





Calderwood Urban Development Project

Section 75W Application

Watercycle and Flood Management Strategy Updates

Lendlease

13 July, 2018

Document Control

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Table of contents

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICIES

1 GLOSSARY

12D Model is a powerful terrain modelling, surveying and civil engineering software package used to develop the underlying surface for the 2D modelling.

Airborne Laser Survey (ALS) is a technique for obtaining a definition of the surface elevation (ground, buildings, power lines, trees, etc.) by pulsing a laser beam at the ground from an airborne vehicle (generally a plane) and measuring the time taken for the laser beam to return to a scanning device fixed to the plane. The time taken is a measure of the distance which, when ground truthed, is generally accurate to + 150mm.

Annual Exceedance Probability (AEP) is the chance or probability of a natural hazard event (usually a rainfall or flooding event) occurring annually and is usually expressed as a percentage.

Average Recurrence Interval (ARI) means the average statistical interval (in years) between occurrences of floods, storms and flows of a particular magnitude.

Australian Rainfall and Runoff (AR&R) refers to the current edition of Australian Rainfall and Runoff published by the Institution of Engineers, Australia.

CatchmentSIM is a 3D-GIS application specifically tailored to hydrology based applications. CatchmentSIM is used to delineate a catchment, break it up into sub catchments, determine their areas and spatial topographic attributes and analyse each sub catchment's hydrologic characteristics to provide insight into the rainfall response of various catchments and the resultant assignment of hydrologic modelling parameters.

Dam Safety Committee (DSC) is a NSW statutory body aligned with Department of Primary Industries. Its function is to ensure the safety of dams within the state.

Digital Terrain Model (DTM) is a spatially referenced three-dimensional (3D) representation of the ground surface represented as discrete point elevations where each cell in the grid represents an elevation above an established datum.

Exceedances per Year (EY) is the number of times a year that statistically a storm flow will be exceeded.

Floodplain Planning Level (FPL) the FPL is a height used to set floor levels for property development in flood prone areas. It is generally defined as the 1% AEP flood level plus 0.5m freeboard

Floodplain Development Manual (FDM) and Guidelines (April 2005), the FDM is a document issued by DECCW that provides a strategic approach to floodplain management. The guidelines have been issued by the NSW DoP to clarify issues regarding the setting of FPL's.

Floodplain Storage Areas are those parts of a floodplain that are important for the temporary storage of floodwaters during the passage of a flood. Loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation.

Floodway is the areas of the floodplain where a significant discharge of water occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.

Hyetograph is the distribution of rainfall over time.

Hydrograph is a graph that shows how the stormwater discharge changes with time at any particular location.

Hydrology The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.

J. Wyndham Prince Pty Ltd (JWP) Consulting Civil Infrastructure Engineers and Project Managers undertaking these investigations

MUSIC is a modelling package designed to help urban stormwater professionals visualise possible strategies to tackle urban stormwater hydrology and pollution impacts. MUSIC stands for Model for Urban Stormwater Improvement Conceptualisation and has been developed by Cooperative Research Centre (CRC),

Peak Discharge is the maximum stormwater runoff that occurs during a flood event

Probable Maximum Flood (PMF) is the greatest depth of precipitation for a given duration meteorologically possible for a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends."

Triangular Irregular Network (TIN) is a technique used in the created DTM by developing a mass of interconnected triangles. For each triangle, the ground level is defined at each of the three vertices, thereby defining a plane surface over the area of the triangle

TUFLOW is a computer program that provides two-dimensional (2D) and one dimensional (1D) solutions of the free surface flow equations to simulate flood and tidal wave propagation. It is specifically beneficial where the hydrodynamic behaviour, estuaries, rivers, floodplains and urban drainage environments have complex 2D flow patterns that would be awkward to represent using traditional 1D network models.

WSUD – Water Sensitive Urban Design

XP-RAFTS runoff routing model that uses the Laurenson non-linear runoff routing procedure to develop a sub catchment stormwater runoff hydrograph from either an actual event (recorded rainfall time series) or a design storm utilising Intensity-Frequency-Duration data together with dimensionless storm temporal patterns as well as standard AR&R 1987 data.

2 EXECUTIVE SUMMARY

This report is an update to the Watercycle and Flood Management Strategy previously prepared to support the Calderwood Concept Plan Approval (MP09_0082) for the Calderwood Urban Development Project (CUDP). It will accompany an Environmental Assessment Report (EAR) for a proposed S75W Modification Application to the approved Concept Plan. This modification is sought to the Approved Concept Plan to allow for increased and more diverse housing supply at Calderwood. The application looks to increase the total number of dwellings within CUDP from approximately 4800 to approximately 6500.

This report addresses key issues 8d and 11 from the Secretary's Environmental Assessment Requirements (SEARs), issued on the 1st February 2018. From a Watercycle Management perspective, the impact of increased lot density will influence both the water quality and flooding within the site. This report provides details of and assesses the proposed amendments to, both water quality and flooding so that compliance with appropriate water management standards is achieved.

Table 2-1 – SEARs Requirements

SEARs Requirements	Strategy Response
8: Riparian Impacts (d)	
Include details of how the NSW Water Quality and River Flow objectives within the receiving waters of Lake Illawarra will be achieved during the future construction and operational phases of the development.	Given that there are no specific water quality or river flow objectives currently established for the Lake Illawarra, the water quality management for CUDP will be consistent with the documented water quality objectives for both Wollongong City and Shellharbour City Council's, i.e. traditional water quality treatment that delivers post-development flows that achieved an 85% reduction in Total Suspended Solid (TSS), 65% reduction in Total Phosphorous (TP) and 45 % reduction in Total Nitrogen (TN)
11: Drainage, Water Quality and Flooding	
Provide an updated assessment of the potential flood risks associated with the proposal in accordance with the NSW Floodplain Development Manual (2005) and consider any new/updated flood studies for the catchment/s and the potential impacts of climate change.	A detailed flood assessment has been undertaken using the latest flood study information from Shellharbour City Council. The assessment has considered the increase in development density and has concluded that comparable flood impacts to that which supported the concept approval and consequent development applications. The latest TUFLOW model for the Macquarie Rivulet (WMAwater 2017) has been used for the purposes of this assessment. Details of the assessment undertaken are provided in Section 8 of this report.
Provide a revised Water Cycle Management Study which identifies the impacts of the proposed modification and how water quality and quantity impacts on the drainage system and natural waterways will be managed both internally and externally to the site	The revised Watercycle and Flood Management study (this report) proposes a treatment train of WSUD elements to manage water quality including on lot controls, gross pollutant traps, raingardens and absorption trenches / level spreaders, consistent with the concept plan approval and subsequent development applications. This system achieves the required water quality objectives. It has been modelled using MUSIC to confirm system performance. Details of the proposed Water Cycle Management system are provided in Section 6 and 7 of this report.

2.1 Water Quality

The proposed increase in lot yield from 4,800 to approximately 6,500 will result in an increase in development density. This increase in turn, will increase the pollutant loads generated from the new housing. The necessary changes to the Water Cycle and Flood Management Strategy to ensure the water quality objective listed in the original concept plan will be achieved by an increase in the treatment device sizing for those listed in the original concept plan Strategy [1]. This proposed increase will ensure the water quality objectives of the original concept plan are maintained with the proepsoed lot amendment.

This report provides the basis for detailed design and development of the site to ensure that the environment, urban amenity, engineering and economic objectives for stormwater management can be achieved.

The revised Water Cycle and Flood Management Strategy consists of a treatment train including on lot treatment, street level treatment and subdivision/development treatment measures. The structural elements proposed for CUDP consist of:

- Proprietary GPT units at each stormwater discharge point.
- 27 wetlands, or other suitable alternative treatment device scattered across the development

2.2 Flooding

Flooding and flood evacuation are also major considerations for the site. The current developable footprint will be maintained, the increase in lot density will be facilitated by provision of an increase in smaller lots. Therefore, runoff characteristics from the increased density will have minimal impact on flood affectation in both the Macquarie Rivulet and Marshall Mount Creek, the two major watercourses within the CUDP. These impacts will be managed as part of the ongoing development of CUDP.

As part of the S75W assessment, the adopted flood model from Shellharbour City Council (SHCC) has been used in order to establish the updated 'existing' conditions. It is noted that the SHCC model did not allow for the CUDP. A new 'base' condition which includes all approved development has also been assessed.

The investigation concludes that the development of CUDP in accordance with this strategy will be consistent with the controls and principles established by the NSW Government and both Shellharbour City Council and Wollongong City Council. Though there has been a refinement of design, the revised water cycle and flood management strategy remains consistent in philosophy with the original 2010 concept approval.

The report supports the proposed amendments to CUDP and provides the framework with which to support the ongoing development from a watercycle and flooding management perspective.

Yours faithfully

J. WYNDHAM PRINCE

DAVID CROMPTON

Manager - Stormwater and Environment

[1] Calderwood Urban Development Project WCMS, Cardno, February 2010

3 INTRODUCTION

Lendlease has engaged J. Wyndham Prince Pty Ltd to undertake a review of the flooding and water quality controls associated with a potential increase in proposed lot yield for the CUDP.

This Watercycle Management Strategy (WCMS) update for the total CUDP accompanies an Environmental Assessment Report (EAR) for a proposed S75W Modification Application to the Calderwood Concept Plan Approval (MP09_0082) (Approved Concept Plan) for the Calderwood Urban Development Project (CUDP).

A modification is sought to the Approved Concept Plan to allow for increased and more diverse housing supply at the CUDP site. The increase in housing supply is proposed to ensure that the existing area of urban zoned land at the CUDP is efficiently used for the continued supply of a range of housing types and sizes that both meet market demand and will assist address housing affordability pressures in the Illawarra region.

3.1 Site Description

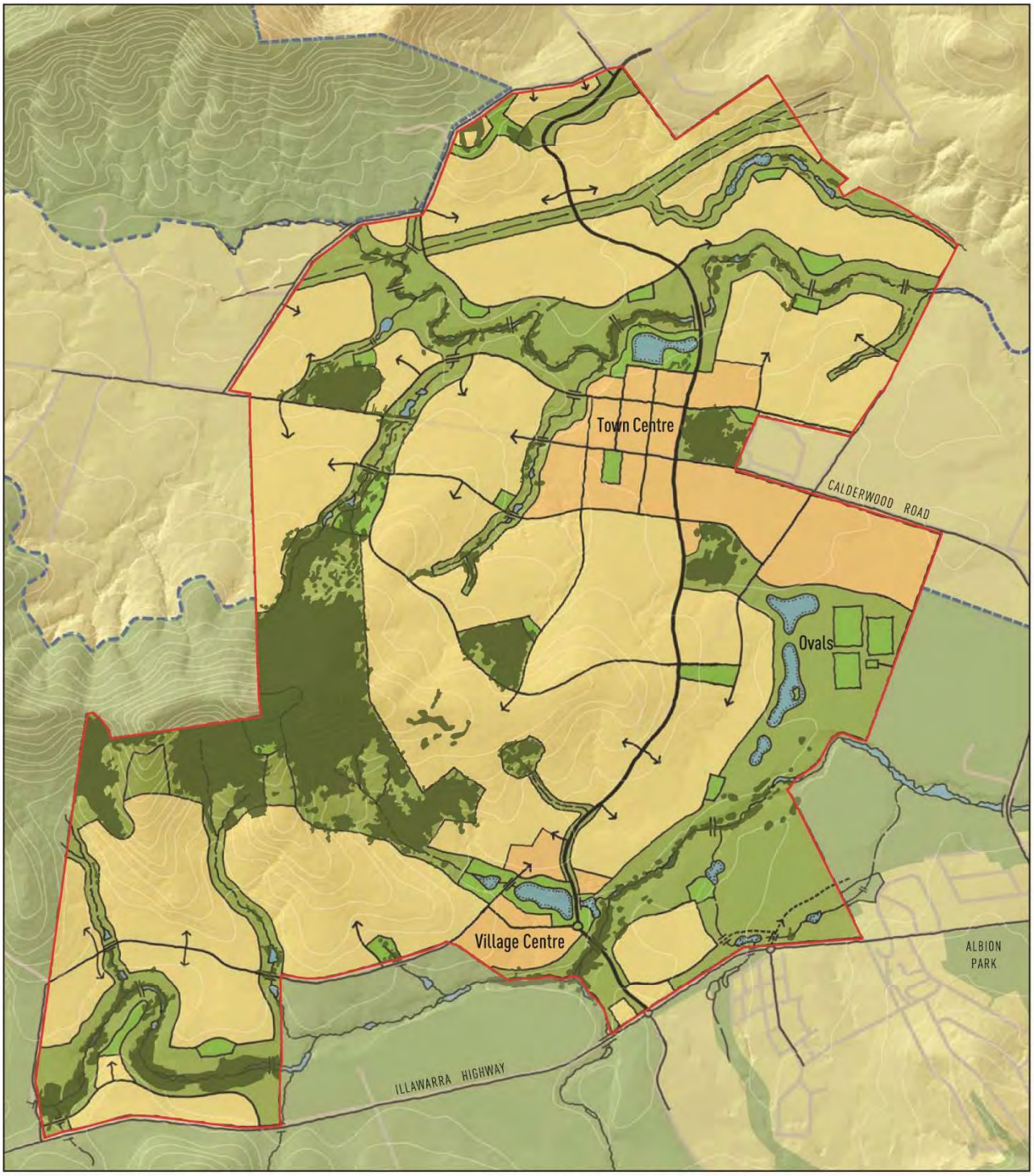
The CUDP site is located within the Calderwood Valley in the Illawarra Region. It is approximately 700 hectares in area with approximately 107 hectares of land in the Wollongong LGA (15%) and the balance in the Shellharbour LGA (85%). An aerial photograph of the site is provided at Plate 3-1.

The CUDP site is bound to the north by Marshall Mount Creek (which forms the boundary between the Shellharbour and Wollongong LGAs), to the south by the Macquarie Rivulet, to the south-west by Johnston's Spur and to the west by the Illawarra Escarpment. Beyond Johnston's Spur to the south is the adjoining Macquarie Rivulet Valley within the locality of North Macquarie. The CUDP site extends south from the intersection of North Marshall Mount Road and Marshall Mount Road to the Illawarra Highway.

There are a number of 'non-core' landowners within CUDP that Lendlease (LL) will not be developing (refer Plate 3-1 for their location) The development in these non-core lands will remain consistent with current application and the understanding of the development layouts. The approved concept plan from the 2010 approval is provided in Plate 3-2.

Lendlease has commenced the development of its component of the overall CUDP, and will continue to develop the project in stages over an approximately 15+year period. To date, Lendlease has obtained development consents for some 1,200 dwellings within Stages 1, 2a, 2b and 2c and 3a, and lodged development applications for another 650 dwellings in Staged 3b south and 3c of the overall project. Other developers have also lodged development applications for a further 824 lots on land within the Concept Plan boundary that Lendlease does not own or control. Plate 3-3 illustrates the development status of the project.

Plate 3-1 –The Site
Source: Lendlease Communities



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 2011

Plate 3-2 –Approved Calderwood Concept Plan 2010
Source: Lendlease Communities

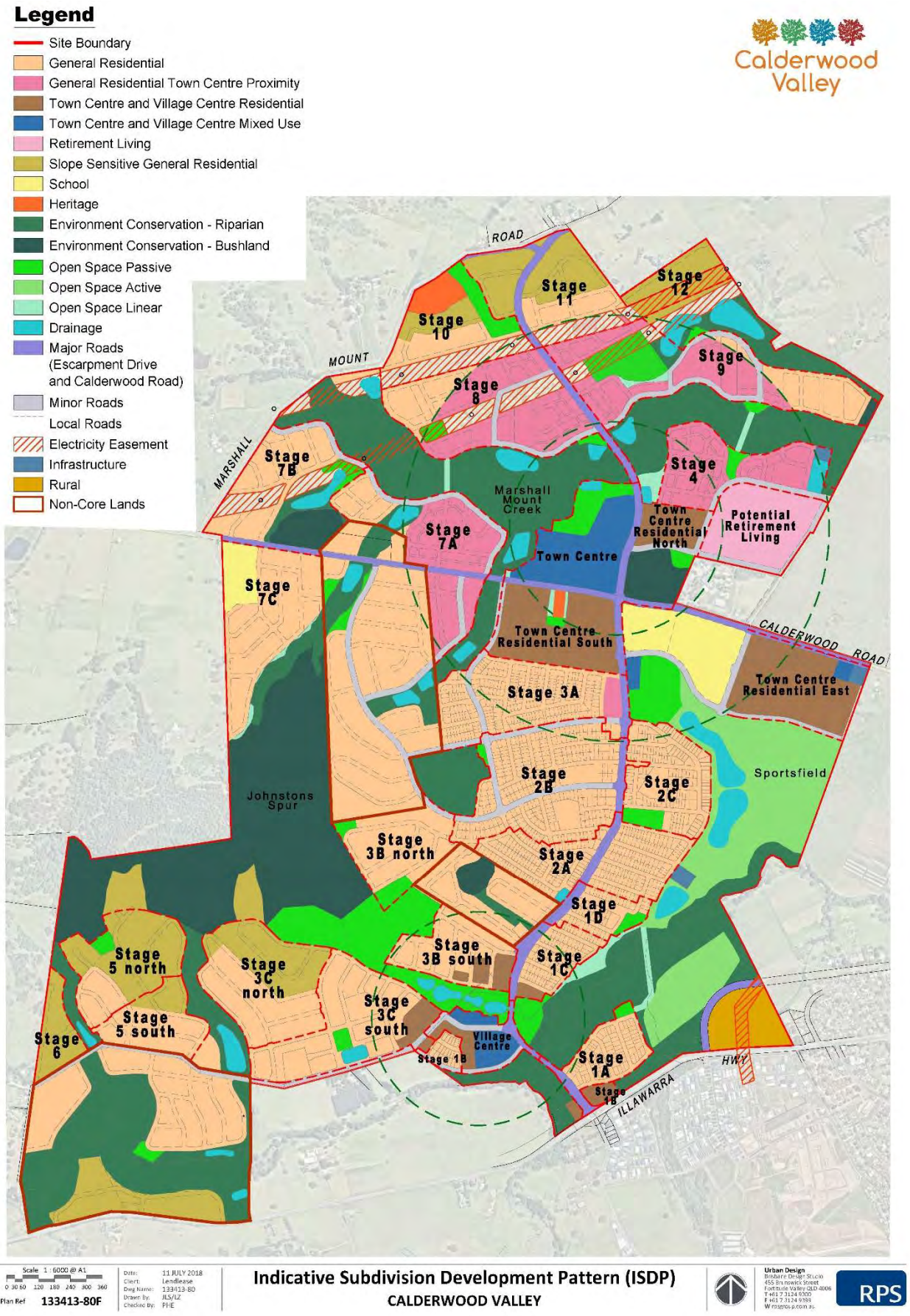


Plate 3-3 – Indicative Subdivision Development Plan
Source: Lendlease Communities

3.2 Proposed Concept Plan Modification

The proposed modification to the Approved Concept Plan seeks to increase the total provision of housing (approximate number of dwellings) within the overall CUDP to respond to market demand for the provision of smaller housing types / lot sizes at affordable price points and to ensure the efficient use of urban zoned land within this context for the supply of housing.

It is proposed to increase the overall number of dwellings to be delivered within the existing area of land zoned R1 General Residential and B4 Mixed Use and also approved for urban development as shown on the Approved Concept Plan from approximately 4,800 to approximately 6,500 dwellings.

The increased residential yield is predominantly due to affordability pressures that are driving stronger demand for smaller and more diverse housing types. Those stages of development already approved at Calderwood include a more diverse mix of housing types and lot sizes than was supported by the market at the time the Concept Plan was approved in 2010, both in the Lendlease holdings and those developments being progressed by others.

Within the Approved Concept Plan framework, the proposed increased dwelling yield will be achieved via the delivery of a greater diversity of dwelling types and lot sizes within the R1 General Residential and B4 Mixed Use zones generally as follows:

- Within the R1 General Residential zone, additional yields will be achieved through the delivery of a more diverse range of housing types such as seniors housing and integrated housing and also by a different mix of lot sizes than was anticipated at the time of the Approved Concept Plan in 2010 (including a greater number of smaller lots). This changes is in response to the changing and more diverse market expectations and housing affordability pressures;
- Within the B4 Mixed Use zone, the number of dwellings to be provided will be increased through the provision of a combination of more shop top housing, mixed use development and stand-alone residential development.

A range of new provisions are proposed to be incorporated into the Development Control Strategy to allow for the broader range of housing typologies, lot sizes and affordable housing options that are proposed to meet current market demand.

Further detail of the statutory framework in which the Concept Plan will be amended with will be provided separately to this report.

The proposed modified Concept Plan is shown on

Plate 3-4.

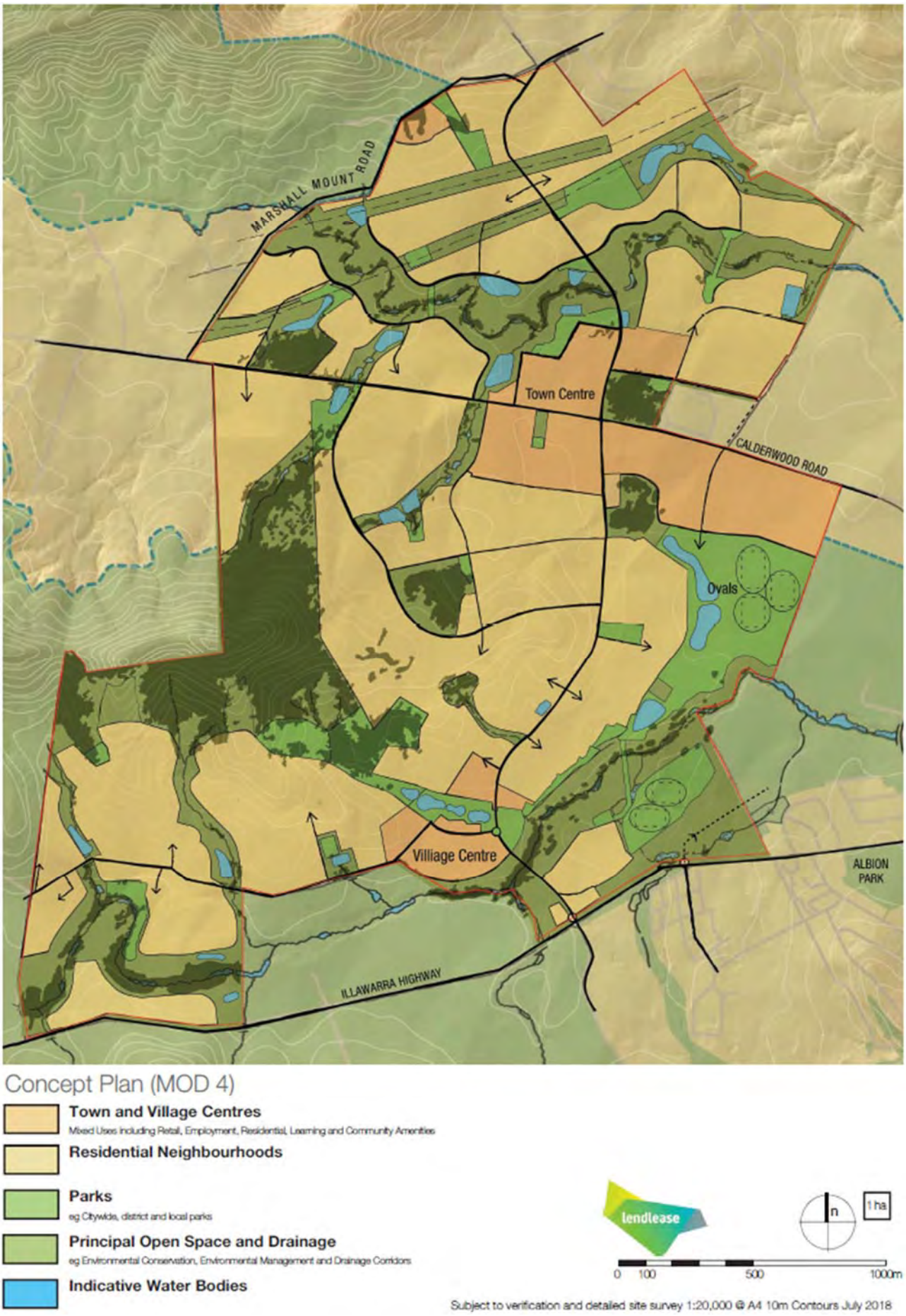


Plate 3-4 – Proposed Modified Concept Plan
Source: Lendlease Communities

4 RELEVANT PREVIOUS DOCUMENTS

A series of reports were reviewed to inform this assessment. Provided below are details of the relevant documents.

4.1 Original Concept Plan

4.1.1 Flood Modelling report – Macquarie Rivulet below Sunnybank, Rienco Consulting (2009)

Rienco Consulting was commissioned by Lendlease to investigate existing flood conditions in the lower reaches of the Macquarie Rivulet in order to quantify flood behaviour associated with the CUDP.

A hydrologic model (WBNM) of the Macquarie Rivulet was established in conjunction with a hydraulic model (TUFLOW) spanning from downstream of the Albion Park Gauge to the outlet of the Macquarie Rivulet into Lake Illawarra. The hydrologic model was calibrated to June 1991 flow hydrographs at the Albion Park and Princes Highway gauges on the Macquarie Rivulet. Hydraulic modelling of the study area was undertaken using a 7 x 6 km TUFLOW domain based on a 10 m cell size. Again, calibration of the hydraulic model was based on the June 1991 event due to the availability of data.

The report provided the following information for the 1% AEP (100 year ARI) and PMF events:

- Peak flood levels,
- Velocities and
- Flood hazard categories (Velocity x Depth)

This modelling determined that 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. 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."* (Rienco, 2009).

4.1.2 Floodplain Risk Management Study, Cardno (March 2011)

Cardno was commissioned by Lendlease to prepare a Floodplain Risk Management Study (FPRMS) to accompany the original Concept Plan Application for the CUDP. The Reinco model was used to inform the assessments made in this report.

The 2D hydraulic modelling was then modified to simulate the effects of the proposed development. This included the following changes:

- The DTM has been modified to reflect the developed surface. However, this surface was represented by "vertical walls" where there was limited consideration given to the shape of the future development Pad
- Consideration of the appropriate roughness in all riparian corridors has been included in the assessment, and the TUFLOW manning's has been adjusted to account for this.
- The proposed Macquarie Rivulet bridge was modelled as part of this assessment
- The hydrological input to this assessment remains unchanged from the original Reinco assessment

This study was accepted by the Land and Environment Court (LEC) as the basis for the current Concept Plan.

4.2 Macquarie Rivulet Flood Study (WMAwater 2017)

The Macquarie Rivulet Flood Model provided by Shellharbour City Council was used as the basis for both the hydrologic and hydraulic modelling for this assessment. The Macquarie Rivulet Flood Study report (WMAwater, 2017) outlines the approach taken in this model, which is summarised below:

A hydrologic (WBNM, Watershed Bounded Network Model) model was established for the catchment to determine inflows into the hydrodynamic model. Stream gauge data was available within the catchment with a period of record of 63 years thus enabling the use of a flood frequency approach for the estimation of design flows in an appropriate range. The results of the flood frequency analysis were used to validate results from the hydrologic models. WBNM parameters (such as loss, stream routing) were adjusted where appropriate to reconcile the WBNM flows against the results of the flood frequency analysis.

A combined one and two dimensional hydrodynamic (TUFLOW) model was used to define the flood behaviour using ALS, bathymetric and structure survey. The hydrologic and hydraulic models were calibrated to a range of historical events and then used to assess the flood levels and hydraulic hazard for a range of design events.

4.3 Development Guidelines

The following Documents have been read and reviewed and have formed the basis for the decision making behind this report

- NSW State Rivers and Estuaries Policy
- Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-Use Planning Decisions
- Illawarra Floodplain Risk Management Study and Plan 2012
- Wollongong City Council Development Control Plans
- Shellharbour City Council Development Control Plans

5 SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS

The NSW Department of Planning and Environment issued a set of Secretary's Environmental Assessment Requirements (SEARs) in order to approve the modification to the Concept plan.

SEARs were issued by the NSW Department of Planning and Environment on the 1st February 2018. The requirements that relate to CUDP that are addressed in this report, key issues 8d and 11, are detailed below in Table 5-1, with responses provided on how they are addressed. Key issues 8a, b and c will be addressed in a separate report, prepared by EcoLogical.

Table 5-1 – SEARs Requirements

SEARs Requirements	Strategy Response
8: Riparian Impacts (d)	
Include details of how the NSW Water Quality and River Flow objectives within the receiving waters of Lake Illawarra will be achieved during the future construction and operational phases of the development.	Given that there are no specific water quality or river flow objectives currently established for the Lake Illawarra, the water quality management for CUDP will be consistent with the documented water quality objectives for both Wollongong City and Shellharbour City Council's, i.e. traditional water quality treatment that delivers post-development flows that achieved an 85% reduction in Total Suspended Solid (TSS), 65% reduction in Total Phosphorous (TP) and 45 % reduction in Total Nitrogen (TN)
11: Drainage, Water Quality and Flooding	
Provide an updated assessment of the potential flood risks associated with the proposal in accordance with the NSW Floodplain Development Manual (2005) and consider any new/updated flood studies for the catchment/s and the potential impacts of climate change.	A detailed flood assessment has been undertaken using the latest flood study information from Shellharbour City Council. The assessment has considered the increase in development density and has concluded that comparable flood impacts to that which supported the concept approval and consequent development applications. The latest TUFLOW model for the Macquarie Rivulet (WMAwater 2017) has been used for the purposes of this assessment. Details of the assessment undertaken are provided in Section 8 of this report.
Provide a revised Water Cycle Management Study which identifies the impacts of the proposed modification and how water quality and quantity impacts on the drainage system and natural waterways will be managed both internally and externally to the site	The revised Watercycle Management study (this report) proposes a treatment train of WSUD elements to manage water quality including on lot controls, gross pollutant traps, raingardens and absorption trenches / level spreaders, consistent with the concept plan approval and subsequent development applications. This system achieves the required water quality objectives. It has been modelled using MUSIC to confirm system performance. Details of the proposed Water Cycle Management system are provided in Section 6 and 7 of this report.

As part of the initial SEARs, consultation with a series of government authorities was undertaken. The Environmental Protection Authority (EPA) has provided comments that directly relate to the Watercycle and Flood Management update. Details of the comments from the EPA are provided in Table 5-2.

Table 5-2 – EPA Recommendations for water quality

EPA Recommendations	Strategy Response
Provide an assessment of any potential impacts of the proposal on the hydrology and hydrogeology in accordance with the OEH/EPA Risk-based Framework for Considering Waterway Health Outcomes in Strategic Land-Use Planning Decisions'. Include particular focus on water quality, the extent to which development protects, maintains or restores water health and the community's environmental values and use of waterways also known as the NSW Water Quality Objectives for Lake Illawarra and its supporting catchment.	The OEH/EPA Risk based framework establishes the recommended process for establishing high level goals for water quality and river flow objectives and establishing a framework for how these will be applied in a particular catchment. This guideline indicates that "*the framework is best implemented at the catchment and sub catchment scale by an overall managing authority such as a council or regional or state agency*." Neither Shellharbour City nor Wollongong City Councils indicated that this work had already been performed for the Lake Illawarra catchment and did not indicate expectations that the proponent would develop or apply such a framework to the CUDP. The hydrology and water quality solutions proposed and approved for the CUDP were based on compliance with Council, and industry standard objectives that are still relevant in current LEP's and other controls. The modification being sought to the Concept Approval is minor in terms of impacts on water quality and flows, and this study demonstrates that the current planning objectives for these are maintained.
A Soil and Water Management Plan should be prepared in accordance with the Managing urban stormwater: soils and construction, vol. 1 (Landcom 2004) and vol. 2 (A. Installation of services; B Waste landfills; C. Unsealed roads; D. Main Roads; E. Mines and quarries) (DECC 2008).	A Soil and Water Management Plan will be provided for all stages of the development as part of the development application submissions.
Provide a concept Stormwater Management Plan outlining the general stormwater.	An updated Stormwater Management Plan for the CUDP is provided in Sections 6 and 7.
Management measures for the proposal, including the use of sustainability measures such as Water Sensitive Urban Design (WSUD) to create more resilient and adaptable urban environments. This should also include measures for ongoing maintenance including any associated funding approaches for ongoing management.	Details of the proposed Water Cycle Management system, which incorporates WSUD elements are provided in Section 6 and 7 of this report. Maintenance of these facilities will be undertaken by the relevant local Council (public assets) or the property owner (private assets) and involves established maintenance practices. Operation and maintenance plans for the WSUD elements can be developed in support of future development applications.

EPA Recommendations	Strategy Response
Outline opportunities for the use of integrated water cycle management practices and principles to optimise opportunities for sustainable water supply, wastewater and stormwater management across the development.	The water cycle management strategy proposes the use of on lot rainwater tanks, bioretention systems, floating wetlands and other water quality treatment solutions to provide best practice stormwater management solutions that maximise reuse opportunities. Water supply and wastewater services on the CUDP are provided by Sydney Water Corporation using conventional and proven solutions. Details of the proposed Water Cycle Management system are provided in Section 6 and 7 of this report.
Provide details of sewage management and an assessment of any potential impacts on the community's uses and environmental values of waterways and public health.	The sewage system will be provided consistent with that which exists across the CUDP and all waterway health is considered as part of the ongoing approval of the sewage management system. The design of this system will ensure that surcharges of effluent to the local waterways is in accordance with the authorities' own guidelines.

6 WATER QUALITY MANAGEMENT OPTIONS

The Water Cycle Management Strategy proposed for the CUDP has been prepared with consideration of the statutory requirements and guidelines listed in the various local government authority guidelines. The strategy focuses on mitigating the impacts of the development on the total water cycle and maximising the environmental, social and economic benefits achievable by utilising responsible and sustainable stormwater management practices.

6.1 Potential Water Sensitive Urban Design Measures

A critical consideration for the Water Cycle and Flood Management strategy is the long term ecological sustainability of the development and both the Marshall Mount Creek and Macquarie Rivulet corridors. To maintain stormwater quality at the required levels, a 'treatment train' approach is proposed where various types of pollutants are removed by a number of devices acting in series.

A range of water sensitive urban design measures may be adopted as part of the proposed development for the management of stormwater runoff. Each of these management measures were evaluated and compared with consideration of a range of environmental, social/amenity, economic, maintenance and engineering criteria. Additional information on these devices is provided in Appendix C.

The devices proposed for the CUDP are as follows:

- **Wetlands** are the preferred option to provide "end of line" treatment prior to discharge to Marshall Mount Creek and Macquarie Rivulet. They will enhance the natural elements of the site and provide an attractive solution. Floating wetlands are also considered as an alternative to traditional wetlands.

- **Bio-retention "raingardens"** are proposed as a viable alternative to Wetlands within the overall Water Cycle Management Strategy for the CUDP where they will provide "end of line" treatment prior to discharge to the Macquarie Rivulet or Marshall Mount Creek and minimise land take.

- **Vegetated Swales** are proposed as a supplement for other devices, as they provide an effective means of removing pollutants, particularly Total Suspended Solids (TSS) while minimising land take. They are suggested as a secondary treatment mechanism within the CUDP.

- **Ponds** are proposed to house and potential floating wetlands to provide additional pollutant removal as well as to provide an attractive focal design point for the development.

- **Gross Pollutant Traps** are effective in removing gross pollutants from stormwater runoff generated from large urbanised catchments. They provide a single point of maintenance, which is beneficial to the long-term viability and cost effectiveness of the water quality treatment system.

7 PROPOSED WATER CYCLE MANAGEMENT STRATEGY

7.1 Previous Water Cycle Management Study

The watercycle management strategy for the approved Concept Plan[2] showed that catchments for the CUDP divided into ten (10) subcatchments, as shown on the following Plate 7-1 and Plate 7-2 shows a further refinement of proposed locations.

The purpose of this assessment is to analyse the implications of an increase in the proposed lot yield.

The overall inputs and parameters of this assessment have not been significantly changed from approved WCMS methods[2]. Notwithstanding, minor modifications have been made in this assessment to cater for the increased yield plan. There has been some refinement of catchments in the northern parts of the development which drain to Marshall Mount Creek have also been undertaken. The majority of the proposed increase in density takes place in this northern portion, which will primarily impact on the Marshall Mount Creek. To cater for the increase in lot density, catchments in the north have been split into smaller catchments to better assess the localised treatment devices.

It is important to note that as part of this assessment, the proposed online and offline basin locations of treatment devices are consistent with the original approved locations

7.1.1 Modifications to the Previous Water Cycle Management Study

Since the development of the approved Concept Plan, a number of Stages have been developed across the site.

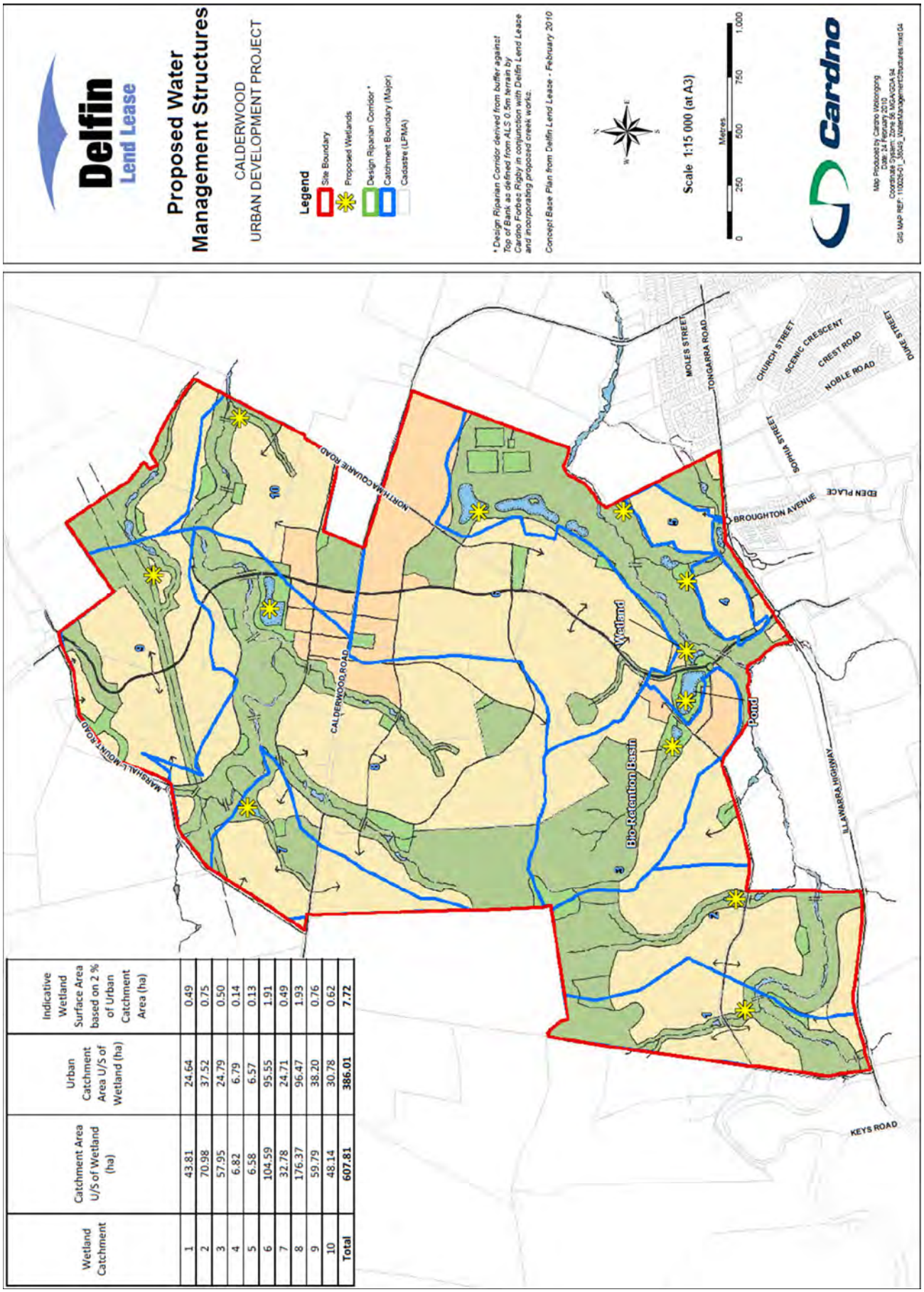
Cardno was commissioned by Lendlease to prepare Water Cycle Management Study (WCMS) for the development applications for Stage 1[3], Stage 2[4], Stage 2C[5] and Stages 3B South[6] & 3A[7]. Arcadis was commissioned to provide a water quality treatment for Stage 3C, and both Fortnum and Sunglow Development Groups have provided further details of how their developments will manage water quality.

Development Consent has been received or are pending approval from SHCC for all these stages. WCMS supporting each development stage will provide more detail on water quality management for that stage. Where the approved devices are not affected by the density uplift, no change is proposed from that submitted as part of the development application for each stage. These devices have therefore not been modelled as part of this report. Only areas which will be affected by the proposed density uplift have been remodelled, particularly where these catchments are also draining to the same treatment devices approved as part of the above-mentioned stages.

There are also a number of future stages, where final detailed layouts for the development have not yet been confirmed. For these devices, it has been established that a wetland sized at five percent (5%) of the urban area that drains to it should be sufficient to deliver the required water quality objectives. As forested areas will not be modified as part of the development, these areas have been excluded from the calculated catchment area. This estimate is similar to previously constructed devices within CUDP and should provide an appropriate level of treatment.

The areas proposed for each stage are shown in further detail on Plate 7-3 together with the area that already have development consent. The final locations of the proposed/approved water devices for each stage are also shown on Plate 7-4.

[2] Calderwood Urban Development Project WCMS, Cardno, February 2010
[3] Calderwood Urban Development Project Stage 1, Cardno, Rev 3 March 2011
[4] WCMS Calderwood Urban Development Stage 2, Cardno, 29 July 2016
[5] Calderwood Urban Development Stage 2C Detailed Design, Cardno, 7 February 2018
[6] WCMS Calderwood Urban Development Stage 3B South, Cardno, 21 December 2016
[7] WCMS Calderwood Urban Development Sage 3A, Cardno, 20 December 2017



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**

Plate 7-1 – Original Water Cycle Management Plan
Source: Original Concept Plan, Appendix D (Cardno February 2010)

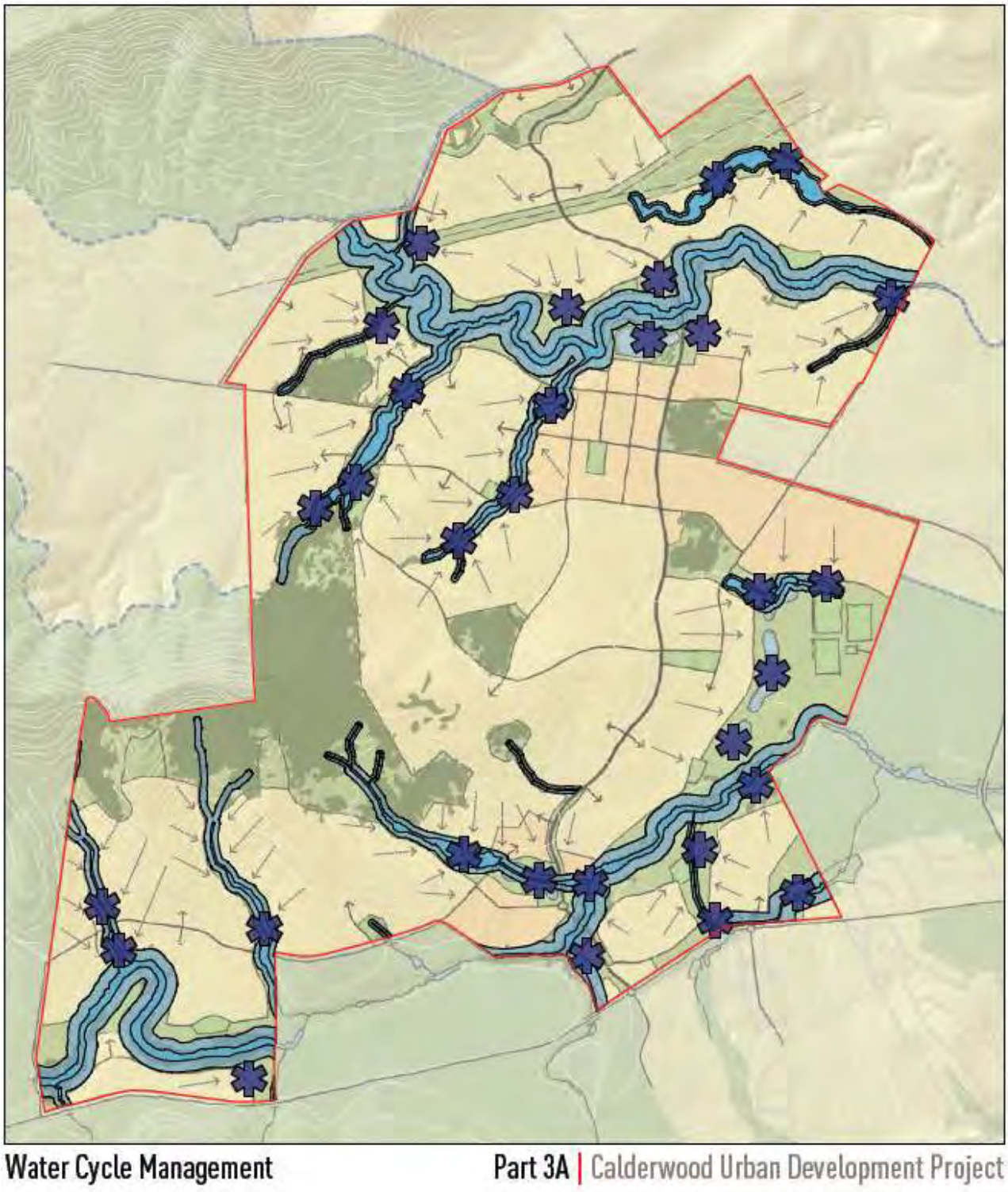


Plate 7-2 – Original Water Cycle Device Locations
Source: Consolidated Concept Plan, Figure 15 (JBA March 2011)

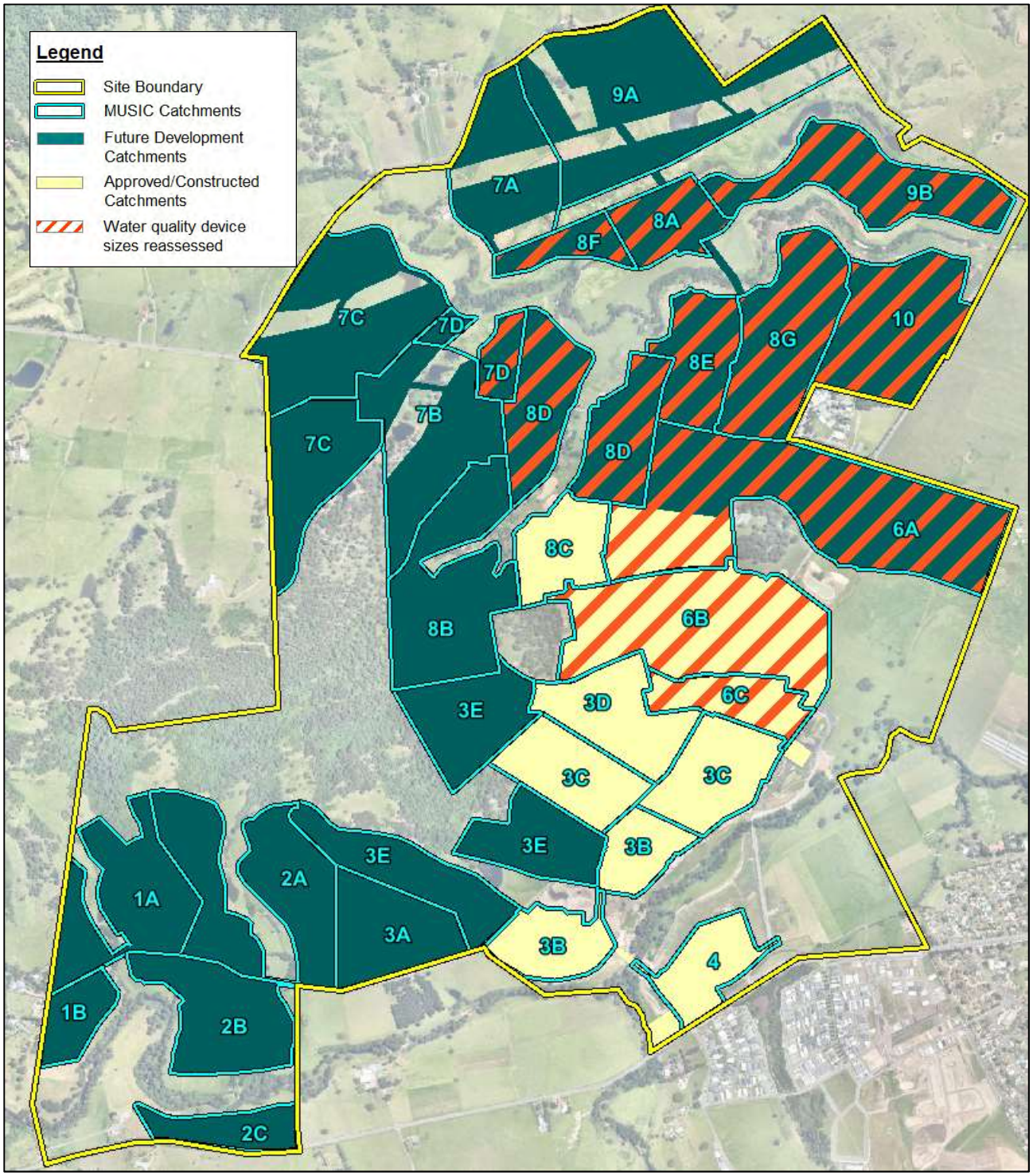


Plate 7-3 – Current Development Status

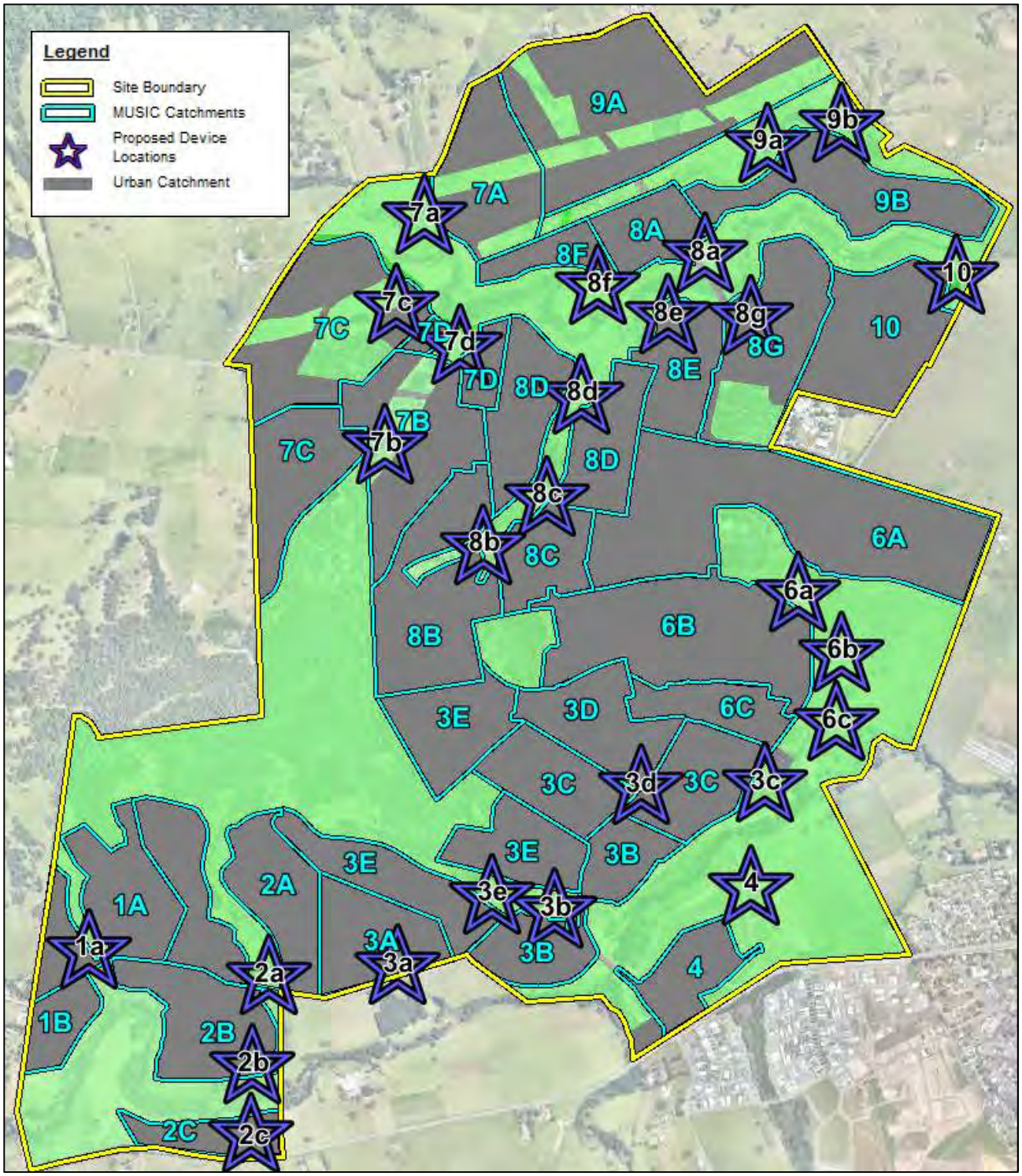


Plate 7-4 – Proposed Device Locations

7.2 Detailed MUSIC modelling for Catchment 6a, 6b and 6c

Stages 2A and 2B, located within catchments 6b and 6c, have been previously approved, and the proposed devices for these stages was sized appropriately. However, the catchments containing this development, catchment 6a, 6b and 6c, shown on Plate 7-4, will be affected by the density uplift in the proposed town centre and education precinct. Therefore, detailed modelling was undertaken to demonstrate that the watercycle management system originally proposed as part of the concept plan approved, with minor modifications, can cater for the increased densities proposed as part of this modification. The stormwater quality management for this study was undertaken using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC). This water quality modelling software was developed by the Cooperative Research Centre (CRC) for Catchment Hydrology, which is based at Monash University and was first released in July 2002. Version 6.3 was released in 2016 and has been adopted for this study.

The model provides a number of features relevant for the development:

- It is able to model the potential nutrient reduction benefits of gross pollutant traps, constructed wetlands, grass swales, bio-retention systems, sedimentation basins, infiltration systems, ponds and it incorporates mechanisms to model stormwater re-use as a treatment technique
- It provides mechanisms to evaluate the performance of water quality against Council objectives.

The modelling has adhered to industry accepted parameters for MUSIC models to represent the generation of various pollutants by different land uses. A MUSIC model representing the proposed development was prepared to demonstrate compliance with industry standard post development annual load reductions consistent with the original concept plan approval. The target reductions are shown in Table 7-1.

Table 7-1 – Pollutant Removal Targets

Pollutant	Target Reduction Required
Total Suspended Solids (TSS)	85%
Total Phosphorus (TP)	65%
Total Nitrogen (TN)	45%
Gross Pollutants (GP)	90%

The proposed increase in lot yield results in an increase in development density and an increase in impervious area. This will in turn increase the pollutant loads generated. Therefore, Water Quality measures previously proposed for the approved concept design will need to be increased in order to meet the pollutant targets for an increased lot yield.

7.2.1 Catchment Layout

A MUSIC model was established to represent the proposed development. The approved WCMS has proposed Wetland 6b (9,000 m^2) east of Stage 2C to treat catchments 2B1, 2B2 and 2C (referred to as catchment 6B on Plate 7-4). Furthermore, as part of the approved Stage 3A DA submission, catchment 3A2 was also designed to drain east of Stage 2C by providing an additional 3,000 m^2 Wetland, Wetland 6a, next to Wetland 6b.

As part of the most recent Stage 2C submission for these devices, Wetland 6a and 6b have been merged into one device, Flows from Wetland 6a and 6b cascade into Wetland 6c. Wetlands 6a, b and c have been modelled with the device sizes proposed in the latest DA submission. Device sizes are shown in Table 7-2.

Table 7-2 – Device Sizes

Device	Size (m^2)
Pond 1	17,690
Wetland 6a and 6b	4470
Pond 2	21,180
Wetland 6c	4750

As part of the proposed increase in density, Town Centre East, a portion of the main Town Centre and the Education Precinct are all proposed to drain to Wetland 6a and 6b, along with the above-mentioned existing catchments. To further assess the implications of the increase in density, these areas were initially modelled with an assumed density of 60% total impervious area and then increased to 85% total impervious area to cater for the increased lot density as a result of the increase in lot yield, as shown in Plate 7-5

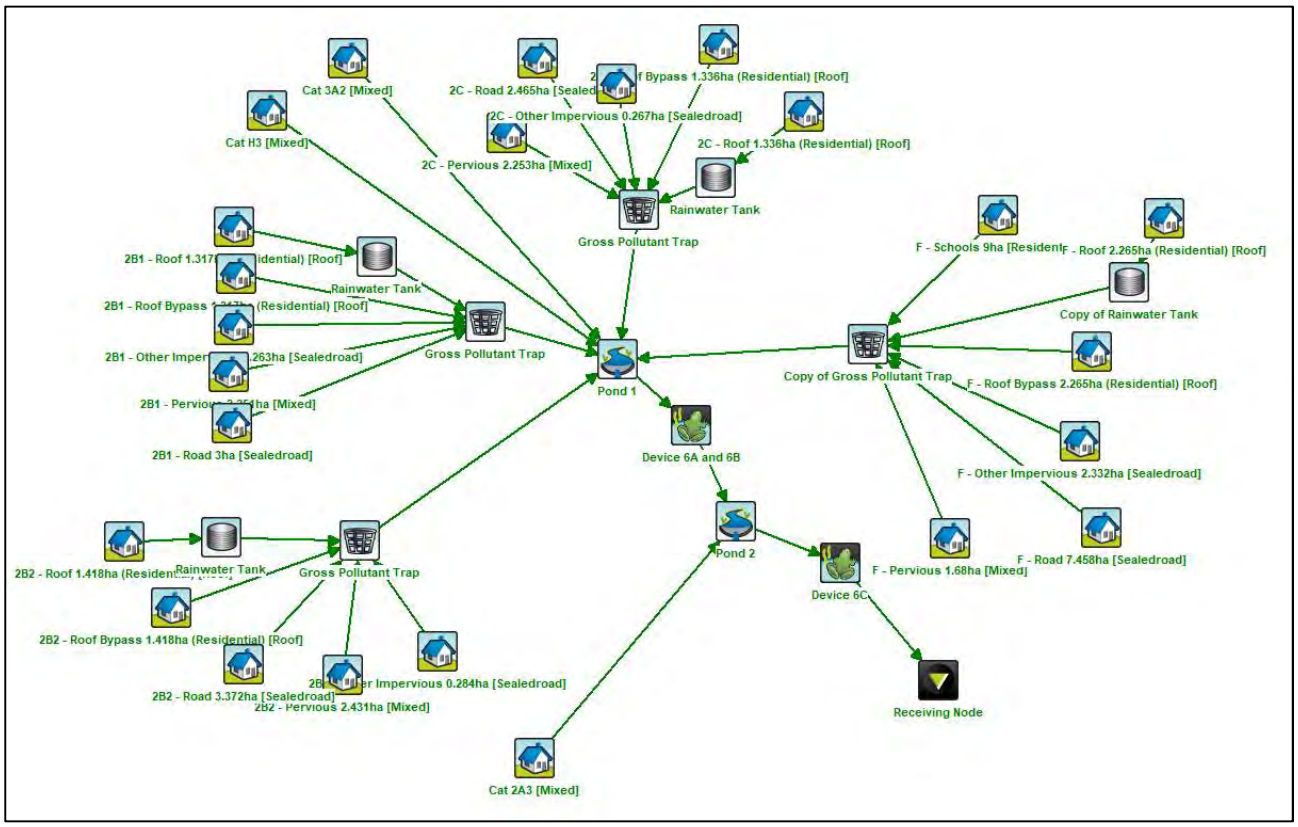


Plate 7-5 – MUSIC Model Layout (Catchment F – 85% Impervious)

7.2.2 Parameters

The parameters adopted in the MUSIC model were consistent with the parameters adopted in the original concept plan. Each catchment was broken up into the following areas: Roads, residential lot areas, open space and special use areas (such as schools and commercial areas)

Table 7-3 – Modelling Input Parameters

Area Type	Impervious Area %
Proposed Town Centre North	90%
Proposed Town Centre East	85%
Low Density Residential (R1)	50%
Low Density Residential (R2)	60%
Low Density Residential with proposed density uplift (R2)	75%
Education Precinct	50%
Non core-Invividual	60%
Non core-Other Developer	63%
Commercial/industrial	95%
Road Reserve	90%
Active Open Space	50%
Passive Open Space	10%
Forested Lands	0%

Note: All % are to total lot area

The values within Table 7-3 were used to further refine the lot and special use areas. Details of the MUSIC node arrangement used in this assessment are provided in Appendix B.

7.2.3 Results

The annual pollutant load estimates were derived from the results of the MUSIC model based on a stochastic assessment of the developed site incorporating the proposed water quality treatment system. The estimated amount of pollutant loads and reductions for TSS, TP, TN and Gross Pollutants exiting the site are presented in Table 7-4.

Table 7-4 – Estimate Mean Annual Pollutant Loads (Devices 6a-c)

Pollutant	Total Developed Source Loads (kg/yr)	Minimum Reduction Required (kg/yr)	Total Residual Load From Site (kg/yr)	Total Reduction Achieved (kg/yr)	Target Reduction Required (%)	Total Reduction Achieved (%)
TSS	68800	58480	6690	62110	85%	90%
TP	139	90.350	31.400	107.6	65%	77%
TN	978	440.10	413	565	45%	58%
GP	11400	10260.0	1.87	11398.1	90%	100%

Furthermore, as detailed in the current Bulk Earthworks development application, the current sizes for Wetlands 6a, 6b and 6c used in this assessment result in reduced targets that exceed minimum standard even with the proposed density uplift. Hence, no increase to the device size is required to support the current Concept Plan amendments.

7.3 Water Quality Summary

The following devices, which form part of the updated watercycle management plan, and will be further assessed during the stage delivery of the development is provided below:

Table 7-5 – Estimated treatment device sizes

Refined Device				
Catchment Name	Urban Catchment Area	Device Size (m^2)	% Urban Catchment	Approved/Pending DA's
1a	15.66	6300	4.0%	No density uplift
1b	4.88	Rural lots, Fortnum Developments Ltd to provide treatment		
2a	21.63	8700	4.0%	No density uplift
2b	13.70	Device sizes are consistent with those constructed/ approved		
2c	5.48			
3a	11.07			
3b	13.39			
3e	30.44			
3c	20.79			
3d	11.66			
4	7.41			
5	Development no longer proposed in this area			
Sub Total	**156.11**		**0.0%**	-
6a & 6b	68.03	17,690	2.6%	Sports Fields & Education Precinct
6a & 6b		4470	0.7%	Sports Fields & Education Precinct
6c	7.39	21,180	28.7%	Stage 2C DA plan
6c		4750	6.4%	Stage 2C DA plan
7a	11.42	5800	5.0%	-
7b	14.46	15185	10.5%	Sunglow Development Group
7c	27.44	13800	5.0%	-
7d	4.49	2300	5.0%	-
8a	7.21	3700	5.0%	-
8b	20.46	20719	10.1%	Sunglow Development Group
8c	8.359	300	0.4%	Stage 3A (Raingarden)
8d	20.12	10100	5.0%	-
8e	9.54	4800	5.0%	-
8f	4.49	2300	5.0%	-
8g	14.11	7100	5.0%	-
9a	26.63	13400	5.0%	-
9b	16.34	8200	5.0%	-
10	17.35	8700	5.0%	-
Sub Total	**277.82**	**164,494**	**5.9%**	**N/A**

Note: Greyed out areas indicate catchments unaffected by CUDP concept plan modification and/or where these water treatment devices have previouslty been approved. These devices have not been modelled unless the catchment is associated with a density uplift

Table 7-5 indicates that the required water quality solution has increased from the original Concept plan approval. The following reasons are contributing factors to this increase in treatment areas:

- The original assessment used MUSIC version 3.0, while the current assessment uses version 6.2. In the past eight (8) years there has been significantly improved in the assessment tool and in turn, the effectiveness of water quality treatment device better understood. This together with the increase in the dataset used in MUSIC has resulted in an improved understanding the treatment train needs and is considered to be a better representation of the treatment devices sizes in comparison to the 2010 assessments.

- In 2010 the target treatment parameters where 80% reduction in TSS, 45% reduction in TP, 45% reduction in TN. The appropriate standard now requires 85% reduction in TSS, 65% reduction in TP, 45% reduction in TN thus increasing the size and configuration of the treatment devices needed to deliver these elevated targets.

- The modelled catchments have been refined to be consistent with constructed or approved development and result in a larger treated area when compared to the original Concept Plan. However, it should be noted that there is no increase in the overall development footprint.

It should be noted that some of the devices approved as part of recent DA's within the southern catchment have resulted in device sizes that in the order of 5% of the catchment in which they are treating.

Preliminary MUSIC modelling demonstrates that the combination of rainwater tanks, GPT and Wetlands at 5% of developable area should achieve the required removal rates of 85% TSS, 60% TP and 45% TN.

It is recommended that as the development of CUDP continues, refined water quality modelling be undertaken to support the ongoing CUDP.

8 FLOOD MANAGEMENT

To assess the flood impacts associated with the proposed modification to density across the CUDP, we have reviewed and undertaken a series of modelling tasks to support the application. The following design approach has been undertaken:

- Review all available existing flood models in the area including:
    - The Reinco Flood Study (2009)
    - The Cardno Model (2011)
    - The WMAwater Macquarie Rivulet Model (2017)
- As detailed in the SEARs we have used the latest TUFLOW model for the Macquarie Rivulet and modelled the following three (3) scenarios in both the WBNM and TUFLOW models.
    - **Existing Conditions** –Catchment conditions prior to any urban development associated with the CUDP.
    - **Approved Development Conditions** – Includes approved development within the CUDP only, which has been used in this assessment as the basis for all comparisons to assess the impacts associated with the S75W amendments.
    - **Proposed Developed Conditions** - Modelling updated to consider the CUDP concept plan layout.
- The developed conditions model was then assessed against the Reinco Flood and Cardno Model to ensure any reported impacts are consistent with the overarching concept plan proposal and any Land and Environment Court approval.

8.1 Hydrologic Analysis

A Watershed Bounded Network Model (WBNM) was used as the hydrological model for the development, consistent with the Macquarie Rivulet Flood Model, as well as all other previous modelling approaches. WBNM is widely used throughout Australia and particularly the south coast of NSW. WBNM simulates a catchment and its tributaries as a series of sub-catchment areas linked together to replicate the rainfall and runoff process through the natural stream network. Input data includes the definition of the physical catchment characteristics including area of sub-catchments, proportion of impervious surfaces and temporal and spatial rainfall patterns over the catchment.

In the existing case, the hydrologic model was kept consistent with the calibrated Macquarie Rivulet Flood model. Refer to Figure 01 for the catchment breakup.

In the developed case, the hydrologic model was also kept consistent with the calibrated Macquarie Rivulet Flood model with the following key changes were made to the WBNM model to ensure that it accurately reflected the developed conditions in support of this S75W application:

8.1.1 Sub catchment Delineation

The catchment breakup was modified to better reflect the updated development conditions (Figure 02). This was completed using digital terrain models that reflects the existing discharge locations, and ensuring a similar discharge point, considered for the developed conditions.

8.1.2 Roughness Parameters

The pervious and impervious areas for the catchment were updated to reflect likely developed conditions. As the existing site was farmland, there will be a significant increase in the impervious area across the site that may result in an increase the local peak flows from the development.

8.1.3 WBNM Results

Potential increases in peak flows were considered as part of this assessment. While the proposed wetlands and water cycle strategy for the site will ensure that peak flows entering the creek systems will not influence geomorphic change as a result of the development, a worst-case scenario has been modelled that excludes these devices to determine if there is a need for formal detention across the site.

Our analysis demonstrated that local peaks from site run off do not coincide with peak flows from upstream of the site for the both the Macquarie Rivulet and Marshall Mount Creek. Refer Plate 8-1 with the location of the comparison point shown in Plate 8-2 below.

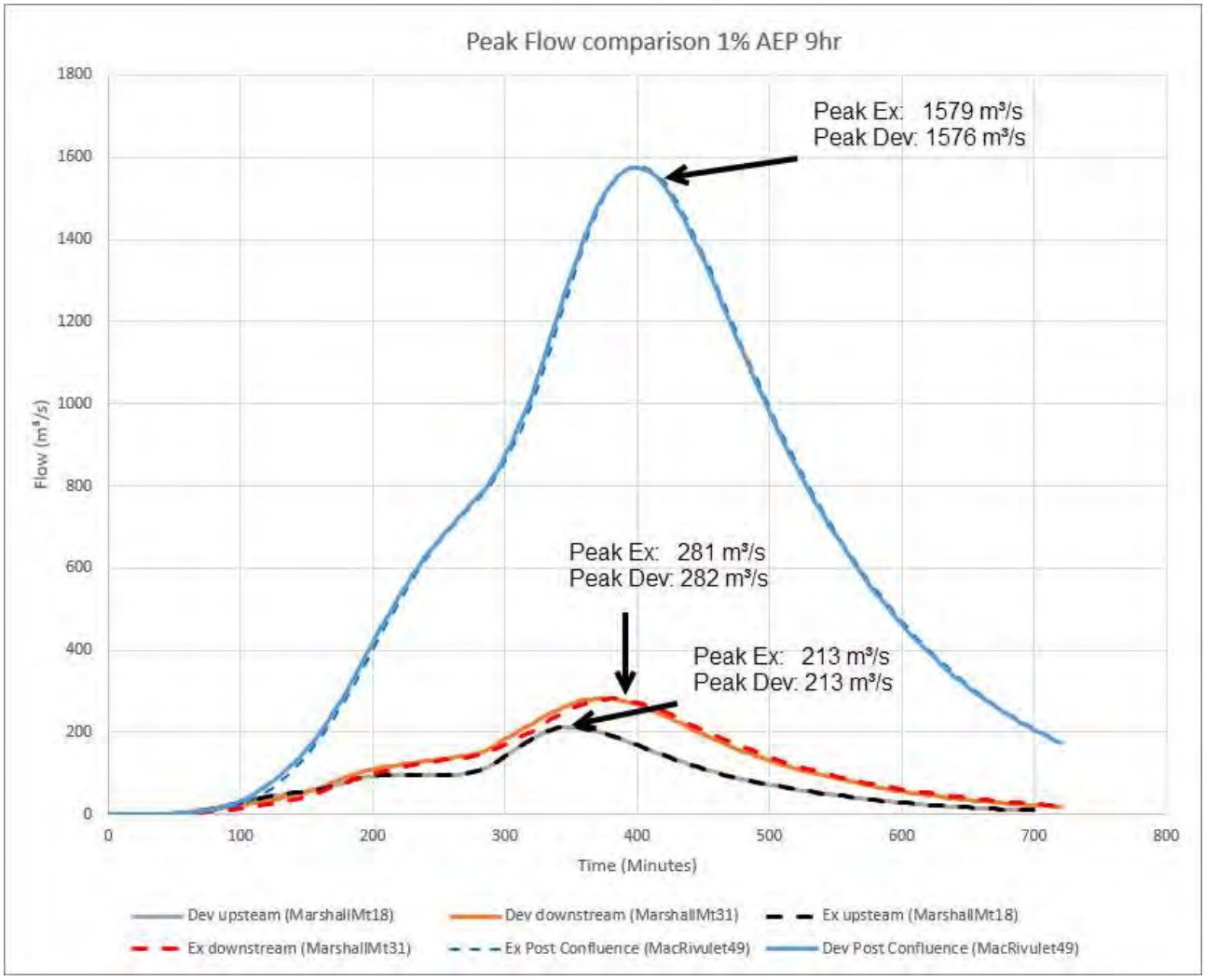


Plate 8-1 – WBNM flow comparison in Marshall Mount Creek

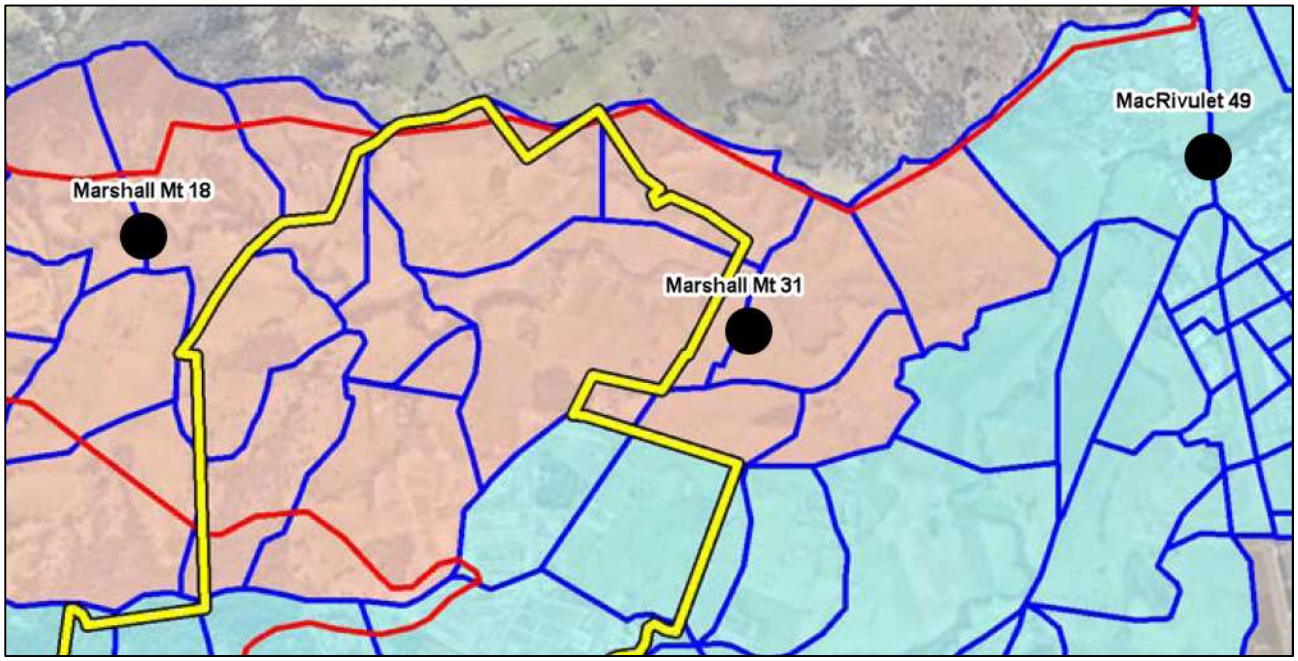


Plate 8-2 – WBNM flow comparison locations

The modelling demonstrates that there is a marginal increase in peak flows downstream of the site of 1.36 m³/s (i.e. 0.5% increase in the 1% AEP event) with no detention. However, the shift in peak timing associated with the earlier release of local flows arising from the urbanisation of the CUDP improves existing flooding downstream of the confluence of the Macquarie Rivulet and Marshall Mount Creek. Therefore, there is no need for formal detention within the site.

8.1.4 Detention Basins

Modelling indicates that formal detention is not needed to reduce impacts downstream of the site as peak discharge levels throughout both the Macquarie Rivulet and Marshall Mount Creek are not unmanageably increased as a result of development. This is because the increase in local peaks caused by the development do not coincide with the total river peaks.

Increased flows caused by smaller and more frequent events will be managed within the proposed water quality treatment train.

8.2 Hydraulic Analysis

The Macquarie rivulet TUFLOW model was provided by Shellharbour Council. In the existing case, the hydrologic model was kept consistent with the calibrated Macquarie Rivulet Flood model with the following changes:

- The TUFLOW model was updated to run on TUFLOW Build 2018-03-AB
- Some outdated model components (such as flow constrictions and unsupported shapes) were updated so that the latest version of TUFLOW could be used.
- Models were run using a HPC solver solution instead of a CPU solver to improve run times.
- Additional survey of the Macquarie Rivulet undertaken as part of the original concept plan approval was added to the model to augment the accuracy of this model.

The above changes were compared to the original SHCC model results, and no significant difference was observed.

8.2.1 Developed Conditions

The Macquarie Rivulet model TUFLOW model was used as the base for the assessments for the developed conditions model. Changes were made where appropriate to represent developed model conditions. In order to remain consistent with the original proposed concept design strategy, some parameters were also adopted from the modelling undertaken by Cardno to support the original concept Design Plan. The following changes were made to the model:

- The developed catchments from the WBNM model were used to replace existing conditions in developed areas.
- Existing development was represented by surfaces used to inform the DA design for each approved stage.
- Fill areas were created for the future development pads, particularly in Marshall Mount Creek to ensure that they are flood free in the 1% AEP event (with 0.5m freeboard) across the site.
- Cut areas were provided within the E2 land adjacent to the creek to improve flow conditions. The locations of these cut areas are consistent with those proposed in the original concept plan. A cut fill plan showing these changes is shown in Figure 03.
- Parks were raised above the 20% AEP flood level
- The Macquarie Rivulet Bridge was added to the model as a layered flow constriction using the same parameters as the approved Concept Design Plan Model
- A bridge with similar parameters was added that crosses Marshall Mount Creek, also as a layered flow constriction. The bridge deck is proposed to be above the PMF level for the creek.
- Riparian planting that will be undertaken in the creek corridors as part of the approved development was represented in the model by a mannings roughness consistent with Cardno assessments.

8.2.2 Discussion of Flood Modelling Results

Refer to Figures 04 and 09 for figures showing existing flood modelling results for the 1% AEP and PMF events respectively.

Flood results for the approved development only are shown on Figures 05, 06, 10 and 11.

8.2.2.1 Under “Developed” conditions:

The refined modelling of the northern portion (Marshall Mount Creek) of CUDP confirms that during the both the 1% AEP event and the PMF event (Figures 07 and 12), flooding within the main channel of Marshall Mount Creek is deeper than in existing conditions, as many of the secondary flowpaths that are present under existing conditions have been redirected back toward the main channel. This results in increased flows in the main section of the creek within the site. Flood difference maps are shown on Figure 08 and 13.

Flooding within the Macquarie Rivulet has also become more consolidated. There are no impacts upstream or downstream of the site, with the exception of a small local increase just downstream of the site consistent with the impact documented in the original Concept Plan. Nearby Albion Park properties have less flood affectation than in the existing case. Thus, CUDP will provide significant flooding benefits for the local community.

In the 1% AEP event, the proposed urban development is effectively flood free, and there are no impacts upstream of the site. There are also no measurable impacts downstream of the site.

During the PMF event, there are no impacts greater that 300 mm external to the site which are consistent impacts to what was accepted by the Land and Environment Court (Figure 14).

It is noted that portions of the High School site, within the Education Precinct, are flood affected during a PMF event. However, the risks associated with PMF flooding can be managed by either appropriate land use within the school site or raising the site to be flood free in a PMF event.

Therefore, within the site, no critical infrastructure will be flood affected during a PMF event.

8.2.3 Comparison to Approved Concept Plan

The model for the developed conditions, using Shellharbour City Council's approved TUFLOW model, was compared to the approved CUDP model. Along Marshall Mount Creek, the flood impacts upstream of the development have been removed, and the development is no longer causing far-reaching flood impacts downstream of the site. Impacts are otherwise consistent with the approved Concept Plan.

Impacts were also found to be generally consistent with those in the previous model for constructed areas in the Macquarie Rivulet. However, they do differ, due to the existing condition change from the Reinco TUFLOW model to Shellharbour City Council's approved TUFLOW model. The modelling completed as part of this assessment is seen as an improvement in flood understanding and suitable to inform the ongoing development of CUDP.

8.2.4 Flood Evacuation

The safety of people from flood affected areas during an event is a key consideration for the planning of the CUDP.

As indicated in the flood mapping, refer Section 8.2.2, parts of the precinct are inundated by mainstream flows from both Marshall Mount Creek and the Macquarie Rivulet during the PMF event. However, as the PMF is a short duration event, a flood evacuation strategy that provides residents with enough time to mobilise and evacuate the development is not available and it is necessary to ensure the safety of the future population that use / reside within the development.

Therefore, consistent with the originally approved concept plan, the primary flood evacuation strategy is a "shelter in place" strategy as this option presents the Lowest Risk to Life.

However, even with a "shelter in place" strategy, it is important that access to the site is available to emergency vehicles. As with the recently constructed bridge across Macquarie Rivulet as part of CUDP, the bridge proposed as part of the Escapement Drive construction across Marshall Mount Creek will ensure that flood free access in the locall PMF event is achieved to the north portion (Wollongong City Council side) of the CUDP.

This will ensure that even during these extreme rainfall events, the ability for emergency vehicles to access all points of the CUDP is provided.

8.2.5 Flood Planning Level

The future development pads have been set at or above the flood planning level for the site. The flood planning level has been set 0.5m above the 1% AEP event level, which varies throughout the site (Figure 15). This ensures that the proposed urban development will be flood free in a 1% AEP event.

9 RIPARIAN IMPACTS

Minimising riparian impacts is a major consideration for the site. The current developable footprint will be maintained for this Concept Plan amendment, the increase in lot density will be facilitated by provision of an increase in smaller lots.

The provided cut/fill plan on Figure 03 demonstrates that environmentally sensitive lands are located outside of proposed earthwork areas, so the environmentally sensitive lands will not be additionally impacted as a result of the proposal.

Other than where there are identified environmentally sensitive lands, the existing riparian vegetation is generally sparse or non-existent across the site, which is predominantly grazing pasture. It is proposed that these sparse riparian zones are restored by full planting of the riparian corridor post construction. Therefore, riparian vegetation condition will be consistent with the original Concept Plan.

There will be no additional riparian impacts other than those accepted as part of the original Concept Plan.

10 CONCLUSION

This report is an update to the Watercycle and Flood Management Strategy previously prepared to support the Calderwood Concept Plan Approval (MP09_0082) for the Calderwood Urban Development Project (CUDP). It will accompany an Environmental Assessment Report (EAR) for a proposed S75W Modification Application to the approved Concept Plan. This modification is sought to the Approved Concept Plan to allow for increased and more diverse housing supply at Calderwood. The application looks to increase the total number of dwellings within CUDP from approximately 4,800 to approximately 6,500.

Section 7 and 8 addresses key issue 8d and 11 from the Secretary's Environmental Assessment Requirements (SEARs), issued on the 1st February 2018. The key changes to the approved concept plan are detailed below.

10.1 Water Quality

The revised Water Cycle and Flood Management Strategy consists of a treatment train including on lot treatment, street level treatment and subdivision/development treatment measures. The structural elements proposed for CUDP now consist of:

- Proprietary GPT units at each stormwater discharge point.
- 27 wetlands, or other suitable alternative treatment device scattered across the development. Some of these devices have already been constructed.

10.2 Flooding

Flooding and flood evacuation are major considerations for the site. The current developable footprint will be maintained for this amendment. However, the increase in lot density will be facilitated by provision of an increase in smaller lots.

Therefore, runoff characteristics from the increased density will have minimal impact on flood affectation in both the Macquarie Rivulet and Marshall Mount Creek, the two major watercourses within the CUDP. These impacts will be managed as part of the ongoing development of CUDP.

The investigation concludes that the development of CUDP in accordance with this strategy will be consistent with the controls and principles established by the NSW Government and both Shellharbour City Council and Wollongong City Council. Though there has been a refinement of design and solutions offered, the revised water cycle and flood management strategy remains consistent in philosophy with the original 2010 Concept Plan approval.

The report is suitable to support the proposed amendments to CUDP and provides the framework with which to support the ongoing development from a watercycle and flooding management perspective.

10.3 Riparian

As the developable footprint will remain consistent with the approved Concept Plan, the revised Concept Plan will have no additional impacts on the riparian vegetation when compared to the approved Concept Plan.

APPENDIX A – FIGURES

APPENDIX A – FIGURES

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LEGEND

- Site Boundary
- TUFLOW Boundary

Existing Catchments

- Macquarie Rivulet
- Marshall Mount Creek

N

0 2,000
meters
Scale 1:50,000 @ A3

Projection: GDA 1994 MGA Zone 56

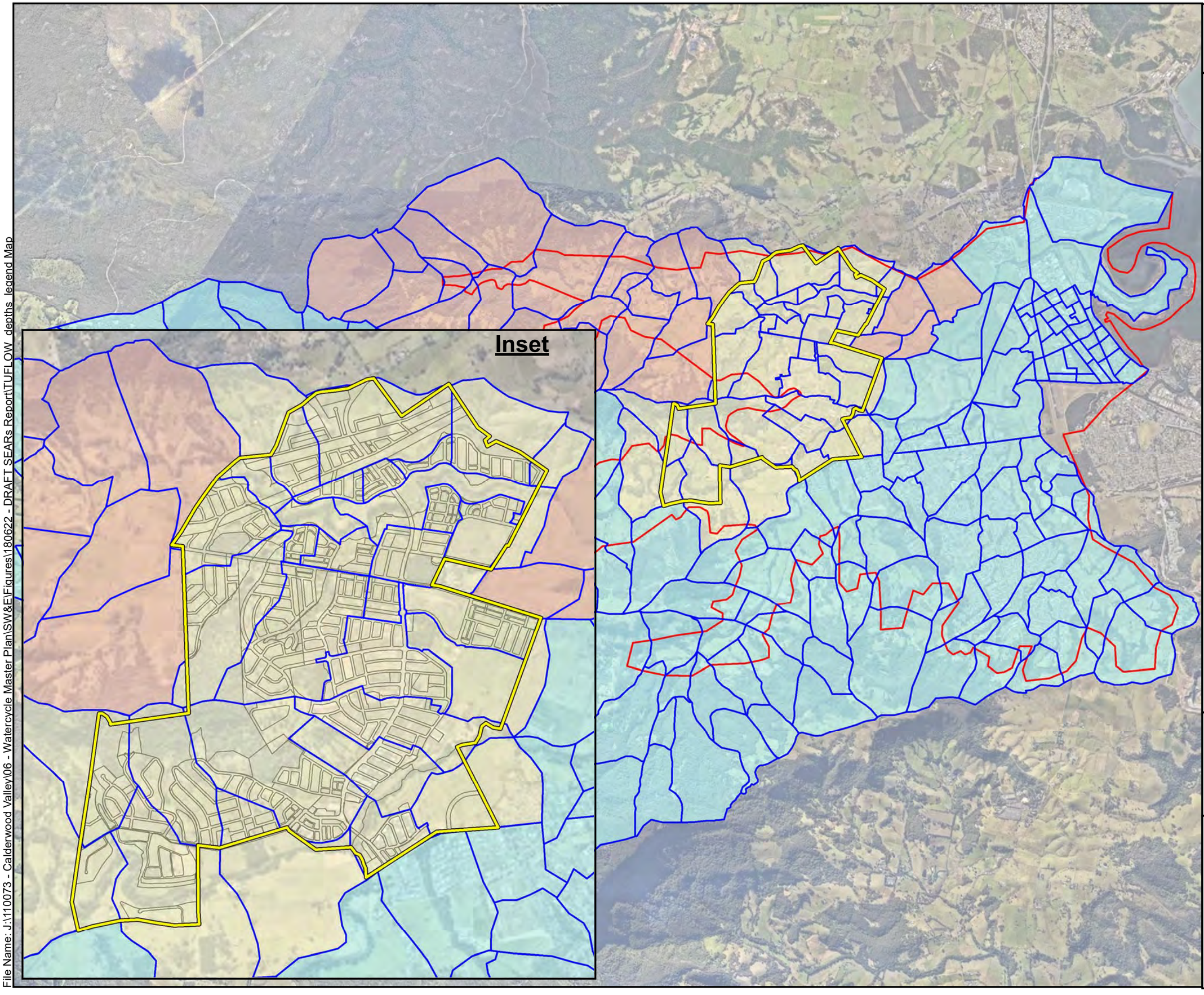
Figure 01

Calderwood Urban Development Project

**WBNM Catchments-
Exisitng Case**

Date: 21/06/2018 Issue: A

File Name: J:\110073 - Calderwood Valley\06 - Watercycle Master Plan\SW&E\Figures\180622 - DRAFT SEARs Report\TUFLOW depths legend Map



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LEGEND

- Site Boundary
- TUFLOW Boundary

Developed Catchments

- Macquarie Rivulet
- Marshall Mount Creek
- Updated Catchments

N

0 2,000
meters
Scale 1:50,000 @ A3

Projection: GDA 1994 MGA Zone 56

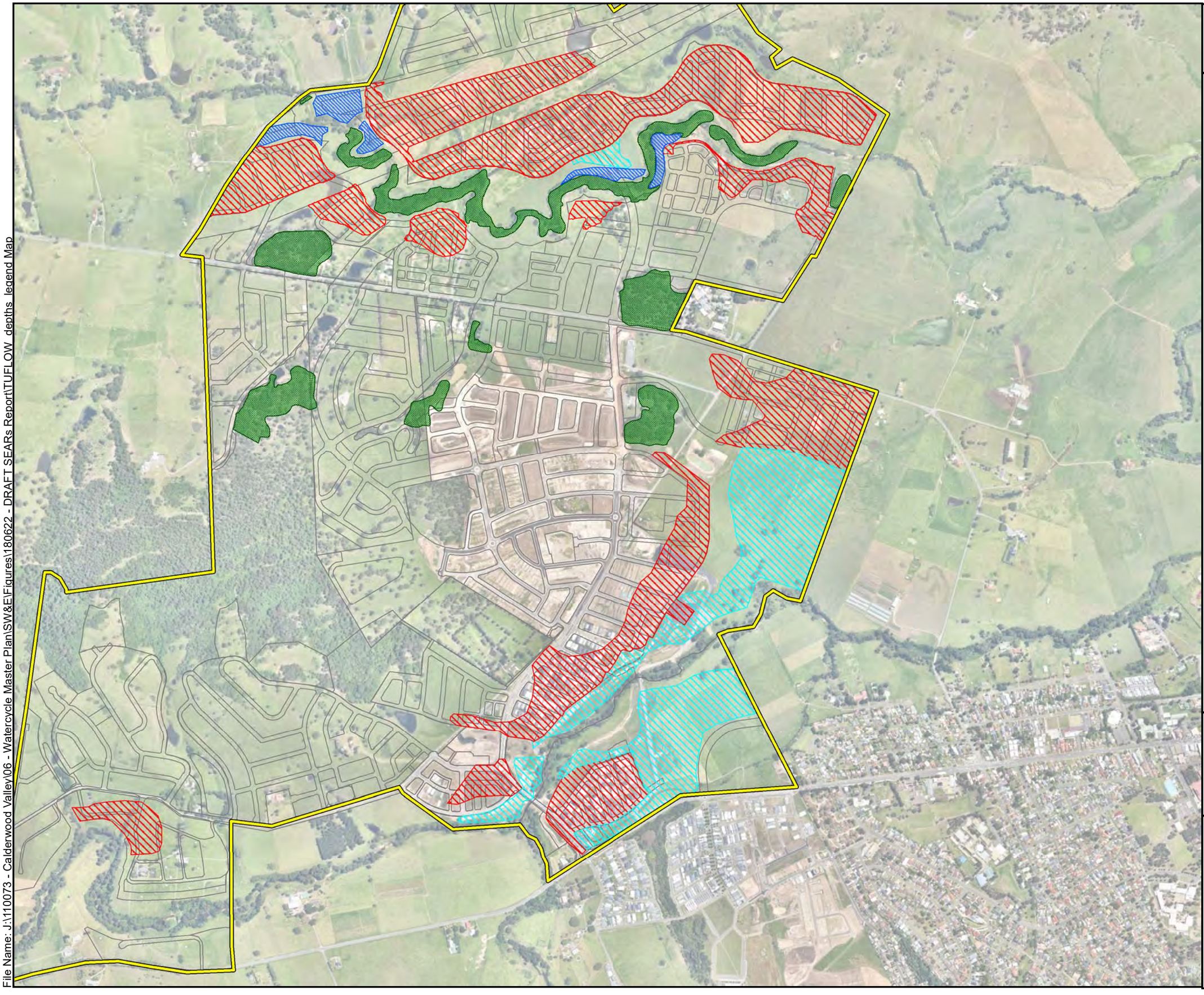
Figure 02

Calderwood Urban Development Project

WBNM Catchments-Developed Case

Date: 5/07/2018 Issue: B

File Name: J:\110073 - Calderwood Valley\06 - Watercycle Master Plan\SW&E\Figures\180622 - DRAFT SEARs Report\TUFLOW depths legend Map



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LEGEND

- Site Boundary
- Proposed Development
- Environmentally Sensitive Lands
- Proposed Cut
- Proposed Fill
- Proposed Flood Runner

N

0 500
meters
Scale 1:12,500 @ A3

Projection: GDA 1994 MGA Zone 56

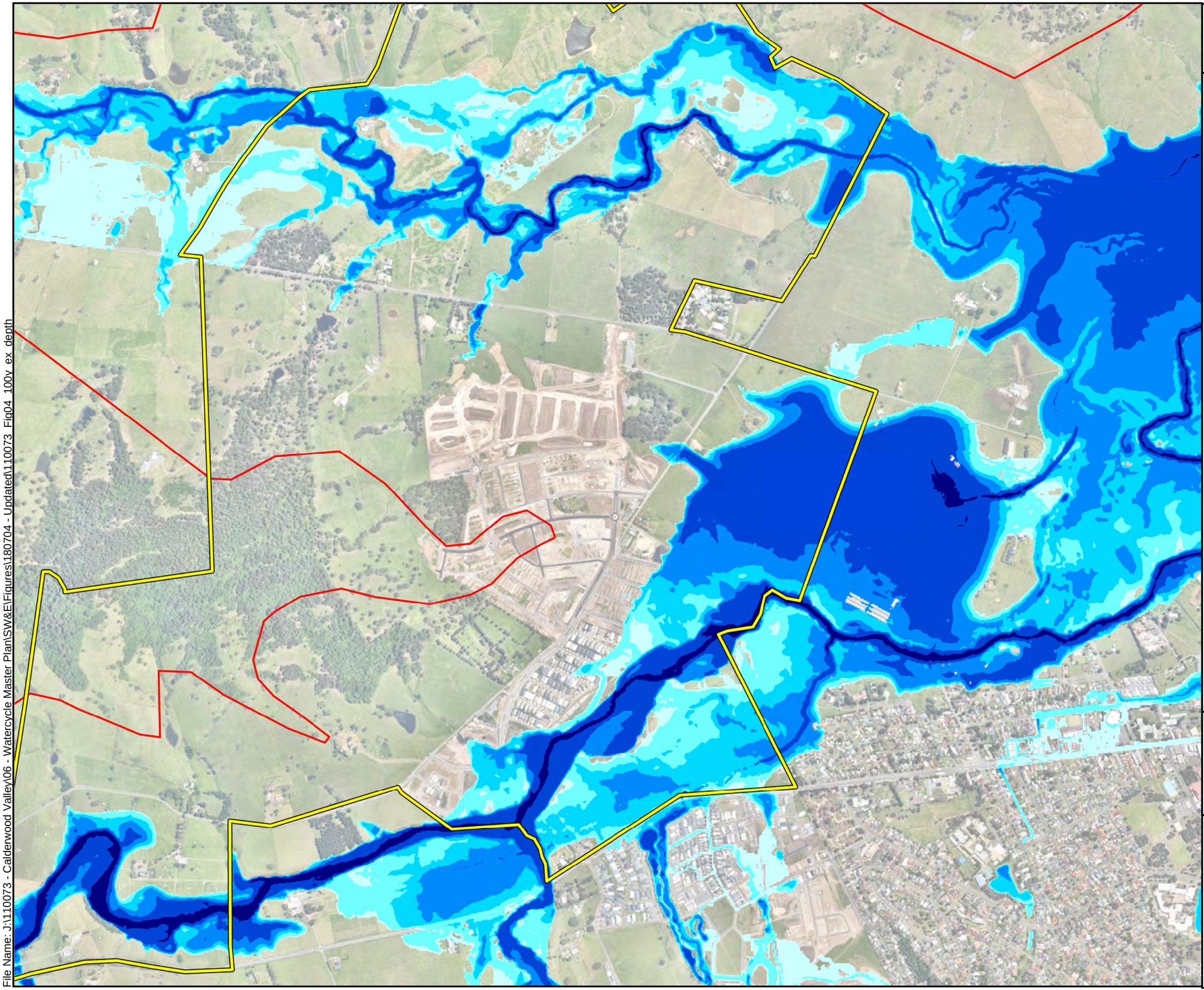
Figure 03

Calderwood Urban Development Project

Cut/ Fill Plan
Marshall Mount Creek

Date: 11/07/2018 Issue: B

File Name: J:\110073 - Calderwood Valley\06 - Watercycle Master Plan\SW&E\Figures\180622 - DRAFT SEARs Report\TUFLOW depths legend Map



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LEGEND

- Site Boundary
- TUFLOW Boundary

Depth (m)

- 0.0 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- 3.0+

N

0 500
meters
Scale 1:12,500 @ A3

Projection: GDA 1994 MGA Zone 56

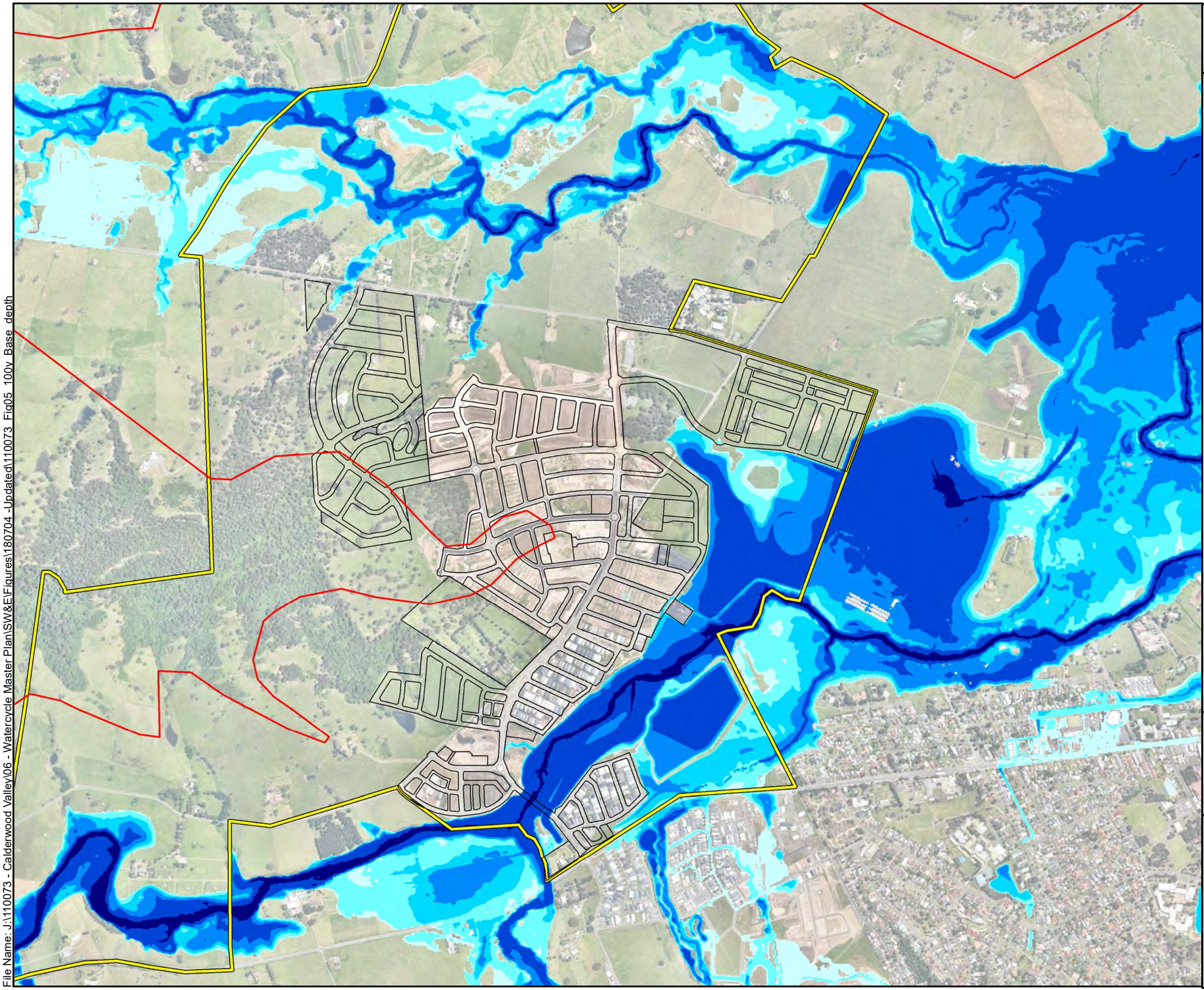
Figure 04

Calderwood Urban Development Project

1% AEP Event
Flood Depth
Exisitng Conditions

Date: 4/07/2018 Issue: B

File Name: J:\110073 - Calderwood Valley\06 - Watercycle Master Plan\SW&E\Figures\180704 - Updated\110073_Fig04_100y_ex_depth



File Name: J:\110073 - Calderwood Valley\06 - Watercycle Master Plan\SW&E\Figures\180704 -Updated\110073_Fig05_100y_Base_depth

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LEGEND

- Site Boundary
- TUFLOW Boundary

Depth (m)

- 0.0 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- 3.0+

N

0 500
meters
Scale 1:12,500 @ A3

Projection: GDA 1994 MGA Zone 56

Figure 05

Calderwood Urban Development Project

1% AEP Event
Flood Depth
Approved Developemnt

Date: 4/07/2018 Issue: B

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LEGEND

- Site Boundary
- TUFLOW Boundary
- Site Layout

Increase in Flood Levels (m)

-0.40+	0.02
-0.25	0.05
-0.10	0.10
-0.05	0.25
-0.02	0.40+

- -0.02 to 0.02
- Area Now Flood Free in Modelled Event
- Area Now Flood Affected in Modelled Event

N

0 500
meters
Scale 1:12,500 @ A3

Projection: GDA 1994 MGA Zone 56

Figure 06

Calderwood Urban Development Project

1% AEP Event
Flood Difference
Approved Developement - Existing

Date: 4/07/2018 Issue: B

File Name: J:\110073 - Calderwood Valley\06 - Watercycle Master Plan\SW&E\Figures\180704 - Updated\110073_Fig06_100y_Base_diff

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LEGEND

- Site Boundary
- TUFLOW Boundary

Depth (m)

- 0.0 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- 3.0+

N

0 500
meters
Scale 1:12,500 @ A3

Projection: GDA 1994 MGA Zone 56

Figure 07

Calderwood Urban Development Project

1% AEP Event
Flood Depth
Proposed Development

Date: 4/07/2018 Issue: A

File Name: J:\110073 - Calderwood Valley\06 - Watercycle Master Plan\SW&E\Figures\180704 - Updated\110073_Fig07_100y_Dev_depth

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LEGEND

- Site Boundary
- TUFLOW Boundary
- Site Layout

Increase in Flood Levels (m)

-0.40+	0.02
-0.25	0.05
-0.10	0.10
-0.05	0.25
-0.02	0.40+

- -0.02 to 0.02
- Area Now Flood Free in Modelled Event
- Area Now Flood Affected in Modelled Event

N

0 500
meters
Scale 1:12,500 @ A3

Projection: GDA 1994 MGA Zone 56

Figure 08

Calderwood Urban Development Project

1% AEP Event
Flood Difference
Proposed Development - Existing

Date: 4/07/2018 Issue: A

File Name: J:\110073 - Calderwood Valley\06 - Watercycle Master Plan\SW&E\Figures\180704 - Updated\110073_Fig08_100y_Dev_diff

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LEGEND

- Site Boundary
- TUFLOW Boundary

Depth (m)

- 0.0 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- 3.0+

N

0 500
meters
Scale 1:12,500 @ A3

Projection: GDA 1994 MGA Zone 56

Figure 09

Calderwood Urban Development Project

PMF Event
Flood Depth
Exisitng Conditions

Date: 4/07/2018 Issue: A

File Name: J:\110073 - Calderwood Valley\06 - Watercycle Master Plan\SW&E\Figures\180704 - Updated\110073_Fig09_PMF_ex_depth

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LEGEND

- Site Boundary
- TUFLOW Boundary

Depth (m)

- 0.0 to 0.2
- 0.2 to 0.5
- 0.5 to 1.0
- 1.0 to 2.0
- 2.0 to 3.0
- 3.0+

N

0 500
meters
Scale 1:12,500 @ A3

Projection: GDA 1994 MGA Zone 56

Figure 10

Calderwood Urban Development Project

PMF Event
Flood Depth
Approved Development

Date: 4/07/2018 Issue: A

File Name: J:\110073 - Calderwood Valley\06 - Watercycle Master Plan\SW&E\Figures\180704 -Updated\110073_Fig10_PMF_Base_depth