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WATER CYCLE MANAGEMENT AND FLOODING

CATHERINE FIELD (PART) PRECINCT

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CATHERINE FIELD (PART) PRECINCT WATER CYCLE MANAGEMENT AND FLOODING CATHERINE FIELD, NSW

ON BEHALF OF DEPARTMENT OF PLANNING AND INFRASTRUCTURE

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LIST OF ABBREVIATIONS

AEP	Annual Exceedance Probability
AHD	Australian Height Datum
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
DIPNR	Department of Infrastructure, Planning and Natural Resources
DLWC	Department of Land and Water Conservation NSW
DEM	Digital Elevation Model
DTM	Digital Terrain Model
FPDM	Floodplain Development Manual
FPL	Flood Planning Level
FPMM	Floodplain Management Manual
FPRMS	Floodplain Risk Management Study
FSL	Flood Surface Level
GIS	Geographic Information System
ha	Hectare (Area = $10{,}000m^2$)
LEP	Local Environmental Plan
LGA	Local Government Area
MGA	Map Grid Australia
m^3/s	Cubic meters per second
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCP	Reinforced Concrete Pipe
RCBC	Reinforced Concrete Box Culvert
RTA	Roads and Traffic Authority of NSW
SEPP	State Environmental Planning Policy
SMP	Stormwater Management Plan
TIN	Triangular Irregular Network

EXECUTIVE SUMMARY

This report presents the stormwater quantity and flooding management for the Catherine Field (Part) Precinct. Its objectives are to provide a stormwater management strategy that ensures that the proposed development adequately considers and manages flooding within local tributaries, South Creek and within detention basins.

The proposal provides for stormwater detention within the catchments of the Catherine Field (Part) Precinct. This will take the form of detention storage associated with water quality improvement features and manage major flows up to the 100 year average recurrence interval (ARI). The storages located through the site will be used to attenuate bank-full flows (up to the 2 year ARI) to mitigate erosion and ensure ecologically sustainable creeks through the site. The large detention storages will be used to ensure that flooding in South Creek is not worsened as a result of the development in the Catherine Field (Part) Precinct.

The level of detention storage required in the Catherine Field (Part) Precinct was estimated using the XP-RAFT hydrological model. This model is widely accepted in the industry and is suitable for conducting investigations on green field development sites, whereby existing versus developed scenarios are modelled. This model estimated stormwater detention requirements for the proposed development to manage flows off the developed catchment and ensure that peak flows and flood levels in South Creek are not increased. The stormwater detention requirements include:

- 86,000 m^3 within stormwater detention basins is required for Catherine Field (Part Precinct). This level of storage through the site approximately equates to a site storage requirement (SSR) of approximately 360 m^3/ha across the precinct (excluding riparian zones and basin areas).

The proposal provided stormwater quality control through bioretention facilities. The water quality improvement devices have been sized to ensure that the pollutant reduction objectives are met.

This report also examines the existing flooding regime within the Precinct, including South Creek and its three major tributaries. The hydraulic analysis was undertaken using the SOBEK hydraulic model, which is a fully integrated 1D/2D hydraulic model. This model enables efficient integration between river/creek channel hydraulics, where flow can be considered 1D, and the floodplain where flows are best described by a 2D model.

The SOBEK modelling has shown that the 100 year ARI flood extent in South Creek is predominantly contained within the proposed Category 1 riparian buffer required on South Creek with some flood fringe areas outside of the buffer.

CATHERINE FIELD (PART) PRECINCT
WATER CYCLE MANAGEMENT AND FLOODING
CATHERINE FIELD, NSW

ON BEHALF OF DEPARTMENT OF PLANNING AND INFRASTRUCTURE

1 INTRODUCTION

This study has been undertaken by Brown Consulting NSW Pty Ltd on behalf of the Department of Planning and Infrastructure, and it specifically examines the stormwater quantity, quality and flooding management for the Catherine Field (Part)

To meet these challenges, effective management of stormwater and flooding issues need to be addressed at the masterplan stage. Specifically, this study investigates the local and regional flooding, stormwater detention and water quality improvement issues for the Catherine Field (Part) Precinct.

This report seeks to spell out in the broadest of terms, the strategies, concepts and treatment mechanisms, to be employed in managing the progressive development of the catchments within the study area.

While the water quantity and quality modelling undertaken, (and reported on) herein is comprehensive and detailed enough, to form the framework for development of an actionable basis for the detailed design of these treatment devices on a catchment by catchment structure, it must be remembered, that, as planning and stakeholder strategies change and evolve, it will become necessary to review these baseline strategies, as each catchment grows and changes, it is, therefore our intention to review the strategies detailed by this report at the time of Development Application consent for each future Precinct in turn, to achieve a narrower and more focussed strategy outcome, applicable to that catchment, as it stands, at the time, by means of an individual “Precinct Stormwater Management Plan and Report” to support each application.

Likewise the treatment and attenuation of stormwater quantity, will also be addressed by these individual “Precinct Stormwater Management Plans” and Reports”, to ensure that all planning and finished form elements are blended together to give the best possible targeted outcomes in respect of stormwater treatment within the individual sub-catchment areas.

1.1 SITE LOCATION & CATCHMENTS

The Catherine Field (Part) Precinct is located immediately downstream of Camden Valley Way, approximately 2.5 km downstream of the uppermost headwaters of South Creek. Kolombo Creek (tributary of South Creek) forms the boundary between Catherine Fields and Oran Park and Cobbitty Road/Oran Park Drive forming the boundary with Harrington Grove. The catchment area of South Creek upstream of the Catherine Field (Part) Precinct is approximately 520ha.

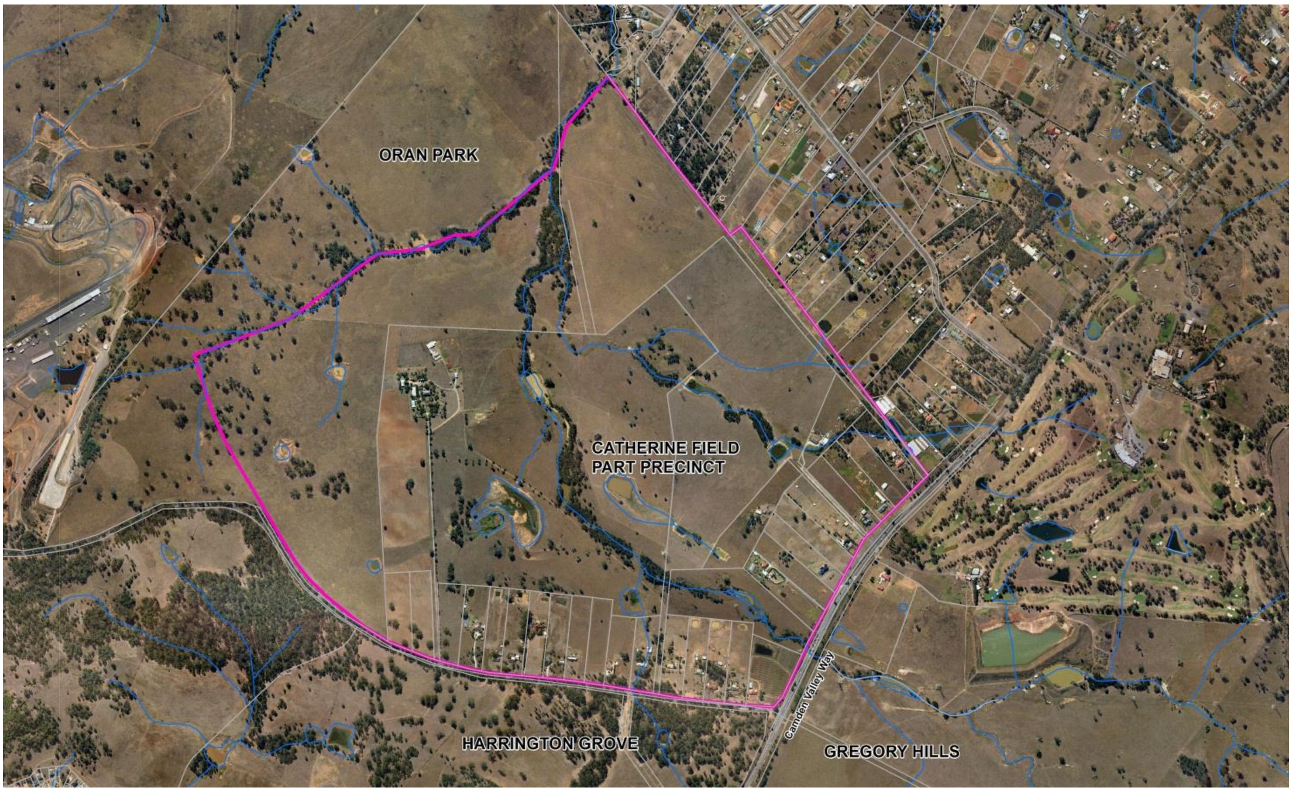

Figure 1.1 Aerial Photograph (2006)

Catherine Fields includes three tributaries that discharge into South Creek. Kolombo Creek runs along the boundary with Oran Park and adjoins South Creek downstream of the site. Kolombo Creek has a catchment area of approximately 140 ha, upstream of the creek is a large detention/water quality basin (denoted as OS4) that treats the runoff from Oran Park and discharges flows less than pre developed rates.

A small tributary collects flows from Harington Grove via a number of box culverts under Cobbitty Road/Oran Park Drive. As part of the Cobbitty Road Upgrade a number of detention/water quality basins are proposed within Harrington Grove upstream of the culvert crossings. The basins are designed to over detain the flows and reduce the peak storm flows to achieve a total site discharge equal or less then pre-developed culvert capacities. The strategy will reduce the flows arriving at the Catherine Field site as the discharges in excess of existing culvert crossing capacities will be attenuated within the active storage zone of the proposed detention basins, ensuring that no broad crested weir overflow will exit the site in the 100 year ARI storm event. The proposal will include a basin located within the tributary, allowing the riparian corridor and flows to meander around the basin.

A category 2 stream classification tributary exists through the site. The tributary collects flows from Camden Valley Golf Resort upstream of Camden valley Way. The tributary is heavily modified with patches of riparian vegetation.

The catchment area is predominantly cleared grazed land, homestead and farm dams. While some of the creek lines contain remnant vegetation, most are predominantly cleared. Average catchment slopes range between 1% and 8%.

2 BACKGROUND - PREVIOUS STUDIES

2.1 SOUTH CREEK FLOOD STUDY (DWR 1990)

The South Creek Flood Study undertaken by the Department of Water Resources (1990) is a hydraulic/hydrological study that has been conducted in the study area. That study is confined to the main reach of South Creek, which bisects the precinct. In addition, the representation of the site is 'coarse', in that the catchment and creek cross sections within the study area are limited as the study extends over the entire length of South Creek and its tributaries.

That particular flood study used the XP RAFTS hydrological model to estimate catchment hydrology and the Mike-11 hydraulic model to derive flood levels. The following sections discuss modelling assumptions used in that modelling.

The hydrological parameters of the upper reaches of RAFTS model as used in the South Creek Flood Study (DWR 1990) are:

Pervious Fraction

Initial loss	36mm	Continuing loss	0.94mm/hr

Impervious Fraction

Initial loss	1mm	Continuing loss	0mm/hr

Bx 1.3

The Study reported a flow of 299 m^3/s upstream of the Bringelly Road crossing.

2.2 SOUTH CREEK FLOODPLAIN MANAGEMENT STUDY (DWR 1991)

The floodplain management study for South Creek was based on the hydrological modelling undertaken for the 1990 flood study.

The floodplain management study calculated flows for two scenarios being, existing conditions and full development of the catchment based on assumed future planning considerations at the time. The impervious areas adopted for catchments are shown in **Table 2.1**.

Table 2.1 South Creek Flood Study (DWR 1991) - Percentage Impervious Area

	Impervious Area %	
Rafts Node	**Existing**	**Developed**
1.00	0	70
1.01	0	35
1.02	1	35
1.03	0	35
1.04	0	40
1.06	0	69
2.00	0	70
2.01	1	70

The study reported a flow upstream of Bringelly Road Bridge of 299 m^3/s for existing conditions and 307 m^3/s for a developed catchment.

2.3 SOUTH CREEK FLOODPLAIN RISK MANAGEMENT STUDY (LIVERPOOL COUNCIL, 2004)

The South Creek Floodplain Management Study was undertaken for Liverpool Council by Bewsher Consulting (2004). This study lies outside of the study area, being located South of Bringelly Road in the Liverpool local government area (LGA). Key points from the study include:

- A peak flow of 299 m^3/s was noted at Bringelly Road based on the DWR (1990) study.
- A peak 100 year ARI flood level of 59.30 m AHD was estimated just upstream of Bringelly Road (Mike-11 chainage 8.923).
- A peak 100 year ARI flood level of 58.30 m AHD was estimated just downstream of Bringelly Road (Mike-11 chainage 9.003).
- Bringelly Road is not overtopped by the 100 year ARI flood.

The South Creek 1991 Floodplain Management Study recommended a detention basin on South Creek just upstream of Bringelly Road, by damming South Creek near its confluence with Rileys Creek and Lowes Creek. The area of water was estimated to be 1 km^2 with a storage volume of 2,500ML. It was noted that such a detention basin would impact on the land availability for the Southwest Release Area if it was adopted. This option was also suggested in the DWR (1991) South Creek Floodplain Management Study.

2.4 ORAN PARK PRECINCT MASTERPLAN STORMWATER QUANTITY MANAGEMENT AND FLOODING (BROWN CONSULTING, 2007)

This report presented the stormwater quantity and flooding management for the Oran Park Precinct.

The proposal provided stormwater detention within the catchments of the Oran Park Precinct to manage all flows up to and including the 100 year average recurrence interval (ARI). The larger detention storages ensure that flooding in South Creek is not worsened as a result of the development in the Oran Park Precinct.

This report also examines the existing flooding regime within the Oran Park Precinct, including South Creek and its three major tributaries in Oran Park Precinct East and a tributary of Cobbitty Creek and Cobbitty Creek in Oran Park Precinct West. The hydraulic analysis was undertaken using the SOBEK hydraulic model, which is a fully integrated 1D/2D hydraulic model. The model extended from the downstream extents of Catherine Field to 1 km downstream of Bringelly Road.

The SOBEK modelling has shown that the 100 year ARI flood extent in South Creek is predominantly contained within the proposed Category 1 riparian buffer required on South Creek. In addition, a portion of the development lies within the fringes of the PMF extent, although generally there will be some filling of the PMF flood fringe to accommodate the current development proposal.

2.5 UPPER SOUTH CREEK FLOOD STUDY (WMA WATER 2011)

The study was undertaken for Camden Council and developed hydrological and hydraulic modelling tools for South Creek. The flood modelling was undertaken for the 20, 50, 100, 200 and 500 year ARI events and PMF. The study area extended from its headwaters to 500m downstream of Bringelly Road.

The study used Airborne Laser Scanning (ALS) survey from 2008. The ALS derived a raster with an accuracy of ±0.15m vertical and ±0.27m horizontal.

The study modelled two scenarios, Existing and Semi-developed. The semi-developed included the fully developed Oran Park and Turner Road Precincts. The study modelled the developments but did not model any mitigation works proposed by the development, therefore the modelling did not account for any detention basins or filling constructed and/or proposed as part of Oran Park or Turner Road. Due to this the results of this study could be seen as conservative as the floodways defined in the study are likely to be larger than if flood mitigation was taken into account as part the Oran Park or Turner Road developments.

Much of the study designated regions of the existing 100 year ARI flood extent is shown to be a depth of 1- 4 mm to the existing surface which is below the accuracy of the topographical survey and areas around existing farm dams embankments area shown to have this shallow flood depth above. The regions identified in the study as having a flood depth greater than or equal to 150 mm (which is greater than the accuracy of the topographical survey) in the 100 year ARI flood extent are shown to be largely conveyed within the South Creek riparian corridor. The large flood extent depicted in the study may be attributed to the level of accuracy of the survey used.

3 METHODOLOGY

3.1 HYDROLOGICAL MODELLING METHODOLOGY

The hydrology of the proposed site was modelled using XP-RAFTS to estimate design flows along the tributaries through the site and aid in determining stormwater detention requirements.

3.1.1 South Creek RAFTS Model Parameters

For the regional South Creek flood modelling, the existing RAFTS model was used, but updated to reflect existing landuse. As discussed in Section 2.0, a RAFTS model was originally established and calibrated for the entire South Creek catchment as part of the DWR (1990) Flood Study for South Creek and updated/used in the 1991 Floodplain Management Study. It was also reviewed and used in the Bewsher Consulting (2004) Floodplain Management Study for Liverpool Council.

The hydrological modelling of South Creek has adopted the same RAFTS model used in those studies, although it has revised the impervious proportions of the catchment based on aerial photography of the catchment. A developed model was not established for upstream areas as it is assumed all future development in the upper catchment of South Creek (eg Turner Road Precinct) will provide stormwater detention to mitigate any impacts on flooding in South Creek (for all storm durations).

The XP-RAFTs flows at Camden Valley Way (South Creek at the upstream Boundary) were increased to closer reflect the flows reported in the 2011 Upper South Creek Flood Study (WMAwater).

3.1.2 Catherine Field Precinct Catchments Areas

Catchments within the Catherine Field Precinct were digitised from the ALS data within the study area, representing various sub-catchments within the site that corresponded to natural catchment lines and locations of possible hydraulic controls such as proposed road crossings and basins. Refer to Section 4 for the catchment areas of the Catherine Field Precinct RAFTS model.

Manning values used in the catchments were 0.045 for existing catchments, 0.025 for the impervious fraction and 0.035 for the pervious fraction, representing urban and well grazed pasture landuses. The impervious fractions used for each landuse included:

- Residential 75%
- Open Space 5%

The impervious fractions listed above are based on Camden Council's Engineering Design Specifications.

3.1.3 Catherine Field (Part) Precinct – RAFTS Loss Model Parameters

The RAFTS model for local catchments within the Catherine Field (Part) Precinct was developed using the two catchment approach, whereby pervious and impervious proportions of the catchment are represented by their own sub-catchment in the RAFTS model sub-catchment properties. The parameters used in the RAFTS model included:

Pervious Fraction

- Initial loss 10 mm
- Continuing loss 3 mm

Impervious Fraction

- Initial loss 1.5 mm
- Continuing loss 0 mm

3.1.4 RAFTS Design Storms

Both the local catchment RAFTS model and the South Creek RAFTS model analysed the 2, 20 and 100 year ARI design storms. Storm durations from 15 minutes to 9 hours were examined for the local catchments within the Catherine Field (Part) Precinct. The critical storm duration estimated for the local catchments within the Catherine Field (Part) Precinct was 2 hours.

The 2 hour and 36 hour storm duration was examined for South Creek. The modelling estimated a critical duration storm of 2 hours in the upper catchment of South Creek however, the 36 hour duration was critical within the study area.

3.2 HYDRAULIC MODELLING METHODOLOGY

The hydraulic modelling of South Creek and the local tributaries through the site has been undertaken in SOBEK developed by Delft Hydraulics. This model enables efficient integration between river hydraulics, where flow can be considered 1D, and the floodplain where flows and associated storage effects are best described by a 2D model. Plate 4 shows the river and floodplain elements as treated by SOBEK. The 1D element is represented by a cross section which bisects the 2D surface, which is represented by a raster surface (often referred to as a Digital Elevation Model – DEM). SOBEK allows stacked raster grids of varying resolution to derive a surface detailed with the required accuracy.

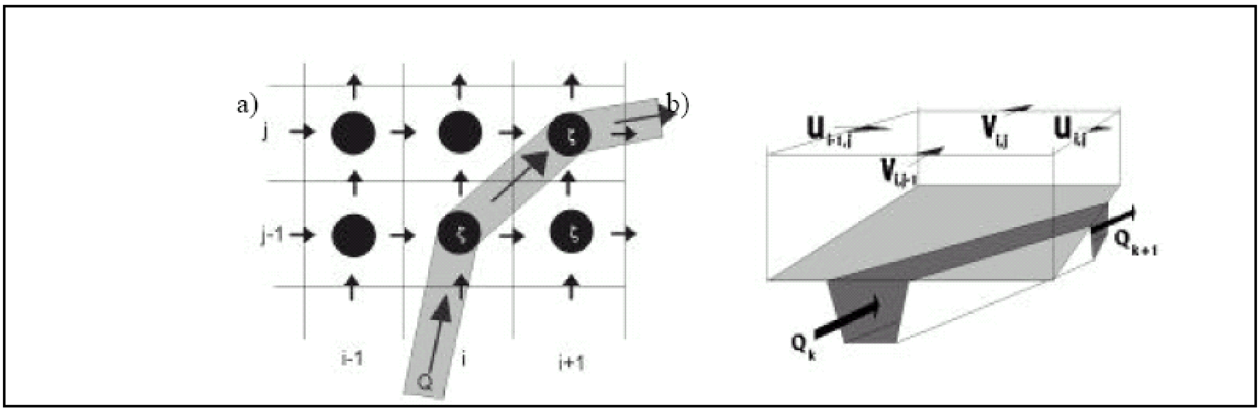

Figure 3.1 Schematic Representations of the Integrated 1D/2D SOBEK Hydraulic Model

3.2.1 Survey Sources

The survey sources for the generation of the DEM for the hydraulic modelling included:

Catherine Field

- Ground survey within riparian corridor
- Airborne Laser Scanning (ALS) used for the Upper South Creek Flood Study (2011) with an accuracy ± 150mm vertical and ± 270 mm horizontal.

Downstream of Catherine Field

- Ground survey involving 50-100m wide cross sections taken along South Creek and its tributaries. These sections were spaced at approximately 200m intervals and extended from the downstream boundary of the site to Bringelly Road, approximately 7.5 km downstream.
- Survey of the bridge across South Creek at Bringelly Road, including the bridge deck centre line, upstream and downstream creek section and piers/abutments.

3.2.2 Digital Elevation Model (DEM)

A DEM was produced for Catherine Field in ESRI ArcGIS from the updated survey data undertaken by John M. Daly and the ALS, and is shown in Figure A2 in Appendix A. This DEM represented a raster surface in the GIS which was used as the terrain surface in the 2D component of the hydraulic model. A raster is a regular grid of a user defined size containing representative elevations. The resolution of the raster is a function of grid size, with smaller grid sizes providing a better resolution of the terrain. Therefore, unless very small grid sizes are adopted there will always be some simplification of the terrain.

However, in selecting the raster grid size (resolution) a quantitative assessment was undertaken using ArcGIS to select the largest grid size possible which would still show the large hydraulic controls. A DEM grid size of 5m x 5m was adopted for the South Creek flood model, as that resolution accurately depicted the floodplain and resulted in manageable model run-times.

For downstream of the site it was observed that most of the 100 year flow was occurring in the 1D surveyed channel reach, therefore downstream of the site was modelled as 1D components.

3.2.3 SOBEK Model Boundary Conditions

The SOBEK model is a fully dynamic model using inflow hydrographs from the RAFTS hydrological modelling. For the local tributaries within the Catherine Field Precinct, the upstream boundary consisted of hydrographs representing the inflows into the creeks at various locations. The downstream boundary was a nominal water level representing a low flow level or a nominal flood level in an existing dam.

The boundary conditions for the South Creek SOBEK model were inflow hydrographs according to the RAFTS model catchment nodes. The downstream boundary condition was a rating curve specified 1 km downstream of Bringelly Road derived from a normal depth calculation. However, it should be noted that the Bridge at Bringelly Road acts as the hydraulic control to floodwater and the rating curve was used to ensure the Bringelly Road Bridge controls the model hydraulics.

3.2.4 Design Storms – Hydraulic Analysis

The SOBEK hydraulic modelling was undertaken 100 year ARI storms for both the local tributaries in the Catherine Field Precinct and South Creek.

4 EXISTING HYDROLOGICAL CONDITIONS

4.1 HYDROLOGY – SOUTH CREEK

The RAFTS model was used to estimate the 100 year ARI peak flows within South Creek for existing conditions. The peak flows from those ARI storms are shown in **Table 4.1** below.

Table 4.1 Existing Peak Flows - South Creek

Location	Chainage	Rafts Node	100Yr ARI Peak Flow	20Yr ARI Peak Flow	2Yr ARI Peak Flows
			(m^3/s)	(m^3/s)	(m^3/s)
South Creek upstream Boundary	-	Sth Ck	34	19.7	7.85
South Creek	8050	1.01	59.52	43.3	13.9
South Creek	6500	1.02	71.5	48.2	21.1
South Creek	4800	1.03	108	71.8	31.4
South Creek	2500	1.04	123	81.6	35.7
South Creek Tributary	-	2.00	35.2	24.2	11.2
South Creek Tributary	-	2.01	72.6	61.6	22.0
Confluence of Tributary with South Creek	2200	1.05	195	141	57.7
South Creek	2100	1.06	195	141	57.8
Rileys Creek	-	3.00	31.7	22.6	12.4
Rileys Creek	-	3.01	60.6	44.3	27.0
U/s Confluence of Rileys Creek and South Creek	1800	3.02	82.1	60.3	35.7
South Creek Bringelly Road (u/s)	300	1.08	299	214	93.7

Note: Chainage refers to meters (m) upstream from a point starting 300m downstream of Bringelly Road Bridge

The existing flows at Camden Valley Way (South Creek at the upstream Boundary) were increased to closer reflect the flows reported in the 2011 Upper South Creek Flood Study (WMAwater).

5 HYDRAULIC MODELLING RESULTS – SOUTH CREEK

5.1 EXISTING CONDITIONS – SOUTH CREEK

5.1.1 Flood Depths and Levels

Appendix A Figure A3 shows the flood depths through the study area for existing conditions and **Figure A4** presents the flood levels.

The highest flow depths (generally 500-800mm) are contained to creek banks and within the riparian corridor. Some greater flood depths are shown to occur at existing farm dams where the embankment provides a flow obstruction.

The existing flood modelling shows a minor break out of flow from South Creek at an existing dam approximately 350m downstream of Camden Valley Way (refer to **Figure 5.1**). The 2011 Upper South Creek Flood Study (WMAwater) identified this are as being neither a floodway or flood storage. The flood depths within the flood fringe identified a typically 0.01m with greater flood depths at areas effected by farm dam embankments.

Another break out was shown at the upstream boundary of the tributary, the breakout was shown to cross the front yard of the Camden Valley Way property. This is understood to be a result of the topography data not effectively identifying the capacity of the tributary. This area has been identified as flood fringe.

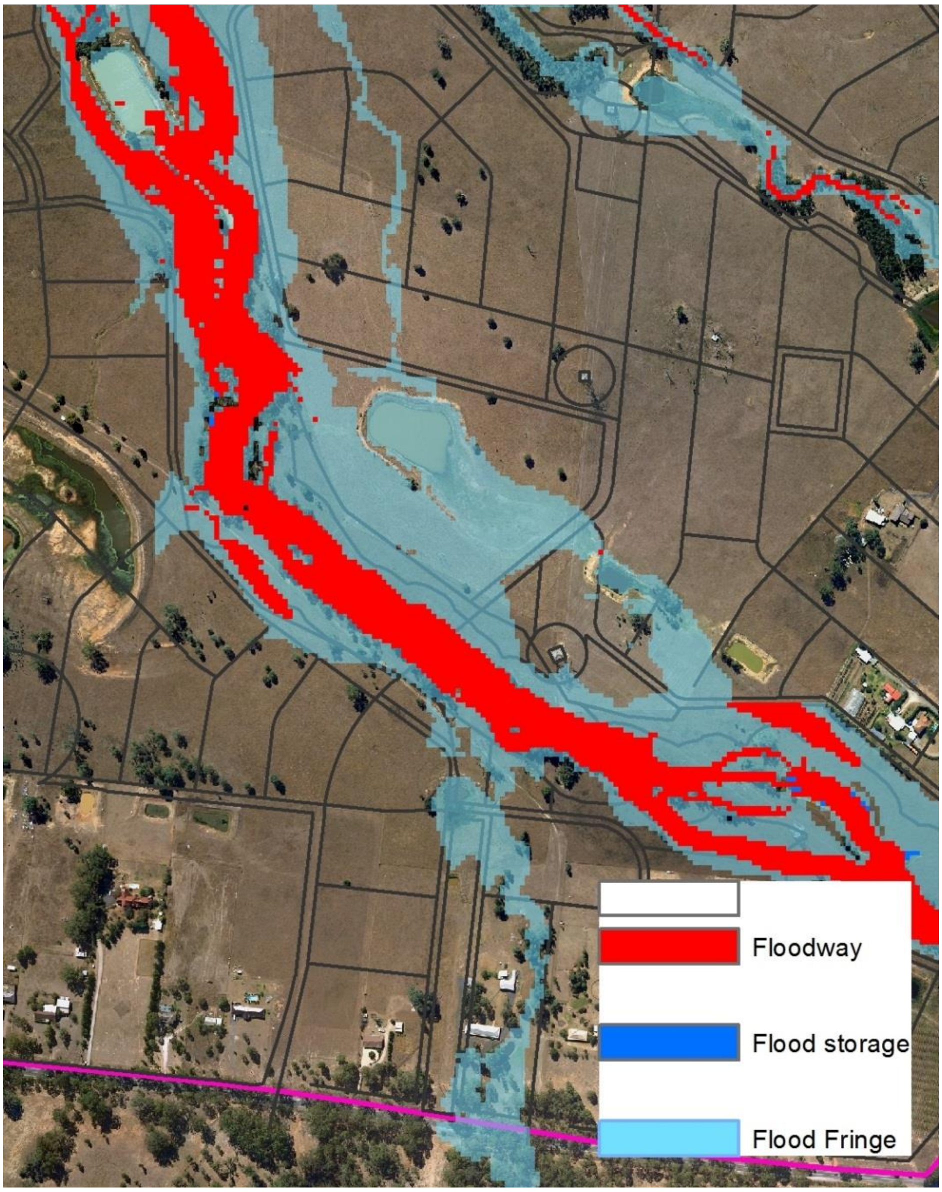

Figure 5.1 Existing Flood Fringe

The hydraulic modelling results show that the existing peak 100 year ARI flood level in South Creek varies from 90.8 m AHD at the upstream boundary of the site (Camden Valley Way) to 78.5 m AHD at the downstream boundary.

The existing SOBEK modelling utilised the ground survey and ALS topographical data adopted for the Upper South Creek Flood Study (WMAwater, 2011), the two flood studies closely matched the flood extents. This provided an effective tool to assess the developed scenario and land forming options.

5.1.2 Flow Velocity & Hazard Categorisation

Existing flood velocities for the 100 year ARI storm event are shown in **Figure A5 Appendix A**. Flood velocities less than 2 m/s are experienced within the banks of South Creek and values of 0.6-1 m/s are shown within the tributary. Areas within the flood fringe are generally less than 0.2 m/s.

Figure A6 Appendix A identifies the Velocity Depth (VD) ratio for the existing 100 Year ARI storm Event. Generally the VD is less than 0.4 for the study area. Values greater than 0.6 are experienced within South Creek but contained within the banks of the creek.

5.1.3 Probable Maximum Flood (PMF)

The PMF flood levels are provided in **Figure A7 Appendix A**. The flood levels vary 79.17 to 91.2 m AHD in South Creek.

5.2 DEVELOPED CONDITIONS – South Creek

5.2.1 Development scenario

The proposed development proposes to fill the area identified as flood fringe over the existing farm dams. The proposed stormwater masterplan and extent of flood fringe filling is identified in Figure A8 **Appendix A** (existing flood extents).

5.2.2 Flood Depths and Levels

The hydraulic modelling for the developed scenario looked at land forming works and flood fringe filling.

The developed scenario assessed the flood fringe filling and the 100 year ARI flood depths and levels are present in **Figure A9 and A10** Appendix A.

5.2.3 Flood Level Difference

Figures A13 in Appendix A show the flood level difference resulting from the proposed development for the 100 year ARI storm events.

For the 100 year ARI the figures show the expected afflux is generally 0-0.03m, with some isolated areas showing greater flood level difference within the site extents. Generally the flood level differences of 0.05-0.15m are a result of inline dams. Any flood level difference within the precinct boundary could be managed with land forming and removal of farm dams within the Riparian corridor. The flood level difference are reduced to 0m outside the precinct boundary, suggesting that the proposed flood filling would not have any adverse effects on properties outside the precinct boundaries.

The flow at the headwaters of the tributary can be managed by allowing a swale along the North East precinct boundary to direct any overland flow back into the tributary. The particulars of the swale will be detailed when more accurate topography data is available as part of the design process. However the provision of the swale has shown to ensure no flood level difference outside the precinct boundary.

Furthermore as discussed the 2D hydraulic modelling of the concept design terrain was represented by a raster surface used in SOBEK. A raster is a regular grid of user defined size containing representative elevations, therefore there will always be some simplification of the terrain when converting a triangle TIN file to a grid.

5.2.4 Flow Velocity & Hazard Categorisation

The proposed flood velocities for the 100 year ARI storm event are shown in Figure A11 Appendix A. Flood velocities less than 2 m/s are experienced within the banks of South Creek and values of 0.6-1 m/s are shown within the tributary. The proposed development does not aggravate flood velocities.

Figure A12 Appendix A identifies the Velocity Depth (VD) ratio for the existing 100 Year ARI storm Event. Generally the VD is less than 0.4 for the study area. As per existing conditions the values greater than 0.6 are experienced within South Creek but contained within the banks of the creek. The proposed development does not aggravate flood velocities.

5.2.5 Flood Storage and Floodway

The Camden Council Flood Risk Management Policy identified that flood fringe areas could be filled following a hydraulic investigation. The policy defines flood fringe as the remaining areas affected by flooding, after floodway and flood storage areas have been identified. The Upper South Creek Flood Study (2011) prepared for Camden Council by WMAwater mapped the floodway and flood storage area. Figure 20 from the 2011 report presented the classification. The hydraulic categorisation calculated as part of this study is shown below (figure 5.2 of this document) showed the floodway in red and flood storage in blue. The study recognised that the results provided using the method adopted are conservative and are likely to describe a greater floodway then might otherwise be defined. The areas around the existing farm dams, proposed to be filled, are not identified as floodway or flood storage. Therefore flood plain filling of areas not identified as floodway or flood storage is a feasible option.

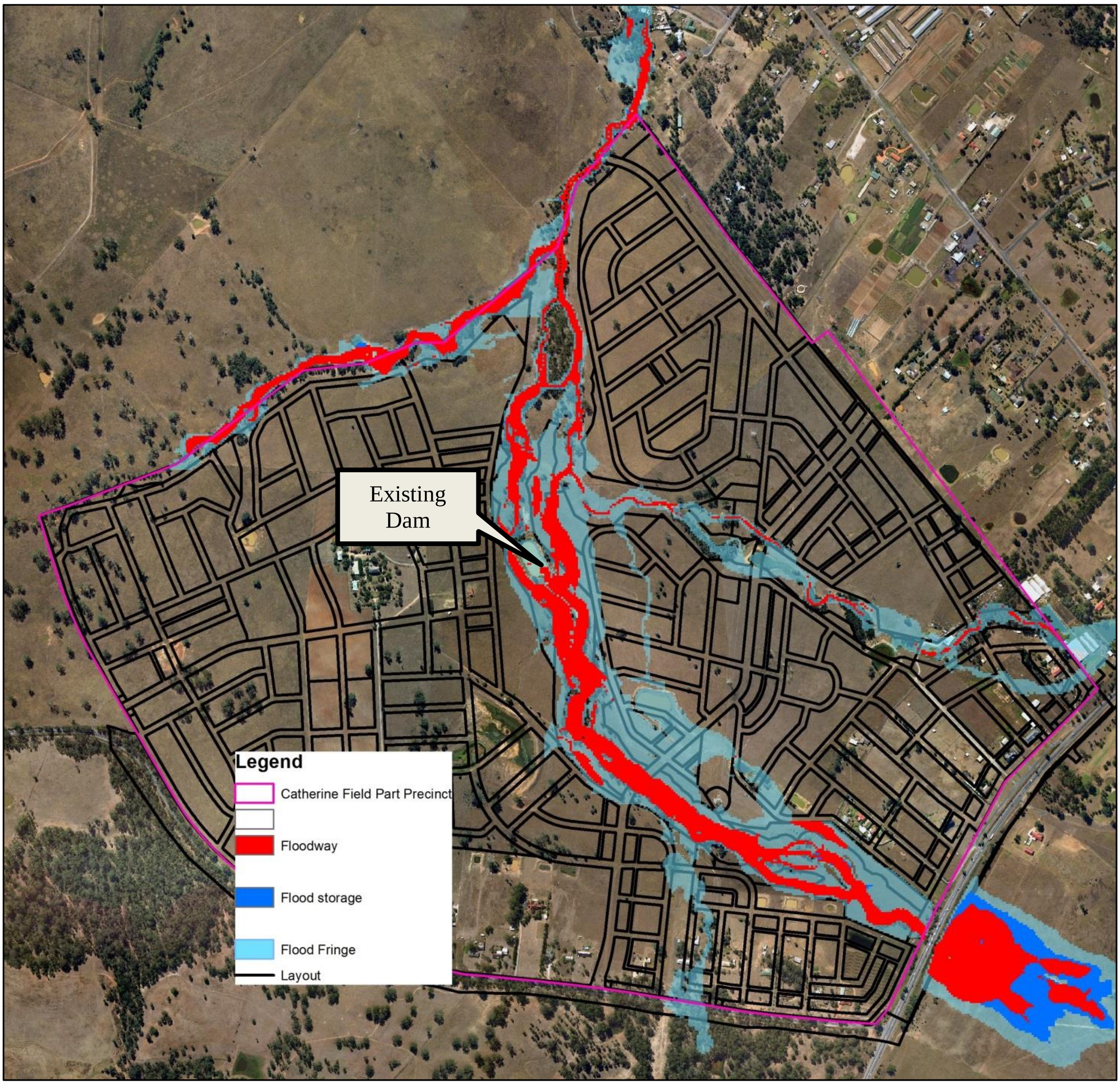

Figure 5.2: Hydraulic Categorisation

The results from the hydraulic categorisation support that the proposed flood filling is limited to flood fringe areas, with the flood levels differences contained within localised areas and existing flood levels are maintained upstream and downstream of the site. Any storage within the fringe areas is not considered to be active storage and is less than 5% of the flood storage volume during the 100 year ARI storm event.

5.2.6 Probable Maximum Flood (PMF)

The PMF flood levels are provided in **Figure A14** Appendix A. The flood levels vary 79.17 to 91.2 m AHD in South Creek.

5.2.7 Flood Planning Level

The proposed development will provide a flood planning level of the 100 Year AI storm event flood levels plus a 600mm freeboard for habitable floor levels. Allotment ground levels shall be provided 300mm above the 100 year ARI Storm event.

5.2.8 Climate change impacts

A sensitivity analysis was undertaken to assess the changes in flood levels as a result of potential climate change. The rainfall intensities were increased by 15% in accordance with the study prepared for the Sydney Metropolitan Catchment Authority, Impacts of Climate Change on Urban Stormwater Infrastructure in Metropolitan Sydney (J. Wyndham Prince, 2012). The Developed flood levels as a result of potential climate change are presented in **Figure A15** Appendix A.

The results show flood level increases generally less the 100mm within South Creek and less the 300mm within the tributary. The flood level increases as a result of potential climate change will be accounted for within the provide freeboard.

5.2.9 Flood Evacuation

The modelling has shown that during the extreme events including the PMF, the site is predominately flood free with no dwelling subject to inundation.

It is understood that the culverts under Oran Park Dr and Camden Valley Way have capacity greater than the 100 year storm event. The roads could provide an evacuation route, until such time as the roads became unsafe to drive. During an extreme rainfall event, the intensity of rainfall as well as other factors (wind and debris ect) would make driving either difficult or potentially more dangerous than shelter in place. The proposed development remains flood free during all storm events upto the PMF event, and is unlikely to be isolated for extended periods of time.

5.2.10 Cumulative Impacts

The proposed stormwater management ensure no aggravating of flood levels and flows outside the precinct boundary in accordance with Councils specifications. Any development upstream and downstream will need to also ensure that flood levels are not aggravated as a result of the development. Therefore there will not be any cumulative impacts as a result of development within the South Creek Catchment.

5.2.11 Existing Dams

The flood modelling included the option of maintaining the existing dams within South Creek, the study showed that the existing dams could be managed as part of the development. As part of the design the dams will be referred to the Dam Safety Committee for assessment. The proposal will include a bypass channel bypassing the existing dams.

6 IMPACTS OF DEVELOPMENT ON STORMWATER QUANTITY

Development without the use of stormwater management measures has the potential to affect the existing hydrology of both the site and downstream areas. Potential impacts on stormwater quantity that have been identified include:

- Increases in bank forming flows - a result of increased impervious area and a quicker catchment response time, leading to the increased erosion potential of existing tributaries and South Creek.
- Increases in peak flows to South Creek resulting in increases in flood levels downstream of the Precinct.

6.1 HYDROLOGICAL IMPACTS

Stormwater detention within the Catherine Field (Part) Precinct is necessary as the hydrological modelling has shown that without significant detention storage the development of this precinct would significantly increase (> 100% increase) the peak flow from the catchment (refer to **Table 6.1**).

Table 6.1 Post Developed Flows - No Stormwater Detention

Catchment	Existing 100 Y ARI Flow (m^3/s)	Developed (No OSD) 100 Y ARI Flow (m^3/s)	Peak Flow Increase (%)
B1	9.78	13.04	133
B2	2.45	3.75	153
B3	19.28	28.77	149
B4	2.14	5.21	243
B5+B6	6.06	11.72	193
B7	6.23	9.07	146
B8	2.34	3.70	158
B9	5.95	7.70	129
B11	3.54	6.02	170
B12	4.15	6.64	160
B13	2.91	4.99	171
B15	0.76	1.21	159
South Creek	79.87	92.62	116

7 STORMWATER QUANTITY MITIGATION MEASURES

The stormwater quantity management strategy for the Catherine Field Precinct is designed to mitigate large scale flooding impacts on South Creek and the Nepean River and meet DEC guidelines for reducing erosion within the local tributaries.

7.1 STORMWATER QUANTITY MANAGEMENT STRATEGY

The stormwater quantity management strategy for the Catherine Field (Part) Precinct is shown in **Figure A6** Appendix A. The objectives of the stormwater detention strategy will require the use of strategically placed large detention basins, as shown in those figures. These detention basins will generally include a water quality component (bioretention) with the stormwater detention occupying approximately 1 m to 1.5 m of extended detention depth above the basin floor in the case of a dry detention basin.

The stormwater detention surface areas as estimated by the RAFTS hydrological model are shown in **Table 7.1**.

Table 7.1 Stormwater Detention Requirements

Catherine Field (Part) Precinct Basin ID	Detention Component Surface Area (m^2)
B1	9,100
B2	3,100
B3	26,000
B4	5,900
B5+B6	13,000
B7	6,200
B8	1,440
B9+B15	7,500
B11	4,400
B12	5,400
B13	3,900

The specific objectives for the stormwater quantity management strategy for the Catherine Field (Part) Precinct include:

- Management of ‘minor’ flows using piped systems for the 5 year ARI (residential landuse) and 10 year ARI (commercial landuse) as per Camden Council’s Development Guidelines.
- Management of ‘major’ flows using dedicated overland flow paths such as open space areas, roads and riparian corridors for all flows in excess of the 5 year ARI.
- Where practically possible, attenuate up to the 2 year ARI peak flow for discharges into Category 1 and 2 creeks. This will be achieved using detention storage within water quality features and detention basins.

- Facilitation of stormwater retention including the use of rainwater tanks and other water quality improvement features.
- Integration of stormwater quality and stormwater quantity management techniques.
- Provision of appropriate infrastructure to enable conveyance of 100 year ARI flows off the development to proposed detention storages.

7.2 DEVELOPED HYDROLOGY & HYDRAULICS

The post developed flows with stormwater detention as estimated by RAFTS are shown in **Table 7.2** for discharges to South Creek from the Catherine Field (Part) Precinct.

Table 7.2 Post Developed Flows with Stormwater Detention

Catchment	Existing 100 Y ARI Flow (m^3/s)	Developed with OSD 100 Y ARI Flow (m^3/s)
B1	9.78	9.34
B2	2.45	1.85
B3	19.28	18.7
B4	2.14	2.13
B5+B6	6.06	5.97
B7	6.23	5.87
B8	2.34	2.31
B9	5.95	5.25
B11	3.54	3.50
B12	4.15	4.15
B13	2.91	2.35
B15	0.76	0.58
South Creek D/s of Precinct	79.87	78.73

8 STORMWATER QUALITY MANAGEMENT

8.1 MODELLING METHODOLOGY

Water quality modelling of the proposed development has been undertaken using the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) software package developed by the Cooperative Research Centre for Catchment Hydrology (CRCCH). MUSIC enables the user to model the transfer of pollutants through a catchment and provides an aid in determining the treatment strategy required to meet the water quality objectives applicable to the site. The critical pollutants to be modelled are Gross Pollutants, Total Nitrogen (TN), Total Phosphorous (TP) and Total Suspended Solids (TSS).

The generation, transfer and removal of these critical pollutants will be modelled through the treatment strategy employed. Only the critical pollutants will be further addressed in this report, however the treatment devices will provide mitigation of other pollutant loads, such as heavy metals, since they are predominantly associated with fine sediment. The Primary Pollutant trap will intercept pollutants such as litter, rubbish, leaves etc therefore minimising the runoff of oxygen demanding substances.

The rainfall data within the MUSIC model utilised a 20year time series (1954 – 1974) with a mean annual rainfall of 870mm and evapo-transpiration of 1201mm. The mean annual rainfall for Camden Airport is 814mm. The MUSIC input parameters recommended in the Growth Centres – guidance for Precinct Planning were adopted for the updated MUSIC model.

8.2 MODELLING STORMWATER OF MANAGEMENT STRATEGIES

Pollutant export analysis has been undertaken for three scenarios using MUSIC. The three models are:

- Existing Scenario – Pre-developed site
- Developed Scenario – site developed as proposed, without any stormwater quality treatment; and
- Mitigated Scenario – site developed as proposed with stormwater quality treatment.

It should be noted that the updated version of the MUSIC program (v.4.10) was used for the modelling.

8.2.1 Source Nodes

For modelling with MUSIC, subject sites have to be classified into different land uses that are represented as source nodes. The source nodes that have been used in the modelling are Agriculture and Urban. Each is used for various land uses within the site for the existing and developed scenarios.

The two types of source nodes used in the MUSIC modelling have used the following total impervious percentages:

- Agriculture - An impervious percentage of 5% was used for the existing scenario and areas of open space
- Urban – An impervious percentage of 75% was used for residential areas.

Soil properties for each source node are set as defaults use by MUSIC for the two respective source node types. Mean estimation and serial autocorrelation set to zero has also been adopted.

8.2.2 Drainage Links

No routing has been adopted for all drainage links within each model. This assumption is due to the type of SQID's modelled and the limited overland flow lengths. It is believed this assumption will produce more conservative results.

8.3 RESULTS FOR THE EXISTING & DEVELOPED SCENARIO'S

Table 8.2 and 8.3 summarises the results of the developed (without mitigation) and developed scenario pollutants loads generated from the site.

Table 8.2 Developed (no mitigation) pollutant Loads

	TSS Conc. (mg/L)	**TP** Conc. (mg/L)	**TN** Conc. (mg/L)
10th	12.1	0.09	0.88
mean	22.3	0.15	1.25
90th	20	0.19	1.49
Mean Annual Loads (kg/Yr)	288,000	510	3220

Table 8.3 Developed pollutant Loads

	TSS Conc. (mg/L)	**TP** Conc. (mg/L)	**TN** Conc. (mg/L)
10th	0	0	0
mean	2.07	0.08	0.51
90th	2.90	0.11	0.6
Mean Annual Loads (kg/Yr)	15,500	146	1,040
Removal (%)	94.6	71.4	67.8

The objective of the stormwater quality treatment strategy is to treat stormwater to an acceptable level such that pollutant loads meet the requirements of Camden Council.

8.4 PROPOSED STORMWATER TREATMENT STRATEGY

The water quality treatment for Catherine Field (Part) Precinct will consist of:

- Stormwater re-use of dwelling roof runoff by utilising rainwater tanks,

- Primary pollutant trap capable of removing gross pollutants, sediment and oils to pre-treat road and lot drainage, and
- A bioretention basin which will receive flows from the pollutant traps.
- The proposed basin along the tributary draining from Harrington Grove (basin A4) will be located within the drainage corridor. The flows will meander within the corridor and around the basin within an engineered creek line capable of conveying the flow.

The stormwater bioretention surface areas as estimated by the MUSIC model are shown in **Table 8.4**.

Table 8.4 Stormwater Quality Requirements

Catherine Field (Part) Precinct Basin ID	Bioretention Component Surface Area (m^2)
B1	3,800
B2	600
B3	11,400
B4	2,600
B5+B6	5,000
B7	2,700
B8	700
B9+B15	3,200
B11	1,900
B12	2,300
B13	1,700

8.4.1 Bioretention Basin Concept Design

Water Quality Basin Sizing

Bioretention Filter Media depth	600 mm
Extended Detention Depth	300 mm

Bioretention Filter Media Specification

Filter Media Type	Loamy Sand (0.45 mm)
Hydraulic Conductivity	min 120 mm/h
Sub-surface Drain Type	Ag Drain (min 0.5% grade) 100 & 150mm slotted pipe

Bioretention Surface Treatment on Filter Media

Plants selected for use in bioretention systems need to be able to tolerate periods of inundation, as these systems can be expected to have a proportion of the soil profile saturated for several days. The selection of a loamy sand soil with a hydraulic conductivity in the range of 100-200mm/h will normally ensure soils are not waterlogged, which has been accommodated in the concept design.

Plants with extensive fibrous root systems are generally preferred as they prevent the filter media from clogging. Plants with a spreading, rhizomatous or suckering habit are also preferred. The filter must be planted to ensure it does not clog.

Sub-surface Drainage
100 mm & 150mm Ag drain will be placed in a 150-200 mm thick fine gravel layer below a 100 mm thick sand transition layer located immediately below the filter media. The grading of the transition layer should be:

- 1.4 mm 100% passing
- 1.0 mm 80%
- 0.7 mm 44%
- 0.5 mm 8.4% passing

The proposed bioretention filter will incorporate a ***HPDE or Bentofix liner*** or equivalent beneath the gravel layer to ensure no infiltration into the surrounding soil occurs.

8.5 MAINTENANCE

The pollutant traps shall be inspected every three months to establish the frequency of cleaning required. At a minimum the traps will require cleaning every six months.

The bioretention basins will be self cleaning when planted appropriately and fitted with a back flush system (pipe riser). Maintenance will be limited to landscaping and weed control.

8.6 MOSQUITO RISK

Mosquitoes require still permanent water bodies to lay eggs. As the bioretention basins do not hold water and will be self draining, the risk of mosquito breeding is considered minimal to none.

8.7 STREAM EROSION INDEX (SEI)

The Camden Council Engineering Design Specification (2009) identified a stream erosion index of 3.5 – 5.0 as a stormwater management objective. The specification identified the 'stream forming flow' as 50% of the 2 year flow rate.

The MUSIC model developed for the precinct was used to calculate the SEI from the basin outlets. Generally the basins achieved an SEI between 1 and 3. The overall SEI within the creek for the developed scenario is 1.4. As part of the development approval and detailed design the basin outlets will be further optimise to achieve a SEI closer to 1, where possible.

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9 FLOOD EVACUATION STRATEGY

Generally, the majority of the Catherine Field Part Precinct is not considered flood prone, and therefore the issue of flood evacuation does not have to significantly influence urban design as areas along South Creek within the flood fringe are proposed to be filled. As such, a flood evacuation plan will be required as part of the future development application process. Given that flood free ground is close by, evacuation should be considered an acceptable solution to manage flood risk.

As recommended by Camden Council and Australian Rainfall and Runoff (2001), a 'minor' and 'major' drainage system approach is proposed to manage for local runoff. This typical requirement allows safe passage of flood flows along the road once the drainage pipe capacity is exceeded. Flows are also accommodated in the drainage corridors where riparian buffers are located.

Proposed lot and habitable floor levels would at a minimum conform to Camden Council requirements, with the habitable floor levels being 600 mm above the 100 year ARI flood levels throughout the site. The relevance of this planning control is restricted to lots fronting riparian corridors and South Creek. All flood affected land along South Creek in the current layout would be filled.

It is understood that the culverts under Oran Park Dr and Camden Valley Way have capacity greater than the 100 year storm event. The roads could provide an evacuation route, until such time as the roads became unsafe to drive. During an extreme rainfall event, the intensity of rainfall as well as other factors (wind and debris ect) would make driving either difficult or potentially more dangerous than shelter in place. The proposed development remains flood free during all storm events up to the PMF event, and is unlikely to be isolated for extended periods of time.

10 CONCLUSION

The stormwater hydrological and hydraulic analysis has shown that the flooding constraints have been considered by the layout plans, although further development of the strategy will need to occur through the development application process.

The objectives of the stormwater quantity management strategy for the Catherine Field (Part) Precinct have been achieved by;

- Ensuring no increase in peak flows in South Creek for all storm events up to the 100 year ARI event. The strategy utilises a number of large detention basins to manage flows from the developed catchment.
- Mitigate erosion and ensure ecological sustainable creeks throughout the site by providing smaller storages within the site to attenuate bank-full flows
- Provide fill levels within South Creek flood fringe that achieve Camden Council requirement of floor levels 600mm above the proposed 100 year ARI flood level
- Proposal managers major and minor stormwater flows using structures
- Ensure the water quality reducing targets are met
- Ensure development does not encroach into riparian zones.

11 REFERENCES

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12 GLOSSARY OF TERMS

Afflux	The rise in water level upstream of a hydraulic structure such as a bridge or culvert, caused by losses incurred from the hydraulic structure.
Australian Height Datum	National survey datum corresponding approximately to mean sea level.
Annual Exceedance Probability	The chance of a flood of a given size or larger occurring in any one year, generally expressed as percentage probability. For example, a 100 year ARI flood is a 1% AEP flood. An important implication is that when a 1% AEP flood occurs, there is still a 1% probability that it could occur the following year.
Average Recurrence Interval	Is the long term average number of years between the occurrence of a flood as big as, or larger than the selected flood event.
Catchment	The catchment at a particular point is the area of land which drains to that point.
Design floor level	The minimum (lowest) floor level specified for a building.
Design flood	A hypothetical flood representing a specific likelihood of occurrence (for example the 100 year or 1% probability flood). The design flood may comprise two or more single source dominated floods.
Development	Existing or proposed works which may or may not impact upon flooding. Typical works are filling of land, and the construction of roads, floodways and buildings.
Discharge	The rate of flow of water measured in terms of volume over time. It is not the velocity of flow which is a measure of how fast the water is moving rather than how much is moving. Discharge and flow are interchangeable.
Digital Terrain Model	A three-dimensional model of the ground surface that can be represented as a series of grids with each cell representing an elevation (DEM) or a series of interconnected triangles with elevations (TIN).
Effective warning time	The available time that a community has from receiving a flood warning to when the flood reaches their location.
First Flush	The initial surface runoff of a rainstorm. During this phase, water pollution in areas with high proportions of impervious surfaces is typically more concentrated compared to the remainder of the storm.
Flood	Above average river or creek flows which overtop banks and inundate floodplains.
Flood awareness	An appreciation of the likely threats and consequences of flooding and an understanding of any flood warning and evacuation procedures. Communities with a high degree of flood awareness respond to flood warnings promptly and efficiently, greatly reducing the potential for damage and loss of life and limb. Communities with a low degree of flood awareness may not fully appreciate the importance of flood warnings and flood preparedness and consequently suffer greater personal and economic losses.
Flood behaviour	The pattern / characteristics / nature of a flood.
Flooding	The State Emergency Service uses the following definitions in flood warnings:

	Minor flooding: causes inconvenience such as closing of minor roads and the submergence of low level bridges *Moderate flooding:* low-lying areas inundated requiring removal of stock and/or evacuation of some houses. Main traffic bridges may be covered. *Major flooding:* extensive rural areas are flooded with properties, villages and towns isolated and/or appreciable urban areas are flooded.
Flood frequency analysis	An analysis of historical flood records to determine estimates of design flood flows.
Flood fringe	Land which may be affected by flooding but is not designated as a floodway or flood storage.
Flood hazard	The potential threat to property or persons due to flooding.
Flood level	The height or elevation of flood waters relative to a datum (typically the Australian Height Datum). Also referred to as "stage".
Flood liable land	Land inundated up to the probable maximum flood – flood prone land.
Floodplain	Land adjacent to a river or creek which is inundated by floods up to the probable maximum flood that is designated as flood prone land.
Flood Planning Levels	Are the combinations of flood levels and freeboards selected for planning purposes to account for uncertainty in the estimate of the flood level.
Flood proofing	Measures taken to improve or modify the design, construction and alteration of buildings to minimise or eliminate flood damages and threats to life and limb.
Floodplain Management	The coordinated management of activities which occur on flood liable land.
Floodplain Management Manual	A document by the NSW Government (2001) that provides a guideline for the management of flood liable land. This document describes the process of a floodplain risk management study.
Flood source	The source of the flood waters.
Floodplain Management Standard	A set of conditions and policies which define the benchmark from which floodplain management options are compared and assessed.
Flood standard	The flood selected for planning and floodplain management activities. The flood may be an historical or design flood. It should be based on an understanding of the flood behaviour and the associated flood hazard. It should also take into account social, economic and ecological considerations.
Flood storages	Floodplain areas which are important for the temporary storage of flood waters during a flood.
Floodways	Those areas of the floodplain where a significant discharge of flow occurs during floods. They are often aligned with naturally defined channels. Floodways are areas that, even if they are partially blocked, would cause significant redistribution of flood flows, or a significant increase in flood levels.
Freeboard	A factor of safety usually expressed as a height above the flood standard. Freeboard tends to compensate for the factors such as wave action, localised hydraulic effects and uncertainties in the design flood levels.

Geographical Information System	A form of computer software developed for mapping applications and data storage. Useful for generating terrain models and processing data for input into flood estimation models.
High hazard	Danger to life and limb; evacuation difficult; potential for structural damage, high social disruption and economic losses. High hazard areas are those areas subject to a combination of flood depth and flow velocity that are deemed to cause the above issues to persons or property.
Historical flood	A flood which has actually occurred – Flood of Record.
Hydraulic	The term given to the study of water flow in rivers, estuaries with coastal systems.
Hydrograph	A graph showing how a river or creek's discharge changes with time.
Hydrology	The term given to the study of the rain-runoff process in catchments.
Low hazard	Flood depths and velocities are sufficiently low that people and their possessions can be evacuated.
Management plan	A clear and concise document, normally containing diagrams and maps, describing a series of actions that will allow an area to be managed in a coordinated manner to achieve defined objectives.
Map Grid Australia	A national coordinate system used for the mapping of features on a representation of the earths surface. Based on the geographic coordinate system 'Geodetic Datum of Australia 1994'.
Peak flood level, flow or velocity	The maximum flood level, flow or velocity occurring during a flood event.
Probable Maximum Flood	An extreme flood deemed to be the maximum flood likely to occur at a particular location.
Probable Maximum Precipitation	The greatest depth of rainfall for a given duration meteorologically possible over a particular location. Used to estimate the probable maximum flood.
Probability	A statistical measure of the likely frequency or occurrence of flooding.
Riparian Zone	Areas that are located adjacent to watercourses. Their definition is vague and can be characterised by landform, vegetation, legislation or their function.
Runoff	The amount of rainfall from a catchment which actually ends up as flowing water in the river of creek.
Stage	Equivalent to water level above a specific datum- see flood level.
Stage hydrograph	A graph of water level over time.
Triangular Irregular Network	A mass of interconnected triangles used to model three-dimensional surfaces such as the ground (see DTM) and the surface of a flood.
Velocity	The speed at which the flood waters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section.

13 APPENDICES

Appendix A Report Figures

APPENDIX A

Report Figures