Cabramatta Creek Flood Study and Basin Strategy Review

Final Report

September 2011

Bewsher

LIVERPOOL CITY COUNCIL

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PREFACE

The Cabramatta Creek Flood Study and Basin Strategy Review was prepared by Bewsher Consulting Pty Ltd for Liverpool City Council.

The study reviews flood behaviour in the Cabramatta Creek catchment. This includes the establishment of a new computer model, analysis of flood behaviour over different time periods, and a review of the performance of Council's detention basin strategy to mitigate the impacts of catchment development.

A draft copy of the report was presented to Council's floodplain management committee on 17th March 2011. The report was reviewed by committee members and subsequently placed on public exhibition between 13th July and 9th August 2011. The report is to be further considered by Liverpool City Council prior to being formally adopted.

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EXECUTIVE SUMMARY

Reasons for the Study

The Cabramatta Creek catchment is one of the most rapidly developing catchments in NSW. Vast areas of land have been rezoned for residential and industrial development, new suburbs built, a new motorway constructed through the middle of the catchment, and other infrastructure provided. All of these activities have the potential to exacerbate existing flooding problems experienced in the lower catchment, where some 124 homes and 104 commercial and industrial buildings are estimated to be inundated above floor level in a 100 year flood.

The study is divided into two parts. Part 1 aims to provide an advanced computer model of flood behaviour in the catchment for existing (2008) flood conditions. The model is also to be used to assess flood behaviour under previous (1989) catchment conditions, and to review the performance of Council's detention basin strategy to mitigate the impact of catchment development on flood behaviour within this time frame. Part 2 investigates the performance of the basin strategy under future (2026) conditions, including full development of the new release areas and construction of the remaining basins from the basin strategy.

Responsibilities

The prime responsibility for planning and management of flood prone land in New South Wales rests with local government. The New South Wales Government provides assistance on state-wide policy issues, technical support, and funding for studies and other measures. The current study was commissioned by Liverpool City Council in May 2008.

The Study Area

Cabramatta Creek is a major tributary of the Georges River, in Sydney's south-west. It has a catchment area of $74km^2$, which is mostly located within the Liverpool City Council Local Government Area. Smaller portions of the catchment are also located within the Fairfield and Campbelltown Council areas.

Hinchinbrook Creek and Maxwells Creek are also included in the study area.

Available Data

Available data for the study includes:

i) digital aerial photography, dated 1996, 2002, 2005 and 2007;

ii) digital elevation models derived for 1996, 2005 and 2008;

iii) past surveys of creeks and waterway areas;

iv) details of numerous culverts, bridges and detention basins;

v) digitised building footprints for 1996 and 2008 conditions; and

vi) extensive flood data from events that occurred in August 1986 and April 1988, which have been used to calibrate the new flood model;

The Basin Strategy

The detention basin strategy aims to compensate for new release area development that was identified in the catchment in the late 1980s. It was not a strategy to solve existing problems, but rather a strategy to ensure that new development does not make flooding any worse in the lower catchment.

The principle aim in sizing and locating the detention basins was quoted (Kinhill, 1992, page 6-1) as:

> *"to effectively control 1% AEP post-development flows to pre-development levels. This reduction in flow was not only to apply at the outlet of the basin. Using a combination of basins, the discharge from the outlet of the Cabramatta Creek catchment (at the Main Southern Railway Line) had to also be maintained to pre-development levels."*

The basin strategy has evolved since 1989. Some basins have been split into smaller basins; others have been moved; and some have been replaced. The current basin strategy comprises 13 major detention basins constructed within the catchment to date, with another 6 basins identified for future construction.

Flood Modelling Approach

The adopted modelling approach has been to update an existing RAFTS hydrologic model of catchment runoff, and to input these flows to a new TUFLOW hydraulic model to estimate flood levels, velocities and extents. TUFLOW is a two-dimensional computer model that has been used in over 200 applications in NSW, Queensland, Victoria, South Australia, Tasmania, and also in the UK.

The models have been calibrated to historic data collected in the August 1986 and April 1988 floods. Both floods were significant, with the 1988 event being estimated to be close to a 100 year event throughout much of the catchment. Calibration data consisted of stage and flow hydrographs at a gauging station at Orange Grove Road, 29 flood height observations for the 1988 flood, and 44 flood height observations for the 1986 flood.

Two different flood models have been developed representing existing (2008) and previous (1989) catchment conditions. A third model was developed representing future (2026) catchment conditions during Part 2 of the Study.

Culvert Blockage Assumptions

The current study makes no allowance for the potential blockage of culverts, bridges, or detention basin outlets. It is recommended that sensitivity testing be undertaken as part of any subsequent investigations to determine how flood behaviour may be affected under various blockage scenarios.

Climate Change Considerations

Climate change investigations are beyond the scope of the current project. Studies currently in progress for Fairfield City Council indicate that Cabramatta Creek would be relatively unaffected by potential sea level rises. However, greater impacts are likely to be associated with potential changes in rainfall intensities. A 10% increase in rainfall intensities over the Georges River catchment was estimated to increase the 100 year flood level by +0.33m at the mouth of Cabramatta Creek. Further investigation into the sensitivity of design flood level estimates in Cabramatta Creek to potential increases in rainfall intensities is recommended.

Review of Flood Behaviour

Design flood behaviour has been analysed for a range of floods for existing (2008) and previous (1989) catchment conditions. A map showing the extent of flood inundation and design flood level contours for the 100 year flood is provided on Figure 6.1 under existing (2008) conditions. Results for other events will be provided digitally for incorporation in Council's GIS. A flood risk management map is also provided on Figure 6.2 for the floodplain.

A map showing the difference in the latest estimate of the 100 year flood from the previous estimate from the RMA-2 model is provided on Figure 6.3. The mapping indicates some localised areas where flood level estimates have either increased or reduced, although the majority of the study area has not changed significantly (within 0.2m).

A map showing the difference in TUFLOW estimates over the period form 1989 to 2008 is provided on Figure 6.4. With the exception of some localised areas, the majority of the study area shows relatively minor changes (within 0.2m) over this period.

Performance of the Basin Strategy as whole

The main objective of the basin strategy is to limit the estimated 100 year peak flows throughout the catchment to flows that existed prior to the new release area development.

The latest model results suggest that over the period from 1989 to 2008, flood level estimates have stayed relatively uniform throughout the majority of the catchment. Peak flow estimates have marginally reduced in the lower reaches of Hinchinbrook Creek and Upper Cabramatta Creek, with more significant reductions in Maxwells Creek. There is negligible change in peak flow estimates at the downstream end of Cabramatta Creek.

It is reasonable to conclude that the basins that have been constructed in the catchment to date have been sufficient to mitigate the impacts of new release area development on flooding over the period from 1989 to 2008 in most areas. The impact of the remaining new release area development (post 2008) and construction of the remaining basins is discussed under Part 2 of the Study.

Recommendations for individual basins constructed to date

It is recommended that safety aspects of all basins are reviewed, particularly in events that overtop the basin embankment and events more extreme than the 100 year flood. Consideration should be given to prescribing the larger dams in the catchment with the Dam Safety Committee (if not already done).

Other specific recommendations include:

i) Basin 200 – check on potential blockage problems associated with the grate over the basin outlet.

ii) Basin 18 – Check on potential blockage problems in the vicinity of the basin outlet. Consider the installation of a trash barrier to minimise potential blockage problems. Verify and monitor crest heights separating the three basin compartments to ensure that the basin performs as intended.

iii) Government Road Basin – Further review flood behaviour on the Hinchinbrook Creek floodplain, where localised increases in design flood level estimates have been noted adjacent to this basin. Review and monitor the stability of the embankment separating the basin from Hinchinbrook Creek.

Assessment of Future Conditions (Part 2 of Study)

The flood models were updated to represent future (2026) catchment conditions. This includes the development of all new release areas and all detention basins identified in the basin strategy. The date of future conditions has been nominated as 2026 for consistency with previous studies.

There are six detention basins from the basin strategy that have not yet been constructed. These basins have been included in the flood models based on the most recent preliminary design or concept plan for each basin. Some specific comments in relation to these basins include:

i) Basin 3B – the performance of this basin is similar to that quoted in a concept report prepared by Cardno (2010).

ii) Basin 4 – Special consideration will be required for this basin, given its location within the Hinchinbrook Creek floodplain. The design needs to be based on a hydraulic model (such as TUFLOW) rather than a hydrologic model (such as RAFTS). The basin is likely to be expensive to construct given the amount of excavation that is required and the costs may outweigh the benefits of the basin.

iii) Basin 6 – the performance of this basin is similar to that quoted in a report by JWP (2010). The footprint of the basin has been modified by JWP and is inconsistent with the current zone boundaries.

iv) Basin 11C – the performance of this basin is consistent with the design recently prepared by GHD.

v) Basin 12 – the proposed outlet for this basin (advised by Council) was reduced to utilise more of the available storage from this site, with a design storage capacity of $90{,}000m^3$.

vi) Basin 14 – the proposed outlet and spillway for this basin (advised by Council) was modified to prevent the basin from spilling in the 100 year flood, with a design storage capacity of $48{,}000m^3$.

Design flood behaviour for the 100 year flood under future (2026) conditions is included in Figure 8.7. The difference in flood levels over the period from 1989 to 2026 is shown on Figure 8.8 and Figure 8.9 for the 20 year and 100 year floods. The results indicate that the basin strategy provides more beneficial results for the 100 year flood than it does for more frequent floods, particularly in the lower reaches of Cabramatta Creek. Flood level reductions of 0.2 to 0.3m are evident in the 100 year flood along much of Cabramatta Creek, between Hoxton Park Road and Orange Grove Road. In contrast, some flood level increases are evident in the 20 year flood.

The impact of omitting Basin 4 from the basin strategy has been briefly reviewed. The 100 year flood level for future (2026) conditions is estimated to increase generally by between 0.04 to 0.06m throughout Hinchinbrook Creek and Lower Cabramatta Creek if Basin 4 was omitted. However, these levels are still lower than the estimated levels for previous (1989) conditions. Further evaluation of the costs and benefits associated with the construction of Basin 4 are recommended. Pending these investigations, it is recommended that the basin be given a lower priority for construction than the other basins that remain to be constructed. The basin could be reserved in case required due to further (unforseen) development within the catchment, or if new assessment methods provide a less favourable review of the performance of the basin strategy in the future.

1 BACKGROUND TO THE STUDY

1.1 INTRODUCTION

Bewsher Consulting was commissioned by Liverpool City Council in May 2008 to review flood behaviour in the Cabramatta Creek catchment. The review includes the establishment of a new computer flood model, analysis of flood behaviour over different time periods, and a review of the performance of Council's detention basin strategy to mitigate the impacts of catchment development.

The Cabramatta Creek catchment is one of the most rapidly evolving catchments in NSW. Vast areas of land have been rezoned for residential and industrial development, new suburbs constructed, floodplain areas filled, a motorway built through the catchment, a bus transitway constructed, and other infrastructure built. All of these activities have the potential to have a significant impact on flood behaviour.

Some of this development was foreseen in the late 1980s, and a detention basin strategy formulated for the catchment. The objective of the basin strategy was to ensure that flooding within the catchment would not increase as a result of the development that was anticipated at the time. The strategy originally involved the construction of up to 17 detention basins within the catchment. The strategy itself has evolved over time, with some basins being split into smaller basins, others have been relocated, and some have been omitted. To date, 13 major basins have been constructed, and 6 other basins identified for future construction.

The Cabramatta Creek Floodplain Management Study (Bewsher Consulting, 2004) was the last major study undertaken on the Cabramatta Creek catchment. The study investigated flood behaviour in the catchment, and recommended a range of floodplain management measures to manage the flood risk. A flood model was developed as part of the study, which provided information on flood behaviour for 1996 catchment conditions. Design flood levels and flood inundation mapping from the study were adopted by both Liverpool and Fairfield Councils during 2004. These flood levels have been used to specify minimum floor level controls and other building controls throughout the catchment since 2004.

The current study aims to develop a new flood model for the catchment, taking account of new modelling techniques that are now available, and incorporating changes that have occurred within the catchment since the previous study. Some changes in estimated design flood levels throughout the catchment are anticipated as a result of these investigations. The new modelling also provides an opportunity to review the performance of Council's basin strategy in mitigating the affects of development that has occurred within the catchment.

Finally, the study provides Council with an up-to-date flood model in which other development proposals in the catchment can be assessed.

1.2 THE STUDY AREA

Cabramatta Creek is a major tributary of the Georges River, located in the southwest of the Sydney Metropolitan region. The catchment, which is shown on **Figure 1.1**, has an area of 74 km^2. It is bordered roughly by the South-Western Freeway and the Hume Highway in the east, Denham Court in the South, Sydney Water's "Water Race" at West Hoxton in the west, and the suburbs of Cabramatta, Mt. Pritchard, Heckenberg, Busby, Hinchinbrook, Green Valley and Cecil Hills to the north.

Most of the catchment area is located within the Liverpool City Council area. The north side of Lower Cabramatta Creek, downstream of Elizabeth Drive, is located within the Fairfield

City Council area. A small proportion of the upper catchment is also located within the Campbelltown City Council area, and the Ingleburn Military Camp.

The Cabramatta Creek catchment comprises five major subcatchments. These are:

i) Upper Cabramatta Creek;

ii) Hinchinbrook Creek;

iii) Lower Cabramatta Creek;

iv) Maxwells Creek;

v) Brickmakers Creek.

These major creeks have a number of tributaries that have been named Creeks A to M in previous studies.

The study area includes the Cabramatta Creek catchment upstream of the Hume Highway, but does not include Brickmakers Creek. Brickmakers Creek joins Cabramatta Creek near the downstream end of the catchment. It was excluded from the study area as a separate investigation for this creek was recently undertaken (GHD, 2007), and its catchment has experienced little change in recent years.

It has been estimated that approximately 124 residential homes and 104 commercial and industrial buildings would be inundated above floor level in a 100 year flood (Bewsher Consulting, 2004). Of the 124 residential homes affected, 74 are located within the Liverpool Council part of the catchment and 50 are located in the Fairfield Council part of the catchment. Significantly larger numbers of properties have been constructed just above the estimated 100 year flood level, with a total of 2,838 homes potentially affected by the probable maximum flood (PMF).

The total flood damage in the catchment has been estimated at $21M in a 100 year flood (Bewsher Consulting, 2004). The average annual flood damage from all floods has been estimated at $4.8M per annum.

1.3 SPECIFIC AIMS AND OBJECTIVES

The project is divided into two parts. Part 1 involves the establishment of a new TUFLOW model for the catchment, and the analysis of previous (1989) and existing (2008) catchment conditions. Part 2 of the project involves the analysis of future (2026) catchment conditions.

The specific aims and objectives of the study are to:

Part 1

i) establish a RAFTS and TUFLOW model for the Cabramatta Creek catchment;

ii) calibrate and verify these models;

iii) evaluate the performance of the basin strategy over the period 1989 to 2008 based on the analysis of the 100 year flood;

iv) provide flood extent maps and flood level contours for 2008 conditions for a range of flood events from the 20 year flood to the PMF flood;

v) prepare a flood risk management map for the catchment;

Part 2

vi) update the flood models to represent future (2026) catchment conditions, including the full development of the new release areas and the construction of the remaining basins from the detention basin strategy; and

vii) review the performance of the basin strategy to mitigate the impact of development on flood behaviour over the period from 1989 to 2026.

1.4 STRUCTURE OF REPORT

This report is divided into the following chapters:

Chapter 1	–	Background to the study
Chapter 2	–	A summary of previous studies that are relevant to these investigations
Chapter 3	–	Catchment information available for the study
Chapter 4	–	An overview of changes in the catchment that will influence flood behaviour
Chapter 5	–	The flood modelling approach, assumptions and limitations
Chapter 6	–	A description of flood behaviour throughout the catchment
Chapter 7	–	A review of the performance of Council's basin strategy up to 2008
Chapter 8	–	A review of the performance of Council's basin strategy up to 2026
Chapter 9	–	List of references
Chapter 10	–	Glossary of terms used in this report.

FIGURE 1.1
The Study Area

PART 1 – PREVIOUS (1989) AND EXISTING (2008) CONDITIONS

2 PREVIOUS STUDIES

A summary of the main reports that are relevant to the assessment of flood behaviour within the Cabramatta Creek catchment are briefly discussed in this section.

2.1 CABRAMATTA CREEK FLOOD STUDY

The Cabramatta Creek Flood Study was completed by the (then) Department of Water Resources in July 1988. The study was undertaken following the August 1986 flood, and was probably the first comprehensive flood study to have been undertaken on the catchment. The principal purpose of the study was to report on flood levels and flood behaviour in those areas of the Cabramatta Creek catchment upstream of Elizabeth Drive, which was recognised at the time as being subject to considerable development pressure.

The study analysed catchment runoff using the RSWM model (a former version of the current RAFTS model) and a HEC-2 hydraulic model to estimate flood levels throughout the catchment. The HEC-2 model is a relatively simple steady-state backwater model that was typically used at the time, and is still used today for simple analysis where flood storage or two-dimensional flood effects are not important. These models have been further refined and used in some of the subsequent flood investigations undertaken within the catchment.

A number of cross sections were surveyed by the Department for the study. A flood debris survey was also carried out immediately following the 1986 flood. Debris flood marks were established at 40 of the model cross section locations. This data has also been used in subsequent studies, including the current investigation, to calibrate the flood model.

2.2 LOWER CABRAMATTA CREEK FLOODPLAIN MANAGEMENT STUDY

This study was completed by Kinhill Engineers for Fairfield City Council in 1991. The study presents a floodplain management study for Lower Cabramatta Creek, downstream of Elizabeth Drive. A series of flood mitigation measures were proposed comprising levees, channel works, floodways, the removal of obstructions, the improvement of bridge waterway openings, flood proofing of individual properties and house raising. These measures were subsequently reviewed in the 1999 Floodplain Management Study that was undertaken for Liverpool and Fairfield Councils.

The study used similar flood models to those used in the 1988 Flood Study. Catchment runoff was analysed using the RAFTS model with a refined catchment subdivision. A similar HEC-2 model was also used to analyse flood behaviour downstream of Elizabeth Drive. Cross sections for the model were provided from a survey of 27 creek sections undertaken by Dalland and Lucas in 1989.

The model was calibrated to both the 1986 and 1988 floods.

2.3 HOXTON PARK STAGE II RELEASE AREA STUDY

This study was undertaken by Kinhill Engineers for Liverpool City Council between 1989 and 1992. The study assessed flooding issues associated with proposed development from a major urban release area, known as the Hoxton Park Stage II Release Area. The study largely forms the basis of Council's detention basin strategy for Cabramatta Creek.

The study assessed the impact of proposed development in terms of both the quantity and quality of runoff from the new release area. The investigation assessed the likely increase in peak flows throughout the catchment as a result of proposed development, and investigated means of limiting post-developed 100 year flows to pre-developed flows. A trunk drainage strategy, known as Option A-3, was recommended that included the construction of 9 detention basins to act as both flood mitigation and water quality structures. This is in addition to other basins that had previously been recommended for an earlier (Stage 1) release area within the catchment.

The study was based on similar RAFTS and HEC-2 flood models developed by Kinhill Engineers at this time for concurrent studies within the catchment.

2.4 CABRAMATTA CREEK CATCHMENT MANAGEMENT STUDY

A third study was undertaken at this time by Kinhill Engineers for the (then) Water Board, under its Special Environmental Programme. This was essentially an extension of the Hoxton Park Study to also include the area below Elizabeth Drive.

A preferred floodplain management plan for the catchment was presented, with three major components:

i) measures directly associated with development of the Hoxton Park Stage II Release Area that would attract a Section 94 contribution;

ii) flood damage mitigation measures for the existing urban area; and

iii) stormwater quality control measures to reduce pollutants in Cabramatta Creek to that of rural conditions.

2.5 CABRAMATTA CREEK FLOODPLAIN MANAGEMENT STUDY & PLAN

A comprehensive floodplain management study and plan was commissioned by Liverpool City Council, in conjunction with Fairfield City Council and the (then) Department of Land and Water Conservation in 1996. A report was prepared in 1999, and later updated in 2004. The study was undertaken by Bewsher Consulting, with assistance provided by the Water Research Laboratory (flood modelling), Don Fox Planning (planning issues), Nelson Consulting (environmental matters) and Southern Aerial Surveys (aerial mapping).

Flood behaviour was analysed using the RAFTS hydrologic model to simulate flows and the RMA-2 hydraulic model to simulate the depth and extent of flooding. The RMA model was a significant advancement over the previous HEC-2 model. It was both an unsteady model (simulating a full flood hydrograph) and two-dimensional (allowing flood behaviour to vary across the floodplain). A significant limitation was the need to divide the study area into seven upstream models and one lower model, due to computer resources available at the time.

The flood models were used to determine design flood levels, flood inundation extents and flood risk mapping within the catchment. Whilst flood conditions were reviewed for various time periods, the main results were presented for 1996 catchment conditions. These model results are still used by Liverpool and Fairfield Councils today.

3 CATCHMENT DATA

3.1 CATCHMENT INSPECTION

Various catchment inspections have been undertaken during the project, which has assisted in the identification of:

i) the condition of the creek,

ii) dimensions of hydraulic structures;

iii) features of the detention basins within the catchment; and

iv) the extent of recent catchment development.

A number of photos have been taken during these inspections. The photos have been geographically referenced and included in a GIS database of available data.

3.2 AERIAL PHOTOGRAPHY

Aerial photography is an important data source for the study, which helps to define the drainage network and other catchment characteristics required for modelling flood behaviour.

Digitally rectified aerial photography was initially provided by Liverpool Council for 1996, 2002 and 2005. More recent photography, flown in 2007, was subsequently provided to better represent existing catchment conditions and for consistency with photography available from Fairfield Council.

Comparison of the photography over these years provides a visual record of the changes that have occurred within the catchment, including:

i) the extent of catchment development;

ii) the intensity of recent development;

iii) any modification or realignment of the natural creek system; and

iv) the hydraulic roughness of the creek and floodplain over different time periods.

All aerial photography has been incorporated into a MapInfo geographical database. The photography provides a good mapping base to overlay other sources of information, including flood inundation mapping results from the flood model.

3.3 TERRAIN SURFACE

Good terrain data is required for flood modelling, mapping of flood inundation extents, and for identifying changes that have occurred within the catchment.

Extensive photogrammetry was prepared for the catchment as part of the Cabramatta Creek Floodplain Management Study. The photogrammetry was based on low level aerial photography of the catchment flown in 1996. A series of 43 A1 sized orthophotomaps were prepared for the catchment with 1m ground contours. Additional 0.25m contours were provided in digital form only.

Airborne laser scanning (ALS) survey was acquired by Council from AAMHatch during 2005. This technique captures the elevation of millions of ground points by a laser fitted on the underside of an aircraft. The points are then filtered and used to define a regular grid of ground points describing the terrain surface.

Council more recently acquired 2008 ALS survey from AAMHatch for the full Cabramatta Creek catchment. The 2008 ALS has improved resolution over the 2005 ALS, having captured points at sub-1m spacing. This is likely to provide improved definition of creeks, waterways and other features within the catchment. It also provides a consistent terrain surface across the entire catchment, including those parts of the catchment that lie within the Fairfield and Campbelltown LGAs. The 2008 ALS is considered to provide the best representation of 'existing' catchment terrain.

Digital elevation models (DEMs) have been prepared for the catchment representing the:

i) 1996 photogrammetry;

ii) 2005 ALS; and

iii) 2008 ALS.

The DEMs provide regular grid of elevation points across the study area at 1m spacing. The flood model for existing (2008) catchment conditions is based on the 2008 ALS. The flood model for previous (1989) conditions is based on the 2008 ALS and 1996 ALS where changes in catchment topography have been identified. All three DEMs have been used to identify those parts of the catchment where changes in topography have occurred. This is reported further in Section 4.4.

The accuracy of the ALS survey method is typically $\pm$0.15m on clear ground. In heavily vegetated areas, or within narrow watercourses or drains, the ALS survey is less reliable and more traditional ground survey is sometimes required.

3.4 CREEKS AND WATERWAYS

The catchment contains numerous creeks and waterways, including Cabramatta Creek, Hinchinbrook Creek, Maxwells Creek, and a number of smaller tributary channels.

A survey of creek sections was undertaken by the Department of Water Resources in 1986 to define cross sections used in a HEC-2 model developed for the Cabramatta Creek Flood Study (DWR, 1988). Additional survey was undertaken by Kinhill Engineers as part of subsequent investigations in the late 1980s using a similar HEC-2 model (Kinhill, 1991, 1992). It is not known whether the original survey still exists, however, cross section details are available from the HEC-2 model data files that were developed by Kinhill.

More recent survey is available in areas where works have been subsequently undertaken or designed, including:

i) a cycleway crossing over Cabramatta Creek just downstream of the Main Southern Railway bridge (Bewsher Consulting, 2001);

ii) studies on flood improvement works in the vicinity of the Elizabeth Drive crossing of Cabramatta Creek, including works in Blamfield Park, under the Elizabeth Drive bridge and downstream of the Tresalam Street levee (Bewsher Consulting, 1996–1998);

iii) studies to assess filling proposals for subdivisions adjacent to Cabramatta Creek and Creek A (Bewsher Consulting, 1994–1996);

iv) studies on detention basin options on Maxwells Creek between Jedda Road and Camden Valley Way (Bewsher Consulting, 1999–2001);

v) channelisation of Creek C, between Hinchinbrook Creek and Second Avenue (1996–2001); and

vi) construction of new channels on tributaries of Maxwells Creek, on the west side of Ash Road.

Representation of the creeks and waterways in the flood model is based on a composite of data from the 2008 ALS, the original HEC-2 cross section data, and other available survey sources.

3.5 CULVERTS AND BRIDGES

There are numerous culverts, bridges and other hydraulic structures within the Cabramatta Creek catchment. Details on the majority of structures in the catchment during 1996 are available from the Cabramatta Creek Floodplain Management Study (Bewsher Consulting 2004).

Significant development has occurred within the catchment since 1996, and a number of new structures have been constructed or updated. The most significant changes have resulted from the construction of the M7 Motorway, upgrading of Hoxton Park Road, and construction of the Bus Transitway. Details on the majority of these new structures have been obtained from the M7 Motorway flood model, or from works-as-executed drawings.

A number of other structures have also been upgraded within the catchment since 1996, and needed to be included in the flood model for existing (2008) conditions. These structures include:

i) cycleway crossing over Cabramatta Creek downstream of the Southern Railway line;

ii) improvements to the Elizabeth Drive Bridge on Cabramatta Creek;

iii) new culverts under Hoxton Park Road in the vicinity of the Catholic Club;

iv) new culverts under Camden Valley Way on Cabramatta Creek;

v) new culvert at Hoxton Park Road on Maxwells Creek;

vi) new culvert on Jedda Road on Maxwells Creek;

vii) new culverts on Ash Road along tributaries of Maxwells Creek;

viii) new culverts under Cowpasture Road and Hoxton Park Road, on Tributary C;

ix) a number of smaller culverts associated with various subdivisions.

Details on the above structures were extracted from design drawings or works-as-executed drawings where available. Dimensions of a number of structures were also verified through field inspection.

Significant upgrading of Cowpasture Road is currently underway, including the construction of new culverts on Hinchinbrook Creek. These are relatively significant changes, and have not been included in the model for existing (2008) catchment conditions. Further assessment of these structures is warranted when future (post 2008) conditions are assessed.

3.6 BUILDINGS AND OBSTRUCTIONS

The presence of existing buildings and other structures within the catchment can have a potential impact on flood behaviour, particularly if they are in the floodplain or adjacent to an overland flow path.

Some buildings will be elevated on fill and may totally obstruct floodwater around the footprint of the building. Other buildings may be inundated, in which case floodwater can temporality pond within the building. Others may be elevated on piers, allowing some limited flow under the building. To complicate matters further, the impact of individual buildings will vary depending on the height of floodwater.

The footprint of all buildings within the study area has been digitised from aerial photography. These building footprints have then been included in the flood model to restrict the flow that is able to pass through each building (by assigning a high roughness coefficient to the building footprint).

Fences are another potential obstruction to flood flows. Many of these will have an impact in low flood conditions, but are likely to collapse as flood levels increase. The approach has been to allow an average impact (through increased roughness coefficients applied to urban blocks) for all fences within the study area. Other types of obstructions, including earth embankments and retaining walls, are identified in the terrain surface.

3.7 AVAILABLE FLOOD DATA

The Cabramatta Creek catchment has a history of flooding. Over the last 50 years there has been at least 10 significant floods that have been experienced within the catchment. These have resulted in floodwaters overtopping the creek banks and flooding large areas of low-lying land adjacent to Cabramatta Creek and its tributary creeks. A number of residential, commercial and industrial properties have been flooded in the past.

The most recent floods that have occurred include:

- August 1986;
- April 1988;
- July 1988;
- April 1989;
- February 1990; and
- January 2001.

The August 1986 and April 1988 floods are the largest of the recent floods experienced. Both events coincided with major flooding on the Georges River, which contributed to the flooding problems in the lower catchment. The April 1988 flood was the larger of the two events, and has been estimated to be similar to a 100 year flood.

Flood level data in the lower catchment is available for the 1986 and 1988 events from post-flood surveys conducted by the Public Works Department's Manly Hydraulics Laboratory (PWD, 1987, 1989). More extensive post-flood surveys were conducted throughout the catchment by the Department of Water Resources for the 1986 flood, which is documented in the Cabramatta Creek Flood Study (DWR, 1988). Other flood level data for both floods are documented in studies undertaken by Kinhill Engineers (Kinhill, 1992, 1993).

Much of the flood data provided in the Department of Water Resources and Kinhill reports provide the location of flood marks relative to the HEC-2 flood model cross section that had been developed at this time. These reports provide limited information on the precise location of individual flood marks, for example whether the observation was adjacent to the creek, or on the edge of the floodplain. Similarly, there is no information on the type of observation, or of its accuracy.

In addition to the above flood marks, the Department of Water Resources established a stream gauging station on Cabramatta Creek in May 1986, just upstream of Orange Grove Road. A complete stage hydrograph and flow hydrograph (using an appropriate rating table) is available for the 1986 and 1988 floods. The station is still operable today.

Some 29 flood mark observations are available within the study area for the April 1988 flood, and 44 flood mark observations available for the August 1986 flood. These flood marks have been used to calibrate the current flood model, and are discussed further in Section 5.6.

3.8 ASSEMBLY OF DATA WITHIN A GIS DATABASE

All data that has been collected for the study has been assembled within a GIS database using MapInfo software, suitably tagged with a source identifier. This allows the data to be spatially represented across the study area, and allows for easy retrieval of the data as required. The data is stored in different “layers” which can be displayed individually, or superimposed onto other layers. Results from the flood model are also provided as GIS layers.

The database and model results can also be exported to other GIS systems.

4 CHANGES IN THE CATCHMENT SINCE 1989

There have been significant changes within the Cabramatta Creek catchment since 1989, which will potentially affect design flood level estimates and other flood mapping results adopted by Council. The changes will also have an impact on Council's detention basin strategy for the catchment, and for other flood mitigation measures that may be considered to alleviate existing flooding problems.

The main changes in the catchment that can potentially affect flood behaviour are discussed below.

4.1 CATCHMENT DEVELOPMENT

During the 1980s, the Cabramatta Creek catchment was predominantly rural, with most development concentrated in the lower one-third of the catchment. Since that time, however, there has been significant pressure for further urban expansion, with major urban release areas identified as part of the Metropolitan Planning Strategy for Sydney. As a consequence, rapid development within the catchment has been experienced, commencing from about 1989.

The two urban release areas are shown on **Figure 4.1**. The first area, known as the Hinchinbrook/Green Valley (Stage I) Release Area, was designated by the Minister of Environment and Planning in 1982. The release area allowed for the development of 340 ha of the Cabramatta Creek catchment, which represents 5% of the total catchment area. Residential development commenced in this area in the late 1980s, and to date the majority of an estimated 4,800 residential lots has been developed.

A second area within the catchment was later identified for urban expansion, known as the Hoxton Park (Stage II) Release Area. The Stage II Release Area allows for the development of 2,300 ha of the Cabramatta Creek catchment, representing a further 31% of the total catchment area. The release area is divided into six residential precincts and two industrial precincts, and has been estimated to yield approximately 18,400 lots. Development commenced in 1989, and will continue for a number of years to come.

The development that has occurred within the Cabramatta Creek catchment, and that will continue to occur over the coming years, will result in an increase in the impervious areas within the catchment. Without compensatory flood mitigation measures, this would result in an increase in both the rate and volume of flood runoff. Council's detention basin strategy has been formulated specifically to compensate for the increase in runoff due to the new release area development.

The extent of existing catchment development that has occurred since 1989 has been identified through previous studies (Bewsher Consulting, 2004) and by reviewing the aerial photography available for the catchment from 1996, 2005 and 2007. The average impervious percentage of each subcatchment has been determined by estimating the proportion of each area within one of eight different landuse categories, and by calculating a weighted average impervious percentage. The landuse categories are tabulated in **Table 4.1**.

Figure 4.1
Release Areas Identified for Future Urban Development

Table 4.1
Landuse Categories and Assumed Impervious Percentage

Landuse Category	Average Impervious Percentage
Residential	
New	65%
Old	50%
Rural	10%
Business	
New	95%
Old	80%
Schools	20%
Ponds/roads	100%
Open Space	0%

4.2 M7 MOTORWAY AND OTHER INFRASTRUCTURE

A major motorway was constructed through the Cabramatta Creek catchment between February 2003 and December 2005. The motorway, known as the M7 Westlink (previously referred to as the Western Sydney Orbital) traverses the floodplain of Maxwells Creek, Cabramatta Creek and Hinchinbrook Creek.

The Motorway is a major development within the catchment and can potentially impact flood behaviour through:

i) loss in floodplain storage along the three creeks;

ii) reduction in the capacity of these creeks to convey floodwater;

iii) an increase in the impervious area in the catchment;

iv) local increases in flood levels at creek crossings; and

v) the route of the motorway traverses one of the proposed basins in the basin strategy (Basin 6) which will necessitate its relocation.

The potential flooding impacts of the highway were investigated by the M7 Design team, and reported to Liverpool Council officers. A strategy was formulated to mitigate adverse flooding impacts, which included the construction of bridges, culverts, and three detention basins. The three detention basins are known as:

i) Basin 18 on Maxwells Creek;

ii) Basin 22 on Cabramatta Creek; and

iii) Government Road Basin on Hinchinbrook Creek.

Basin 18 performs a dual role with Council's basin strategy for future development.

Flooding impacts were assessed by the M7 design team using a TUFLOW hydraulic model. The model represents only a small portion of the Cabramatta Creek catchment, but has been useful in defining culvert and bridge dimensions for a number of M7 structures for the present study.

Other major infrastructure constructed within the catchment includes the Bus Transitway and upgrading of Hoxton Park Road and Cowpasture Road. Details are provided in works-as-executed drawings provided by Council.

4.3 COUNCIL'S BASIN STRATEGY

A detention basin strategy was developed for Cabramatta Creek as a flood mitigation strategy to compensate for development that was anticipated to occur within the catchment. It was not a strategy to solve existing flooding problems, but rather a strategy to ensure that new development would not exacerbate flooding in the lower catchment.

The principle aim in sizing and locating the detention basins was quoted (Kinhill, 1992, page 6-1) as:

> *"to effectively control 1% AEP post-development flows to pre-development levels. This reduction in flow was not only to apply at the outlet of the basin. Using a combination of basins, the discharge from the outlet of the Cabramatta Creek catchment (at the Main Southern Railway Line) had to also be maintained to pre-development levels."*

As the basin strategy has been progressively implemented, certain changes have been necessary to account for development and other site constraints. In some instances, basins have been constructed in different locations, or have been divided into two or more smaller basins. The proposed storage volumes and outlet structures have also varied in suit site constraints.

The current basin strategy is considered to comprise those basins constructed to date and all other basins previously identified from the original strategy. Details of basins from previous reports are provided in **Table 4.2** and the location of basins shown in **Figure 4.2**.

Some specific changes that have occurred to the basin strategy include:

i) Basins 100 and 200 in the upper reaches of Hinchinbrook Creek were not specifically mentioned in the Hoxton Park Stage II Release Area report, but have subsequently been constructed;

ii) Basin 4 currently exists as a number of smaller water quality basins;

iii) Basin 10 was divided into two interconnected basins, which are now referred to as Basins 10A and 10B;

iv) Basin 11 was divided into three smaller basins, including two interconnected basins (Basins 11A and 11B) and a proposed third basin (Basin 11C).

v) Basin 22 and a basin at Government Road have been constructed to mitigate the impacts of the recently constructed M7 Motorway;

vi) Basin 18 has been expanded and now forms dual purposes of mitigating the impacts of the M7 Motorway and future development in the catchment.

Further changes to basins that have not yet been constructed are also likely. For instance, two proposed basins in the Edmondson Park precinct (Basins 12 and 14) are likely to be relocated in accordance with a master plan developed for this area.

Works-as-executed drawings were provided by Council for all constructed detention basins.

Table 4.2
Basin Details from Previous Reports

Figure 4.2
The Current Basin Strategy (as of 2008)

4.4 CHANGES IN TERRAIN SURFACE (FILLING)

Changes in the terrain surface of the catchment can potentially affect flood behaviour within the catchment, either through a reduction in flow conveyance of the waterway area, or a loss in floodplain storage. A loss in flow conveyance usually results in an increase in upstream flood levels, whilst a loss in flood storage volume usually results in an increase in downstream flood levels. Steady-state models, such as the HEC-2 model that has been used in previous investigations within the catchment, are unable to properly assess changes in flood behaviour due to flood storage changes.

The identification of areas of the floodplain that have been filled or otherwise modified is an important consideration for the current study. Changes in the floodplain need to be identified so that surface conditions are accurately represented for both 1989 and 2008 catchment conditions.

Areas of the catchment that have been either filled or excavated have been identified by subtracting the 2008 DEM from the 1996 DEM, and presenting the difference in surface levels as a thematic map in MapInfo. Differences in surface levels, as depicted in **Figure 4.3**, are represented as follows:

i) areas where the difference is less than 300mm are coloured yellow;

ii) areas where levels have increased by more than 300mm (eg through filling) are shaded red; and

iii) ares where levels have decreased by more than 300mm (eg through excavation) are shaded blue.

A 300mm tolerance was adopted for this comparison given the likely range in errors from both DEMs. Whilst there is still some degree of random fluctuation across the catchment, the mapping highlights areas where major changes have occurred. Some of the more significant changes include:

i) the M7 Motorway, with embankments and cuttings clearly evident;

ii) the elevation of the bus transit way, on the west side of Banks Road;

iii) detention basins that have been formed through excavation, and the location of embankments around these basins;

iv) the reconstruction/raising of Cowpasture Road on the south side of the M7 Motorway;

v) filling associated with the Stocklands Development on the eastern side of Hinchinbrook Creek;

vi) filling associated with industrial development at Prestons, between Maxwells Creek and the M7;

vii) filling associated with recent subdivisions carried out to the north of Camden Valley Way;

viii) industrial development to the east of the M5 motorway and south of Camden Valley Way;

ix) filling associated with the construction of the Megacentre retail complex, on the north side of Orange Grove Road; and

x) possible siltation through the lower reaches of Cabramatta Creek, which is explored further in Section 4.5.

More quantitative information on landform changes have been provided through works-as-executed plans provided by Council officers for specific subdivision sites, constructed detention basins; drainage schemes and other infrastructure projects.

FIGURE 4.3
Changes in Terrain Surface (1996 to 2008).

4.5 SILTATION IN LOWER CREEK

A comparison of the three DEMs covering the period from 1996 to 2008 suggests that the much of Cabramatta Creek and Hinchinbrook Creek is more clearly defined and with a deeper invert in the 2008 ALS. This is thought to be a result of the higher resolution in the latest ALS data, where ground points were acquired at sub-1m spacing. However, within Lower Cabramatta Creek, the latest DEM shows a shallower creek section. A comparison of the three DEMs suggested a gradual rising, possibly through siltation, of the lower creek over recent time. This was discussed with Council during September 2009, and it was agreed that further investigation was warranted.

Siltation within the creek system can sometimes be a by-product of catchment development. Not only can catchment development lead to increased catchment runoff, but erosion and downstream siltation can further exacerbate flooding problems through a reduction in the capacity of the downstream channel.

To verify whether siltation was occurring through the lower catchment, five test sections were established between the Hume Highway and Orange Grove Golf Course, as shown on **Figure 4.4**. Cross sections from the three DEMs were extracted along these lines and compared with surveyed cross sections from the original 1989 Kinhill HEC-2 model. New field survey along each of the test sections was commissioned by Council during 2009, and also used in the comparison.

FIGURE 4.4
Location of Cross Section Comparisons

Results from the survey comparison are shown on **Figure 4.5**. The comparison confirmed no significant change in creek sections between the 1989 and 2009 field surveys. This implies that the recent ALS is not picking up the true invert of the creek, either due to vegetation or the presence of standing water in the creek bed. Subsequently, cross sections included in the flood model for the lower creek were adjusted in accordance with the original Kinhill survey.

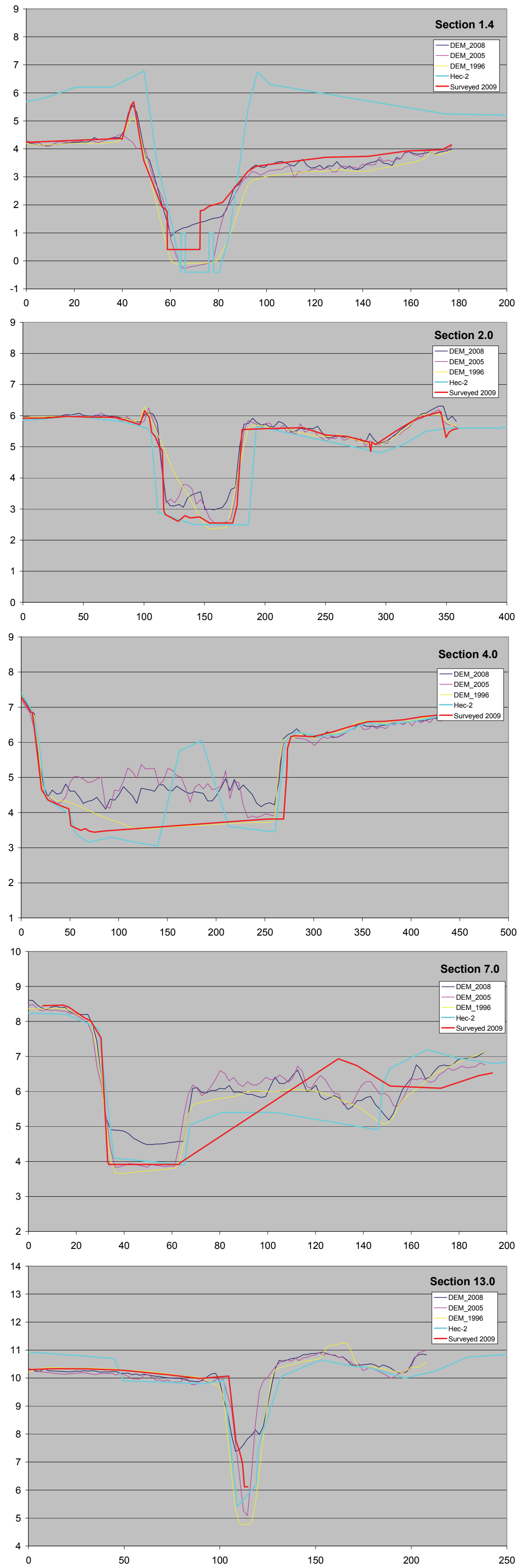


FIGURE 4.5
Comparison of Creek Sections in Lower Cabramatta Creek

5 FLOOD MODELLING APPROACH

This Section provides a discussion on the adopted flood modelling approach. It provides an overview of the types of models used for the assessment; details of catchment conditions that have been analysed; and further information on the RAFTS and TUFLOW flood models. It also provides information on the model calibration, blockage assumptions, potential climate change impacts, and a discussion on modelling limitations.

5.1 MODELLING OVERVIEW

It is usual to use two different types of computer models to analyse flood behaviour. The first type of model is a hydrologic model that simulates the rainfall-runoff process within the catchment. This model produces flows throughout the catchment which are then input to a second hydraulic model to calculate flood levels and flood velocities throughout the creek and drainage system.

The modelling approach adopted for this study involves the use of a RAFTS hydrologic model for estimating catchment flows and a TUFLOW hydraulic model to estimate flood levels and velocities.

RAFTS is a commercially available rainfall-runoff computer model that was developed in Australia by WP Software. The model has been widely applied to flood studies undertaken in Australia, particularly in NSW. Application of the RAFTS model requires the catchment to be divided into a number of smaller subcatchment areas. Rainfall is applied to each subcatchment and a runoff hydrograph generated at the outlet of these areas. These runoff hydrographs are then used as input to the hydraulic model. This is a similar model to that which was used in the floodplain management study, although some rainfall parameters and modelling assumptions have differed. Further details about the RAFTS model is provided in **Section 5.4**.

TUFLOW is a hydraulic model that was developed by BMT WBM in Queensland. This flood model that has been used in over 200 applications in NSW, Queensland, Victoria, South Australia, Tasmania, and also in the UK. TUFLOW is a two-dimensional model that is capable of modelling urban overland flow paths and surface flows where there are numerous obstacles and other variations in flow paths. The surface terrain is represented as a regular grid of ground points across the study area, which has been derived using Council's ALS survey. A 5m grid size was adopted for this study. Digitised building outlines and aerial photography have also been used to identify obstructions and surface conditions within the 2D model.

TUFLOW has the ability to include creeks and other watercourses as nested 1D elements within the 2D network. The majority of creeks and watercourses within the catchment have been included in the model as 1D elements. These elements are described by a series of cross sections, derived using a combination of Council's ALS data and other available survey. Bridges, culverts and other hydraulic structures are also included as 1D elements within the model.

TUFLOW is a more recent and different type of two-dimensional computer model than the RMA-2 model that was used in the floodplain management study. Together with increases in computer resources, it has been possible to model the whole study area as a single model. An advantage over the RMA-2 model is that the model grid does not have to be pre-defined and generally a smaller grid spacing is now possible. Further details about the TUFLOW model are provided in **Section 5.5**.

5.2 CATCHMENT CONDITIONS MODELLED

Two different flood models have been developed representing different catchment conditions. These are:

i) Existing (2008) Conditions

ii) Previous (1989) Conditions

Existing (2008) conditions represent catchment conditions existing at the time that the flood model was developed. It is based on 2008 ALS data throughout the catchment and aerial photography that was flown in 2007. Other parts of the catchment where known changes had occurred (to 2008) were also incorporated in the model. Model results for 2008 conditions will be used to provide updated design flood levels and flood mapping throughout the catchment.

Previous (1989) conditions have been selected for the assessment of flood behaviour prior to the new release area development and Council's detention basin strategy. It also predates a number of other major development activities in the catchment, including construction of the M7 Motorway and the bus transitway. These conditions have also been adopted when calibrating the flood models to the August 1986 and April 1988 floods.

A comparison of flood behaviour between 1989 and 2008 will give an indication as to changes in flood levels that may have occurred within the catchment, and the success of Council's detention basin strategy to mitigate the affects of catchment development over this period.

5.3 MODELLING OF DETENTION BASINS

A summary of detention basins that have been constructed within the catchment is provided in **Table 5.1**, including details on how these basins have been represented within the RAFTS and TUFLOW models.

Table 5.1
Modelling of Detention Basins

Basin	Catchment	Previous (1989 Conditions)		Existing (2008 Conditions)	
		RAFTS	TUFLOW	RAFTS	TUFLOW
Basin 100	Hinchinbrook	-	-	✓	✓
Basin 200	Hinchinbrook	-	-	✓	✓
Basin 3a	Hinchinbrook	-	-	✓	✓
Basin 4 (Water quality)	Hinchinbrook	-	-	✓	✓
Lord Howe Drive Basin	Hinchinbrook	-	-	✓	✓
Cowpasture Rd Basin	Hinchinbrook	-	-	✓	✓
Banks Road Basin	Hinchinbrook	-	-	✓	-
Basin 11a	Upper Cabramatta	-	-	✓	✓
Basin 11b	Upper Cabramatta	-	-	✓	✓
Basin 10a	Upper Cabramatta	-	-	✓	✓
Basin 10b	Upper Cabramatta	-	-	✓	✓
Daruk Park	Brickmakers	✓	-	✓	-
M7 – Basin 18	Maxwells	-	-	-	✓
M7 – Basin 22	Upper Cabramatta	-	-	-	✓
M7 – Government Road	Hinchinbrook	-	-	-	✓

Only the Daruk Park Basin, at the top of Brickmakers Creek, had been constructed by 1989. This basin was constructed to alleviate existing flooding problems in Brickmakers Creek, and is not considered to be one of the new release area basins. The basin is not included in the TUFLOW model, as the model does not extend up Brickmakers Creek. The impact of the basin on flood behaviour therefore relies on results from the RAFTS model, which provides the inflows from Brickmakers Creek. The basin is included in the RAFTS model for both previous (1989) and existing (2008) conditions.

All other existing (2008) basins have been included in the TUFLOW model, with the exception of the Banks Road Basin. This basin is in an urbanised part of the catchment that is remote from the main floodplain. It is also beyond the extent of the TUFLOW model, and again relies on impacts to be assessed using the RAFTS model to provide inflows from this part of the catchment.

Apart from the Daruk Park Basin and the Banks Road Basin, there is no need to incorporate the other 2008 basins in the RAFTS model, as the TUFLOW model provides the analysis of catchment flows through each basin. However, most of the basins have been included in the RAFTS model for comparison purposes. The M7 basins were not included in the RAFTS model as these basins have been constructed within the floodplain with complex inflow and outflow arrangements, and can only be properly assessed using the TUFLOW model. Flows from the RAFTS model downstream of the three M7 basins may therefore overestimate the actual flow in the creek. It is more appropriate to extract flow estimates from the TUFLOW model for the mid to lower part of the Cabramatta Creek catchment.

5.4 RAFTS HYDROLOGIC MODEL

Design flows throughout the catchment were determined using the RAFTS hydrologic model (Version 5.0). These flows were subsequently used as inflows to the TUFLOW hydraulic model to simulate flood behaviour throughout the study area.

The catchment was divided into 212 smaller subcatchments for the RAFTS analysis. Subcatchment boundaries were based on topography, the existing drainage regime, and other areas where inflows to the TUFLOW hydraulic model were desirable. This is the same catchment subdivision as was adopted for the latest floodplain management study. A map of the catchment subdivision is shown on **Figure 5.1**.

Each subcatchment was further divided into pervious and impervious fractions. This was determined by measuring the area of different landuse categories within each subcatchment (from aerial photography) and applying an average impervious percentage for each landuse category. The following landuse categories were adopted:

i) new residential;

ii) old residential;

iii) rural residential;

iv) new business;

v) old business;

vi) schools;

vii) ponds and roads; and

viii) open space.

FIGURE 5.1
RAFTS Catchment Layout Plan

Two models were developed, one representing existing (2008) conditions and another representing previous (1989) conditions. The previous (1989) condition was used to assess flood behaviour prior to new release area development and also for modelling the historic floods that occurred in August 1986 and April 1988.

Rainfall hyetographs are applied to each subcatchment to determine catchment runoff. Rainfall hyetographs are derived by calculating an average rainfall intensity and applying a rainfall pattern to distribute this rainfall over the duration of the storm. Rainfall intensities were based on standard Intensity-Frequency-Duration data provided to Liverpool City Council for use in the Georges River catchment by the Bureau of Meteorology in December 2000. This data was found to be similar to values calculated in accordance with *Australian Rainfall and Runoff*. Rainfall totals were distributed in accordance with patterns recommended in *Australian Rainfall and Runoff*.

Areal reduction factors are sometimes applied to rainfall intensities to account for likely variation of rainfall across the catchment. *Australian Rainfall & Runoff* notes that no areal reduction factor would normally be required for smaller catchment areas (eg $4km^2$) or where short duration floods are critical. The total area of the Cabramatta Creek catchment is 74 km^2, so application of an areal reduction factor is appropriate when analysing flood behaviour in the lower catchment. However, application of an areal reduction factor in upper catchment areas may be less appropriate. The approach taken in this study has been to apply a 0.9 areal reduction factor for all storm durations in excess of 2 hours (which will be critical in the lower catchment areas) and no areal reduction factor for storm durations less than or equal to 2 hours (which will be critical in the upper catchment areas).

Rainfall loss rates are also applied to each individual subcatchment in the RAFTS model to account for infiltration into the ground. Different loss rates were applied to pervious areas and to impervious areas. Adopted loss rates were as follows:

Pervious areas	IL=10mm	CL=1.5mm/hr
Impervious areas	IL=1.5mm	CL= 0mm/hr

RAFTS has a calibration parameter (Bx) that can be adjusted to calibrate the model when flow gauging records are available. The previous floodplain management study attempted to calibrate the RAFTS model to the 1986 and 1988 floods, using records from a gauging station at Orange Grove Road. It was found that a slightly better fit to the recorded data could be obtained by adjusting the default value of Bx=1 to Bx=2. Whilst this had a fairly small impact on the flow hydrograph at Orange Grove Road, it was subsequently found to significantly reduce catchment flows in the upper catchment. This led to inconsistencies with studies being undertaken in other areas of the catchment, where the default Bx value had been adopted. The default Bx value was adopted for this study, which ensures consistency with local investigations and still maintains an adequate calibration at Orange Grove Road and other locations within the catchment. Further details on the model calibration are provided in Section 5.6.

A range of storm durations was tested to determine which durations provided the highest flows throughout the catchment. These tests were undertaken for storm durations varying between 25 minutes to 36 hours. Storm durations of 90 minutes to 2 hours were found to be critical throughout most of the upper catchment area, with longer durations approaching 6 to 9 hours critical in the lower catchment.

Design flow estimates have been determined for the 20 year, 50 year, 100 year, 200 year, 500 year and probable maximum flood (PMF). Design flow estimates from the RAFTS model for existing (2008) conditions are provided for the 20 year, 100 year and PMF in **Appendix A**.

RAFTS provides two types of flow hydrographs for each subcatchment. Local flow hydrographs are calculated for the individual subcatchment area alone, whilst total hydrographs provide a cumulative total moving downstream. The total hydrograph relies on simple lagging and addition of upstream hydrographs, based on distance travelled and an average velocity. More rigorous routing through flood storage areas occurs in the TUFLOW model, and flows derived from this model are more reliable in the mid to lower reaches of the catchment.

5.5 TUFLOW HYDRAULIC MODEL

Different modelling methods can be applied according to the floodplain's hydraulic characteristics and the objectives of the study. The simpler methods lump the left and right overbank floodplain areas with the main channel in a one-dimensional (1D) representation. This approach is relatively simple and the computational process fast. The main limitation, however, is that flow is assumed to occur in a linear direction, and the levels across the floodplain are assumed to be at the same level as the main channel. The HEC-2 model, used extensively within the catchment in the late 1980s, is an example of this type of model.

A more detailed two-dimensional (2D) approach is recommended in areas where significant differences can occur between the channel flood levels and the floodplain flood levels. This approach is also preferable where separate flow paths and flow around catchment obstructions occur, as is likely in the Cabramatta Creek catchment. This is a more complex analysis, which requires greater data requirements and computer resources.

The TUFLOW model adopted for the current study consists of a two dimensional (2D) grid across the surface terrain, and a number of one-dimensional (1D) elements within the grid that represents the flow in creeks, channels or other main drainage lines. Culverts and other hydraulic structures are also included as 1D elements.

The model generally covers the entire floodplain of the Cabramatta Creek catchment up to the probable maximum flood, including Upper Cabramatta Creek, Hinchinbrook Creek, Maxwells Creek and a number of smaller tributaries. Only the lower portion of Brickmakers Creek was included in the model as a separate TUFLOW model was recently developed for this creek (GHD, 2007). The contribution of flood flows from Brickmakers Creek to the main Cabramatta Creek TUFLOW model was provided directly from the GHD model.

The 2D grid is based on a 5m square grid, with ground topography sampled from the DEM at 2.5m spacing. There are over 1 million grid elements within the TUFLOW model, making it one of the largest 2D flood models to have been developed in NSW. This represents a considerable improvement in model resolution over the previous 10m grid used in the TUFLOW model developed to analyse the M7 Motorway, or the previous RMA-2 model that contained 13,000 elements over eight separate models.

TUFLOW is a dynamic model that simulates the complete progress of a flood, from the commencement of rainfall to the peak of the flood, and whilst the flood subsides. A time step of 2 seconds has been adopted for the modelling.

The roughness of the creek and floodplain is represented in the model using the Manning's roughness coefficient, *n*. Roughness coefficients were initially assigned on the basis of catchment inspection, assessment of aerial photography, and experience with the model. The roughness coefficients were adjusted during the calibration of the model to match flood levels that were recorded from the August 1986 and April 1988 floods. Adopted roughness coefficients for the Cabramatta Creek catchment are shown in **Table 5.2**.

Table 5.2
TUFLOW Roughness Coefficients

Surface Type (Material)	Manning's Roughness Coefficient
2D Elements	
Urban – fences and typical gardens, backyards	0.1
Urban – units and strata titled land	0.035
Roads and paved/concrete areas	0.025
Maintained (short) grass and bare earth	0.035
Unmaintained vegetated area	0.06
Dense vegetated floodplain/forest/bushes	1.0
Building footprints	1.0
1D Elements	
Natural channels	0.035 to 0.20 (variable)
Concrete lined channels	0.015
Pipes and concrete stormwater drains	0.015

Two different models were developed to represent previous (1989) catchment conditions and existing (2008) catchment conditions. The 1989 model has been used to calibrate model parameters and to assess flood behaviour prior to new release area development.

Boundary conditions are normally specified at the downstream end of a model to provide information on the starting flood level. Previous studies have assumed that flooding on Cabramatta Creek will occur with a similar magnitude flood on the Georges River. Given the occurrence of joint flooding on Cabramatta Creek and the Georges River in both the 1986 and 1988 floods, this assumption appears reasonable. The same philosophy was retained for the current study.

Tailwater levels have been based on results published in the Georges River Flood Study (PWD, 1991). Peak levels for various design events are reproduced in **Table 5.3**.

Table 5.3
Downstream Boundary Conditions

Average Recurrence Interval of Flood	Peak Flood Level at Georges River/Cabramatta Ck	
	Flood Level (m AHD)	Source
20 Year	6.0	PWD, 91
50 Year	6.4	PWD, 91
100 Year	6.8	PWD, 91
200 Year	7.1	Extrapolated
500 Year	7.5	Extrapolated
PMF	10.6	PWD, 91

Storm durations of 2 hours and 9 hours were simulated in the TUFLOW model, based on the results provided from the RAFTS model, and other recent investigations undertaken in the catchment. The 2 hour flood was found to provide higher flood levels throughout much of the upper catchment areas, whilst the 9 hour flood provided higher flood levels throughout the lower catchment. Both storm durations were simulated in the model and the maximum flood level extracted as an envelope from both runs.

The model produces a grid of results at 2.5m intervals over the study area. These results include flood levels, flood depths, and flood velocities at regular time intervals throughout the flood simulation. The peak values are also recorded as separate grids. These grids can be interrogated at any point within the study area using a GIS database, such as MAPINFO.

The grid results can be depicted as colour-coded thematic maps of flood levels, depths and flood velocities for each design flood. The results can also be superimposed onto other base mapping, such as aerial photography and cadastral plans showing property boundaries.

Flood level contours have also been derived using the results from the peak flood level grid. These contours show the height of flooding likely to be experienced throughout the study area. This is an important outcome from the flood study, as it provides Council with the necessary information to specify minimum building floor levels and other controls for future development.

5.6 FLOOD MODEL CALIBRATION

It is usual practise to calibrate or verify flood models against historic data where such information exists. The process includes simulating a known flood event and comparing computed flood levels with recorded flood levels. Model parameters can also be adjusted (calibrated) to match the recorded flood heights.

Significant flooding was experienced throughout the Cabramatta Creek catchment during August 1986 and April 1988. The 1988 flood was the larger of the two events, with flood heights approaching the estimated 100 year flood level in many places. The 1986 flood was slightly lower, but the collection of flood data more widespread. Both floods provide an opportunity to calibrate the Cabramatta Creek flood models.

Available flood data includes:

i) information on the pattern of rainfall across the catchment from a number of daily read rainfall stations and shorter term pluviograph stations;

ii) complete stage and flow hydrographs for both floods from a gauging station established at Orange Grove Road during 1986; and

iii) a number of peak flood level observations at various locations within the catchment.

Rainfall data was collected from a number of daily read rainfall gauges and pluviograph data within and adjacent to the catchment for both events. Data for the 1986 storm was available from seven daily rainfall stations and 3 pluviographs stations, and for the 1988 storm from 4 daily rainfall stations and 7 pluviograph stations. The data is summarised in the Hoxton Park Stage II Release Area report (Kinhill, 1992).

The rainfall data has been entered into the RAFTS model to simulate flows within the catchment for both events. These flows are then input to the TUFLOW model to simulate flood levels along the main waterways.

A gauging station in the catchment was established at Orange Grove Road by the (then) Department of Water Resources during 1986. The station was gauged by the Department during a number of small to moderate floods to establish a rating table between measured flood height and estimated creek discharge. The rating table was later extended to account for additional flow that occurs through a series of higher level culverts to the south of the main bridge (WRL, 1999). An automatic water level recorder at the station recorded complete stage hydrographs for both floods. Estimated flow hydrographs are also available using the rating table developed for the station. This provides useful data in which to compare discharge estimates simulated from both the RAFTS and TUFLOW models.

Whilst the RAFTS model provides the inflows to the TUFLOW model, more rigorous routing down the creek and floodplain occurs in the TUFLOW model. It is anticipated that flow estimates provided by the TUFLOW model will be more attenuated and more accurate throughout the middle and lower catchment.

The observed flow hydrographs at the Orange Grove Station are illustrated on **Figure 5.2**, and compared with the simulated hydrographs determined from the RAFTS and TUFLOW models. The general shape of observed and simulated hydrographs is similar for both events. The RAFTS and TUFLOW models underestimate the peak discharge in the 1988 flood by between 5 and 10%. The RAFTS model overestimates the peak discharge for the 1986 flood, whilst the TUFLOW model provides close agreement. On the basis of these two events, it is concluded that the models provide a reasonable match to the observed discharge hydrographs at the Orange Grove Road gauging station. As such, no adjustment to the default RAFTS calibration parameter was considered necessary.

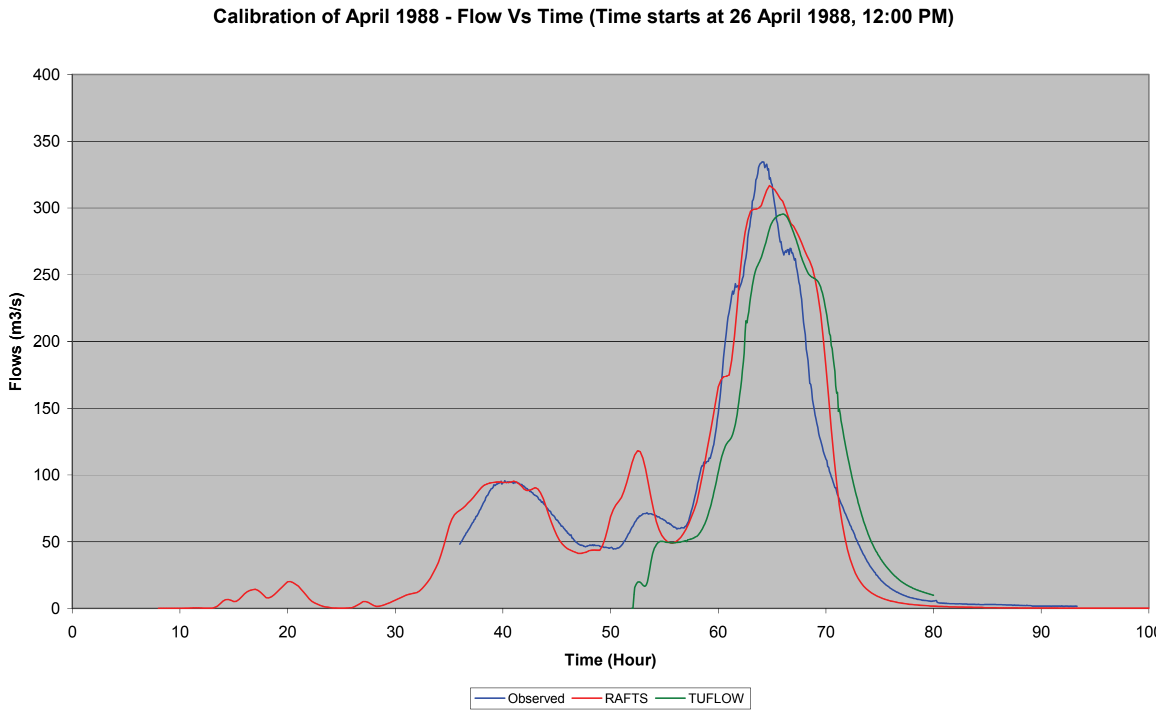
Historical flood heights were available from a flood debris survey by the Department of Water Resources immediately following the 1986 flood (DWR, 1988). Post flood surveys were also conducted by the Public Works Department throughout the Georges River and Cabramatta Creek for both floods (PWD, 1987, 1989). Other flood height observations are noted in flood studies conducted in the early 1990s (Kinhill, 1991, 1993). In total, there are some 29 flood height observations for the 1988 flood and some 44 flood height observations for the 1986 flood.

Roughness coefficients in the TUFLOW model have been adjusted to provide the best overall match between simulated flood levels and observed flood levels for both floods.

Table 5.4 lists the available flood observations and a comparison of observed and computed flood levels for the 1988 flood. The location and difference is also illustrated on **Figure 5.3**. The mean difference between all observed and computed flood levels is -0.02m, and 83% of all points lie within 0.3m.

Table 5.5 lists the available flood observations and a comparison of observed and computed flood levels for the 1986 flood. The location and difference is also illustrated on **Figure 5.4**. The mean difference between all observed and computed flood levels is +0.10m, and 73% of all points lie within 0.3m.

It has not been possible to provide a close match to every observation recorded. Indeed, in some cases there is a considerable discrepancy between observed levels that are close to each other, which suggests that some of the observations are not accurate. In many cases the original source of the flood observation and its precise location is not known, which makes it impossible to verify the reliability of the record itself. However, given the number of observations across the study area, and the number of points that match within 0.3m, it is considered that the TUFLOW model has been adequately calibrated to the available data.



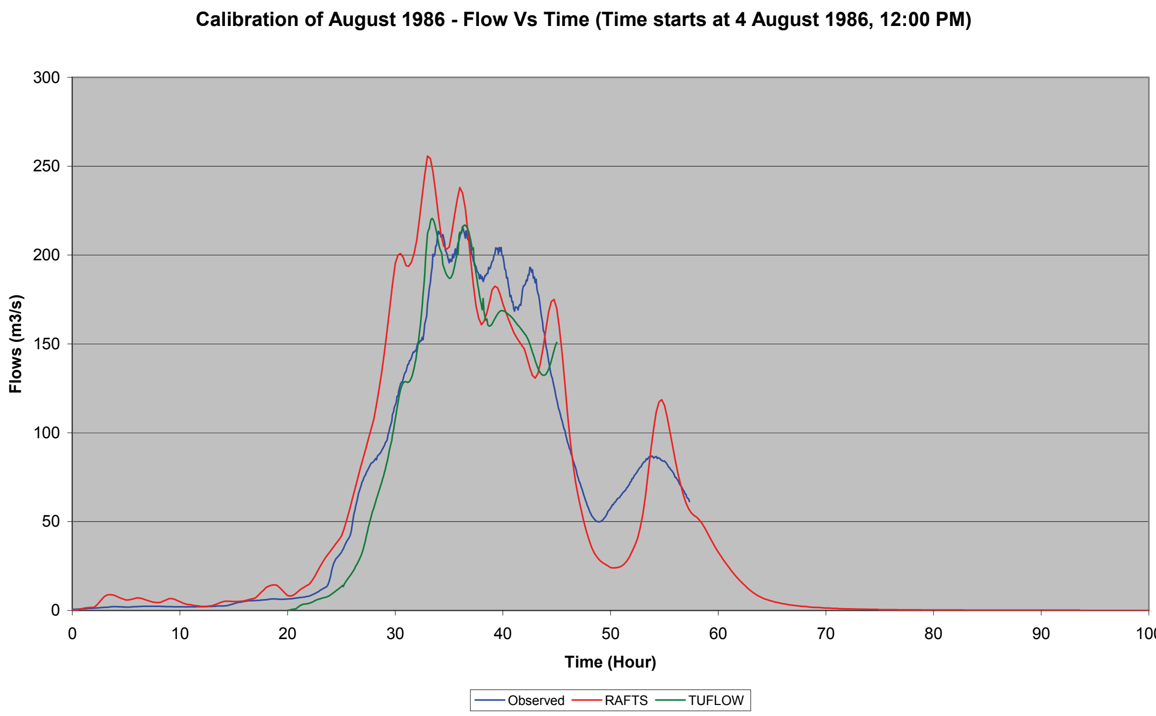


FIGURE 5.2
Calibration to Gauging Station at Orange Grove Road

Table 5.4
Flood Model Calibration to April 1988 Flood

ID	Type	Waterway	Location	HEC-2	Source	Observed	Model	Diff (m)
1	Flood mark	Cabramatta Ck	Hume Highway	1.4	PWD, 89	6.32	6.45	0.13
2	Flood mark	Cabramatta Ck	DS Hume Highway	1.6	PWD, 89	6.27	6.42	0.15
3	Flood mark	Cabramatta Ck		1.3	Kinhill. 91	6.3	6.45	0.15
4	Flood mark	Cabramatta Ck		1.2	Kinhill. 91	6.4	6.46	0.06
5	Flood mark	Cabramatta Ck	Sussex & Railway	1.1	PWD, 89	6.76	6.66	-0.1
6	Flood mark	Cabramatta Ck	Sussex & Church	1.10-1.0	PWD, 89	6.66	6.67	0.01
7	Flood mark	Cabramatta Ck	Cab Sports Ground	1	PWD, 89	6.84	6.74	-0.1
8	Flood mark	Cabramatta Ck	Cab Sports Ground	3	PWD, 89	6.9	6.92	0.02
9	Flood mark	Cabramatta Ck	Jasmine Cr	4.5	PWD, 89	7.05	7.02	-0.03
10	Flood mark	Cabramatta Ck		7	Kinhill. 91	7.5	7.57	0.07
11	Auto gauge	Cabramatta Ck	Orange Grove Rd	10.3	DWR	10.17	10.09	-0.08
12	Flood mark	Cabramatta Ck	Golf Club	11	Kinhill 92	11.1	10.45	-0.65
13	Flood mark	Cabramatta Ck		14	Kinhill. 91	11.4	11.44	0.04
14	Flood mark	Cabramatta Ck		14.5	Kinhill 92	12.1	12.03	-0.07
15	Flood mark	Cabramatta Ck		16	Kinhill 92	12.2	12.06	-0.14
16	Flood mark	Cabramatta Ck	Florence St	16.0-17.0	Kinhill 92	12.4	12.09	-0.31
17	Flood mark	Cabramatta Ck		17	Kinhill 92	12.4	12.36	-0.04
18	Flood mark	Cabramatta Ck	Blamfield Oval	19	Kinhill 92	13.1	13	-0.1
19	Flood mark	Cabramatta Ck	Lehmans Oval	20	Kinhill 92	12.9	13.13	0.23
20	Flood mark	Cabramatta Ck	Lehmans Oval	20	Kinhill 92	14.1	13.13	-0.97
21	Flood mark	Cabramatta Ck	Bunce Road	101	Kinhill 92	13.6	13.56	-0.04
22	Flood mark	Cabramatta Ck	Pilbarra Pl	109	Kinhill 92	18.8	18.61	-0.19
23	Flood mark	Cabramatta Ck	Pilbarra Pl	109	Kinhill 92	18.9	18.63	-0.27
24	Flood mark	Cabramatta Ck		110	Kinhill 92	19.2	19.27	0.07
25	Flood mark	Cabramatta Ck		110.3	Kinhill 92	19.3	19.96	0.66
26	Flood mark	Cabramatta Ck		110.5	Kinhill 92	19.4	20.46	1.06
27	Flood mark	Hinchinbrook Ck		Conf-400	Kinhill 92	27.5	27.42	-0.08
28	Flood mark	Wilson Road	Banks Rd	4004	Kinhill 92	25.3	25.23	-0.07
29	Flood mark	Wilson Road	Whitford Rd	4013-4015	Kinhill 92	27	27.08	0.08
							Mean Difference	-0.02
							Within 0.1	48%
							Within 0.3	83%

ID refers to location shown on Figure 5.3.
HEC2 refers to HEC-2 cross section location referred to in previous reports

Table 5.5
Flood Model Calibration to August 1986 Flood

ID	Type	Waterway	Location	HEC-2	Source	Observed	Model	Diff (m)
1	Max ht	Cabramatta Ck	Hume Hwy	1.51	PWD, 87	5.6	5.98	0.38
2	Flood mark	Cabramatta Ck	Liverpool/Lovoni St	1.4	PWD, 87	6.0	5.98	-0.02
3	Max ht	Cabramatta Ck	Hume Hwy	1.17	PWD, 87	6.1	6.14	0.04
4	Flood mark	Cabramatta Ck	Jasmine Cr	3	DWR, 88	6.4	6.55	0.15
5	Flood mark	Cabramatta Ck		5	DWR, 88	6.5	7	0.5
6	Flood mark	Cabramatta Ck	Bowden St	6	DWR, 88	7.0	7.22	0.22
7	Flood mark	Cabramatta Ck		8	DWR, 88	7.9	8.81	0.91
8	Auto gauge	Cabramatta Ck	Orange Grove Rd	10.2	DWR	9.54	9.6	0.06
9	Flood mark	Cabramatta Ck		13	DWR, 88	11.0	11.1	0.1
10	Flood mark	Cabramatta Ck		14	Kinhill, 91	11.1	11.18	0.08
11	Flood mark	Cabramatta Ck		14.5	Kinhill, 91	11.2	11.36	0.16
12	Flood mark	Cabramatta Ck		16	DWR, 88	11.5	11.49	-0.01
13	Flood mark	Cabramatta Ck	Florence St	16.0-17.0	DWR, 88	11.5	11.57	0.07
14	Flood mark	Cabramatta Ck		17	DWR, 88	12.6	12.19	-0.41
15	Flood mark	Cabramatta Ck	Blamfield Oval	19	DWR, 88	12.8	12.76	-0.04
16	Flood mark	Cabramatta Ck	Cartwright Ave	107	DWR, 88	17.7	17.83	0.13
17	Flood mark	Cabramatta Ck		111	DWR, 88	20.0	20.66	0.66
18	Flood mark	Cabramatta Ck		112	DWR, 88	22.0	22.23	0.23
19	Flood mark	Cabramatta Ck	Hoxton Park Rd	115	DWR, 88	23.7	24.14	0.44
20	Flood mark	Hinchinbrook Ck	Twentieth Ave	400	DWR, 88	26.9	27.11	0.21
21	Flood mark	Cabramatta Ck	Nineteenth Ave	119	DWR, 88	28.8	28.97	0.17
22	Flood mark	Cabramatta Ck	Kurrajong Rd	122	DWR, 88	32.8	32.36	-0.44
23	Flood mark	Cabramatta Ck		123	DWR, 88	32.9	32.47	-0.43
24	Flood mark	Cabramatta Ck	Camden V Way	127	DWR, 88	38.8	39.39	0.59
25	Flood mark	Wilson Road	Banks Rd	4004	DWR, 88	25.0	25.16	0.16
26	Flood mark	Wilson Road		4005	DWR, 88	25.4	25.32	-0.08
27	Flood mark	Wilson Road		4009	DWR, 88	25.8	25.81	0.01
28	Flood mark	Wilson Road	Whitford Rd	4013-4015	DWR, 88	27.0	26.93	-0.07
29	Flood mark	Hinchinbrook Ck		4025	DWR, 88	27.6	27.5	-0.1
30	Flood mark	Hinchinbrook Ck		404	DWR, 88	28.3	28.34	0.04
31	Flood mark	Hinchinbrook Ck		405	DWR, 88	29.2	29.08	-0.12
32	Flood mark	Hinchinbrook Ck		405	DWR, 88	29.2	29.11	-0.09
33	Flood mark	Hinchinbrook Ck		d/s 406	DWR, 88	29.8	30.12	0.32
34	Flood mark	Hinchinbrook Ck		u/s 406	DWR, 88	31.5	30.73	-0.77
35	Flood mark	Hinchinbrook Ck		407	DWR, 88	32.8	33.03	0.23
36	Flood mark	Hinchinbrook Ck		408	DWR, 88	34.8	35.09	0.29
37	Flood mark	Hinchinbrook Ck		409	DWR, 88	35.4	35.64	0.24
38	Flood mark	Hinchinbrook Ck		410	DWR, 88	35.7	35.78	0.08
39	Flood mark	Hinchinbrook Ck		413	DWR, 88	37.7	38.04	0.34
40	Flood mark	Maxwells Ck	Hoxton Park Rd	202	DWR, 88	15.3	15.55	0.25
41	Flood mark	Maxwells Ck	Hoxton Park Rd	204	DWR, 88	15.6	15.78	0.18
42	Flood mark	Maxwells Ck		207	DWR, 88	17.5	17.36	-0.14
43	Flood mark	Maxwells Ck	Lyn Pde	211	DWR, 88	19.4	19.35	-0.05
44	Flood mark	Maxwells Ck	Jedda Rd	215	DWR, 88	5.6	5.98	0.38
							Mean Difference	0.10
							Within 0.1	32%
							Within 0.3	73%

ID refers to location shown on Figure 5.4.
HEC2 refers to HEC-2 cross section location referred to in previous reports

FIGURE 5.3
Comparison of Computed and Observed Flood Levels – April 1988 Flood

FIGURE 5.4
Comparison of Computed and Observed Flood Levels – August 1986 Flood

5.7 BLOCKAGE ASSUMPTIONS

The potential for culverts or other hydraulic structures to become blocked by debris during floods has gained increased recognition in recent years. Fallen trees, vegetation, shopping trolleys, garbage bins, mattresses and floating cars can all potentially become trapped on the upstream side of culverts, significantly reducing the capacity of these structures.

Blockage problems were identified as a major contributor to the devastation caused throughout the Wollongong area during the August 1998 floods. In many cases, the hydraulic capacity of culverts, bridges and underground pipe systems was completely eliminated or severely restricted as a result of the blockages. In response to these problems, Wollongong City Council adopted a culvert blockage policy that assumes 100% blockage of all structures where the clear diagonal opening is less than 6m. Many other councils have since adopted a 50% blockage policy.

It is understood that Liverpool City Council has not yet formally adopted a blockage policy for catchments within their jurisdiction. Previous studies on Cabramatta Creek have ignored the potential for bridges and culverts to become blocked by debris. As the main objective of the current study is to assess differences in flood behaviour due to development within the catchment, and in the absence of a formal council policy on blockage, the previous assumption of no blockage has been retained.

Many of the culverts and bridges in the lower creek are relatively large, and the propensity of these structures to become blocked by debris is fairly low. Culverts in the upper catchment are smaller, and may be more likely to suffer potential blockage problems. The potential blockage of detention basin outlets could also pose a significant flood risk, leading to premature overtopping and possible basin failure.

The analysis of potential blockage problems is outside the scope of the current investigations. However, it is recommended that sensitivity testing be undertaken as part of subsequent investigations to determine how flood behaviour may be affected under various blockage scenarios. Where the impact on flood behaviour is low, it may be possible to accommodate these increases within the freeboard allowance that is normally added to design flood levels. In other cases it might be appropriate to increase the freeboard allowance to cater for larger increases. In critical areas it may be necessary to construct trash barriers to reduce the likelihood of culvert blockage, or to instigate regular maintenance programs to keep the waterway free of debris.

Further investigation of the impact of potential culvert blockage on flood behaviour throughout the catchment is recommended.

5.8 CLIMATE CHANGE CONSIDERATIONS

There is increasing evidence that the earth’s atmospheric and ocean temperatures have increased over the last century, and that the accumulation of greenhouse gases in the earth’s environment will accelerate this process in future years.

Future climate change can potentially affect flood behaviour through:

i) increased sea levels; and

ii) increased severity of flood producing storms or other weather systems.

The NSW Government recently adopted sea level rise planning benchmarks to be considered in all coastal and flood hazard assessments. (NSW Government, October 2009). The NSW sea level rise planning benchmarks are an increase above 1990 mean sea levels of 40cm by 2050 and 90cm by 2100. The impact of climate change on rainfall is less certain. Evidence to date suggests that whilst mean annual rainfall over Australia is likely to reduce, the intensity of extreme daily rainfall could increase.

Studies currently in progress for Fairfield City Council (Bewsher Consulting, 2010) indicate that an increase in sea level of 90cm would increase the design 100 year flood level at the confluence of the Georges River and Cabramatta Creek by 5cm. This is considered a relatively minor impact, and implies that flood levels in Cabramatta Creek will be relatively unaffected by potential sea level rises. The impact of increased rainfall intensities is more pronounced, with results indicating a further rise of 33cm should rainfall intensities increase by 10%.

An assessment of the potential impact of climate change on flood behaviour in the Cabramatta Creek catchment is beyond the scope of the current study. However, in view of the findings from the Fairfield study, it is likely that climate change impacts will be largely limited to those resulting from increased rainfall intensities. Further investigation into the sensitivity of design flood level estimates to potential increases in rainfall intensities is recommended.

5.9 MODELLING LIMITATIONS

There are certain limitations in all flood models. This can include sources of inaccuracies with the physical representation of the catchment and drainage system; the ability of the model to simulate the nature of flooding; and assumptions that are made as to how different structures behave during floods, including blockage assumptions.

A limitation of the TUFLOW model for the Cabramatta Creek catchment concerns the 5m grid size adopted for the analysis of flood behaviour. This is a vast improvement over previous models applied in the catchment, but is still relatively coarse when modelling overland flow paths between houses and other constrictions. However, the objective of study is to develop a catchment-wide flood model, and the use of a smaller grid size is not feasible with current computing facilities. Future use of the model to analyse specific development proposals, or to provide improved resolution in key areas, could incorporate a finer nested grid to represent the area of interest if required.

No attempt has been made to model the stormwater pipe system throughout the catchment, except for those drainage lines that form the outlet to detention basins, culverts under roads, or major drainage lines identified by Council (for instance the major drain down Jedda Road to Maxwells Creek).

The representation of the terrain surface through the ALS survey has an order of accuracy of $\pm$0.15m, and some artificial fluctuation of the terrain surface is evident. Prediction of flood depths that are less than 0.15m is therefore uncertain. Some areas may therefore exhibit a 'fuzzy' boundary within this tolerance when mapping flood extents. In some areas, filtering of the flood inundation extents may be warranted to provide a more rational boundary.

The reliability of the model to estimate flood behaviour has been improved by calibrating the model to historical floods that occurred in April 1988 and August 1986. Both events were significant, with the 1988 flood similar to the estimated 100 year flood. The model has been able to match observed flood heights within $\pm$0.3m for 83% of observations made in 1988 and 77% of observations made in 1986. It should also be recognised that there are limitations in the observed data. Some observations may have been poorly recorded; the exact location of others is uncertain; whilst others may not have been observed at the peak of the flood.

Given the uncertainties discussed above it is considered that flood level results from the model have an absolute accuracy of about ± 0.3m. This should not be confused with the relative accuracy of the model to assess flooding impacts from proposed development and flood mitigation options, which would typically have an accuracy of ± 0.01m with this type of model.

6 REVIEW OF FLOOD BEHAVIOUR

The TUFLOW model produces a grid of results at 2.5m intervals over the study area. The grid results can be depicted as colour-coded thematic maps of flood levels, depths and flood velocities for each design flood. The results can be superimposed onto other base mapping, such as aerial photography or cadastral plans.

A plan showing the estimated extent of flood inundation in the 100 year flood and flood level contours has been provided in this report for existing (2008) conditions. A flood risk management precinct map has also been prepared based on the new model results.

A comparison has been made of the latest design flood level estimates with levels previously adopted by Council from the RMA-2 model. A comparison has also been made of flood behaviour over the period of 1989 to 2008, so that the impact of catchment development and of Council's basin strategy can be evaluated.

6.1 DESIGN FLOOD BEHAVIOUR (1989 CONDITIONS)

Flood behaviour for previous (1989) conditions has been analysed for the 20 year and 100 year floods. This event was simulated for comparison purposes only, so that the change in flood behaviour over the period from 1989 to 2008 can be reviewed. This provides information on how flood behaviour may have changed, as a result of:

i) new release area development;

ii) other development in the catchment over this period; and

iii) the performance of Council's detention basin strategy.

Flood level results for 1989 conditions have been used to provide a map showing the difference in flood level estimates between 1989 and 2008, which is discussed further in Section 6.4.

6.2 DESIGN FLOOD BEHAVIOUR (2008 CONDITIONS)

Flood behaviour under existing (2008) conditions has been analysed for the 20 year, 50 year, 100 year, 200 year and 500 year floods, as well as a probable maximum flood.

A map showing the extent of flood inundation and flood level contours for the 100 year flood is provided in **Figure 6.1**. This plan will also be provided to Council at A1 size to provide improved resolution of the mapping results. Flood level contours show the height of flooding likely to be experienced throughout the study area. This is an important outcome from the study, as it provides Council with the necessary information to specify flood planning levels and other controls for future development.

Model results for all design events will be provided to Council in digital format for incorporation in Council's GIS computer system.

FIGURE 6.1
Design 100 Year Flood for Existing (2008) Conditions

6.3 MAPPING OF FLOOD RISK MANAGEMENT PRECINCTS

Flood risk management precinct maps were previously prepared as part of the Cabramatta Creek Floodplain Management Study. Flood risk management controls were also formulated so that different development controls could be applied recognising the type of development proposed and the flood risk precinct in which the development is to be located. These controls are now largely incorporated within the Liverpool Development Control Plan 2008.

Whilst it is not the role of this study to review the development controls previously formulated for the Cabramatta Creek catchment, there is a need to update the flood risk management precinct mapping that defines the different flood risk areas, based on the latest modelling results.

The flood risk management precincts are divided into three different categories for the Cabramatta Creek catchment:

High Flood Risk Land below the 100 year flood that is either subject to a high hydraulic hazard (ie provisional hazard in accordance with the Floodplain Development Manual) or where there are significant evacuation difficulties.

Medium Flood Risk Land below the 100 year flood level that is not subject to high hydraulic hazard and where there are no significant evacuation difficulties.

Low Flood Risk Comprises all remaining areas of the floodplain (ie. Within the PMF extent) but not identified as either in a high flood risk or medium flood risk precinct.

Flood risk precincts consider the probabilities and consequences of flooding over the full spectrum of flood frequencies that might occur at a site. When expressed in mathematical notation:

$$\textit{Flood Risk} = \int_{\substack{\textit{all}\\\textit{floods}}} \textit{Probability} * \textit{Consequence}$$

where _probability_ is the chance of a flood occurring, and _consequence_ is the property damage and personal danger resulting from the site's flood characteristics. Note that in carrying out this assessment, the existing land uses and any private warning/evacuation plans at the site are ignored, and typical residential land uses and the normal public warning/evacuation plans are assumed.

An updated flood risk management precinct map has been prepared for the Cabramatta Creek catchment, which is included as **Figure 6.2**.

FIGURE 6.2
Flood Risk Management Precincts

6.4 COMPARISON WITH PREVIOUS DESIGN FLOOD LEVEL ESTIMATES

A map showing the difference in design 100 year flood levels between the TUFLOW model estimates and the previous RMA-2 model estimates is provided on **Figure 6.3**.

The difference map has been determined by subtracting the 100 year flood grid results from the TUFLOW model from the flood grid derived from the previous RMA-2 model. The resulting grid is shown as a thematic map showing the change in flood levels between the two models. It is important to note that this mapping does not show how the extent of flooding varies between the two models, and it only shows the change in flood levels at locations where flood levels exist in both models.

The difference in flood levels between the two estimation methods may be due to a combination of factors, including:

i) differences in modelling technique;

ii) differences in the source of data describing the terrain surface (ie differences in the 1996 photogrammetry and the 2008 ALS); or

iii) changes in catchment conditions from when the RMA model was developed (1996) and when the TUFLOW model was developed (2008).

The majority of the study area shows little change (within $\pm$0.2m) in the design 100 year flood level estimates. Other areas show fairly localised variations that represent either an increase or decrease in design flood levels. Some of the more significant changes include:

i) Changes that have occurred at the location of detention basins. Some of these changes are due to the construction of new basins (eg the three M7 basins) or where basins have been modified to adjust their performance (eg Basin 3A).

ii) Significant increases of up to 1.0m in flood levels over a distance of approximately 1km along the upper reaches of Hinchinbrook Creek (adjacent to the Basin 4 site). Most of this difference is thought to be attributed to differences in surface levels between the 1996 photogrammetry and the 2008 ALS. The RMA-2 model results also appear to be poorly defined within this area.

iii) Other increases of up to 0.4m in isolated areas along Hinchinbrook Creek. Again, this is likely to be a result of differences in representation of the terrain surface.

iv) An increase in flood levels generally between 0.2 and 0.5m near the junction of Cabramatta Creek and Hinchinbrook Creek, upstream of the M7 Motorway Bridge. There are also significant discrepancies between the photogrammetry and the 2008 ALS at this location.

v) A reduction in flood levels of up to 0.4m near the Catholic Club and Hoxton Park Road, possibly due to drainage improvements or improved modelling methods.

vi) A reduction in flood levels of around 0.3m throughout a significant portion of Maxwells Creek. This is most likely a benefit of Basin 18 that has been constructed on Maxwells Creek.

vii) A reduction in flood levels of up to 0.5m on Cabramatta Creek immediately upstream of Elizabeth Drive. This reduction is most likely due to waterway area improvements that were undertaken to increase the capacity of this structure.

viii) An increase of around 1.0m downstream of Orange Grove Road, adjacent to the Megacentre development, which is likely due to the development itself.

ix) A reduction of 0.2 to 0.3m on Cabramatta Creek, between the Hume Highway and the Railway bridge.

6.5 CHANGE IN FLOOD BEHAVIOUR SINCE 1989

The change in flood behaviour over the period from 1989 to 2008 has been investigated using the TUFLOW model. This essentially shows the impact of development within the catchment on flood behaviour over this period, and the performance of Council's detention basin strategy to mitigate this impact. The difference map has been determined using the same model, so changes due to modelling techniques or different modelling assumptions are removed from the comparison.

A map showing the difference in design 100 year flood levels over this time period is provided on **Figure 6.4**.

The impact of changes that have occurred within the catchment from 1989 to 2008 is limited to less than ± 0.2m throughout most of the study area. Exceptions include:

i) Where detention basins have been constructed or modified, and flood levels have increased within the basin footprint.

ii) Immediately downstream of Basin 3A on Hinchinbrook Creek, due to changes in the configuration of the outlet from this basin.

iii) Adjacent to the Government Road Basin on Hinchinbrook Creek, where flood levels have increased locally by up to 400mm. Construction of the Government Road Basin has restricted the natural floodplain of Hinchinbrook Creek, resulting in flood level increases.

iv) Along Creek A, where channel works have led to a significant lowering of flood levels.

v) Along Creek E, where channel works and the construction of Basins 10A and 10B have generally reduced flooding by around 0.2 to 0.3m.

vi) Upstream of the M7 Embankment across Cabramatta Creek, where flood levels have increased by up to 0.2m.

vii) Along Maxwells Creek, where flood levels have reduced by around 0.2m as a result of the construction of Basin 18.

viii) Several areas within Prestons industrial area, where the construction of the M7 embankment and other areas that have been filled have increased flood levels locally.

ix) Immediately upstream of the Elizabeth Drive bridge over Cabramatta Creek, where flood levels have reduced by around 0.2m as a result of waterway improvements recently undertaken to improve the capacity of this structure.

x) Upstream of Orange Grove Road, where floodway improvements through the Golf Course have led to flood level reductions of up to 0.3m.

FIGURE 6.3
Change in 100 Year Flood Level Estimates
TUFLOW (2008) compared to RMA (1996)

FIGURE 6.4
Change in 100 Year Flood Level Estimates
Due to Catchment Development (1989 to 2008)

7 BASIN STRATEGY REVIEW

This section provides a review of Council's detention basin strategy for the Cabramatta Creek catchment. The performance of the strategy as a whole is reviewed in light of the TUFLOW modelling of flood behaviour over the period from 1989 to 2008. The performance of individual basins is also reviewed. The remaining basins in the strategy that have not yet been constructed are also briefly discussed. Much of this discussion is based on a previous review undertaken for Council (Bewsher Consulting, draft 2006).

7.1 OBJECTIVES OF THE BASIN STRATEGY

Council's basin strategy was originally developed by Kinhill Engineers to mitigate the impacts of increased runoff due to new release area development under consideration at that time. The strategy, shown on **Figure 4.2**, involves the construction of up to 19 detention basins throughout the catchment. To date, 13 major basins have been constructed within the catchment, and another 6 basins have been identified for future construction.

The objective of the basin strategy was stated (Kinhill, 1992, page 6-1) as:

> "*to effectively control 1% AEP post-development flows to pre-development levels. This reduction in flow was not only to apply at the outlet of the basin. Using a combination of basins, the discharge from the outlet of the Cabramatta Creek catchment (at the Main Southern Railway Line) had to also be maintained to pre-development levels.*"

The basin strategy has progressively evolved over time as development and other changes in the catchment have taken place. Consequently from time to time there is a need to revisit the strategy and check whether or not the objectives of the strategy are being fulfilled.

7.2 PERFORMANCE OF THE STRATEGY AS A WHOLE

A check on the performance of the basin strategy over the period from 1989 to 2008 has been made by comparing flood behaviour in the TUFLOW model for 1989 and 2008 conditions. This assessment includes consideration of the new release area development that has been carried out to 2008, and the construction of 13 detention basins within the catchment over this period.

The assessment also considers other development and flood mitigation works that have been carried out in the catchment over this period, including the M7 motorway (plus their associated detention basins), and other culvert and bridge amplification measures.

The change in flood levels over the period from 1989 to 2008 was discussed in Section 6.5, and a map showing the difference in flood levels for the 100 year flood shown on Figure 6.4. Apart from expected changes at detention basin locations and other locations adjacent to the M7 Motorway, there has been little change in flood levels (within $\pm$0.2m) throughout the majority of the catchment. The main exception includes the lower reaches of Maxwells Creek, where flood level reductions of approximately 0.2m are evident. This is most likely attributable to the construction of Basin 18, which is the largest basin within the catchment. Construction of the motorway embankment may also have contributed to this reduction by preventing a breakout from Cabramatta Creek to Maxwells Creek.

Apart from the minimal change in flood levels noted above, an objective of the original strategy was to ensure that flood flows in the 100 year event do not increase throughout the lower catchment. This has been reviewed by extracting flow hydrographs from the TUFLOW model at key locations in the catchment. The flow hydrographs are illustrated on **Figure 7.1**.

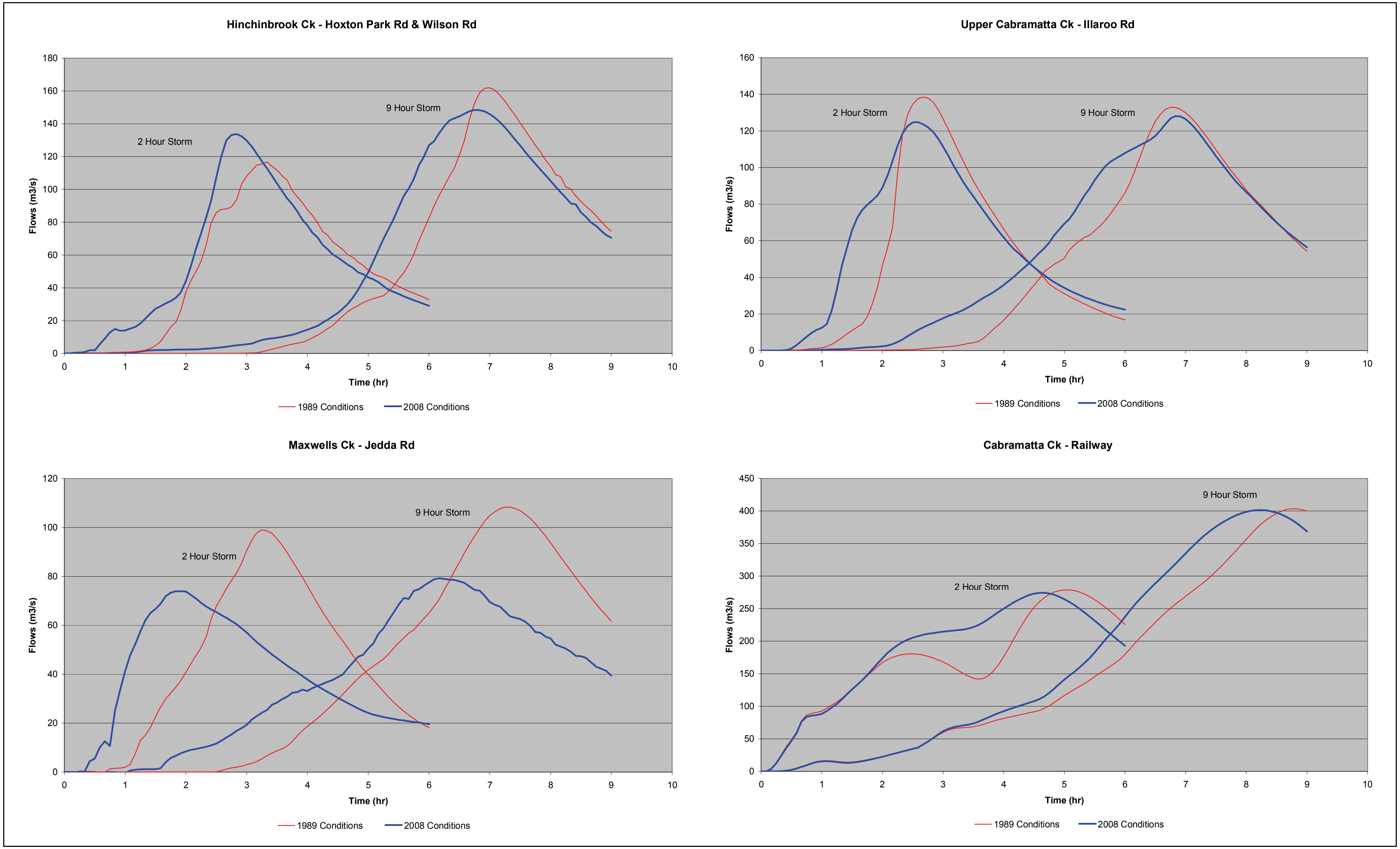


FIGURE 7.1
Flow Hydrographs in 100 Year Flood: 1989 to 2008

The lower end of Hinchinbrook Creek shows an increase in peak flows during the period 1989 to 2008 for the 2 hour storm (from 117m^3/s to 134m^3/s), and a reduction in peak flows for the 9 hour storm (from 162m^3/s to 148m^3/s). The 9 hour storm is critical in this part of the catchment, and results in the higher flood levels.

Upper Cabramatta Creek (upstream of the motorway) shows a reduction in peak flows in the 2 hour storm (from 139m^3/s to 125m^3/s), and a minor reduction in the 9 hour storm (from 133m^3/s to 128m^3/s). Both 2 and 9 hour storms produce similar flood levels in this part of the catchment.

The lower end of Maxwells Creek shows significant reductions in peak flows for both the 2 hour and 9 hour storms. The 9 hour storm is critical at this location, with peak flows being reduced from 108m^3/s to 79m^3/s.

At the downstream end of Cabramatta Creek, near the railway line, there is virtually no change in peak flow estimates in both the 2 hour and 9 hour storms. The 2 hour storm showed a minor reduction from 279m^3/s to 274m^3/s, and the 9 hour storm a minor reduction from 403m^3/s to 401m^3/s).

On the basis of the above, it is reasonable to conclude that the basins that have been constructed in the catchment to date have been sufficient to mitigate the impacts of new release area development on flooding over the period from 1989 to 2008 in most areas.

The impact of the remaining new release area development (post 2008) and construction of the remaining basins is beyond the scope of the current investigations.

7.3 PERFORMANCE OF INDIVIDUAL BASINS

7.3.1 Lord Howe Drive Basin

The Lord Howe Drive detention basin forms one of the Stage I Release Area basins. It is located in Paramor Reserve, to the east of Cowpasture Road. The basin controls runoff from a sub-area of Green Valley, that drains in a westerly direction to Cowpasture Road, and then to Hinchinbrook Creek. This drainage path was identified in the Cabramatta Creek Floodplain Management Study as Creek J.

Seven basins were originally identified in the basin strategy for the Stage I Release Area. The location of these basins was not well defined in the original report (Sinclair Knight, 1983), but the strategy shows 4 detention basins (Basins 1 to 4) controlling discharge from the Green Valley development area to Hinchinbrook Creek. The Lord Howe Drive basin appears to correspond with Basin 1 from that strategy.

Basin details were extracted from design drawings prepared by J. Wyndham Prince in 1998. The main outlet from the basin is via twin 1350mm diameter pipes that lead directly to a twin 3000x1500 box culvert under Cowpasture Road. The basin has a 35m long spillway at RL 47.92m AHD. The available basin storage to the spillway level is approximately 21,000m^3 (2005 ALS).

Results from the TUFLOW model indicate that the basin fills to a maximum height of RL 48.18m AHD in the 100 year flood. At this level, the spillway is overtopped by 0.26m. Safety aspects concerning basin overtopping should be verified for the 100 year flood and more extreme events.

7.3.2 Cowpasture Road Basin

The Cowpasture Road detention basin forms another of the Stage I Release Area basins. It is located on the eastern side of Cowpasture Road, within a reserve bounded by Rotnest Avenue, Lord Howe Drive and Cape Baron Avenue. The basin controls runoff from the Green Valley development area that drains west to Hinchinbrook Creek.

It appears that the Cowpasture Road basin corresponds to Basin 2 from the original strategy. The other two basins from the original strategy that drain to Hinchinbrook Creek (Basins 3 and 4) have not been constructed, and it is feasible that an enlarged Basin 2 was designed to fulfil the purpose of all three basins.

The Cowpasture Road basin was designed by the Rose Consulting Group, and constructed during 1996/97. Design details are available from works-as-executed drawings prepared by Hill Brothers. The drainage system within the basin consists of three separate 600mm diameter pipe drainage lines leading into the basin, in addition to surface flows down two defined flow paths. The drainage lines converge near the outlet of the basin, and continue as twin 1200mm diameter pipes under the embankment and under Cowpasture Road.

The works-as-executed drawing indicates a 25m wide spillway at RL 42.10m AHD, and a total storage volume of 36,100m^3 at the spillway level. This agrees closely with the 2005 ALS.

Results from the TUFLOW model indicate that the basin fills to a maximum height of RL 41.85m AHD in the 100 year flood. This is 0.25m below the spillway level. The basin would appear to be performing relatively well in the design flood. Safety aspects in larger flood events should be verified.

7.3.3 Banks Road Basin

The Banks Road detention basin forms the final Stage I Release Area basin within the Cabramatta Creek catchment. The basin is located upstream of Banks Road and south of Dotterel Street in the suburb of Hinchinbrook. The basin controls runoff from the eastern side of the Stage I Release Area which drains through the street drainage system to Cabramatta Creek.

The Banks Road basin appears to correspond to Basin 7 from the original strategy. The other basins controlling runoff to the east (Basins 5 and 6) do not appear to have been constructed, with development now located within these areas.

The basin was designed by Liverpool City Works in 1995/96, and was constructed in 1996/97. The basin contains two soccer fields and a cricket pitch. Design plans show a spillway crest height of RL 33.10m AHD and a storage volume of 40,500m^3. This is consistent with the 2005 ALS. The outlet of the basin is through a 1350mm diameter pipe that leads directly into the piped drainage system.

This basin is not included in the TUFLOW model due to its remote location from the floodplain, and results must be extracted from the RAFTS model.

A previous review of this basin indicated that the basin was operating close to optimum capacity in the 100 year flood. No modifications to the storage volume or outlet pipes were recommended, although it was recommended that the capacity of the downstream pipe drainage system be verified. It was also noted that the spillway may be inadequate in extreme floods, and it was recommended that consideration be given to increasing the spillway capacity (by increasing its length) or by raising the main embankment (subject to confirmation that no houses would be affected by this action.

7.3.4 Basin 100

Basin 100 is a relatively small detention basin located at the top end of the Hinchinbrook Creek catchment, within the Hoxton Park Stage II Release Area. The basin was not originally proposed in the basin strategy, but was later included to allow development to proceed in the Cecil Hills area, prior to the construction of other basins in the strategy.

Basin 100 was constructed around 1993 through the construction of an earth embankment on the south side of the site and excavation within the site itself.

Basin details are provided from works-as-executed plans prepared by Peter Warwick in 1996. The basin outlet consists of a 2.7m wide x 0.9m high box culvert. A spillway is located over the outlet at RL 63.3m AHD. The storage volume at the spillway level is 35,500m^3. The 2005 ALS suggests a slightly lower storage volume 29,000m^3.

Results from the TUFLOW model indicate that the basin fills to a maximum height of RL 62.86m AHD in the 100 year flood. This is 0.44m below the spillway level.

A previous review (Bewsher Consulting, 1999) noted that the basin was only partially filling in the 100 year flood, and that there may be some opportunity to fine tune its hydraulic performance. It was also cautioned that the embankment may overtop in extreme floods, which could threaten a number of homes located immediately downstream of the basin in Balmoral Circuit.

During 2006 work was underway to strip and re-compact the earthen embankment. It is understood that the final embankment height is similar to the previous design level.

7.3.5 Basin 200

Basin 200 is a small basin that did not form part of the original basin strategy, but was included along with Basin 100 to allow development in the Cecil Hills area to proceed prior to construction of other downstream basins. The basin is located on the western side of Cowpasture Road, downstream of Frederick Road in Cecil Hills.

The basin was designed by J Wyndham Prince and constructed in about 1993. Works-as-executed plans were undertaken by Peter Warwick in 1996.

The basin outlet consists of a single 750mm diameter pipe discharging to a small grassed channel that eventually connects with Hinchinbrook Creek. A 35m spillway is provided at RL 49.75m AHD over the basin outlet. The storage volume at this level is 13,900m^3. A second stage spillway at RL 50.0 is located on the other side of the basin near a power transmission easement. These details are generally consistent with the 2005 ALS, which shows a spillway level at about RL 49.6m AHD and a storage volume at this level of 9,500m^3.

Results from the TUFLOW model indicate that the basin fills to a maximum height of RL 50.04m AHD in the 100 year flood. This is 0.29m above the spillway level.

A previous review (Bewsher Consulting, 1999) also estimated that the basin would fill to just above spillway level in the 100 year flood. In a more extreme flood, it was estimated that the main embankment would also overtop by about 0.1m, which would then threaten a number of houses built in Harewood Place and Dowding Close. It was recommended that consideration be given to raising the top of the embankment by up to 0.3m to restrict the likelihood of overtopping in extreme floods, or alternatively to diverting additional overflow down the power transmission easement on the western side of the basin.

An inspection of the basin in July 1998 also noted a potential blockage problem with the steel grates over the basin outlet structure. If not already attended to, it is recommended that these grates be replaced with wider spaced grates that are less likely to become blocked by grass or other debris.

7.3.6 Basin 3A

Basin 3A, otherwise known as Cecil Hills Wetland, is one of the larger basins included in the basin strategy. The basin contains a series of three permanent wetlands with flood storage above the normal water level formed by the construction of an earth embankment. The basin is a major water feature in Cecil Hills, located between Spencer Road and Feodore Drive.

The site was originally the location of a large farm dam, which was reconstructed to form the current basin in 1993.

The basin has been modified on several occasions. The outlet was shown on original design drawings as 4 x 2400W x 900H box culverts. A later design by J Wyndham Prince Pty Ltd refers to twin 1500 diameter pipes. The basin was originally constructed with the main outlet as a channel around the western end of the embankment. More recently, the basin embankment has been totally rebuilt and strengthened, and a new outlet constructed. Current details are provided in works-as-executed drawings prepared by Craig & Rhodes in June 2008. The current outlet consists of 4 x 1500mm pipelines that discharge to a wet basin downstream of the main basin. There are also three spillways provided at RL 54.8 (110m and 75m long) and at RL55.5 to 55.9m AHD (90m long).

The available storage volume to the lower spillway level is estimated at approximately 180,000m^3.

Results from the TUFLOW model indicate that the basin fills to a maximum height of RL 54.42m AHD in the 100 year flood. This is 0.38m below the lower spillway level. The basin performs satisfactorily in the 100 year flood, and it appears that significant provisions have been provided for more extreme flood events.

Some concern over the stability of the basin embankment had previously been expressed (Bewsher Consulting, 2006). It would appear that these deficiencies have now been rectified. It is understood that the basin is prescribed with the Dam Safety Committee, and is listed as a 'significant risk dam' (Dam Safety Committee, 2005).

7.3.7 Basins 10A and 10B

Basins 10A and 10B are adjoining basins that are located on a tributary of Cabramatta Creek, known as Creek A. Basin 10A is located near the entrance to the Carnes Hill Estate, on the western side of Cowpasture Road. Basin 10B is located immediately upstream of the lower basin.

A single basin (Basin 10) with a storage volume of 126,000 m^3 was proposed at this location in the original basin strategy. Adjoining basins were subsequently designed by J Wyndham Prince in 1993. Works as executed drawings were prepared in 1995 by Lean Lackenby & Hayward. These plans indicate storage volumes (at spillway level) of 54,000 m^3 and 91,800 m^3.

Basin 10A was originally constructed as a 'wet' basin, with permanent water below the level of the basin outlet. The basin was recently drained and converted to a 'dry' basin with playing fields located within the basin (May 2006).

The normal outlet for Basin 10A is shown as a single 1500 mm diameter pipe that discharges into a small wetland between the basin and Cowpasture Road. No formal spillway is evident, with excess flows spilling across the full length of the embankment (starting at RL 47.25m AHD). Further work on the embankment was evident in May 2006, including the construction of a concrete pathway along the crest of the embankment, which would help to stabilise the structure in overtopping events.

Basin 10B is immediately upstream of Basin 10A. It has been constructed as a 'dry' basin with playing fields within the basin. The normal outlet from the upper basin is through an 1800mm diameter pipe. There also does not appear to be any formal spillway, with flows in excess of the basin capacity spilling over the embankment into the lower basin.

Results from the TUFLOW model indicate that Basin 10A (the lower basin) fills to RL 47.28m AHD. This is very close to the spillway/embankment level of RL 47.25m AHD. Basin 10B (the upper basin) fills to RL 48.85m AHD. This is 0.10m above the embankment crest, resulting in flow cascading from the upper basin into the lower basin in addition to flows from the normal outlet.

It should be noted that results from the RAFTS model for Basin 10B (the upper basin) will not be accurate, as the water level in the lower basin reduces the discharge capacity from this basin. The outflow from the upper basin will therefore be overestimated in the RAFTS model and consequently the basin water level will be underestimated.

A review of safety aspects related to overtopping of the lower basin embankment in floods more extreme than the 100 year event is recommended.

7.3.8 Basins 11A and 11B

Basins 11A and 11B are located on a small tributary of Cabramatta Creek, known as Creek E, in Horningsea Park. Both basins are located upstream of the recent deviation of Cowpasture Road. Basin 11A is the upper basin, which contains permanent water storage, and cascades into the lower Basin 11B.

A single basin (Basin 11) with a storage capacity of 55,000 m^3 was originally proposed in this vicinity. Basins 11A and 11B are two of three basins which are intended to replace Basin 11. The third basin (Basin 11C) is proposed a short distance further downstream, and is yet to be constructed.

Basins 11A and 11B were designed by J Wyndham Prince in 1997, and constructed shortly afterwards. The outlet for Basin 11A is shown as two 825mm diameter pipes and spillway flows discharging to Basin 11B. The lower basin then drains through a piped drainage system to an open channel, and then on to the future Basin 11C.

Spillway levels for Basins 11A and 11B are shown as RL 53.1m AHD and 51.2m AHD respectively. Storage volumes at these levels are 18,000 m^3 and 26,700m^3. This is consistent with the 2005 ALS.

Results from the TUFLOW model indicate that Basin 11A (the upper basin) fills to RL 53.20 m AHD. This is 0.1m above the spillway level, resulting in some flow cascading over the spillway into the lower basin. Basin 11B (the lower basin) fills to RL 51.58. This is

380mm above the spillway level of the lower basin, allowing floodwater from the basin to spill onto Cowpasture Road.

A review of safety aspects related to Basin 11B overtopping in both the 100 year flood and more extreme events is recommended.

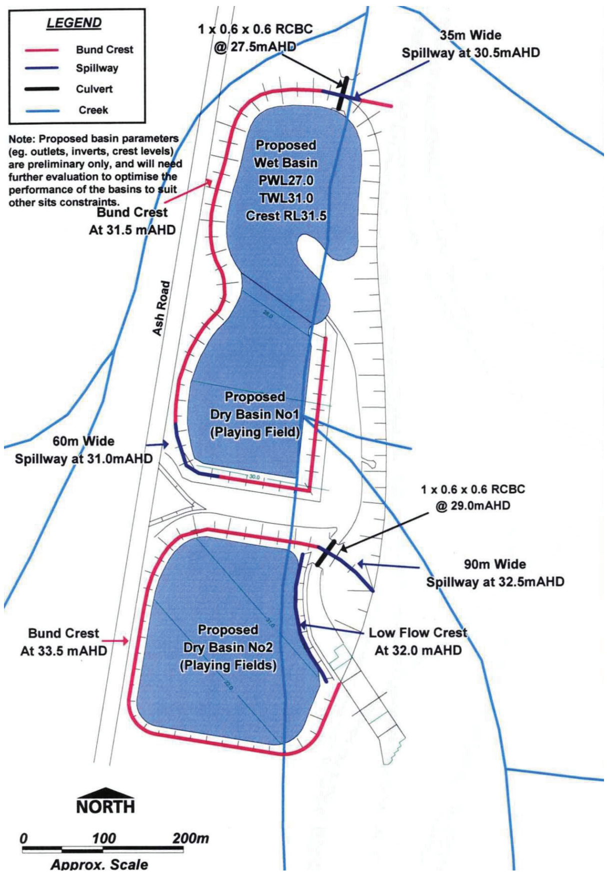
7.3.9 Basin 18

Basin 18 is a dual purpose basin that mitigates adverse flooding impacts from construction of the M7 Motorway and also future development within Maxwells Creek (ie it also forms part of Council's basin strategy).

The original basin strategy proposed a basin with a storage volume of 170,000m^3 located downstream of Kurrajong Road. The basin volume would also need to be increased to offset the natural loss in floodplain storage at this location. A previous review identified that the proposed basin, in addition to a smaller basin that was also proposed further upstream, was not sufficiently reducing post-developed flows and that further storage volume would be required.

The design and subsequent construction of the M7 Motorway bisected the proposed site of Basin 18, reducing its capacity. The flooding impact of the motorway also had to be mitigated by providing additional flood storage either within Basin 18 or elsewhere in the catchment. Consequently, the RTA and Liverpool Council agreed to construct an enlarged, dual purpose basin further upstream, in conjunction with the M7 Motorway construction.

The dual purpose basin was first investigated by Bewsher Consulting and WBM Oceanics for the RTA during 2001/2002. The preliminary proposal for the basin is shown on the sketch opposite. The basin was divided into three separate compartments. The lower compartment contained permanent water storage, whilst the upper two compartments were designed as 'dry' basins and included proposed playing fields.



The creek bypasses the first two basins and discharges directly into the lower basin. The upper basins were designed to fill through floodwater backing up from the lower basin. Runoff from development west of Ash Road (through Creek D) was proposed to be directed into the basin.

The basin had a proposed total storage volume of 405,000 m^3. The outlet consisted of a 600 x 600 low flow culvert and a higher level 35m wide spillway.

The proposed configuration was shown to be successful in reducing peak flows in Maxwells Creek due to the combined impact of the motorway and future catchment development.

The detailed design of Basin 18 was undertaken as part of the contract let by the RTA to design and construct the M7 Motorway. Details of the final design are provided on Drawing No. C001-DR-261171 prepared for the Abigroup Leighton Joint Venture in January 2004. These plans show a number of changes to the previous concept, including:

i) Changes to the low flow outlet and spillway;

ii) The top water level in the lower basin was increased by approximately 1.5m so that all three basins contained the same top water level of RL 33.0m AHD;

iii) The total storage volume for the 100 year flood was reduced from 405,000 m^3 to 300,000m^3;

iv) Runoff west of Ash Road, via Creek D, was diverted around the western edge of the basin, reducing the catchment area controlled by the basin.

A letter from the Abigroup Leighton Joint Venture to Council dated 24th February 2004 notes the reduced storage capacity of Basin 18 and indicates that their investigations had concluded that the reduced basin volume was still adequate.

Results from the latest TUFLOW model indicate that Basin 18 fills to a maximum level of RL 33.08m AHD. This is very similar to the level quoted in the M7 design of RL 33.0m AHD. At this level, the gabion spillway structure is overtopped by up to 0.5m. The water level in the upstream basin compartments are reduced to RL 32.8m AHD, 0.2m below the M7 design.

The basin has not been included in the RAFTS model due to the nature of the inlet/outlet conditions, and its location in the natural floodplain. In these circumstances, the basin can only be analysed accurately in a hydraulic model, such as TUFLOW.

Despite some discrepancies with the previous design, Basin 18 appears to have a significant impact on reducing downstream flows and flood levels in the 100 year flood. Significant vegetation was noted in the vicinity of the outlet structure during an inspection in January 2009. It is recommended that the likelihood of this structure becoming blocked by debris, and the impact on the performance of the basin, be further reviewed. A review of safety aspects related to overtopping in both the 100 year flood and more extreme events is also recommended.

7.3.10 Basin 22

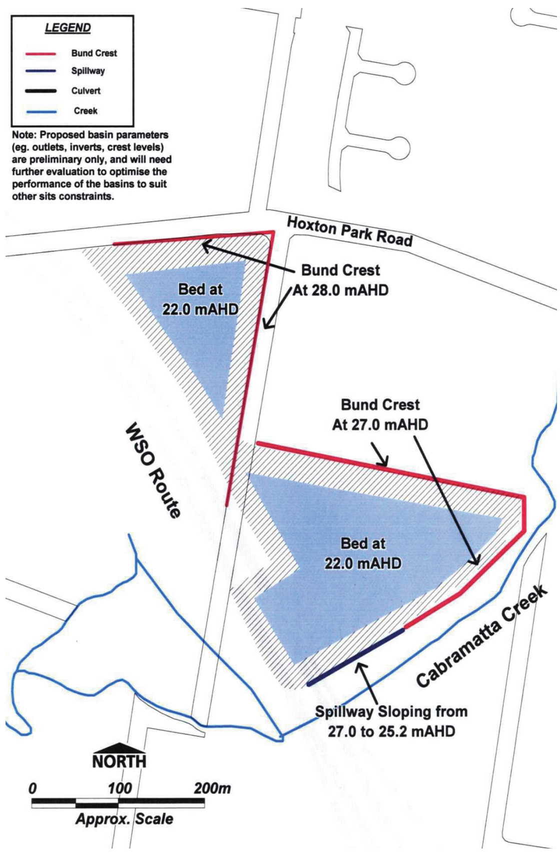
Basin 22 was not originally included in Council's detention basin strategy; although a smaller basin with a storage volume of 51,000 m^3 had been proposed for water quality purposes. During the review of the basin strategy in 1999, the possibility of providing a significantly larger basin at this location was proposed.

Land acquisition costs for the basin increased significantly as the proposed motorway became more of a certainty. The land is zoned industrial; and its close proximity to entry and exist ramps from the motorway made the land increasingly valuable for freight and other transport purposes. Other technical problems emerged as further investigations were undertaken in relation to a basin at this location. A high saline water table was found to be present close to the surface, limiting the depth of excavation permissible within the basin.

Consequently, a much smaller basin was proposed for the site to mitigate any adverse flooding impacts due to the construction of the M7 Motorway only.

A conceptual design of the basin was undertaken by Bewsher Consulting and WBM Oceanics for the RTA during 2001/2002. The basin was divided into two compartments, immediately downstream of the proposed M7 Motorway embankment. Both basin compartments were to be largely formed through excavation and the provision of an earth embankment around the downstream perimeters. The preliminary proposal for the basin is shown on the sketch opposite.

The upper basin largely collects runoff that spills out from Hinchinbrook Creek and crosses Hoxton Park Road. The lower basin accepts discharge form the upper basin in addition to overflows from Cabramatta Creek.



The total storage volume proposed for the basin was 336,000 m^3. Top water levels in the 100 year flood were RL 28.0 and 26.9m AHD.

The detailed design of Basin 22 was undertaken as part of the contract let by the RTA to design and construct the M7 Motorway. Details of the final design are provided on Drawing No. C001-DR-251171 prepared for the Abigroup Leighton Joint Venture in February 2004. These plans show a similar basin configuration to the earlier concept plans, although top water levels were slightly reduced (by 0.5m for the top basin and 0.1m for the lower basin). It is also understood that salinity problems reduced the proposed excavation depths and reduced the available storage volumes.

A letter from the Abigroup Leighton Joint Venture to Council dated 24th February 2004 notes that the storage capacity of the two basins had been reduced from 336,000m^3 to 115,000 m^3.

Results from the TUFLOW model indicate that the two basin compartments will fill to RL 27.9m AHD and RL 26.8m AHD.

The basin has not been included in the RAFTS model due to the nature of the inlet/outlet conditions, and its location in the natural floodplain. In these circumstances, the basin can only be analysed accurately in a hydraulic model, such as TUFLOW.

The reduced basin size is such that it can not be considered to play any significant role in Council's basin strategy

7.3.11 Government Road Basin

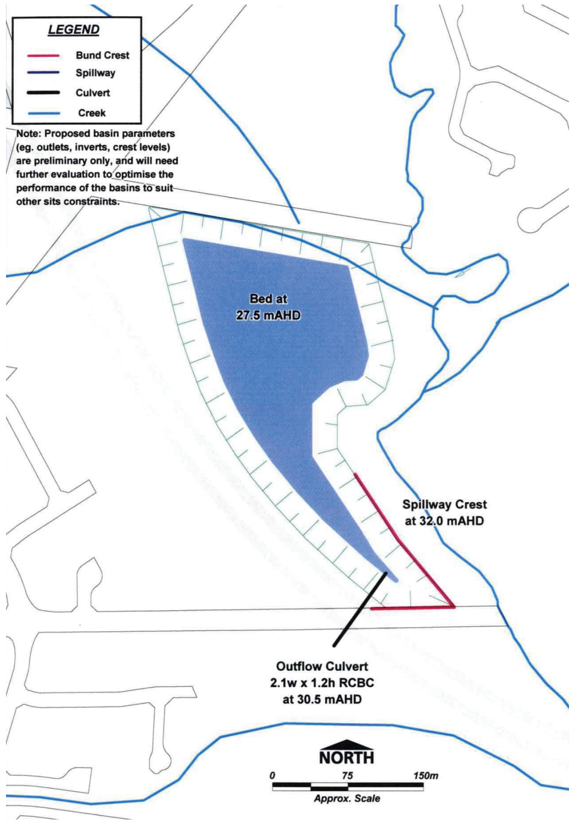
The Government Road Basin is a new basin which was included in the design of the M7 Motorway to mitigate any adverse flooding impacts within Hinchinbrook Creek. A basin at this location was proposed by the RTA and it does not play a significant role in Council's basin strategy.

A conceptual design of the basin was undertaken by Bewsher Consulting and WBM Oceanics for the RTA during 2001/2002. A preliminary proposal for the basin is shown on the sketch opposite.

The basin was intended to provide additional storage on the floodplain to compensate for the lost floodplain storage volume. It was intended to be formed largely through excavation within the floodplain.

Inflow to the basin is from Creeks N and L that drain a small subcatchment on the western side of the Motorway. Some floodplain flows from the western bank of Hinchinbrook Creek will also be directed towards the basin.

A storage volume in the 100 year flood of 205,000 m^3 and a top water level of RL 32.4m AHD was proposed for the basin. A small outlet structure to drain flows back to Hinchinbrook Creek was also proposed.



The detailed design of the Government Road Basin was undertaken as part of the contract let by the RTA to design and construct the M7 Motorway. Details of the final design are provided on Drawing No. C001-DR-252171 prepared for the Abigroup Leighton Joint Venture in February 2004. These plans differ substantially to the earlier concept plans. It is also understood that salinity problems reduced the proposed excavation depths and reduced the available storage volumes. The type of outlet structure is also significantly different.

A letter from the Abigroup Leighton Joint Venture to Council dated 24th February 2004 notes that the storage capacity of the basin had been reduced from 205,000m^3 to 125,000 m^3.

Inspection of Council's ALS survey indicates a storage volume of 129,000m^3. It also indicates a crest height of the embankment that separates the basin from Hinchinbrook Creek to be at a height of between RL 34.0m AHD to RL 34.5m AHD. This is 0.8 to 1.3m higher that the embankment height shown on the final design drawings. The reason for the increased height is not known.

Results from the TUFLOW model indicate that the basin fills to a maximum height of RL 33.1m AHD. Results also indicate that flood levels have increased locally by up to 400mm in Hinchinbrook Creek, adjacent to the basin. This is attributed to the constriction of the natural Hinchinbrook Creek floodplain due to the embankment that has been constructed near the creek bank.

An inspection of the constructed basin was undertaken in May 2006. The embankment between the basin and Hinchinbrook Creek was noted as being extremely steep and poorly compacted. This is likely to experience significant scouring and possible failure during floods. Apart from the threat of embankment failure, increased siltation further downstream will be a potential problem, which could reduce the capacity of the downstream creek system and exacerbate flooding. Further review of the performance and stability of this basin embankment is recommended.

PART 2 – FUTURE (2026) CONDITIONS

8 FUTURE CATCHMENT CONDITIONS

Further development within the catchment will occur as the new release areas are progressively developed. The additional development will result in further increases in the impervious area in the catchment, and a consequent increase in catchment runoff. This is anticipated to be mitigated by the construction of the remaining six detention basins in Council's basin strategy.

Future catchment conditions assumes the complete development of the new release areas within the catchment that have been identified to date, and the construction of all detention basins from Council's detention basin strategy. The date of future catchment conditions is referred to as 2026 for consistency with previous studies (Bewsher Consulting, 2004).

This Section represents Part 2 of the study brief for the project.

8.1 FUTURE DEVELOPMENT ASSUMPTIONS

A RAFTS model for future (2026) conditions was initially developed as part of the Cabramatta Creek Floodplain Management Study (Bewsher Consulting, 2004). This model was based on development of the new release areas identified on Figure 4.1 and other advice from Council officers. Since this date, some new release area boundaries have been amended and additional industrial and business areas defined. The Liverpool Local Environmental Plan 2008 (LLEP 2008) now provides additional details on the extent and permissible development within the new release areas. The RAFTS model for future (2026) conditions was updated in accordance with LLEP 2008, including LLEP 2008 Delayed Rezoning (north of Campbelltown Road at Ingleburn) and LLEP 2008 LZN Amendment 1 (north of Hoxton Park Airport in Cecil Hills), as shown on **Figure 8.1**.

The RAFTS flows have been input to an updated TUFLOW model to determine the impact of increased catchment flows on flood behaviour. The TUFLOW model includes all existing and proposed detention basins within the catchment, but does not allow for potential changes to the existing creek system, including change in floodplain storage or flood conveyance. Major upgrades to Cowpasture Road and Camden Valley Way are also excluded from the current assessment.

Special consideration was given to a development at Middleton Grange that is now underway. Middleton Grange occupies a small portion of the Hinchinbrook Creek catchment on the western side of the M7. The development includes a water management plan that includes the construction of up to 10 wetlands (including detention storage), a number of 'rain gardens', and other channel treatment works. These water management features have been designed (by others) to mitigate the impact of the Middleton Grange development on flood behaviour. This area was not included in the TUFLOW model for future (2026) conditions given the complexity of these measures and the level of investigations previously undertaken. Post-developed flow hydrographs were extracted from the previous investigations at the downstream boundary of the Middleton Grange development and used as inflow conditions to the TUFLOW model.

Further consideration was also given to the Yarrunga Industrial Estate at Prestons, where a proposed drain beside Bernera Road will divert a small portion of natural catchment flows from Maxwells Creek to Cabramatta Creek. Whilst the drain is not included in the TUFLOW model for future (2026) conditions, the RAFTS catchment flows have been re-proportioned in the TUFLOW model to account for this diversion.

FIGURE 8.1
Liverpool LEP 2008 & Delayed Zoning

8.2 FUTURE DETENTION BASINS

The six future detention basins have been included in the flood models for future (2026) conditions. These have been based on the latest design drawings (where available) or alternatively from details included in the original basin strategy. The basins have been analysed in both the RAFTS and TUFLOW models. The TUFLOW analysis is considered to be the most reliable assessment, as it accounts for the hydraulic impact of the basin on the natural floodplain and the effects of downstream flood levels on basin outflows.

Results from the analysis of these basins are discussed below. The overall impact on flood behaviour throughout the catchment is discussed in Section 8.4.

8.2.1 Basin 3B

Basin 3B is located in the upper reaches of Hinchinbrook Creek on a small tributary creek, previously referred to as Creek K. Its location coincides with an existing farm dam, and it was originally assumed that the existing dam wall could be raised by about 2m to provide additional flood storage. A geotechnical assessment of the embankment carried out in 1990 revealed that the dam wall was not sufficiently stable to permit further raising. The existing dam wall would therefore need to be totally reconstructed in order to provide additional flood storage.

The original basin strategy identified a storage volume of 84,000 m^3 for this basin.

This is a particularly good site for a basin, which could be formed with little or no site excavation apart from the foundations for the new embankment. Increased flood storage can also be provided relatively easily with only a modest increase in embankment height (of the order of 1.0 to 1.5m). **Figure 8.2** shows a possible basin configuration (Bewsher Consulting 2006) which provides a flood storage volume of approximately 180,000m^3. In view of the ease of providing additional storage at this location, the enlarged basin storage is recommended for further consideration.

A concept design report for the basin was recently prepared for Mirvac (Cardno, 2010). The concept design provides for a reduction in the normal water level in the existing dam (to RL 52.0m AHD) and an increase in embankment height (to RL 57.5m AHD). The normal outlet for the basin is via a 1350mm diameter pipe and 3x2400x1200 box culverts at a higher level. There is also a bank of 20x3000x1200 box culverts that act as a spillway in floods greater than a 100 year event. The concept design notes a 100 year top water level of RL 55.7m AHD, and an active storage volume of 180,000 m^3.

The basin was included in the RAFTS and TUFLOW models using the basin parameters described above. The DEM for the basin footprint was adjusted to account for the lowering of the permanent water level from RL 53.8m AHD (at the date of the 2008 ALS survey) to RL 52.0m AHD. The adjustment was based on an inspection of available aerial photography and an estimated water surface area of 1.5Ha at RL 52.0m. The storage provided from the adjusted DEM is about 8% greater than the volume quoted in the Cardno concept report (at RL 55.7m AHD). Further survey will be required prior to detailed design, particularly below the existing water surface area.

Details of the results of the RAFTS and TUFLOW assessment for Basin 3B is provided in **Table 8.1**. Results indicate that the basin provides a significant reduction in peak flows for both the 2 hour and 9 hour floods. The maximum storage occurs for the 9 hour flood, where it is estimated that the basin will reach a level of RL 55.86m AHD. This level is 0.16m higher than the level estimated in the concept design report. The difference is relatively small, and most likely due to different modelling assumptions and differences in the assumed stage/storage characteristics of the site. Consideration could be given to increasing the low flow outlet pipe (to 1500mm diameter) to reduce the maximum level in the basin to the spillway level (RL55.74).

Table 8.1
Basin 3B Assessment

Design Parameters		
Low Flow Outlet	1x1350 diameter pipe at RL52.0m AHD	
Supplementary low flow outlet	3x2400x1200 RCBC at RL 55.4m AHD	
Spillway	20x3000x1200 RCBC at RL 55.74m AHD	
Embankment Height	RL 57.5m AHD	
RAFTS Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Peak Inflow (m^3/s)	44.1	31.6
Peak Outflow (m^3/s)	7.7	12.9
Maximum Stage (m AHD)	55.48	55.81
Maximum Storage (m^3)	173,400	205,000
TUFLOW Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Maximum Stage (m AHD)	55.58	55.86
Maximum Storage (m^3)	182,900	210,400

8.2.2 Basin 4

Basin 4 is located within the Hinchinbrook Creek floodplain at Cecil Hills, and would replace an existing water quality basin. The basin receives flood flows from a tributary creek, referred to as Creek J. Two upstream detention basins have been constructed on this tributary (Basin 200 and the Lord Howe Drive basin). Given the proximity of the basin to Hinchinbrook Creek, it is also possible for the basin to receive flood flows from Hinchinbrook Creek as well.

The original basin strategy nominated a storage volume of 183,000m^3 for the basin. A preliminary basin layout, shown on **Figure 8.3**, was prepared during an earlier basin strategy review (Bewsher Consulting, 2006). The preliminary layout provided a slightly smaller storage volume of 170,000m^3 and relied on extensive excavation from within the basin footprint. A revised DEM covering the basin footprint was developed using the latest 2008 ALS survey and allowing for the proposed excavation within the basin. This revised DEM indicates that the available storage within the basin may be limited to about 159,000m^3 at the proposed top water level of RL 44.0.

This is a difficult basin site to obtain the nominated storage volume included in the basin strategy. The basin embankment has to be kept well clear of Hinchinbrook Creek to: avoid disturbance to existing vegetation within the creek corridor; for stability issues; and to minimise any reduction in the flood conveyance of the Hinchinbrook Creek floodplain. Substantial excavation within the basin footprint is required which will significantly increase the cost of the basin. The top water level within the basin is also constrained by the proximity of houses in Athlone Street, immediately upstream of the basin.

The basin was included in the RAFTS and TUFLOW models using the latest site storage parameters. A single cell 1800x900 box culvert was assumed for the normal outlet, as per the original strategy. Results of the assessment are included in **Table 8.2**.

Table 8.2
Basin 4 Assessment

Design Parameters		
Low Flow Outlet	1x1800x900 RCBC at RL41.2m AHD	
Supplementary low flow outlet	No	
Spillway	Assumed 50m wide at RL 44.0m AHD	
Embankment Height	Assumed 44.50m AHD merging with NGL	
RAFTS Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Peak Inflow (m^3/s)	22.4	16.5
Peak Outflow (m^3/s)	5.2	6.0
Maximum Stage (m AHD)	42.83	43.21
Maximum Storage (m^3)	87,500	110,900
TUFLOW Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Maximum Stage (m AHD)	43.96	44.30
Maximum Storage (m^3)	156,400	177,000

The RAFTS and TUFLOW assessments for this basin varies markedly. RAFTS indicates that the basin is only partly filling, whilst TUFLOW indicates that the basin fills to a level 0.3m above the assumed spillway.

The RAFTS model is not considered to be an appropriate model for the assessment of this basin for the following reasons:

i) Flows from Hinchinbrook Creek spill into the basin on the upstream side, which is not considered in the RAFTS model;

ii) The outlet from the basin is affected by the tailwater level in Hinchinbrook Creek and RAFTS will overestimate the discharge from the basin;

iii) There is natural floodplain storage within the basin site before the basin is constructed, therefore results from the RAFTS analysis will overestimate the benefit of the basin in reducing downstream flows;

iv) The basin embankment itself will reduce the flood conveyance on the Hinchinbrook Creek floodplain, which can potentially increase flood levels along Hinchinbrook Creek.

Special care will need to be exercised when designing Basin 4. The design will need to be based on a hydraulic model (such as TUFLOW) rather than a hydrologic model (such as RAFTS), for the reasons listed above. The basin is also likely to be expensive to construct given the amount of excavation that is required and the costs may outweigh the benefits of the basin.

The benefit of Basin 4 to the overall basin strategy is further evaluated in Section 8.4.

8.2.3 Basin 6

Basin 6 was proposed in the Hinchinbrook Creek catchment, on the western side of Hoxton Park Airport, on a tributary known as Creek M. The original basin strategy proposed a basin with a storage capacity of 170,000 m^3 at this location.

Construction of a basin at this location was impacted by the construction of the M7 Motorway, which passes directly through the middle of the original basin site. The proposal is also potentially impacted by the Middleton Grange development on the southern side of the basin site.

A review of the basin was undertaken by Bewsher Consulting in June 2007, taking account of the various site constraints affecting the basin. The basin was relocated downstream by approximately 150m to avoid the Motorway embankment. A revised layout, shown on **Figure 8.4**, was able to provide a maximum storage volume of approximately 122,000m^3.

The reduced storage capacity of the basin was considered to provide reasonable performance in reducing downstream peak flows. The peak inflow to the basin was estimated to be reduced from about 19m^3/s to 4m^3/s in the 100 year flood.

A report on a modified version of this basin was prepared by J Wyndham Prince in February 2010. The report maintains a similar storage volume and outlet pipe size, but relies on additional excavation within the basin to reduce the basin footprint. The maximum water level within the basin has also been raised by 1m to RL 45.5m AHD (the level of the spillway). This provides additional development potential to the east of the basin. Council advised that the modified basin should be included in the flood models.

A revised DEM representing the proposed excavation within the basin was prepared and included in the flood models. Results from the assessment of the modified basin are included in **Table 8.3**.

Table 8.3
Basin 6 Assessment

Design Parameters		
Low Flow Outlet	1x1050 diameter pipe at RL41.5m AHD	
Supplementary low flow outlet	No	
Spillway	60m wide at RL 45.5m AHD	
Embankment Height	46.50m AHD (north) to 47.0m AHD (south)	
RAFTS Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Peak Inflow (m^3/s)	19.5	14.2
Peak Outflow (m^3/s)	3.4	3.7
Maximum Stage (m AHD)	44.25	44.73
Maximum Storage (m^3)	82,700	105,500
TUFLOW Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Maximum Stage (m AHD)	44.36	44.95
Maximum Storage (m^3)	87,900	115,900

The TUFLOW model and RAFTS model results are relatively similar, with TUFLOW providing slightly higher levels within the basin, and a maximum storage volume of 115,900m^3. This is marginally below the 122,000m^3 storage capacity from the previous basin layout. The water level in the basin is below the level of the spillway and there may be some scope to fine tune the basin outlet to maximise the available storage volume.

The basin site has been zoned SP2 – Special Purpose (Infrastructure). The zone boundary is closely aligned with the previous basin layout, shown on Figure 8.4. The modified basin has a different basin footprint and is not totally consistent with the current zone boundaries. Some amendment to the zoning boundaries may therefore be required.

8.2.4 Basin 11C

Basin 11C is located in the upper reaches of Cabramatta Creek, on a small tributary known as Creek E. A single basin with a storage volume of 55,000m^3 was originally nominated in the basin strategy at this location. This basin was subsequently divided into three smaller basins, known as Basins 11A, 11B and 11C. Basin 11C is the last of these basins to be constructed.

The preliminary basin layout, shown on **Figure 8.5**, is based on a design prepared by Liverpool City Council during 2004. It provides a storage volume of just less than 35,000m^3 to the spillway level. Detailed design drawings have also recently been prepared by GHD, which are consistent with the earlier design.

Basin 11C has been included in the RAFTS and TUFLOW models. Results of the assessment of the basin are summarised in **Table 8.4**.

Table 8.4
Basin 11C Assessment

Design Parameters		
Low Flow Outlet	1x1500x1200 RCBC at RL 39.0m AHD	
Supplementary low flow outlet	No	
Spillway	30m wide at RL 42.7m AHD	
Embankment Height	43.0m AHD	
RAFTS Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Peak Inflow (m^3/s)	21.3	11.0
Peak Outflow (m^3/s)	8.8	8.4
Maximum Stage (m AHD)	41.96	41.68
Maximum Storage (m^3)	15,600	11,400
TUFLOW Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Maximum Stage (m AHD)	42.33	42.65
Maximum Storage (m^3)	24,100	33,500

The TUFLOW model results are consistent with the design objectives for the basin. The basin fills to a maximum level within 0.05m of the spillway, with an estimated maximum storage volume of 33,500m^3 in the 9 hour 100 year flood.

8.2.5 Basin 12

Basin 12 was originally located on Cabramatta Creek, immediately upstream of Camden Valley Way. The original basin strategy nominated a storage volume of 89,000m^3 for the basin.

The basin was relocated approximately 600m upstream to Jardine Drive, as part of a Masterplan developed for the Edmondson Park Release area. The location of the new basin is shown on **Figure 8.6**, as proposed in the masterplan.

A DEM was prepared for the basin based on a digital survey of the proposed basin provided by Council, including proposed embankments and excavation levels within the basin footprint. Details of the proposed outlet structure were provided in a design drawing prepared by J Wyndham Prince (Plan No. 8982/SK1 and 8982/SK2). Details shown on the plan show a 3 cell 2400x2100 box culvert outlet, with a 300mm thick substrate layer reducing the effective height of the culverts to 1800mm. A notation on the plan suggests that these culverts are to be amended to 2x2400x1800 plus 1x2700x1800 culverts, with an effective height of 1500mm.

Basin 12 was initially included in the RAFTS and TUFLOW models with the amended dimensions shown above. Results from both analysis indicated that the basin was only partly filling in both the 2 hour and 9 hour 100 year floods. The 2 hour flood filled the basin to RL 46.15m AHD (approximately 0.85m below the proposed spillway level) with an estimated storage volume of 55,000m^3. The 9 hour flood was even less effective, with a maximum height of RL 45.78m AHD and an estimated storage volume of 33,000m^3. Consequently, it was decided to further reduce the size of the basin outlet to better utilise the storage available within the basin. The basin outlet was reduced to 3x1800x1800 box culverts (with an effective height of 1500mm). Results from the analysis with the reduced basin outlet are provided in **Table 8.5**.

Table 8.5
Basin 12 Assessment

Design Parameters		
Low Flow Outlet	3x1800x1500 (effective) RCBC at RL 42.3m AHD	
Supplementary low flow outlet	No	
Spillway	75m wide at RL 47.0m AHD	
Embankment Height	Assumed infinitely high	
RAFTS Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Peak Inflow (m^3/s)	70.2	48.3
Peak Outflow (m^3/s)	41.6	37.4
Maximum Stage (m AHD)	46.64	46.07
Maximum Storage (m^3)	91,400	49,200
TUFLOW Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Maximum Stage (m AHD)	46.62	46.20
Maximum Storage (m^3)	90,000	58,700

With the reduced basin outlet, Basin 12 now fills to a maximum height of RL 46.64m AHD in the 2 hour 100 year flood. This is still some 380mm below the proposed spillway level, but provides a maximum storage volume of 90,000m^3, which is consistent with the volume originally nominated in the basin strategy for Basin 12. The smaller outlet also helps to improve the performance of the basin in the 9 hour flood, which is more critical for flood behaviour downstream of Camden Valley Way.

8.2.6 Basin 14

Basin 14 was originally located on a tributary of Maxwells Creek, upstream of Croatia Avenue. The original basin strategy nominated a storage capacity of 50,000m^3 for the basin. The basin was relocated approximately 400m downstream as part of the Edmondson Park Master Plan, and is now located immediately upstream of Camden Valley Way, as shown on **Figure 8.6**.

A DEM was prepared for the site based on a digital survey and contour levels provided by Council. A layout plan was also provided that includes details of the proposed basin outlet (Maxwells Creek, North Riparian Park, Plan 8183SK6). The plan shows a single 1200x1200 box culvert and a 15m wide spillway at RL 39.65m AHD.

The basin was included in the RAFTS and TUFLOW models with the outlet details shown above. Results from the analysis indicated that the basin filled to a maximum height 0.34m above the spillway level in the 2 hour 100 year flood. The storage provided at this level is estimated at 57,300m^3.

It is unclear whether or not the basin spillway is intended to operate in floods more frequent than the 100 year flood. Assuming that this is not intended, a larger basin outlet would be required and/or the height of the spillway increased. A revised outlet was adopted for the basin, comprising 2x1200x1200 box culverts and the spillway raised to RL 40.0m AHD. Details of the assessment are included in **Table 8.6**.

Table 8.6
Basin 14 Assessment

Design Parameters		
Low Flow Outlet	3x1500x1200 RCBC at RL 36.65m AHD	
Supplementary low flow outlet	No	
Spillway	15m wide at RL 40.0m AHD	
Embankment Height	Assumed infinitely high	
RAFTS Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Peak Inflow (m^3/s)	33.7	18.6
Peak Outflow (m^3/s)	16.6	13.9
Maximum Stage (m AHD)	39.70	39.10
Maximum Storage (m^3)	37,000	16,700
TUFLOW Results (100yr)	**2 Hour Flood**	**9 Hour Flood**
Maximum Stage (m AHD)	39.98	39.42
Maximum Storage (m^3)	48,000	27,000

With the revised outlet, the basin fills to a maximum level of RL 39.98m in the 2 hour 100 year flood. The storage provided at this level is estimated at 48,000m^3, which is relatively consistent with the storage volume nominated in the original basin strategy.

FIGURE 8.2
Basin 3B Layout

FIGURE 8.3
Basin 4 Layout

FIGURE 8.4
Basin 6 Revised Concept Layout

FIGURE 8.5
Basin 11C Layout

FIGURE 8.6
Basin 12 and Basin 14

8.3 DESIGN FLOOD BEHAVIOUR (2026 CONDITIONS)

Flood behaviour under future (2026) conditions has been analysed for the 20 year and 100 year floods. A map showing the extent of flood inundation and flood level contours for the 100 year flood is provided on **Figure 8.7**. This represents the maximum from the 2 hour and 9 hour flood simulations.

Future (2026) conditions allow for the increase in catchment runoff from the full development of the new release areas, and the construction of all remaining basins in the basin strategy. It does not allow for upgrading of other infrastructure within the catchment, such as the upgrading of Cowpasture Road and Camden Valley Way, or for potential changes to the existing creek and floodplain system.

Future (2026) flood behaviour can be compared with flood behaviour for existing (2008) or previous (1989) catchment conditions, to determine any changes in flood behaviour over these time periods. The change in flood level over the period from 1989 to 2026 has been determined for the 20 year and 100 year floods, and is shown on **Figure 8.8** and **Figure 8.9**.

8.4 PERFORMANCE OF BASIN STRATEGY (1989 to 2026)

The change in the 20 year flood over the period from 1989 to 2026 is shown on **Figure 8.8**. A large portion of the floodplain shows little change in flood levels (within 0.2m). The main exceptions include:

i) the location of detention basins, where flood levels increase due to the deliberate containment of floodwater at these locations;

ii) Lower Cabramatta Creek, between Cartwright Avenue and the Hume Highway, where flood levels have increased generally by 0.2 to 0.3m; and

iii) localised areas adjacent to the M7 motorway where some ponding of floodwater is evident.

The change in the 100 year flood over the period from 1989 to 2026 is shown on **Figure 8.9**. These results are generally similar to the 20 year results, with a large portion of the floodplain showing little change in flood levels (within 0.2m). The main exceptions include:

i) the location of detention basins, where flood levels increase due to the deliberate containment of floodwater, as noted for the 20 year flood;

ii) Lower Cabramatta Creek, between Hoxton Park Road and Orange Grove Road, where flood levels are generally reduced by 0.2 to 0.3m, which is in contrast to the flood level increases in this region that were noted for the 20 year flood;

iii) Hinchinbrook Creek, where flood levels have generally reduced by around 0.2m;

iv) Maxwells Creek, where flood level have reduced by up to 0.2m; and

v) localised areas adjacent to the M7 motorway where some ponding of floodwater is evident, as noted for the 20 year flood.

The flood level reductions for the 100 year flood over the period from 1989 to 2026 (Figure 8.9) are more significant than the flood level reductions derived for the period from 1989 to 2008 (Figure 6.4). This indicates that the remaining basins still to be constructed will more than compensate for the additional development that is anticipated to occur.

The results also indicate that the basin strategy provides more beneficial results for the 100 year flood than it does for more frequent floods, particularly in the lower reaches of Cabramatta Creek. Whilst flood level reductions of 0.2 to 0.3m are evident in the 100 year flood, much of this area experiences small increases in flood levels during the 20 year flood.

It is noted that all basins in the catchment have been designed on the basis of optimal performance in the 100 year flood. The basins are less effective in reducing peak flows in more frequent events, and consequently the basin strategy is less successful in mitigating the full impact of catchment development.

Practical issues associated with the construction of Basin 4 have previously been noted (in Section 8.2.2). Council subsequently requested further evaluation of the merits of constructing this basin. A second TUFLOW model was prepared for 2026 conditions without Basin 4. Results from this model were again compared with 1989 conditions for the 100 year flood to see how the omission of the basin impacts on the overall success of the basin strategy. The difference in flood levels, shown on **Figure 8.10**, indicates that there is still an overall reduction in flood levels throughout the majority of the catchment. This suggests that Basin 4 is not critical to the overall success of the basin strategy.

Whilst the basin strategy is not reliant on the construction of Basin 4, the omission of the basin will lead to an increase in design flood levels in future (2026) conditions than would otherwise have occurred. The estimated increase in the 100 year flood is shown on Figure 8.10. Flood levels are estimated to increase by an average of 0.04 to 0.06m along Hinchinbrook Creek, with some locally higher increases evident upstream of Cowpasture Road (0.09m) and opposite the Government Road basin (0.19m). Similar increases of between 0.04 to 0.06m persist throughout much of Lower Cabramatta Creek. Despite these increases, the estimated 100 year flood level under future (2026) conditions is still generally lower than the estimated 100 year flood level under previous (1989) conditions.

There are benefits in constructing Basin 4. There is existing development that is subject to flooding along Lower Cabramatta Creek, and the additional reduction in flood levels may provide some benefit to these residents. Basin 4 may also provide more significant benefit in the more frequent floods, where some increases over the period from 1989 to 2026 have previously been noted.

Further evaluation of the costs and benefits associated with the construction of Basin 4 are recommended. Pending these investigations, it is recommended that the basin be given a lower priority for construction than the other basins that remain to be constructed. The basin could also be reserved in case required due to further (unforseen) development within the catchment, or if new assessment methods provide a less favourable review of the performance of the basin strategy.

FIGURE 8.7
Design 100 Year Flood for Future (2026) Conditions

FIGURE 8.8
Change in 20 Year Flood Level Estimate
Due to Catchment Development (1989 to 2026)

FIGURE 8.9
Change in 100 Year Flood Level Estimate
Due to Catchment Development (1989 to 2026)

FIGURE 8.10
Change in 100 Year Flood Level Estimate
Due to Catchment Development (1989 to 2026)
Basin 4 Omitted

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10 GLOSSARY

Note that terms shown in bold are described elsewhere in this Glossary.

100 year flood	A **flood** that occurs on average once every 100 years. Also known as a 1% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
50 year flood	A **flood** that occurs on average once every 50 years. Also known as a 2% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
20 year flood	A **flood** that occurs on average once every 20 years. Also known as a 5% flood. See **annual exceedance probability (AEP)** and **average recurrence interval (ARI)**.
afflux	The increase in flood level upstream of a constriction of flood flows. A road culvert, a pipe or a narrowing of the stream channel could cause the constriction.
annual exceedance probability (AEP)	AEP (measured as a percentage) is a term used to describe **flood** size. It is a means of describing how likely a flood is to occur in a given year. For example, a 1% AEP flood is a **flood** that has a 1% chance of occurring, or being exceeded, in any one year. It is also referred to as the ‘100 year flood’ or 1 in 100 year flood’. The terms **100 year flood**, **50 year flood**, **20 year flood** etc, have been used in this study. See also **average recurrence interval (ARI)**.
Australian Height Datum (AHD)	A common national plane of level approximately equivalent to the height above sea level. All **flood levels**, floor levels and ground levels in this study have been provided in metres AHD.
average annual damage (AAD)	Average annual damage is the average flood damage per year that would occur in a nominated development situation over a long period of time.
average recurrence interval (ARI)	ARI (measured in years) is a term used to describe **flood** size. It is the long-term average number of years between floods of a certain magnitude. For example, a 100 year ARI flood is a flood that occurs or is exceeded on average once every 100 years. The terms **100 year flood**, **50 year flood**, **20 year flood** etc, have been used in this study. See also **annual exceedance probability (AEP)**.
catchment	The land draining through the main stream, as well as tributary streams.
Development Control Plan (DCP)	A DCP is a plan prepared in accordance with Section 72 of the *Environmental Planning and Assessment Act, 1979* that provides detailed guidelines for the assessment of development applications.
DNR	Department of Natural Resources, formerly the Department of Infrastructure, Planning & Natural Resources (DIPNR).
discharge	The rate of flow of water measured in terms of volume per unit time, for example, **cubic metres per second (m^3/s)**. Discharge is different from the speed or **velocity** of flow, which is a measure of how fast the water is moving.
ecologically sustainable development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the *Local Government Act 1993*.

effective warning time	The time available after receiving advice of an impending **flood** and before the floodwaters prevent appropriate flood response actions being undertaken. The **effective warning time** is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport their possessions.
emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
EP&A Act	*Environmental Planning and Assessment Act, 1979*.
extreme flood	An estimate of the **probable maximum flood (PMF)**, which is the largest flood likely to occur.
flood	A relatively high stream flow that overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or local overland flooding associated with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
flood awareness	An appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
flood hazard	The potential for damage to property or risk to persons during a **flood**. Flood hazard is a key tool used to determine flood severity and is used for assessing the suitability of future types of land use.
flood level	The height of the **flood** described either as a depth of water above a particular location (eg. 1m above a floor, yard or road) or as a depth of water related to a standard level such as **Australian Height Datum** (eg the flood level was 7.8m AHD). Terms also used include **flood stage** and **water level**.
flood liable land	Land susceptible to flooding up to the **probable maximum flood (PMF)**. Also called **flood prone land**. Note that the term flood liable land now covers the whole of the **floodplain**, not just that part below the **flood planning level**.
flood planning levels (FPLs)	The combination of flood levels and **freeboards** selected for planning purposes, as determined in **floodplain management studies** and incorporated in **floodplain management plans**. The concept of flood planning levels supersedes the designated flood or the flood standard used in earlier studies.
flood prone land	Land susceptible to flooding up to the **probable maximum flood (PMF**). Also called **flood liable land**.
flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate damages during a **flood**.
flood stage	see **flood level**.
flood study	A study that investigates flood behaviour, including identification of flood extents, **flood levels** and flood velocities for a range of flood sizes.
floodplain	The area of land that is subject to inundation by floods up to and including the probable maximum flood event, that is, **flood prone land** or **flood liable land**.
Floodplain Risk Management Plan	The outcome of a **Floodplain Risk Management Study**.

Floodplain Risk Management Study	Studies carried out in accordance with the *Floodplain Development Manual* (NSW Government, 2005) that assesses options for minimising the danger to life and property during **floods**. These measures, referred to as 'floodplain management measures/options', aim to achieve an equitable balance between environmental, social, economic, financial and engineering considerations. The outcome of a Floodplain Risk Management Study is a **Floodplain Risk Management Plan**.
floodway	Those areas of the **floodplain** where a significant discharge of water occurs during **floods**. Floodways are often aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in **flood levels**.
flow	see **discharge**
foreshore building line	A line fixed by resolution of Council in respect of land fronting any bay, river, creek, lagoon, harbour or ocean, which provides a setback distance where buildings or other structures would normally be prohibited.
freeboard	A factor of safety expressed as the height above the **design flood level**. Freeboard provides a factor of safety to compensate for uncertainties in the estimation of flood levels across the **floodplain**, such and wave action, localised **hydraulic** behaviour and impacts that are specific event related, such as levee and embankment settlement, and other effects such as "greenhouse" and climate change.
high flood hazard	For a particular size **flood**, there would be a possible danger to personal safety, able-bodied adults would have difficulty wading to safety, evacuation by trucks would be difficult and there would be a potential for significant structural damage to buildings.
hydraulics	Term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and **velocity**.
hydrology	Term given to the study of the rainfall and runoff process; in particular, the evaluation of **peak discharges**, flow volumes and the derivation of hydrographs (graphs that show how the discharge or stage/flood level at any particular location varies with time during a flood).
Local Environmental Plan (LEP)	A Local Environmental Plan is a plan prepared in accordance with the *Environmental Planning and Assessment Act*, 1979, that defines zones, permissible uses within those zones and specifies development standards and other special matters for consideration with regard to the use or development of land.
low flood hazard	For a particular size flood, able-bodied adults would generally have little difficulty wading and trucks could be used to evacuate people and their possessions should it be necessary.
m AHD	metres **Australian Height Datum (AHD)**.
m/s	metres per second. Unit used to describe the **velocity** of floodwaters.
m^3/s	Cubic metres per second or 'cumecs'. A unit of measurement for creek or river flows or **discharges**. It the rate of flow of water measured in terms of volume per unit time.

merit approach	The principles of the merit approach are embodied in the *Floodplain Development Manual* (NSW Government, 2005) and weigh up social, economic, ecological and cultural impacts of land use options for different **flood prone** areas together with flood damage, **hazard** and behaviour implications, and environmental protection and well being of the State's rivers and **floodplains**.
overland flow path	The path that floodwaters can follow if they leave the confines of the main flow channel. Overland flow paths can occur through private property or along roads. Floodwaters travelling along overland flow paths, often referred to as 'overland flows', may or may not re-enter the main channel from which they left — they may be diverted to another water course.
peak discharge	The maximum **flow** or **discharge** during a flood.
present value	In relation to flood damage, is the sum of all future flood damages that can be expected over a fixed period (usually 20 years) expressed as a cost in today's value.
probable maximum flood (PMF)	The largest flood likely to ever occur. The PMF defines the extent of **flood prone land** or **flood liable land**, that is, the **floodplain**. The extent, nature and potential consequences of flooding associated with the PMF event are addressed in the current study.
reliable access	During a **flood**, reliable access means the ability for people to safely evacuate an area subject to imminent flooding within **effective warning time**, having regard to the depth and **velocity** of floodwaters, the suitability of the evacuation route, and other relevant factors.
risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
runoff	The amount of rainfall that ends up as flow in a stream, also known as rainfall excess.
SES	State Emergency Service of New South Wales.
stage–damage curve	A relationship between different water depths and the predicted flood damage at that depth.
velocity	the term used to describe the speed of floodwaters, usually in **m/s**.
water level	see **flood level**.
water surface profile	A graph showing the height of the **flood** (**flood stage**, **water level** or **flood level**) at any given location along a watercourse at a particular time.

APPENDIX A

RAFTS Model Flow Estimates For 2008 Catchment Conditions

(Note: M7 detention basins not included in the RAFTS model.
TUFLOW estimates will be more accurate through the mid to lower catchment.)

Table A.1
2008 Peak Flow Estimates: Cabramatta Creek – Down to Hinchinbrook Creek

Link No.	Subcatchment Description	20 YEAR		100 YEAR		PMF	
		Flow (m^3/s)	Crit. Dur. (min)	Flow (m^3/s)	Crit. Dur. (min)	Flow (m^3/s)	Crit. Dur. (min)
1.00A	Denham Court	2	120	3	120	13	60
1.00B	Denham Court	6	120	8	120	36	60
1.00C	Denham Court	8	120	12	120	51	60
1.00D	Denham Court	10	120	15	120	65	60
1.00G	Denham Court	3	120	5	120	20	60
1.00E	Denham Court	3	120	4	120	15	60
1.00F	Denham Court	9	120	12	120	53	60
1.00H	Denham Court	21	120	29	120	129	60
1.00I	Denham Court	25	120	35	120	154	60
1.00J	Denham Court	3	120	4	120	17	60
1.00K	Denham Court	6	120	8	120	31	60
1.00L	Denham Court	34	120	47	120	201	60
1.00M	Denham Court	36	120	50	120	216	60
1.01	Cab Ck J'dine Dr	42	120	59	120	257	60
1.02	Cab Ck J'dine Dr	46	120	65	120	286	60
1.03	Cabramatta Creek	51	120	72	120	312	60
2.00A	Lawn Cemetery	2	120	3	120	13	60
2.00B	Lawn Cemetery	4	120	6	120	33	60
2.00C	Lawn Cemetery	7	120	10	120	55	60
2.00D	Lawn Cemetery	4	120	6	120	27	60
2.00E	Lawn Cemetery	12	120	17	120	90	60
2.01A		2	120	3	120	15	60
2.01B		4	120	6	120	31	60
2.01C		17	120	24	120	123	60
2.02		19	120	26	120	133	60
1.04	Cam. Valley Way	67	120	94	120	403	60
1.05	Cabramatta Creek	68	120	95	120	405	60
25.00		11	90	13	90	42	15
1.06	Cabramatta Creek	69	120	96	120	404	120
26.00		8	90	11	90	33	15
1.07	Cab Ck. Bazaar	70	120	98	120	413	120
1.08A	Cabramatta Creek	71	120	99	120	421	120
3.00A	Creek E	4	120	5	120	24	60
3.00B	Ck E C'psture Rd	6	120	8	120	37	60
3.01	Creek E	9	120	12	120	52	60
4.00A	Ck E C'psture Rd	7	90	9	90	26	30
4.00B	Creek E	8	120	11	120	37	60
3.02	Creek E	11	120	14	120	71	60
3.03A	Ck E C'psture Rd	9	90	11	90	37	15
3.03B	Ck E C'psture Rd	10	90	13	120	45	15
3.03C	Ck E Golf Course	15	120	19	120	89	60
3.04		20	120	25	120	107	120
1.08B	Cabramatta Creek	81	120	111	120	527	120
1.09A		8	90	10	90	31	15
1.09B		10	90	12	90	43	15
1.09C	Cab Ck K'jong Rd	83	120	113	120	545	120
1.10A		4	90	6	90	21	60
1.10B		6	90	8	90	33	60
1.10C	Cab Ck Y'nga Rd	86	120	116	120	582	120
1.10D		87	120	118	120	599	120
5.00A	Creek A	2	540	3	120	15	120
5.00B	Creek A	6	120	9	120	47	60
5.01A	Creek A	3	120	5	120	24	60
5.01B	Creek A	4	120	5	120	25	60
5.01C	Creek A	10	120	14	120	74	60
5.01D	Creek A	11	120	16	120	79	60
5.02	Creek A	15	120	21	120	90	120
27.00	Creek A	3	120	4	120	27	60
5.03	Creek A	18	120	25	120	106	120
5.04	Ck A C'psture Rd	18	90	23	90	114	120
5.05	Ck A 19th Ave	16	90	21	720	118	240
5.06	Ck A 1st Ave	18	90	23	90	122	240
1.11	Cabramatta Creek	98	120	130	120	674	120

Note: For detention basins, critical duration is shown for inflow only. M7 Basins not included in RAFTS.

Table A.2
2008 Peak Flow Estimates: Hinchinbrook Creek

Link No.	Subcatchment Description	20 YEAR Flow (m³/s)	20 YEAR Crit. Dur. (min)	100 YEAR Flow (m³/s)	100 YEAR Crit. Dur. (min)	PMF Flow (m³/s)	PMF Crit Dur. (min)
11.00	Creek J	8	90	10	90	29	60
11.01	Creek J	11	90	14	90	46	60
12.00A	Creek J	13	90	16	90	46	15
12.00B	Ck J C'psture Rd	20	90	25	90	78	60
11.02	Creek J	13	120	21	120	117	60
11.03	Creek J	14	120	23	120	122	60
9.00A	Creek K	4	120	6	120	27	60
9.00B	Creek K	6	120	8	120	36	60
9.00C	Creek K	4	120	6	120	26	60
9.00D	Creek K	12	120	16	120	72	60
9.00E	Creek K	3	120	4	120	18	60
9.00F	Ck K Liv. R'voir	9	120	12	120	48	60
9.00G	Creek K	13	120	19	120	79	60
9.00H	Creek K	24	120	33	120	141	60
10.00A	Creek K	4	120	5	120	20	60
10.00B	Creek K	6	120	8	120	34	60
9.01	Ck K Ex. Dam	32	120	44	120	184	60
9.02	Creek K	35	120	49	120	194	60
6.00A	Elizabeth Dr.	5	120	8	120	35	60
6.00B	Creek K	15	90	19	90	59	60
7.00A	Elizabeth Dr.	6	540	8	540	40	120
7.00B	Creek K	21	90	26	90	65	15
6.01	Creek K	27	90	33	90	116	60
6.02	Creek K	32	90	40	90	132	60
8.00C	Creek K	4	120	6	120	22	30
8.00A	Creek K	5	120	7	120	22	30
8.00B	Creek K	7	120	9	120	31	30
8.00D	Creek K	12	120	17	120	59	30
8.00E	Creek K	16	120	22	120	75	60
6.03	Cecil Hls Wetland	40	90	51	90	203	60
6.04	Hinchinbrook Ck	20	540	24	540	200	60
6.05	Hinchinbrook Ck	53	120	70	120	390	60
6.06A		3	90	4	90	10	15
6.06B		6	90	7	90	26	60
6.06C	Hinchinbrook Ck	56	120	74	120	417	60
6.07	Hinchinbrook Ck	70	120	95	120	535	60
13.00A	Creek M	3	120	4	120	20	60
13.00B	Creek M	7	120	9	120	45	60
13.01	Creek M	9	120	12	120	59	60
14.00A	Creek M	2	120	3	120	17	60
14.00B	Creek M	4	120	6	120	30	60
13.02	Creek M	12	120	18	120	87	60
13.03	Ck M H Pk A'drme	15	120	21	120	99	60
6.08	Hinchinbrook Ck	84	120	116	120	632	60
6.09	Hinchinbrook Ck	86	120	120	120	640	60
28.00	C'psture Rd	27	90	33	90	94	15
6.10	Hinchinbrook Ck	94	120	130	120	663	60
6.11	Hinchinbrook Ck	96	120	132	120	665	60
6.12	Hinchinbrook Ck	96	120	133	120	664	60
15.00A	Creek N	3	120	4	120	19	60
15.00B	Ck N Mciver	5	120	7	120	35	60
15.01	Creek N	8	120	11	120	51	60
15.02	Ck N C'psture Rd	13	120	18	120	85	120
16.00A	Creek L	5	120	7	120	36	60
16.00B	Ck L 2nd Ave	7	120	10	120	48	60
16.01	Ck L C'psture Rd	13	120	18	120	84	60
15.03		25	120	35	120	163	120
6.13	Hinchinbrook Ck	114	120	160	120	811	120
6.14A		7	90	8	90	27	15
6.14B	Hinchinbrook Ck	115	120	161	120	823	120
6.14C		15	90	18	90	58	15
6.14D	Hinchinbrook Ck	118	120	166	120	859	120
17.00A	Creek C	4	120	5	120	26	60
17.00B	Ck C 2nd Ave	8	120	11	120	55	60
17.01	Ck C C'psture Rd	18	90	23	90	75	120
17.02B	Creek C	4	90	5	90	19	15
17.02A	Creek C	24	90	31	90	116	60
6.15	Hinchinbrook Ck	129	120	183	120	958	120
6.16		130	120	183	120	969	120

Note: For detention basins, critical duration is shown for inflow only. M7 Basins not included in RAFTS.

Table A.3
2008 Peak Flow Estimates: Cabramatta Creek – Hinchinbrook Creek to Maxwells Creek

Link No.	Subcatchment Description	20 YEAR		100 YEAR		PMF	
		Flow (m^3/s)	Crit. Dur. (min)	Flow (m^3/s)	Crit. Dur. (min)	Flow (m^3/s)	Crit Dur. (min)
1.12	Cab Ck I'roo Rd	219	120	293	120	1591	120
1.13	Cab Ck H. Pk Rd	221	120	296	120	1612	120
1.14C	Miller Creek	10	90	13	90	44	30
1.14A	Miller Ck Banks Rd	29	90	36	90	121	15
1.14B	Miller Creek	17	90	21	90	95	60
1.14D	Miller Ck Cart. Ave	24	90	30	90	139	60
1.14E	Miller Ck Cart. Ave	26	90	33	90	147	60
1.14F	Miller Ck Cart. Ave	226	120	303	120	1683	120
1.14G	Miller Ck Cart. Ave	226	120	304	120	1692	120
1.15	Miller Ck Cart. Ave	226	120	304	120	1697	120

Note: For detention basins, critical duration is shown for inflow only. M7 Basins not included in RAFTS

Table A.4
2008 Peak Flow Estimates: Maxwells Creek

Link No.	Subcatchment Description	20 YEAR		100 YEAR		PMF	
		Flow (m^3/s)	Crit. Dur. (min)	Flow (m^3/s)	Crit. Dur. (min)	Flow (m^3/s)	Crit Dur. (min)
23.00A	Creek I	8	90	10	90	32	60
23.00B	Creek I	9	90	11	90	41	60
23.01A	Creek I	13	90	17	90	78	60
23.01B	Creek I	14	120	19	90	85	60
22.00A	Creek B	5	90	7	90	23	60
22.00B	Ck B Skipton Lane	6	90	8	90	28	60
20.00A	Creek D	3	120	4	120	20	60
20.00B	Ck D Croatia Ave	5	120	7	120	37	60
20.01	Ck D C V Way	12	120	17	120	73	120
20.02	Ck D Ash Rd	13	120	18	120	81	120
21.00	Ck D Bernera Rd	16	90	20	90	55	15
21.01	Ck D Ash Rd	20	90	26	90	74	60
20.03		28	120	37	120	125	60
18.00A	I'burn Army Camp	7	90	9	90	26	60
18.00B	I'burn Army Camp	13	90	16	90	60	60
18.00C	I'burn Army Camp	17	90	23	90	88	60
18.00D	C'town Road	19	90	26	120	101	60
19.00A	I'burn Army Camp	4	90	5	90	20	60
19.00B	I'burn Army Camp	7	120	10	120	45	60
19.01A	I'burn Army Camp	13	120	18	120	78	60
19.01B	C'town Road	15	120	21	120	92	60
18.01	Maxwells Creek	33	120	47	120	191	60
18.02	Max Ck SW F'way	39	120	56	120	236	120
18.03A		9	90	12	90	38	60
18.03B	Max Ck C V Way	42	120	60	120	250	120
18.04A	Max Ck M5	42	120	59	120	250	120
18.04B	Maxwells Creek	43	120	60	120	254	120
18.05	Maxwells Creek	56	360	79	120	331	120
29.00A	Ck B M5	11	90	14	90	38	15
29.00B	Creek B	12	90	15	90	41	15
18.06	Maxwells Creek	58	120	81	120	340	120
18.07	Maxwells Creek	59	360	79	120	342	240
18.08	Maxwells Creek	63	120	80	360	354	240
18.09A		4	90	5	90	17	60
18.09B	Max Ck K'jong Rd	70	120	90	60	378	240
18.10	Max Ck Showgrnd	76	120	98	90	419	60
18.11	Max Ck Jedda Rd	80	120	100	90	430	60
18.12	Maxwells Creek	80	120	101	90	429	60
18.13	Max Ck Lyn Pde	93	120	113	90	513	60
18.14A	Maxwells Creek	99	120	118	90	525	60
18.14B	Max Ck Hox Pk Rd	105	120	121	120	549	120
18.15	Maxwells Creek	105	120	122	120	554	120

Note: For detention basins, critical duration is shown for inflow only. M7 Basins not included in RAFTS.

Table A.5
2008 Peak Flow Estimates: Cabramatta Creek – Maxwells Creek to Brickmakers Creek

Link No.	Subcatchment Description	20 YEAR		100 YEAR		PMF	
		Flow (m³/s)	Crit. Dur. (min)	Flow (m³/s)	Crit. Dur. (min)	Flow (m³/s)	Crit Dur. (min)
1.16	Cabramatta Creek	305	360	399	360	2162	120
1.17	Cab Ck Eliz Dr	310	360	407	360	2176	120
1.18A	Prout Ck	17	90	22	90	61	30
1.18B	Prout Ck	20	90	26	90	72	30
1.18C	Cabramatta Ck	315	360	414	360	2185	120
1.18D	Cab Ck O Grve Rd	318	360	420	360	2197	240
1.19	Cabramatta Creek	321	360	424	360	2216	240

Note: For detention basins, critical duration is shown for inflow only. M7 Basins not included in RAFTS.

Table A.6
2008 Peak Flow Estimates: Brickmakers Creek

Link No.	Subcatchment Description	20 YEAR		100 YEAR		PMF	
		Flow (m³/s)	Crit. Dur. (min)	Flow (m³/s)	Crit. Dur. (min)	Flow (m³/s)	Crit Dur. (min)
24.00C		4	90	5	90	15	60
24.00A		12	90	15	90	40	15
24.00B	Casula Mall Basin	18	90	23	90	82	60
24.00D	B'mkrs Ck K'jng Rd	12	90	13	90	93	60
24.01A	B'makers M5	19	90	22	90	111	60
24.01B		24	90	29	90	120	60
24.02D		20	90	25	90	72	60
24.02E		35	90	44	90	148	120
24.02F	B'm Ck Reilly Rd	39	90	50	90	176	60
24.02A		18	90	23	90	63	60
24.02B		23	90	30	90	93	60
24.02C	Hoxton Pk Road	28	90	35	90	112	60
24.02G	B'mkrs Ck H P Rd	60	120	78	120	286	60
24.03A	B'm Ck Memorial	64	120	84	120	299	60
24.03B	B'mkrs Ck Eliz Dr	67	120	89	120	306	60
24.04A	B'm Ck H'pde Ave	69	120	91	120	319	120
24.04B	Brickmakers Ck	72	120	93	120	339	120

Note: For detention basins, critical duration is shown for inflow only. M7 Basins not included in RAFTS.

Table A.7
Peak Flow Estimates: Cabramatta Creek - Brickmakers Creek to Georges River

Link No.	Subcatchment Description	20 YEAR		100 YEAR		PMF	
		Flow (m³/s)	Crit. Dur. (min)	Flow (m³/s)	Crit. Dur. (min)	Flow (m³/s)	Crit. Dur. (min)
1.20	Cabramatta Creek	354	540	462	360	2450	240
1.21	Cab Ck Railway	357	2160	465	360	2467	240
1.22	Cabramatta Creek	360	2160	467	360	2479	240
1.23	Cab Ck George R	364	2160	471	360	2496	240