Table 4.2 - Calculated Peak Flows for Existing Conditions

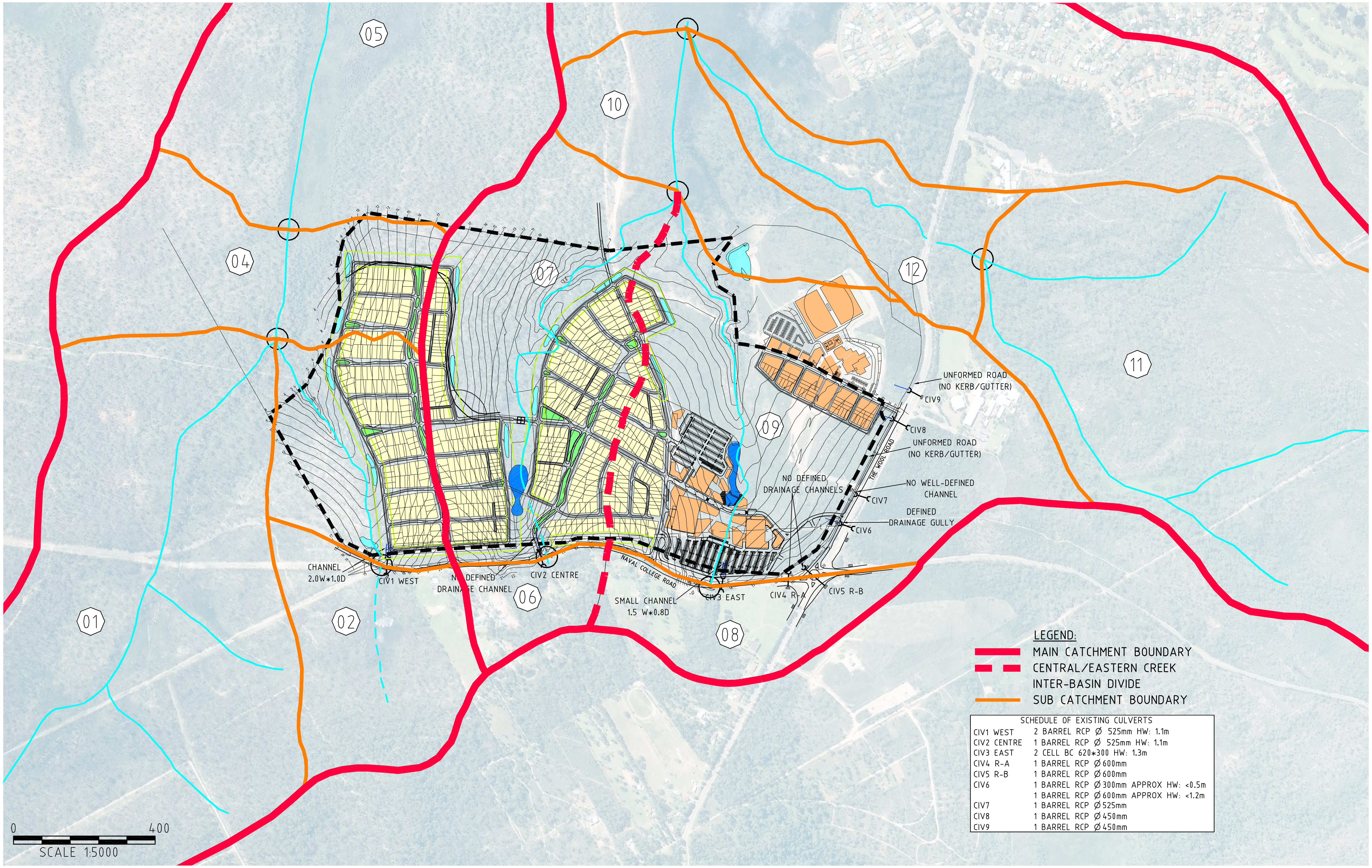
Event	**Calculated Peak Flows at Project Downstream Boundary [m^3/s]**			
AEP Frequency	**Western Ck**	**Central Creek**	**Eastern Creek**	**Confluence of Central & Eastern Creeks**
"1 in 1" AEP (1-yr ARI)	4.2	5.2	7.3	12.8
1 in 2 or 50% AEP	5.9	7.2	10.2	17.8
1 in 5 or 20% AEP	8.6	10.3	14.7	25.6
1 in 10 or 10%AEP	10.2	12.3	17.5	30.6
1 in 20 or 5% AEP	12.4	14.9	21.2	37.2
1 in 50 or 2% AEP	14.7	17.6	25.1	44.3
1 in 100 or 1% (AEP)	16.9	20.4	28.9	51.2
PMF	50.6	59.6	86.7	167.2

The WBNM model was then modified to reflect the proposed changes to impervious cover post-development. Areas of future development were assumed to have an impervious cover of 45%. (Cardew, et al 1999)

The model was re-run with a spectrum of storm durations to check the critical design storm duration for the catchment under proposed conditions. It was found for events up to and including the 1% AEP event the critical duration dropped to 90 minutes, while for the PMF the critical duration remained at 60 minutes.

Discharges were computed for the developed catchment. The resulting peak flood discharges, from storms of critical duration, are reproduced in **Table 4.3** below, and full model results in **Appendix B**. These estimated peak discharges do not include the attenuation benefits of dynamic storage within the proposed wetlands, or the effects of rainwater tanks proposed at each house.

DO NOT SCALE IF IN DOUBT ASK



SCHEDULE OF EXISTING CULVERTS

CIV1 WEST	2 BARREL RCP Ø 525mm HW: 1.1m
CIV2 CENTRE	1 BARREL RCP Ø 525mm HW: 1.1m
CIV3 EAST	2 CELL BC 620*300 HW: 1.3m
CIV4 R-A	1 BARREL RCP Ø 600mm
CIV5 R-B	1 BARREL RCP Ø 600mm
CIV6	1 BARREL RCP Ø 300mm APPROX HW: <0.5m 1 BARREL RCP Ø 600mm APPROX HW: <1.2m
CIV7	1 BARREL RCP Ø 525mm
CIV8	1 BARREL RCP Ø 450mm
CIV9	1 BARREL RCP Ø 450mm

REV	DATE	BY	APP.	DETAILS

DRAWING STATUS

DESIGN BY	AW/SR	22/10/03
DRAWN BY	AP	06/05/04
DRAFTING CHECK	PJS	10/02/05
DESIGN CHECK	AW	14/12/04
FINAL APPROVAL	PSN	10/02/05

PRELIMINARY

SCALE: (on A1 Original) 1:5000

HEIGHT DATUM AHD

FORBES RIGBY PTY LTD
Engineers Planners & Scientists
Quality Endorsed Company, ISO 9001 LIC QEC 10508, Standards Australia
278 KEIRA STREET, WOLLONGONG, NSW 2500
Ph: (02) 4228 4133 Facsimile: (02) 4228 6811 ACN 003 936 981

PROJECT TITLE

VINCENTIA COASTAL VILLAGE & DISTRICT CENTRE for STOCKLAND DEVELOPMENTS PTY LT

DRAWING TITLE

HYDROLOGIC CATCHMENT PLAN

Project No.	Com No.	Drawing No.	REV
104016	03	Fig 4	P2

A1

File Plotted: U:\2004\104-016-03 - VINCENTIA DISTRICT CENTRE - WSUD STUDY\MONITORING\DRAWING\BUILD\3-01-06\FIG4-CATCHMENT-PLAN.DWG
January 13, 2006 4:06:26 p.m.
Xrefs: x104016-03_base_3.DWG x104016-Aerial.DWG

Table 4.3 - Calculated Peak Flows for Proposed Conditions

Event	Calculated Peak Flows at Project Downstream Boundary [m3/s]			
AEP Frequency	**Western Ck**	**Central Creek**	**Eastern Creek**	**Confluence of Central & Eastern Creeks**
"1 in 1" AEP (1-yr ARI)	4.7	7.3	10.2	14.8
1 in 2 or 50% AEP	6.5	9.9	13.9	20.6
1 in 5 or 20% AEP	9.3	13.8	19.4	29.2
1 in 10 or 10%AEP	11.0	16.2	22.7	34.6
1 in 20 or 5% AEP	13.2	19.4	27.2	41.6
1 in 50 or 2% AEP	15.4	22.3	31.2	49.1
1 in 100 or 1% (AEP)	17.7	25.4	35.7	56.4
PMF	50.6	61.9	90.1	174.2

Comparison of peak flows pre- and post-development show a 4.5% increase for the Western Creek and an increase of 9% at the confluence of the Central and Eastern Creeks for the 100-year ARI event. For the PMF event, there is no increase in peak flow for the Western Creek and an increase of 4% at the confluence of the Central and Eastern Creeks.

Such increases in peak discharges would result in a negligible increase in flood levels in the large wetland complexes downstream. Preliminary modelling confirms that the increase in flood levels in the 50-ha wetland below the confluence of the Central and Eastern Creeks would be of the order of 5 mm. This is also likely to be an over-estimate given that the attenuation benefits of dynamic storage within the proposed wetlands and individual rainwater tanks at each house would further reduce this notional impact. The rainwater tanks at each house could be modified to include an OSD component, however this would reduce the amount of water potentially available for re-use.

No specific measures are recommended to reduce peak discharges given the downstream watercourses are naturally insensitive to changes in flood hydrology. The WSUD focus for the Vincentia Coastal Village and District Centre is therefore directed to the optimisation of water quality controls and stormwater re-use, which will bring the key environmental benefits to this site.

4.3. EXTENT OF FLOODING

Hydraulic modelling was conducted using HECRAS 3.1.1 with the input flows taken from the WBNM modelling. Input flows were determined for locations between WBNM sub-catchment outlets by interpolation.

HECRAS is a 1-Dimensional river/channel analysis tool developed by the US Army Corps of Engineers and capable of steady and unsteady flow simulation. The model permits supercritical, sub-critical and mixed mode simulations, and provides significantly increased functionality over its early predecessor HEC2, including enhanced graphics allowing ready checking and comparison of calculated flood profiles and levels.

Two scenarios were modelled, using post development peak flows:

- Manning's n=0.10 (representative of existing site conditions)
- Manning's n=0.20 (representative of the upper limit of possible vegetation density).

Cross sections were extracted from a DTM (Digital Terrain model) at 40 m centres along each of the creek lines. The complete flood spectrum was modelled, ranging from 1-year ARI to the PMF event.

The modelling indicates that the 1% AEP flood extents are generally contained within the proposed riparian corridors (refer **Figure 5**), reflecting the well-defined topography of the site. The exception to this is in the lower reaches of the Central Creek, where there is an incursion of the flood inundation limits into the proposed residential area at a topographic irregularity. Minor filling of the order of 0.5 m to 1.0 m is proposed in this localised area.

HECRAS modelling output is included in **Appendix C**.

The model results also indicate that an increase in Manning's n from 0.1 to 0.2 had minimal impact on the inundation limits. The average increase in flood depth associated with the upper limit of possible vegetation density (ie, Manning's n=0.2 scenario) is of the order of 300mm for the 100-yr ARI event. The valley flanks at the edge of the valley floor are relatively steeply sloped, and as a result this 300-mm increase in flood height is essentially contained within the valley floor (as can be seen in **Figure 5**). The exception to this is at the confluence of the Central and Eastern Creeks where the valley side slopes flatten out and merge with the downstream wetland. The increase in flood extents in this region however is still relatively small and does not affect development proposals as the area forms part of the heathland recommended for protection in the ecology study.

In summary, 1% AEP flood inundation extents are generally contained within the proposed riparian corridors. The hydrologic sub-catchments are small with only limited areas upstream draining through the site. This results in relatively small flows, which are essentially confined to the valley floors. The 1% AEP flood inundation limits are therefore a secondary constraint to the ecological requirements, which often necessitate larger areas to be preserved (in the form of riparian corridors and heathland) than are inundated by the 1% AEP flood event.

Flood flows from the catchment above the commercial area will be directed into a large box culvert sized to carry the 1% AEP event with an oversized inlet arrangement to accommodate the entire 1% AEP flow even when 50% blocked. This is described further in **Section 7.2**. There will still be a requirement to provide for overflow paths in excess of the culvert capacity but these will be integrated with overflow paths catering for the substantial paved and roofed areas of the District Centre itself. These overflow paths are not shown on **Figure 5** as they are not related to creek flooding as such, and will be more closely defined during detailed design of the District Centre platform and finished surface levels.

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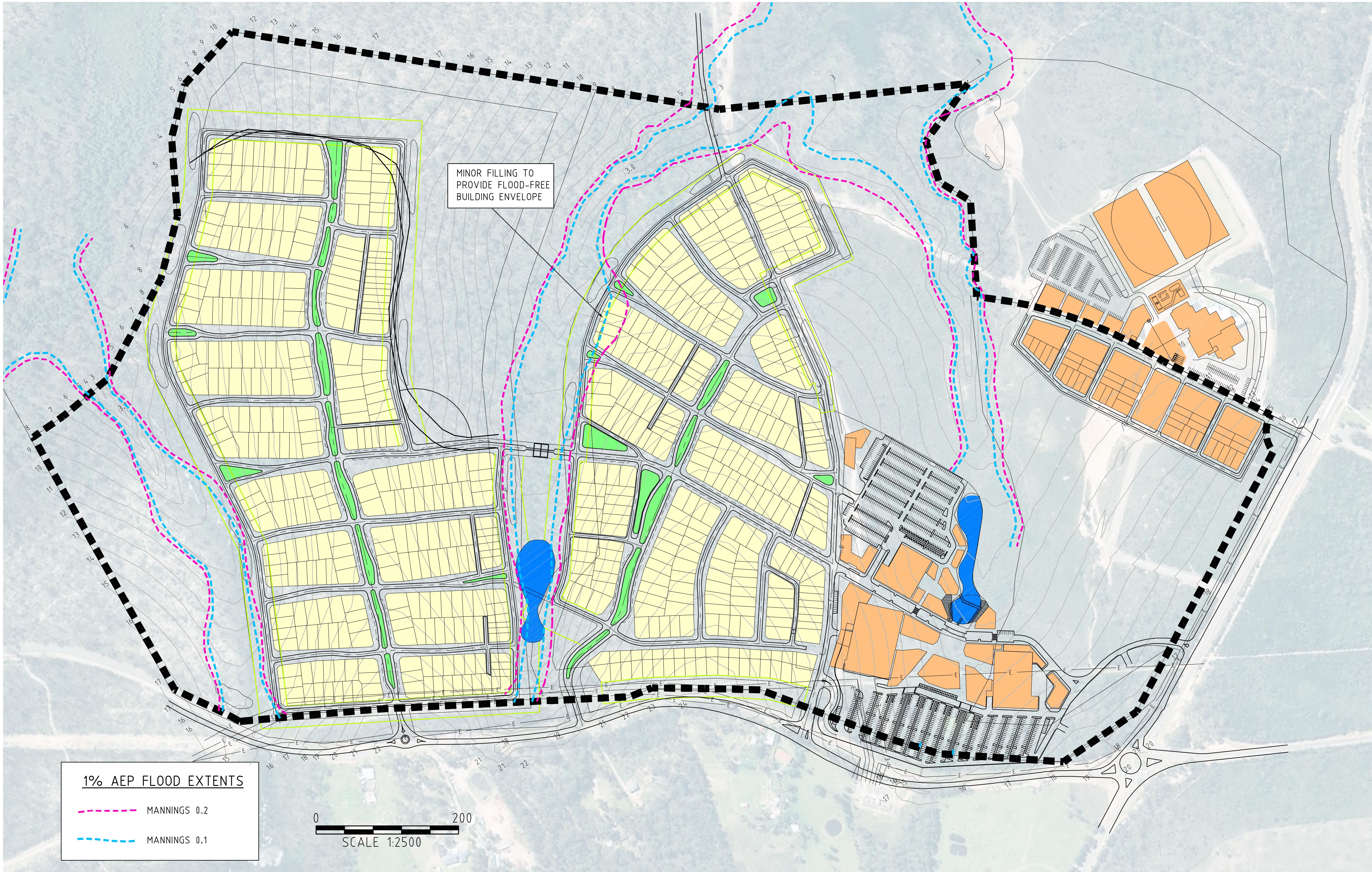

REV	DATE	BY	APP.	DETAILS
P2	13/01/06	AP	AW	UPDATED FOR DEC 2005 DEVELOPMENT FOOTPRINT

DRAWING STATUS		
DESIGN BY	AW/SR	10/05/04
DRAWN BY	AP	10/05/04
DRAFTING CHECK	PJS	10/02/05
DESIGN CHECK	AW	14/12/04
FINAL APPROVAL	PSN	10/02/05

PRELIMINARY

N E S W

SCALE: (on A1 Original) 1:2500

HEIGHT DATUM AHD

FORBES RIGBY PTY LTD
Engineers Planners & Scientists
Quality Endorsed Company, ISO 9001 LIC QEC 10508, Standards Australia
Quality Systems
278 KEIRA STREET, WOLLONGONG, NSW 2500
Ph: (02) 4228 4133 Facsimile: (02) 4228 6811 ACN 003 936 981

PROJECT TITLE
VINCENTIA COASTAL VILLAGE and DISTRICT CENTRE for STOCKLAND DEVELOPMENTS PTY LT

DRAWING TITLE
FLOOD INUNDATION LIMITS

Project No.	Com No.	Drawing No.	REV
104016	3	FIG 5	P2

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January 13, 2006 4:53:44 p.m.
Xrefs: x104016-03_base_3.DWG

A1

5. WATER SENSITIVE URBAN DESIGN (WSUD) PHILOSOPHY

5.1. POSSIBLE ADVERSE URBAN IMPACTS

In the absence of adequate water quality controls, changes in the type and concentrations of water borne pollutants in stormwater runoff caused by development can cause a decline in the ecological health of downstream water bodies.

During the construction phase, accelerated erosion from disturbed areas causes an increase in the amount of fine sediment wash-off and associated water quality impacts.

In the longer term, additional impervious surfaces and changes in land use introduce a wider range of anthropogenic pollutants including:

- Plastics litter and other debris
- Sediment
- Nutrients and other bio-stimulants (principally nitrogen and phosphorus compounds)
- Trace metals (lead, cadmium, zinc and copper)
- Toxic organic compounds (eg, pesticides)
- Oil and grease
- Pathogens affecting humans (including pet excreta, sewage overflows)
- Propagules of exotic plant species.

A recent US study found that parking areas and streets covered about 6% of the catchment but produced 25% of trace metals and 64% of oil and grease in total catchment runoff (Pews Oceans Commission, 2001). Such research suggests that treatment measures targeting runoff of road pavements will be important.

The potential impacts of typical urban stormwater pollutants are as follows:

- Trace metals can accumulate in sediments resulting in adverse ecological impact - half of the cadmium and zinc in San Francisco bay is attributable to tyre wear (Pews Oceans Commission, 2001). The same study also found that brake pad wear contributed to half of the copper in urban stormwater
- Toxic compounds can have bio-accumulation effects (eg, PCBs accumulate in fatty tissues and hence bio-accumulate in fish species and in birds and mammals that are predators of fish)
- Phosphorus encourages the growth of exotics in low-phosphorus Australian conditions, resulting in degradation of riparian vegetation. Once established, their propagules wash downstream and promote further invasion
- Nutrient over-enrichment of estuarine and coastal waters, particularly nitrogen forms, can result in algal blooms and eutrophication of coastal waters. The Gulf of Mexico 'Dead Zone' varies in size up to 20,000 km^2 depending on river runoff and oceanographic factors. It is caused by depletion of oxygen induced by excess nutrient runoff (principally nitrogen-based fertilisers) from the Mississippi basin. Lake Illawarra also suffers from frequent algal blooms from nutrient enrichment (whereas the Moona Moona Creek wetlands downstream of Vincentia Coastal Village and District Centre and the Moona Moona Creek estuary are in relatively good environmental condition)
- Oil and grease result in oxygen depletion and surface scums and films
- Suspended sediment causes light depletion and smothers plants and benthic organisms

- Plastics litter and other debris are unsightly and can present a threat to some animal species through ingestion or entanglement
- Pathogens represent a public health risk.

It should be noted that the above impacts are *'potential'* impacts only and that appropriate management of development, as subsequently discussed, will avoid and/or minimise these impacts.

As well as stormwater quality impacts, the development also has a wider ecological footprint external to the site through the possible need to upgrade townwater supply infrastructure and/or sewage treatment and effluent disposal facilities. These impacts can also be reduced through application of modern principles of Water Sensitive Urban Design (WSUD), to reduce demand.

5.2. WSUD COMPONENTS

The four main elements of WSUD (Water Sensitive Urban Design) are as follows:

(i) Stormwater management measures to minimise impacts of litter, sediments and nutrients on water quality

(ii) Water supply management to reduce townwater water usage

(iii) Wastewater management to optimise opportunities for recycling

(iv) Groundwater management.

The then named DIPNR (now DNR) expressed a desire to see the application of leading-edge WSUD. There are some high profile demonstration projects that are desirable models, but they need to be able to be replicated at a cost-effective scale. It is important to also consider how much the community (and/or the developer) is prepared to pay. In this context, measures considered applicable to the Vincentia Coastal Village & District Centre are presented in **Table 5.1** below.

Table 5.1 - WSUD Measures applicable to Vincentia Coastal Village & District Centre

WSUD Component	Specific Measure	Considered Applicable to Vincentia?
Stormwater management	Gross Pollutant Traps (GPTs)	Yes. GPT's (proprietary litter/sediment traps) should be provided at locations where the piped drainage system discharges to riparian corridors.
	Bio-retention swales	Yes. Provide swales with 1 to 2 m wide 0.5m deep gravel filled trench around perimeter roads and/or within riparian buffer zones.
	Water quality control ponds/ artificial wetlands	Yes, adjacent to road crossings within the riparian corridor, where permitted. In such locations they are visible to the residents and thus add to the overall amenity of the area. Also a key measure for the District Centre, where such pondage could also be used to promote groundwater recharge. Design principles for mosquito control in urban wetland systems to be followed, to minimise opportunities for mosquito breeding. Use of gambusia (mosquito fish) and certain species of macrophyte also to be avoided in this regard.
	Detention storage	Not considered essential given nature of downstream catchment (ie, large natural wetland which would be minimally impacted by increased peak flows in extreme events. Nevertheless, can be provided via dynamic storage in artificial wetlands and by setting aside a proportion of rainwater tanks for OSD - but not considered necessary in this instance.
	Site Specific Outlet Design	Yes. Pipe outlets to the riparian zone to be subject to individual site-specific designs to ensure minimal adverse environmental impact.
	Post construction monitoring & maintenance	Yes. It is recommended that developer work scope include monitoring and maintenance of wetland and creek systems to ensure establishment and functioning in accord with desired objectives.
Water supply management	Rainwater tanks to collect roof runoff	Yes, for all lots and for District Centre. Recent Gold Coast study has shown 20-kL tanks can reduce townwater demand per dwelling from 300kL/yr to 100 kL/yr. This however is a very large tank size. Site-specific analysis by Cundall Johnston & Partners has identified a tank size of 3 to 5-kL as optimal for Vincentia (depending on lot size and roof area).
	Demand management	Yes. Promote use of water efficient showerheads & dishwashers, and tap aerators. Provide native landscaping with a lower water demand than traditional urban planting regimes.
Wastewater management	Reclaimed water use (incl. greywater reuse)	No. Cost v environmental benefits questioned. Greywater reuse can be an environmental risk. Wetland treatment systems for greywater are relatively new technology and rely on good maintenance, thus representing an environmental risk to Moona Moona Creek wetlands downstream (if not properly maintained).
	Dual reticulation (potable/ non-potable)	Only to the extent of using tank water for toilet flushing (and externally for garden watering). Combination of economics & environmental returns for a more elaborate system unlikely to be attractive for this site.
Groundwater management	Aquifer recharge	Yes. Development of ridge crest upgradient of orchids could potentially decrease recharge to aquifer system. Can be mitigated against with bioretention swales and water quality control ponds/ artificial wetlands. Specific design methodology to suit recommendations of hydrogeology and ecological studies.

As can be seen from **Table 5.1**, WSUD measures considered most appropriate to the Vincentia Coastal Village & District Centre are in the areas of water supply management, stormwater quality control and groundwater management.

Further detail on water supply management proposals is provided in the Cundall Johnston & Partners ESD Opportunities report.

Options relating to stormwater quality control and groundwater management are discussed in **Sections 5.3** and **5.4** below.

5.3. STORMWATER QUALITY MANAGEMENT

Pollutants can be removed from stormwater runoff by way of screening or trapping of litter and debris, and by sedimentation and various microbiological processes in water quality control ponds/constructed wetlands.

Sedimentation is an effective way of removing many of the pollutants in urban stormwater, particularly heavy metals. The removal mechanism is principally by geochemical adsorption onto sediments, particularly clay particles and metal salts such as iron and manganese oxyhydroxides. Relatively coarse particles (> 0.1 mm) such as silica sand in comparison hold very little pollutant. Removal of the clay fraction, which contains the major portion of pollutants (except oil), by sedimentation requires a longer time than the mean settling time for all size ranges. Following Stokes Law, it takes typically days to settle out the majority of the clay fraction (particle size < 2 microns). Soil chemistry can further inhibit settling and result in even longer settling times.

Where the local sediments lack the capacity to fix soluble pollutants artificial wetlands can be used. Wetlands can be effective in reducing nutrient loads, but performance can be affected by poor design (such as lack of sunlight, poor circulation, unsuitable substrate and inappropriate macrophyte selection).

The removal of nutrients (particularly phosphorus) is best achieved in a shallow marsh type wetland which features a dense macrophyte stand and slow velocities to ensure biofilms on macrophyte stems are not stripped off by the flow of water. The biofilms help to immobilise phosphorus. The biofilm builds up and eventually sloughs off and the phosphorus is retained in the wetland bed material.

Oil and grease is best removed by attachment to the stems of macrophytes in wetlands where it would then continuously bio-degrade.

For stormwater quality management at the Vincentia Coastal Village and District Centre a combination of proprietary litter/sediment traps, bio-retention swales and water quality control ponds/ artificial wetlands is proposed. All of the pollutant removal mechanisms described above are thus provided as part of the proposed WSUD measures to be incorporated into the development.

An important aspect of modern water sensitive design is recognising that rainfall patterns are inherently variable and that a pollutant removal system should be designed with variable treatment mechanisms. These must perform across a range of pollutant concentrations (generally governed by the duration of the inter-event period), and for a range of hydraulic loadings (a function of rainfall intensity during any given storm event). For this reason a treatment 'train' commencing at an early stage in the runoff cycle is advocated.

The proposed water quality treatment system for Vincentia takes account of this recent research by incorporation of a range of physical and chemical/biological mechanisms occurring at different locations within the treatment train and which provide optimum performance at different pollutant and hydraulic loadings. The expected performance of the various components in the proposed treatment system is described in **Table 5.2** below.

Table 5.2 - Proposed Treatment Train

Treatment Measure	Purpose	Comment
GPTs	• Removal of coarse pollutants and letter	Selection of such devices to recognise maintenance issues. Some devices (such as the CDS units) rely on wet well storage of captured gross pollutants and require servicing with a suction truck, whereas dry-type units (eg, Baramy traps) can be serviced with more conventional maintenance equipment and are potentially cheaper to maintain, although they are less efficient at trapping sediment. Capture of sediment was less critical in some locations than others (eg, in places where a sediment-capture zone can readily be provided within a particular pond). The optimal arrangement may thus be a combination of different type GPTs.
Bio-swales	• Physical filtration and capture of fine sediments (within subsurface gravel filter) • Exfiltration to Groundwater	Small particle sizes will be removed by the bio-swale system including fine sands. The subsurface filter component of the swales is able to effectively treat (via filtration) trickle flows up to a maximum of a few litres per second. It is likely that in dry periods additional flow will be lost through the base of the trench, and contribute to recharge of the groundwater system.
Wetlands (deep water zone)	• Sedimentation and storage of sediments	Wetland deepwater zones provide for removal of those particle size ranges and hydraulic loadings that are not captured and assimilated at earlier stages in the treatment train. A minimum 24 hour hydraulic residence time is preferred for the capture of fine sediments. Fine sediments are stored within the bottom of the wetland and adsorbed nutrients made available for plant uptake.
Wetlands (macrophyte zone)	• Physical filtration and capture of fine sediments • Enhanced sedimentation and storage of fine sediments • Biological uptake	The wetland macrophyte zone provides for enhanced sedimentation through provision of direct filtration by plant stems and reduced re-suspension of bottom sediments (less wind and turbulence). Within these zones the minimum size of particles captured is reduced, leading to increased pollutant capture. Macrophytes actively take up nutrients and convert them into a less bio-available form.

The challenge for the consultant team was to locate bio-swales and wetlands in ways sympathetic to the other environmental constraints of the site. The opportunity presented by Asset Protection Zones (APZ's) and advice from the then-named DIPNR (now DNR) that ponds could be placed in the riparian buffer zones was recognised as a key driver in siting the ponds/wetlands.

Mr Geoff Sainty of Sainty and Associates also provided input to this key system definition phase, and highlighted the importance of trying to extend treatment facilities up to the top 20% of the residential catchment. This philosophy was fed through to Stockland's planning workshops and the original road layout involving contour roads was discarded in preference for a road system with roads running directly down the valley flanks. The advantage of this arrangement are:

- Reduced bulk earthworks associated with road works (ie, roads can be at grade rather than cut into the valley sides with corresponding fill batters on the downhill side where running along a contour)

- A shortening of the urban drainage travel path to the buffer to the riparian corridor, which enabled treatment facilities to be located within the APZs adjoining the riparian corridors, yet still penetrating into the upper 20% of the residential catchment.

Another important area of focus for treatment includes coarse particulates such as litter generated from retail/commercial areas; organic material derived from garden beds/ landscaping; and coarse sediment material eroded from construction sites. Strategic use of Gross Pollutant Traps (GPT's) will be required to decrease loadings of coarse particulates and improve the amenity of wetlands and ponds.

Bio-swales are proposed along the riparian corridor buffer strips to reduce the potential for migration of weed propagules into the riparian zone in addition to improving water quality. They will comprise a coarse filtration system (eg. small diameter pipe within a gravel filled trench) at the base of a vegetated swale incorporating native vegetation where possible to assist with the take up of nutrients. More widespread use of bio-retention systems as roadside swales throughout the subdivision was not considered appropriate for the Vincentia Coastal Village and District Centre. The local clay based soils in combination with high rainfall is likely to compromise the effectiveness of such systems. Bio-retention systems also create additional maintenance burden and decrease land utilisation. Strategic use of bio-retention systems was considered in wider feature streets, but modelling indicated no significant increase in system performance with such an arrangement.

The location of the wetlands has also been governed by characteristics and constraints of the site. The basic configuration of the proposed wetland system consists of a combination of permanent and intermittently inundated ponds and wetlands, mostly positioned so that they lie within the APZs. The shape of the wetlands and interlinking bio-swales will be varied to retain mature trees where possible. Aesthetic considerations have also influenced the preferred wetland location. The wetlands have been placed to maximise viewing from the development site, and shaped to create visual interest for residents.

The proposed WSUD measures for stormwater quality management as described above are also important as measures to assist in the retention of threatened species and general biodiversity across the site. The proposed gross pollutant traps, bioswales and wetlands in particular are of high importance in removal of pollutants and fine sediments and in the maintenance of existing hydrologic regimes which will enhance retention of the Giant Dragonfly.

The general configuration of stormwater quality control measures described above was modelled and the layout optimised to enhance system performance. Details of the modelling are described in **Section 6**.

5.4. GROUNDWATER MANAGEMENT

The ERM Hydrogeological Study identifies two groundwater regimes at the site: a perched water table in the shallow unconfined sediments and a deeper confined/semi-confined aquifer system within the weathered bedrock profile.

The hydraulic head in both systems declined during the period of monitoring undertaken for the ERM study. This was attributed to below average rainfall conditions during the monitoring period.

Development of the ridge crest upgradient of the leek orchids was considered to potentially affect recharge of the aquifer system due to increased impermeable surfaces, which could result in decreased water levels in both the shallow and deep groundwater systems.

Nevertheless, the Hydrogeological Study noted that it was unlikely that the root zone of the orchids extends to the perched water table, and may rely more on soil moisture.

In recognition of the above concern with groundwater recharge and the importance of maintaining soil moisture levels, the following measures are proposed:

(i) Provision of a bio-swale within the reserve of the (slightly relocated) Moona Creek Road within an allocation 3-m wide on the south-eastern side (to help increase soil moisture levels and groundwater recharge on the north-western side of the leek orchid area)

(ii) Leaving the lower part of the proposed District Centre pond system unlined, again to assist maintenance of soil moisture levels and groundwater recharge upstream of the leek orchid area

(iii) Ensuring that flows from the piped creek underneath the District Centre are not concentrated, but are spread out as sheet flow as they would have more likely occurred under natural conditions

(iv) Again, to assist in maintaining soil moisture levels and groundwater recharge on the south-eastern side of the heathlands/leek orchid area, the provision of a bio-swale within the reserve of the Village East precinct perimeter road.

DEC requested in their 15 November 2004 letter that potential impact on groundwater quality due to aquifer recharge from swales/ponds be discussed.

We have consulted previously with groundwater chemistry expert Dr S Short on this matter, in connection with similar projects. Dr Short advised that most contaminants would not pass to groundwater, but would be removed by precipitation, adsorption and sedimentation before entry to groundwater. For example, heavy metals are highly adsorbed on to sediment and all suspended solids would be filtered out and would therefore not access groundwater. Only dissolved conservative contaminants such as nitrate-N and soluble organic contaminants (eg, some pesticides, but not ones likely to be used in an urban context) would pass into the groundwater system. The impacts of the relatively small proportion of contaminants entering the groundwater system would be further reduced by the significant attenuative mechanisms applying within the underlying aquifers itself (eg, the natural attenuation of Ammonia-N). Most conceivable contaminants potentially accessing groundwater would thus be fully immobilised or biodegraded.

6. WATER QUALITY PERFORMANCE MODELLING

6.1. MODELLING APPROACH

The water quality software package MUSIC v2.01 (Model for Urban Stormwater Improvement Conceptualisation) was to optimise the configuration of the various WSUD measures identified above and to ensure water quality objectives are met.

MUSIC was developed by the Co-operative Research Centre for Catchment Hydrology located at Monash University. The model is designed to evaluate conceptual stormwater treatment designs by simulating the performance of stormwater quality improvement measures and allowing comparison with water quality targets.

MUSIC was used to predict pollutant loads under both pre-development and post-development conditions, based on a range of project-specific input data including daily rainfall, monthly evapo-transpiration rates, sub-catchment characteristics and soil types. Total Suspended Solids was one of the key water quality parameters modelled as a proxy for heavy metal removal.

MUSIC comprises 3 sub-models:
- A daily rainfall-runoff (which predicts daily runoff from daily rainfall)
- A pollutant export model (which calculates the daily export of a range of pollutants from different land use areas using user defined algorithms)
- A pollutant retention model (which simulates pollutant retention within stormwater treatment devices).

MUSIC is able to model three different land use types: urban, forest and agricultural. Different runoff and pollutant export characteristics, including proportion of impervious area, soil properties and base flow and storm flow pollutant concentrations, are then assigned by the model to each of these discrete land uses.

Pollutant export rates, derived from measured data for a variety of rural and urban catchments, are commonly expressed in the form of Log-mean Event Mean Concentrations (EMC's). An EMC is the estimated mean concentration for a given pollutant/land-use type over all monitored storm events. It is calculated by firstly converting recorded instantaneous concentrations over a storm event into flow weighted averages. The superset of these flow weighted averages are then converted to their natural logarithms. These logarithmically transformed values are summed and their overall average computed. The anti-logarithm of that average is then taken as the representative EMC for that land use type. This approach is based on the discovery during the United States Nationwide Urban Runoff Program (NURP) that the superset of all storm event or sampling period flow weighted average concentrations are themselves log-normally distributed about an overall average value.
The MUSIC software includes an extensive library of EMCs for Total Suspended Solids (TSS), Total Nitrogen (TN), Total Phosphorous (TP) and Gross Pollutants, under base flow and storm flow conditions. The parameters of the log-normal distributions can be altered for each pollutant type. Standard deviations are also specified for each data set. The model stochastically generates an EMC for each runoff event to ultimately produce a mean and standard deviation as specified by the user. This reflects the natural variability between different catchments, and the influence of spatial and temporal factors.

For pollutant retention (ie, removal in wetlands or bioswales), MUSIC utilises the Universal Stormwater Treatment Model, which is a first order kinetic decay model calibrated for Australian conditions.

Once the complete suite of input data was entered (refer **Section 6.2** below for further detail), the model was run for a 100-year continuous simulation period. It is noted that 100 years of data represents a substantial record set. Continuous simulation over such a period given increased confidence in modelling output, and reduces the effects of assumed starting water levels and allows wetland performance to be predicted over a range of climatic conditions.

6.2. MODEL INPUT DATA & PARAMETERS

6.2.1. Rainfall Data

A total of 104 years worth of daily rainfall data (July 1899 to November 2003) from the Bureau of Meteorology gauging station No 68034 at Point Perpendicular Lighthouse was used for continuous simulation purposes. The lighthouse is approximately 17 km from the proposed Vincentia Coastal Village and District Centre, and so provides an accurate meteorological template on which to model the proposed system.

6.2.2. Evapo-Transpiration Data

Monthly average evapo-transpiration data input to the model was taken from Bureau of Meteorology mapping for the region (as summarised in **Table 3.2**).

6.2.3. Catchment Land Use Characteristics

The overall catchment was partitioned into water quality sub-catchments corresponding to existing and proposed land uses. The general partitioning used is shown on **Figure 6** and assigned land use characteristics in **Table 6.1**.

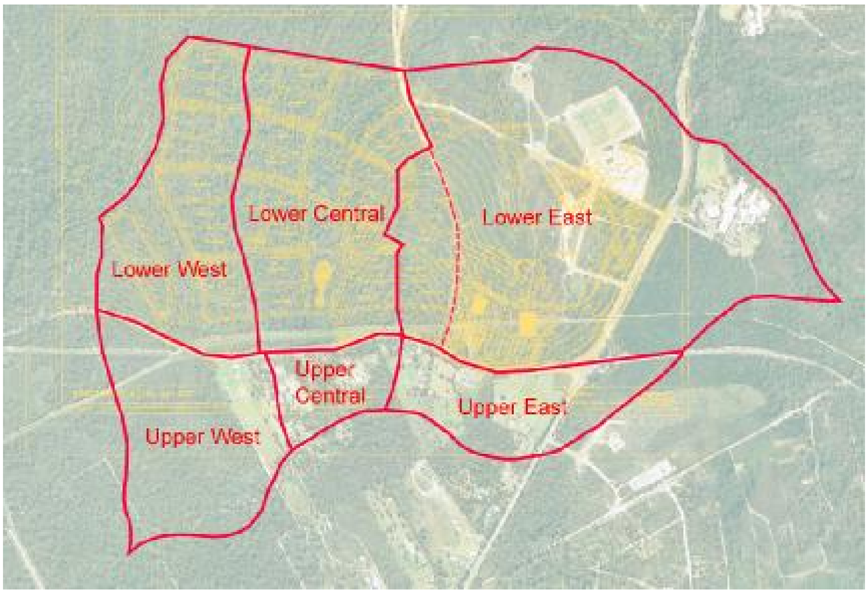

Figure 6 - MUSIC - Water Quality Sub-Catchment Layout

The Lower Western, Lower Central and Lower Eastern Sub-areas are those to be developed for urban purpose (ie, houses, roads, district centre, etc) with a part retained as forest, representing riparian corridors and area of heath land to be preserved. The ‘upper’ sub-areas lie outside of the site boundary and their land-use is assumed to remain unchanged under post-development conditions. Although some treatment is provided future development of these upper areas will require its own water quality controls.

The Lower East subcatchment includes land to the north of the proposed Village & District Centre which already has some urban type land use in the form of the Bay & Basin Leisure Centre and High School.

The sub-catchment partitioning used in the MUSIC modelling is essentially the same for existing and post-development conditions. The same subcatchments are used in both cases, except that 11 ha of the Lower Eastern sub-catchment to the north of the commercial area is directed to the Lower Central sub-catchment (ie, north of the dashed line on **Figure 6**).

Table 6.1 - Pre-Development Model Sub-Catchments

Sub-catchment	Area (ha)	Existing Land Use	Post-Development Land Use
Upper Western	29.7	Forest/Agricultural	Forest/ Agricultural
Lower Western	32.5	Forest	Urban/Forest
Upper Central	9.2	Agricultural	Agricultural
Lower Central	46.5 [a]	Forest	Urban/Forest
Upper Eastern	19.2	Agricultural/Forest	Agricultural/Forest
Lower Eastern	86.7 [a]	Forest/Urban	Urban/Forest

[a] Areas stated are for the model of existing conditions. For modelling of proposed conditions, the Lower Eastern sub-catchment was reduced by 11 ha (from 86.7 ha to 75.7 ha) and the Lower Central sub-catchment increased by the same amount (from 46.5 ha to 57.5 ha)
[b] Partitioning shown is general only, for descriptive purposes. Further portioning of the main water quality sub-catchments was undertaken as part of the detailed MUSIC modelling.

6.2.4. Estimated Proportions of Impervious Area

The impervious area for each sub-catchment was assessed based on land use and proposed 'vegetated' areas (including parks, nature strips as well as riparian corridors). The adopted impervious percentages for each land use are summarised in **Table 6.2.**

Table 6.2 - Proportion of Impervious Area For Different Land Uses

Land Use	Impervious Area (%)
Urban (Residential)	45%
Urban (Commercial)	90%
Forest	0%
Agricultural	5%

Studies have shown that low-medium density housing typically has an impervious cover of around 35% (refer Cardew, et al). The adopted impervious cover of 45% for residential areas of the Vincentia Coastal Village is 28% higher than the value usually adopted for modelling, reflecting an element of conservatism and also recognising the trend in recent years to smaller lot sizes (and therefore increased impervious surfaces).

6.2.5. Runoff Generation

Infiltration and soil moisture storage parameters are required by MUSIC in the generation of runoff volumes from the various subcatchments (and for water seepage losses in wetlands and swales due to infiltration of water through the base material). Guidance is given in the MUSIC software based on site soil conditions. Parameters have been selected based on the soil descriptions in the Networks Geotechnics report. Further details of the parameters adopted are presented in **Appendix D**.

A check on the validity of the parameters selected was made by calculating the proportion of total annual rainfall that the pre-development model predicted as runoff, which was 39%.

Literature on water yields from Illawarra catchments (Boyd M.J. and Baki A.M 1998) has indicated that for rural catchments the proportion of total annual runoff to the total annual rainfall typically varies from 30% to 40%. This is in good agreement with the model results for the existing catchment and thus gives confidence in the parameters selected.

6.2.6. Event Mean Concentrations

The EMCs adopted for the MUSIC modelling are summarised in **Table 6.3**.

Table 6.3 - Event Mean Concentrations For Target Pollutants

Land Use	Flow Condition	TSS (mg/L)	TP (mg/L)	TN (mg/L)
Urban	Storm flow	158	0.36	2.63
	Base flow	12.6	0.15	2.09
Agricultural	Storm flow	200	0.54	3.89
	Base flow	25.1	0.13	1.19
Forest	Storm flow	79.4	0.079	0.84
	Base flow	7.9	0.032	0.72

These above values are based on a comprehensive review of urban catchments by Duncan (1999) which included a variety of different urban surfaces including roads, roofs, industrial and forest.

We note that the EMC values for forest (the predominant land use for modelling of existing conditions) are low and represent significantly higher water quality than indicated by the baseline water quality monitoring conducted to date (refer **Appendix A**).

6.2.7. Pollutant Retention

MUSIC utilises the Universal Stormwater Treatment Model (USTM) to calculate pollutant removal. This is a first order kinetic model that assumes contaminant concentrations in a parcel of water entering a wetland or other vegetation based treatment measure will undergo exponential decay towards an equilibrium value. C* is the equilibrium or background concentration, and k is the exponential rate constant. The MUSIC software recommends values for k and C* derived from theoretical equations validated by empirical analysis of observed data for wetland performance.

In wetlands located in the lower end of the treatment train in the central creek (where the inflows were relatively clean due to the substantial treatment received higher in the treatment chain), the default C* values for phosphorus and nitrogen resulted in an anomaly where the outflows from the treatment measure had higher loads than the inflows. The C* values were thus adjusted accordingly to match the baseline inflow concentrations (refer **Appendix D** for details).

6.3. MODEL RESULTS

Modelling results for existing conditions and following the construction of the Vincentia Coastal Village and District Centre are presented in **Table 6.4**.

Table 6.4 – Predicted Average Annual Runoff/Pollutant Export at Catchment Outlets

Pollutant/Runoff	West	Central	East [a]
Existing Conditions			
Total Suspended Solids (TSS)	26,200 kg	14,600 kg	27,700 kg
Total Nitrogen (TN)	535 kg	290 kg	615 kg
Total Phosphorus (TP)	65 kg	28.6 kg	56.9 kg
Runoff	280 ML	244 ML	543 ML
Developed / No treatment			
Total Suspended Solids (TSS)	42,100 kg	56,700 kg	66,300 kg
Total Nitrogen (TN)	792 kg	957 kg	1090 kg
Total Phosphorus (TP)	103 kg	124 kg	136 kg
Runoff	328 ML	409 ML	584 ML
Post Development including Treatment			
Total Suspended Solids (TSS)	19,300 kg	8,020 kg	17,600 kg
Total Nitrogen (TN)	430 kg	286 kg	514 kg
Total Phosphorus (TP)	51 kg	23	39 kg
% Reduction in Loads from existing to developed conditions ('with treatment')			
Total Suspended Solids (TSS)	26%	45%	36%
Total Nitrogen (TN)	20%	1%	16%
Total Phosphorus (TP)	22%	20%	32%

[a] The results for the Eastern catchment allow for the inclusion of the existing Bay & Basin Leisure Centre pond as a water treatment measure.

These results show that the proposed wetlands and bio-swales are capable of reducing the mean pollutant loads to the same (or reduced) levels expected to occur under existing (mostly forested) conditions. The proposed wetland and bioswale system will therefore ensure the low pollutant loads currently entering the wetlands downstream of the site are not increased beyond existing (low) levels.

It is also confirmed that modelled average concentrations in post-development conditions (calculated from the load data presented in **Table 6.4**) indicate a water quality matching that from a natural forest (refer **Table 6.3**).

7. DETAIL OF ADOPTED WSUD MEASURES

7.1. WESTERN & CENTRAL VILLAGE AREAS (RESIDENTIAL)

The Western and Central Creeks are the two subcatchments affected by the proposed Village (residential) development.

The stormwater management approach to each of these creeks systems is similar:

(i) A permanent pond is placed in the upper part of the subcatchment, immediately downstream of Naval College Road ('off-line' for the western subcatchment and 'online' for the central subcatchment). The purpose of these ponds, from a water quality perspective, is to intercept flows and provide a sedimentation function with respect to runoff from the upper catchments south of Naval College Road. These ponds will also serve an aesthetic function, particularly the (larger) pond on the central creek which will be a prominent entry feature. The pond on the western creek is located on the western side of the riparian corridor to reduce impact on the more valuable important riparian vegetation. Low to medium flows from the culvert under Naval College Road will be directed into this pond, with high flows (spilling over the road) bypassing it.

(ii) Intermittently inundated wetlands (some with river gravel sub-strate) linked by bio-retention swales to receive and treat stormwater runoff from the proposed residential