The flora and fauna investigation by Peter Parker has identified threatened flora on and adjacent to the site. These are located in the littoral rainforest on the southern boundary of the site, the coastal fontainea is located in Amber Drive Reserve and the hairy-joint grass is located in a small area on the bank of the proposed riparian corridor. Peter Parker has recommended suitable buffer distances between development and the littoral rainforest and the Amber Drive Reserve. An "ecological polygon" has been established by Peter Parker in the area of the hairy-joint grass to define buffer protection (refer **Figure 1**). No works are permitted in this polygon and special precautions have been incorporated in the erosion and sediment control works during construction of the development as detailed in the PBP Construction Environmental and Waste Management Plan report. This Water Cycle Management report details measures to ensure the hydrology of the site and especially the area of the hairy-joint grass is not significantly affected by the development.

2 WATER CYCLE MANAGEMENT

The design of the water components of the development has been based on an integrated water cycle management approach in order to promote an environmentally sustainable outcome for water. The water cycle management approach deals with all aspects of the cycle including stormwater runoff, groundwater, potable water and sewage. The aims of the water cycle management strategy formulated for this development to achieve a sustainable outcome are to:

- maintain peak flow rates of stormwater runoff as the same as for existing conditions – this would ensure no adverse impacts on flooding behaviour downstream and on bank stability in drainage lines;
- mimic the existing stormwater runoff frequency as closely as possible to control impacts on creek stability and aquatic habitats in downstream creeks;
- maintain or improve stormwater runoff water quality to contribute to the long term improvement in receiving water quality;
- maintain subsoil throughflows in order to maintain a contribution to baseflows in the downstream creeks and aquatic habitats;
- minimise potable water use to reduce the pressure on the limited water resources and extraction of water from existing water bodies; and
- maximise reuse of recycled water (either effluent or stormwater) to minimise use of potable water and the discharge of effluent to water bodies.

This report deals with stormwater management while the proposed water and sewer infrastructure are detailed in a separate report entitled Infrastructure Strategy. The integration of all elements of the water cycle is discussed in **Section 9** of this report.

3 STORMWATER MANAGEMENT STRATEGY

3.1 AIMS

The proposed stormwater management strategy has been based on principles of water sensitive urban design with a treatment train approach which emphasises control of runoff from the source to the outlet. The strategy has been formulated to achieve the following aims established for environmentally sustainable water cycle management, viz:

- maintain peak flow rates of stormwater runoff at the same for existing conditions;
- mimic the existing stormwater runoff frequency as closely as possible;
- improve stormwater runoff water quality; and
- promote subsoil throughflows and baseflow contributions to receiving waters.

In addition to these aims, further objectives of the stormwater management strategy are to:

- remove or stabilise existing side drainage lines eroded by flows from external areas;
- provide a safe environment for pedestrians and cars during severe rainfall events (up to 100 yr ARI);
- provide a pipe drainage system which conforms to Ballina Council's requirements;
- conform to Ballina Council's DCP No 11 – Mosquito Management and DCP No 13 – Stormwater Management;
- achieve industry best management runoff pollutant load reductions in the development as set by DEC – 80% reduction in total suspended solids and 45% reduction in total phosphorus and total nitrogen;
- provide protection and control of erosion and sediment loads in runoff from disturbed areas during the construction phase;
- protect the hairy-joint grass, coastal fontainea and littoral rainforest areas by ensuring no significant changes in the hydrology of the areas of these species;
- assist to protect the "ecological polygon" by not undertaking any runoff or stream related works within this area; and
- comply with the Director General's requirements relating to water as issued for this project.

This report forms the Stormwater Management Plan required in Section 2 of the Department of Planning Director General's (DG) requirements issued for this project on 15 May 2006.

3.2 STORMWATER MANAGEMENT MEASURES

A number of stormwater runoff treatment measures have been proposed for this site. Before entering into a detailed analysis of the expected effectiveness of the proposed treatment measures the following information is provided to allow an explanation of why the adopted treatment measures have been chosen.

The adopted stormwater runoff treatment measures include:

- Infiltration trenches;
- Bioretention/Vegetated swales;
- Gross Pollutant Traps; and
- Raingardens/Bioretention Basins.

The stormwater runoff treatment train consists of:

- runoff from the lots and the road is initially directed to either an infiltration trench or vegetated swale in which treatment and infiltration occurs;
- overflow from the infiltration trenches is directed to the vegetated swales which further treat the runoff and promote infiltration;
- flow from the swales is treated in gross pollutant traps;
- flow is then treated in raingardens which also promote infiltration;
- excess flow overtops the basin along a long weir to promote distributed discharge (rather than concentrated discharge) into the drainage corridor.

The stormwater treatment measures have special drainage media underlying the surface to promote infiltration for storage and treatment. The measures do not rely on infiltration into the surrounding existing subsoils for their performance. However, the storage of low flows will provide further opportunities for infiltration to occur into the subsoils.

The overall stormwater management strategy has been formulated over consultation with the government authorities and has evolved as described in the following sections providing more details on each of the proposed treatment measures.

Ballina Council's DCP No. 13 – Stormwater Management recommends adoption of a water sensitive urban design approach as proposed for this development. The DCP also promotes use of the stormwater management measures proposed in this development.

3.2.1 Raingardens/ Bioretention Basins

3.2.1.1 Ballina Council

It is understood that previous development applications and associated court appeals have suggested the use of artificial wetlands as the main stormwater quality treatment strategy. However, Council has raised issues with the incorporation of artificial wetlands including:

- safety issues; in particular issues related to safety of children in the vicinity of an unfenced permanent water body;

- mosquito breeding; Council currently have a development control plan that considers the affect of development and the creation of potential mosquito breeding habitats. Council has raised issues with the potential for increased breeding habitat if a constructed wetland was included;

- maintenance; Council indicated that a wetland that has been constructed within a recent development has not been properly maintained due to the lack of knowledge of the required maintenance and the lack of information regarding maintenance passed on by the developer. This situation has resulted in a wetland that is not operating as designed.

The strategy adopted for the development includes dry and shallow features which are easy to maintain and hence address all the issues raised by Council. These features or measures include raingardens, vegetated swales and infiltration trenches.

Raingardens are vegetated areas incorporating a perimeter mound to promote temporary ponding of water. A drainage media consisting of sandy loam and gravel with an agricultural pipe drainage system at the base promotes infiltration of ponded water for treatment. A more detailed description is given in **Section 4.3.1**.

Raingardens would not introduce any significant safety issues as they would be ephemeral (*dry the majority of the time*) which would be the same behaviour as the nearby creeks. Raingardens would not introduce any significant mosquito breeding habitat to the site because they would only have ponded water for short periods of time (say up to 5 hours) and with the proposed under drain system would not promote standing pools of surface water. As such, the raingardens would conform to Council's DCP No 11 - Mosquito Management. Raingardens would require minimal maintenance as detailed in **Section 7** of this report.

3.2.1.2 Department of Primary Industries

During a site inspection, it was indicated by the Department of Primary Industry officer *(Patrick Dwyer)* that there was no significant fish habitat on the site. However, it was suggested that stormwater treatment measures be located offline. As such, the raingardens have been located offline from areas of expected stormwater flow. This is also in conformance with the Section 2.2 requirement in the Key Issues of the DG's requirements.

3.2.2 Gross pollutant traps

Gross pollutant traps remove litter, coarse sediment and oils/greases and will protect the raingardens from deposition of these pollutants. A more detailed description is presented in **Section 4.3.2**.

Ballina Council has not suggested the use of any particular brand of gross pollutant trap. However, Council has suggested that they should be located behind the kerb line and be able to utilise a straight vertical lift for cleaning of collection baskets. In addition, Council has suggested that the gross pollutant traps should be able to be cleaned with Councils existing street sweeper with vacuum attachment.

The gross pollutant traps proposed for the site would meet the Council's requirements and provide the level of gross pollutant removal as specified in Council's DCP No. 13 – Stormwater Management. Details of the maintenance required for the gross pollutant traps are described in **Section 7**.

3.2.3 Bioretention/Vegetated Swales

Bioretention/vegetated swales consist of a wide depression which is vegetated and has a gravel trench to promote infiltration. Runoff is stored temporarily as ponded water in the swale to promote infiltration and treatment. Runoff flowing along the swale is also treated by filtration as it passes through the vegetation. A more detailed description is provided in **Section 4.3.3**.

Council has raised concerns with the required maintenance of the proposed vegetated swales. However subsequent discussions and correspondence with Council have suggested that with a proposed maintenance regime they would be able to maintain the proposed swales. The maintenance regime proposed for the swales is presented in **Section 7** of this report.

3.2.4 Infiltration Trenches

The proposed upslope lots will drain runoff into an interallotment drainage pipeline along the rear boundaries. In order to promote infiltration, pipe flows from the residences will be discharged into a gravel infiltration trench prior to flow into the interallotment drainage system. Also, the infiltration trenches will collect overland flow from these lots.

This system of infiltration trenches will alleviate the Council's stormwater drainage engineer concern regarding the quantity of nuisance runoff entering downslope properties. The infiltration trenches along the downstream property boundaries will intercept nuisance flows before they enter these properties. Details of the proposed infiltration trenches are included in **Section 4.3.4**.

In addition to intercepting nuisance flows, these infiltration trenches would provide at source runoff water quality treatment.

3.3 STORMWATER DRAINAGE SYSTEM

3.3.1 Ballina Council

A formal pipe drainage system would be constructed to convey expected runoff from the 5 year ARI storm event as required by Council's DCP No 13 – Stormwater Management. Overland flow paths would be provided to convey flows safely up to and including the 100 year ARI event.

The proposed stormwater drainage system would be located in the lots and along the road network and discharge to the raingardens located adjacent to the riparian corridor. A stormwater easement would be required through Lots 14 and 15 to drain the proposed road located along the eastern boundary of the site.

An interallotment drainage system would also be constructed that would discharge to the road stormwater drainage network. The interallotment drainage system would drain roof runoff from each lot and the proposed infiltration trenches.

Runoff from external areas would be piped to the drainage corridor. This would alleviate the extensive erosion being caused at present on the site due to these uncontrolled flows.

3.3.2 Geotechnical Investigations

Geotechnical investigations undertaken by Coffey in August 2006 have identified a localised area of groundwater seepage or spring on the site. As part of this investigation it has been recommended that trench drains be constructed to intercept the seepage and discharge it to the riparian corridor via the proposed stormwater system. Details of the proposed trench drains are presented in the Coffey report dated August 2006. The indicative locations of the proposed trench drains and connection to the stormwater network are shown on **Figure 1**. This approach will ensure that the hydrology of the riparian corridor and "ecological polygon" will remain unchanged. This spring water will continue to reach the drainage corridor as occurs at present.

3.4 DRAINAGE CORRIDOR

The drainage line through the middle of the site is located at the top end of the catchment and is considered a first order stream in terms of the classification system used by DNR. The drainage line is considered to be a swale in a minor valley given its limited catchment and lack of any well defined banks. As such, it would not be classified as a 'river' under the Rivers and Foreshores Improvement Act, and hence would not be 'protected lands' requiring approval of works within 40m of the top of bank. DNR has responsibility for administering this Act.

During an onsite meeting, the Department of Primary Industries *(Patrick Dwyer)* suggested that a defined low flow channel be created to allow groundwater seepage and minor runoff to readily drain from the site along the drainage corridor. In its existing condition there are a number of areas that allow runoff to pool which creates mosquito habitat. It was agreed that these areas should be removed. However, a section of endangered hairy joint grass has since been located within the drainage corridor on the southern end of the site (refer **Figure 1**). As such, reshaping to form a low flow channel would not be undertaken, except in the areas of the pedestrian/cycleway crossing and the proposed roadway crossing. Restriction of these shaping works would assist in mimicking the existing flow regime to these endangered flora species. Rock bars would be incorporated across the drainage channel at regular intervals to assist with the long term management of the drainage corridor.

DPI also recommended a 20m riparian corridor at the northern end of the site increasing to 25m further to the south. This riparian corridor has been incorporated into the landscape design for the development. The raingardens would be located outside this corridor.

DPI considered that road and pedestrian/cycleway crossings of this corridor as proposed in the development were acceptable.

3.5 NORTHERN RIVERS CATCHMENT MANAGEMENT AUTHORITY

The Northern Rivers Catchment Management Authority was contacted in regards to the proposed development. They indicated that no further consultation would be required provided areas zoned environmental protection were retained and there was protection of existing significant vegetation.

These requirements have been adhered to in the proposed development. The issue of vegetation is addressed in the flora and fauna report by Peter Parker.

4 STORMWATER QUALITY

4.1 AIMS AND REQUIREMENTS

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

- contribute to the long term improvement in the receiving water quality;
- achieve a minimum reduction in runoff pollutant load of 80% for total suspended solids and 45% for nutrients (total nitrogen and total phosphorus); and
- reduction in litter, debris, coarse sediment and oils/greases as required by the Council DCP No. 13 – Stormwater Management.

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

4.2 MUSIC STORMWATER QUALITY MODEL SET-UP

A long-term MUSIC model was established for the site to assess the potential water quality impacts of the proposed development. The model was used to estimate the annual pollutant load that would be generated under both existing and developed conditions.

MUSIC is a continual-run conceptual water quality assessment model developed by the Cooperative Research Centre for Catchment Hydrology (*CRCCH*). MUSIC can be used to estimate the long-term annual average stormwater volume generated by a catchment as well as the expected pollutant loads. MUSIC is able to conceptually simulate the performance of a group of stormwater treatment measures (*treatment train*) to assess whether a proposed water quality strategy is able to meet specified water quality objectives.

The MUSIC model was used to estimate the annual pollutant load generated under existing state and developed conditions over a 6 year period of a range of rainfall years, including three below average, one average and two above average.

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

- it can account for the temporal variation in storm rainfall throughout the year;
- modelling steps can be as low as 6 minutes to allow accurate modelling of treatment devices;
- it can model a range of treatment devices;
- it can be used to estimate pollutant loads at any location within the catchment; and
- it is based on logical and accepted algorithms.

4.2.1 Subcatchment Characteristics

The site has been divided into subcatchments as shown in **Appendix B**. The total impervious percentage adopted for each subcatchment is shown in **Table 4.1**. These impervious percentages are based on an assessment of the anticipated proportion of hard surfaces such as roads, roofs and paved areas across the proposed development.

Table 4.1 Adopted areas and imperviousness

Catchment	Area *(ha)*	Impervious Percentage Undeveloped *(%)*	Impervious Percentage Developed *(%)*
S1	0.51	5	50
S2	5.16	10	40
S3	6.73	0	40
Total	12.4		

Note: Water Quality modelling has included the existing rainforest area on the southern portion of the site.

In addition to the subcatchments contained on the site there are also external catchments that contribute runoff to the site. The locations of the external catchments are shown in **Appendix B**.

The properties adopted for these external catchments are presented in **Table 4.2**.

Table 4.2 Properties of external catchments

Catchment	Area	Imperviousness
	(Ha)	*(%)*
A	4.25	60
B	3.34	60
C	10.37	60
D	10.26	10
E	0.08	0
Total	28.3	

4.2.2 Rainfall

In order to develop a model that could comprehensively assess the performance of water quality treatment devices such as bioretention systems, the use of 6 minute interval pluviograph data was considered necessary.

The nearest pluviometer (*i.e. 6 minute interval data instrument*) station to the site is located at Alstonville. The long term average annual rainfall for Ballina as provided by the Bureau of Meteorology is 1654mm. Based on the available data from the nearest rain gauges, it is considered that an annual average of approximately 1657mm is reasonable for the site.

For this study, the pluviograph record from Alstonville from 1st January 1995 through until 31st December 2000 was selected for the MUSIC modelling because this period had an annual average rainfall of 1657mm. This period contains wet and dry years as shown in **Table 4.3**. The selection of wet, dry and average years provides a more rigorous analysis of the treatment measures than an average year alone.

Table 4.3 Annual Rainfall Adopted

Year	Total Rainfall (mm)	Classification
1995	1653	Average
1996	1989	Wet
1997	1192	Dry
1998	1121	Dry
1999	2626	Wet
2000	1362	Dry
Long Term Average	*1657*	

4.2.3 Evaporation

Monthly areal potential evapotranspiration values were obtained for the site from Bureau of Meteorology data and are shown in **Table 4.4**.

Table 4.4 Monthly Areal Potential Evapotranspiration

Month	Areal Potential Evapotranspiration (mm)
January	195
February	165
March	150
April	120
May	80
June	55
July	55
August	70
September	100
October	165
November	180
December	195
Annual Average	*1530*

The rainfall and evaporation data is represented graphically on **Figure 4.1**.

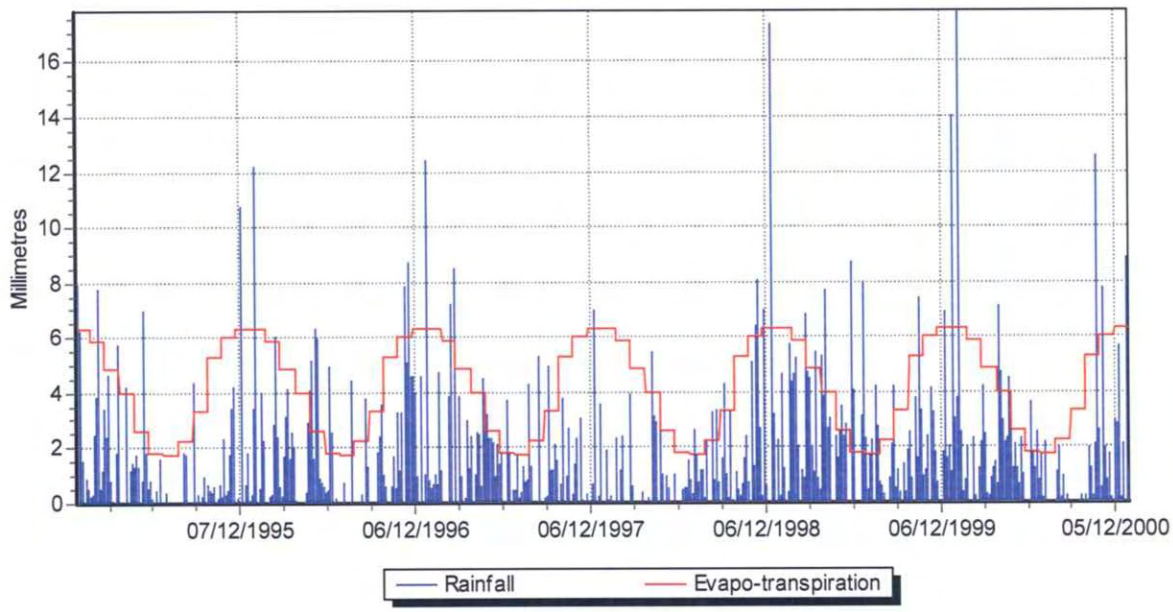

Figure 3-1 – Rainfall and Evaporation data

4.2.4 Soil Data and Model Calibration

A rainfall-runoff calibration was undertaken for existing site conditions. The default MUSIC values gave an existing state annual volumetric runoff coefficient of 0.36. This was considered appropriate for the site in its undeveloped state.

The default and adopted MUSIC rainfall run-off parameters along with the resulting run-off co-efficient are presented in **Table 4.5**.

Table 4.5 Adopted rainfall run-off parameters

	Default Parameters
Impervious Area Properties	
Rainfall Threshold (mm/day)	1
Pervious Area Properties	
Soil Storage Capacity (mm)	120
Initial Storage (% of capacity)	30
Field Capacity (mm)	80
Infiltration Capacity Coefficient (a)	200
Infiltration Capacity Exponent (b)	1