STORMWATER FLOODING IN BANKSTOWN – THE HIDDEN THREAT, A CONSISTENT APPROACH TO MANAGING THE RISK

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Abstract

Bankstown Local Government Area (LGA) covers 77 square kilometres and is located 20 kilometres south west of Sydney. The LGA is fully developed with 60,000 dwellings and a population of 189,000, but was given a mandated target of accommodating an additional 22,000 dwellings by 2031 in the Governments Metropolitan Strategy. To ensure future development takes flood risk into consideration Bankstown City Council (BCC) accelerated the flood study and risk management program for stormwater catchments across its LGA.

Fully integrated one-dimensional / two-dimensional hydrodynamic modelling, using the TUFLOW software, has been utilised for simulating stormwater runoff. Several new features were implemented during the course of the studies, including direct rainfall modelling and pit inlet capacity curves. These features have allowed detailed catchment representation and the most accurate inundation and hazard mapping possible to aid in delivering the highest quality risk management and planning solutions.

Consistent use of one modelling software has allowed a streamlined transition to undertaking flood risk management plans on a major catchment basis i.e. two or more sub-catchments. Council actively engage with the community at this stage of the process and are committed to increasing flood awareness through information sessions and making flood information readily available on Councils website.

To date, Council has adopted Flood Studies in 16 of its 21 stormwater catchments; the remaining five Flood Studies are about to be adopted. Flood Risk Management Plans for six of these catchments are almost complete.

BCC have been at the forefront of developing innovative approaches to address the stormwater flooding problem. The paper highlights the strategic approach to flood risk management in Bankstown LGA, the significance of advances in methodologies in meeting Councils targets and the transition from flood study to flood risk management plan.

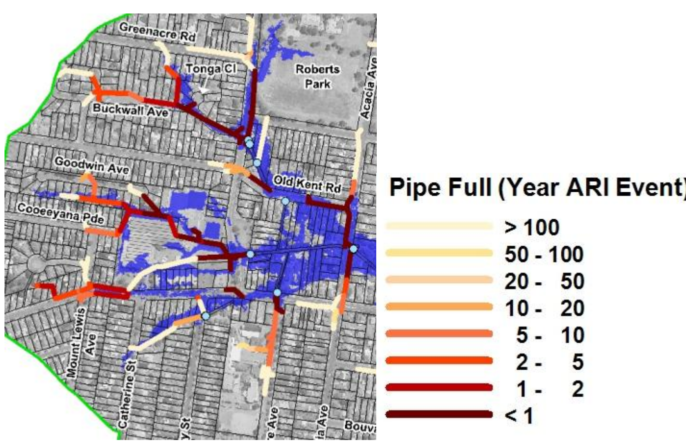

Figure 1: Example Study Output
Conduit Capacity and Overland Flow Mapping

Introduction

Bankstown Local Government Area (LGA) is located 20 kilometres south west of Sydney and covers an area of 77 square kilometres. The LGA is fully developed with 60,000 dwellings, which were mostly constructed in the 1950's and 1960's. In 2010, the LGA sustained a population of 189,000, which is the 4th largest population in a Sydney LGA (Australian Bureau of Statistics, 2011).

The Bankstown LGA is largely defined by the Georges River and its tributaries, Salt Pan Creek and Prospect Creek, its boundaries to the southeast, south and west. Other boundaries are a number of main roads on the north east and the Sydney Water supply pipeline to the north. Most of the LGA lies within the catchment of the Georges River. A small portion in the north is within the catchment of the Duck River which flows to the Parramatta River, and another small catchment in the north-east flows to the Cooks River. The LGA is comprised of 21 stormwater catchments, falling into five major catchments.

The Georges River has a long history of flooding. Most flood observations have been recorded at Liverpool weir, which was constructed in 1836 as a causeway crossing of the river. Major floods of the Georges River occurred in 1988, 1986, 1956 and in the late 1800's. Three of the floods of the late 1800's exceeded the 100 year ARI flood event at the Liverpool weir (Bewsher Consulting, 2001). In recognition of the long history of flooding of the Georges River, Sutherland, Fairfield, Bankstown and Liverpool Councils commissioned a Flood Risk Management Study and Plan to address riverine flooding. This study was adopted in 2004.

Compared to the Georges River, very little is known about flooding in the 21 stormwater catchments of the Bankstown LGA. This is generally because there was a lack of awareness of flooding from stormwater, and when flooding occurred in the past it was not systematically recorded. Some flood information has recently been collected from long term residents during the community consultation of 2011, providing elusive evidence of the stormwater flood threat.

Planning Context

The following three documents all have important implications for flood planning in Bankstown, and shaped the requirement to accelerate the Flood Study and Flood Risk Management Plan Program:

- The 2005 *Metropolitan Strategy for Sydney*, and its subsequent revision The 2010 *Metropolitan Plan for Sydney 2036*;
- BCC's *Residential Development Strategy*; and,
- *State Environmental Planning Policy: Exempt and Complying Developments Code 2008*

Details of these planning documents are provided below.

Metropolitan Strategy for Sydney

In 2005 the NSW Government released the Metropolitan Strategy - City of Cities: A Plan for Sydney's Future. The 2005 Metropolitan Strategy identified that Sydney's population would grow by a further 1.1 million people from 4.2 million people to 5.3 million people in the period up to 2031 (NSW Department of Planning and Infrastructure, 2005). However, recent trends suggest that Sydney is growing faster than predicted and this figure has now been revised to 1.7 million people by 2036, which is an average annual rise of 56,650 people. As a result 770,000 additional homes will be required, a 46% increase on the current 1.68 million homes (Department of Planning, 2010).

The Metropolitan Strategy sets the direction for future urban development and identified the strategic centres best placed to focus sustainable commercial and residential growth in the future. Bankstown was identified to be a major centre in the strategy and the LGA was given a mandated target of accommodating an additional 22,000 dwellings by 2031 (Department of Planning, 2007).

Residential Development Strategy

To respond to the strategic directions set in the Metropolitan Strategy and achieve the mandated development target prescribed by the Department of Planning, BCC prepared a Residential Development Strategy (RDS). The RDS applies the Metropolitan Strategy's Centre Typology such that over time, it is possible to increase densities and heights within a certain radius of local shopping centres to make optimal use of the infrastructure provided.

Generally, the Bankstown Residential Development Study recommended that:

- 60% of new dwellings should be provided within local centres. An additional dwelling target was set for each local centre and a radius around the centre within which to realise this target.
- 40% of new dwellings should be met by infill development within neighbourhood areas outside the centres.

Housing Code

In early 2009, changes were made to the State Environmental Planning Policy - Exempt and Complying Developments Code (also known as the Housing Code or Codes SEPP) to allow developers to choose whether they wished to undertake complying development under the Housing Code or a Councils LEP/DCP, providing that land based requirements were met. This meant that that complying development would be permissible in areas that were not constrained by one of the land based exclusions, one of which included being defined as a Flood Control Lot (i.e. affected by flood related development controls, which in BCC's case included land identified as being in the Provisional High and Medium Flood Risk Precincts). Other land based requirements included being identified as a heritage item, affected by acid sulphate soils or being in an environmentally sensitive area.

At this time, Bankstown had only flood mapped four of its stormwater catchments, and these were being remapped using more up to date technology or using a newer version of the TUFLOW model. As all other land based requirements had been adequately mapped, a decision was made to accelerate the flood study and risk management program for stormwater catchments across its LGA to:

- Facilitate the uptake of complying development across the LGA.
- Ensure that achieving the mandated future development target took flood risk into consideration.

Flood Risk Management Process

As a first step to accelerate the flood study and Flood Risk Management Plan program, BCC developed and adopted a generic Flood Risk Management process. This process sets up key activities and milestones and ensures a consistent approach to flood risk management. The main activities and milestones are generally grouped under the Flood Study and Flood Risk Management Plan; these are described in more detail in the following two Sections.

Flood Studies

In recent years, there has been a significant increase in the number of Flood Studies investigating flood risk due to stormwater inundation (or overland flow), as opposed to main river flooding. Whilst there has long been Council investment in modelling and designing drainage infrastructure, previously the focus tended to be on network performance during design capacity storm events; typically 2 to 10 year ARI rainfall events. Whilst effort was sometimes made to investigate the risk of exceeding capacity (e.g. using simplified model representation of flow along roads etc), this was limited by the capabilities of the traditional network one-dimensional model software. These models are appropriate for simulating the behaviour of pipe networks however, when capacity is exceeded, two-dimensional schematisation can better represent overland flow through a complex urban environment including buildings, roads, fences, embankments and other infrastructure.

In the past decade, the increasing availability and affordability of high quality topographic survey via LiDAR, together with advances in both hardware and software (with products from both stormwater network and riverine origins) has enabled fully integrated one- and two-dimensional hydrodynamic modelling of both the underground drainage system and overland flow. This has been a significant development in the broadening of Flood Studies to include more detailed understanding of stormwater behaviour, and the ability to address this source of flooding through a holistic risk management process.

Methodology

BCC have closely followed this development in data, software and hardware capabilities for modelling of stormwater networks and overland flow, first employing a combination of DRAINS and TUFLOW in 2003, MIKE-STORM and TUFLOW in 2004, and then fully integrated pit, pipe and overland flow modelling in TUFLOW from 2005 onwards.

The Bankstown stormwater Flood Studies were the first to utilise TUFLOW for both the stormwater network and fine scale (5 metre grid) overland flow in an urban environment. TUFLOW is a grid based (finite difference) hydraulic model that was originally developed by BMT WBM for fluvial systems. Extensive research and development was invested by the proprietors in incorporating stormwater modelling functionality in the early 2000s, with ongoing developments since to the model engine, set up and output. The application of TUFLOW to 21 subcatchments in BCC has played a significant role in the development of the software, particularly in identifying features to maximise useability, efficiency and outputs tailored to Councils' needs.

The methodology underpinning BCC's Flood Studies for each of the 21 stormwater subcatchments generally reflects that applied to a typical riverine study, however there are a number of extra challenges when applying it to the urban stormwater environment. The following summarises some of the key considerations that have arisen over the past 8 years (though this is not an exhaustive list!) and how these have been tackled, either through software or methodology, to enable an efficient roll out to multiple subcatchments whilst maintaining detail and accuracy.

Model schematisation

- **Direct rainfall:** A 'direct rainfall' (also known as 'rainfall on grid') approach was adopted in the first and all following studies, as opposed to the more traditional lumped subcatchment inflows derived from a separate rainfall-runoff (hydrological) model. At the time of the first studies this was a relatively new approach in the industry, and the first commercial application for TUFLOW, though is now in common use. The issue (both then and now) is a general lack of suitable gauge data for calibration or verification. In lieu of this, numerous comparisons have been made against alternative approaches (hydrological models, alternative hydraulic models, and other simple flow estimation techniques such as the Rational Method) both by the proprietors and others, and as part of model verification for the BCC Flood Studies. With appropriate model schematisation, these comparisons have generally been reasonable, and the benefits of this approach significantly outweigh the limitations in urban, whole-of-catchment applications. It is noted that direct rainfall and urban flood modelling are specific topics under review as part of the AR&R update, which will be a source of further guidance in the future.

- **Grid size:** Grid size (of any model, direct rainfall or traditional) must also strike an appropriate balance between the level of detail / accuracy required for the objectives of the study (e.g. this may differ between a Flood Study, development assessment or stormwater infrastructure design) and the useability / hardware requirements. BCC subcatchment models developed to 2010 adopted a 5m grid, with recent models reducing to 2m in line with ongoing improvements in computer speed, memory and storage. This allows higher resolution of the floodplain whilst still maintaining manageable model simulation times. It is noted that this reduction in grid size would typically lead to an increase in run times by a factor of 15 (for equivalent hardware specifications) due to the increase in grid cells and associated decrease in timestep. The grid size was also carefully reviewed for its effect on overland flow routing, due to the adoption of the direct rainfall method and the general lack of calibration data. Whilst there were localised differences, peak flood levels across the study areas were generally comparable between a 2 and 5m grid.

- **Simulation management:** Large numbers of simulations were typically undertaken for the BCC studies. Numerous storm magnitudes were desired; for identifying network capacity constraints (e.g. typically 1, 2, 5, 10, 20 year ARI) and overland flow risk mapping (typically 50, 100, 200, 500, 1000 year ARI and PMF). In addition for an urban environment, multiple blockage scenarios were assessed, plus the usual Flood Study requirements for critical storm duration analysis and climate change scenarios. The management and quality control of large numbers of simulations has been significantly enhanced by the recent introduction of several features in TUFLOW. New logical controls enables one command to run a range of scenarios (typically blockage, future development, mitigation) and new 'event' files enable one command to run a range of storms (typically durations, magnitudes and future climate).

Terrain, buildings and obstructions

- **DEM development:** Whilst the availability of filtered ALS provides high quality topographic data, the creation of a model DEM in an urban environment remains relatively complex. Numerous approaches and combinations were trialled to generate a smooth surface between and through buildings for model stability, whilst maintaining topographic definition and accuracy. Ultimately a multi-step methodology was adopted including a combination of inverse distance weighting in open areas supplemented by both DEM and model triangulation within large buildings.

- **Land use:** As a relatively new approach, there is little guidance on the appropriate parameterisation of direct rainfall models. Some research has been undertaken, though as mentioned, is limited by suitable calibration data. Extensive research, testing and comparison was undertaken, particularly in the earlier studies. As part of this process, depth-varying Manning's 'n' was incorporated into TUFLOW, to represent initial runoff of direct rainfall on buildings (low Manning's 'n' at shallow depths) and the obstruction / restriction to overland flow (higher Manning's 'n' at larger depths). This feature also enabled an increase of relative resistance for very shallow flow (e.g. <30mm) transitioning to more typical Manning's 'n' values once nominal depths were reached (e.g. 100mm).

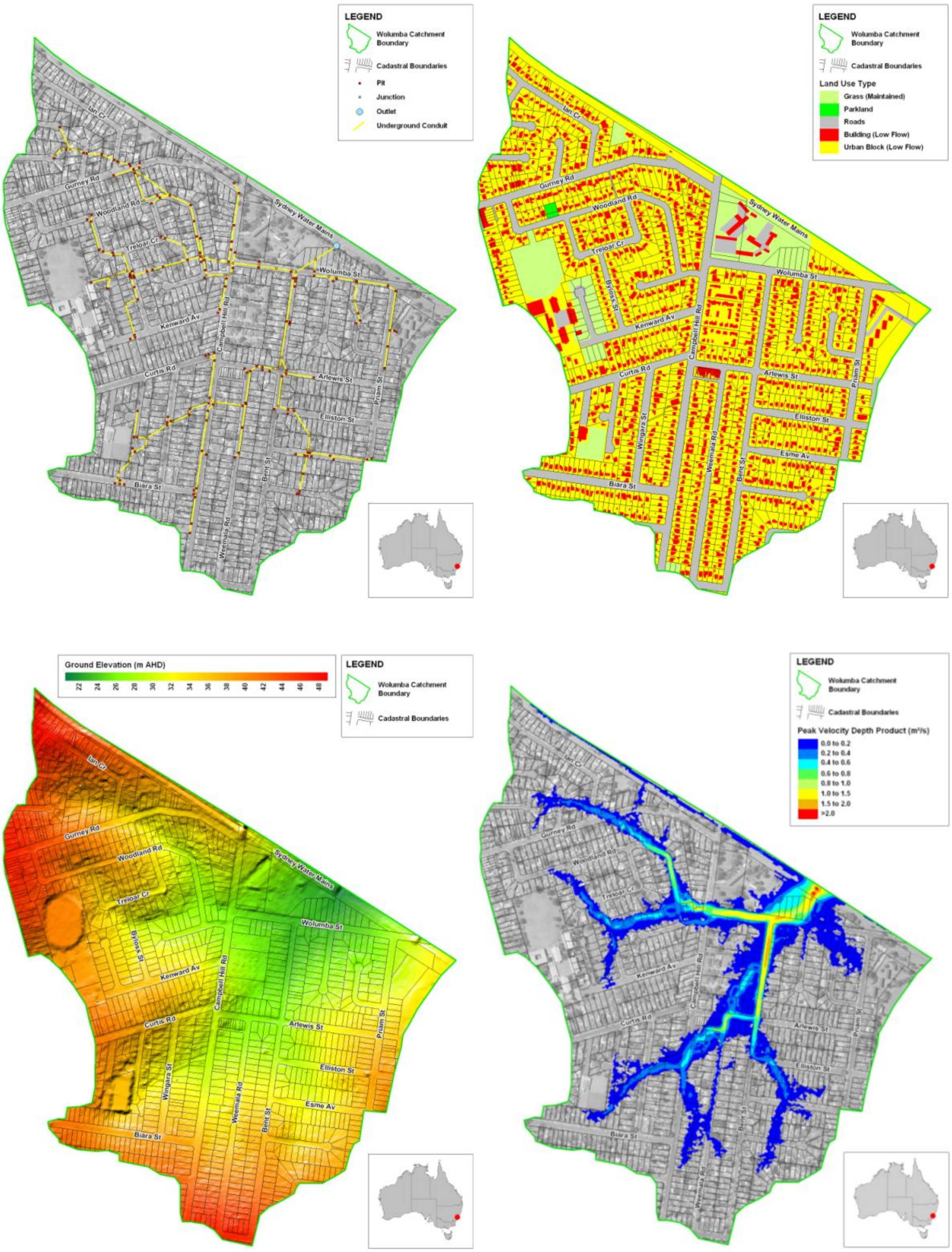

Figure 2: Typical Stormwater Model Inputs and Outputs
Asset database (top left), land use (top right),
DEM (bottom left), overland flow velocity (bottom right)

- **Building representation:** The presence of existing buildings within the catchment can have a potential impact on flood behaviour, particularly if they are in or near an overland flow path. Some buildings will be elevated on fill and totally obstruct floodwater, others may be inundated with floodwater ponding inside the building, whilst others may be elevated on piers allowing flow under the building. The footprints of all buildings were digitised from aerial photography and represented as high 'roughness'. Larger buildings within overland flowpaths (nominally greater than 1000 m^2 floor area) have also been represented topographically, with upstream 'breaklines' to prevent water flowing directly into the building.

- **Fence representation:** Fences are another potential obstruction to flows. Many of these will have an impact in low flood conditions, but are likely to collapse as flood levels increase. Whilst this can be explicitly modelled, it was felt this was beyond the level of detail appropriate to a catchment scale study, and instead an average impact approach was adopted (through increased roughness to all urban areas) to allow for fences and other similar sub-grid scale obstructions.

Stormwater network and hydraulic structures

- **Asset database:** All drainage asset data collected for the studies have been incorporated into a GIS database. This allows the data to be spatially represented across the study area and easily retrieved as required. Information in the database includes data for thousands of stormwater pits and drainage pipes or culverts. Both the database and models include the entire network down to pipe diameter 300mm. At the conclusion of each study, the database is also updated with model results, including information on the conduit capacity throughout the simulation of various flood events.

- **Pit inlets:** In the first studies, grates and lintels were originally modelled as rectangular conduits and weirs respectively. This provided a reasonable approximation, however to improve representation, additional coding was incorporated into TUFLOW to enable explicit definition of pit inlet curves based on industry standards. This was considered a significant improvement and earlier models were updated to incorporate the curves.

- **Various other developments:** Numerous other techniques have also evolved during the 8 year program of BCC studies to improve representation and / or model set up efficiencies, including the ability to model irregular shaped culverts, pit blockage, use a pit search distance (where asset data location is not highly accurate), and automatic manhole losses (based on bends, inverts and junctions).

Debris blockage

- **Scenarios:** Culverts and other hydraulic structures have the potential to become blocked by debris during floods. Council's blockage policy is to allow a 50% blockage factor to the waterway area of all bridges, box culverts or pipe culverts where the clear diagonal opening is less than 6 metres. Blockage factors of 20% and 50% have been applied to all lintel and grated pits respectively. All flood scenarios have been assessed for both a blocked scenario and an unblocked scenario, with the worst case of the two scenarios adopted throughout the study area.

Calibration / verification

- **Community consultation:** Community letter and questionnaire was distributed to property owners potentially affected by the 100 year flood by post and online (response rates have ranged from 9 to 19%, averaging 13%). These responses generally did not include any suitable calibration data, however the responses will inform the subsequent flood risk management studies.

- **Calibration:** Flood models are normally calibrated to historical flood data where such information exists. However, generally within stormwater subcatchments there are insufficient historical flood records to allow a conventional calibration of the TUFLOW model. Whilst a number of residents provided information on historical flooding via the community questionnaire, there was usually insufficient detail on recorded peak stormwater flood levels for model calibration.

- **Verification:** Model parameters were generally based on the experience gained from other catchment studies and sensitivity tests undertaken within the BCC LGA, including:
  - Sensitivity tests on the effects of modifying roughness coefficients for buildings and building blocks within the catchment;
  - Comparing computed flood extents for various frequency floods with Council's Stormwater System Report Register (based on records of stormwater problems, community complaints, long term Council staff knowledge and previous studies or reports where available) and other local / anecdotal knowledge;
  - Comparison of flow hydrographs computed by TUFLOW with flow hydrographs derived using the MIKE-STORM and DRAINS models;
  - Limited calibration of observed flood heights; and
  - Comparisons with Rational Method estimates.

Outputs

- **Flood risk mapping rationalisation:** Mapping of flood risk from direct rainfall models is more difficult than traditional lumped inflow models as the whole model area is subject to rainfall and is therefore 'inundated'. The rationalisation process required multiple iterations, including differentiating between sheet flow and flooding, removing isolated areas of ponding, and refining the model output to the finer scale DEM.

- **Recent developments:** There have also been a number of recent developments in TUFLOW specifically designed to provide additional output of interest to the flood risk management process.
  - Time to, and duration of, inundation, based on depths or hazard, of either key routes and infrastructure, the whole road network, or the whole floodplain;
  - New hazard mapping for people (infants, children, adults, elderly etc) based on the recent AR&R Project 10; and
  - Linkage of gauge heights to individual properties (ground level inundation, floor level inundation, evacuation route inundation etc).

The above briefly describes some of the key items for consideration when undertaking urban stormwater Flood Studies. There are many other challenges not explored here; such as interaction with other sources of flooding and combination of risk; and inter-catchment or sub-catchment flows.

Outcomes

The methodology outlined above, and enhancements developed to support it, have allowed detailed catchment representation and the most accurate inundation and hazard mapping possible to aid in delivering the highest quality risk management and planning solutions. The key issue with 'flash flooding' is of course limited advance warning; thus it is particularly important that the community is made aware of the risk and what they can do to reduce the impact (e.g. flood resilient / resistant construction, safe / flood free locations).

To date all Flood Studies have been adopted when they have been presented to the Floodplain Management Committee and have subsequently been adopted by Council. After Council has formally adopted the Flood Study, Planning Certificates issued under Section 149 of the Environmental Planning and Assessment Act are updated to reflect the new information.

Flood Risk Management Study and Plan

Perhaps the most challenging milestone associated with the Flood Risk Management Study and Plan is undertaking the community consultation as part of the Flood Risk Management Study and Plan and another important activity is generally conveying information pertaining to flood risk. These two activities are described below.

Community Consultation

Methodology

The approach to community consultation that Bankstown undertakes occurs in flood study phase and the flood risk management phase of the flood risk management process, with the bulk of the consultation occurring in the risk management phase. Details are provided below:

1. Flood Study
    - Letters are sent to property owners preliminarily identified as being affected by the 100 year ARI Flood event, informing them that the Council is undertaking a Flood Study and inclusion of community information flood survey for completion. In recent flood studies, a link to a web based community information flood survey has also been provided.

2. Flood Risk Management Study and Plan
    - Letter Notification - Letters are sent to property owners identified as being affected by the 100 year ARI Flood event. This letter advises that the flood study has been completed, the availability of the Flood Study for inspection at local libraries and Council offices, the commissioning of the FRMS&P. Property owners are also invited to book into one of a number of community flood information session at a nearby location within the catchment. Included with the letter is a basic catchment information sheet and another community flood information survey. Phone queries are responded to.
    - Community Information Sessions – First Round - Material covered in the first round of information sessions includes an introduction to flooding and the flood risk management process, provides details of how the flood study was prepared, a description of the results and outlines options to reduce flooding. Property owners are also able to view their properties on Councils GIS system via lap top, which contains information on flood levels, flood depths, floor levels, and if the property is affected by above floor flooding. To maximise community attendance, community information sessions are held at a number of times during the day and evening over several days.

- Community Information Sessions – Second Round – A second round of information sessions will be offered to review the draft flood risk management study and evaluation of the management options. Again multiple sessions at a number of times during the day and evening will be offered over the course of several days to maximise attendance.
- Exhibition of the Final Flood Risk Management Study and Plan.

Application

In 2011 BCC began to actively undertake comprehensive community consultation for stormwater flood risk. Consultation activities had only ever occurred for riverine flooding previously. Approximately 6000 letters were sent out to the owners of properties affected by the high and medium flood risk precincts.

The table below shows the responses to the surveys and the attendances at the community information sessions.

Table 1: Community Consultation Statistics

	Duck River Flood Risk Management Study	**Salt Pan Creek Flood Risk Management Study**	**Total**
No. Letters / Surveys Sent	2804 (March)	3084 (January)	~ 6000
No. Surveys Returned	386 (14%)	471 (15%)	855 (14.5%)
No. Community Forums Held	7 (May)	4 (August)	11
People Attending Community Forums	130	40	170

The response rate to the surveys is considered to be good. Approximately 18% of respondents had experienced a flood at the property before, and a further 12% conceded that it was possible that a flood at their property could occur.

Considering the experiences of other Councils in undertaking community consultation where there have been very few property owners in attendance, attendance at BCC's information sessions can perhaps be regarded to be exceptional. It is considered that there are several of reasons for heightened community interest:

- The letters were sent between two weeks and three months after the 2011 Queensland floods.
- The interest is a reflection of the lack of awareness of flood risk in those catchments, as only one of the six catchments had ever had face to face community consultation undertaken.
- A range of times and dates were provided for property owners to attend, including a choice of sessions at 10 am, 12pm, 1pm and 6pm.

Overall, the opinions presented in the sessions from the community were mainly positive with many attendees expressing gratitude that Council is trying to do something about flooding.

Conveying Flood Information via Councils Website

Over the past 18 months significant advances have been made towards making flood information more readily available on Councils website. Prior to this, the only information available on Councils website were flood risk maps that had been adopted by Council for Riverine and Stormwater flooding. These were available as Adobe Portable Document Format (PDF) maps.

GIS Public Viewer

Approximately 18 months ago, Council launched their GIS (Geographic Information System) public viewer on the Council website. The GIS public viewer allows users to find properties and determine what affectations are applicable, including whether the property is fully or partially affected by a flood risk precinct for riverine or stormwater flooding and whether complying development is possible. Customers are able to search for their property by address and print it for future reference.

Hosting eBooks on Councils Website

In the past six months, BCC have begun converting the Flood Study Reports into eBooks and hosting these on our website. eBooks offer a number of advantages:

- Flood Studies are easily and quickly accessible to the stakeholders anywhere there is an internet connection, including residents in their own homes. Council officers are able to talk to customers over the phone while viewing the same map thus increasing understanding.
- eBooks allow efficient usage of Councils time and financial resources by reducing the need to for Council to burn CDs and print reports.
- eBooks can also be printed by customers or saved in pdf format where it is able to be electronically searched.
- eBooks increase Councils transparency in relation to flooding risk management.

Translation of Information

Information available on the Councils website can be translated automatically into one of over 50 languages, providing another avenue of educating our customers and residents. Previous to this answers to frequently asked questions had been translated into the three main languages spoken in Bankstown: Vietnamese, traditional Chinese and Arabic.

Outcomes

Consistent use of one model has facilitated Flood Risk Management Plans being prepared on a major catchment basis, which has resulted in the potential 21 individual Risk Management Plans being reduced to five risk management plans. Draft Flood Risk Management Studies for six of these catchments in two major catchments, covering 15 square kilometres (20% of the LGA) have been completed.

The above section briefly describes some of the key activities for consideration when undertaking Flood Risk Management Studies in urban environments. There are many other challenges not explored here; including devising appropriate planning controls in areas affected by shallow overland flooding.

Conclusions

Preparing flood risk management plans within a strategic framework facilitates rapid completion of flood studies and streamlines the transition from flood study to flood risk management plan. The main advantages of the adopted approach are:

1. Provision of Consistent and Comprehensive Information

Undertaking the Flood Studies for the 21 BCC stormwater catchments using the TUFLOW software has produced consistent and comprehensive information on stormwater flood risk across the LGA, including the following key outputs which underpin the subsequent Flood Risk Management Studies:

- Provisional flood risk precincts;
- Detailed flood behaviour (levels, depths, velocities, flows, hazard) for a large range of design events (1, 2, 5, 10, 20, 50, 100, 200, 500, 1000 year ARI, Probable Maximum Flood and climate change scenario) for critical storm duration(s);
- Comprehensive and quality checked asset database of stormwater drainage infrastructure;
- Conduit capacity mapping and database; and
- Property flood risk / floor immunity mapping and database.

2. Tailoring of Outputs to Councils Needs

The application of TUFLOW to the 21 BCC subcatchments has played a significant role in:

- The development of the software and its features; and,
- Tailoring and maximising the usefulness of the outputs to meet Councils existing and emerging needs which can be used:
  - In assessing potential flood modification measures (e.g. upgrading hydraulic structures, provision of detention storage, increasing the capacity of the network in problem areas).
  - In estimating the hydraulic, economic and community benefits of each option, to inform decisions on effective management of stormwater risk in the catchment.
  - For various other measures including community consultation, awareness and education; evacuation and access constraints; critical infrastructure flood risk; voluntary purchase schemes; and planning controls.

3. Efficient usage of Council temporal and financial resources

Consistent use of the TUFLOW modelling software using the single defined methodology maximises the use of Council officers time, and minimises financial resources required by:

- Allowing flood studies to be produced efficiently and rapidly. To date, Council has adopted Flood Studies in 16 of its 21 stormwater catchments; the remaining five Flood Studies have been completed and will be adopted by June 2012. This has a flow on effect of having a Floodplain Management Committee that has a familiarity with the models and model outputs which consequently allows flood studies to be adopted by the Committee with a greater understanding and confidence.

- Facilitating Flood Risk Management Plans being prepared on a major Catchment basis; this has resulted in the potential 21 individual Risk Management Plans being reduced to five Risk Management Plans. Draft Flood Risk Management Studies for six of these catchments in two major catchments have been received and the next round of community consultation is about to occur.

4. Whole of Catchment Response to Flood Risk Management

The flood risk management study is able to look at the full range of issues and opportunities present within an entire catchment, when coming up with a plan, resulting in a more cohesive and comprehensive plan than could be achieved with a number of stand alone plans, particularly in relation to planning controls.

5. Facilitating Confidence in Flood Mapping and Risk Management Measures

Council actively and comprehensively engage with the community at the Risk Management Phase and are committed to increasing flood awareness through information sessions and making flood information readily available on Councils website. Use of a consistent software within a strategic platform assists in reinforcing that Council are confident with the method used and the results of the flood modelling. This in turn improves the confidence of our customers in the flood mapping undertaken and the risk management measures proposed and may facilitate community acceptance.

Acknowledgments

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References

Australian Bureau of Statistics (March, 2011). 3218.0 *Regional Population Growth, Australia 2009-10.*

Bewsher Consulting Pty Ltd (2001). *Have We Forgotten About Flooding on the Georges River?* 2001 Floodplain Management Authorities Conference.

Department of Planning (December, 2007). *West Central Subregion Draft Subregion Strategy.* NSW Government.

Department of Planning (December, 2010). *Metropolitan Plan for Sydney 2036.* NSW Government.

NSW Department of Planning and Infrastructure (December 2005). *Metropolitan Strategy*, *City of Cities—A Plan for Sydney's Future.* NSW Government.

TUFLOW Users Manual (www.tuflow.com)