the maximum 80mm depth*) is –648 m^3 (*ie down to 10 mm at the end of the four year study period*).

The overflow volume from all areas (*ie all catchments apart from the forested area*) to the bio-retention/infiltration systems was 159,366 m^3. Evapotranspiration and infiltration from the infiltration systems was 6,873 m^3 and 60,388 m^3 respectively. The change in storage volume from the initial storage level of the infiltration systems (*ie starts at 50% full*) is –315 m^3 (*ie empty at the end of the four year study period*).

Note that the change in storage volume that is observed for all sources above is due to the difference between the starting and end points of each of the storage modules over the four year period.

Introduction of the proposed water management practices reduces the fraction of runoff from 55% to 31% of the total rainfall, compared to 46% for existing conditions (*ie achieving a post development volumetric runoff co-efficient that is equivalent to that of existing conditions*). The water management practices would reduce the percentage of runoff to a value similar to that calculated in the IWMS (*36%*) using the (*NAM*) model for the Warriewood Valley.

The resultant irrigation requirement over the 4 year period was 15,277 m^3. This results in an average irrigation rate of 118 L/house/day (*note that only 15% of the development area is assumed to be subjected to irrigation*). This rate is significantly lower than that measured by NSW Planning for a single dwelling (*222 L/house/day*) but slightly higher than a townhouse (*96.9 L/house/day*) and hence is considered achievable in Sector 3.

6 WATER QUALITY ASSESSMENT

6.1 MONITORING PLAN OBJECTIVES

Prior to urbanisation of Sector 3, a monitoring plan was developed in accordance with Council's Water Management Specification (*February 2001*) and AS/NZ 5667.6: 1998 "*Water Quality Sampling – Guidance on Sampling of Rivers and Streams*".

The objectives of the monitoring plan are to:-

- develop an understanding of the existing conditions present in the waterways of Sector 3;
- continually assess the quality of these waterways during the construction phase of Sector 3; and
- assess the impact of constructed water quality measures following construction to ensure the development is ecologically sustainable.

Monitoring undertaken prior to the development of Sector 3 will be used to establish the present quality of the waterways within Sector 3 (*termed "baseline data"*). This data will be compared with future results to determine whether pollution controls are operating adequately and if the water quality is improving.

During the development stage of Sector 3, implementation of the monitoring plan will also allow early detection of any adverse impacts likely to risk the health of the public or the quality of receiving waters.

6.2 SCOPE OF MONITORING PLAN

6.2.1 Monitoring Locations

Narrabeen Creek is the major receiving waterway for the site runoff, but it will also be affected by many sources other than Sector 3 (*ie upstream sectors*). As such, two monitoring locations have been selected on Narrabeen Creek (*ie an upstream site and a downstream site, refer to* ***Drawing 5194-01*** *for details*) so that some of these outside sources can be isolated from those loads being generated by Sector 3.

However, it is not possible to isolate the loads being generated by Sector 3 completely. Sector 1 and Sector 2 lie upstream and on the opposite bank of Narrabeen Creek to Sector 3, and as such also contribute runoff to the creek in the same reach as Sector 3.

As there are no incoming waterways between the upstream and downstream sites and the reach length is relatively short (approximately 350 m), a third intermediate site was not considered necessary. Both upstream and downstream sites will continue to be monitored during and following development.

6.2.2 Types of Monitoring

The monitoring plan for Sector 3 consists of three main categories:-

- physico-chemical water quality monitoring;
- ecosystem/rapid biological assessment monitoring; and
- riparian sediment toxicant monitoring.

6.2.3 Water Quality Monitoring (*Discrete Sampling*)

The water quality monitoring component of the plan consists of:-

- dry weather sampling for at least 3 events; and
- wet weather sampling undertaken for at least 2 events (*recording a rainfall depth greater than 20mm over the catchment in a 24 hour period*) spread evenly over the year and sampling throughout the rainfall event (*rising and falling limbs of storm hydrograph*).

Samples are tested for the constituents listed in Council's WMS and reported to conform with Council's specification.

Following construction of the proposed stormwater treatment devices, sampling will be undertaken at the major inflow points to the bio-retention basins and at the outlet point to monitor water quality during wet weather. A wet weather event will be monitored at least once every 4 months (*dependant on rainfall*) and reported to conform with the Council's specification.

6.2.4 Rapid Biological Assessment Monitoring

Habitat monitoring has also been undertaken in Narrabeen Creek at the upstream and downstream boundaries of the site.

Samples will also be collected and reported in the DA stage water management report (*ie prior to commencement of construction*). A further monitoring exercise (*ie third round of habitat monitoring*) will be initiated immediately before commencement of the subdivision construction.

All habitat monitoring shall use the Biotic Index Signal to measure biological activity. Reporting shall conform to the Council's specifications.

6.2.5 Sediment Toxicant Monitoring

Sampling and testing of bed sediment for Narrabeen Creek, shall be undertaken on an annual basis. The first sediment sample has already been collected at both the upstream and downstream sites and further sampling will be undertaken immediately prior to commencement of the subdivision construction.

All sediment samples shall be tested for metals, pesticides and oils/greases. Reporting shall conform to the Council's specifications.

6.2.6 SQUID Monitoring

Following completion of the subdivision construction, all stormwater quality improvement devices (*SQUID's*) will be monitored until handover. This will include:

- Measurement of volume/mass of material removed from GPTs and an assessment of its relative composition; and
- Discrete sampling at the major inlets/outlets of the proposed major bio-retention basins.

Reporting shall conform to the Council's specifications.

6.2.7 Flow Gauging for Monitoring

To assess the magnitude of wet weather events and determine the position of a particular sample within a storm event, both the rainfall depth and flood depth will be recorded. Rainfall depth data will be obtained from the BoM, whilst flood depths will be recorded at the closest available flood gauge to the site (ie *crossing of Narrabeen Creek*). Flood depth will also be recorded at the time of sampling for each sampling site.

The total depth of rainfall experienced during the event will allow PBP to determine if the event sampled will comply with Council's minimum 20 mm depth over 24 hours criteria and a sustained length of record of the water levels at the Macpherson Street flood gauge will allow PBP to determine if the sample has been taken on either the rising or falling limb of the regional storm hydrograph.

6.2.8 Quality Assurance/Measurement Accuracy

All samples collected for the monitoring plan will be tested by a NATA certified laboratory. Copies of all original data testing certificates will be provided along with information detailing the collection and preservation status upon delivery at the laboratory. The laboratory testing detection limits will also be included on all test certificates.

6.3 MONITORING RESULTS

6.3.1 Water Quality and Monitoring Results

To date water samples have been collected as follows:

Date	Sample Name	Time	Dry/Wet & Location
8 July, 2004	WS301US	12:30	Dry weather – upstream site
8 July, 2004	WS301DS	13:00	Dry weather – downstream site
17 August, 2004	WS302US		Wet weather, rising limb – upstream site
17 August, 2004	WS302DS		Wet weather, rising limb – downstream site
18 August, 2004	WS303US	14:25	Wet weather, falling limb – upstream site
18 August, 2004	WS303DS	14:35	Wet weather, falling limb – downstream site
18 October, 2004	WS304US	14:30	Dry weather – upstream site
18 October, 2004	WS304DS	14:45	Dry weather – downstream site
23 February, 2005	WS310US	15:15	Dry weather – upstream site
23 February, 2005	WS310DS	15:30	Dry weather – downstream site
30 June 2005	WS311US	12:15	Wet weather, rising limb – upstream site
30 June 2005	WS311DS	12:30	Wet weather, rising limb – downstream site
4 July 2005	WS312US	12:00	Wet weather, falling limb – upstream site
4 July 2005	WS312DS	12:15	Wet weather, falling limb – downstream site

The resultant quality of these samples is detailed in **Appendix D** and summarised in **Table 2**.

Dry Weather

Three dry weather events have been sampled to date.

Generally, it can be seen that during dry weather the present quality complies with Council's long term goals where this goal is defined.

Table 2 Summary of Water Sampling Results

Parameter	Units	Short-Term Goal	Medium-Term Goal	Long-Term Goal*	8 Jul 2004 1st Dry	8 Jul 2004 1st Dry	17 Aug 2004 1st Wet-Rising Limb	17 Aug 2004 1st Wet-Rising Limb	18 Aug 2004 1st Wet-Falling Limb	18 Aug 2004 1st Wet-Falling Limb	18 Oct. 2004 2nd Dry	18 Oct. 2004 2nd Dry	23 Feb. 2005 3rd Dry	23 Feb. 2005 3rd Dry	30 June 2005 2nd Wet-Rising Limb	30 June 2005 2nd Wet-Rising Limb	4 July 2005 2nd Wet Falling Limb	4 July 2005 2nd Wet Falling Limb
					US site	**DS site**	**US site**	**DS site**	**US site**	**DS site**	**US site**	**DS site**	**US site**	**DS site**	**US site**	**DS site**	**US site**	**DS site**
Total rain over 5 days preced. Sampling	mm				0	0	14.4	14.4	48.6	48.6	35.8	35.8	59.6	59.6	73	73	96.4	96.4
Ammonia – N	mg/L	<2.3	<0.3	<0.3	0.01	0.07	<0.01	0.04	0.02	0.04	0.03	0.05	0.02	0.05	0.02	0.02	0.02	0.05
Total Nitrogen (TN)	mg/L	SQ	<1.6	1.0	1.4	1.2	0.7	1.2	1.0	1.6	0.5	0.8	0.9	1.2	1.4	*2.2*	*1.8*	*2.2*
Nitrate	mg/L	NS	NS	NS	0.9	0.6	0.34	0.75	0.4	0.82	0.14	0.41	0.41	0.61	0.23	0.59	1.17	1.63
Nitrite	mg/L	NS	NS	NS	<0.01	0.03	0.02	0.03	0.02	0.02	0.01	0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Filterable Phosphorous	mg/L	NS	NS	NS	0.02	0.07	0.06	0.13	0.15	0.09	0.03	0.12	0.03	0.12	0.20	0.41	<0.05	0.06
Non-Filterable Phosphorous	mg/L	NS	NS	NS	<0.01	0.05	<0.01	<0.01	<0.1	0.2	0.06	0.08	<0.01	0.01	0.06	0.13	<0.01	<0.01
Total Phosphorous (TP)	mg/L	SQ	<0.1	0.04	<0.02	*0.12*	0.06	*0.13*	*0.15*	*0.29*	0.09	*0.2*	0.03	*0.13*	*0.26*	*0.54*	<0.02	0.03
Suspended Solids (SS)	mg/L	SQ	<20	<6	5	*170*	*24*	*31*	*50*	*83*	*32*	*54*	1	3	*130*	*290*	1	5
Turbidity	NTU	SQ	<50	<20	24	*336*	*103*	*107*	*142*	*209*	*90*	*157*	31	10				
Faecal Coliforms	cfu/ 100 ml	<1000	<150	<150			*990*	*880*	**1,900**	**1,900**	**15,000**	**9,300**	*520*	*390*	**7,200**	**6,300**	*190*	*270*
Total Kjeldahl Nitrogen	mg/L	NS	NS	NS	0.4	0.7	0.3	0.5	0.6	0.9	0.4	0.4	0.02	0.05	1.2	1.6	0.5	0.5
Ph	Ph unit	6.6-8	6.6-8	6.6-8	7.22	7.57	**8.37**	**8.08**	7.53	7.48	7.07	7.06	6.87	7.01	**8.69**	**8.38**	6.96	7.04
Dissolved Oxygen (field)	mg/L	SQ	<90% sat.	<90% s	8.24	7.57	7.58	6.89	8.19	8.10	6.22	6.04	4.77	3.82	5.61	5.52	5.53	5.50
Conductivity	mS/cm				0.292	0.320	0.09	0.185	0.109	0.114	0.05	0.082	0.265	0.335	0.1	0.14	0.23	0.28
Temperature (field)	°C	SQ	SQ	SQ	11.8	13.0	15.3	15.3	12.5	12.5	16.1	16.3	25.8	24.1	15.3	15.3	14.2	16.3
Flow depth	cm																	
Salinity	%				0.01	0.01	0	0	0	0	0	0	0.01	0.01	0	0	0	0.01
Arsenic	ug/L	SQ	50%SQ	50	<0.002	<0.002	NR	NR	NR	NR	<0.005	<0.005	<0.002	0.002	NR	NR	NR	NR
Chromium	ug/L	SQ	50%SQ	10	<0.005	<0.005	NR	NR	NR	NR	<0.005	<0.005	<0.005	<0.005	NR	NR	NR	NR
Copper	ug/L	SQ	50%SQ	2	<0.005	<0.005	NR	NR	NR	NR	<0.005	<0.005	<0.005	<0.005	NR	NR	NR	NR
Lead	ug/L	SQ	50%SQ	1	<0.002	0.004	NR	NR	NR	NR	<0.005	<0.005	<0.002	<0.002	NR	NR	NR	NR
Mercury	ug/L	SQ	50%SQ	0.1	<0.002	<0.002	NR	NR	NR	NR	<0.00005	<0.00005	<0.00005	<0.00005	NR	NR	NR	NR
Zinc	ug/L	SQ	50%SQ	50	<0.01	0.02	NR	NR	NR	NR	0.03	0.05	0.01	0.02	NR	NR	NR	NR
Organo chlorine Pesticides (OCP)	ug/L	SQ	50%SQ	NS	<1	<1	NR	NR	NR	NR	<1	<1	<1	<1	NR	NR	NR	NR
Phenols	mg/L	SQ	50%SQ	NS	<0.01	<0.01	NR	NR	NR	NR	<5	<5	<5	<5	NR	NR	NR	NR
Organo phosphate Pesticides (OPP)	ug/L	SQ	50%SQ	NS	<10	<10	NR	NR	NR	NR	<10	<10	<10	<10	NR	NR	NR	NR
Hardness	mg/L	NS	NS	NS	93	97	NR	NR	NR	NR	16	28	79	100	NR	NR	NR	NR
Chlorophyll A	mg/L	15	15	10	<0.005	<0.005	NR	NR	NR	NR	<0.005	<0.005	<0.005	<0.005	NR	NR	NR	NR
Oil & Grease	mg/L	50	20	5	<5	<5	NR	NR	NR	NR	<5	<5			NR	NR	NR	NR
PAH	ug/L				<1	<1	NR	NR	NR	NR	<1	<1	<1	<1	NR	NR	NR	NR
Algal Count	No cells/ml				740	1100	NR	NR	NR	NR	0	low			NR	NR	NR	NR

1. Long-Term water quality goals are derived from ANZECC, 1992 guidelines and Councils WMS Table C2 – Feb 2001.
2. Figures in normal case satisfy long-term water quality goals where they are specified by Pittwater Council.
3. Figures underlined do not achieve the long term water quality goals where they are specified by Pittwater Council.
4. Figures in *italics* do not achieve the medium and long term goals where they are specified by Pittwater Council.
5. Figures in **Bold** do not achieve the short, medium or long term goals where they are specified by Pittwater Council.
6. Rainfall data obtained from Bureau of Meteorology.
7. NS – Not Specified by Council, SQ – Status Quo
8. DS=downstream sampling site, US=upstream sampling site, NR = not required to be measured by WMS

Total Nitrogen and Total Phosphorus levels are near or above Council's long term goals at the downstream site. TN results were generally better than TP.

Overall, the surface water chemistry results at the downstream sampling location indicate a higher level of nutrients than the upstream sites, indicating that the site itself and/or the opposite creek bank is a source of nutrients for the creek. This result is not surprising, given the site's horticultural land use.

The measured levels of metals tested is low and usually below detectable levels at both the upstream and downstream locations.

The Suspended Solid (*SS*) concentrations generally did not comply with Councils medium or long term goals. Further, the TSS concentrations increased from upstream to downstream locations. This indicates that the site itself and/or the opposite creek bank contribute a suspended solids load to the creek.

Faecal Coliform (*FC*) levels at both locations tested are very high and generally did not comply with the Council's goals. However, the levels either fell or remained constant from upstream to downstream locations, which indicates that the site is not the source of this pollution. This indicates that sewer overflow or septic sewage may potentially be feeding this waterway from upstream of the site in question.

OC/OP pesticide, phenol, oils/grease and metal concentrations all complied with Council's long term water quality goal and were in most cases below the detection limits.

The dry weather TN, TP and TSS concentrations collected within Sector 3 are generally in or below the range of concentrations identified for Narrabeen Creek (*refer to report titled "Warriewood Valley water Quality Annual Report 2001-2002" L&T January 2003*), with the most notable exception being TSS levels being unusually high for one event at the downstream end of the site.

Wet Weather

Two wet weather events have been sampled. Samples were obtained at both upstream and downstream sites, for both the rising and falling limbs of the storm hydrograph.

Generally, it can be seen that during wet weather the present quality of the waterway sampled does not comply with Council's long term goals where this goal is defined.

The downstream site exhibited higher concentrations of TN, TP and SS compared with the upstream site for both rising and falling limbs. This indicates that the site contributes additional loads of these pollutants to the creek.

In wet weather, Total Suspended Solids (*TSS*) concentrations were generally in excess of Council's long term goal of less than 6 mg/L at both sites.

Equally, Total Phosphorus (*TP*) concentrations were generally in excess of Council's long term goal of less than 0.04 mg/L at both locations.

Faecal Coliform (*FC*) levels were well in excess of even the short term goal at both sites, for two events. However, the levels either fell or remained constant from upstream to downstream locations, which indicates that the site is not the source of this pollution. This indicates that sewer overflow or septic sewage may potentially be feeding this waterway from upstream of the site in question.

OC/OP pesticide, Phenol, oils/grease and metal concentrations were not required by Council's WMS to be tested in wet weather events.

The wet weather TN, TP and TSS concentrations collected within Sector 3 are generally in or below the range of concentrations identified for Narrabeen Creek (*refer to report titled "Warriewood Valley water Quality Annual Report 2001-2002" L&T January 2003*).

The water quality monitoring results indicate that metals, hydrocarbons, phenols and OCP are generally below detection limits. This is supported by Douglas Partners "Report on Preliminary Contamination Assessment" (November 2004), which states that concentrations of heavy metals, hydrocarbons, phenols and OCP in soil samples tested were generally very low.

6.3.2 Rapid Biological Assessment Monitoring Results

Results of this monitoring indicate that "Narrabeen Creek is accommodating a variety of different fauna including some pollutant sensitive taxa". Further details can be found in **Appendix E**.

Further samples will be collected and reported in the DA stage water management report (*ie prior to commencement of construction*). A further monitoring exercise (*ie third round of habitat monitoring*) will be initiated immediately before commencement of the subdivision construction.

6.3.3 Bed Sediment Toxicant Monitoring Results

Bed sediment samples have been collected to date as listed below:

2 February, 2005	S3S1US	Bed sediment – upstream site
2 February, 2005	S3S1DS	Bed sediment – downstream site

The toxicant results for both samples are included in **Appendix D** of this report and comply with all of Council's specified long term objectives.

6.4 ACID SULPHATE SOILS

According to the Douglas Partners' "Report on Preliminary Geotechnical Assessment" (December 2004), Acid Sulphate Soil (ASS) screening indicated the potential presence of ASS. It was recommended that qualitative analysis be carried out for any bulk excavation works.

7 WATER QUALITY MANAGEMENT

7.1 CONSTRUCTION PHASE

During bulk earthworks and construction of roads and associated infrastructure for the proposed development, sediment and erosion control facilities will be designed and constructed/installed in accordance with Council's specifications and with the requirements of the publication "*Managing Urban Stormwater – Soils and Construction*" *(Dept of Housing, 1998)*.

A sediment and erosion control plan will be prepared prior to construction, outlining the strategies proposed to prevent excessive pollutant loads being exported from the site in runoff during and immediately following construction.

7.2 POST DEVELOPMENT PHASE

As required in Council's WMS, the objective of the water quality management strategy for the proposed development of Sector 3 is to ensure a "*no net increase*" in pollutant loads discharged from the developed site compared to the existing conditions.

The proposed water quality management system consists of the following elements (*refer to **Drawing 5194-02** for details*):

- the maximisation of pervious areas *(on road reserves and each development lot)* so as to maximise the infiltration potential;
- use of rainwater storage tanks (*average 2m^3/lot*) for reuse in non-potable supply purposes such as toilet flushing, washing machine use, carwashing and irrigation;
- use of permeable paving for part of the creekline road to treat its runoff;
- use of bio-retention basins and infiltration trenches *(described earlier in this report)*; and
- installation of underground Gross Pollutant Traps *(GPTs).*

The software package developed by the CRC for Catchment Hydrology termed "MUSIC" (*Model for Urban Stormwater Improvement Conceptualisation*) was used to assess the effectiveness of the proposed "*treatment train*" compared with two other landuse scenarios.

The three landuse scenarios analysed were as follows:

- Existing conditions;
- Post development conditions with no treatment measures; and
- Post development conditions with treatment measures.

Details of the MUSIC model results are included in **Appendix G** and summarised below.

7.2.1 MUSIC

"*MUSIC simulates the performance of a group of stormwater management measures, configured in series or in parallel to form a treatment train*." In this case, MUSIC has been run on a continuous basis (*30 minute intervals from January 1996 to December1999*), allowing rigorous analysis of the merit of proposed strategies over the long-term.

"*The adoption of a continuous simulation approach is recommended in water quality modelling. This stems from the fact that impacts of poor stormwater quality on aquatic ecosystem health are associated with cumulative pollutant loads and frequency of aquatic ecosystem "exposure" to poor water quality. Pollutant loads delivered to receiving waters from many of the small storm events (e.g. of magnitude less than the 3 month ARI peak discharge) can make up in excess of 90% of the annual loads discharged from the catchment.*

The evaluation of the adequacy's of the stormwater management systems is based on a risk-based approach associated with examination of the long-term mean annual pollutant load delivered to the receiving waters.

MUSIC is designed to simulate stormwater systems in urban catchments and have the capability to operate at a range of temporal and spatial scales, suitable for catchment areas from 0.01 km^2 to 100 km^2. Modelling time step can range from 6 minutes to 24 hours to match the range of spatial scale.

The model's algorithms are based on the known performance characteristics of common stormwater quality improvement measures. These data, derived from research undertaken by CRCCH and other organisations, represent the most reliable information currently available in our industry" MUSIC Manual, CRC for Catchment Hydrology (*Version 1*) May 2002.

7.2.2 Site Characteristics

The entire 6.07 ha site was modelled in MUSIC under existing and proposed conditions.

The impervious fractions adopted for MUSIC modelling are as follows:

- Existing (*total*) 35%
- Proposed (*total*) 50%

7.2.3 Rainfall and Evaporation

Rainfall and evaporation data was sourced from the Bureau of Meteorology (*BoM*).

Thirty minute pluviograph data was utilised in the MUSIC models for a range of rainfall years representing a mix of average, wet and dry years for the region (*1996 to 1999*). The closest rainfall station to the site with 30 minute data was Middle Creek. Details of the rainfall records are included in **Appendix H**.

The average annual rainfall depth experienced over the study period (1996 to 1999) at Middle Head was 1402mm. The long term average for the region is approximately 1230mm. Hence, the study period used represents a wetter than average range of years.

Evaporation data was extrapolated for the site using the BoM publication titled "*Climatic Atlas of Australia - Evapotranspiration*" (*BoM 2001*).

7.2.4 Soil Properties

Table 3 includes a summary of the adopted soil properties used for input into the runoff module of MUSIC. The parameter values adopted were based on those adopted for similar sites and the resultant volumetric runoff coefficients were comparable with published values. It should be noted that the model is "*significantly more sensitive to the accurate definition of the fraction impervious and the selection of simulation time step*" MUSIC Manual (*CRCCH, 2002*).

Table 3 Adopted MUSIC Soil Properties

Parameter	Existing	Urban
Rainfall Threshold for Impervious area (mm/d)	1.5	1.5
Soil Storage Capacity (mm)	200	200
Initial Storage (% of Capacity)	50	50
Field Capacity (mm)	150	150
Infiltration Capacity Co-efficient "a" (mm/d)	100	100
Infiltration Capacity Co-efficient "b"	1	1
Groundwater initial depth (mm)	10	10
Groundwater daily recharge rate (%)	25	25
Groundwater daily baseflow rate (%)	10	10
Groundwater daily seepage rate (%)	50	50

7.2.5 Pollutant Loads

Table 4 includes a summary of the adopted pollutant Event Mean Concentrations (EMCs) for the various landuse scenarios. The EMC values are based on values derived from

Council's WMS assuming an existing landuse of 70% horticultural, 20% urban (commercial) and 10% rural-residential.

Table 4 Adopted EMC's

Landuse Scenario	SS (mg/L)	TP (mg/L)	TN (mg/L)
Existing	55	0.21	2.15
Urban	100	0.3	1.5

7.2.6 Pollutant Reduction Assumptions

The following treatment assumptions were made for the proposed water quality measures:

- Available rainwater tank volume = 2m^3/lot. Volume reused for toilet flushing, washing machine, carwashing and irrigation (*261 L/day/ET*). This will assist in reduction of runoff volume and hence a reduction in pollutant load as the load = runoff volume x EMC;
- GPT's will be used as pre-treatment of stormwater before basins and achieve the following removal rates:
  - TSS 80%;
  - TN 13%
  - TP 30%
- Permeable paving will be used to treat the creekline road runoff (*only*) and achieve the following removal rates and a flow reduction of 2%, based on infiltration into underlying subsoil:
  - TSS 80%;
  - TN 80%
  - TP 60%
- The available Bio-Retention systems are as follows:

Node	*Retention Area (m^2)*	*Retention Volume (m^3)*	*Filter Area (m^2)*
Basins	605*	292*	330

* The retention area and volume modelled is the minimum available for all storm events before the bio-retention basin begins to operate as a detention basin. Hence, the actual retention area and volume available would be increase with the intensity of the storm event.

In order to achieve the water quality objectives for all pollutants it is proposed to install gross pollutant traps and bio-retention basins. Bio-retention basins are systems that promote the filtration of stormwater through a prescribed filter medium. The infiltration system typically comprises a surface detention system overlaying a filter medium *(eg. sand or gravel)* in which the detained water infiltrates into. The filtered flow is collected by an underdrain and is returned to the watercourse. The location of these proposed treatment strategies is shown in **Drawing 5194-02**.

7.2.7 MUSIC Modelling Results

Table 5 includes a summary of the annual pollutant loads for all three scenarios.

Table 5 Estimated Average Annual Runoff Pollutant Loads

Scenario & Catchment	Runoff (ML/yr)	TSS (kg/yr)	TP (kg/yr)	TN (kg/yr)
Existing				
Out	35.2	2300	8.08	68.6
Post Development (No Treatment)				
Out	44	4320	13.0	64.8
Increase above existing (%)	*25*	*88*	*61*	*-6*
Post Development (With Treatment)				
Out	36.9	639	4.82	35.9
Reduction Below Existing (%)	-4.8	72.2	40.3	47.7
Treatment Train Effectiveness (% Reduction)	16	85	63	45

Table 5 shows that the results for the proposed development meet the required objectives for reduction of TP, TN and SS.

7.2.8 Maintenance Programme

The proposed maintenance program for the sites water quality control measures will consist of the following:

- Periodic *(6 monthly)* inspection and removal of any gross pollutants & coarse sediment that is deposited in the bio-retention basins and replacement of vegetation as necessary;
- Periodic *(3 monthly)* and episodic *(post storm greater than 1 yr ARI)* inspection and removal of trapped pollutants from all GPTs; and

7.2.9 Preliminary Mosquito Risk Assessment

A preliminary assessment of the mosquito risk for all water quality control measures has been undertaken.

As no permanent water bodies are proposed for Sector 3 (*as part of the treatment train*), the risk of increasing mosquito activity is minimal.

Stormwater will be temporarily stored in both the bio-retention basins, however due to the proposed high infiltration rates of these systems the water will not pond for a sufficient period of time to allow mosquitos to breed.

The proposed GPT's will contain a sump that will permanently hold water. However, this is not considered a high risk for mosquito breeding as the volume stored is minor and similar GPT's are installed in urban areas throughout Sydney.

8 STORMWATER QUANTITY MANAGEMENT

The integrated strategy proposed for management of stormwater runoff quantity on the site is comprised of:

- source control which includes:
  - use of rainwater tanks (*$2m^3$/lot* ***(260 m^3)****, of which 25% is counted as effective OSD storage –* ***65 m^3***) to reduce runoff volume, maximise non-potable supply/re-use and minimise peak flows discharging from individual allotments;
  - minimising impervious surfaces (*limited to 50% site wide*) to maximise infiltration potential and reduce runoff volumes;
  - the use of landscaping which encourages the maximisation of infiltration.

- the conveyance system which includes:
  - road and accessway's (*effective detention storage volume =* ***73 m^3***) to reduce peak flow rates in events between the 20 year and 100 year ARI events;
  - the proposed 20 year ARI piped drainage system (*effective detention storage volume =* ***66 m^3***) to reduce peak flow rates in events between the 20 year and 100 year ARI events;

- formal detention system:
  - on-site detention tanks (10 m^3 each) (*effective detention storage volume =* ***250 m^3***) for 25 lots fronting Macpherson Street.
  - bio-retention basins (*effective detention storage volume =* ***1782 m^3***) to maximise the potential of infiltration and provide detention storage volume, which in turn will reduce peak flow rates and volumes for frequent events. This will directly reduce peak runoff rates for all storm events;

The total stormwater detention volume proposed for Sector 3 is **2,236 m^3**. Hence, a stormwater detention storage is proposed at the rate of **466 m^3/ha** *(based on a proposed road and lot area of 4.8 ha)*, to mitigate localised increases in peak flow rates exiting the site**.** The proposed storage rate exceeds the detention rate of **368 m^3/ha** required by Council in their WMS.

8.1 STORMWATER DETENTION

The proposed rainwater tanks will assist in reduction of peak flow rates for the more frequent events. Studies (*Coombes et al*) indicate that approximately 25% of a 2 kL is available as OSD storage.

A detention volume is also available for the less frequent events in the roadways due to their proposed conveyance characteristics. This volume is effective detention storage for events greater than the capacity of the existing piped drainage system (*ie 20 year up to the 100 year ARI event*).

All runoff from the urbanised surfaces within Sector 3 is directed to the proposed bio-retention basins (*refer to* ***Drawing 5194-02*** *for details*). A volume of storage is also available beneath the basins in the porosity of the filter medium due to the adoption of single graded large aggregate (*adopted void ratio=0.3*). In total, these basins will hold **1746 m^3** of runoff. This storage is available for all events.

A stabilised overflow weir will be constructed such that flows in excess of the 100 year ARI event are delivered to Narrabeen Creek. The proposed Narrabeen Creek design will ensure that no interaction occurs between flows in Narrabeen Creek and the proposed bio-retention detention storage up to at least the 20 year ARI event.

Whilst the volume within the proposed piped drainage systems is not considered effective detention volume for events up to the 20 year ARI event, this volume does become effective when the piped drainage system capacity is exceeded (*ie larger events such as the 100 year ARI*).

RAFTS modelling has been undertaken to assess the impact on outflows from Sector 3 due to implementation of the proposed detention systems, details of which are included in **Appendix F** and summarised in **Table 6.**

The modelling ensures that the proposed post development outflows comply with the Permissible Site Discharges (PSDs) in Councils WMS.

The RAFTS parameters detailed in Councils WMS (*Table A3*) were utilised. The 100 year, 20 year and 5 year ARI events were run for a range of storm durations. Generally, the ninety minute storm proved to be critical in terms of peak flow.

In order to achieve the PSDs as shown in **Table 6**, a multiple staged outflow system is proposed with discharge rates of 57, 123 and 148 L/s/ha for the appropriate storm events.

Table 6 RAFTS Modelling Results for 100yr ARI (1% AEP) (Comparison with PSDs)

Storm Duration	Peak Flow with Detention at Outlet to Narrabeen Creek (m^3/s)	PSD (m^3/s)	PSD (L/s/ha)
30 minutes	0.274	0.274	57
1 hours	0.59	0.59	123
2 hours	0.71	0.71	148
3 hours	0.59	0.672	140
6 hours	0.59	0.739	154

Note: Above flows are based on a developable area of 4.8 of the total site area of 6.07 ha. The total Sector 3 area is 8.13 ha as reported in Table A3 of the WMS.

8.1.1 Flood Flow Gauging

No flood flow gauging has been undertaken to date, however we assume that data recorded by Council for Narrabeen Creek will be made available by Council at DA stage.

8.2 FLOODING

8.2.1 Flood Levels

Due to its proximity to the Narrabeen Creek, Sector 3 is primarily impacted by floodwaters generated by this watercourse. Overland flowpaths along Macpherson Street and transverse crossings of the site could also be a source of flooding on the site. Lawson & Treloar are currently undertaking flood modelling to assess the flooding under developed conditions with the proposed filling in place.

Existing flood levels from the "Warriewood Valley Flood Study", January 2004 (Pty Ltd for Pittwater Council) for the 5, 20, 100 year ARI floods and Probable Maximum Flood (PMF) events are illustrated in **Drawing 5194-03**. Existing flood levels will be improved by the proposed creekline rehabilitation, which is anticipated to result in the creekline road being above the 100 year ARI flood and the basin being at least above the 20 year ARI flood. Further details will be provided at the development application stage.

Modelling by Lawson & Treloar indicates that under existing conditions, three flood cross connections between Narrabeen Creek and Macpherson Street exist across Sector 3, as shown in **Drawing 5194-06**. These cross connections would be maintained under post-development conditions by creating local roads at these locations and maintaining finished surface levels at or near existing levels, as shown in **Drawing 5194-05**.

Using the above flood levels, a proposed earthworks regrading scheme within Sector 3 has been conceptualised that ensures all habitable floors will be located at least 500mm above the 100 year ARI flood and above the PMF level. The intention is to preclude any flooding notations on S194 certificates for the new allotments.

8.2.2 Narrabeen Creek Design

A design for Narrabeen Creek is proposed for Sector 3 as detailed in **Drawing 5194-04** and **5194-07**. The design is based on a Manning's equation calculation to determine the approximate extents of batters based on the 2 and 5 year ARI flood levels as per Council's specification (*i.e. batter slopes to be 1:3 within the 2 year ARI flood extents or inbank area, then 1:6 to the 5 year ARI flood extents and then 1:8 to the 100 year ARI flood extents*). More detailed hydraulic analysis and creek design will be provided with the development application once results of developed conditions flood modelling are available from Council / Lawson and Treloar.

Due to the extent of cut works proposed within the first 25 m of Narrabeen Creek as illustrated in **Drawing 5194-04**, it is anticipated that the 100 year ARI flood and PMF levels will be substantially lower than under existing conditions.

It is proposed that Narrabeen Creek be rehabilitated in accordance with Council's specification and to ensure no detrimental influence (*in terms of flood levels*) on the upstream creek design. The proposed design will provide a natural 50m wide creekline corridor that provides both flood conveyance and habitat.

Rock bed control structures will be utilised below the proposed design invert of the creekline to form habitat pools and to aid in scour protection.

A Part 3A Permit would be applied for from DIPNR as part of the detailed design phase.

It should be noted that all dwelling floor levels will be sited above the PMF level and such that a minimum of 500mm freeboard exists to the post development 100 year ARI level.

8.2.3 Creek Corridor Widths

Compliance with the 50 m wide buffer strip allocations, including 25 m in public land, is illustrated in **Drawing 5194-01** and **5194-07**.

8.2.4 Creekline Corridor Planting

The proposed creekline corridor planting, monitoring and management plan is to be prepared by the project landscape architects (*Oculus*) and included under separate cover within the Rezoning Application package submitted to Council.

The planting proposed has been based on Council WMS.

8.3 FLOOD EVACUATION

A flood emergency response plan is proposed to be operational for all major event floods up to and including a Probable Maximum Flood *(PMF*). Sector 3 would be impacted by the PMF flood waters from Narrabeen Creek and Macpherson Street.

Based on information provided by Lawson and Treloar, it is anticipated that in combination with Narrabeen Creek and Macpherson Street, the total PMF extents will cause inundation of the majority of Sector 3 roadways. However, all lots are to be filled to be above the PMF level.

According to the Flood Study, the existing escape route crossing of Narrabeen Creek via Macpherson Street to Warriewood Road will be overtopped in events as frequent as the 5 year ARI flood.

Notwithstanding, Council has included the upgrade of bridges at Narrabeen Creek in its identified Flood Evacuation Strategy funded through a Section 94 Contributions Plan. However, it is anticipated that the proposed flood emergency response plan for Sector 3 will not need to rely on the Council's Evacuation Strategy, as vertical evacuation options are available.

In any case, the evacuation of residents and visitors of Sector 3 during short duration flooding in a major event *(eg, a PMF)* cannot rely on the existing creek crossing as a safe route in the short term *(until the upgrade of the bridges)*.

However, vertical evacuation is possible, as all lots will be filled such that they become PMF free land. Furthermore, all residences are proposed to be two storey, so vertical evacuation will be possible for all lots.

9 STORMWATER DRAINAGE CONCEPT PLAN

The elements of the proposed Stormwater Drainage Concept Plan for Sector 3 are presented in **Drawing 5194-02.**

A minor/major storm drainage system philosophy has been adopted in which flows up to the 20 year ARI storm event are conveyed in the piped system leading to the bio-retention basins. Flows in excess of the 20 year ARI event, up to and including the 100 year ARI event, would be conveyed overland in the road carriageways.

All flows generated as runoff are proposed to be directed to retention and infiltration infrastructure (*rainwater tanks, on-site detention tanks and bio-retention basins*) such that peak flows and long-term runoff volumes do not exceed the existing runoff characteristics of the site.

Runoff water quality is proposed to be managed through a combination of treatment measures, with special emphasis on source control. On-line treatment measures such as gross pollutant traps and bio-retention basins are proposed.

It has been estimated that the anticipated pollutant loads discharging from the developed site will match and in some circumstances be lower than for the existing site conditions, making a substantial contribution to long-term improvements in receiving water quality.

10 REFERENCES

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FIGURES

APPENDIX A

COUNCIL CHECKLIST

APPENDIX B

WATER CYCLE RESULTS

APPENDIX B1

EXISTING CONDITIONS

APPENDIX B2

PROPOSED CONDITIONS – NO MEASURES

APPENDIX B3

PROPOSED CONDITIONS – INCLUDING MEASURES

APPENDIX C

INFILTRATION TEST RESULTS

APPENDIX D

WATER QUALITY AND BED SEDIMENT MONITORING RESULTS

APPENDIX E

HABITAT MONITORING REPORT

APPENDIX F

RAFTS DETENTION MODELLING RESULTS

APPENDIX G

MUSIC MODELLING RESULTS

APPENDIX H

MUSIC RAINFALL PERIOD

APPENDIX I

DEVELOPMENT PROPOSAL