ORAN PARK PRECINCT MASTERPLAN STORMWATER QUANTITY MANAGEMENT & FLOODING

MARCH 2007

Report No. X06061-03A

Prepared for the Growth Centres Commission

BROWN CONSULTING

Engineers & Managers

PEOPLE & PROJECTS

COMMERCIAL IN CONFIDENCE

March 2007

DOCUMENT CONTROL

X06061-03A

Issue	Date	Issue Details	Author	Checked	Approved
01A	15 Jan 07	Draft Report – Internal Review	JL		
02A	18 Jan 07	Draft Report	JL	TE / JL	RP
03A	23 Mar 07	Final report	JL	RP	

Brown Consulting (NSW) Pty Ltd
Engineers & Managers ABN 30 109 434 513
Telephone 02 **9900 1000** Facsimile 02 **9900 1099**
Level 2, 82 Waterloo Road Macquarie Park PO Box 1484 Macquarie Centre North Ryde NSW 2113
E-mail macquarie@brownconsulting.com.au Website www.brownconsulting.com.au

ORAN PARK PRECINCT MASTERPLAN STORMWATER QUANTITY MANAGEMENT & FLOODING ORAN PARK, NSW

FOR GROWTH CENTRES COMMISSION

TABLE OF CONTENTS

BROWN

LIST OF APPENDICIES

LIST OF ABBREVIATIONS

AEP	Annual Exceedance Probability
AHD	Australian Height Datum (m)
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
DNR	Department of 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	Discharge in cubic meters per second
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
RCP	Reinforced Concrete Pipe
RCBC	Reinforced Concrete Box Culvert
SEPP	State Environmental Planning Policy
SMP	Stormwater Management Plan
TIN	Triangular Irregular Network

EXECUTIVE SUMMARY

The North West and South West Growth Centres will provide for 180,000 homes over the next 30 years with the combined cost of associated regional infrastructure estimated at $7.5 billion. The Oran Park Precinct has been identified by the New South Wales government as being one of the first land releases to be released, in addition to the Turner Road Precinct.

This report presents the stormwater quantity and flooding management for the Oran Park 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 Oran Park Precinct. This will take the form of small detention storage associated with water quality improvement features, and larger detention basins to manage major flows up to the 100 year average recurrence interval (ARI). The smaller 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 larger detention storages will be used to ensure that flooding in South Creek is not worsened as a result of the development in the Oran Park Precinct. In addition to detention basins, the commercial land use of town centre is proposed to incorporate lot based onsite detention (for the 2 year ARI) to protect the creeks immediately downstream. This would form an OSD component of their rainwater storage.

The level of detention storage required in the Oran Park 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 and Cobbitty Creek are not increased. The stormwater detention requirements include:

- 242,600 m^3 within stormwater detention basins is required for Oran Park Precinct East, with most (approximately 135,500 m^3) located in a large water body where the existing large dam is situated on Creek B. This level of storage through the site approximately equates to a site storage requirement (SSR) of approximately 380 m^3/ha across the precinct (excluding riparian zones and basin areas).
- Oran Park Precinct West requires 66,300 m^3 of detention storage, with the majority being located in the existing large dam (referred to as Cobbitty Dam) located onsite.

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. 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. In addition, a portion (approximately 7.5ha) 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.

The hydraulic analysis has shown that flooding within the local creeks in Oran Park Precinct East is generally confined to the proposed riparian corridors for the 100 Y ARI developed flows. Although most creeks in this area will not be required to be reconstructed to convey flows, some category 3 creeks will require creek reconstruction works to confine the floodwater to the riparian zone. Generally, Creek A and Creek D require the least modification, where Creek B will require reconstruction of the large dam and creek diversions near the top of its catchment.

On the Oran Park Precinct West the floodwater occupies significant areas of the proposed development. Creeks within the precinct will be reconstructed to confine flood waters to the riparian zones.

ORAN PARK PRECINCT MASTERPLAN
STORMWATER QUANTITY MANAGEMENT & FLOODING
ORAN PARK, NSW

FOR GROWTH CENTRES COMMISSION

1 INTRODUCTION

This study has been undertaken by Brown Consulting NSW Pty Ltd for the Growth Centres Commission, and it specifically examines the stormwater quantity and flooding management for the Oran Park Precinct to support the development of the South West Growth Centre (SWGC). The general locality of the Oran Park Precinct within the SWGC is shown in **Plate 1**.

The land release plan will deliver on a number of key challenges, including:

- staged delivery of infrastructure coordinated with staged land release;
- management and delivery through new governance arrangements, release sequencing, streamlined planning and funding administration; and
- sustainability to achieve world's best practice standards.

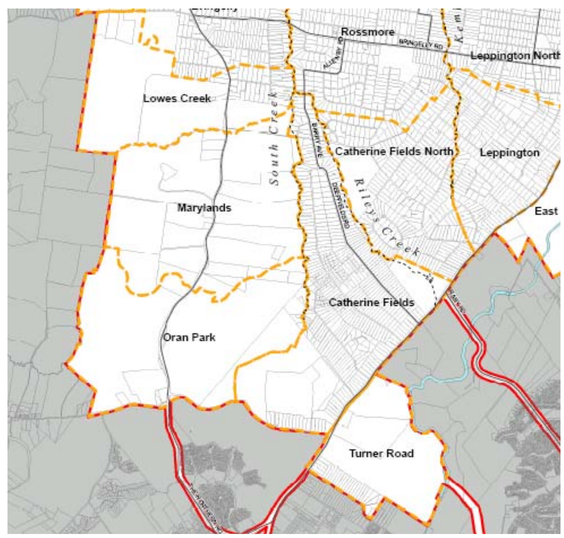

Plate 1. The Oran Park Precinct
Source (Growth Centres Commission)

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 and stormwater detention issues for the Oran Park Precinct.

1.1 SITE LOCATION & CATCHMENTS

The Oran Park Precinct is located approximately 4.8 km downstream of the uppermost headwaters of South Creek, and 2.3 km downstream of Camden Valley Way. South Creek forms the boundary between Oran Park and Catherine Fields South and Cobbitty Road, along with a large bush corridor along the northern edge of Harrington Park, set the southern boundary of Oran Park. Bringelly Road is approximately 5.7 km downstream of the Oran Park

Precinct (10.8 km downstream of Camden Valley Way) and represents the southern most part of the flood investigation area. The catchment area of South Creek upstream of the Oran Park Precinct is approximately 871 ha.

For the purposes of this report, the Oran Park precinct has been divided into two distinctive areas (as shown in **Plate 2**), which for the purposes of this report are referred to as:

- Oran Park Precinct West (areas of the Oran Park Precinct that lies west of Northern Road), and
- Oran Park Precinct East (the remaining area located east of Northern Road).

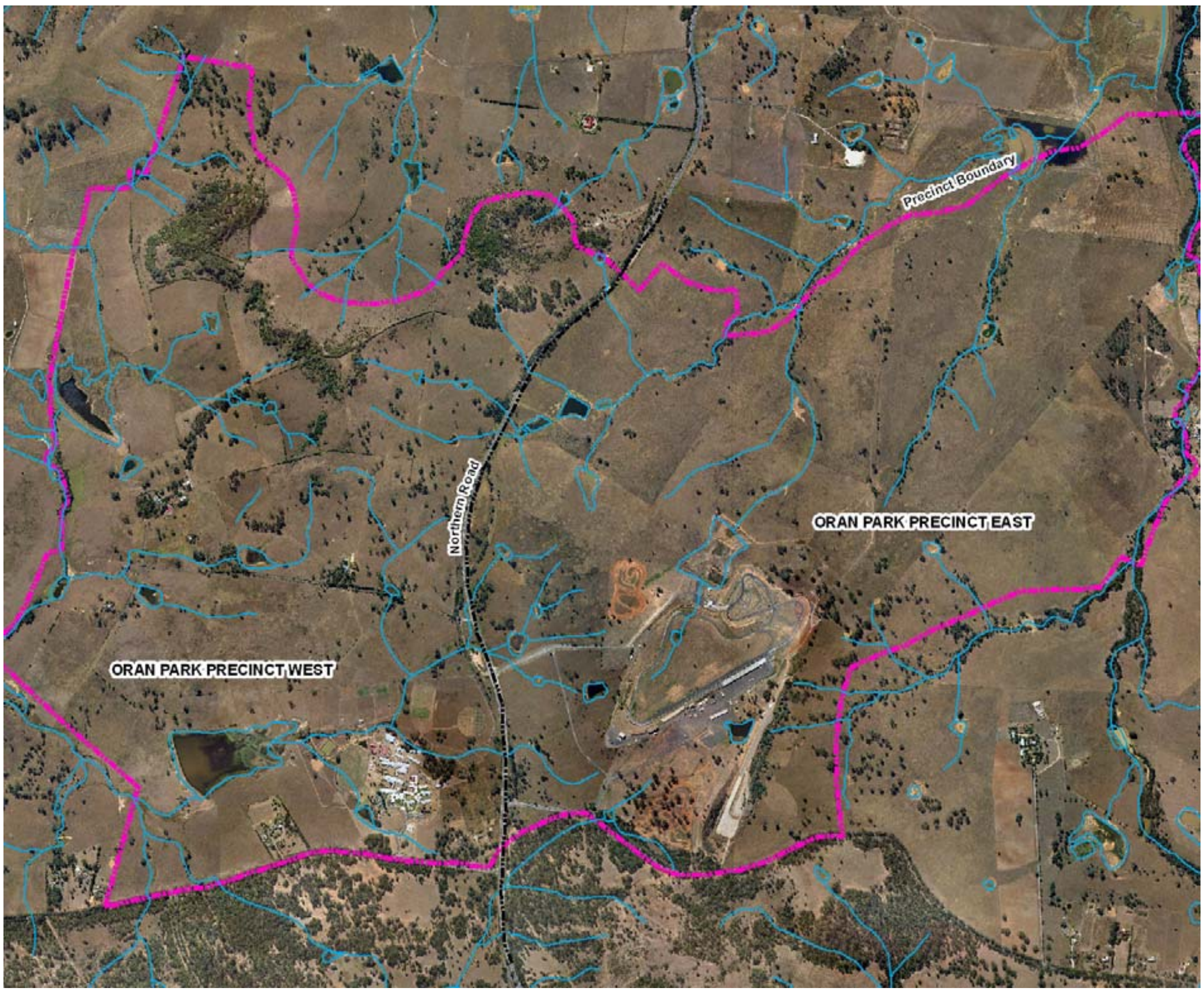

Plate 2 Aerial Photograph (2006) & the Oran Park Precinct

1.1.1 Oran Park Precinct East

Oran Park Precinct East includes three major tributaries that discharge to South Creek, with a combined 608 ha area that drain east of Northern Road to South Creek, as shown in **Figure 1.1**. The largest of the three tributaries (denoted in this report as Creek B) is approximately 377 ha in size and drains to an existing large dam with an estimated storage capacity of 1,500 ML at crest level. This dam has water level control in the form of a valved outlet, which would restrict water from discharging from the dam during a flood unless open. This outlet discharges into an excavated channel that leads to another dam further downstream and South Creek.

A smaller tributary (denoted as Creek A) of approximately 81.3 ha also drains to this dam, thereby giving a total dam catchment area of approximately 458 ha. Further to the south, another tributary (denoted Creek D) of approximately 148 ha connects to South Creek at the most upstream point of the Oran Park Precinct through Cobbitty Creek.

In addition to those tributaries, there is approximately 120ha of land fronting South Creek (denoted as South Creek Direct) that drains directly to South Creek. A further 64.9 ha drains west under Northern Road and into The Nepean River catchment side of the Oran Park Precinct.

The catchment area is predominantly cleared grazed land on ridges. While some of the creek lines contain remnant vegetation, most are predominantly cleared. Average catchment slopes range between 1% and 4%.

1.1.2 Oran Park Precinct West

The majority of the Oran Park Precinct West area drains to the Nepean River via Cobbitty Creek, as shown in **Figure 1.1**. The catchment of Cobbitty Creek is located predominantly southwest of the Oran Park Precinct, although a small proportion of land within the Oran Park Precinct East also drains to Cobbitty Creek. This creek has a catchment area of 220 ha at Cobbitty Road, where it passes through a culvert consisting of five (5) 1200 mm RCP's and discharges into a broad low lying area as shown in **Plate 3**. Cobbitty Creek then continues along the southern boundary of the Oran Park Precinct travelling in a north-westerly direction past Chittick Lane (2.14 km) and through Cut Hill Reserve at Cut Hill Road (4 km from Cobbitty Road). The confluence of Cobbitty Creek with the Nepean River is approximately 6.3 km downstream of Cobbitty Road. The total catchment of Cobbitty Creek at the most west boundary of the Oran Park Precinct is approximately 390ha.

Approximately 214.7 ha of the proposed development on the indicative layout plan drains to a large existing dam located in Oran Park Precinct West (denoted in this report as Cobbitty Dam). Only 149.8 ha (approximately 70%) of that catchment is from the Oran Park Precinct West. Most of the northern part of the Oran Park Precinct West drains to South Creek via Creek B (58 ha) or depressions north of the Precinct that drain to Lowes Creek (33.4 ha), which is also a tributary of South Creek.

The main stormwater features present on the site are two existing drainage lines that convey stormwater flows from Oran Park Precinct East to the large existing dam and Cobbitty Creek that runs along the southern boundary of the Precinct. The lower slopes of the catchment area are generally cleared and used for grazing, while the steeper ridge top areas contain remnant vegetation. Macarthur Anglican School is also located within the catchment, off Cobbitty Road.

Plate 3 -Cobbitty Creek Looking Towards Cobbitty Rd

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 the only hydraulic/hydrological study that has been conducted in the study area. That study is confined to the main reach of South Creek, which forms the eastern boundary of the precinct, and does not provide information on flooding within the tributaries through the study area. 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 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.

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 recently 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 2006 aerial photography of the catchment, which are shown in **Table 3.1**. 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).

Table 3.1 Revised Existing RAFTS Model Impervious Areas

Rafts Node	Impervious Area % Existing
1.00	7
1.01	9
1.02	17
1.03	10
1.04	11
1.06	52
2.00	5
2.01	7

3.1.2 Oran Park Precinct Catchments Areas

Catchments within the Oran Park Precinct were digitised from 1m contours of 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 Oran Park Precinct RAFTS model.

Manning values used in the catchments were 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 70%
- Commercial 90%
- Open Space 5%

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

3.1.3 Oran Park Precinct – RAFTS Loss Model Parameters

The RAFTS model for local catchments within the Oran Park 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 Oran Park Precinct - Existing Farm Dams

The existing dams within the Oran Park Precinct were included in the RAFTS model as basin nodes. The following assumptions were made in the model;

- The assumption of dam storage was based on 1m contours of the study area.
- The large dam in the Oran Park Precinct East had an existing full storage (RL 83 m) of approximately 1.5 ML.
- Smaller dams throughout the precinct had a combined available storage of 92,400m^3.
- The smaller dams throughout the precinct were assumed to have approximately 40-50% of the dam total storage available at the beginning of the storm. This ensures that the estimated existing peak discharge from the site to South Creek is lower than that which would occur with a full storage. Hence, this is a more conservative estimate as the detention storage required as part of the development is not underestimated using this method (note: this assumption only applied to existing dams, not proposed detention facilities).

3.1.5 Oran Park Precinct - RAFTS Model Calibration / Verification

While the site specific loss parameters were used RAFTS from Camden Council's guidelines, the parameters were verified against the choice of manning values based on calibration work undertaken by the Upper Parramatta River Catchment Trust (UPCRT). That area is generally a good representation of the Oran Park annual average rainfall, soil types and proposed landuse (being a mix of commercial/residential densities and open space). In addition, the ARBM catchment parameters recommended by Blacktown City Council (which are based on the UPCRT RAFTS model) were applied to the catchments within the site.

The verification model was shown to produce peak 100 and 1 year ARI flows within 0.7% to 1.7% to the loss model derived peak flows as used for the Oran Park Precinct. Those ARBM parameters are shown in **Table 3.2**. Therefore the choice of loss model parameters was considered suitable for this study, producing the highest peak flows and hydrograph volumes.

Table 3.2 Verification Model - ARBM RAFTS Model Parameters

Parameter	Value
Storage Capacities	
Impervious capacity	1.5
Impervious initial	0.5
Interception capacity	1.5
Interception initial	0.5
Depression capacity	5
Depression initial	0
Upper Soil capacity	25
Upper Soil initial	20
Lower Soil capacity	100
Lower Soil initial	80
Infiltration	
Sorptivity of Dry Soil	3
Saturated Hydraulic Conductivity	0.33
Lower Soil Drainage Factor	0.05
Evapotranspiration	
Proportion of Evapotranspiration Intercepted by Vegetation	0.7
Max. potential Evapotranspiration from Upper Soil Zone	10
Max. potential Evapotranspiration from Lower Soil Zone	10
Proportion of Evaporation in the Upper Zone	0.7
Rate of Potential Evaporation from "A" Class Pan	0.7

3.1.6 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. The Probable Maximum Flood (PMF) was analysed within the South Creek RAFTS model only. Storm durations from 15 minutes to 9 hours were examined for the local catchments within the Oran Park Precinct. The critical storm duration estimated for the local catchments within the Oran Park Precinct was 2 hours.

The 2 hour and 40 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 40 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.

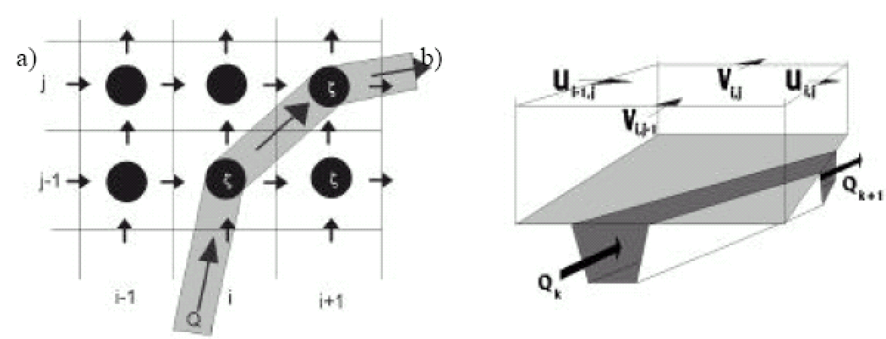

Plate 4 **Schematic Representations of the Integrated 1D/2D SOBEK Hydraulic Model**

3.2.1 Survey Sources

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

Oran Park Precinct East

- Photogrammetry of the Precinct – This data was controlled by a 200m grid of ground survey points and the additional ground survey stated below, providing a relative accuracy better than ± 500mm.
- Ground survey involving 50-100m wide cross sections taken along South Creek and it tributaries. These sections were spaced at approximately 200m intervals and extended

from the upstream boundary of the site to Bringelly Road, approximately 7.5 km downstream.

- Ground survey of the invert along tributaries within the study area.
- Survey of the bridge across South Creek at Bringelly Road, including the bridge deck centre line, upstream and downstream creek section and piers/abutments.

Oran Park Precinct West

- Ground survey of Cobbitty Creek and minor creeks within the site using cross sections spaced approximately 100m apart and extending wholly through the floodplain.

3.2.2 Digital Elevation Model (DEM)

A DEM was produced of the floodplain in ESRI ArcGIS from the survey sources described above, and is shown in **Figure 3.1** 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 10m x 10m was adopted for the South Creek flood model, as that resolution accurately depicted the floodplain and resulted in manageable model run-times. Furthermore, while developing the model it was observed that most of the 100 year flow was occurring in the 1D channel reach, therefore the 2D surface was only required for modelling any break-outs from the channel and flood storage areas.

A 10m DEM was also used for modelling local flooding in the Oran Park East and West Precincts.

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 Oran Park 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 for the 2, 20 and 100 year ARI storms for both the local tributaries in the Oran Park Precinct and South Creek. The PMF was also analysed for South Creek only.

The SOBEK model was run for four (4) simulation scenarios, being:

1. South Creek model — 40 hour critical storm duration
2. Existing Tributary models — 2 hour critical storm duration
3. Developed Tributary Models — 2 hour critical storm duration
4. South Creek PMF — 6 hour

3.2.5 Hydraulic Model Friction Losses - Existing

Friction was represented by Manning's roughness values in the 1D and 2D components of the SOBEK model. The values used were interpreted from site inspections and aerial photography, and included:

- 1D South Creek channel — 0.055
- 1D South Creek bank — 0.10
- 1D South Creek floodplain — 0.03-0.06
- 2D South Creek floodplain — 0.045-0.06
- 1D Tributary Creek channels & banks — 0.045
- 1D Bringelly Rd Bridge — 0.04

3.2.6 Developed Scenario – Friction Loss Sensitivity Analysis

The Manning's values within the South Creek SOBEK model were increased to model the vegetated riparian zone within the proposed buffer and test the SOBEK models sensitivity to the roughness parameter. The Manning's value within the 1D channel was increased to 0.1 (approximately 180% increase) and 2D floodplain manning increased to achieve Manning's values of between 0.065 – 0.08. Site inspections indicated that these roughness values were far in excess of that expected for existing conditions, but may reflect a fully revegetated riparian corridor in the future.

The results from this analysis have been used to set the FPL for the lots along South Creek using a freeboard of 600 mm (as per council guidelines).

4 EXISTING HYDROLOGICAL CONDITIONS

4.1 HYDROLOGY – SOUTH CREEK

The RAFTS model was used to estimate the 2, 20 and 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	100 Yr ARI Peak Flow	20 Yr ARI Peak Flow	2 Yr ARI Peak Flows
			(m^3/s)	(m^3/s)	(m^3/s)
South Creek upstream of model area	-	1.00	27.7	19.0	7.85
South Creek	8800	1.01	48.3	32.5	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 peak flows listed above are from a 40 hour critical duration storm. Whilst the modelling estimated a critical duration storm of 2 hours in the upper catchment of South Creek (also verified by GHD at Turner Road Precinct), that particular duration storm is not critical within the study area.

4.2 HYDROLOGY – COBBITTY CREEK

The peak flows from those ARI storms are shown in **Table 4.2** below.

Table 4.2 Existing Peak Flows - Cobbitty Creek

Location	Chainage	Rafts Node	100 Yr ARI Peak Flow	20 Yr ARI Peak Flow	2 Yr ARI Peak Flows
			(m^3/s)	(m^3/s)	(m^3/s)
	-	N106	5.52	4.38	2.39
Upstream of Northern Road	-	N105	8.20	6.16	2.98
	-	N104	16.9	11.8	4.85
	-	N103	21.8	14.8	6.04
Cobbitty Road Culverts	1260	N102	29.8	20.2	8.38
	720	N101	35.9	24.3	10.0
Western Boundary of Oran Park Precinct	0	N100	43.8	29.5	12.1

4.3 HYDROLOGY – LOCAL PRECINCT CATCHMENTS

The RAFTS model has shown that the critical storm for the 2, 20 and 100 year ARI storms is the 2 hour duration on all tributaries within the Oran Park Precinct. The corresponding maximum 100 Y ARI peak flow along each creek in Oran Park Precinct East & West is shown in **Figure 4.1** and **Figure 4.2**, and are listed in **Table 4.3**.

Table 4.3 Existing Peak Flows – Local Precinct Catchments

	ARI Storm		
Oran Park East	**100 Y**	**20 Y**	**2 Y**
Creek A	10.9	7.59	3.12
Creek B	63.2	42.8	16.0
Creek C	18.5	12.2	3.37
Creek D	30.4	21.1	8.44
Oran Park West			
Existing small dam	4.28	2.92	1.23
Box Culverts under Northern Rd	8.98	6.22	2.54
Pipes under Northern Rd	4.64	3.27	1.29
School	9.79	6.85	2.82
Cobbitty Dam	23.5	16.6	6.70

5 HYDRAULIC CONDITIONS

5.1 HYDRAULIC MODELLING RESULTS – SOUTH CREEK

5.1.1 Existing Scenario

The hydraulic modelling results show that the existing peak 100 year ARI flood level in South Creek varies from 82.68 m AHD at the upstream boundary of the site to 72.92 m AHD at the downstream of the Oran Park Precinct boundary. The 100 year ARI flood depths and the PMF extent in South Creek is shown in **Figure 5.3** for the Oran Park Precinct.

As shown in **Table 5.1**, the PMF level is approximately 500 mm to 1.04 m above the 100 year ARI flood level through South Creek. The 2 year ARI flood levels represent bankfull flow levels in South Creek.

Table 5.1 South Creek – Existing 2, 20 & 100 Y ARI Flood Levels

	Flood Level (m AHD)			
Chainage	100 Y ARI	20 Y ARI	2 Y ARI	PMF
5990	72.92	72.59	72.30	73.75
6290	73.49	73.11	72.72	74.29
6500	73.83	73.39	73.00	74.87
6755	74.22	73.76	73.67	75.25
6845	74.76	74.59	73.83	75.51
6955	75.16	74.90	74.26	76.04
7095	75.36	75.06	74.38	76.26
7305	76.24	75.85	75.09	77.07
7460	76.73	76.50	75.90	77.44
7595	77.16	76.95	76.35	77.97
7850	78.02	77.78	77.27	78.84
8050	78.89	78.56	77.87	79.69
8250	79.65	79.30	78.60	80.69
8375	80.39	79.91	79.13	81.35
8640	81.94	81.79	81.54	82.44
8795	82.68	82.57	82.27	83.18

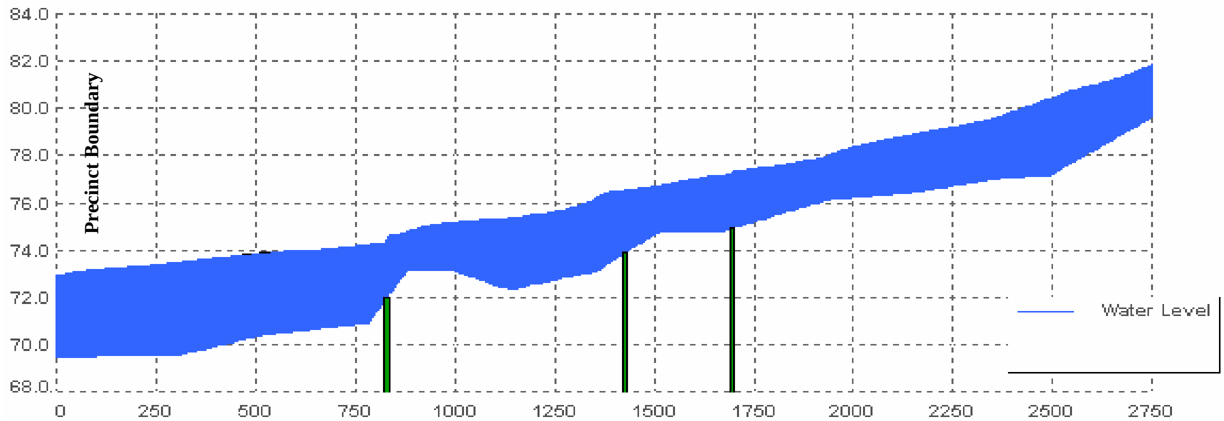

Figure 5.4

South Creek - 100 Year ARI Flood Profile

Note: Chainage 0 on graph refers to chainage 5990 in **table 5.1**

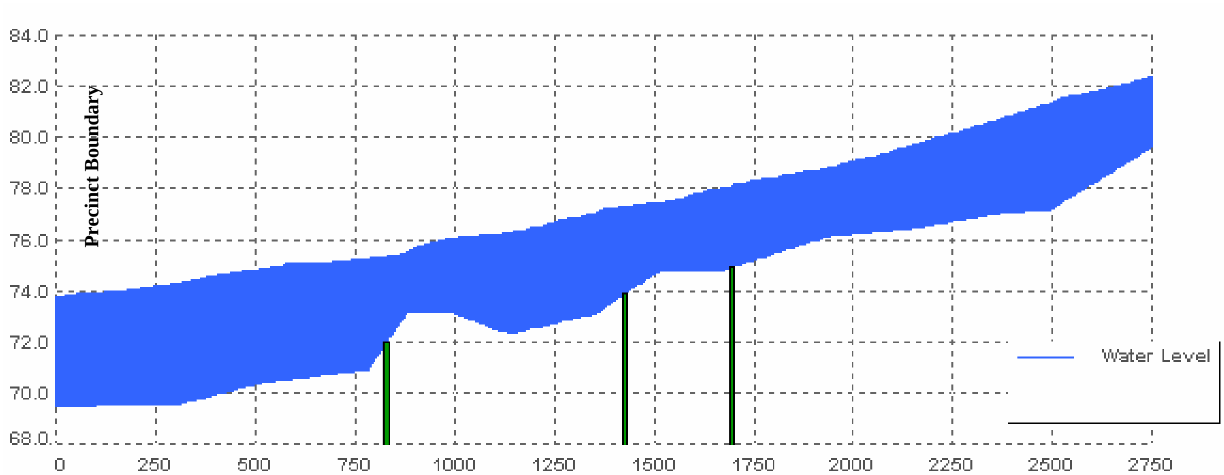

Figure 5.5

South Creek – PMF Flood Profile

Note: Chainage 0 on graph refers to chainage 5990 in **table 5.1**

5.1.2 Developed Scenario

The hydraulic modelling for the developed scenario increased the mannings roughness within the proposed South Creek buffer to model the vegetated riparian zone and modelled the floodplain filling of the flood fringe slightly. The modelling also assumed removal of existing earth weirs/dams on South Creek along the precinct boundary. The results show that the peak 100 year ARI flood level in South Creek varies from 82.83 m AHD at the upstream boundary of the site to 73.19 m AHD at the downstream of the Oran Park Precinct boundary. The modelling showed a maximum increase in flood level for the proposed 100 Year ARI storm event of 0.42m.

Table 5.2 South Creek – Developed 100 Y ARI, PMF Flood Levels and Flood Planning Level

Chainage	Developed Q100 (m AHD)	Developed PMF (m AHD)	Min Flood Planning Level (Dev Q100 + 600mm)
5990	73.19	74.00	73.79
6290	73.75	74.53	74.35
6500	74.20	75.15	74.80
6755	74.57	75.55	75.17
6845	74.88	75.77	75.48
6955	75.42	76.29	76.02
7095	75.67	76.54	76.27
7305	76.52	77.31	77.12
7460	76.91	77.68	77.51
7595	77.39	79.29	77.99
7850	78.23	79.13	78.83
8050	79.21	80.20	79.81
8250	80.07	81.02	80.67
8375	80.78	81.61	81.38
8640	82.02	82.59	82.62*
8795	82.83	83.40	83.43*

*Note: At some locations the minimum statutory FPL is actually greater than the estimated PMF level. In such a situation it is recommended that the FPL be the lesser of the PMF level or the FPL.

5.1.3 Distribution of Flow in South Creek

Figure 5.6 to **Figure 5.9** shows the channel (1D) and total (1D & 2D) discharge at four locations (Ch 7850m, 6500m, 4760m, and 2970m) along South Creek for the 100 year ARI storm. The results show that the majority of creek discharge is conveyed within the 1D channel for cross sections through the Oran Park Precinct (chainages 7850m and 6500m). Downstream of the Oran Park Precinct (Ch 4760m and 2970m) a greater proportion (30-50%) of creek discharge is conveyed within the floodplain of South Creek.

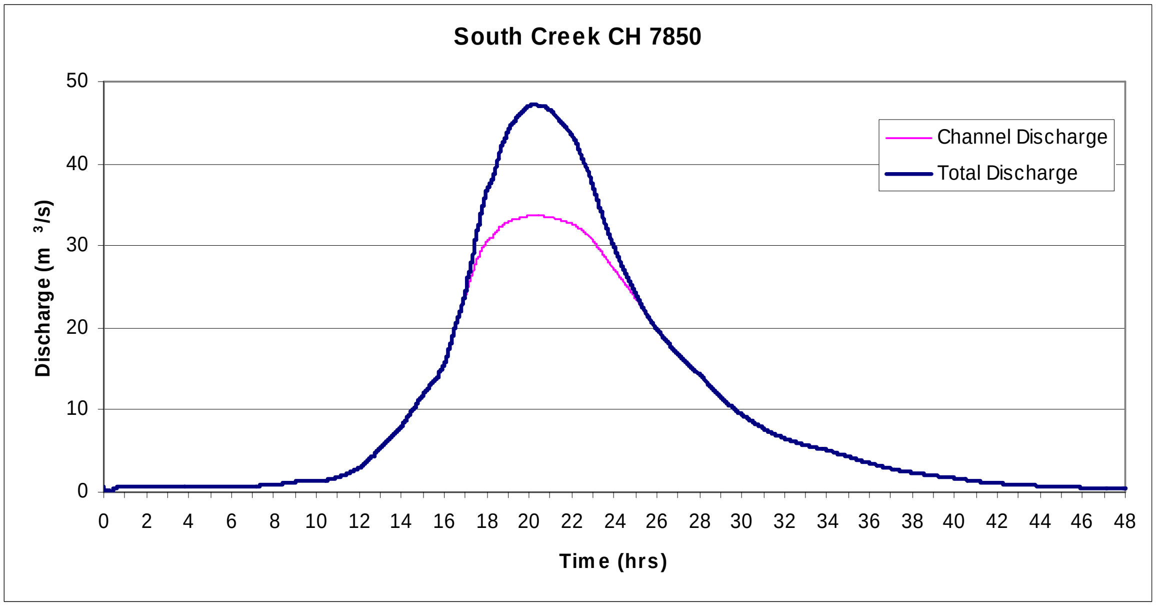

Figure 5.6
South Creek – 1D Channel and Total Discharge (CH 7850m)

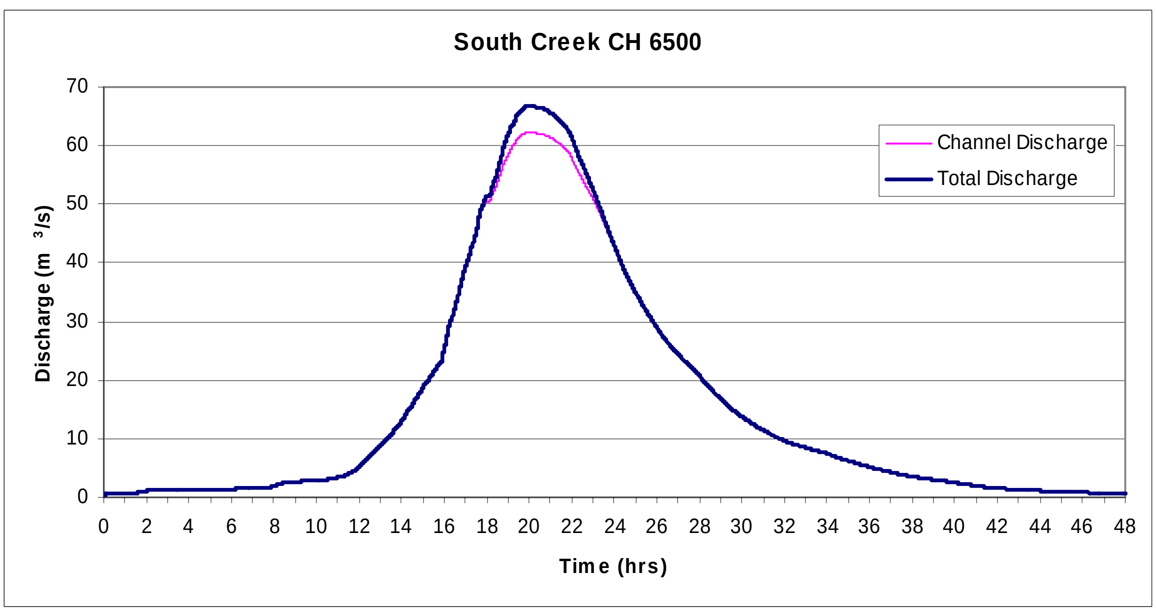

Figure 5.7
South Creek – 1D Channel and Total Discharge (CH 6500m)

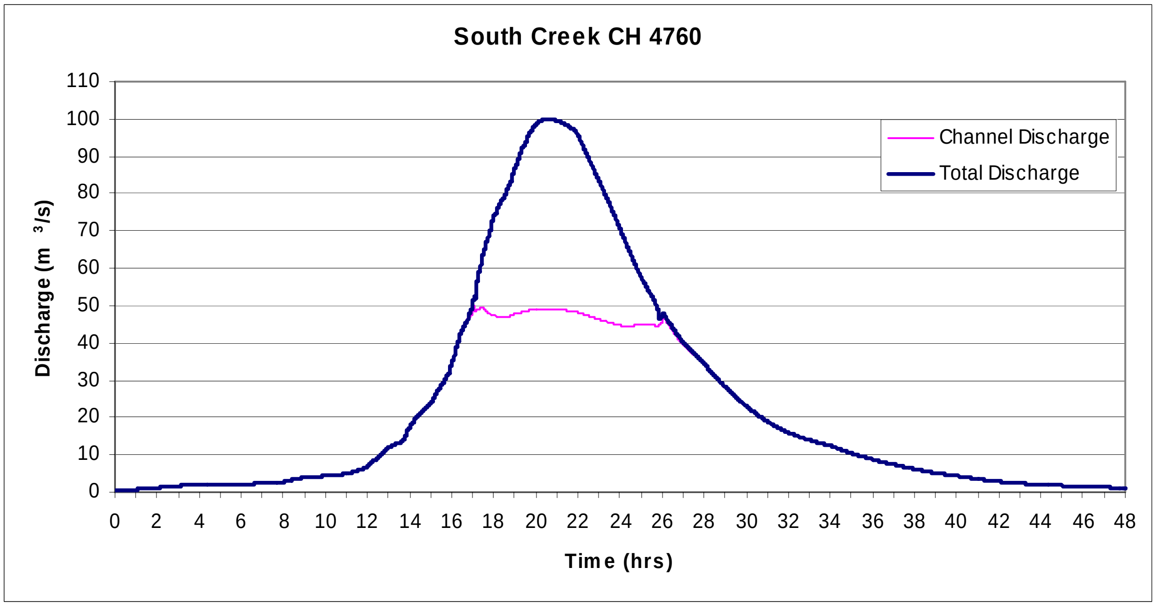

Figure 5.8
South Creek – 1D Channel and Total Discharge (CH 4760m)

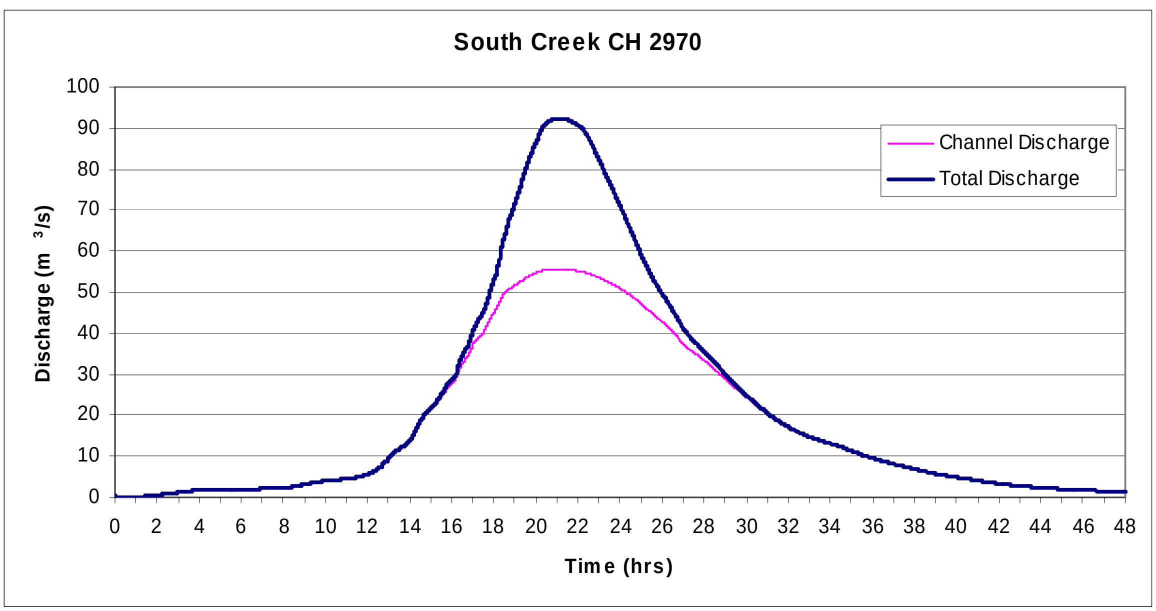

Figure 5.9
South Creek – 1D Channel and Total Discharge (CH 2970m)

5.1.4 Bringelly Road Bridge

Bringelly Road is the only existing significant bridge crossing over South Creek within the study area. The bridge is located approximately 5.5km downstream of the Oran Park Precinct and consists of a concrete abutment bridge forming a trapezoid shape opened cross section area with 3 pillars.

Plate 5 - Bringelly Road Bridge Looking d/s

The Bridge was modelled in SOBEK as a 1D abutment bridge node. The cross section area was taken from 2006 survey and the inlet co-efficient was adjusted to account for the flow obstructions of the pillar type. The SOBEK model results estimate a flood level of 58.71 m AHD at the bridge node. As a verification of bridge hydraulics, a HEC-RAS unsteady state model was developed for the bridge. That model estimated flood levels slightly lower then those calculated by SOBEK.

The South Creek Flood Study (1990) reported flood levels of 59.3 m and 58.3 m AHD upstream and Downstream of Bringelly Road respectively. Those results estimate a flood level approximately 90 mm higher at the Bringelly Road Bridge then the SOBEK model. The difference in flood level may be due to a difference in topographical data as the Mike 11 (1990) section downstream of Bringelly Road is 250mm higher then the 2006 surveyed bridge section which may affect the tailwater sufficiently to account for the level difference.

While testing bridge loss assumptions and tailwater conditions, there was no significant effect on flood levels through the Oran Park Precinct, as that area is beyond the area of effect that Bringelly Road Bridge has on South Creek flooding.

5.2 HYDRAULIC MODELLING RESULTS – COBBITTY CREEK

The hydraulic modelling results show that the existing peak 100 year ARI flood level in Cobbitty Creek varies from 72.97 m AHD at the upstream boundary to 66.51 m AHD at the downstream of the Oran Park Precinct boundary. The 100 year ARI flood depths and the PMF extent in South Creek is shown in **Figure 5.10** for the Oran Park Precinct - West.

A figure **(Plate 6)** from a Camden Council flood study shows the 100 Year ARI and PMF Flood line from backwater flooding from the Nepean River. From the figure it would appear that the local flooding (as modelled in Sobek) gives a greater flood extent for the 100 year ARI. The PMF flood line shown on the Camden Flood Study appears extend into the development site, however this will need to be verified in future studies.

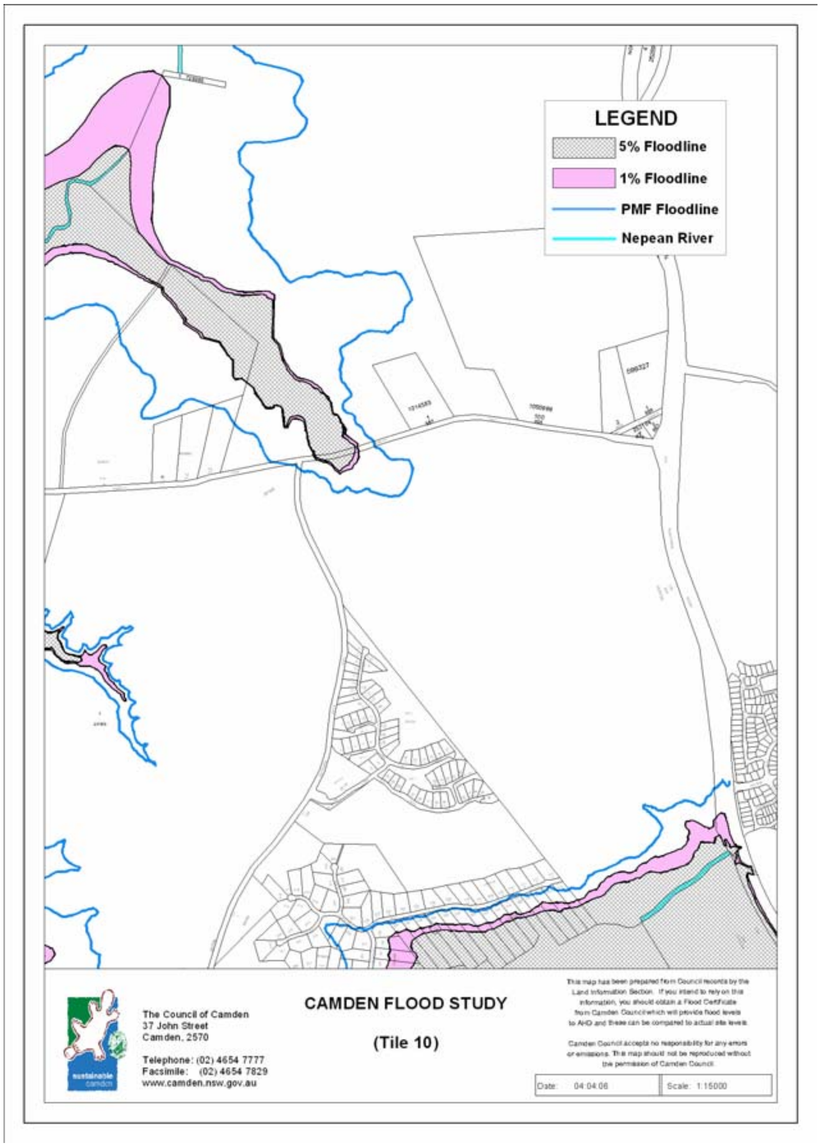

Plate 6 Figure from Camden Flood Study

5.3 HYDRAULIC MODELLING RESULTS – LOCAL CREEKS

The 100 year ARI flood depths and extent for the Oran Park Precinct East and West are shown in **Figure 5.3** and **Figure 5.10**. The existing flood levels in the local creeks in Oran Park Precinct East are shown in **Table 5.3**.

Table 5.3 Existing Flood Levels (m, AHD)

Chainage (m)	100 Y ARI	20 Y ARI	2 Y ARI
Creek A			
975	88.03	87.89	87.73
680	85.34	85.26	85.11
148	79.25	79.18	79.05
Creek B			
2116	93.15	92.96	92.52
1680	89.16	88.92	88.36
1177	85.39	85.31	85.08
925	83.36	83.04	82.47
496	81.08	80.67	80.04
193	79.53	79.30	79.02
Creek C			
1074	94.93	94.88	94.81
429	88.57	88.45	88.29
72	85.41	85.28	85.09
Creek D			
1415	93.88	93.65	93.30
925	88.91	88.79	88.45
130	81.36	81.21	80.78

100 year ARI flood profiles for existing conditions in the tributaries of Oran Park Precinct East are shown in **Figures 5.11** to **Figure 5.14**.

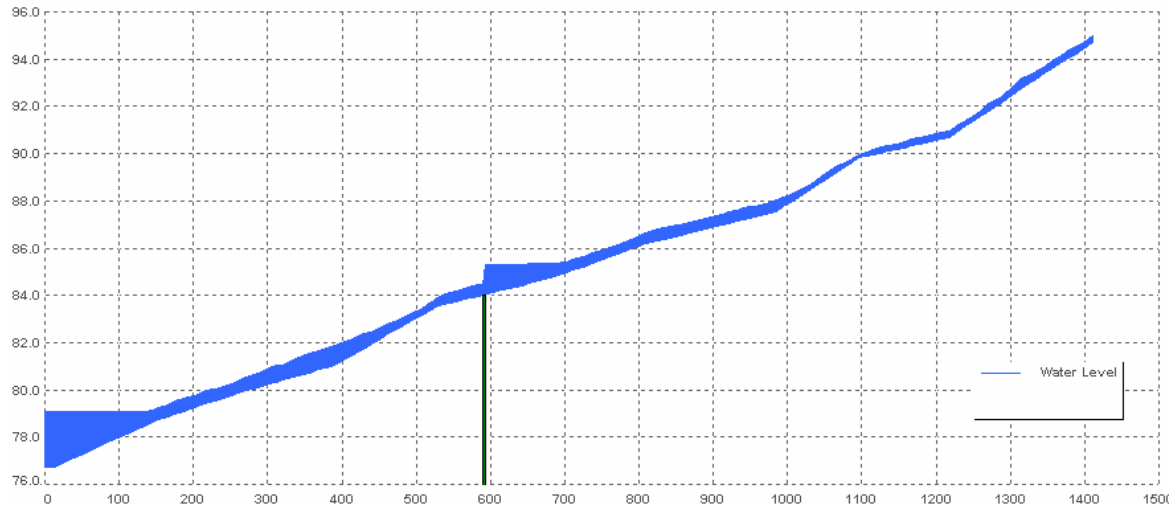

Figure 5.11

Creek A – 100 Y ARI Existing Flood Profile

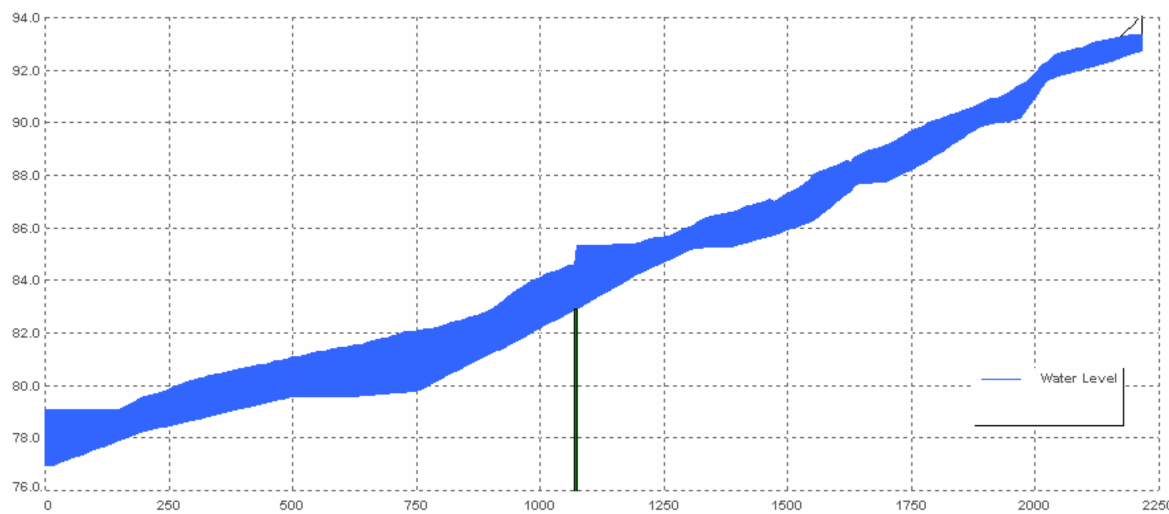

Figure 5.12

Creek B – 100 Y ARI Existing Flood Profile

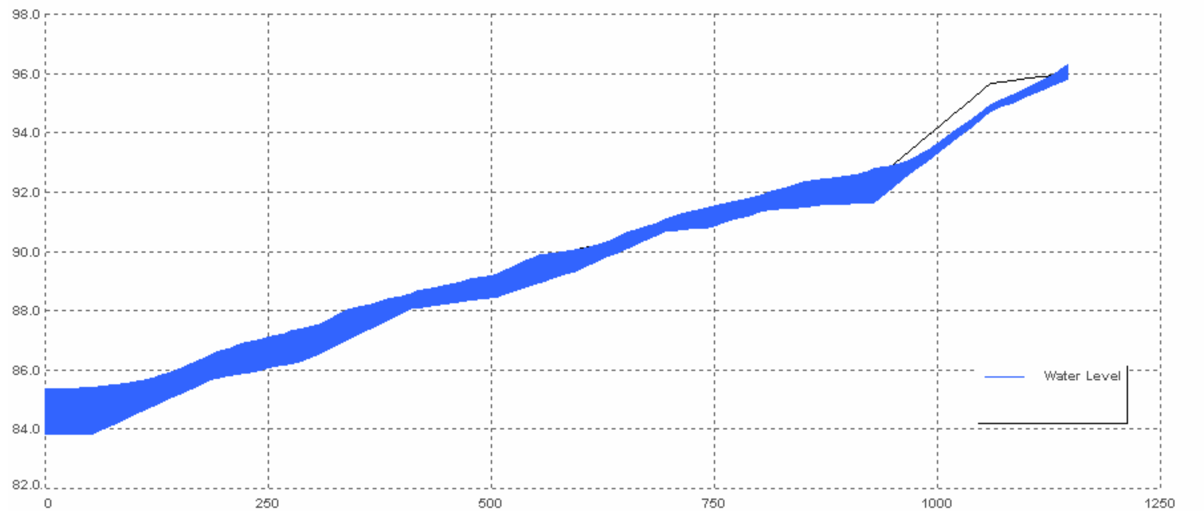

Figure 5.13

Creek C – 100 Y ARI Existing Flood Profile

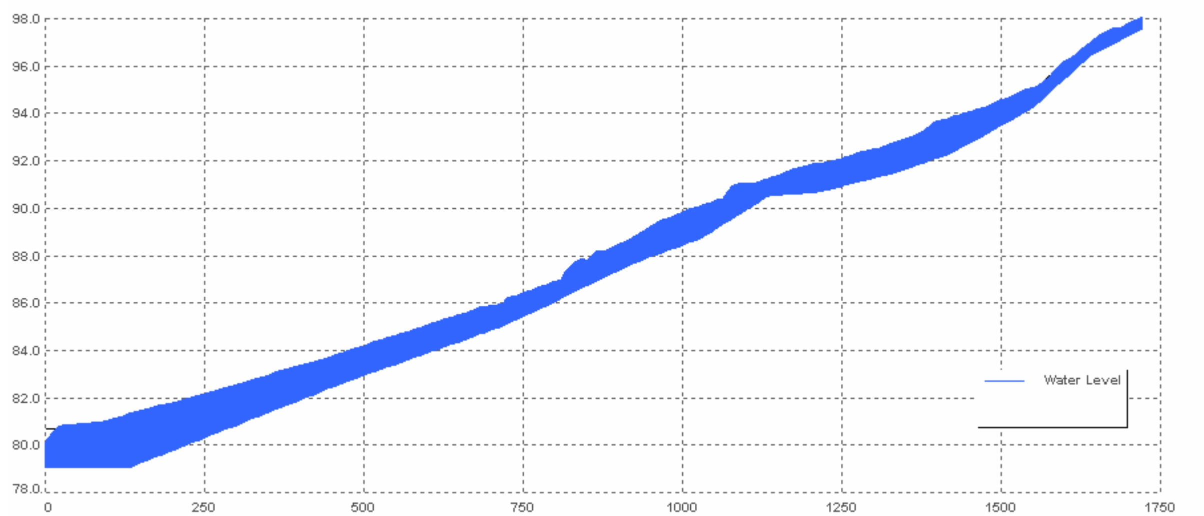

Figure 5.14

Creek D – 100 Y ARI Existing Flood Profile

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 and Cobbitty Creek resulting in increases in flood levels downstream of the Oran Park Precinct.
- Impediments to flow in the form of creek crossings – the two proposed crossings of South Creek could lead to afflux at those structures, thereby increasing flood levels on South Creek and affecting flood planning levels of adjacent development.

6.1.1 Hydrological Impacts

Stormwater detention within the Oran Park Precinct is necessary as the hydrological modelling has shown that without significant detention storage the development of this precinct would significantly increase (> 150% 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 (%)
D1.0	63.2	104	164
N6.0	6.44	17.0	264
N7.0	5.76	14.7	255
N8.0	3.35	7.62	227
N9.0	2.43	5.22	215
South Creek	42.2	66.7	158

The 2, 20 and 100 year ARI peak flows are shown in **Appendix B** for all RAFTS model catchments within the Oran Park Precinct.

7 STORMWATER QUANTITY MITIGATION MEASURES

The stormwater quantity management strategy for the Oran Park 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 (refer to Ecological Engineering, 2007).

7.1 STORMWATER QUANTITY MANAGEMENT STRATEGY

The stormwater quantity management strategy for the Oran Park Precinct is shown in **Figure 7.1** and **Figure 7.2**. 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 (permanent pool) with the stormwater detention occupying approximately 1 m to 1.5 m of extended detention depth above the permanent pool level, or basin floor in the case of a dry detention basin.

The stormwater detention strategy assumes an existing condition scenario with the large dam on Creek B removed. The reasoning for this approach is that the dam is a recent feature that did not existed during any recent major flood, and was not included in any prior hydrological modelling of South Creek.

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

Table 7.1 Stormwater Detention Requirements

Oran Park Precinct East Basin ID	Detention Component Volume (m^3)	Oran Park Precinct West Basin ID	Detention Component Volume (m^3)
SC1	5,000	B4	20,000
SC2	6,500	CC1	10,900
SC3	6,000	CC2 (Cobbitty Dam)	28,000
SC4	12,000	CC3	7,400
B1 (Reconstruction of Existing Dam)	135,500		
B2	13,000		
C1	15,500		
D1	13,500		
D2	5,100		
D3	10,500		
Nth R1	3,000		
Nth R2	5,000		
Nth R3	12,000		

The specific objectives for the stormwater quantity management strategy for the Oran Park 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.

Management measures specific to Oran Park Precinct East include:

- The existing large dam will be rebuilt into a structure with less storage, and should be required to safely discharge flows up to the PMF.
- Ensure post developed flows entering South Creek at Creek B and Creek D do not exceed the existing peak flow, for all storms up to the 100 year ARI.
- Provision of onsite detention storage in the Oran Park town centre commercial areas for the 2 year ARI event to ensure bankfull flows can be mitigated for the downstream Category 2 creeks to meet DEC guidelines. This will require a site storage requirement (SSR) of 175 m^3/ha. As the storage is principally to reduce peak flows from smaller ARI events, and as rainwater tanks have been shown to mitigate 1 to 3 month flows, it is recommended to allow at least 30% of this storage to be incorporated within the rainwater reuse storage component.

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 Oran Park Precinct East.

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)
D1.0	63.2	58.8
N6.0	6.44	6.15
N7.0	5.76	4.41
N8.0	3.35	3.22
N9.0	2.43	2.21
South Creek	42.2	37.9

100 Y ARI Flood profiles within the Oran Park Precinct East are shown in **Figures 7.3** to **Figure 7.6** for the proposed stormwater management strategy. The corresponding flood levels are shown in **Appendix C**.

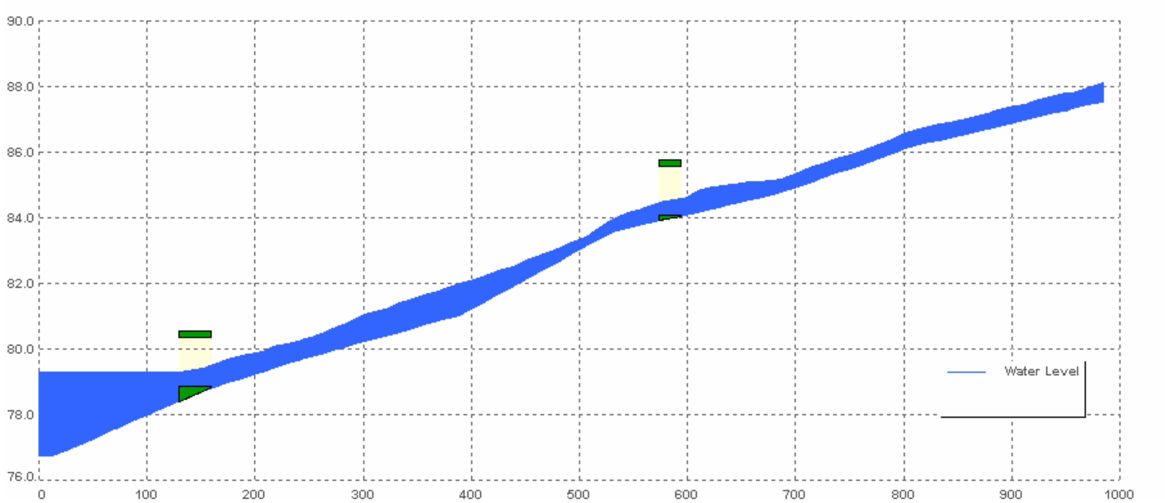

Figure 7.3 100 Y ARI Developed Flood Profile - Creek A

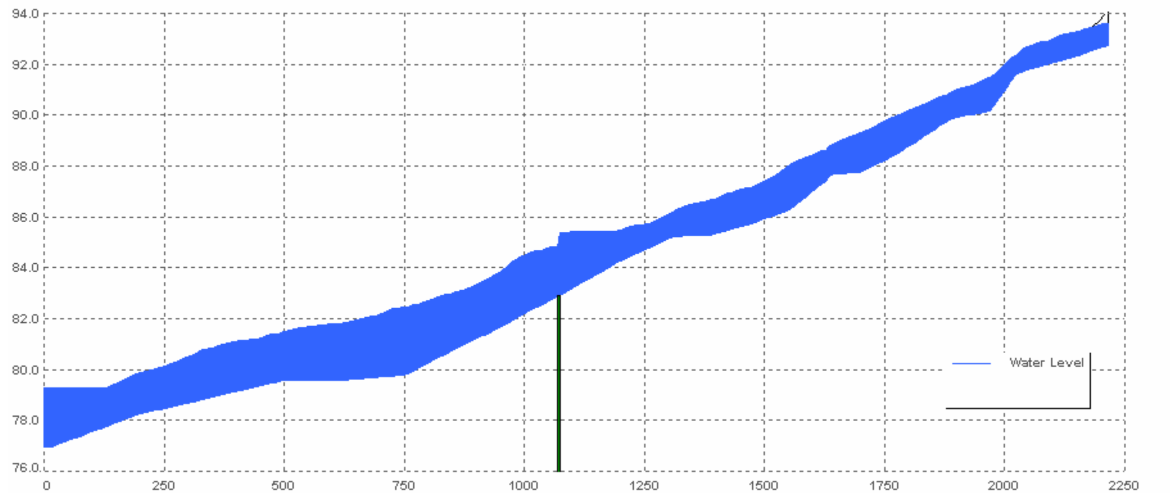

Figure 7.4 100 Y ARI Developed Flood Profile - Creek B

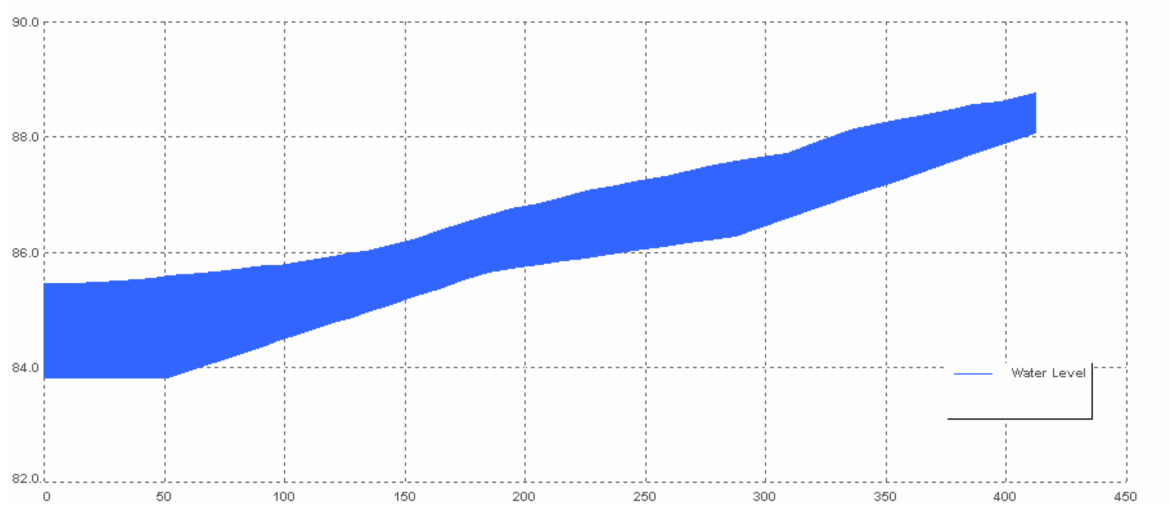

Figure 7.5 100 Y ARI Developed Flood Profile - Creek C

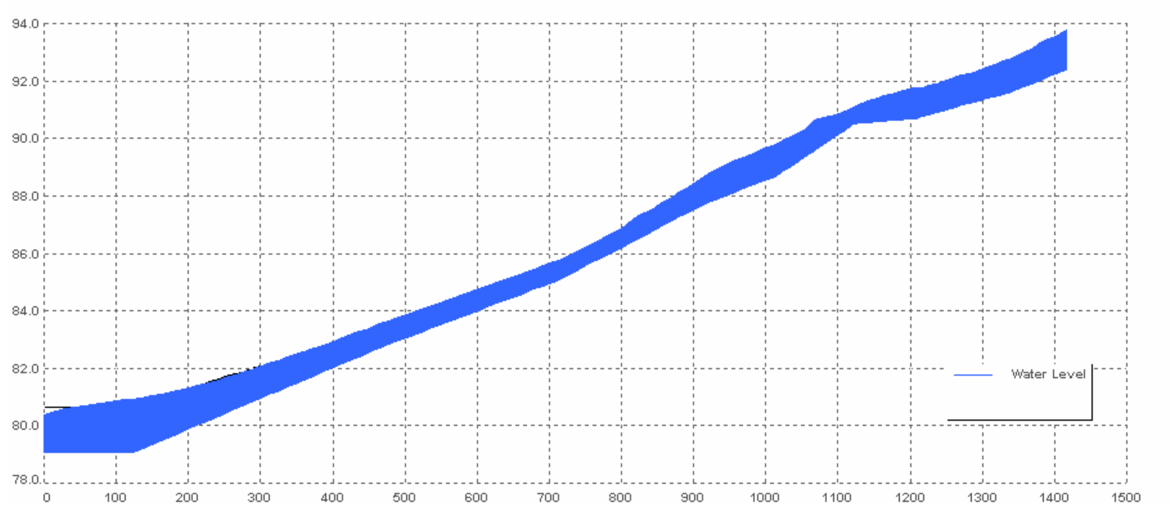

Figure 7.6 100 Y ARI Developed Flood Profile - Creek D

8 FLOOD EVACUATION STRATEGY

Generally, the majority of the Oran Park Precinct East 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 (PMF) are proposed to be filled. Within Oran Park Precinct West, the Regional PMF from the Nepean River extends into the development. 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. Furthermore, the PMF extent shown in Figure 7.2 requires verification as it is digitised from the Camden Flood Study.

As recommended by Camden Council and Australian Rainfall and Runoff (2001), a 'minor' and 'major' drainage system approach is proposed to mange 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 to the PMF level.

Around the proposed large dam (B1) in Oran Park Precinct East, the level of flood immunity recommended is greater, being equivalent to the greater of the 100 year ARI flood with 500mm freeboard or the 500 year ARI flood level to account for uncertainty in climatic conditions. It is proposed that by using a suitable high flow weir outlet, this would not increase fill requirements more than existing planning controls.

9 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 Oran Park 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 600mm above the proposed 100 year ARI flood level
- Proposal managers major and minor stormwater flows using structures
- Ensure development does not encroach into riparian zones.

Within Oran Park Precinct West, existing 100 year ARI flooding extends into a significant proportion of the proposed development and will require further modelling to determine if that area is capable of being filled. Those issues should be examined in the proposed regional flood study and the development application process.

10 REFERENCES

Bewsher Consulting Pty Ltd (2004). South Creek Floodplain Risk Management Study. Prepared for Liverpool Council. Final Report.

Department of Water Resources (1990). South Creek Flood Study

Department of Water Resources (1991). South Creek Floodplain Management Study.

Delft Hydraulics (2006). SOBEK.

Ecological Engineering (2006). Water Sensitive Urban Design Report for Oran Park Precinct.

Growth Centres Commission (2006). Development Code.

Institution of Engineers Australia (2001). Australian Rainfall and Runoff.

11 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.
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 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.