- construction works related to providing physical infrastructure and services including some vegetation clearing.

The concept plan for the district town centre includes:

- building footprints
- an indicative total floor area of 32,000 square metres with approximately 20,000 square metres proposed in Stage 1 and 12,000 square metres proposed in Stage 2
- a range of uses including a discount department store, supermarket, medical centre, child care centre, restaurants, bulky goods, potential housing and specialty retail
- a site (Stage 3) for future bulky goods development
- a road network that includes a main street, access to The Wool Road and access to a proposed road in the subdivision
- an indicative total of 1,399 car parking spaces to be provided in two car parking areas and at the upper level of future buildings
- a water feature and open space areas.

The concept plan for the adaptable housing area adjacent to the Bay and Basin Leisure centre includes an internal road network, indicative residential lot layout and access to The Wool Road.

The project is described as the Vincentia Coastal Village and District Centre.

1.4. PURPOSE OF THIS STUDY

The *objectives* of the WSUD study for the Vincentia Coastal Village & District Centre are to:

- Identify flood-affected areas in the 1% AEP event and consider evacuation in the PMF event.
- Assist refine the initial riparian corridor widths and road crossing configuration indicated by the then named DIPNR (now DNR).
- Select a combination of WSUD approaches that will be both acceptable to the future residents and represent value for money in terms of the environmental benefits they deliver
- Identify water quality objectives for the catchment that recognise the sensitivity of receiving water bodies
- Establish appropriate wetland and water quality design principles
- Identify stormwater management infrastructure that is compatible with the environmental sensitivities of the site, including maintenance of the existing groundwater regime
- Develop and document preliminary concept designs for the water quality treatment system
- Describe the modelling process carried out to determine the effectiveness of the adopted wetland configuration
- Demonstrate that the wetland proposal meets the necessary water quality objectives.

It should be noted that the preliminary wetland designs presented in this report have been developed to sufficient detail to convey the design intent only. Further detailed design will be required prior to construction. At detailed design the proposed ponds and wetlands may require some changes to suit detailed local issues. It is not anticipated however that

significant changes will be required to the physical parameters which govern wetland performance (ie, volume, surface area, bathymetry, length to width ratio and detention time). The wetlands are thus not likely to require significant modification. Nevertheless, it should be demonstrated to Council that any changes made are consistent with the preliminary designs presented in this study. Additionally, further water quality modelling should be undertaken at the detailed design stage to confirm system performance. In this regard, we note that it may be possible (based on further detailed stormwater quality modelling) to reduce the number of GPTs (CDS units) by constructing additional drainage pipelines within the roads parallel to the riparian corridors, thus reducing the number of entry points to the bioswales adjacent to the riparian corridors. This would reduce the number of CDS units, but would increase the cost of drainage pipelines. Optimisation of the number of CDS units would thus be determined during detailed design.

1.5. INTERFACE WITH OTHER CONCURRENT STUDIES

There are a number of concurrent studies that inter-relate with this study. These are as follows:

- Hydrogeology Study by Environmental Resources Management (ERM)
- ESD Study by Cundall Johnston & Partners Pty Ltd
- Landscape Study by Clouston Associates
- Flora and Fauna Study by GHD
- Geotechnical Study by Network Geotechnics
- Stakeholder and community consultation by Elton Consulting Pty Ltd.

1.6. REPORT STRUCTURE

This report has been structured as follows:

Chapter 1 gives an overview of the proposed development, concurrent studies and the approach to the combined water study.

Chapter 2 describes the initial consultation with stakeholders, the project vision, and the implications on water-related aspects of the project.

Chapter 3 reviews the relevant standards and guidelines and describes the available data which was used in carrying out this study (including survey, geotechnical, meteorological and water quality data).

Chapter 4 provides a description of the catchments and the receiving waters, and documents the results of surface water hydrology modelling and the extent of flood inundation.

Chapter 5 provides an overview of the possible impacts of the development and appraises a range of WSUD options that would mitigate against those impacts.

Chapter 6 details the outcome of water quality modelling, which was used to evaluate the effectiveness of the various measures and options identified in Chapter 5 and to confirm that the measures proposed meet adopted water quality objectives.

Chapter 7 describes the components of the recommend scheme in more detail with respect to the District Centre (shopping centre), Village East (adaptable housing) and the residential area (Village West and Village Central).

Chapter 8 examines a number of operational issues including staging, soil and water management during construction, maintenance and post-construction monitoring.

Chapter 9 considers other water-related issues including changes to the hydrologic regime applying to the Moona Moona Creek wetlands downstream, creek crossings, flood evacuation, and the long term persistence of open water in the larger ponds (which also serve an ornamental function).

Supporting graphical material is included in the report figures and appendices with a full listing provided in the table of contents.

This report was issued in draft form to the government authorities in June and September 2004. Responses to comments received from the authorities on the draft reports have been incorporated into this Final Report.

2. CONSULTATION & PROJECT VISION

2.1. PROJECT VISION & IMPLICATIONS ON WATER RELATED ASPECTS

The project vision is *to create a high quality, active, integrated and sustainable coastal community, with its character formed by the unique bushland setting and undulating topography and where ecological impacts are minimised.*

On the basis of the above vision, the two principal water-related environmental outcomes sought from the project are:

- A high degree of protection for existing streams (including their riparian vegetation) and receiving water bodies
- A high level of amenity and safety for future residents.

These outcomes must be achieved in a sustainable manner that does not unnecessarily limit development, generate significant life cycle costs or limit other planning initiatives to achieve a functional living place and community.

2.2. CONSULTATION WITH STAKEHOLDERS

Following a meeting with the developer and consultant team on 30 July 2003, the (then named) DIPNR (now DNR) advised that 'category 2' objectives/outcomes would apply to each of the 3 creeks that flow through the development site. This requires a vegetated riparian corridor for 30 m on each side of the watercourse (measured from the top of bank) plus a 10-m vegetated buffer on each side. Given that the watercourse channels are quite small (typically 1 or 2 m wide), the (then named) DIPNR's requirement implies a 62-m wide core riparian area within an overall riparian corridor 82 m wide (ie, inclusive of buffers). The exception to this requirement was the (then-named) DIPNR's assessment that the upper part of the Central Creek was not defined as a 'river', which means that drainage management measures above the proposed road crossing in the middle of this reach of creek would not require any approval from the (then named) DIPNR (now DNR).

The specific requirements of the (then named) DIPNR for each creek are summarised in **Table 2.1** below.

Table 2.1 – DIPNR's (now DNR) Preliminary Requirements for Watercourses in Study Area

Watercourse	Riparian Corridor [a]	Road Crossings [b]
Western creek	Corridor (82m total width) applies to whole length of creek passing through the site.	• Any more than two crossings seen as an impediment to overall riparian connectivity
Central creek	Riparian corridor only applies to lower part of creek.	• The proposed road crossing in middle of this reach of creek passing through the site is a defining location • Land upstream of road crossing can be fully urbanised. • Water quality pond/ artificial wetland immediately downstream of road crossing acceptable. • Off-line facilities to capture and treat stormwater runoff can be located within buffer zone on either side of creek at the bottom of the urban catchment
Eastern creek	Corridor (82m total width) applies to whole length of creek passing through the site.	• Some areas (eg, near road crossings) may be given less 'natural' riparian treatment, given the 'parkland' nature of residential/commercial interface

[a] Preference for roads (or open space) rather than lots to adjoin the riparian corridors
[b] Minimal stream crossings preferred, with preference to piered structures to allow light penetration where corridor connectivity required

Stormwater quality and riparian corridor management measures were subsequently developed on the basis of the initial advice presented above. A series of meetings was held with the then named DIPNR during the course of design development with respect to:

- The road layout vis-a-vis the riparian corridors
- Typical cross-sections of the creeks and adjoining lands
- Proposed stormwater quality measures in the District Centre and the Villages.

In-principle support was obtained from the (then named) DIPNR as designs were progressed to ensure that the Stockland proposal was developed in a manner leading to an integrated design with input from all stakeholders, rather than designs being prepared in isolation by a developer team.

Detailed discussions were held with the (then named) DIPNR and Council in the evolution of an alternative development theme for the District Centre that better accommodated the environmental sensitivity of the site arising from an increased knowledge of ecological issues from ERM's studies. Further record of this detailed consultation process relating to the District Centre is provided in Section 7.2 of this report.

Broader consultation with stakeholders was also undertaken by way of a series of three Community Information Sessions and two Planning Focus Meetings, which are separately reported on by Elton Consulting Pty Ltd.

A draft copy of this WSUD report ('rev 0') and documentation for related studies were submitted to the government authorities for comment prior to the second Planning Focus Meeting which was held on 15 July 2004. The WSUD report was revised ('rev 1') to take into account the comments made by the authorities at that meeting.

Following issue of the revised ('rev1') WSUD report, further authority consultation was undertaken with DEC by way of a series of meetings in October and November 2004. Issues discussed at these meetings of relevance to the WSUD report included:

- The need to consider in more detail the impact of additional surface water flows on the downstream wetlands
- The position of the District Centre and the need to balance environmental, social and economic objectives
- The need to amplify the discussions dealing with maintenance of the WSUD measures.

The WSUD report has been revised further to take into account the comments made by DEC and the re-issued to Stockland (as 'rev 2' in December 2004 and 'rev 3' in February 2005).

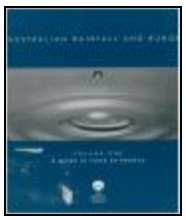
The report has subsequently been additionally amended to reflect changes to the development footprint in the western part of the site adjoining the Jervis Bay National Park to meet DEC requirement and is now issued as 'rev 4' dated January 2006.

3. AVAILABLE DATA

3.1. STANDARDS & GUIDELINES

3.1.1. Flooding & Drainage

Key Standards/Guidelines applicable to the management of mainstream flooding include:



Australian Rainfall & Runoff
(The Institute of Engineers, 1998)
This is the default national code of practice covering the application of hydrology and hydraulics to catchment yield, urban drainage and mainstream flooding.

Floodplain Management Manual
(NSW State Government, 2001)
This is the key document controlling development on floodplains in NSW, which Local Government is obliged to follow.

NOW SUPERCEDED BY APRIL 2005 FLOOD PLAIN MANAGEMENT MANUAL)

Shoalhaven City Council Development Control Plan 100
(Shoalhaven City Council, 1999)
This document sets out Council's specifications for subdivision design, including detailed requirements for stormwater drainage design.

3.1.2. Surface Water Quality

In comparison with flooding and drainage, standards for surface water quality controls in new developments are less definitive. Most of the literature is in the form of guidelines. This to some extent reflects the rapidly changing nature of this field of engineering.

The Vincentia Coastal Village and District Centre however will be closely scrutinised by government authorities and the public. Surface water quality controls will therefore require a combination of environmentally sustainable best practice and leading edge solutions.

Some specific documents that have been widely used on similar sites and provide relevant guidance in achieving desired environmental outcomes include:

Managing Urban Stormwater : Treatment techniques
(NSW EPA, 1997)
This document is an industry guideline on selection of stormwater treatment measures. It provides generic advice on a range of measures including smaller scale measures (eg, grass swales) through to large scale measures (eg, constructed wetlands).

Managing Urban Stormwater : Council Handbook DRAFT
(NSWEPA, 1997)
This handbook was produced to assist Council's with the preparation of stormwater management plans. The document also contains useful guidance for Council's on how to adequately assess new developments and appropriate methodology for numerical modelling of performance.

Water Sensitive Urban Design Strategy
(Landcom, 2004)
This recently published document comprises three separate books. Book one includes an overview of Landcom's WSUD strategy, Book 2 describes technical and non-technical issues associated with implementations and Book 3 provides a number of case studies. Whilst this document is not a guideline is does provide a valuable collation of modern practices in WSUD.

Managing Urban Stormwater – Soils and Construction
(Department of Housing, 1998)
A guideline to assist developers and contractors manage pollution caused by erosion and sedimentation principally during the construction phase. Also known as the Blue Book. New edition just released (4th Edition 2004)

Urban Stormwater Pollution
(CRC for Catchment Hydrology, 1997)
An industry report that concisely describes the concepts associated with generation and wash-off of the full range of urban stormwater pollutants. Does not address selection or design of treatment measures.

The Constructed Wetlands Manual
(DLWC, 1998)
A comprehensive manual (2 volumes) that documents all aspects of the design, construction and maintenance of constructed wetlands for stormwater pollution control.

Shoalhaven City Council Development Control Plan 100
(Shoalhaven City Council, 1999)
This document sets out Council's specifications for subdivision design, including detailed requirements for erosion control during construction and the design of constructed wetlands

Jervis Bay Settlement Strategy
(DIPNR, October 2003)
This document relates specifically to the Jervis Bay area and identifies objectives and policy actions across a range of environmental factors including water quality and flow, biodiversity, soils, urban stormwater management and residential development.

Water Quality and River Flow Interim Environmental Objectives for the Clyde River and Jervis Bay
(EPA, 1999)
This document sets out objectives for water quality and flow regimes within the Jervis Bay catchment area

Pending

Managing Urban Stormwater – Council Handbook (FINAL)
(NSWEPA, in progress Draft)

A final version of the EPA's 1997 publication. This document will provide state guidelines for pollution treatment objectives for new developments.

Australian Runoff Quality
(Institution of Engineers, 2005)
A collation of current best practice guidelines on urban stormwater serving as a national guideline on water quality treatment best practice. The document strongly advocates the use of Water Sensitive Urban Design (WSUD).

The principal water quality objective often applied to recent urban release areas has been *"the maintenance of water quality within receiving water bodies at pre-development levels".* This is also the approach advocated by Appendix H1 of the Draft Managing Urban Stormwater – Council Handbook (1997). This is an appropriate water quality objective for the Vincentia Coastal Village and District Centre. However, given that almost the whole site is forested or heathland and with only small portions of the headwaters of each of the 3 subcatchments covering the site subject to a rural land use, meeting an objective of *no net increase in pollutant loadings* will be a demanding requirement.

To achieve this level of performance, current industry guidelines such as Australian Runoff Quality advocate the use of Water Sensitive Urban Design (WSUD) principles. Essentially these encourage the management of the urban water cycle through maximisation of re-use opportunities and the distribution of water quality controls across the development (rather than focussing on "end of pipe" solutions).

The above approach is consistent with the water quality and flow objectives set out in the Jervis Bay Settlement Strategy, which calls for new development to be located and designed to avoid detrimental impacts on water bodies and watercourse, including groundwater.

3.2. SURVEY

At the outset of this study topographic mapping of the study area with 1-m contours was available, based on survey work conducted in 1981 by Allen Price & Associates.

Supplementary survey work was carried out by Allen Price & Associates in September/October 2003 for the WSUD study. This included detailed creek cross sections of the creeks within the site and several additional creek cross sections downstream of the site boundary. The Allen Price & Associates 2003 survey was used to extract cross-sections for HECRAS flood modelling.

Ortho-rectified aerial photography of the site and environs was also obtained from LPI in November 2003 and is used as a backdrop for a number of the figures presented in this report.

3.3. GEOTECHNICAL DATA

Geological mapping shows the majority of the site to be underlain by Wandrawandian Siltstone with the low-lying north eastern portion underlain by Quaternary alluvium (flood plain sands, gravels and clays).

The geotechnical study observes that soil on the ridges and slopes pose little or no risk in terms of salinity risk (Network Geotechnics, 2004). The only salinity risk identified was on the valley floors, which are to be deliberately left undisturbed. Similarly, the geotechnical report found it unlikely that potential acid sulfate soil would be encountered on the site. In this regard however, there was a recommendation to take care with earthworks or foundations below RL +3 m AHD (but development of such areas is an unlikely scenario as the lower lying parts of the site are to be designated as riparian corridors).

3.4. RAINFALL AND EVAPORATION

Daily rainfall data was available for the Bureau of Meteorology Jervis Bay gauge at Point Perpendicular Lighthouse (gauge no. 68034), approximately 17 km from the Vincentia

Coastal Village site. The total record period used for modelling purposes extended from July 1899 to November 2003. A summary of annual rainfall statistics is reproduced in **Table 3.1** below. Daily rainfall for the record period is presented graphically in **Figure 2**.

Table 3.1 – Jervis Bay Annual Rainfall Statistics (BOM Gauge No 68034)[a]

	Annual Rainfall (mm)	Corresponding Year
Minimum	585.9	1940
10th Percentile (Dry) Year	826.9	1907
Median	1144.6	1964
90th Percentile (Wet) Year	1767.1	1914
Maximum	2493.6	1961
Average	**1241.2**	**1911** [b]

[a] Excluding years 1899, 1919, 1994, 2003 for which partial data only was available
[b] Calendar year closest to the long-term annual average rainfall of 1241 mm (actual 1911 rainfall 1253 mm)

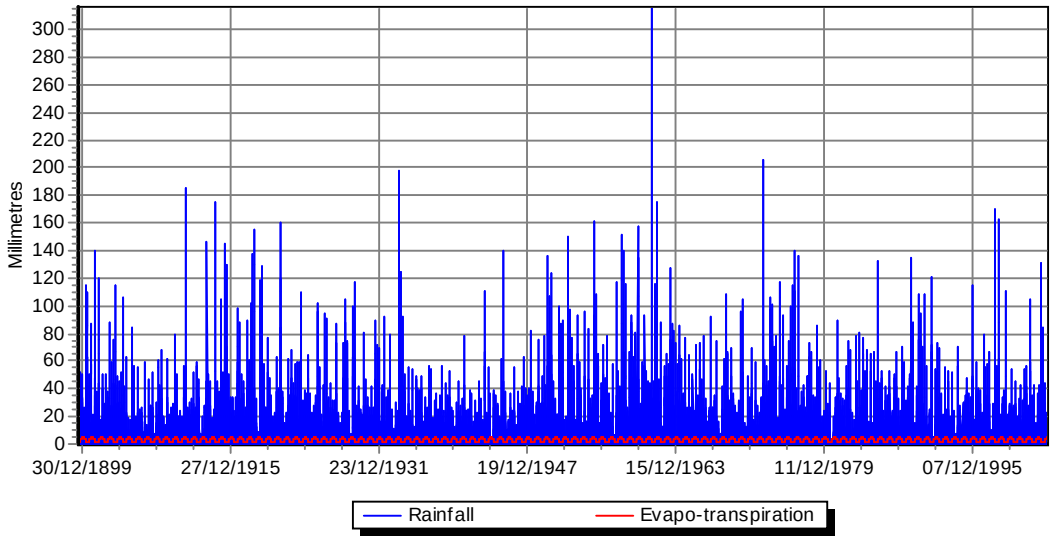


Figure 2 Daily Rainfall and Evapo-transpiration (Jervis Bay)

Evapo-transpiration values for the region were determined from maps provided by the Bureau of Meteorology. The data used for the evapo-transpiration is shown in **Table 3.2**.

Table 3.2 - Average Monthly Potential Evapo-Transpiration (mm/Month)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Evapo-transpiration	170	130	120	85	55	43	43	58	82	128	142	158	1214

3.5. WATER QUALITY DATA PRIOR TO COMMENCEMENT OF THIS STUDY

Whilst there is no comprehensive long term water quality data available for the Moona Moona Creek wetlands (approximately 0.5 km downstream of the site boundary), there is reference in Lyall & Macoun's 1998 report to a limited sampling program undertaken by Council in the Moona Moona Creek estuary over the period 1992-97. Parameters measured were turbidity, dissolved oxygen and faecal coliforms. The data indicates good water quality, but there is no information on the estuary's nutrient status. The Lyall & Macoun report also refers to a study by Broadbent in 1988 which indicates no sign of degradation to

the wetlands by human activity other than sediment associated with the Collingwood Beach development and the sewerage line behind Collingwood Beach.

Further enquiries were made of Shoalhaven City Council in regard to any more recent data that may be available. Mr Andrew Gibbs of SCC advised water quality testing is undertaken regularly in Moona Moona Ck and at other locations along the Vincentia beachfront. However, the samples are primarily tested for bacterial pathogens associated with sewage contamination (such as faecal coliforms) and not for analytes that are indicators of stormwater quality (such as total suspended solids, phosphorous and nitrogen). Council is currently in the process of collating the available water quality data and has undertaken to provide it to the Stockland consultant team.

Some initial baseline water quality monitoring was also arranged by Stockland prior to the commencement of this WSUD study. This involved an initial sampling campaign by Network Geotechnics comprising grab samples at 3 locations immediately after a moderate rainfall event and tested them for a wide range of analytes including total dissolved solids, turbidity, heavy metals, pesticides and some nutrients.

The test results indicate that some trace metals (aluminium, chromium, lead and zinc) and also ammonia are at elevated levels, when compared with the default trigger values for 99% protection of species criteria for category 1 high conservation/ecological value (refer ANZECC/ ARMCANZZ 2000 Table 3.4.1 for metals; and Table 3.3.2 “South-East Australia, slightly disturbed low land rivers” for nutrients and biodegradable inorganic matter). The trace metals are typical of the urban suite of pollutants associated with runoff from road surfaces, and the ammonia may be indicative of the rural landuse to the south of Naval College Road.

Results for all tested analytes are reproduced in **Table 1 of Appendix A**.

3.6. WATER QUALITY DATA OBTAINED AS PART OF THIS STUDY

Further baseline monitoring has been conducted as part of this study in response to agency requests for more extensive predevelopment baseline data. This has included more detailed testing of nutrients (ie, various forms of nitrogen and phosphorus) coupled with flow measurements. Sampling parameters include: total suspended solids; oil & grease; ammonia-nitrogen; total oxidised nitrogen; Total Kjeldahl Nitrogen; total phosphorus; and reactive phosphorus.

Four surface water quality sampling campaigns were carried out between October 2004 and January 2005, each involving collection of samples at 5 locations (monitoring was not possible earlier than this time because of the dry winter experienced in the south coast region in 2004).

The sampling locations comprised 3 upstream locations, on each of the Western, Central and Eastern creeks (at culvert locations on Naval College Road), and at 2 downstream locations on the Central and Eastern Creeks (at existing track crossings of these creeks). Refer to **Figure 3** for sampling locations (location SW1 to SW5).

Results for the four campaigns are presented in **Table 3 of Appendix A**.

The water quality results are analogous to mildly polluted stormwater runoff when compared to published event mean concentrations for mixed rural and urban catchments. For further discussion, refer to **Appendix A** (an internal report on the outcomes of the water quality monitoring program prepared in March 2005).

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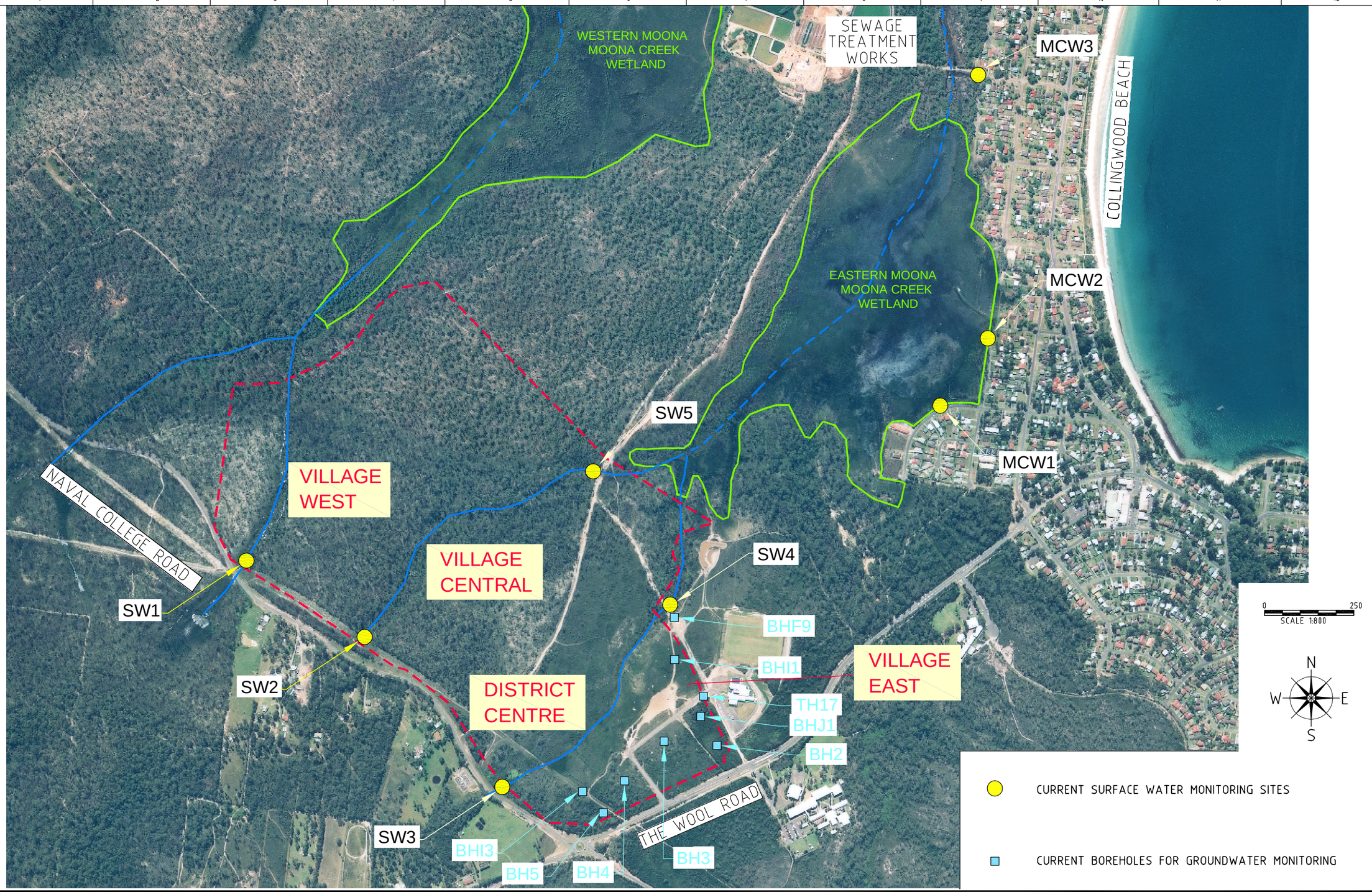

REV	DATE	BY	APP.	DETAILS
P1	13/01/06	AP	AW	UPDATED FOR DEC 2005 DEVELOPMENT FOOTPRINT

DRAWING STATUS		
DESIGN BY	AW	26/10/04
DRAWN BY	AW	26/10/04
DRAFTING CHECK	CM	26/10/04
DESIGN CHECK	AW	26/10/04
FINAL APPROVAL	PSN	26/10/04

PRELIMINARY

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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 and DISTRICT CENTRE VINCENTIA
for
STOCKLAND DEVELOPMENTS PTY LTD

DRAWING TITLE
CURRENT MONITORING SITES

Project No.	Com No.	Drawing No.	REV
104016		FIG 3	P1

File Plotted: U:\2004\104-016-03 - VINCENTIA DISTRICT CENTRE - WSUD STUDY\MONITORING\DRAWING\BUILD\13-01-06\FIG3_RPT 004-MONITORING SITES LOCATIONS DETAIL.DWG
January 13, 2006 4:48:26 p.m.
Xrefs: x104016-03_Base_3.DWG

A1

It is observed baseline from the baseline monitoring program conducted to date that storm water quality from areas upstream of Naval College Road is relatively poor. This suggests that treatment measures should target (where possible) stormwater running on the site from above Naval College Road.

More recently (in September 2005), Stockland has instructed Forbes Rigby to conduct further surface water quality monitoring, as a continuation of the baseline monitoring program discussed above. This includes sampling at the 5 previous locations within or near Stockland's site (SW1 to SW5), providing for 2 wet and 2 dry weather sampling campaigns, and additionally involves testing for faecal coliforms as well as nutrient parameters, suspended solids and grease & oils. The scope of monitoring work has also been expanded to include additional water quality monitoring points within the Moona Moona Creek wetlands (MCW1 to MCW3).

To date, one further (wet weather) campaign has been carried out, in late November 2005. This recent campaign was preceded by and undertaken in quite wet conditions with 52mm experienced in the week of sampling which includes approximately 25mm on the actual day of sampling.

Results for faecal coliforms (not analysed in previous campaigns) for the 8 surface water sites sampled (including 3 sites in Moona Moona Ck wetlands) were all well below the National Water Quality Guidelines (Recreational Waters) for Secondary contact (median of 1000cfu/100mL). Only one site (SW3) exceeded the guideline value for primary contact (median of 150/100mL).

As a whole, the results from the recent December 2005 campaign indicate similar water quality compared to previous campaigns. One trend observed however in the most recent data is that 'natural' treatment of Nitrogen and Phosphorus appears to be occurring within the Eastern Moona Moona Creek wetland, with higher concentrations recorded in the sites near the Collingwood Beach development (MCW1 and MCW2), and significantly lower concentrations at the downstream monitoring location within this wetland which is located at the road crossing leading to the sewage treatment plant (MCW3).

4. HYDROLOGY & EXTENT OF FLOOD INUNDATION

4.1. CATCHMENT DESCRIPTION & RECEIVING WATERS

As indicated in the introductory section, there are three valleys draining the site which are separated by two ridges, running in a north-easterly direction. These valleys extend a short distance south of Naval College Road.

Creek morphology within the site is generally not well defined except in the lower reaches, as the streams are ephemeral, valley slopes relatively gentle and the catchments limited in size.

The westernmost sub-catchment drains to a Moona Moona Creek wetland immediately to the west of the exiting sewage treatment works.

The central and eastern subcatchments join at the northern boundary of the site and drain to another Moona Moona Creek wetland, immediately behind the existing residential area on Collingwood Beach.

Both of these wetlands form part of the Moona Moona creek estuary wetland complex (see **Figure 1**).

4.2. CALCULATED PEAK FLOWS

The computer model 'Watershed Bounded Network Model' WBNM2003v100 (Boyd et al, 2003) was used as the primary tool for hydrological modelling of the catchment. WBNM is an advanced storage-routing model that allows simulation of complex catchment behaviour. This particular model was considered most appropriate to the task of modelling the subject catchment, given its prior use in the region and its ability to model a wide range of catchment characteristics. The model allowed peak flows to be established at various locations throughout the subject site.

The constructed model reflected input from:

- Council's GIS database for cadastral information
- Aerial photography for the establishment of impervious/pervious areas
- 1m contours from survey data (for subject site and majority of catchment) for determination of catchment and sub-catchment boundaries
- 10m contours from 1:25,000 topographic map (for areas not included in survey data) for determination of catchment and sub-catchment boundaries.

The WBNM parameters used for analysis are listed in **Table 4.1** below. Details of the sub-catchment breakdown used for the hydrologic modelling are presented in **Figure 4**.

Table 4.1 - WBNM Model Parameters

Parameter	Value	Comment
Initial loss (pervious surface)	0 mm	Reflecting prior rainfall not accounted for in storm 'burst'
Initial loss (impervious surface)	0 mm	
Continuing loss (pervious surface)	2.5 mm/hr	Cordery (1974)
C (Lag parameter)	1.29	Regional default [a]
Stream routing factor	1.00	Model default [b]

[a] *This value was adopted given to the large amount of calibrated modelling in the Illawarra and NSW South Coast based on this value*.
[b] *Appropriate for natural streams*

The model was re-run with a spectrum of storm durations to allow determination of the critical design storm duration for the existing catchment. It was established for events up to and including the 1% AEP flood that the critical duration is 120 minutes, while for the PMF the critical duration is 60 minutes.

Discharges were computed for the catchment for a range of design events from the 1-year ARI up to the PMF. The resulting peak flood discharges at various locations in the catchment and from storms of critical duration are reproduced in **Table 4.2** below.