Delfin Lend Lease

Cardno
Shaping the Future

Calderwood Urban Development Project

Water Cycle Management Study

Project Number: 110026-03/Report 003 Rev 0
Prepared for: Delfin Lend Lease
February 2010

Cardno Forbes Rigby Pty Ltd
ABN 41 003 936 981
278 Keira Street, Wollongong
NSW 2500 Australia
Telephone: 02 4228 4133
Facsimile: 02 4228 6811
International: +61 2 4228 4133
Cardno@cardno.com.au
www.cardno.com.au

Document Control

Version	Date	Author		Reviewer	
Rev 0	February 2010	Mark Favetta	MBF	Anthony Barthelmess	AJB

Prepared by
for and on behalf of
CARDNO FORBES RIGBY PTY LTD

Mark Favetta
Environmental Engineer

Reviewed by

Anthony Barthelmess
Project Director

Executive Summary

This Water Cycle Management Study (WCMS) has been prepared by Cardno Forbes Rigby to accompany a Concept Plan Application under Part 3A of the *Environmental Planning & Assessment Act, 1979* (EP&A Act) and a proposal for State significant site listing under Schedule 3 of *State Environmental Planning Policy Major Development 2005* (SEPP Major Development) in relation to the Calderwood Urban Development Project.

The Calderwood Urban Development Project is a master planned community development by Delfin Lend Lease (DLL).

The Calderwood Urban Development Project proposes a mix of residential, employment, retail, education, conservation and open space uses. The development proposes approximately 4,800 dwellings and approximately 50 hectares of retail, education, community and mixed use / employment land. The overall development will accommodate approximately 12,400 people and will deliver an estimated $2.9 billion in development expenditure and create approximately 8,000 full time equivalent jobs by 2031.

The Calderwood Urban Development Project site is located within the Calderwood Valley in the Illawarra Region. It is approximately 700 hectares in area with approximately 600 hectares of land in the Shellharbour LGA and the balance located within the Wollongong LGA.

The Part 3A process under the EP&A Act allows the CUDP to be planned, assessed and delivered in a holistic manner, with a uniform set of planning provisions and determination by a single consent authority. This Water Cycle Management Study (WCMS) has been prepared to fulfil the Environmental Assessment Requirements issued by the Director General for a Project approval for Stage 1 of the overall development. In accordance with the Director General's Requirements this WCMS has been prepared following consultation with the following agencies:

- Department of Environment and Climate Change and Water (DECCW)
- Shellharbour City Council
- Wollongong City Council
- Lake Illawarra Authority

This study investigates a range of Water Sensitive Urban Design (WSUD) features that could be suitably incorporated into the Calderwood Urban Development Project.

Existing water quality is investigated and compared to water quality expected once the development is complete. A future climate change scenario is also considered. Several WSUD features are then recommended based on the concept level water quality modelling.

- The modelling results presented in this report indicate that the development will improve stormwater quality for water originating from the site. The pollutant load reduction also meets the required annual load reductions of 80%, 45%, 45% TSS, TP and TN respectively from urban developed areas, in accordance with the national water quality guideline Australian Runoff Quality.

Operational issues are also discussed in terms of soil and water management during construction, maintenance and post-construction water quality monitoring. This report meets the DGR's for water quality and water sensitive urban design related issues.

It is recommended that the Calderwood Urban Development Project adopt the proposed water quality treatment measures identified in **Table 4.3** of this report for the Concept Plan and Project Applications.

Table of Contents

List of Tables

List of Figures

Annexes

1 Introduction

1.1 Background

This Water Cycle Management Study (WCMS) has been prepared by Cardno Forbes Rigby to accompany a Concept Plan Application under Part 3A of the *Environmental Planning & Assessment Act, 1979* (EP&A Act) and a proposal for State significant site listing under Schedule 3 of *State Environmental Planning Policy Major Development 2005* (SEPP Major Development) in relation to the Calderwood Urban Development Project.

The Calderwood Urban Development Project is a master planned community development by Delfin Lend Lease (DLL).

The Calderwood Urban Development Project proposes a mix of residential, employment, retail, education, conservation and open space uses. The development proposes approximately 4,800 dwellings and approximately 50 hectares of retail, education, community and mixed use / employment land. The overall development will accommodate approximately 12,400 people and will deliver an estimated $2.9 billion in development expenditure and create approximately 8,000 full time equivalent jobs by 2031.

The Calderwood Urban Development Project site is located within the Calderwood Valley in the Illawarra Region. It is approximately 706 hectares in area with approximately 600 hectares of land in the Shellharbour LGA and the balance located within the Wollongong LGA.

The Calderwood Valley is bounded to the north by Marshall Mount Creek (which forms the boundary between the Shellharbour and Wollongong LGAs), to the east by the Macquarie Rivulet, to the south by Johnstons Spur and to the west by the Illawarra Escarpment. Beyond Johnstons Spur to the south is the adjoining Macquarie Rivulet Valley within the suburb of North Macquarie. The Calderwood Urban Development Project land extends south from the Calderwood Valley to the Illawarra Highway. Refer to Location Plan at **Figure 1**.

The Calderwood Valley has long been recognised as a location for future urban development, firstly in the Illawarra Urban and Metropolitan Development Programmes and more recently in the Illawarra Regional Strategy (IRS).

The IRS nominates Calderwood as an alternate release area if demand for additional housing supply arises because of growth beyond projections of the Strategy, or if regional lot supply is lower than expected.

In 2008, the former Growth Centres Commission reviewed the proposed West Dapto Release Area (WDRA) draft planning documents . The GCC concluded that forecast housing land supply in the IRS cannot be delivered as expected due to implementation difficulties with the WDRA, and the significantly lower than anticipated supply of housing land to market in the Illawarra Region is now been recognised as a reality.

The GCC Review of the WDRA also recognised that there is merit in the early release of Calderwood in terms of creating a higher dwelling production rate and meeting State government policy to release as much land to the market as quickly as possible. Given the demonstrated shortfall in land supply in the Illawarra Region and the WDRA implementation difficulties highlighted in the GCC Report, the release of Calderwood for urban development now conforms to its strategic role under the IRS as a source of supply triggered by on-going delays in regional lot supply. The Calderwood Urban Development Project can deliver about 12% of the IRS' new dwelling target.

Changes in outlook arising from global, national and regional factors influencing investment and delivery certainty, housing supply and affordability and employment and economic development also add to the case for immediate commencement of the Calderwood Project.

In April 2008 the Minister for Planning issued terms of reference for the preparation of a Justification Report to address the implications of initiating the rezoning of Calderwood for urban development including associated staging, timing and infrastructure considerations.

In February 2009 the Minister for Planning considered a Preliminary Assessment Report for the Calderwood Urban Development Project that provided justification for the planning, assessment and delivery of the project to occur under Part 3A of the EP&A Act, having regard to the demonstrated contribution that the project will have to achieving State and regional planning objectives.

Subsequently, on the 16 April 2009, pursuant to Clause 6 of SEPP Major Development, the Minister for Planning formed the opinion that the Calderwood Urban Development Project constitutes a Major Project to be assessed and determined under Part 3A of the EP&A Act, and also authorised the submission of a Concept Plan for the site. In doing so, the Minister also formed the opinion that a State significant site (SSS) study be undertaken to determine whether to list the site as a State Significant site in Schedule 3 of SEPP Major Development.

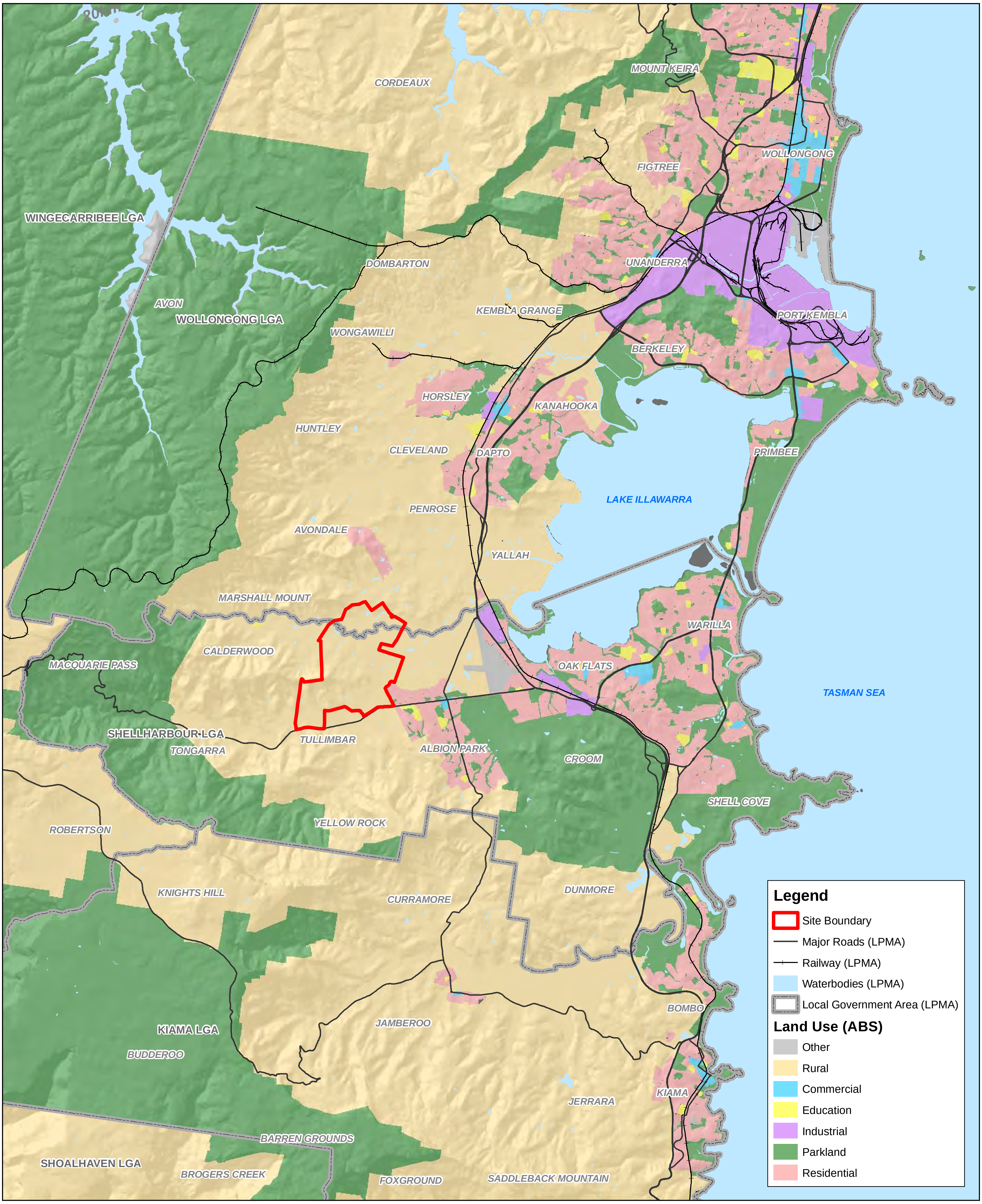
The Part 3A process under the EP&A Act allows for the Calderwood Urban Development Project to be planned, assessed and delivered in an holistic manner, with a uniform set of planning provisions and determination by a single consent authority. Given the scale of the proposal, the Concept Plan and SSS listing provide the opportunity to identify and resolve key issues such as land use and urban form, development staging, infrastructure delivery and environmental management in an integrated and timely manner.

This WCMS has been prepared to fulfil the Environmental Assessment Requirements issued by the Director General for the inclusion of the Calderwood site as a State Significant Site under SEPP Major Development, and for a Concept Plan approval for the development. Specifically, this WCMS addresses the Director General Requirements relating to Floodplain Risk Management, as described in Section 1.2 of this report.

In accordance with the Director General's Requirements this WCMS has been prepared following consultation with the following agencies:

- Department of Environment and Climate Change and Water (DECCW)
- Shellharbour City Council
- Wollongong City Council
- Lake Illawarra Authority

Details of the consultation are further discussed in **Section 1.2**.



Delfin Lend Lease

Scale 1:100,000 (at A3)

Metres

0 1000 2000 3000 4000 5000

Location Plan

FIGURE 1

CALDERWOOD URBAN DEVELOPMENT PROJECT

Cardno

Map Produced by Cardno Wollongong
Date: 15 February 2010
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF: 110026-01_18022_LocationPlan.mxd 06

1.2 Director General's Requirements

This study is required to address the DGR's as they relate to water cycle management. These are shown in **Table 1.1**:

Table 1.1 – Director General's Requirements

DGR	Section of this Report where Compliance is Confirmed
Flooding assessment of any flood risk for the site should be conducted in accordance with the NSW Government's Flood Prone Land Policy as set out in the Floodplain Development Manual 2005	Assessment of flood risk has been undertaken in accordance with the principles of the Floodplain Development Manual. Refer to Macquarie Rivulet Flood Study (Rienco, 2009).
Flood Study Report for existing conditions is to be prepared to include hydrologic and hydraulic models, calibration against existing local flood records, downstream and upstream conditions, and floodplain characteristics.	A detailed flood study has been prepared. Refer to Macquarie Rivulet Flood Study (Rienco, 2009). This study wholly meets the requirements of the DGR's and the principles of the Floodplain Development Manual.
Flood Risk Management Assessment Report for the development including estimation of Flood Planning Levels and Flood Planning Area, extent of flood prone and mapping, flood behaviour, flood risks up to the PMF, evacuation, and impacts of climate change.	The FPRMS (Cardno, 2010) addresses the range of issues requested in the DGR's.
Consider Shellharbour Council's Floodplain Risk Management DCP and justify any departure.	Shellharbour Council's Floodplain Risk Management DCP has been explicitly considered in the development of strategies for flood related planning controls presented in FPRMS (Cardno, 2010)
Consideration of upstream and downstream flows and impacts of development yet to be built.	As all development is required to have no impacts on peak flows upstream or downstream, it has been assumed that any future development would have no impacts on the Calderwood project. This is further described in detail in the Macquarie Rivulet Flood Study (Rienco, 2009) under separate cover.
Assess geomorphic impacts on the watercourses and floodplain area affected by the proposal.	Such an assessment has been undertaken and is issued under separate cover.
Surface Water and Groundwater assessment including any proposed surface water and groundwater extraction volumes, function and location of proposed storage/ponds, design, layout, pumping and storage capacities, and all associated earthworks and infrastructure works.	This WCMS addresses these issues in chapters 4, 5 6 and 7. Further detail on watercourse and riparian corridors requirements are addressed in the Ecology and Bushfire Studies (Eco Logical Australia)
Details on any water management structures/dams both existing and proposed including size and storage capacity.	Wetlands and Ponds will be sized at typically 2 – 3% of the upstream urban catchment area.
Identify groundwater issues including predicted highest groundwater table at the site, works likely to affect groundwater surfaces, and proposed extraction, prevention of groundwater pollution.	Information on groundwater issues can be found in the Land Capability, Contamination and Geotechnical Studies (Douglas Partners, 2010)
Assess any potential impact on surrounding waterways and wetlands in terms of water quality, aquatic ecosystems and riparian corridors. This should include but not be limited to Onsite pollution such as accidental spills and sewer overflows, Risks such as weed invasion, encroachment and litter; and Vegetated buffer zones.	Impacts in terms of water quality are discussed in this report in chapters 5 and 6. Impacts on ecosystems and riparian corridors can be found in the Ecology and Bushfire Studies report (Eco Logical Australia).
The EA should address drainage and stormwater management issues, including on site detention of stormwater; water sensitive urban design (WSUD) and drainage infrastructure.	This WCMS addresses the range of issues requested in the DGR's.

1.3 Concurrent Studies

The WCMS should be read in conjunction with the following studies:

- Flood Study (Rienco)
- Floodplain Risk Management Study (Cardno)
- State Significant Site Listing and Concept Plan Application (JBA Urban Planning)
- Project Application Stage 1 (Cardno)
- Ecology and Bushfire Studies (Eco Logical Australia)
- Land Capability, Contamination and Geotechnical Studies (Douglas Partners)
- Transport Study (Cardno)
- Landscape and Visual Study (Environmental Partnership NSW)
- Community Facilities and Open Space Study (Elton Consulting)
- European Heritage Study (Eco Logical Australia / Paul Davies)
- Aboriginal Heritage Study (Eco Logical Australia / Austral Archaeology)

1.4 Purpose of this Report

The objectives of the WCMS study for the Calderwood Urban Development Project are to:

- establish a water cycle management strategy based on water sensitive urban design (WSUD) principles that:
    - o is acceptable to the DoP, DECCW, Shellharbour City and Wollongong City Council's and which contributes to relevant water quality objectives;
    - o meets stormwater targets required by the Lake Illawarra Authority;
    - o effectively and efficiently manages the quality and quantity components of stormwater within the catchment;
    - o meets potable water supply conservation targets and identifies sustainable integrated options for water supply, wastewater and stormwater servicing;
    - o optimises the land take to implement the above strategies with consideration for integration with urban design, salinity risk and riparian corridor protection measures;
    - o recognises the potential for each site to operate as independent systems in terms of wastewater treatment; and
    - o includes an implementation plan to ensure the early provision and effective ongoing management of appropriate services and facilities.
- address, where appropriate, environmental site management issues likely to arise during the construction phase.

It should be noted that the recommendations presented in this reports relate to concept designs only. The preliminary wetland/pond designs 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 (i.e. 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 Councils that any changes made are consistent with the preliminary design intent presented in this study.

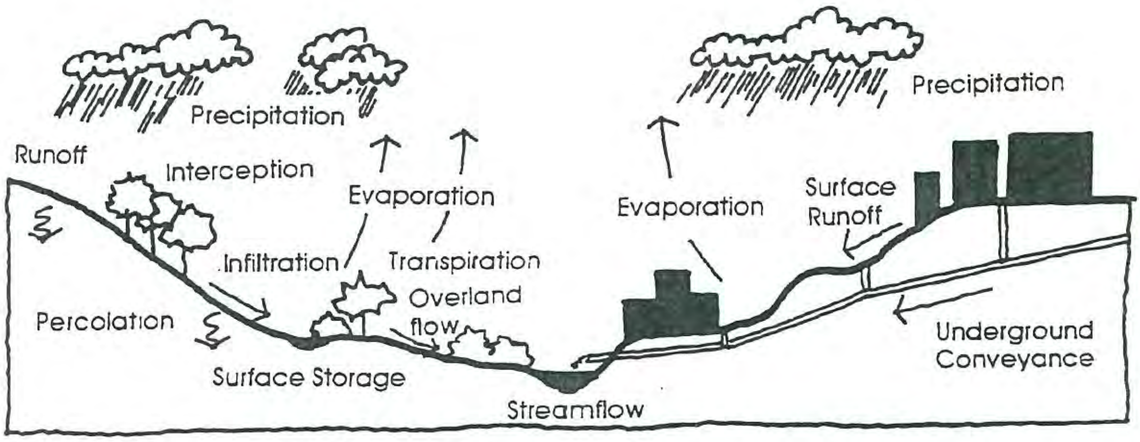
Additionally, further water quality modelling should be undertaken at the detailed design stage to confirm system performance. In this regard, we note that it may be possible (based on further detailed stormwater quality modelling) to reduce the number of Gross Pollutant Traps (GPT's) by constructing 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 GPT's, but would increase the cost of drainage pipelines. Optimisation of the number of GPT's would thus be determined during detailed design.

1.5 The Urban Water Cycle

The urban water cycle is shown in graphical form in **Figure 2**, which is extracted from the NSWEPA Council handbook (EPA, 1997). This figure however is a simplified depiction of what is now described as water cycle management in the urban development context. Urban water cycle management comprises four key components:

- stormwater management (eg, wetlands, swales, bioretention systems)
- water supply management (with a current focus on rainwater tanks and demand management)
- wastewater management (with a focus on reclaimed water use; dual reticulation for potable and recycled non-potable water)
- groundwater management (eg, preserving current groundwater flow patterns for site-specific environmental reasons; possible aquifer storage of recycled water where suitable aquifers exist; and salinity management).

Figure 2 – Typical Urban Water Cycle



1.6 Structure of this Report

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** 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 3** 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 4** provides an overview of the possible impacts of the development and appraises a range of WSUD options that would mitigate against those impacts.
- **Chapter 5** proposes suitable WSUD measures that can be implemented to meet adopted water quality objectives.
- **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.
- **Chapter 7** describes the components of the recommended scheme in more detail with respect to the Concept Plan.
- **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 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.

1.7 Agency Consultation

1.7.1 Consultation with DECCW

A meeting with DECCW was held at the DoP offices on 20 October 2009. DECC's comments (combined with notes of the meeting and their comments to DoP) are summarised in **Table 1.2** below; followed by comments relating to which sections of the report address DECCW's comments.

Table 1.2 – Summary of DECCW's Requirements

DECCW's Comment	How and Where Addressed in this Study
The impact of flooding on the development (for example, inundation and structural adequacy)	Inundation maps are presented in the FPRMS
The impact of the development on flood behaviour including any management measures to mitigate adverse flood impacts	The impacts of the development on flood behaviour have been quantified using the same methodology as modeled by Council, DECCW and SES for other regionally significant projects. These impacts have been quantified and are presented in the FPRMS.
The implications of climate change on flooding and Flood Planning Levels (FPL)	The impacts of climate change on the proposed site have already been undertaken by Council, DECCW and SES for other regionally significant projects. Our strategies are discussed in the FPRMS.
The impacts of bridges on the flood behaviour including impacts of debris and blockage of waterway openings	The impacts of these structures have been modelled and described in the FPRMS.

1.7.2 Consultation with Shellharbour City Council

A meeting with SCC was held at their offices on 25 November 2009. SCC's comments are summarised in **Table 1.3** below; followed by comments relating to which sections the report address SCC's comments.

Table 1.3 – Summary of SCC Requirements

SCC Comment	How and Where Addressed in this Study
SCC noted that model scenarios for a climate change scenario should include the latest research into increased levels in Lake Illawarra as well as % increases in rainfall intensity	Climate change, taking into account all catchment and Lake related factors, has been undertaken and described the FPRMS.
SCC described the importance of dealing with Soil & Water Management issues both during construction and throughout the life of the development	Soil & Water Management Plans would be provided at the Project Application stage for each development phase.
SCC noted that any large basins should stay below the trigger volumes/sizes for Dam Safety Committee prescription	Basins have been sized such that DSC prescription is not required.
SCC described the need for any floodplain risk management strategy adopted as part of the project to not prejudice any future development (or flood risk management strategy) that may occur as part of Council's future studies in the catchment	Every effort has been made to allow a flexible concept plan design such that any future flood mitigation works undertaken by Council will not be compromised.

1.7.3 Consultation with Wollongong City Council

A meeting with WCC was held at their offices on 14 December 2009. WCC's comments have been summarised in **Table 1.4** below; followed by comments from Cardno relating to which sections of the report address WCC's comments.

Table 1.4 – Summary of WCC Requirements

WCC Comment	How and Where Addressed in this Study
WCC enquired as to any part of the site that may drain to Duck Creek, as WCC have a concurrent study underway in Duck Creek and may need to take into account parts of the proposed development in their study	Cardno confirm that no part of the site drains to Duck Creek.
Model scenarios for a climate change scenario should include the latest research into increased levels in Lake Illawarra (2100 year) as well as 20% increases in rainfall intensity	Climate change impacts in terms of water quality have been quantified in this report and in terms of flooding impacts in the FPRMS.
The need to consider increased riparian roughness values in the modeling, to ensure that such increases are accounted for in the determination of design flood levels.	These requirements have been fully met as described in the FPRMS.

1.7.4 Consultation with the Lake Illawarra Authority

A meeting with the Lake Illawarra Authority (LIA) was held at their offices on 18 November 2009. The LIA's comments have been summarised in **Table 1.5** below; followed by comments from Cardno relating to which sections of the report address LIA's comments.

Table 1.5 – Summary of LIA Requirements

LIA Comment	How and Where Addressed in this Study
LIA noted the potential increase in runoff from urban areas having any flow-on effects in the Lake.	Increased runoff potential has been quantified, and mitigation measures such as OSD proposed. This is further described in the FPRMS.
LIA noted the requirement for an assessment of climate change and the inclusion of the latest Lake Illawarra Climate Change assessment in the flood study and water cycle management studies.	Climate change, taking into account all catchment and Lake related factors, has been undertaken and described in Section 5.3 of this report.

1.8 Consultation with the Community

A community consultation session was held at Albion Park Neighbourhood Centre on 18th October 2009. A summary of the communities concerns relating to flooding and watercourse management is presented below:

- The community felt that existing detention basins in the surrounding area did not work. They felt that such basins filled up with flood waters before the main burst of the storms, and as such the basins didn't work. The community felt care was required when designing new basins.

This express concern has been taken into account in the preparation of this report. The specific design procedures and methodology applied for this study (such as the use of the 'Embedded Design Storm' concept) is specifically targeted at estimated runoff volumes more accurately and as such, better informing basin design.

1.9 Consultation with the SES

The SES did not respond to a formal request for consultation. Notwithstanding, the SES (and other agencies) will have the opportunity to comment on the project during the formal exhibition period.

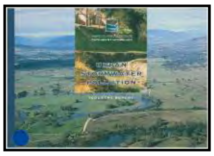
2 Available Data

2.1 Standards & Guidelines

Documents providing guidance in achieving best practice stormwater quality 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 (e.g. grass swales) through to large scale measures (e.g. constructed wetlands).

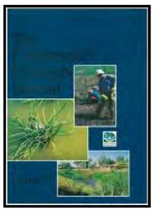


Urban Stormwater Pollution (CRC for Catchment Hydrology, 1997)

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.

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.



The Constructed Wetlands Manual (DLWC, 1998)

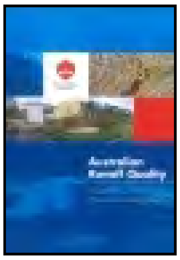
A comprehensive manual (2 volumes) that documents all aspects of the design, construction and maintenance of constructed wetlands for stormwater pollution control.

National Water Quality Management Strategy: Australian and New Zealand Guidelines for Freshwater And Marine Water Quality (ANZECC & ARMCANZ, 2000)

National risk-based guidelines based on site-specific trigger values. The guidelines promote a decision tree approach whereby further assessment is undertaken if measured concentrations exceed default triggers.

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.



Australian Runoff Quality (Institution of Engineers, 2005)

A collation of current best practice guidelines on urban stormwater. Commonly referred to as a companion document to Australian Rainfall & Runoff and is likely to become a national guideline on water quality treatment best practice. The document strongly advocates the use of Water Sensitive Urban Design (WSUD).

Whilst these guidelines produce much information, ultimately Council will have carriage over water quality issues and therefore must be satisfied as to the suitability of the adopted water quality objectives.

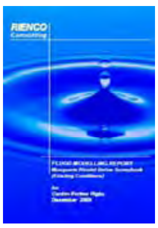
Key Standards/Guidelines applicable to the management of mainstream flooding include:

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.

The NSW Flood Plain Development Manual (NSW Gov, 2005)

This is the key document controlling development on floodplains in NSW. Local Government is only protected from litigation in this area if it can be demonstrated that they have proceeded in accordance with the requirements of this manual.



Macquarie Rivulet Flood Study (Rienco, 2009)

This document examines flooding issues relating to the floodplain area associated with the Macquarie Rivulet and Marshall Mount Creek. The study was undertaken specifically for this development.

Guidelines with respect to morphological impacts on streams associated with urban development and riparian zone management includes:

Guidelines for Stabilising Streambanks with Riparian Vegetation (CRC for Catchment Hydrology, 1999).

This document provides guidelines for assisting with planning and design of riparian re-vegetation to protect against channel erosion.

Riparian Corridor Management Study (DIPNR, 2004).

This study documents the current approach being applied by DIPNR to new urban release areas in Wollongong. Whilst the focus of this document relates to setting of riparian corridor limits in Wollongong, it also provides general management principles for any works in and around creeks.

Guidelines with respect to climate change impacts associated with urban development and riparian zone management includes:

Practical Considerations for Climate Change (DECC, 2007)

This document provides guidelines for assisting with planning and design of riparian re-vegetation to protect against channel erosion.

2.2 Survey Data

2.2.1 Aerial Laser Survey

For the present study, aerial survey techniques were used as the primary method of collecting topographic data. Specialist aerial survey firm, AAM Hatch were sub-contracted to prepare this data.

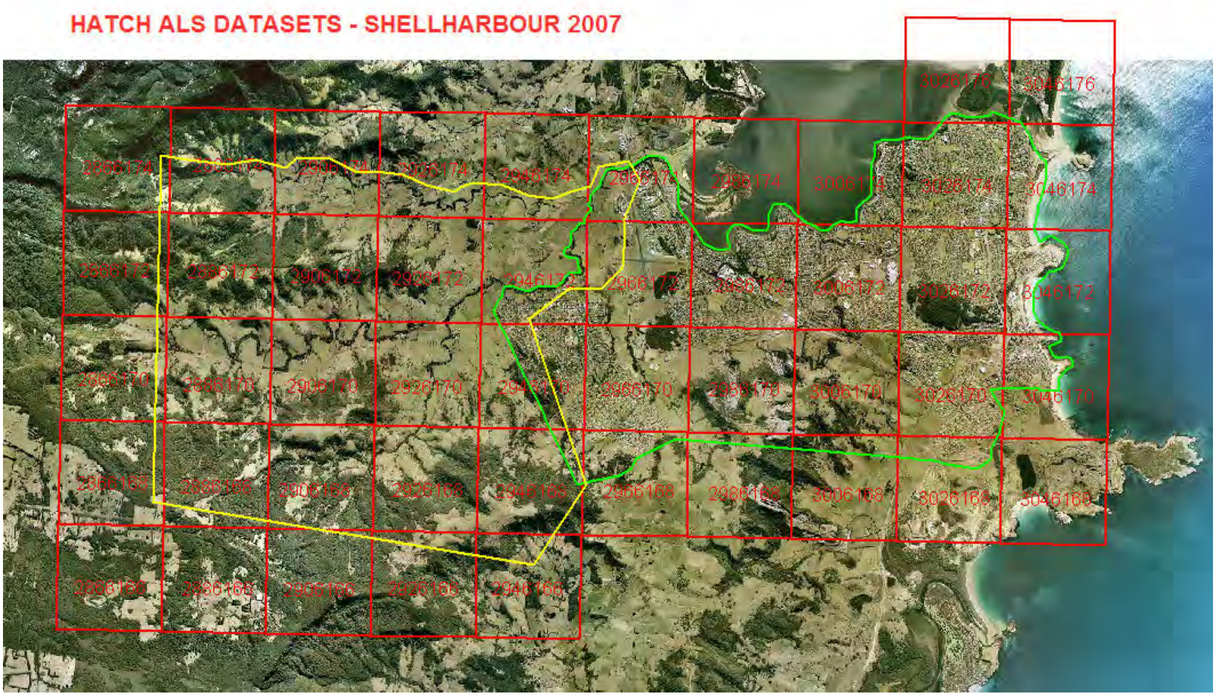
The methodology employed is known as Air-borne Laser Scanning (ALS). The ALS equipment is deployed by fixed wing aircraft flying over the site. The ALS equipment emits a continuous stream of laser beam pulses, and records the time taken for each laser pulse to return to the aircraft. This travel time is used to calculate a distance and therefore height of the ground surface relative to the aircraft. Data filtering algorithms are used to remove data that does not represent the true ground surface such as data points collected from roof surfaces or the canopy of a forest.

While this method of survey capture is useful for collection of data over large areas it is limited in that it is unable to collect ground surface data where laser beam pulses cannot penetrate (e.g. from underneath structures such as culverts and bridges or from beneath the water surface). Separate ground survey and bathymetry was therefore obtained to supplement the ALS data in these areas.

ALS data was collected for the Macquarie Rivulet area where detail 2D hydrodynamic modelling was proposed. The ALS dataset obtained for this study comprised a series of 2000m x 2000m tiles of geo-referenced spot heights. Each tile contained in the order of 500,000 individual spot height data points.

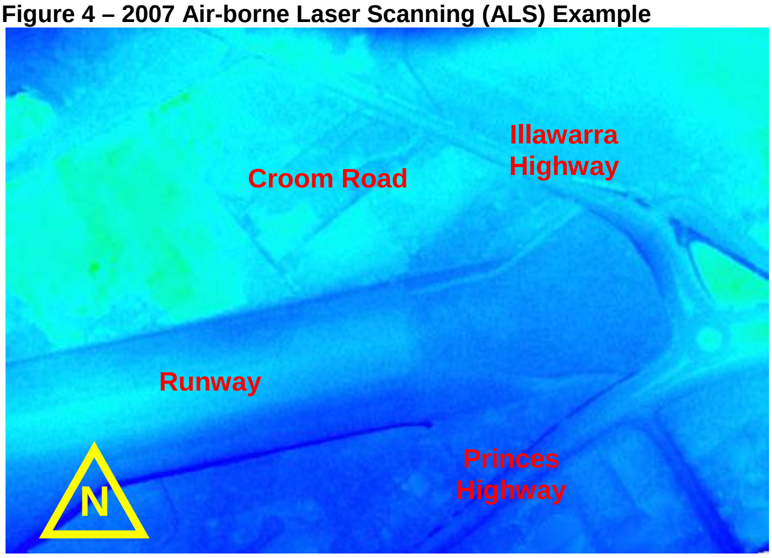
The two datasets of ALS coverage of the Macquarie Rivulet catchment obtained from Hatch are shown shaded outlined in yellow and green in **Figure 3**. When constructing the 2D model it was found desirable to extend the elevation dataset a little further up the northern side slopes of Marshal Mount Creek. Elevation data in the area was created by merging the LPI contour data with the more accurate ALS data.

Figure 3 – 2007 Air-borne Lase Scanning (ALS) Tile Coverage



The filtered data is quoted by the supplier as having an 0.1m vertical accuracy. The spacing of data points varies but typically a spot height has been obtained for every square metre or so of the surveyed surface. This vertical accuracy and dense coverage provides excellent definition of ground features as can be seen from the sample extract of **Figure 3** which shows a small area at the northern end of the main runway, coloured according to elevation. The survey data is of sufficient accuracy that even small drains are well defined and features such as the kerb lines in adjoining streets can be easily identified.

Figure 4 – 2007 Air-borne Laser Scanning (ALS) Example



2.3 Creek & drainage Structures

In order to supplement the Air-borne Laser Scanning data, separate ground survey of the catchment land surface was required at several locations throughout the catchment. This data was a composite of earlier structure survey provided by David Yates (2007) and more recent structure survey (2009) by Cardno.

Data was supplied in both electronic form (for direct input to model construction) and hard copy. All data was supplied in a suitably geo-referenced form.

Bathymetric data for Macquarie Rivulet downstream of the weir was extracted from an earlier survey (1990) undertaken by D Allen Surveyor, reproduced from the report by the WRF(1996).

Bathymetric data for Haywards Bay in the general vicinity of the outfall delta of Macquarie Rivulet was obtained from the Lake Illawarra Authority.

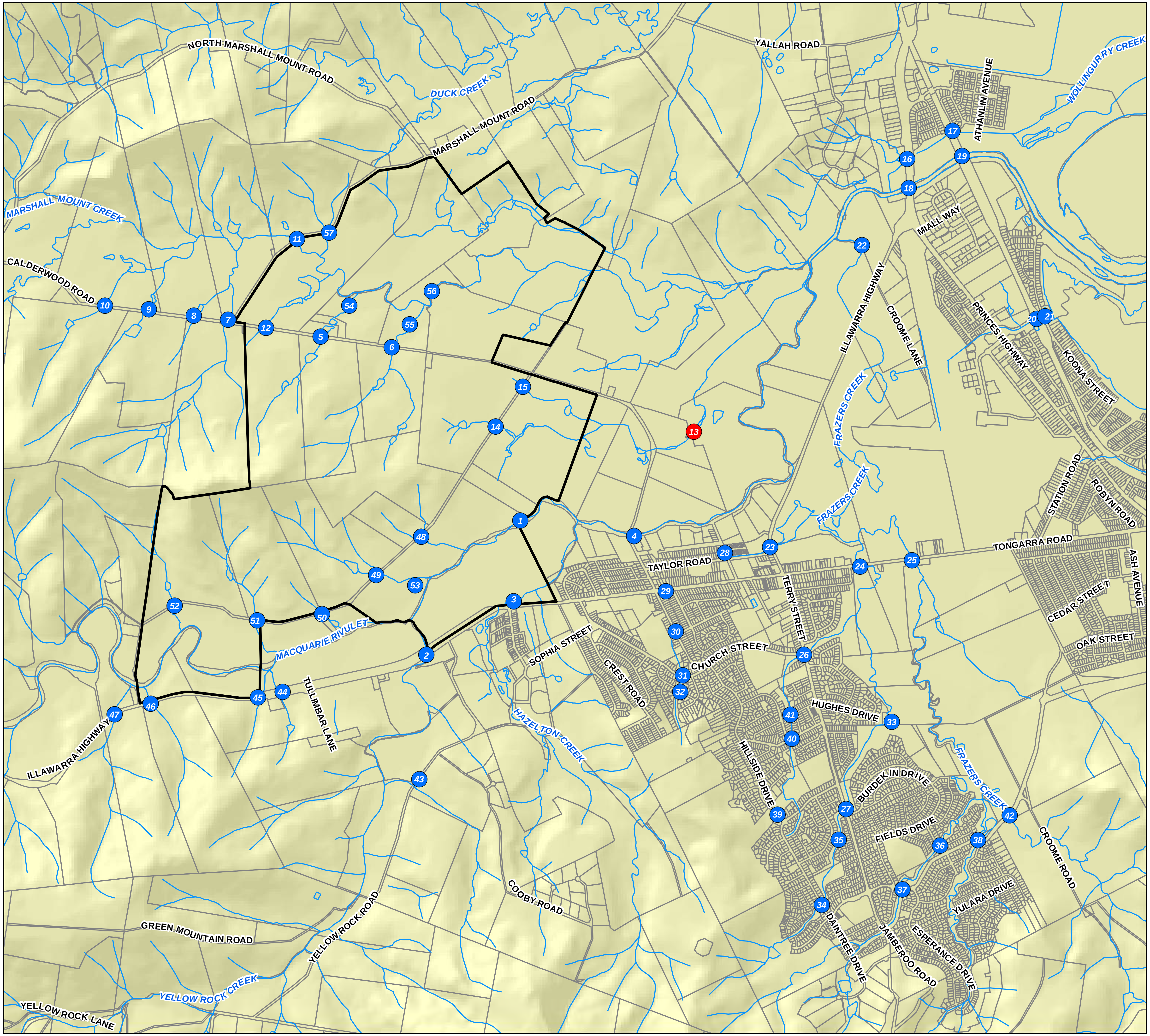
This data was merged with the land based ALS dataset to form a contiguous topographic dataset across the area to be modelled.

A structure survey was undertaken to determine the configuration and dimensions of all significant vehicular, pedestrian and rail crossings in the study area.

An initial review of the catchment was undertaken by RIENCO and each of the structures requiring survey identified. It should be noted that the structures actually incorporated in the hydraulic model were a subset of structures present in the catchment. Only those structures likely to have an impact on flood behaviour in the study area were included. The locations of all structures investigated are shown in **Figure 5**.

A review of drainage infrastructure was undertaken by RIENCO in the latter part of 2006. The objective of this review was to determine the configuration and dimensions of all major trunk drainage lines that might influence flood behaviour within the study area.

This review did not identify any trunk drainage infrastructure that would influence flood behaviour in the study area. It was noted that there is a significant, rapidly expanding drainage network associated with the village of Albion Park, but this would have minimal impact on major flooding in the study area and was not therefore included in this study.



Delfin
Lend Lease

Hydraulic Structures

CALDERWOOD
URBAN DEVELOPMENT PROJECT

Legend

Site Boundary

Hydraulic Structures (Rienco Consulting)

Inspection Completed or Not Required

Visual Inspection Required

Watercourse (LPMA)

Cadastre (LPMA)

N
W E
S

Scale 1:25,000 (at A3)

Metres

0 250 500 1,000 1,500

Cardno

Map Produced by Cardno Wollongong
Date: 16 February 2010
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF: 110026-01_38005_HydraulicStructures.mxd 04

2.4 Aerial Imagery

Cardno has sourced temporal aerial imagery for this project. The Calderwood Spatial Information Store contains 3 images as outlined in **Table 2.1**.

Table 2.1 – Aerial Imagery of Calderwood Development Site

Image	Source	Capture Method	Accuracy/Resolution	Uses
1949	LPMA	Aerial/Hard Copy Scan	0.40m based on 2000dpi scan	Geomorphology
2001	AAM Hatch	Aerial	2m	Modelling
2009	Aerial Acquisitions	Aerial	0.10cm GSD	Data capture and map generation base

2.5 Rainfall, Evaporation and Climate Change Projections

Rainfall data was supplied by the Bureau of Meteorology (BoM) for the Albion Park Gauge (#68241). A complete 50 year daily rainfall dataset was used from 1932 – 1981 for daily simulation modelling. A complete 6 year rainfall dataset 2001 – 2006 of six-minute pluviometer data was also used.

Evapo-transpiration data was sourced from BoM's climate data maps available for the period 1961 – 1990.

Climate change information for the year 2070 for rainfall and potential areal evapo-transpiration was sourced from the Climate Change in Australia Technical Report (CSIRO, 2007) and the CSIRO OzClim database.

Information on rainfall and evaporation change from 1970 – 2008 was sourced BoM's climate trend maps.

2.6 Geotechnical Data

Some geotechnical data was made available to us through liaison with Douglas Partners who are undertaking the concurrent geotechnical study. We have not however been able to fully appraise the partial information provided to us at this draft report stage, but will be able to make further comment and assessment before producing the final report after we have had the opportunity to review Douglas Partners draft report.

3 Hydrology & Flooding

3.1 Catchment Description

The Calderwood Valley study area lies within the Macquarie Rivulet catchment, 15kms southwest of Wollongong and part of the Lake Illawarra sub-basin. The Macquarie Rivulet catchment (approx 10,500 ha) is located between the Illawarra Escarpment to the west and Lake Illawarra to the east. Marshall Mount Creek (approx 1,900 ha), joins Macquarie Rivulet downstream of the village of Albion Park (and the development), forming a broad floodplain at and upstream of the junction of the two streams.

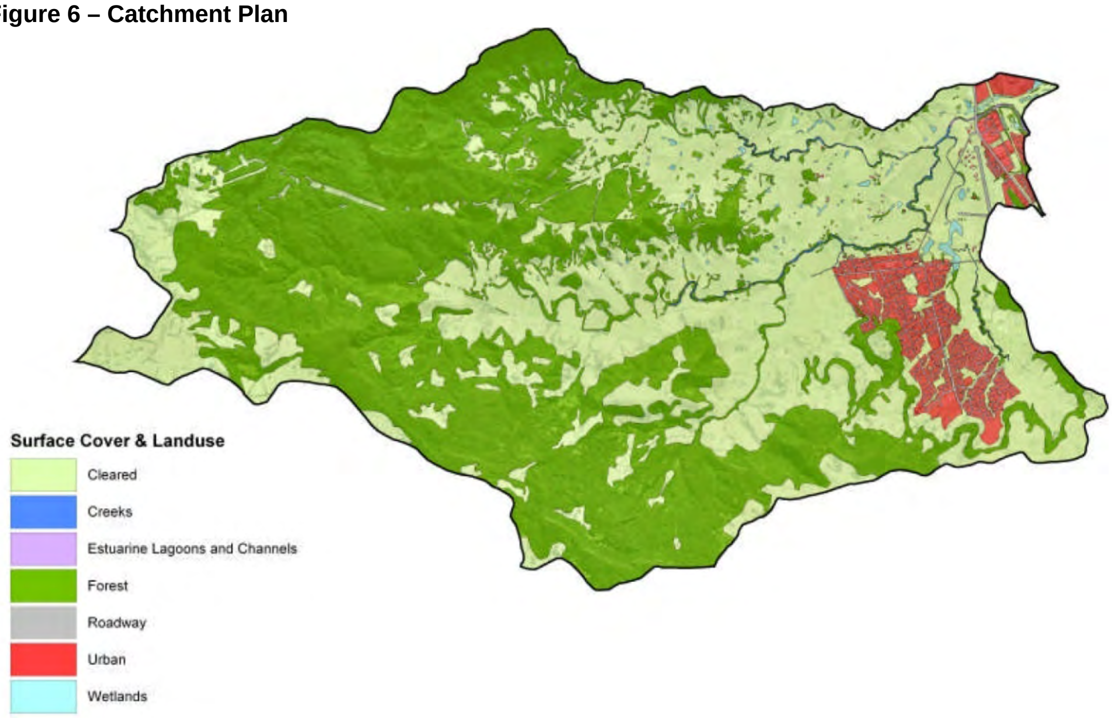
Figure 6 Catchment Plan shows the relationship between these two main watercourse catchments and the proposed Calderwood Valley development area. The specific study area is broadly contained by the mainstream of Macquarie Rivulet to the south, Marshall Mount Creek to the north and the broad floodplain of the merged streams to the east. It straddles the foothills of a major ridgeline known as Johnson's Spur.

The Macquarie Rivulet catchment is principally rural in character and is used for low-scale dairy and beef cattle grazing. However, the headwaters of the catchment, located on the Illawarra Escarpment, retain large tracts of natural forest (as these areas were historically considered unsuitable for grazing). Marshall Mount Creek is a major tributary of Macquarie Rivulet. Its catchment is similar in character to Macquarie Rivulet though it retains a smaller proportion of forest in its headwaters.

Development within the combined catchments is currently limited to the township of Albion Park, the new Haywards Bay residential estate and light industrial areas around Yallah. All these areas are within the lower part of the catchment and drain into Macquarie Rivulet downstream of the proposed Calderwood development.

Other than Calderwood Valley, the only significant future urban development on the current planning horizon is Tullimbar Village (2,000 lots) which occupies the Hazelton Creek Valley. Hazelton Creek drains into Macquarie Rivulet directly opposite the study area at the western edge of Albion Park Township. At the time of writing this report, only a small number of dwellings have been constructed (< 30 dwellings) however it is acknowledged that the current extent of zoned land would allow much more development to be located on this tributary (up to 1,500 dwellings).

Figure 6 – Catchment Plan



The stratigraphy of the catchment generally comprises Triassic age, Narrabeen Group sandstone and siltstone (cliffs), overlying Permian age Illawarra Coal Measures (base of cliffs) with talus foothill slopes (mixture of the above). These in turn run down to residual soils and clays overlying a Permian age Shoalhaven Group, Kiama tuff basement. Quaternary deposits of alluvium, sands and silts are present on flood plains and in swamps (Rienco, 2009).

Throughout the Illawarra, this coastal wedge has a similar east-west profile, with the high (600 metre) escarpment to the west, falling sharply to around the 450 metre contour level, at which point the talus slopes commence (Rienco, 2009). These slopes in turn run down at a 15 to 35% grade to around the 100 metre contour level, where residual soils and clays are encountered. In the residual soil/clay zone, surface slopes are typically in the 5 to 15% range. At around the 4 metre contour level, the profile again changes, to an overburden of recently transported sediments deposited on a relatively flat grade (Rienco, 2009).

In the late seventies and early eighties, a series of ash ponds were constructed at Tallawarra power station, infilling part of the flood plain between Macquarie Rivulet and Duck Creek. Wollingurry Creek was diverted to flow around the south eastern corner of these ponds, at this time. During 1996 earthworks began on the 450 lot Hayward's Bay subdivision. At about the same time, Koona Street was extended north over Albion Creek to service a new subdivision (Macquarie Shores) on land east of the railway line and to the immediate south of Macquarie Rivulet (Rienco, 2009).

Over the last decade, considerable new residential development has occurred around the village of Albion Park. Residential, commercial and light industrial development is generally located in the downstream (eastern) portion of the catchment with pasture in the central portion and remnant forest in the upstream (western) portion of the catchment (Rienco, 2009).

3.2 Extent of Flooding

The southern portion of the study area is located on a spur running down from the escarpment, bounded to the south by the valley containing Macquarie Rivulet, to the north by the valley containing Marshall Mount Creek and to the east by the Albion Park floodplain. A series of short steep ephemeral streams and erosion gullies drain most of the elevated ridge area, north to Marshall Mount Creek. The southern fringe of the study area drains directly to Macquarie Rivulet in a further set of short steep ephemeral streams and erosion gullies.

The northern portion of the site is, for the most part, the catchment of Marshall Mount Creek. A small portion of elevated land is present in the north-western sector of the study area that drains south, to Marshall Mount Creek. The ephemeral streams draining the study area are fed by sheet flow off the grassed paddocks. Most of these small streams have stable beds and banks with limited bank line vegetation. Some of these 'streams' have no defined channel and are merely depressions in the land. Several farm dams have been constructed on these small gullies. Some are of significant capacity. It is likely that low flow discharges to the mainstreams are significantly attenuated by these structures. There are no signs of any other man made modifications to these natural gullies.

Above the village of Albion Park, Macquarie Rivulet runs in a well-defined valley with limited opportunity for overbank flooding, particularly on the northern side of the valley where it abuts the study site. At about the level of the village, the northern floodplain increases rapidly in width and continues at this width for about a kilometre. About a kilometre downstream of the village's western boundary, the floodplain is substantially diminished in width by a significant spur of higher ground, which extends out across the northern floodplain. This spur effectively isolates the floodplain pool of Macquarie Rivulet from the floodplain pool of the merged Macquarie Rivulet and Marshall Mount creeks.

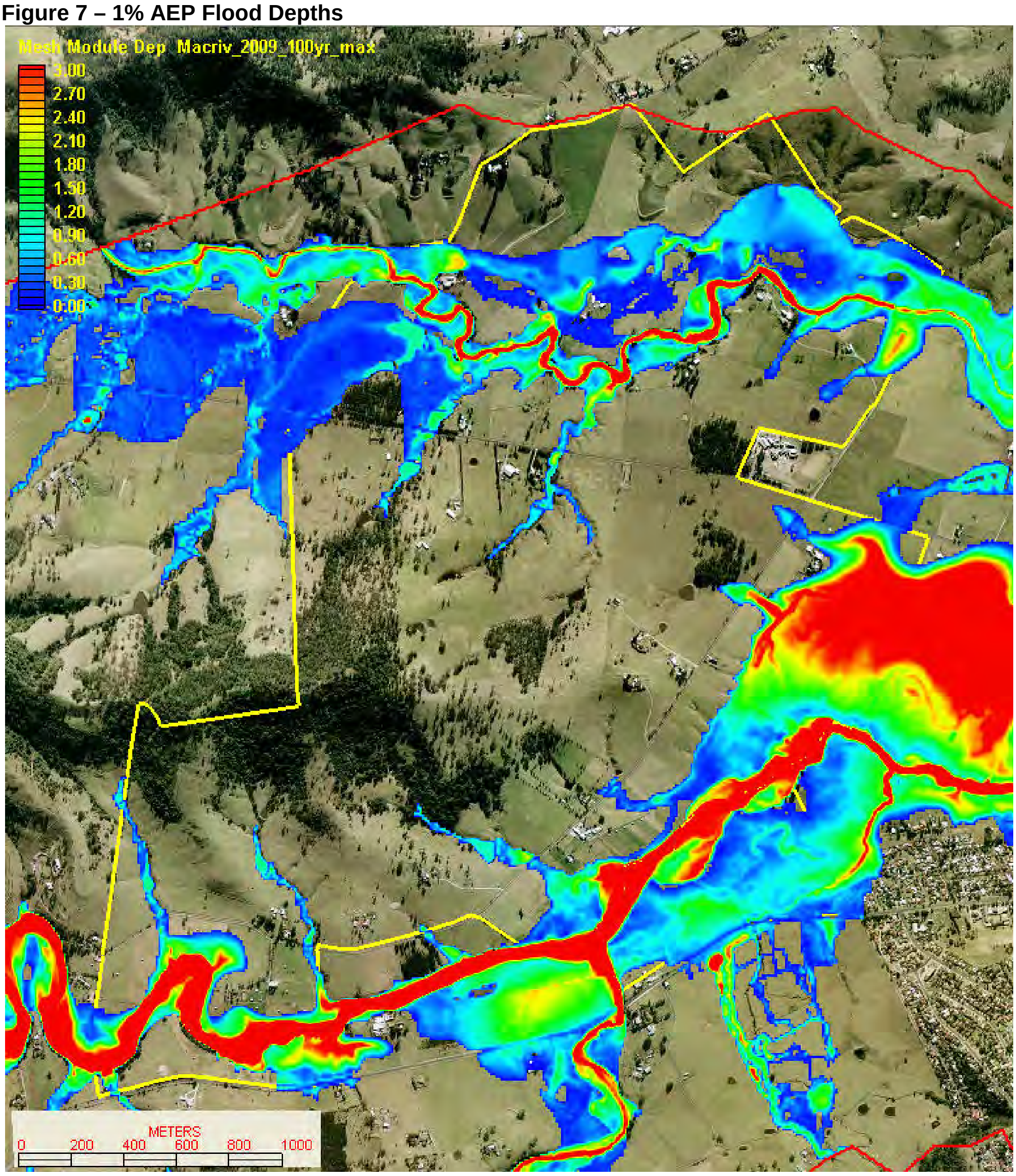
In contrast with the upper reaches of Macquarie Rivulet, Marshall Mount Creek meanders through a relatively wide floodplain, located for the most part within the northern sector of the study site. Most of the floodplain is located on the northern side of the creek.

The combination of limited within-bank capacity of streams and broad, flat, well-defined floodplains, results in the development of significant areas of flood plain inundation, in most significant flood events. The last major flood in the Macquarie Rivulet system occurred in June 1991. It was a reasonably significant flood of about 1 in 10 year ARI. Almost all of the land described as moderate to high flood risk, on the Flood Risk Planning Precinct Plan described in Section 5.3, was inundated in this event.

3.2.1 1%AEP Flood Event

A flood study has been undertaken as part of this project to determine existing flood behaviour across the project area (Rienco, 2009). This modelling quantified flood levels, velocities, depth, unit flow (conveyance) and provisional hydraulic hazard through and in the vicinity of the proposed development site. In a 1% AEP flood event, Macquarie Rivulet inundates most of the low lying land along the southern boundary of the site and Marshall Mount Creek inundates a substantial portion of the low lying land in the northern half of the site (Rienco, 2009). In both zones of inundation substantial secondary overland flow paths are evident, flowing at considerable depth and velocity at the peak of a 1% AEP flood. **Figure 7** below shows the 1% AEP flood depths and levels across the subject site.

Figure 7 – 1% AEP Flood Depths



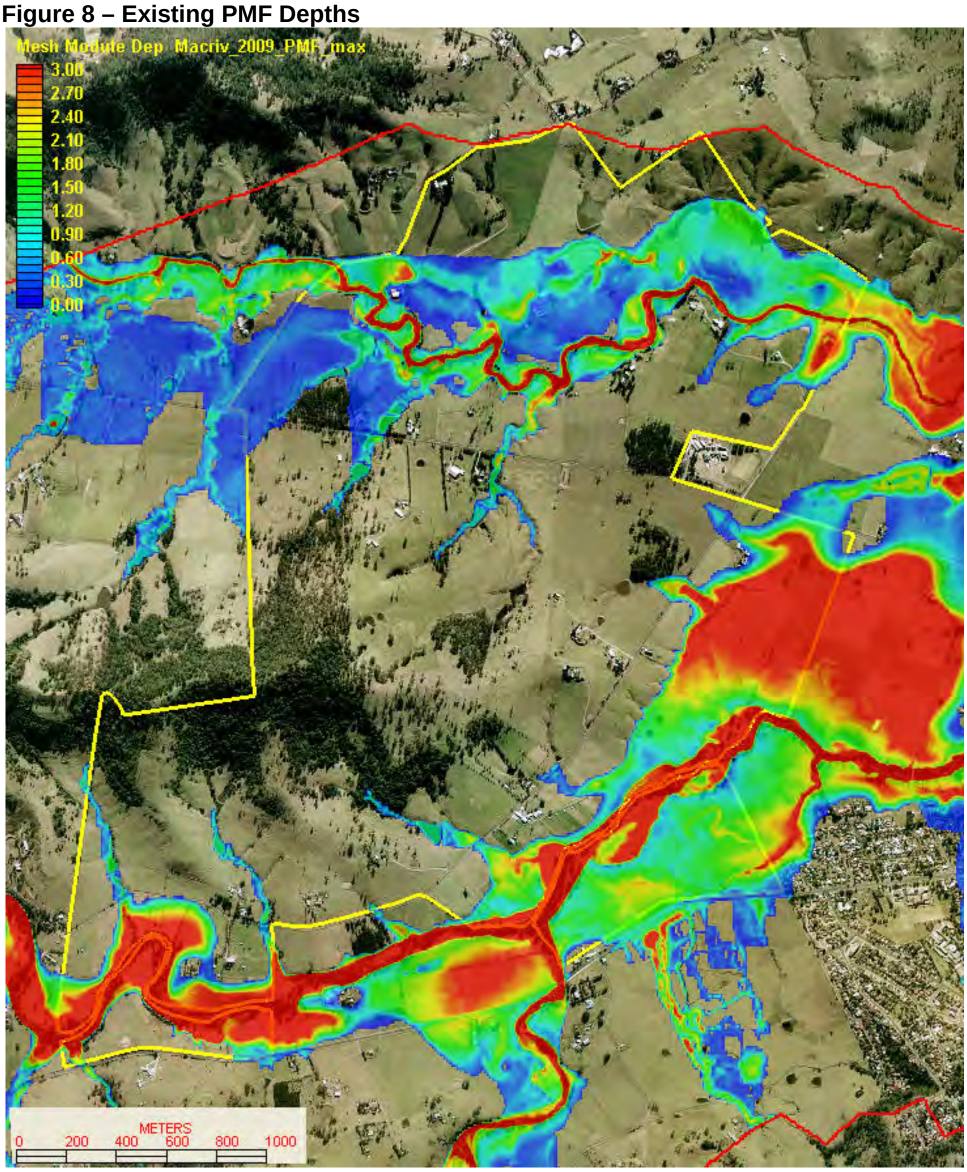
3.2.2 Probable Maximum Flood (PMF) Event

There are flood impacts in the PMF event. Increases in flood levels can be seen immediately upstream of the new Macquarie Rivulet bridge. The road itself is free from flooding in the PMF, but the land immediately upstream is affected. It is not unreasonable to expect that for such a rare flood event, any works on the floodplain would have an impact. Notwithstanding the above, it is important to also note that land affected by this increase is predominantly agricultural or riparian land already significantly flood affected.

Public infrastructure is rarely designed to have no impacts in such a rare flood event. The NSW Government's FPDM (2005) states that the probability of the PMF event occurring is up to one in every 100,000 years. While a PMF event more than doubles peak flows in the two creek systems and substantially increase flood depths, velocities and hazard, it does not greatly increase the plan extents of flooding (the extent of 'flood prone' land) in the vicinity of the proposed development site.

Figure 8 below shows the PMF depths and levels across the subject site.

Figure 8 – Existing PMF Depths



3.3 Potential Impacts and Mitigation Measures

Refer to Cardno Floodplain Risk Management Study for details on the impacts and mitigation measures proposed for the development and analysis of the future effects of climate change.

4 Water Sensitive Urban Design (WSUD) Philosophy

4.1 Existing Environment

The overall Macquarie Rivulet catchment (including Marshall Mount Creek) is the largest contributing sub-catchment of Lake Illawarra. Water quality in Macquarie Rivulet is relatively high compared to the more highly urbanised Lake Illawarra catchments further to the north and east that do not have specific water quality control measures in place. Whilst ambient water quality is of a relatively high standard, continued grazing pressure results in the generation and wash off into Lake Illawarra of fine sediments and nutrients.

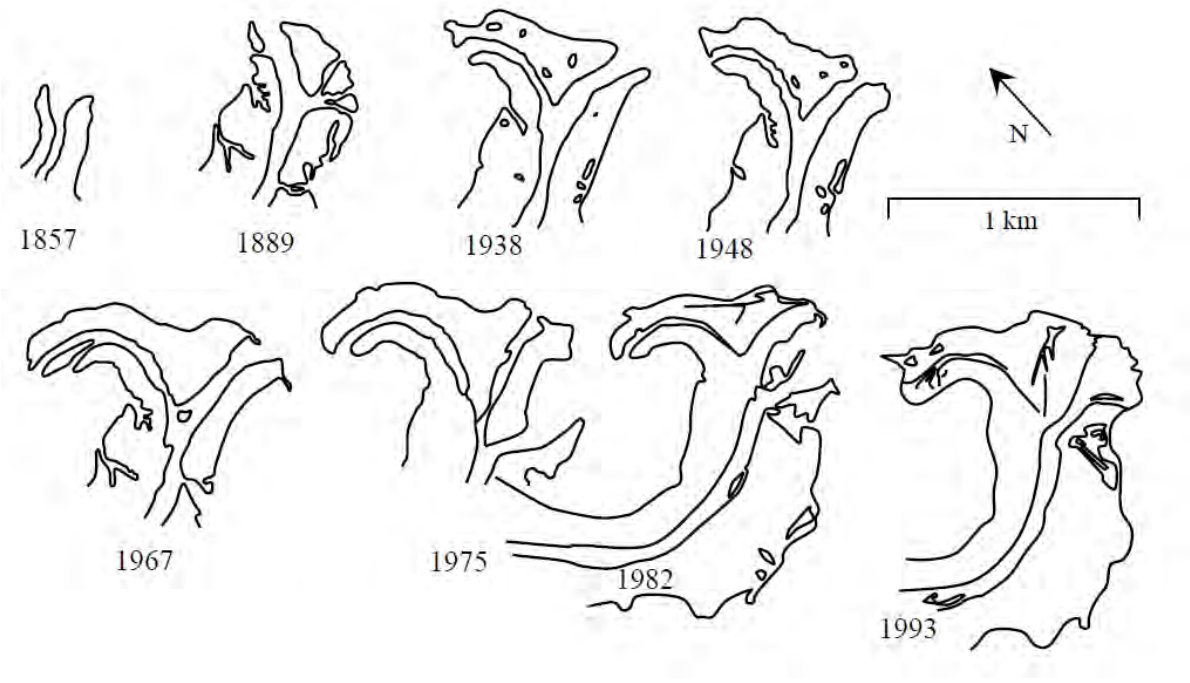
Fine sediments are derived from clearing induced erosion of the valley flanks (sheet erosion) and creek channels (bed & bank erosion). Sediments can destroy habitat for aquatic organisms by excluding light from the water required for plant and algal growth and by smothering plants and animals living on the bottom of the receiving water body.

At the present time, sediment transport in the catchment reflects natural patterns of mass movement and erosion within the upper escarpment areas combined with continued erosion from grazing areas (albeit at a slower rate). The recent rapid expansion of urban development within the area to the south of Albion Park (within the Frazers Creek catchment) has seen the introduction of a further source of sediment, particularly during the shorter-term construction and development phase.

Anecdotal evidence from local long-term residents and graziers suggest that early last century the catchment experienced higher rates of sediment transport because of the combined effects of:

- Catchment clearing in the steeper escarpment areas;
- Agricultural production practices that required tillage and disturbance to the soil (mainly cropping of wheat and similar agricultural produce);
- The absence of thick grass cover (kikuyu grass only became established mid way through the last century);
- High rabbit populations prior to the introduction of the myxoma virus (further reducing grass cover and exacerbating erosion).

Figure 9 – Changes in Delta Form from Macquarie Rivulet (Sloss et al, 2004)



Observations made of the rapid expansion and then stabilisation of the Macquarie Rivulet delta; confirm that massive sediment loads were transported from the catchment over the early period of European settlement (see **Figure 9**). The rate of erosion is now reaching an equilibrium (i.e. channel geomorphology has changed in response to the change in hydrology brought about by catchment clearing). Whilst sediment transport will always continue, its rate will diminish unless new changes occur within the catchment.

Nutrients are the other main pollutant derived from the existing catchment, these can (in high concentrations) cause excessive growth of aquatic plants and lead to eutrophication within pools, slow flowing channel reaches and in poorly flushed parts of the lake. Nutrients are principally derived from fertiliser usage in rural areas including phosphorus (super-phosphate and derivatives) and nitrogen (fowl manure, ammonium nitrate and derivatives).

In terms of nutrient levels in the river systems, the Lake Illawarra Stormwater Management Plan (Forbes Rigby, 2000) indicates that water quality in Macquarie Rivulet routinely exceeds ANZECC criteria for phosphorus. Phosphorus is often found adsorbed onto the surface of sediment particles making sediment control an important mechanism for improving water quality.

In terms of nutrient levels in the Lake, Organic and inorganic pollutant levels in the Lake are relatively high due to industrial land uses in the catchment and urban stormwater runoff. There are 191 stormwater drains discharging into the Lake and these are progressively being fitted with pollution control devices as part of ongoing management of pollution in the Lake. As of 2006 total phosphorus, total nitrogen and chlorophyll-a concentrations were typically recorded above ANZECC (2000) Guidelines levels in the lake (WBM, 2006). In its natural state the Lake is a strongly nitrogen limited ecosystem.

Wollongong City Council has undertaken water quality monitoring at various locations within that Macquarie Rivulet and Marshall Mount Creek catchments. Monitoring of Marshall Mount Creek and Macquarie Rivulet (downstream of the Marshall Mount Creek confluence) was undertaken in 2004-2005. **Figure 10** shows the spatial location of the various water quality monitoring locations.

Figure 10 – Spatial Locations of Various Water Quality Monitoring Locations

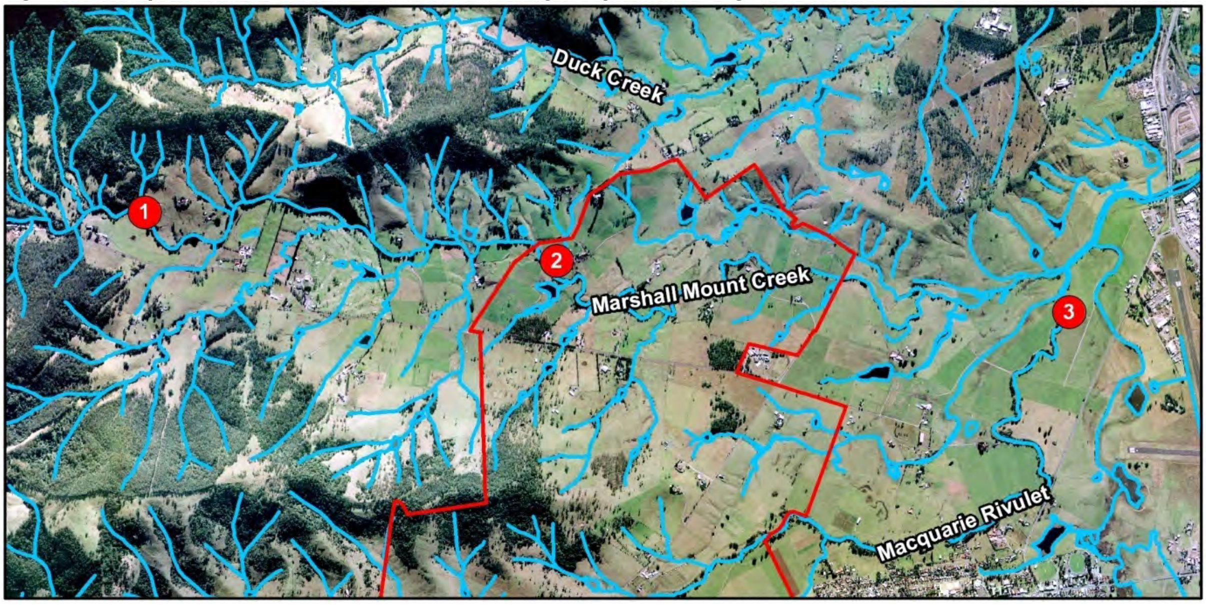


Table 4.1 presents mean nutrient levels measured at the locations shown in **Figure 10**.

Table 4.1 – Mean Water Quality Monitoring Results for Marshall Mount Creek and Macquarie Rivulet (WCC)

Site	Monitored by	pH	Cond (µS/cm)	TSS (mg/L)	Faecal Coliforms (cfu/100ml)	TP (mg/L)	FRP (mg/L)	TN (mg/L)	Ammonia (mg/L)	Nitrate & Nitrite (mg/L)	TKN (mg/L)
1	WCC	7.35	151	1.04	70.31	2.71	0.010	0.227	0.017	0.065	0.169
2	WCC	7.18	298	3.25	651.17	5.39	0.072	0.558	0.087	0.087	0.525
3	WCC	7.34	174	3.54	185.38	4.95	0.038	0.508	0.085	0.130	0.388

NOTE: Table adapted from WCC (2006) and SCC (2010). Refer to Appendix E for a detailed summary of all monitored water quality results, including sample sizes, minimums, maximums, DO, TOC, temperature and metal species.

The introduction of urban development has increased the potential for nutrient based water quality impacts within Macquarie Rivulet. However, it is worth noting that these potential impacts are mitigated by the combined influence of:

- New urban development areas south of Albion Park having incorporated their own water quality controls
- The significant pollutant assimilation and attenuation capacity afforded by Frazers Creek and the large natural wetlands which currently intercept the majority of runoff from Albion Park

It is also noted that most of the existing urban areas drain into Macquarie Rivulet downstream of the proposed Calderwood Valley development area making agriculturally derived nutrients the principal source of nutrient based water quality impacts within the study area.

4.2 Potential Impacts without Water Quality Controls

In the absence of adequate water quality controls, the introduction of development within a catchment can lead to a decline in surface water quality. During the construction phase, accelerated erosion from disturbed areas can cause 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 can 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.

As well as stormwater quality impacts, the development also has a wider ecological footprint external to the site through the need to upgrade town water 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 potable water demand through stormwater reuse.

4.3 Water Quality Philosophy for Calderwood

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 Annex H1 of the Draft Managing Urban Stormwater – Council Handbook (1997).

The environmental implications of surface water quality impacts induced by development depend on the sensitivity of downstream waterbodies. Having regard to the fact that the Calderwood Valley drains into Class P protected waters (Macquarie Rivulet and Marshall Mount Creek) and ultimately into a regionally significant waterbody (Lake Illawarra), it could be argued that the implications of a degradation in water quality within the study area are significant.

It is therefore a priority that current best practice pollutant removal targets for urban development be applied to the Calderwood due to the sensitive downstream water body, Lake Illawarra.

To achieve this level of performance, current industry guidelines such as Australian Runoff Quality (Engineers Australia, 2006) advocate the use of Water Sensitive Urban Design (WSUD) principles. Such guidelines 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).

It should be noted that Shellharbour Council do not have a Water Sensitive Urban Design policy, nor do they have any policy which provides guidelines for water quality expectations from new developments. Wollongong City Council has just released a draft Water Sensitive Urban Design policy and this policy was recently on public exhibition. Cardno has reviewed this policy and is of the view that the policy, at this point in time, should not be included in any setting of water quality objectives for the Calderwood development. The draft WSUD policy is incomplete, and is likely to require some essential changes prior to implementation.

Therefore, the WSUD measures to be incorporated in the Calderwood project would also be designed to meet (or exceed) mean annual pollutant load reductions specified in the national water quality guideline Australian Runoff Quality (Engineers Australia, 2006).

4.4 Potential WSUD Components

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

- Stormwater management measures to minimise impacts of litter, sediments and nutrients on water quality
- Water supply management to reduce potable water usage
- Wastewater management to optimise opportunities for recycling
- Groundwater management.

Based on a review of the literature described in **Chapter 2**, our engineering experience and judgement on similarly scaled regional development, and our understanding of the ongoing maintenance responsibilities and issues with Councils, the measures considered applicable to the Calderwood Development are presented in **Table 4.2** below.

Table 4.2 – WSUD Measures Considered at Calderwood

Treatment Measures	Purpose	Comment
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/bio-retention basins	Yes, but only where suitable conditions permit. The use of bio-retention systems such as roadside bio-swales may not be appropriate for the Calderwood Valley due to the higher slopes and soil geology. 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 if not managed appropriately and decrease land utilisation. However, strategic use of bio-retention systems could be incorporated into parts of the site where: there are deep alluvial soils and gentle grades that encourage infiltration; wider grassed verges (such as 'feature' streets with high landscape requirements); streets adjoining riparian corridors; and streets that are highly trafficked where increased vehicle usage is likely to generate greater pollutant loadings.
	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	Yes. Dual-use ponds serving detention purposes as well as enhanced water quality functionality are well suited to the Masterplan layout and the morphology of the Calderwood Valley.
	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 to achieve BASIX targets.
	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. These mechanisms will contribute to achieving BASIX targets.
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 Lake Illawarra 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	TBA

As can be seen from **Table 4.2**, WSUD measures considered most appropriate to the Calderwood development are in the areas of water supply management and stormwater quality control. Options relating to stormwater quality control and groundwater management are discussed in **Sections 4.5** and **4.6** below. Detailed design of the water supply management systems will be provided at the construction certificate stage, when design inputs are more readily definable.

4.5 Selection of Stormwater Quality Management Measures

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 Calderwood, 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 typical treatment train proposed for the Calderwood Urban Development Project and the expected performance of the various components is described in **Table 4.3** below.

Table 4.3 – Proposed Treatment Train

Treatment Measures	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.
Wetlands / Ponds (deep water zone)	Sedimentation and storage of sediments	Wetland / Ponds 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 72 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 key objective for the Calderwood Urban Development Project was to locate the wetlands in ways sympathetic to the other environmental constraints of the site, specifically the Asset Protection Zones (APZ's) and riparian corridors was recognised as a key driver in siting the ponds/wetlands.

The location of the wetlands is influenced by characteristics and constraints of the site, and urban design considerations. 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 riparian corridors. 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. Moreover, the upper reaches of the site are steep and there are limited opportunities to locate wetlands on these slopes and within these confined valley areas. It is therefore ideal to locate the proposed wetlands within riparian zones where they will be vegetated and contribute to ecological outcomes.

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.

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 **Annex C**.

4.6 Selection of Groundwater Management Measures

Based on the existing investigations undertaken in the adjacent areas, there are broadly three existing groundwater regimes that would be encountered in and around the site:

- A series of discontinuous shallow groundwater aquifers located on slopes and ridgelines surrounding the site. This groundwater is perched above the underlying rock profile and sourced from direct rainfall onto surface soils. The high clay content of sub-soils at the site means that aquifer recharge and discharge rates are typically slow
- A much more extensive groundwater aquifer system adjoining each of the main watercourses. These aquifers are perched above underlying rock profiles are contained within a relatively loose and variable matrix of alluvial soils. These are maintained by a combination of direct rainfall, inflows from shallow slope based groundwater systems and recharge during high flows in the adjoining watercourse during flood. Long term groundwater surface profiles in these systems will vary according to seasonal changes in rainfall patterns however groundwater is likely to be encountered within a few metres of the surface
- A more extensive groundwater aquifer is known to occur downstream of the site near the broad floodplain junction between Macquarie Rivulet and Marshall Mount Creek. This aquifer extends through to Lake Illawarra, and is generally contained within a thin sand layer deposited on the floodplain during the Holocene period when the lake is thought to have extended further to the west possibly as far as Albion Park.

As a result of clearing and intensive dairy grazing, there are no extensive groundwater dependent natural ecosystems located on the floodplain. There are also no extensive agricultural demands for groundwater extraction (e.g. large-scale irrigation schemes). However, it is possible there is some isolated demand for stock watering associated with the existing rural homesteads;

As with most Illawarra streams, groundwater storage provides an important natural source of baseflow to the perennial streams adjoining the site, particularly during drought.

An issue related to the area is generally outside of the area of known occurrence of Acid Sulfate Soils. However, according to the 1:25,000 DLWC Acid Sulfate Soil Mapping, there is a low probability of occurrence of Acid Sulfate Soils at a depth of greater than 3m at the downstream edge of the site adjoining both Macquarie Rivulet and Marshall Mount Ck.

The impervious surfaces associated with new development intercepts a higher proportion of rainfall falling on a site reducing opportunities for infiltration into the underlying groundwater profile. This means that development can lead to long-term reductions in groundwater storage locally around the site. Given the absence of significant ecological or agricultural uses for this groundwater, the impact of groundwater drawdown in this local area is less significant. However, there are two possible impacts that need to be considered and require further investigation These are:

- Possible exposure of Acid Sulfate Soils through long-term reductions in groundwater profile (Acid Sulfate Soils remain innocuous provided they are maintained below the long term groundwater profile)
- Reduction in the availability of groundwater to support long-term base flows in perennial streams.

It should be noted that potential impacts on long-term base flows are likely to be negligible. The cumulative contribution to base-flow provided by existing groundwater systems upstream of the Calderwood site are far greater than those occurring directly opposite the site. These upper systems will remain unchanged by development of Calderwood and will therefore continue to support base flows.

Pollution of groundwater from untreated stormwater is a potential risk that needs to be managed. Uncontrolled discharge into the aquifer system can lead to the development of sub-surface plumes eventually breaking out into the adjoining stream system. This impact is managed through provision of adequate surface water controls, which are readily achieved by the Calderwood Urban Development Project.

5 Water Quality Performance Modelling

5.1 Modelling Approach

The water quality software package MUSIC v4.0 (Model for Urban Stormwater Improvement Conceptualisation) was used 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.

5.2 Modelling Input Data & Parameters

5.2.1 Rainfall and Evapo-Transpiration

Rainfall data was supplied by the Bureau of Meteorology (BoM) for the Albion Park Gauge (#68241). A complete 50 year daily rainfall dataset was used from 1932 – 1981 for daily simulation modelling. A complete 6 year rainfall dataset 2001 – 2006 of six-minute pluviometer data was also used.

Evapo-transpiration data was sourced from BoM's climate data maps available for the period 1961 – 1990.

Climate change information for the year 2070 for rainfall and potential areal evapo-transpiration was sourced from the Climate Change in Australia Technical Report (CSIRO, 2007) and the CSIRO OzClim database.

Information on rainfall and evaporation change from 1970 – 2008 was sourced BoM's climate trend maps.

5.2.2 Catchment Land Use Characteristics

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 5.1**.

Table 5.1 – Impervious Covers used in MUSIC Water Quality Model

Land Use	Impervious Area (%)
Urban (Residential)	60%
Urban (Commercial)	90%
Forest/Riparian	0%
Agricultural	5%

The impervious areas presented in Table 5.1 are similar to those values adopted in the RIenco (2009) assessment. It is however noted that a higher percentage of impervious cover for residential has been adopted. This is to reflect the impervious cover of roads.

5.2.3 Stochastically Generated Pollutant Concentrations (EMC's)

The adopted parameters to stochastically generate pollutant concentrations in the MUSIC modelling are summarised in **Table 5.2**.

Table 5.2 – Adopted Pollutant Model Parameters

Land Use	Flow Condition	TSS Mean (log mg/L)	TSS Std Dev (log mg/L)	TP Mean (log mg/L)	TP Std Dev (log mg/L)	TN Mean (log mg/L)	TN Std Dev (log mg/L)
Urban	Base flow	1.100	0.170	-0.820	0.190	0.320	0.120
	Storm flow	2.200	0.320	-0.450	0.250	0.420	0.190
Agricultural	Base flow	1.400	0.130	-0.880	0.130	0.074	0.13
	Storm flow	2.300	0.310	-0.270	0.300	0.590	0.260
Forest	Base flow	0.900	0.130	-1.500	0.130	-0.140	0.130
	Storm flow	1.900	0.300	-1.100	0.220	-0.075	0.240

<u>Note:</u> *Values adopted are based on MUSIC V4 model defaults*

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.

5.2.4 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 Douglas Partners report. Further details of the parameters adopted are presented in **Annex 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.

5.2.5 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.

5.3 Climate Change Modelling

It is widely accepted that climate change will lead to increased potential evapo-transpiration and decreased rainfall for the south-east of Australia. These conclusions are based on results from global climate model simulations undertaken with over 23 climate models from various institutions around the world. These model simulations also indicate that there will be less frequent but more intense storm events under future climate change scenario.

The future climate is largely uncertain. It will depend human activities, such as energy generation, transport, agriculture, land-clearing, industrial processes and waste. To provide a basis for estimating future climate change, the Intergovernmental Panel on Climate Change (IPCC 2000) prepared 40 greenhouse gas and sulfate aerosol emission scenarios for the 21st century.

The IPCC's scenarios combine a variety of assumptions about demographic, economic and technological factors likely to influence future emissions. Each scenario represents a variation within one of four 'storylines': A1, A2, B1 and B2 (see Box 4.1). Projected carbon dioxide, methane, nitrous oxide and sulphate aerosol emissions based on these scenarios are shown in Figure 4.1.

For the purposes of this report we have selected a medium rate of global change is based on the *Special Report on Emission Scenarios* (SRES) **A1B** storyline and scenario family. This describes a future world where globalisation is dominant. Economic growth is rapid and population growth is low with the rapid development and deployment of more efficient technologies. There is a balance between fossil fuel use and other energy sources. Major underlying themes are economic and cultural convergence and capacity building, with a substantial reduction in regional differences in per capita income. We assume a medium climate sensitivity, i.e. a sensitivity corresponding to a global warming of 2.6 degrees for a doubling of CO2 from 280 ppm to 560 ppm (CSIRO, 2007).

More information of different scenarios can be found in the IPCC's *Special Reports on Climate Change,* 2000.

The 2007 DECC Flood Risk Management guideline titled Practical Consideration of Climate Change guidelines (DECC, 2007) recognises that:

Climate change is expected to have adverse impacts upon sea levels and rainfall intensities, both of which may have significant influence on flood behaviour at specific locations.

In lieu of the above, a 'climate change' rainfall dataset was established for use in MUSIC. This was done by creating a synthetic rainfall sequence that broadly represents expected trends in annual rainfall (decrease) and storm intensity (increase) based on the IPCC SRES A1B storyline and scenario family.

Table 5.3 describes the adopted percentage increase in rainfall under the adopted future climate change scenario. **Table 5.4** describes the adopted percentage increase in evaop-transpiration under the adopted future climate change scenario.

Table 5.3 – Adopted percentage increase in rainfall under future climate change scenario

Season	Percentage rainfall change for A1B storyline in 2070		Modelled percentage rainfall change under future 2070 climate change scenario	Recent average 10 year rainfall trend
	Combined projections from 23 models around the world[a] for 50th percentile best estimate climate change	CSIRO Climate Sensitivity Model CSIRO-Mk3.5 with medium climate sensitivity		
Summer	-2% to +2%	+5% to +10%	**+5.0%**	-11%
Autumn	-10% to -5%	-10% to -5%	**-7.5%**	-10%
Winter	-20% to -10%	-20% to -10%	**-7.5%**	+3%
Spring	-20% to -10%	-30% to -20%	**-20.0%**	-1%
Annual	-10% to -5%	-10% to -5%	**-7.5%**	-4%

Notes:
[a] *Each of the 23 models was given a skill score based on its ability to simulate the average (1961-1990) patterns of Australian temperature, rainfall and mean sea level pressure. These skill scores were used to weight regional climate projections based on the assumption that models with higher skill scores are likely to give more reliable projections of future climate*
[b] *Based on 1970 - 2008 average trends (BoM, 2009)*

The approach adopted to reduce average seasonal rainfall was to set any days with less than 8 – 15 mm of rainfall (depending on season shown in Table 5.3) to 0 mm and to then increase all remaining rainfall intensities by 10% - 15% depending on season. The potential evapo-transpiration (PET) was increased uniformly by 4% – 12% depending on seasonal variation as shown in **Table 5.4**.

Table 5.4 – Adopted percentage increase in evapo-transpiration under future climate change scenario

Season	Percentage evapo-transpiration change for A1B storyline in 2070		Modelled percentage evapo-transpiration change	Recent average 10 year evapo-transpiration trend
	Combined projections from 23 models around the world[a] for 50th percentile best estimate climate change	CSIRO Climate Sensitivity Model CSIRO-Mk3.5 with medium climate sensitivity		
Summer	+4% to +8%	>9%	**+8%**	-3%
Autumn	+8% to +12%	>17%	**+12%**	+5%
Winter	+8% to +12%	+14% - +18%	**+12%**	+9%
Spring	+4% to +8%	+2% - +4%	**+4%**	+4%
Annual	+4% to +8%	+10% - +12%	**+9%**	+1%

Table 5.5 – Modelled climate change dry-days and rainfall intensity increase

Season	Target percentage reduction in rainfall climate change models	Actual percentage reduction in rainfall climate change models	Existing rainfall data set to 0 mm to reflect prolonged dry weather conditions	Actual modelled rainfall intensity increase above threshold	Average No. of wet days per year under existing climate conditions	Average No. of wet days per year under future climate conditions
Summer	+5.0%	+5.0%	0 - 8 mm	+20%	73.7	33
Autumn	-7.5%	-7.7%	0 - 11 mm	+10%		
Winter	-7.5%	-7.6%	0 - 10.5 mm	+10%		
Spring	-20.0%	-20.3%	0 - 15 mm	+15%		

The MUSIC model (as described in **Section 5.1**) was re-run with the 'climate change' synthetic rainfall and PET data. The results of this modelling, and a comparison to the base case model is presented in the following section.

5.4 Modelling Results

The MUSIC model has been used to optimise the size of the various components of the stormwater treatment train. A surface area allowance for wetlands was incorporated into the concept design of the development, sized at approximately 2 – 3% of the upstream respective urban catchment area.

Once indicative layouts are available, the wetland size estimates may be refined to reflect more optimal planning scenarios.

Preliminary modelling using daily data results indicate that the wetland sizing is appropriate to achieve the desired water quality targets and treatment train effectiveness during current climate and the A1B future climate change scenario.

The water quality treatment devices were also sized to ensure that post development mean annual loads were not in excess of pre development levels. **Tables 5.6.** demonstrates this compliance.

Table 5.6 – Comparison of TSS, TP and TN Mean Annual Loads

Pollutant	Macquarie Rivulet	Marshall Mount Creek	Target Percentage Reduction
Pre-Development			
Total Suspended Solids (kg/yr)	188000	215000	
Total Phosphorus (kg/yr)	441	611	
Total Nitrogen (kg/yr)	3510	4950	
Post-Development Baseload[a] (No Treatment)			
Total Suspended Solids (kg/yr)	680000	578888	
Total Phosphorus (kg/yr)	974	784	
Total Nitrogen (kg/yr)	6640	5204	
Post-Development (with Treatment)			
Total Suspended Solids (kg/yr)	54400	52100	
Total Phosphorus (kg/yr)	224	196	
Total Nitrogen (kg/yr)	3320	2810	
Post-Development (with Treatment) under A1B Climate Change Scenario			
Total Suspended Solids (kg/yr)	54100	63300	
Total Phosphorus (kg/yr)	204	217	
Total Nitrogen (kg/yr)	2890	3120	
Percentage Reduction in Loads from Post-Development Baseload (No Treatment) to Post-Development			
Total Suspended Solids	92%	91%	80%
Total Phosphorus	77%	75%	45%
Total Nitrogen	50%	46%	45%

[a] *This refers to the percentage reduction of pollutants measured at the outlet of the catchment based on the level of pollutants generated at the source in the developed catchment*

The modelling results presented in this report indicate that the development will improve stormwater quality for water originating from the site. The pollutant load reduction also meets the required annual load reductions of 80%, 45%, 45% TSS, TP and TN respectively from urban developed areas, in accordance with the national water quality guideline Australian Runoff Quality.

6 Adopted WSUD Measures

6.1 Wetlands & Ponds

6.1.1 Water Quality

The proposed Calderwood Urban Development Project incorporates a number of WSUD components that will reduce pollutant loads flowing into Macquarie Rivulet and Marshall Mount Creek. Wetlands and Ponds will be located in areas sympathetic to the existing environment and in areas that compliment the proposed urban environment. The proposed wetlands and ponds will be designed to treat all urban runoff typically up to the 3 month ARI where the proposed topography permits. In some instances the wetlands and ponds may be required to treat some non-urban areas that are located upstream of urban areas due to topographic limitations.

The primary purpose of wetlands and ponds is to reduce TSS, N & P loads. They are end of line component of the WSUD treatment train before discharge to Macquarie Rivulet and Marshall Mount Creeks. Conceptual locations of ponds and wetlands are presented in Appendix D. It is proposed that wetlands be constructed to service each stage of the development as it is released.

Tail out works will be required for the outlets of the ponds / wetlands into Macquarie Rivulet and Marshall Mount Creek. The proposed 'tail-out' works will be detailed at the construction certificate stage.

6.1.2 Water Quantity Control

The proposed development incorporates a number of WSUD components that serve to reduce the volume of runoff that would otherwise occur post-development. These include:

- The use of rainwater tanks on residential lots to provide water for toilet flushing/garden use;
- Re-use of water from large roof areas in the commercial area to provide top-up water from ornamental ponds and for toilet flushing;
- Use of buffer swales and small wetlands with pervious substrates to enable maintenance of groundwater levels; and
- Provision of suitably located large ornamental ponds.

In order to quantify the potential reduction in annual runoff offered by rainwater tanks and associated water re-use, typical water usage rates were obtained from Sydney Water for Albion Park and the Shellharbour LGA. These figures indicate that the average household water usage is approximately 440 L/day. Of this, 23% (101L) is used for toilet flushing and 25% (110L) is used for outdoor purposes such as garden watering (assumed to be lost to the system through evaporation and deep percolation).

In recent years, rainwater tanks have re-emerged as a means of reducing demand on public water supplies and are able with appropriate design to form part of the OSD requirements for a site. Given the relatively high rainfall in this area, they would prove a practical means of reducing potable water supply demand and assist in meeting the development's OSD requirements. This combined strategy of dual-use ponds and rainwater tanks will offset the impacts of increases in peak flows arising from the development.

However during larger events, rainwater tanks acting for the purpose of OSD could potentially be at capacity due to lead rain. For the Calderwood urban development project modelling of OSD with rainwater tanks therefore not incorporated.

As the proposed development will increase the impervious cover across the site, peak flows during storm events are likely to increase and runoff volumes are likely to increase (if unmitigated). In order to offset the impacts of increased peak discharge and volume, OSD is typically required.

Further to the above, On-Site Detention will incorporated into the development to ensure that post-development peak flows do not exceed pre-development peak flows. WCC have an OSD policy applicable to the smaller portion of the site, whereas SCC does not. In any case, the objective from both Councils is that post-development peak flows are retarded to pre-development peak flows. This objective is adopted for the Calderwood Urban Development Project. This will be achieved by the dual-use ponds serving detention purposes as well as enhanced water quality functionality are well suited to the Concept Plan layout and the morphology of the Calderwood Valley.

This being the case, OSD may be provided as a distributed facility within the site or in a more centralised facility at the point of discharge into the mainstream network. While centralised public detention basins were the most common approach in the past to meeting this requirement, for large scale developments, the current view of the authorities and to a lesser extent the community, is that centralised facilities are not as effective or desirable as more distributed (neighbourhood or single lot) OSD facilities. The present trend is toward the use of rainwater tanks (as multifunction storage devices) in combination with dynamic surface storage on car parking or landscaped areas, supplemented as necessary with dynamic surface storage in neighbourhood ponds.

The best approach to management of surface flows within and discharging from a developed area is not an issue capable of independent consideration. It is very much tied to the package of considerations underlying the concept plan.

The ephemeral nature of flows and steepness of the tributary gullies draining the ridge area suggests that they could be replaced in some areas with piped systems and reshaped (roads/swales) surface systems. Where streams first reach the floodplain and are still elevated above the 1% flood surface in the main stream, there is an opportunity to construct 'dual use' ponds (refer **Figure 8**). These ponds could be designed to manage both the quantity and quality of runoff from the development.

6.2 Gross Pollutant Traps

Gross Pollutant Traps (GPT's) are proposed for the outlet of each major stormwater discharge point. The primary purpose of these will be to reduce the amount of large particulates (principally litter), reaching the creek and wetlands. These units will also however assist (to varying degrees) with improving water quality through removal of sediment.

As these units are essentially part of the stormwater drainage system for the Project, it is proposed to construct these as required by each stage. This avoids potential conflicts between design levels of the GPT and future roads and drainage. Nevertheless, conceptual locations have been nominated for each of the units to guide the concept plan design.

Two types of units are proposed depending on the sensitivity of the site:

- Sensitive sites: CDS units (or their equivalent) proposed for the Village Centre upstream of Village Pond 1 and on discharge points that do not directly drain into a wetland
- Non-sensitive sites: Baramy Traps (or their equivalent) on discharge points that drain into a wetland.

Conceptual locations are shown on the WSUD Measures Plan included in **Annex D**.

The rationale behind this approach is that a high level of sediment removal is less necessary where a wetland with an inlet pond is located downstream (as the wetland is much more effective at removal of sediment).

For sensitive sites, CDS units are preferred over other proprietary products as they are self cleaning and therefore less prone to blockage and bypass. They also do not require head-loss through the pit and will therefore permit steeper pipe grades upstream (reducing pipe drainage costs).

For non-sensitive sites, Baramy Traps (or similar) are preferred as maintenance is simpler (only coarse particulates are targeted and open style basket permits hand cleaning).

For each location, the GPT will require a 'tail-out' channel to transfer flow from the GPT into the adjoining creek or wetland. This tail-out channel will be armoured with appropriately sized cobbles and/or boulders to prevent scour and be evenly graded between the outlet of the GPT and the creek invert. Due to the relatively shallow nature of the floodway significant elevation differences between the GPT and the creek invert are not anticipated.

7 Operational Issues

7.1 Soil & Water Management during Construction

To mitigate against the potential environmental impact of sediment laden water from the construction zone being discharged into nearby watercourses, a comprehensive soil and water management plan (SWMP) will be prepared are part of the design process.

The SWMP outlines the methods through which stormwater run-off is controlled throughout the construction phase. This includes the use of the proposed wetlands as temporary sediment basins (where possible) and the provision of rock check-dams and filter fabric fencing (above and below the works area respectively). Sound environmental practices dictate that these control structures are constructed and established prior to works commencing, and immediately following construction exposed soil will be grassed.

During large flow events in the creek systems, little temporary Soil and Water Management measures are available for implementation, given the context of the site within its catchment and the magnitude of flows in large flood events. This is a view that is advocated in The Department of Housing “Blue Book” (the relevant guideline in NSW for all construction sites), which above all else encourages designers to be aware of the need to create pragmatic designs that don’t go beyond the point of diminishing returns.

For the treatable flow events, the “Blue Book” recommends such measures required to clean any dirty water in the sediment basins as dosing of turbid waters captured with alum or poly-aluminium chloride. This “flocking” will be required from time to time, as directed by the Superintendent on site during construction.

The above approach is also consistent with the Council’s general guidelines which call for best practice soil and water management to be implemented when constructing urban infrastructure so as not to have a detrimental impact on the water quality of receiving waters in the region.

7.2 Maintenance

General maintenance for the Calderwood wetlands will require regular inspections and cleaning of inlet structures and gross pollutant traps. This should occur at least every six months, and after heavy rainfall. Inspection of banks and structures after large storm events is also recommended, with any required repairs being completed. Inspection and maintenance of outlet structures is also essential to the functioning of the wetlands. It should be ensured that outlet structures remain unblocked. Regular cleanout of sediments from ponds or cleaning of macrophyte beds within wetlands is generally not required, apart from the initial phase prior to handover to Council. This is one of the advantages of adopting a wetland system for stormwater treatment.

The ponds and wetlands will however still need management intervention from time to time in the event of invasive species starting to colonise them, or some other ecological disturbance that upsets the desired species balance. For instance heavy populations of water birds have been observed to build up at a recently constructed wetland system in south-western Sydney, with excess bird numbers leading to damage to vegetation and a decline in water quality because of heavy bird manure loads. Reducing the amount of permanent water during the breeding season, which encourages the birds to migrate elsewhere to breed, can control instances such as this.

Monitoring and management of the macrophyte beds is important in the first twelve months of operation to ensure plant establishment, and should be the responsibility of contractors responsible for the land development and building phase. Handover to Council would occur on a staged basis, once 80% of the houses in each stage are constructed and would also only occur after macrophytes are fully established. Establishment may involve manual manipulation of the water levels to allow different species to establish at the appropriate water depth. Water level control will also be appropriate for controlling any weed species which may establish. Manual weeding of non desirable species during the establishment phase may also be required. These aspects should be addressed in the Vegetation Management Plan for the project.

Council would be responsible for the maintenance of the proposed stormwater quality control measures to ensure they meet their performance objectives in the long term. We understand SCC are aware of this issue, which was documented in our consultation with them (see Table 1.5 of this report). During this consultation, SCC advised that maintenance of WSUD measures should be addressed in the approval application submission including ownership, responsibility and goals for on-going management and operation.

7.3 Post-Construction Water Quality Monitoring

It is recommended that post-construction water quality monitoring be undertaken of the proposed ponds and wetlands, particularly during the establishment phase to confirm the water quality performance. This will be particularly important for initial development stages to ensure the WSUD measures are functioning as intended. If necessary, design modifications can be undertaken in subsequent stages to optimise water quality performance.

A typical monitoring methodology may include sampling for a range of typical urban pollutants at selected pond/ wetland inlets and outlets and within the downstream watercourses during both dry and wet weather periods. The typical range of pollutants considered necessary would include:

- Total Phosphorus and Filterable Reactive Phosporus
- Forms of Nitrogen (TKN, NH3-N, NOx)
- Total Suspended Solids
- Oil and Grease.
- Coliforms

These pollutants should be measured on a quarterly basis for say two to three wet weather events per year and occasions where dry weather persists, one to two times per year. Monitoring could cease once it had been demonstrated for a sufficiently long enough period that the ponds were functioning as designed and the upstream catchment is suitably developed.

8 Other Post Development Water-Related Issues

8.1 Water Body Longevity and Reduced Likelihood for Algal Growth

It was a requirement of DLL, for aesthetic reasons, that frequent drying out of the large ponds (especially those with an ornamental component) does not occur. DLL advised that these ponds should preferably remain substantially full for the average year, but may dry out for a month or two in the driest year in ten. During detailed design water body longevity will be assessed with detailed water balance modelling.

The potential for algal growth will also be assessed during detailed design. The likelihood of algal growth can be reduced through incorporation of suitable hydraulic residence times (i.e. increased waterbody turnover), and incorporation of suitable subsurface macrophytes.

8.2 Establishment Phase Watering of Riparian Vegetation

In order to assist with the rapid establishment of riparian vegetation, DLL proposes to utilise local groundwater resources. This will be done either through the installation of deep bores or by excavating temporary deep zones within the deepest sections of the proposed ponds. This may also be achieved by pumping water directly from Macquarie Rivulet.

Locations for three potential water bores have been selected on the basis of recently collected geotechnical test pit locations and their proximity to areas of future water demand.

NSW is currently operating under two pieces of legislation relevant to water licences and water trading (the buying and selling of water licences or annual allocation water):

- The Water Management Act 2000 governs the issue of new water licences and the trade of water licences and allocations for those water sources (rivers, lakes and groundwater) in NSW where water sharing plans have commenced.
- The Water Act 1912 governs the issue of water licences in other areas.

We have liaised with the NSW Office of Water who advised that there is an embargo placed on extraction of groundwater from Macquarie Rivulet catchment. The NSW office of Water also advised that an exemption to the embargo may be possible for watering of vegetation for a period of up to two years, to assist with vegetation establishment.

9 Conclusions & Recommendations

9.1 Conclusions

This WCMS has been prepared by Cardno to accompany a Concept Plan Application under Part 3A of the Environmental Planning & Assessment Act, 1979 (EP&A Act) in relation to the CUDP. It has been prepared in accordance with the DGRs issued by the DoP for the project.

Water Quality Objectives

1. The principal water quality objective often applied to new urban release areas is *"the maintenance of water quality within receiving water bodies at pre-development levels".* This objective is considered an appropriate water quality objective for the Calderwood Urban Development Project.

Proposed WSUD Measures

2. WSUD measures considered most appropriate for the Calderwood Urban Development Project are in the areas of water supply management, stormwater quality control and groundwater management.
3. For water supply management, measures in accordance with NSW government BASIX criteria are proposed.
4. For stormwater quality management a combination of proprietary litter/sediment traps, and water quality control ponds/ artificial wetlands is proposed, located in ways sympathetic to the other environmental constraints of the site.
5. Preliminary concept designs have been developed for the stormwater quality treatment system. The proposed stormwater quality control measures for the Calderwood Urban Development Project are presented in **Appendix D**.
6. MUSIC modelling has been undertaken for a range of scenarios. The results of this modelling show that the proposed development, with WSUD measures, achieves (and at times exceeds) the annual pollutant load reduction targets outlined in the national water quality guideline, Australian Runoff Quality.
7. In terms of groundwater management, provision to line ponds and wetlands will be allowed for during detailed design, however it is likely that wetlands will be left unlined to promote groundwater recharge, whilst ponds will be lined as they will also form ornamental features of the proposed Calderwood Urban Development Project.

Other Issues

8. Operational issues including staging, soil and water management during construction, maintenance and post-construction monitoring are discussed in **Chapter 8** of this report. It is concluded that the site readily lends itself to highly effective soil and water management controls.

9.2 Recommendations

It is recommended the Calderwood Urban Development Project adopt the recommended management strategies identified in Table 5.4 for the Concept Plan and future Project Applications.

10 References

ANZECC (2000), Australian and New Zealand Guidelines for Fresh and Marine Water Quality

CSIRO (2007), Climate Change in Australia - Technical Report

CSIRO (2009), OzClim: Exploring climate change scenarios for Australia, http://www.csiro.au/ozclim/home.do;jsessionid=C22D8588071154EE7C636F92B1C8DF49, accessed 15/12/2009

Engineers Australia (2006), Australian Runoff Quality: A guide to Water Sensitive Urban Design, National Committee for Water Engineering.

EPA (1997), Environmental Protection Agency, Council Handbook

NSWG (2005), NSW Government Floodplain Development Manual

Pittock, A. B. (2007) “The Enhanced Greenhouse Effect: Threats to Australia’s Water Resources Part 1 Scenarios for the Future” Journal of the Australian Water Association

Rienco (2009), Flood Modelling Report: Macquarie Rivulet Below Sunnybank

Sloss, C.R., Jones, B.G., Murray-Wallace, C.V. and Chenhall (2004). Recent sedimentation and geomorphological changes, Lake Illawarra, NSW, Australia. Wetlands (Australia) 21(2).

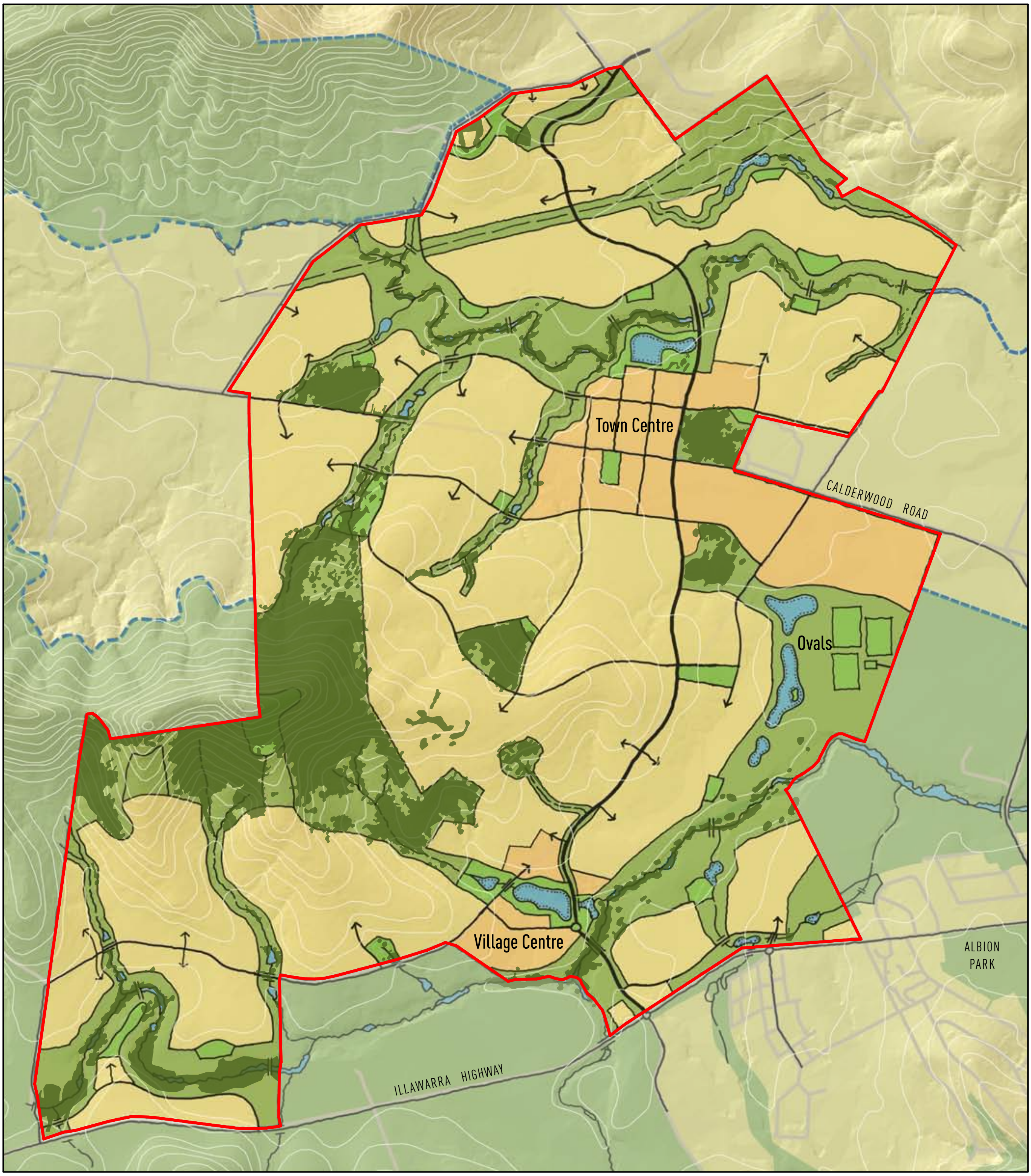
WBM Oceanics, 2006. Lake Illawarra Estuary Management Study and Strategic Plan, March 2006.

WCC (2006), Wollongong City Council, Monitoring of Water Quality in the West dapto Release Area in Conjunction with the Horsley release Area

WRF (1996), E Rigby Ed, Development of Macquarie Rivulet as a Reference Catchment for the Illawarra,,Report prepared for the Water Research Foundation by the Illawarra Regional Sub-committee of the Water Research Foundation, December 1996.

Annex A

A. Concept Plan



Concept Plan

Part 3A | Calderwood Urban Development Project

- **Town and Village Centres**
  Mixed Uses including Retail, Employment, Residential, Learning and Community Amenities
- **Residential Neighbourhoods**
- **Parks**
  eg Citywide, district and local parks
- **Principal Open Space and Drainage**
  eg Environmental Conservation, Environmental Management and Drainage Corridors
- **Indicative Water Bodies**

Delfin Lend Lease

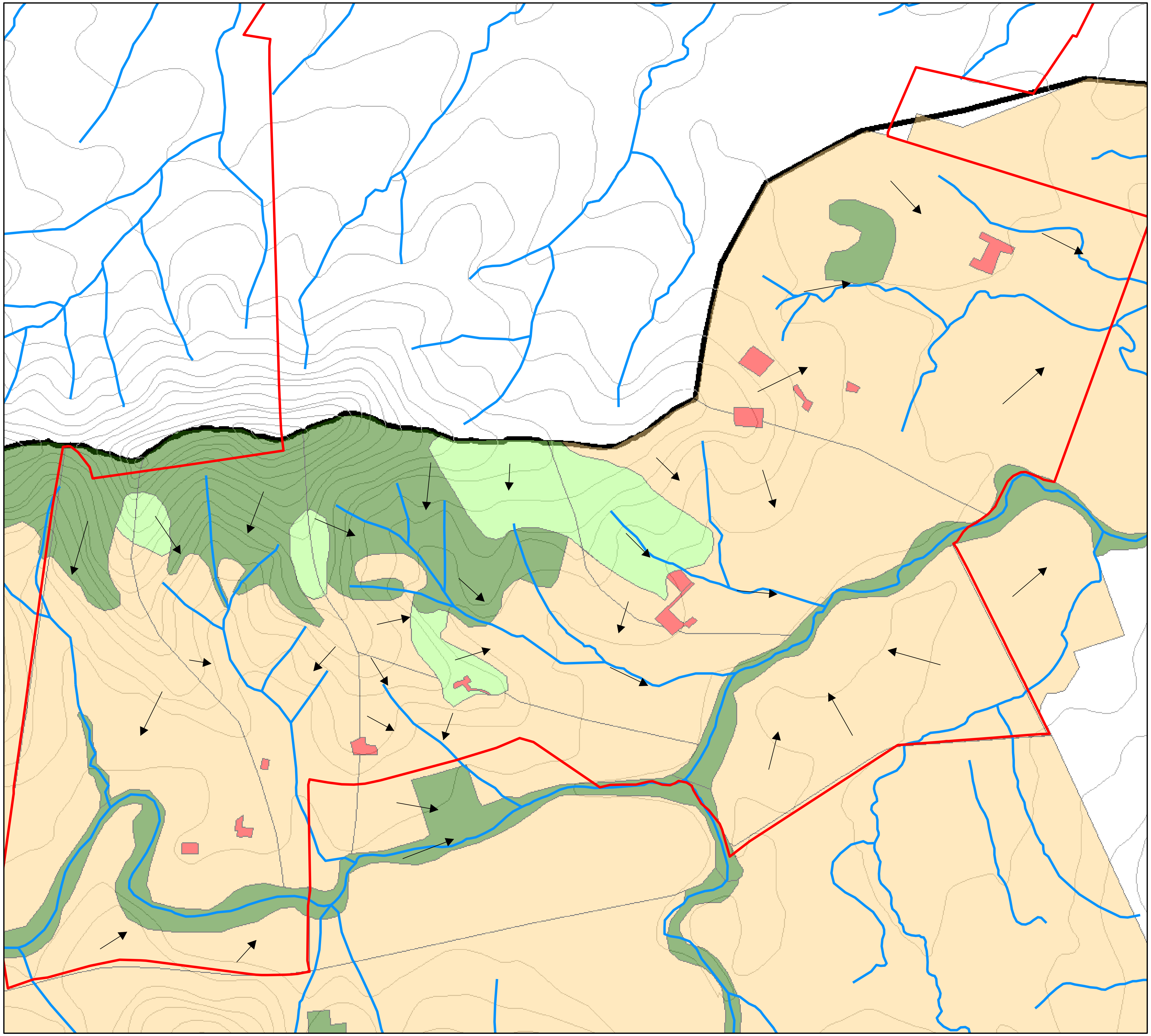
n 1 ha

m 0 100 500 1,000

Subject to verification and detailed site survey 1:20,000 @ A4 10m Contours February 2010

Annex B

B. Catchment Plan



Delfin
Lend Lease

Pre Development MUSIC Subareas Catchment Plan Macquarie Rivulet

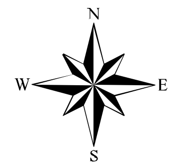
CALDERWOOD
URBAN DEVELOPMENT PROJECT

Legend

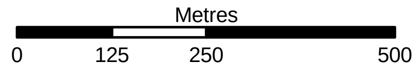
- Site Boundary
- Drainage Direction
- Watercourses (LPMA)
- Catchment Boundary (Cardno)

MUSIC Subareas (Cardno)

- Residential Property
- Rural Landuse
- Dense Vegetation
- Light Vegetation

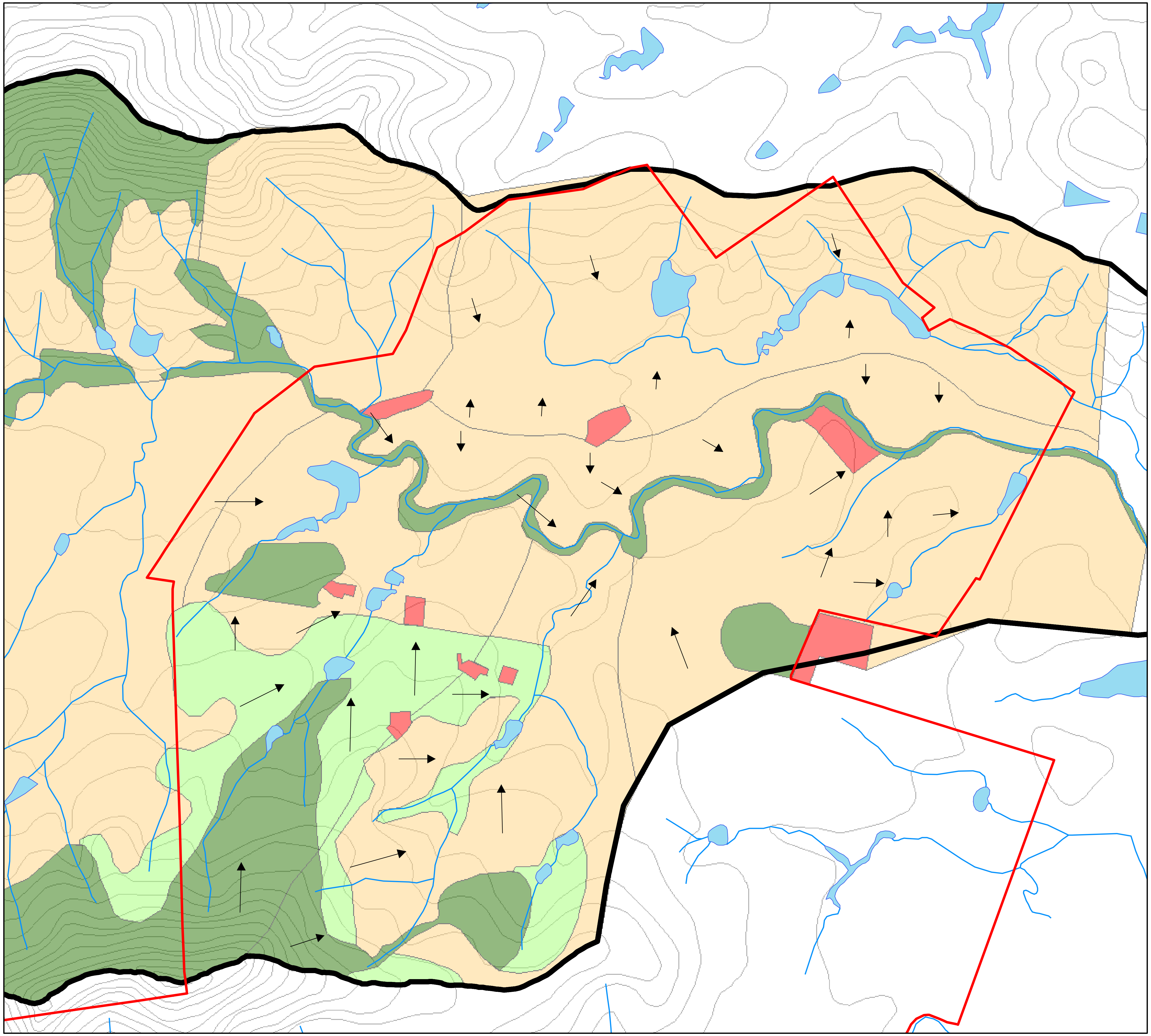


Scale 1:10,000 (at A3)



Cardno

Map Produced by Cardno Wollongong
Date: 24 February 2010
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
110026-03_38026_Pre_Dev_MusicSubareasMacquarieRivulet.mxd 02



Delfin

Lend Lease

Pre Development Music Subareas Catchment Plan Marshall Mount Creek

CALDERWOOD
URBAN DEVELOPMENT PROJECT

Legend

- Site Boundary
- Drainage Direction
- Watercourses (LPMA)
- Catchment Boundary (Cardno)

MUSIC Subareas (Cardno)

- Residential Property
- Rural Landuse
- Dense Vegetation
- Light Vegetation

N
W
E
S

Scale 1:10,000 (at A3)

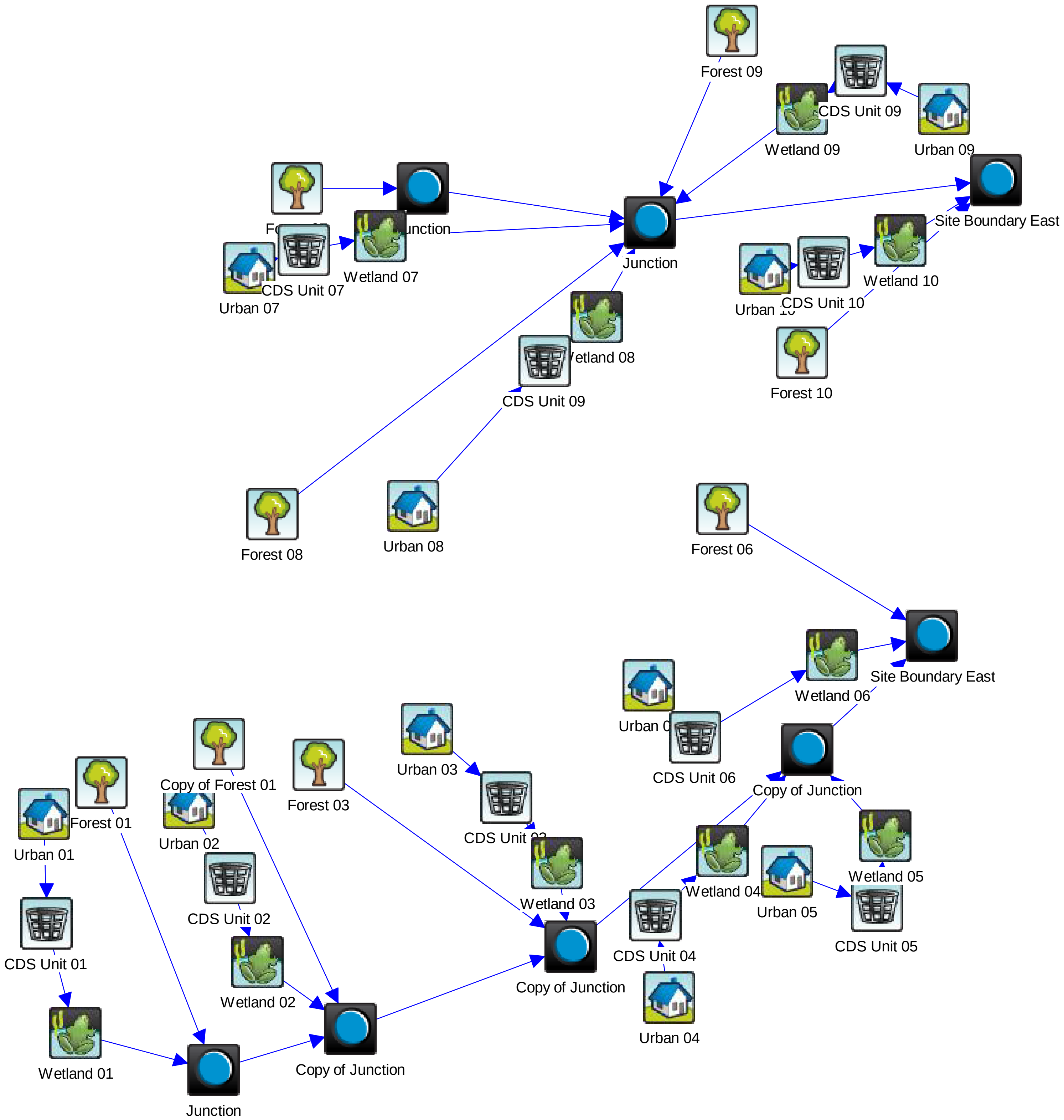
Metres
0 125 250 500

Cardno

Map Produced by Cardno Wollongong
Date: 24 February 2010
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF:
110026-03_38027_Pre_Dev_MusicSubareasMarshallMountCreek.mxd 02

Annex C

C. Water Quality Modelling Results


Forest 09
CDS Unit 09
Urban 09
Wetland 09
Site Boundary East
Junction
Wetland 07
CDS Unit 07
Urban 07
Wetland 10
CDS Unit 10
Forest 10
CDS Unit 09
Forest 08
Urban 08
Forest 06
Site Boundary East
Wetland 06
CDS Unit 06
Copy of Junction
Copy of Forest 01
Urban 01
Forest 01
Urban 02
Forest 03
Urban 03
CDS Unit 02
CDS Unit 01
Wetland 02
Wetland 03
Wetland 04
Urban 05
Wetland 05
CDS Unit 05
CDS Unit 04
Copy of Junction
Urban 04
Wetland 01
Junction
Copy of Junction

MUSIC model results- Marshall Mount Creek Catchment

Model reporting location = Site Boundary East

Concept Plan Pre-Development Marshall Mount Creek Catchment - Site Boundary East - All Data Statistics							
Outflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	0.0449	0.291	0.00538	11.6	0	0.00000172	0.0619
TSS Concentration (mg/L)	53.4	98.6	25.4	2840	0	16.4	120
Log [TSS] (mg/L)	1.51	0.347	1.41	3.45	0.883	1.23	2.09
TP Concentration (mg/L)	0.194	0.232	0.132	4.12	0	0.0851	0.344
Log [TP] (mg/L)	-0.816	0.26	-0.875	0.615	-1.39	-1.05	-0.45
TN Concentration (mg/L)	1.61	1.5	1.23	28.4	0	0.804	2.6
Log [TN] (mg/L)	0.138	0.224	0.0937	1.45	-0.408	-0.0805	0.422
TSS Load (kg/Day)	589	6700	14.2	462000	0	0.00363	250
TP Load (kg/Day)	1.67	17.9	0.068	785	0	0.0000188	0.993
TN Load (kg/Day)	13.6	144	0.632	8170	0	0.000172	8.71
Gross Pollutant Load (kg/Day)	20	106	0	1360	0	0	0
Flow (ML/yr)	1.42E+03						
Total Suspended Solids (kg/yr)	2.15E+05						
Total Phosphorus (kg/yr)	611						
Total Nitrogen (kg/yr)	4.95E+03						
Gross Pollutants (kg/yr)	7.30E+03						

Model reporting location = Site Boundary East

Concept Plan Post-Development - Site Boundary East - All Data Statistics							
Outflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	0.0519	0.309	0.00286	10.6	0	0.000000702	0.0782
TSS Concentration (mg/L)	8.39	5.82	7.48	104	0	5.89	10.9
Log [TSS] (mg/L)	0.9	0.145	0.878	2.02	0.488	0.78	1.04
TP Concentration (mg/L)	0.0397	0.0212	0.0351	0.459	0	0.0239	0.0601
Log [TP] (mg/L)	-1.42	0.162	-1.45	-0.338	-2.06	-1.61	-1.22
TN Concentration (mg/L)	0.846	0.335	0.804	4.22	0	0.546	1.18
Log [TN] (mg/L)	-0.0826	0.134	-0.0897	0.625	-0.743	-0.246	0.0719
TSS Load (kg/Day)	143	1420	1.98	60300	0	0.000505	44
TP Load (kg/Day)	0.536	5.48	0.00801	418	0	0.00000193	0.372
TN Load (kg/Day)	7.68	55.8	0.184	1860	0	0.000044	7.53
Gross Pollutant Load (kg/Day)	0.00224	0.292	0	39.4	0	0	0
Flow (ML/yr)	1640						
Total Suspended Solids (kg/yr)	52100						
Total Phosphorus (kg/yr)	196						
Total Nitrogen (kg/yr)	2810						
Gross Pollutants (kg/yr)	0.818						

Model reporting location = Site Boundary East

Concept Plan Post-Development with climate change(0.25yr ARI treatment) - Site Boundary East - All Data Statistics							
Outflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	5.45E-02	0.353	1.96E-03	12.4	0	5.69E-07	7.08E-02
TSS Concentration (mg/L)	8.51	6.02	7.69	113	0	6.04	10.7
Log [TSS] (mg/L)	0.909	0.141	0.89	2.05	0.333	0.783	1.03
TP Concentration (mg/L)	3.90E-02	2.17E-02	3.42E-02	0.402	0	2.48E-02	5.98E-02
Log [TP] (mg/L)	-1.43	0.156	-1.46	-0.396	-2.01	-1.59	-1.22
TN Concentration (mg/L)	0.835	0.339	0.784	4.15	0	0.562	1.16
Log [TN] (mg/L)	-8.59E-02	0.129	-0.101	0.618	-0.571	-0.234	6.79E-02
TSS Load (kg/Day)	173	1.87E+03	1.35	8.95E+04	0	3.84E-04	39.8
TP Load (kg/Day)	0.594	5.28	5.49E-03	217	0	1.58E-06	0.344
TN Load (kg/Day)	8.54	64.9	0.127	2.27E+03	0	3.54E-05	6.93
Gross Pollutant Load (kg/Day)	7.96E-03	0.856	0	113	0	0	0
Flow (ML/yr)	1.72E+03						
Total Suspended Solids (kg/yr)	6.33E+04						
Total Phosphorus (kg/yr)	217						
Total Nitrogen (kg/yr)	3.12E+03						
Gross Pollutants (kg/yr)	2.91						

MUSIC model results - Macquarie Rivulet Catchment

Model reporting location = Site Boundary East

Concept Plan Pre-Development Macquarie Rivulet Catchment - Site Boundary East - All Data Statistics							
Outflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	4.06E-02	0.266	4.78E-03	10.7	0	1.59E-06	5.54E-02
TSS Concentration (mg/L)	4.90E+01	9.71E+01	2.18E+01	2.89E+03	0	1.45E+01	1.10E+02
Log [TSS] (mg/L)	1.45E+00	3.58E-01	1.34E+00	3.46	0.869	1.18E+00	2.05E+00
TP Concentration (mg/L)	0.172	0.232	0.111	5.49	0	7.33E-02	0.303
Log [TP] (mg/L)	-8.83E-01	0.271	-9.51E-01	0.74	-1.47	-1.12	-5.06E-01
TN Concentration (mg/L)	1.50E+00	1.42E+00	1.13E+00	3.04E+01	0	7.77E-01	2.45E+00
Log [TN] (mg/L)	0.106	2.22E-01	5.51E-02	1.48E+00	-0.413	-9.55E-02	0.397
TSS Load (kg/Day)	514	6.63E+03	1.11E+01	3.94E+05	0	2.89E-03	195
TP Load (kg/Day)	1.21E+00	14.2	5.25E-02	1.07E+03	0	1.33E-05	0.763
TN Load (kg/Day)	9.62E+00	89.1	0.531	3.31E+03	0	1.41E-04	7.08
Gross Pollutant Load (kg/Day)	14.5	76.5	0	985	0	0	0

Flow (ML/yr)	1.28E+03
Total Suspended Solids (kg/yr)	1.88E+05
Total Phosphorus (kg/yr)	441
Total Nitrogen (kg/yr)	3.51E+03
Gross Pollutants (kg/yr)	5.29E+03

Model reporting location = Site Boundary East

Concept Plan Post-Development (0.25yr ARI treatment)- Site Boundary East - All Data Statistics							
Outflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	5.94E-02	0.297	1.41E-02	10	0	4.65E-05	6.68E-02
TSS Concentration (mg/L)	7.72	5.36	6.47	107	0	6.03	9.47
Log [TSS] (mg/L)	8.60E-01	1.39E-01	8.12E-01	2.03	0.474	7.81E-01	9.79E-01
TP Concentration (mg/L)	5.43E-02	2.16E-02	5.50E-02	0.334	0	3.26E-02	6.06E-02
Log [TP] (mg/L)	-1.28	0.135	-1.26	-0.477	-1.85	-1.47	-1.22
TN Concentration (mg/L)	9.95E-01	0.316	9.98E-01	4.25	0	0.738	1.16E+00
Log [TN] (mg/L)	-7.60E-03	1.00E-01	-4.46E-06	6.29E-01	-0.539	-1.18E-01	6.56E-02
TSS Load (kg/Day)	149	1.45E+03	7.96E+00	6.92E+04	0	3.38E-02	39.9
TP Load (kg/Day)	0.613	4.54	6.40E-02	1.57E+02	0	1.30E-04	0.314
TN Load (kg/Day)	9.08E+00	56.4	1.15	1.82E+03	0	2.97E-03	6.32
Gross Pollutant Load (kg/Day)	8.90E-03	0.78	0	95.8	0	0	0

Flow (ML/yr)	1.88E+03
Total Suspended Solids (kg/yr)	5.44E+04
Total Phosphorus (kg/yr)	2.24E+02
Total Nitrogen (kg/yr)	3.32E+03
Gross Pollutants (kg/yr)	3.25

Model reporting location = Site Boundary East

Concept Plan Post-Development with climate change(0.25yr ARI treatment) - Site Boundary East - All Data Statistics							
Outflow	mean	standard deviation	median	maximum	minimum	10 percentile	90 percentile
Flow (cubic metres/sec)	4.67E-02	0.325	1.53E-03	11.3	0	4.42E-07	4.33E-02
TSS Concentration (mg/L)	8.46E+00	5.62	7.81E+00	113	0	6.07	1.02E+01
Log [TSS] (mg/L)	9.12E-01	1.33E-01	8.96E-01	2.05E+00	0.609	7.86E-01	1.01E+00
TP Concentration (mg/L)	3.93E-02	2.25E-02	3.43E-02	4.63E-01	0	2.60E-02	5.99E-02
Log [TP] (mg/L)	-1.42	1.52E-01	-1.46E+00	-3.34E-01	-1.87	-1.57E+00	-1.22
TN Concentration (mg/L)	8.38E-01	0.343	7.85E-01	5.12E+00	0	5.97E-01	1.15
Log [TN] (mg/L)	-8.07E-02	0.121	-0.101	7.10E-01	-0.502	-2.09E-01	6.15E-02
TSS Load (kg/Day)	148	1.63E+03	1.06	1.10E+05	0	3.01E-04	24.7
TP Load (kg/Day)	0.557	5.01	4.24E-03	173	0	1.24E-06	0.203
TN Load (kg/Day)	7.9	63.7	9.73E-02	2.29E+03	0	2.81E-05	4.14
Gross Pollutant Load (kg/Day)	1.80E-02	1.43	0	167	0	0	0

Flow (ML/yr)	1.47E+03
Total Suspended Solids (kg/yr)	5.41E+04
Total Phosphorus (kg/yr)	204
Total Nitrogen (kg/yr)	2.89E+03
Gross Pollutants (kg/yr)	6.57

Outflow of Downstream Wetlands

Macquarie Rivulet Creek Summary	Source	Residual Load	Percentage reduction from baseload pollutant generation
Flow (ML/yr)	1585.2	976.8	-38%
Total Suspended Solids (kg/yr)	309610	25296	-92%
Total Phosphorus (kg/yr)	637.4	149.21	-77%
Total Nitrogen (kg/yr)	4456	2213.2	-50%
Gross Pollutants (kg/yr)	34440	3.24827	-100%

Marshall Mount Creek Summary	Source	Residual Load	Percentage reduction from baseload pollutant generation
Flow (ML/yr)	1541	1108	-28%
Total Suspended Solids (kg/yr)	291200	24980	-91%
Total Phosphorus (kg/yr)	616.7	155.4	-75%
Total Nitrogen (kg/yr)	4334	2329	-46%
Gross Pollutants (kg/yr)	33500	0.8178	-100%

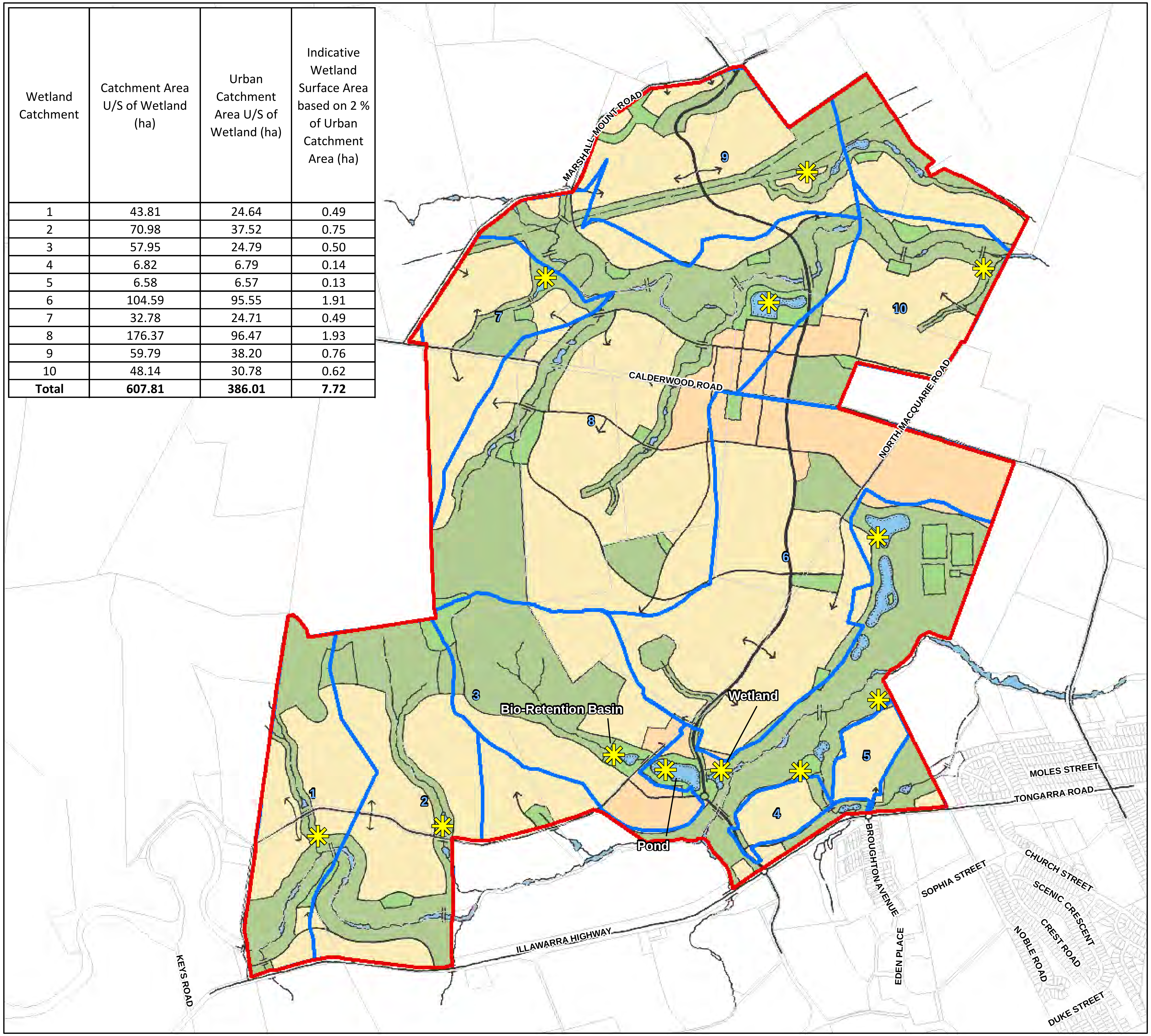
Post Development			
Wetland 01			
Flow (ML/yr)	198	153	22.4
Total Suspended Solids (kg/yr)	3.82E+04	3.23E+03	91.5
Total Phosphorus (kg/yr)	80.4	21.7	73
Total Nitrogen (kg/yr)	549	311	43.3
Gross Pollutants (kg/yr)	4.30E+03	0	100
Wetland 02			
Flow (ML/yr)	304	236	22.2
Total Suspended Solids (kg/yr)	6.12E+04	5.34E+03	91.3
Total Phosphorus (kg/yr)	126	33.8	73.1
Total Nitrogen (kg/yr)	878	511	41.8
Gross Pollutants (kg/yr)	6.61E+03	3.04E-03	100
Wetland 03			
Flow (ML/yr)	201	155	22.6
Total Suspended Solids (kg/yr)	3.94E+04	3.42E+03	91.3
Total Phosphorus (kg/yr)	79.9	20.9	73.8
Total Nitrogen (kg/yr)	570	330	42.2
Gross Pollutants (kg/yr)	4.37E+03	0	100
Wetland 04			
Flow (ML/yr)	55	42.6	22.6
Total Suspended Solids (kg/yr)	1.10E+04	975	91.2
Total Phosphorus (kg/yr)	21.8	5.96	72.7
Total Nitrogen (kg/yr)	152	87.1	42.6
Gross Pollutants (kg/yr)	1.20E+03	1.63E-02	100
Wetland 05			
Flow (ML/yr)	53.2	41.2	22.6

Total Suspended Solids (kg/yr)	9.81E+03	831	91.5
Total Phosphorus (kg/yr)	20.3	5.35	73.6
Total Nitrogen (kg/yr)	147	83.1	43.5
Gross Pollutants (kg/yr)	1.16E+03	8.93E-03	100
Wetland 06			
Flow (ML/yr)	774	349	54.9
Total Suspended Solids (kg/yr)	1.50E+05	1.15E+04	92.4
Total Phosphorus (kg/yr)	309	61.5	80.1
Total Nitrogen (kg/yr)	2.16E+03	8.91E+02	58.8
Gross Pollutants (kg/yr)	1.68E+04	3.22	100
Wetland 07			
Flow (ML/yr)	200	140	30.3
Total Suspended Solids (kg/yr)	3.71E+04	2.97E+03	92
Total Phosphorus (kg/yr)	83.9	20.1	76
Total Nitrogen (kg/yr)	550	282	48.7
Gross Pollutants (kg/yr)	4.35E+03	3.77E-02	100
Wetland 08			
Flow (ML/yr)	782	580	25.8
Total Suspended Solids (kg/yr)	1.46E+05	1.34E+04	90.8
Total Phosphorus (kg/yr)	313	82.7	73.5
Total Nitrogen (kg/yr)	2.20E+03	1.23E+03	44.2
Gross Pollutants (kg/yr)	1.70E+04	0.707	100
Wetland 09			
Flow (ML/yr)	310	215	30.4
Total Suspended Solids (kg/yr)	5.72E+04	4.56E+03	92
Total Phosphorus (kg/yr)	124	29.7	76
Total Nitrogen (kg/yr)	886	460	48.1
Gross Pollutants (kg/yr)	6.73E+03	5.78E-02	100
Wetland 10			
Flow (ML/yr)	249	173	30.6
Total Suspended Solids (kg/yr)	5.09E+04	4.05E+03	92
Total Phosphorus (kg/yr)	95.8	22.9	76.1
Total Nitrogen (kg/yr)	698	357	48.8

Annex D

D. Concept WSUD Layout

Wetland Catchment	Catchment Area U/S of Wetland (ha)	Urban Catchment Area U/S of Wetland (ha)	Indicative Wetland Surface Area based on 2 % of Urban Catchment Area (ha)
1	43.81	24.64	0.49
2	70.98	37.52	0.75
3	57.95	24.79	0.50
4	6.82	6.79	0.14
5	6.58	6.57	0.13
6	104.59	95.55	1.91
7	32.78	24.71	0.49
8	176.37	96.47	1.93
9	59.79	38.20	0.76
10	48.14	30.78	0.62
Total	**607.81**	**386.01**	**7.72**



Delfin Lend Lease

Proposed Water Management Structures

CALDERWOOD
URBAN DEVELOPMENT PROJECT

Legend

- Site Boundary
- Proposed Wetlands
- Design Riparian Corridor *
- Catchment Boundary (Major)
- Cadastre (LPMA)

** Design Riparian Corridor derived from buffer against Top of Bank as defined from ALS 0.5m terrain by Cardno Forbes Rigby in conjunction with Delfin Lend Lease and incorporating proposed creek works.*

Concept Base Plan from Delfin Lend Lease - February 2010

N W E S

Scale 1:15 000 (at A3)

Metres
0 250 500 750 1,000

Cardno

Map Produced by Cardno Wollongong
Date: 24 February 2010
Coordinate System: Zone 56 MGA/GDA 94
GIS MAP REF: 110026-01_38049_WaterManagementStructures.mxd 04