Table 4.5 (cont'd)

	Default Parameters
Groundwater Properties	
Initial Depth (mm)	10
Daily Recharge Rate (%)	25
Daily Baseflow Rate (%)	5
Daily Deep Seepage Rate (%)	0
Runoff Co-efficient	
100% Pervious	0.36
60% Impervious	0.69

4.2.5 Pollutant Concentrations

Each catchment was divided into roofs and general urban areas to allow runoff from each area to be directed to specified treatment measures, for instance runoff from some roads has been directed to bioretention swales. The expected pollutant load from each catchment was determined by applying the pollutant concentrations or Event Mean Concentrations (*EMC's*).

The adopted EMC's for total suspended solids (*TSS*), total phosphorus (*TP*) and total nitrogen (*TN*) are given in **Table 4.6** and are sourced from the findings of a comprehensive review of stormwater quality in urban catchments undertaken by Duncan (*1999*) and adopted by the Department of Environment and Conservation (*DEC*) in March 2004. Analysis by Duncan (*1999*) found event mean concentrations of TSS, TP and TN to be approximately log-normally distributed for a range of different urban land-uses.

Table 4.6 Adopted Pollutant Concentrations

Land Use	TSS	TP	TN
	mg/L	*mg/L*	*mg/L*
Agricultural/Rural	140	0.6	3.0
General Urban	140	0.25	2.0

4.3 STORMWATER TREATMENT STRATEGY

The stormwater management strategy to be implemented on the site would incorporate best practice water sensitive urban design (*WSUD*) measures. The water quality aspect of this strategy would include measures such as gross pollutant traps (*GPT'*s), raingardens/bioretention basins bioretention/vegetated swales and infiltration trenches.

The proposed measures for the site are presented on **Figure 1** and are described in more detail in the following sections.

4.3.1 Raingardens/Bioretention Basins

Raingardens would consist of a local depression in the form of a low basin, which would treat stormwater runoff. A typical cross section of the proposed raingardens is shown on **Figure 2**.

The raingarden would have the following characteristics:

- 500 mm ponding depth for extended detention of stormwater;
- vegetation to ensure the surface remains pervious;
- 600 mm filtration media consisting of sandy-loam;
- a 100 mm thick transition layer of medium – coarse sand, sized to prevent the overlying material including the bio-retention filter media from moving into the subsoil drain;
- a subsoil drainage pipe system with a fine gravel surround to convey the filtered water to the existing overland flow path; and
- gravel layer to allow free drainage of runoff.

A total area of approximately 2,500m^2 of raingardens would be constructed on the site as shown on **Figure 1**.

A stormwater drainage system would convey runoff from the site to the raingardens. The raingardens would perform two main tasks in the stormwater treatment train. Firstly, they would provide stormwater treatment as ponded stormwater peculates through the filtration media. Treatment is also provided by biological action within the filtration media. In addition, the raingardens would provide detention of storm flows during large storm events. This would reduce peak flow rates to match existing conditions while the combination of detention and infiltration will reduce the surface runoff to mimic as close as possible the existing behaviour.

During large storm events it is expected that the stormwater runoff would pond to a maximum of 500mm within the raingardens. Within a few hours this ponded water would infiltrate through the filtration media and be discharged to the existing overland flow path. It is expected that the raingardens would be dry most of the time.

Excess runoff unable to be stored in the first raingarden would cascade downstream to the next raingarden.

The raingardens/bioretention basins would be vegetated to provide a landscape feature and to provide a lasting pervious surface. The following photographs present the range of landscape treatments which can be given to raingardens/bioretention basins.

Vegetated raingarden that is deeper than those proposed for Coastal Grove

Raingarden vegetated with woody species

Turfed raingarden/infiltration basin

4.3.2 Gross Pollutant Traps

A Gross Pollutant Trap (*GPT*) captures litter, coarse sediment, some nutrients, oils and greases from low flows prior to discharge of stormwater into the raingardens/bioretention basins. While the pollutant capture efficiency of various traps may vary, the paper "Removal of Suspended Solids and Associated Pollutants by a Gross Pollutant Trap" (*Cooperative Research Centre for Catchment Hydrology, 1999*) suggests the following efficiencies for a CDS (*"Continuous Deflective Separation"*) unit.

- sediments — up to 70%
- total phosphorous — up to 30%
- total nitrogen — up to 13%

These removal efficiencies have been adopted in the MUSIC model for all GPT's.

Three GPT's are proposed on the development (refer **Figure 1)** to be located to treated pipe flows before discharge into the drainage corridor. They would be designed to achieve the reduction rates for litter, debris, and oils/greases as specified in the Council's DCP No. 13 – Stormwater Management.

4.3.3 Bioretention/Vegetated Swales

It is proposed that vegetated bioretention swales will be located alongside roadways as shown on **Figure 1**. The roads adjacent to swales would have a one way cross fall allowing all runoff to be treated in the swale prior to discharge to the raingardens/bioretention basins. This would improve the quality of water discharging from the site, while also slowing down runoff and infiltrating low flows into the subsoil drainage media. This will assist to mimic the natural pre-development frequency of runoff from the site.

The minimum length of vegetated bioretention swales required for the site is 250 m (3.0m wide and thus totalling 750m^2 in surface area).

The vegetated swales will consist of the following:

- a trench with special drainage media;
- a subsoil drainage pipe system with a medium gravel surround;
- a transition layer of medium – coarse sand. The sizing of the sand and gravel is critical to prevent the overlying material including the bio-retention filter media from moving into the subsoil drain;
- bio-filter material consisting of sandy-loam;
- plantings generally consisting of native sedge plants along the central drainage medium;
- other vegetation such as shrubs and small trees outside central drainage medium; and
- a concrete overflow pit and pipe to accommodate trunk drainage and overflow requirements, where necessary.

A typical cross section through a vegetated is provided on **Figure 3**.

The swales will collect runoff directly from adjacent roadways and overland flow from adjacent lots for at source treatment.

4.3.4 Infiltration Trenches

Infiltration trenches would be constructed along the rear of lots located on the eastern side of the site, refer **Figure 1**. These trenches would be connected to an interallotment drainage system that would discharge to the piped drainage system.

Infiltration trenches would be constructed to minimise the quantity of runoff that enters downstream properties. These trenches would also provide stormwater quality treatment through a similar filtering and biological action to that in the bioretention systems. They would also promote infiltration into the subsoils.

A typical infiltration trench is shown on **Figure 3**.

4.4 WATER QUALITY MODELLING RESULTS

Details of the water quality modelling are included in **Appendix C**.

4.4.1 Existing State Pollutant Export

Table 4.7 presents the expected annual pollutant export rates for the site in its existing/undeveloped state as predicted by the MUSIC model.

Table 4.7 Existing State – Pollutant Export

	TSS*	TP	TN
	kg/year	*kg/year*	*kg/year*
Existing Conditions	7,160	31.5	175

* TSS – total suspended solids
TP – total phosphorus
TN – total nitrogen

The existing state pollutant export estimated for the site has been adopted as the target for the developed site.

4.4.2 Developed (*No Treatment*) Pollutant Export

Table 4.8 presents the expected annual pollutant export for the site in its proposed developed state without water quality treatment.

Table 4.8 Annual Pollutant Export Loads – Developed State (*No Treatment*)

	TSS	TP	TN
	kg/year	*kg/year*	*kg/year*
Without Treatment	12,800	26	231

Comparison of **Table 4.7** and **Table 4.8** shows that a reduction in pollutant load from the development is required to achieve existing state pollutant loads.

4.4.3 Developed (With Treatment) Pollutant Export

Table 4.9 presents the expected annual pollutant export from the site in its proposed developed state with the proposed water treatment strategy presented in **Section 4.3**.

Table 4.9 Annual Pollutant Export Loads – Developed State (*With Treatment*)

	TSS	TP	TN
	kg/year	*kg/year*	*kg/year*
Existing	7,160	32	175
Developed with Treatment	2,610	9	119
% Reduction	64	72	32

Table 4.9 shows that the water quality target to improve runoff water quality from the site would be readily met through the implementation of the proposed water treatment strategy. The expected improvements when compared to the existing state are:-

- Total Suspended Solids (TSS) – 64% reduction
- Total Phosphorus (TP) – 72% reduction
- Total Nitrogen (TN) – 32% reduction

These expected reductions would therefore contribute to a long term improvement in receiving water quality.

DEC require that best management practice stormwater treatment measures are implemented in development. The DEC targets require a minimum reduction in the urban runoff pollution load (comparison of developed state with and without treatment). These targets and the performance proposed in the development are presented in **Table 4.10**. The proposed runoff management measures achieve reductions in runoff pollutant loads better than the DEC best management practice targets.

Table 4.10 Annual Pollutant Export Loads and DEC Targets

	TSS	TP	TN
	kg/year	*kg/year*	*kg/year*
Development without Treatment	12,800	26	231
Development with Treatment	2,610	9	119
% Reduction	80	65	48
DEC Targets	80	45	45

4.5 CONSTRUCTION PHASE

During the construction phase, the runoff water quality would be managed by implementation of control measures in conformance with the Managing Urban Stormwater : Soils and Construction (NSW Landcom, March 2004) also known as "The Blue Book". This guideline represents industry best practice and is listed as an appropriate technical and policy guideline in the DG's requirements. The proposed construction phase runoff water quality control measures are discussed in detail in the PBP Construction Environmental and Waste Management Plan Issue 2 dated September 2006 and it contains an Erosion and Sediment Control Plan for the development.

Specific controls have been incorporated into the Erosion and Sediment Control Plan to protect the hairy-joint grass in the "ecological polygon" in the riparian corridor, the rainforest trees at the southern boundary and the coastal fontainea in Amber Drive Reserve. These controls would include fencing, earth bunds to prevent entry of surface flows, silt fences and hay bales to filter any flows beyond the bunds. No earthworks would be undertaken in the proposed riparian corridor in the vicinity of the "ecological polygon". Surface runoff from the eastern side of the riparian corridor adjacent to the "ecological polygon" would be diverted to downstream of this polygon.

4.6 MONITORING

Monitoring of runoff water quality would be undertaken during construction and for two years after construction of the subdivision to verify the veracity of the proposed controls.

The ANZECC water quality guidelines referenced in the DG's requirements and Council's DCP No. 13 – Stormwater Management are not applicable as targets for wet weather runoff. They are applicable to long term ambient (dry) water quality conditions in waterbodies. As such, the appropriate water quality targets for runoff from the proposed development are those adopted in this study as derived from various government authority guidelines.

5 RUNOFF QUANTITY

5.1 AIMS

The aims for runoff flow management as derived from industry best practice and the DG's requirements are:

- ensure peak flow rates do not exceed those for existing conditions;
- mimic, as closely as possible, the existing runoff frequency;
- promote subsoil throughflows and baseflow contributions to the receiving water; and
- provide a safe environment for pedestrians and vehicle movement during severe storms.

These aims reflect all the local and state government guideline documents which are included in the DG's requirements. These aims were adopted as a minimum target in formulating runoff treatment measures for the proposed development.

5.2 PEAK FLOW RATE

5.2.1 Hydrologic Modelling

The peak storm runoff rates generated by rainfall on the site were estimated using XP-RAFTS software.

RAFTS is a non-linear rainfall/runoff program developed by WP Software and can be used to estimate peak flows for catchments, using actual storm events, or design rainfall data derived from *Australian Rainfall and Runoff (AR&R)* (*IEAust, 1987*). All hydrologic analysis was undertaken in accordance with *AR&R*.

RAFTS was chosen for this investigation because it has the following attributes:

- it can account for spatial and temporal variation in storm rainfall across a catchment;
- it can be used to estimate discharge hydrographs at any location within the catchment;
- it can accommodate variations in catchment characteristics;
- it is able to route hydrographs though detention basins; and
- it has successfully been widely used across NSW.

Hydrologic analysis was undertaken for both the internal and external catchments that contribute runoff to the site. Internal analysis was completed to determine the detention volume required to control post development peak flows to existing rates. Analysis of the external catchment hydrology was undertaken to estimate peak flows within the drainage corridor.

The sub-catchments adopted for this investigation are presented in **Appendix A**. The sub-catchment parameters are presented in **Tables 4.1 and 4.2.**

5.2.2 Internal Catchment Hydrology

Hydrologic analysis was carried out for the site to estimate the peak flow rates and the required stormwater detention volumes. The model was used to estimate design flows under both existing and developed site conditions for the 100, 20, 5, and 1 year Average Recurrence Interval (*ARI*) events.

The following parameters were used in the RAFTS model:

	Pervious Areas	Impervious Areas
Initial Loss (IL)	15 mm	1.5 mm
Continuing Loss (CL)	2.5 mm	0 mm
Manning's n	0.035	0.015

5.2.3 Stormwater Detention

The proposed development would include stormwater runoff retention and detention measures to allow existing runoff regimes to be mimicked as closely as possible in the post development conditions. This would be achieved by using a combination of infiltration trenches located on each lot and extended detention in swales and on raingardens.

It is envisaged that during small storm events surface runoff from each lot would be captured in the proposed infiltration trenches and infiltrate into perforated drainage pipes. Flow would then be directed to the street drainage system which would discharge to the proposed vegetated swales and raingardens. In addition to stormwater treatment, the swales and raingardens would perform a second function as an infiltration and detention basin, allowing storm flows to temporarily pond.

The combination of these measures would promote capture, slow flow and subsoil infiltration thereby assisting to mimic the existing runoff frequency. This would have significant beneficial impacts for the hydrology, stability of the creek banks and the response of the aquatic fauna, both on and downstream of the site.

During large storm events, when the pipe capacity of the street drainage system is exceeded, overland flow would be directed to the raingardens.

Peak flows were derived for the 1, 5, 20 and 100 year ARI storm events for the site under pre- and post-development conditions. Storm durations of 30 minutes to 12 hours were simulated to determine the critical storm. It was determined that approximately **1,250m^3** of detention volume would be necessary to achieve control of peak flow rates for all storm events. **Table 5.1** presents the expected peak flows at the downstream boundary of the site for pre development conditions, post development conditions without detention and post development conditions with detention.

Table 5.1 shows that by providing approximately **1,250m^3** of stormwater detention the post development peak flow rates would be maintained at or below existing flow rates.

This would contribute to ensuring that there was no significant adverse impact on the downstream flooding or bank stability.

RAFTS model output files for the subject site under existing and post-developed conditions (*incorporating detention*) can be found in **Appendix D**.

Table 5.1 Estimated Peak Flows

Development Scenario	Average Recurrence Interval (ARI)			
	1yr	5yr	20yr	100yr
Pre development flow (m^3/s)	6.0	12.1	16.4	20.4
Critical storm (mins)	*90*	*120*	*120*	*120*
Post development flow (m^3/s)	6.0	12.4	16.8	20.9
Critical storm (mins)	*120*	*120*	*120*	*120*
Post development flow with detention (m^3/s)	5.3	11.7	16.3	18.1
Critical storm (mins)	*120*	*120*	*120*	*120*
Detention Volume Required (m^3)	1,250	1,250	1,250	1,250

5.2.4 Detention Storage

The proposed raingardens would primarily act as a stormwater quality treatment measure. However, in addition to this primary function, an extended detention depth of approximately 500mm over the area of the raingardens would be provided. The surface area of the raingardens would be 2,500m^2 which would provide approximately **1,250m^3** of detention as required for the proposed development.

The proposed quantity of extended detention on the raingardens would provide sufficient runoff detention for the proposed development to control peak flows to match those for existing conditions. The detention storage provided in the swales and infiltration trenches would provide added storage beyond that required. This would ensure that peak flows from the development would be below those for existing conditions.

5.2.5 Drainage Corridor Flows

Analysis of both the external and internal catchment hydrology was undertaken to estimate peak flows for the drainage corridor on the site. These estimations have been used to predict flood levels and extents for the drainage corridor.

The parameters as stated in **Section 5.2.2** were used in the RAFTS model.

For the assessment of the drainage corridor traversing the site, contributing upstream catchments were analysed. XP-RAFTS software was used to estimate peak flows for the 20 year and 100 year ARI storm events as well as the Probable Maximum Flood (PMF) for flows traversing the site. Storms of 30 minute to 12 hour duration were simulated for these events.

The total catchment was divided into subcatchments to determine runoff reaching the site. The adopted subcatchments are shown in **Appendix B**.

The estimated peak flow rates determined for the drainage corridor at different locations on the site are presented in **Table 5.2**.

Table 5.2 Expected Peak Flows for Drainage Corridor (m^3/s)

Overland Flow Path	Average Recurrence Interval		
	20 Year	100 Year	PMF
Cross Section 52 (S1 + A)	2.7	3.3	14.2
Cross Section 40 (S2)	11.1	13.7	58.2
Cross section 20 (S3)	16.4	20.4	83.0

Note: Location of Catchment A, S1, S2 and S3 shown in Appendix B and the cross section locations are shown of Figures 4 and 5

The external catchments contributing flow to the subject site are developed. In the flow modelling, the external catchments were assumed to be fully developed by allocating appropriate levels of impervious areas. As such, the flows in the drainage corridor on the site are unlikely to increase significantly in the future. The proposed development would therefore not be adversely affected in the future by any cumulative impacts such as increased flood flows and levels in the drainage corridor.

Appendix D contains RAFTS output data for the external subcatchment analysis.

5.3 RUNOFF FREQUENCY

For regular light rainfall on the existing site there would be capture of rainfall which would minimise the surface runoff in these events. The capture occurs on vegetation, depressions and through infiltration. This captured rainfall is either evaporated, absorbed by plants or flows in shallow depth soils either horizontally as "throughflow" or in heavier rainfall with soaking of the soil profile, vertically down as losses to the groundwater. The throughflow slowly contributes to baseflow in the drainage corridor and downstream creek lines well after the rainfall ceases. It may not provide baseflow in dry conditions but improves the availability of soil moisture for vegetation. The degree of urban development around the site contributing flows to the drainage corridor on the site without any effective controls means that the hydrological behaviour of this area has been significantly modified. However, it is proposed to provide controls for runoff in the development which will, as closely as possible, mimic the runoff frequency for regular small storms on the existing site.

The means of achieving this control is to provide traps for these small runoff volumes and maximise the infiltration into the shallow soil to promote long duration throughflows. The controls proposed include the infiltration trenches, swales and raingardens. These controls would ensure that there is maximum opportunity to capture runoff from the entire site. Even the runoff which does not infiltrate into the subsoils will have a much longer and slower flow path which will assist to replicate the long flat hydrograph of flows to the drainage corridor experienced under existing conditions.

The hydrology of the area of the hairy-jointed grass and the "ecological polygon" would be maintained by the above measures as well as by allowing the existing groundwater spring to continue to provide water to this area of the drainage corridor via gravel trench drains.

The combination of these measures would promote capture, slow flow and subsoil infiltration thereby assisting to mimic the existing runoff frequency. This would have significant beneficial impacts for the hydrology, stability of the creek banks and the response of the aquatic fauna, both on and downstream of the site.

5.4 SAFETY

The pipe and overland flow path components of the stormwater drainage system would be designed to provide safe access by pedestrians and vehicles during a severe storm (up to 100 yr ARI). Also, a flood evacuation route would be available in extreme floods up to the PMF event.

The overland flow along the roads in the 100 yr ARI event would have a maximum flood hazard (velocity x depth) of 0.6 m/s in the carriageway and 0.4 m/s on the footpath or at any critical road crossing point for pedestrians. These flood hazard limits are recommended in the NSW Government Floodplain Development Manual (2005). The stormwater pipe and inlet pit capacity would be varied to achieve these flood hazard limits for overland flow on the roads.

The proposed road crossing of the drainage corridor would have a culvert capacity such that there was no overtopping in the PMF event to provide safe pedestrian and vehicular access.

The pedestrian and cycleway crossing of the drainage corridor would be designed in accordance with the DNR Guidelines for the Design and Construction of Paths and Cycleways along Watercourses and Riparian Areas and the DG's requirements.

6 FLOOD MANAGEMENT

6.1 AIMS

The runoff from the site and the external developed catchment are conveyed through the site along the drainage corridor. These flows need to be managed so that:

- the development and habitable floor levels can be designed to not be adversely affected by the flood flows;
- in extreme floods (PMF), there is safe conditions for residents;
- the proposed development does not adversely impact on the flooding behaviour for existing development; and
- the drainage corridor is able to accommodate the flows of full development of the external catchment without adverse impact on the proposed dwellings or residents on the site.

These aims address industry best practice for flood management, the NSW government Floodplain Development Manual (2005) and the DG's requirements.

Council has adopted the 100yr ARI flood as its flood standard for assessment of appropriate habitable floor levels for residential development. Council requires habitable floor levels to be a minimum of 0.5m above the 100yr ARI flood level. Council and state government policy require consideration of the worst flood conditions (PMF event) to ensure that the risk to personal safety and the potential for flood damages is minimised.

6.2 FLOOD MODELLING METHODOLOGY

The flood profile along the drainage corridor through the subject site was modelled using HEC-RAS, River Analysis System. HEC-RAS is a software package which allows modelling of one-dimensional flow in steady and unsteady state modes.

HEC-RAS was chosen for this investigation because it has the following attributes:

- it allows gradually varied flow along a flowpath;
- it produces graphical and tabular results of input data and water surface elevation calculations;
- it allows the user to determine water surface elevations at any location along the flowpath; and
- it is internationally recognized as the leading one-dimensional hydraulic modelling software.

Flows derived using RAFTS, as detailed in **Section 5.2**, were used to estimate hydraulic behaviour during the 20 and 100 year ARI storms as well as the PMF event.