JOHNSTONS CREEK CATCHMENT

FLOODPLAIN RISK MANAGEMENT STUDY

FINAL REPORT

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FOREWORD

The NSW State Government's Flood Prone Land Policy provides a framework to ensure the sustainable use of floodplain environments. The Policy is specifically structured to provide solutions to existing flooding problems in rural and urban areas. In addition, the Policy provides a means of ensuring that any new development is compatible with the flood hazard and does not create additional flooding problems in other areas.

Under the Flood Prone Land Policy, the management of flood liable land remains the responsibility of local government. The NSW Government, and administered through the Office of Environment and Heritage (OEH), provides financial assistance and specialist technical advice to assist councils in the discharge of their floodplain management responsibilities. The Australian Government may also provide financial assistance in some circumstances.

The Flood Prone Land Policy provides for specialist technical and financial support to Councils by the NSW Government through the stages set out in the "Floodplain Development Manual – the management of flood liable land, NSW Government, 2005". This Manual is provided to assist Councils to meet their obligations and responsibilities in managing flood liable land. These stages are:

1. ***Flood Study***
   - Determine the nature and extent of the flood problem.
2. ***Floodplain Risk Management Study***
   - Evaluates management options for the floodplain in respect of both existing and proposed development.
3. ***Floodplain Risk Management Plan***
   - Involves formal adoption by Council of a plan of management for the floodplain.
4. ***Implementation of the Plan***
   - Construction of flood mitigation works to protect existing development, use of Local Environmental Plans to ensure new development is compatible with the flood hazard.

The Johnstons Creek Catchment Floodplain Risk Management Study and Plan constitute the second and third stages of this management process. This study has been prepared by WMAwater for the City of Sydney (Council) under the guidance of Council's floodplain management committee (Committee). This study provides the basis for the future management of those parts of the Johnstons Creek catchment which are flood liable and within the City of Sydney local government area.

EXECUTIVE SUMMARY

This Floodplain Risk Management Study assesses floodplain management issues in the Johnstons Creek catchment, and investigates potential management options for the area. The study, which follows on from the draft Johnstons Creek Catchment Flood Study (Reference 2), has been undertaken in accordance with the NSW Government's Flood Policy. A full assessment of the existing flood risk in the catchment has been carried out, including flood hazard across the catchment, overfloor flooding of residential, commercial and industrial properties, road flooding and emergency response during a flood event. A range of measures aimed at managing this flood risk were also assessed for their efficacy across a range of criteria, which allowed certain options to be recommended, forming the basis of the Floodplain Risk Management Plan for the area. Measures included upgraded pit and pipe networks, detention basins, bridge raising, emergency management measures and various property modification measures.

Background

The Johnstons Creek catchment has an area of 460 hectares and is located in Sydney's inner city suburbs of Annandale, Camperdown, Forest Lodge, Glebe and Newtown. The study area is the half of the catchment that lies within the City of Sydney Local Government Area (LGA), with an area of 224 hectares. The area has been extensively developed for urban usage. Land use is predominantly medium to high-density housing as well as commercial and industrial developments. The catchment experiences overland flooding, with some tidal influence in the vicinity of Rozelle Bay.

The Johnstons Creek Catchment Flood Study (2012) was carried out to define existing flood behaviour for the Johnstons Creek catchment in terms of flood levels, depth, velocities, flows, hydraulic categories and provisional hazard. A 1D/2D TUFLOW hydraulic model was established and verified by a robust calibration/verification process. Following this, the model was used to define flood liability for the 5 year ARI, 10%, 5%, 2%, 1% AEP design flood and PMF events. Several flooding hot spots were also identified in the study. In addition, a floor level survey and damages assessment were undertaken to identify properties that are liable to over floor inundation.

Existing Flood Environment

A number of locations within the catchment are flood liable. This flood liability mainly relates to the nature of the topography within the study area as well as the capacity of service provided by drainage assets. Urbanisation throughout the catchment occurred prior to the installation of road drainage systems in the 1900s and many buildings have been constructed on overland flow paths or in unrelieved sags. Due to these drainage restrictions, topographic depressions can cause localised flooding as excess flows have no opportunity to escape via overland flow paths. Sub-surface drainage is not able to route flow from these ground depressions unrelieved by overland flow paths, as the majority of the drainage network reaches capacity during small events (i.e. 2 year ARI).

94 properties within the catchment are liable to over floor inundation in the 1% AEP event, while 38 properties are liable in the 5 year ARI event. A flood damages assessment for existing development was undertaken, with the average annual damage estimated to be approximately $2.3 million for the catchment.

Flooding hotspots in the catchment were identified at the following locations: intersection of Minogue Crescent and Coneill Place, The Crescent, intersection of Wigram Road and Ross Street, Glebe Gardens/Hereford Street, the depression upstream of Pyrmont Bridge Road, and the upstream areas in the Lillie bridge culvert catchment. The study identified that effective warning time is zero and that evacuation in place is therefore the default response to extreme floods.

Flood Risk Management Options

A range of floodplain risk management options were investigated as part of the study.

Thirteen options were considered in detail, as shown in the below table, which ranks them according to the results of the multi-criteria assessment. The assessment of management options involved gathering feedback from the community on the options, who were informed about the study and the various options via a brochure and questionnaire, as well as an information session. Options were also considered in the context of relevant policies and planning controls, including City of Sydney’s Interim Floodplain Management Policy.

Rank	Ref	Options
1	FM-JC05	Raise footbridges along Johnstons Creek to above the 1% AEP level
2=	RM-JC02	Prepare DISPLAN for the Sydney West Emergency Management District (SES)
2=	RM-JC03	Prepare Local Flood Plan to inform evacuation centres, identify vulnerable facilities and evacuation routes
4=	PM-JC02	Update Sydney DCP 2012 and LEP 2012 based on FRMS&P outcomes and to inform of Council's Interim Floodplain Management Policy
4=	RM-JC01	Make available flood warnings on Council's website or social media, investigate feasibility of installing flood warning systems at key locations
4=	RM-JC04	Develop ongoing flood awareness programmes for the community
7	PM-JC01	Review FPLs following completion of FRMS&P for Johnstons Creek catchment. Provide case studies to assist DA
8	PM-JC03	Investigate flood proofing techniques for flood affected commercial/industrial properties
9	FM-JC01	Detention basin in part of St Johns Oval, University of Sydney
10	PM-JC04	Investigate potential for property adjustments to manage overland flow at flooding hot spots
11	FM-JC02	Drainage upgrade between Sparkes Street to Johnstons Creek & downstream channel works
12	FM-JC04	Regrade Hogan Park & widen walkway under The Crescent
13	FM-JC03	Drainage upgrade near Hereford Street & detention basins in John Street & Arthur Gray Reserves

The options that are most recommended, as per the table, are as follows:

Raise footbridges along Johnstons Creek to above the 1% AEP level – Raising five pedestrian bridges along Johnstons Creek will improve the conveyance of the creek, increasing flow in areas where it is currently constricted by the bridge structures. This will reduce peak flood levels in the vicinity of the creek, for example, by 0.65 m in the 5% AEP event.

Prepare DISPLAN for the Sydney West Emergency Management District (SES) – The plan would identify responsibilities at a District and Local level with regards to emergency management in preparation for, response to and recovery from. The nature of flooding in the catchment means the focus is likely to be on management of flooded roads in the area. The area does not currently have a DISPLAN.

Prepare Local Flood Plan to inform evacuation centres, identify vulnerable facilities and evacuation routes – A Local Flood Plan prepared by CoS and the SES would determine evacuation centres for use during a flood event, give an overview of the flood behaviour, and identify vulnerable areas, including roads subject to flooding. The Plan could recommend that Variable Message Signs be used to prevent hazardous use of inundated roads and thoroughfares during a flood.

Update Sydney DCP 2012 and LEP 2012 to incorporate FRMS&P outcomes and the Interim Floodplain Management Policy – Detailed assessment of flood risk, as provided by the FRMS&P, can prevent development occurring in areas with a high hazard and/or with the potential to have significant impacts upon flood behaviour in other areas. This prevention occurs primarily via the DCP and LEP, and is currently represented in the Interim Floodplain Management Policy, which will eventually be incorporated into the DCP and LEP.

Following public exhibition of the studies in November and December 2014, the Floodplain Risk Management Study and Plan were adopted by Council on 18th of May 2015.

1. INTRODUCTION

1.1. Study Area

The Johnstons Creek catchment is located immediately west of the Sydney CBD and lies within the City of Sydney (Council) and Leichhardt Council Local Government Areas (LGA). The catchment has a total area of 460 ha, though the study area is limited to the City of Sydney LGA. This study area (224 ha) is approximately half of that of the total catchment area and is located in the inner city suburbs of Annandale, Camperdown, Forest Lodge, Glebe and Newtown (refer Figure 1). This region has been extensively developed for urban usage. Land use is predominantly medium to high-density housing with commercial zoned regions concentrated along Parramatta Road and King Street (Newtown) and industrial land largely situated between Pyrmont Bridge Road and Parramatta Road. Regions of open space are also positioned throughout the catchment particularly in the vicinity of the University of Sydney and in recreational parks such as Camperdown Park, Harold Park, Jubilee Park, Federal Park and Bicentennial Park.

The entire study area (with the exception of the immediate Sydney Harbour foreshore) drains to Sydney Water's major trunk drainage system (known as SWC55). SWC55 is composed of various branches, the main one being Johnstons Creek, which route flow from a number of distinctly separate sub-catchments in the upper regions of the catchment. Flow is discharged into Rozelle Bay via Johnstons Creek which is a large concrete lined channel. The trunk drainage system is linked to Council's feeder drainage system consisting of covered channels, in-ground pipes, culverts and kerb inlet pits.

A number of locations within the catchment are flood liable. This flood liability mainly relates to the nature of the topography within the study area as well as the capacity of service provided by drainage assets. The topography of the catchment is steep in the upper areas, steep and undulating in the middle sections, and then flat particularly in the lower regions close to Rozelle Bay. The upper regions of the catchment experience the greatest relief with a maximum elevation of approximately 45 mAHD occurring in the vicinity of Kings Street (Newtown). Urbanisation throughout the catchment occurred prior to the installation of road drainage systems in the 1900s and many buildings have been constructed on overland flow paths or in unrelieved sags. Due to these drainage restrictions, topographic depressions can cause localised flooding as excess flows have no opportunity to escape via overland flow paths. This creates a significant drainage/flooding problem in many areas throughout the catchment.

Significant development is proposed within the catchment in the form of the Harold Park re-development. This will see a site previously used as a paceway converted into a primarily residential space. Drainage features relating to the sub-catchment will be altered as the current proposal sees the existing Lillie Bridge culvert removed and replaced by an upgraded structure that is also realigned further to the east. Overall it is a requirement that the proposal not impact on upstream or downstream flood levels (Reference 5) and as such the redevelopment is not expected to significantly alter catchment hydrology.

1.2. The Floodplain Risk Management Process

As described in the Floodplain Development Manual (Reference 1), the floodplain risk management process is formed of sequential stages:

- Data Collection;
- Flood Study;
- Floodplain Risk Management Study;
- Floodplain Risk Management Plan; and
- Plan Implementation.

The first key stage of the process has been undertaken with the completion of the Draft Johnstons Creek Catchment Flood Study (Reference 2). Following this, the Floodplain Risk Management Study and Plan (FRMS&P) are undertaken for the catchment in two phases:

Phase I – Floodplain Risk Management Study in which the floodplain management issues confronting the study areas are assessed, management options investigated and recommendations made. The objectives for this phase include:

- Review the current Draft Johnstons Creek Catchment Flood Study (2012) and update hydraulic model;
- Identify requirement of additional floor level survey;
- Review Council's existing environmental planning policies and instruments, identify modifications required to current policies;
- Identify residential flood planning levels and flood planning area;
- Identify and assess works, measures and restrictions aimed at reducing the impacts and losses caused by flooding and consider their impacts if implemented, taking into account the potential impacts of climate change; and
- Review the local flood plan, examine the present flood warning system, community flood awareness and emergency response measures (involvement with the NSW State Emergency Service).

Specific objectives were provided by Council to investigate flood mitigation options for flood affected streets and areas as identified in the current Flood Study including:

- Minogue Crescent and Coneill Place;
- The Crescent;
- Intersection of Wigram Road and Ross Street;
- Glebe Gardens/Hereford Street;
- Upstream areas in the Lillie Bridge culvert catchment – area between Bridge Road and St Johns Road; and
- Depression upstream of Pyrmont Bridge Road.

Phase II – Floodplain Risk Management Plan which is developed from the floodplain risk management study and details how flood prone land within the study areas is to be managed moving forward. The primary aim of the Plan is to reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk at this time and ensuring that such plans are informed to a degree by climate change sensitivity.

The Plan consists of prioritised and costed measures for implementation.

2. BACKGROUND

2.1. Johnstons Creek Catchment

2.1.1. Land Use

The land use zones as identified in the Sydney LEP 2012 are shown as Figure 2. A variety of land use can be found throughout the region including residential, commercial, light industrial and other mixed use with public park lands generally found at the downstream part of the catchment, i.e. Bicentennial Park and Jubilee Park. University of Sydney Camperdown campus is located at the upstream part of the catchment. The catchment has been extensively developed for urban usage and future development in this area is most likely to be in the form of urban consolidation, with aggregation of individual lots creating high density high rise residential developments. Nevertheless, there remain a lot of free standing homes in the study area (as evident from the community consultation results shown in Figure 6) and flood liable properties have been found to consist of both private housing and apartments. Communal car parks (underground) are also flood impacted in some cases.

More information on the early catchment conditions is given in Appendix G, including description of the original creek locations and the foreshore alignment.

2.1.2. Social Characteristics

Information is available from the 2011 census (http://www.abs.gov.au/) to understand the social characteristics of this study area which includes the suburbs of Annandale, Camperdown, Forest Lodge, Glebe and Newtown. Understanding the social characteristics of the area can help in ensuring that the right floodplain risk management practices are adopted. Of note is the percentage of population who are not fluent in English which is useful to understand when considering flood awareness education or when issuing evacuation orders. The 2011 census identifies that in the study area about 25% of people speak a language other than English at home.

The data also shows that a large number of people moved to the area within the 5-year period prior to the census at around 59% to 70% of the residents. This highlights the frequency of change of residents in the area. Additionally, around 55% of the residents are staying in a rented property. Generally residents who have lived in the same place for many years will have a better understanding of the existing flood risks within the area. With respect to age, around 15% of residents are in either the 0-14 years or 65 years and over age brackets. These residents are more likely to require assistance during an evacuation.

2.1.3. Local Environment

The natural environment in the Johnstons Creek catchment is limited to the trees in the area, as well as the limited park land. When considering environmental issues associated with flooding, focus is typically given to ecosystems located around a catchment's watercourses. In this catchment, this is limited to a concrete-lined open channel, which has limited associated ecology. With respect to trees in the catchment, City of Sydney aspires to protect and expand the LGA's urban forest. This includes a list of protected Significant Trees, of which the trees in Jubilee Park are listed, as well as others in the northern section of Glebe, and in the University of Sydney. Mitigation measures assessed by this study will consider the value that is placed upon both the trees in the catchment and the natural environment around the open channel, when there is a potential impact on either.

2.1.4. Drainage System

The catchment is serviced by a major/minor drainage system. Property drainage is directed to the kerb/gutter system where it is then able to enter the Council owned minor street drainage network. Flow is then routed into the Sydney Water Corporation (SWC) owned and maintained SWC55 trunk drainage system. This trunk drainage system is composed of numerous branches that route water from the catchment extents to the main drainage channel running south-north through the catchment. A list of the six main trunk drainage branches that are contained within the study area is presented below and shown in Figure 1.

- Johnstons Creek Branch,
    - Lillie Bridge Branch,
    - Orphan School Creek Branch,
        - Hockey Field Sub-Branch,
        - Physics School Relief Sub-Branch,
        - Saint Andrews College Sub-Branch.

The Johnstons Creek Branch starts as an open channel at Salisbury Road and then runs through the Federal, Jubilee and Bicentennial Parks before discharging into Rozelle Bay. All other branches mentioned above are in ground culverts.

The capacity of the trunk drainage system in the study area varies greatly depending on location. Some reaches in this system are unable to pass an event with a 6 month recurrence interval and the large majority fail for events with flows as small as 3 year ARI discharges (Reference 6).

When the capacity of the drainage system is exceeded there is the potential for velocities and/or flow depths combining to generate high hazard flooding conditions. The lack of capacity of the trunk drainage system indicates that relatively small events can cause these conditions in numerous locations throughout the study area.

2.1.5. Historical Floods

Historical records (i.e. photographs, reports) indicate that rainfall intensities as low as 2 year ARI events can cause flooding at many locations within the catchment. Consequently there have been many instances of flooding in the past with June 1949, November 1961, March 1975, November 1984, January 1991 and April 1998 being some of the most significant storm events causing extensive flooding throughout the catchment.

To further highlight the potential magnitude of flooding in the region, Council has provided photographs (Photo 1 to Photo 4) of Arundel Street/Sparkes Street during a flood that occurred on 30th of May 2011. These photographs were received in a letter from a resident detailing this event. Reports indicated that flood depths of up to 500 mm were experienced. Analysis of the rainfall at the Annandale Gauge revealed that this event had a maximum recurrence interval of 1 year (Reference 2). This location is approximately 1.5 km from the gauge and thus results indicated that this storm may have been highly localised with a large spatial gradient. Localised drainage issues are also likely to have contributed to flooding in this region during this event.

Photo 1: Flooding on Sparkes Street.

Photo 2: Flooding on Sparkes Street

Photo 3: Flooding on Sparkes Street

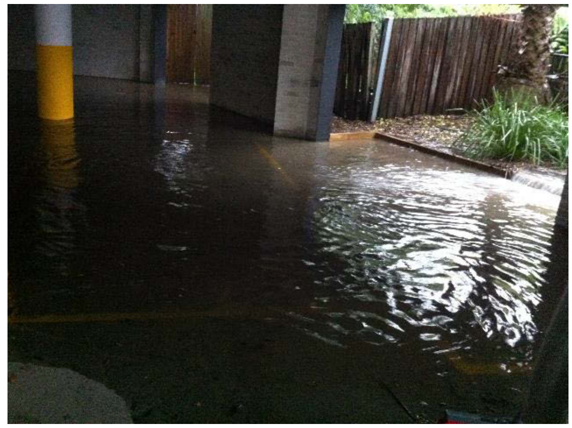


Photo 4: Parking lot on Sparkes Street

2.2. Previous Studies

A number of previous studies have been undertaken for the Johnstons Creek catchment. Most of these are summarised in the Flood Study (Reference 2) however the following sections provide a review of those that are key to this management study.

2.2.1. Harold Park – WSUD & Flood Risk Management (Stage 1), Cardno Lawson Treloar, Prepared for City of Sydney, January 2010 (Reference 3)

The report contains an analysis of the existing Harold Park Paceway site covering 10.5 ha. The site is being considered for redevelopment and this study forms part of an urban design strategy by City of Sydney. The Lillie Bridge culvert catchment has an area of 46 ha which is serviced by the Lillie Bridge culvert that drains to Johnstons Creek via Harold Park. This SWC culvert is to be substantially upgraded as part of the proposed site redevelopment.

The study models on site flood behaviour and identifies constraints on redevelopment, as well as flood mitigation strategies. A 1D/2D hydraulic SOBEK model was used to define flood extent and flooding behaviour. The stormwater management component of the study was modelled using MUSIC.

2.2.2. South Sydney Stormwater Quality and Quantity Study, Blackwattle Bay and Johnstons Creek Catchments, Hughes Trueman & Perrens Consultants, September 2004 (Reference 4)

This report was commissioned by South Sydney Council (now known as City of Sydney) to assess the performance of the trunk drainage systems in the Johnstons Creek and Blackwattle Bay Catchments. The two trunk drainage systems SWC17 and SWC55 (Blackwattle Bay and

Johnston Creek respectively) lie within the City of Sydney LGA. The study aims were to provide stormwater management options. Key issues examined in the report are as follows:

- Analysis of the origin and causes of stormwater flows that contribute to stormwater flooding;
- Strategies for managing stormwater flooding;
- Options for reducing stormwater flooding;
- Water quantity and quality management opportunities; and
- Water quality improvement.

The study modelled stormwater flows using the DRAINS modelling package. The DRAINS model was then used to produce a summary of pipe flows estimates, estimates of potential overland flow paths and estimates of flood depths in sag points. This study is superseded by the latest Flood Study (Reference 2).

2.2.3. Draft Johnstons Creek Catchment Flood Study, WMAwater, May 2012 (Reference 2)

This flood study was carried out as part of the Floodplain Risk Management Programme to define existing flood behaviour for the Johnstons Creek catchment in terms of flood levels, depth, velocities, flows and extents. The mechanisms of flooding examined in this study include local overland flow as well as backwater flooding from receiving waters. A 1D/2D TUFLOW hydraulic model was established utilising the rainfall on grid approach and verified by comparing identified flood prone areas against modelled flood extent for the 5 year ARI design flood. Also, since all parameters adopted such as losses, percent imperviousness and Manning's roughness are the same as the neighbouring Blackwattle Bay catchment, the Johnstons Creek catchment model has been calibrated indirectly via use of the parameters from the Blackwattle Bay catchment model (which undergone limited calibration exercise to historical data). The study investigated the 5 year ARI, 10%, 5%, 2%, 1% AEP design flood and PMF events. Preliminary hydraulic categories were determined for these events as was provisional hazard mapping. Several flooding hot spots were also identified in the study. A floor level survey and damages assessment identified 77 residential and 10 non-residential properties that are liable to over floor inundation in the 1% AEP event. These estimates are revised as additional floor level survey was undertaken as part of the current study.

2.2.4. University of Sydney Flood Risk Management Stage 1 – Campus Flood Study Review, WMAwater, August 2013 (Reference 7)

The main objective of this study was to define the existing flood behaviour on the University of Sydney's Camperdown and Darlington campuses for a range of design events including the 5 year ARI, 5%, 1% AEP design flood and PMF events. The Camperdown campus west of Eastern Avenue is located within the Johnstons Creek catchment. This study utilised the hydraulic models from the Draft Johnstons Creek Catchment Flood Study (Reference 2) and Draft Blackwattle Bay Catchment Flood Study (Reference 10) which were updated to reflect recent developments as well as improved definition of the stormwater drainage network and overland flow paths within the campuses. The flood affected areas within the University were identified and relevant information was provided to inform the University with regards to managing existing and future flood risk within the University.

2.3. Flood Study Review and Update

The Draft Flood Study (Reference 2) described previously in Section 2.2.3 was reviewed. A number of hot spots were identified which include:

- Minogue Crescent and Coneill Place;
- The Crescent;
- Intersection of Wigram Road and Ross Street;
- Glebe Gardens/Hereford Street;
- Depression upstream of Pyrmont Bridge Road; and
- Upstream areas in the Lillie Bridge culvert catchment.

In order to address flooding issues for these key locations, either runoff must be attenuated upstream or conveyance at, and downstream, of the hot spots must be improved. It was noted that for smaller events such as the 5 year ARI event as many as 59 properties are flood liable within the catchment. This estimate has since been revised as further flood prone properties were identified upon completion of the Flood Study and additional floor levels have been surveyed to update the damages assessment and over-floor flood liability mapping (refer Figure B 1).

The study also considered the potential effects of climate change by modelling rainfall increases of 10%, 20% and 30% on the 1% AEP flood event. A 10% increase in design rainfall intensity resulted in approximately 0.1m increase in peak flood levels and a 20% increase in rainfall intensity lead to a 0.1m increase in flood level and 30% to 0.2m.

The key outcomes of the Flood Study which are to be discussed, considered or managed in this Study and Plan are:

- The areas identified as being flooding hot spots;
- Establish the “true” hydraulic category and hazard definitions;
- Identify mitigation measures to address the adverse impacts of new developments; and

- Identify risk management measures to reduce flood costs to properties within the catchment by either structural or non-structural measures.

The hydraulic model developed for the 2012 Draft Flood Study (Reference 2) was reviewed and it was found that major ongoing developments within the catchment are currently ill-defined with regard to site topography and drainage characteristics. These developments include:

- Recent developments within the University of Sydney, i.e. Eastern Avenue walkway; and
- Harold Park development adjacent to Johnstons Creek.

Where details were available they were used to revise the model definition for that particular development site. Some of these changes have been incorporated into the model when undertaking a Flood Study Review (Reference 7) for the University of Sydney as part of the Campus Improvement Plan (CIP). Though developments have occurred at these locations, it is deemed the impact associated with these developments on the 1% AEP flood behaviour is negligible as:

- The sites were already developed previously;
- The intra-lot drainage may have changed but Council assets remain unchanged generally; and
- Developments have been assessed for flood impact downstream and found not to materially affect flood behaviour.

Further, the discovery of an underground flow path and car park storage under Glebe Gardens during a recent field trip has led to re-modelling and re-assessment of the over-floor flood liability for the properties located along the low point on Hereford Street. This flow path allows the floodwaters trapped on Hereford Street to be discharged through the underground car park and subsequently onto Wigram Lane. As such, the flood damages for these properties have been over-estimated and it was found that the properties which were deemed to be inundated over-floor in the 5 year ARI event based on the previous Flood Study results (Reference 2) are no longer inundated above floor level or only in the PMF event.

This updated model was utilised in the assessment of the flood mitigation measures proposed in Section 9.4. All results reported herein are based on inclusion of these model changes.

3. EXISTING FLOOD ENVIRONMENT

3.1. Flood Mechanisms and Liability

A number of locations within the catchment are flood liable. This flood liability mainly relates to the nature of the topography within the study area as well as the capacity of service provided by drainage assets. The topography of the catchment is steep in the upper areas, steep and undulating in the middle sections, and then flat particularly in the lower regions close to Rozelle Bay. The upper regions of the catchment experience the greatest relief with a maximum elevation of approximately 45 mAHD occurring in the vicinity of Kings Street (Newtown). Urbanisation throughout the catchment occurred prior to the installation of road drainage systems in the 1900s and many buildings have been constructed on overland flow paths or in unrelieved sags. Due to these drainage restrictions, topographic depressions can cause localised flooding as excess flows have no opportunity to escape via overland flow paths. This creates a significant drainage/flooding problem in many areas throughout the catchment.

Mainstream flooding from Johnstons Creek is also experienced by some residential properties on Coneill Place and commercial properties on The Crescent which could be exacerbated when the flood event coincides with high tide at the Bay.

A large range of depths (see Figure 7 to Figure 12) and velocities can be observed throughout the catchment for the design flood events. The overland flows are predominantly shallow at the upstream sections of the catchment. In the presence of a flow path restriction (i.e. buildings), the flows experience ponding upstream of the obstructions and these areas which retard flows perform as an informal detention basin. Flood storage areas are found downstream of the catchment, i.e. at Jubilee Park, Federal Park, Bicentennial Park and its surrounds, where lower flow velocity and higher flood depths can be expected.

An assessment of the sub-surface drainage capacity for this catchment found that most pipes/culverts including the Sydney Water trunk drainage flow at capacity (refer to Figure 3) even for smaller events (i.e. 5 year ARI) and the majority of the flows traverse through the catchment via overland flow paths. The limited capacity of the minor and major drainage systems coupled with extensive development (filling of the floodplain and blocking of flow paths) resulted in extensive flood liability throughout the study area.

A floor level survey has been undertaken in order to determine the flood liability of individual properties. The survey, which was undertaken by Council as part of the Flood Study (Reference 2), allows modelled design flood levels to be compared to property floor levels. Further survey was conducted as part of the current study to supplement additional floor levels to the dataset. In total, the survey was performed on more than 170 properties throughout the catchment. The selected property locations and details are provided in Appendix B. A flood damages assessment was carried out using this dataset and the results are presented in Section 5.1.

Referring to Table 1, it was found that 94 properties are liable to over floor inundation in the 1% AEP event. In smaller events such as the 5 year ARI event this figure drops to 38 properties although this estimate is conservative given the prudent blockage assumption. This number is approximately half of the total number of properties that are flood affected, which includes those properties that are inundated in the yard but not above the building floor level. The proportion of residential properties which are flood affected is significantly higher than the commercial/industrial lots. Whilst overall flood liability numbers are not high (compared against a total number of homes of circa 6,500 inclusive of apartments), those that are flood liable are persistently so. The properties that are over floor flood liable tend to be impacted by overland rather than mainstream flows and be located in unrelieved sags. As a result many tend to be flooded in smaller events (i.e. 5 year ARI event), as well as the larger events (i.e. 1% AEP event).

Table 1: Over-floor Flood Liability for Johnstons Creek Catchment

	Properties Flood Affected			No. of Properties Flooded Above Floor Level		
Event	Residential	Commercial/Industrial	Total	Residential	Commercial/Industrial	Total
5Y ARI	97	14	111	32	6	38
10% AEP	114	13	127	54	7	61
5% AEP	124	14	138	66	9	75
2% AEP	134	14	148	73	9	82
1% AEP	145	14	159	84	10	94
PMF	166	14	180	125	14	139

The locations of these flood liable properties are mapped in Figure 4. It can be observed that they are quite distributed across the catchment and primarily located along the major overland flow paths.

3.2. Hot Spots

Three model outputs were overlaid to help identify hotspots in the area: the drainage lines that flow at capacity, the properties with habitable floor levels prone to inundation and the 1% AEP hazard. These are individually shown on Figure 3, Figure 4 and Figure 17 respectively, and are shown combined on Figure 5. The figure also shows the hotspots, which are as follows;

a) Minogue Crescent and Coneill Place - a number of homes on Minogue Crescent suffer from over floor flood liability due to Johnstons Creek levels. Note that inundation of these properties (not over floor level) will tend to occur on a more frequent basis as a result of local stormwater-type flows;

b) The Crescent - commercial property in this area which is slightly raised above natural ground level is subject to inundation via Johnstons Creek. Note that this downstream reach of the creek is relatively sensitive to adopted tail water levels;

c) Intersection of Wigram Road and Ross Street - this area immediately upstream of the Harold Park track will tend to collect water. Note however that inundation above floor levels of adjoining houses does not occur for any of the modelled events;

d) Glebe Gardens/Hereford Street - a few properties here are subject to over floor inundation for the smallest event modelled, i.e. the 5Y ARI event;

e) Depression upstream of Pyrmont Bridge Road - Pyrmont Bridge Road at a level of approximately 15.5 mAHD tends to retard upstream flows from the Orphan Creek catchment, much of which lies within the University of Sydney campus. With no overland flow path water will tend to accumulate causing severe flooding for some properties in this area, particularly low lying property and property closest to the upstream side of Pyrmont Bridge Road; and

f) Upstream areas in the Lillie Bridge culvert catchment - the area between Bridge Road and St Johns Road (west of the Glebe Fire Station).

Alleviating flood risks for these areas should take the highest priority in order to maximise the benefits that could be gained with the proposed flood mitigation measures.

3.3. Hydraulic Categories

The 2005 NSW Government's Floodplain Development Manual (Reference 1) defines three hydraulic categories which can be applied to define different areas of the floodplain; namely floodway, flood storage or flood fringe.

Floodways

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

Flood Storage Areas

"*those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.*"

Flood Fringe
"the remaining area of flood prone land after floodway and flood storage areas have been defined".

There is no precise definition of these 3 categories or accepted approach to differentiate between the various classifications. The delineation of these areas is somewhat subjective based on knowledge of the study area, hydraulic modelling and previous experiences. Based on previous experience and literature review (Reference 12), the Flood Study (Reference 2) defined hydraulic categories as:

Floodway:		Velocity x Depth > 0.25 m^2/s AND Velocity >0.25m/s
	OR	Velocity > 1m/s
Flood Storage:		Land outside the floodway where Depth > 0.2m
Flood Fringe		Land outside the floodway where Depth < 0.2m

The hydraulic categories for all design events are shown as Figure 19 to Figure 24. Utilising the criteria as described above, most of the roads which serve as major overland flow paths in addition to Johnstons Creek are classified as Floodway and parklands as Flood Storage areas (i.e. University Oval, Jubilee Park and Bicentennial Park). There is relatively minimal difference between the classifications in the 5 year ARI event for instance when compared to the 1% AEP event mainly due to the small difference in flood levels between the design events.

3.4. Flood Hazard Classification

Flood hazard is a measure of the overall adverse effects of flooding and the risks they pose. The 2005 NSW Government's Floodplain Development Manual (Reference 1) describes two *provisional flood hazard* categories; High and Low, based on the product of the depth and velocity of floodwaters. The provisional hazard categories are only based on depth and velocity and do not take into account any other factors which may influence the flood hazard (Figure L2 of the Floodplain Development Manual); hence they are a provisional hazard estimates only with "true" hazard to be defined through the process of the current study. The boundary of the provisional High and Low hazard classification will change according to the magnitude of the flood in question.

Provisional hazard was established as part of the Flood Study (Reference 2) based on the Floodplain Development Manual criteria (Appendix L of the Floodplain Development Manual). Due to the combination of high flood depths and velocities, many regions of the catchment are affected by high hazard flows. Figure 13 to Figure 18 show the flow hazard classification throughout the catchment for various design flood events. It can be seen that during the 1% AEP flood event many roads form significant flow paths with high hazard flows, with the situation worsening for the PMF.

To assess the full flood hazard all adverse effects of flooding have to be considered. As well as considering the provisional (hydraulic) hazard it also incorporates threat to life, danger and difficulty in evacuating people and possessions and the potential for damage, social disruption and loss of production including those detailed in Table 2.

High Hazard *- an area or situation where there is possible danger to personal safety, evacuation by trucks is difficult and able-bodied adults would have difficulty in wading to safety. There could also be potential for significant structural damage to buildings.*

Low Hazard - *people and possessions can still be evacuated by trucks if necessary and able-bodied adults would have little difficulty wading to safety.*

The classification is a qualitative assessment based on a number of factors as listed in Table 2.
Table 2: Hazard Classification

Criteria	Weight (1)	Comment
Size of the Flood	Medium	Relatively low flood hazard is associated with more frequent minor floods while the less frequent major floods are more likely to present a high hazard situation.
Depth & Velocity of Floodwaters	Medium	The provisional hazard is the product of depths and velocity of flood waters. These can be influenced by the magnitude of the flood event.
Rate of Rise of Floodwaters	Medium	Rate of rise of floodwaters is relative to catchment size, soil type, slope and land use cover. It is also influenced by the spatial and temporal pattern of rainfall during events.
Duration of Flooding	Low	The greater the duration of flooding the more disruption to the community and potential flood damages. Permanent inundation due to sea level rise is of indefinite duration.
Flood Awareness and Readiness of the Community	High	General community awareness tends to reduce as the time between flood events lengthens and people become less prepared for the next flood event. Even a flood aware community is unlikely to be wise to the impacts of a larger, less frequent, event.
Effective Warning & Evacuation Time	Medium	This is dependent on rate at which waters rise, an effective flood warning system and the awareness and readiness of the community to act.
Effective Flood Access	High	Access is affected by the depths and velocities of flood waters, the distance to higher ground, the number of people using and the capacity of evacuation routes and good communication.
Evacuation Problems	Medium	The number of people to be evacuated and limited resources of the SES and other rescue services can make evacuation difficult. Mobility of people, such as the elderly, children or disabled, who are less likely to be able to move through floodwaters and ongoing bad weather conditions is a consideration.
Provision of Services	Low	In a large flood it is likely that services will be cut (sewer and possibly others). There is also the likelihood that the storm may affect power and telephones. Permanent inundation from sea level rise may lead to permanent loss of services.
Additional Concerns	Low	Floating debris, vehicles or other items can increase hazard. Sewerage overflows can occur when river levels are high preventing effective discharge of the sewerage system.

(1) Relative weighting in assessing the hazard for the Johnstons Creek catchment

Generally, flood event magnitude will impact resultant depths and velocities. Typically one might expect significant differences in flood affectation for events of varying probability. However, due to the nature of the flooding in the Johnstons Creek catchment there is not a significant difference in flood levels between design events. Therefore the hazard is likely to be affected more by other criteria.

The concept of rate of rise of flood waters is more applicable to mainstream flooding scenarios. However, the rate of onset of flooding can influence flood warning and evacuation times. The faster the onset of flooding the more difficult warning becomes and the quicker evacuation may need to occur. Due to the nature of overland flow flooding, there is little warning time in this catchment before the onset of flooding. More information on rate of rise is given in Table 8, which lists the rate of rise at a number of locations in the catchment for design events.

Flooding in the catchment is of short duration, as the catchment is relatively small and fast-draining. A 2 hour storm event (the critical duration for most of the catchment) results in a flood event lasting several hours, save for unrelieved depressions and other small areas which may remain inundated for several days. Longer storm durations will produce less severe flooding, which will last, at most, a few days,

The community within the Johnstons Creek catchment has some degree of flood awareness. Recent flood events such as occurred in May 2011 (refer Section 2.1.5), the community consultation process undertaken as part of the Flood Study (Reference 2) and the current flood risk management study have raised some degrees of awareness of the flood problem within the community. The awareness of the community has a high weight in considering flood hazard as a more aware community will be able to better prepare and therefore potentially evacuate before hazards become high. It is assumed that no particular part of this catchment is likely to be any more prepared for a flood than another.

The availability of effective access routes from flood prone areas can directly influence personal danger and potential damage reduction measures. Effective access means an exit route that remains trafficable for sufficient time to evacuate people and possessions. For the majority of residents, as floodplain extents are not vast, there should be easily available vehicular access to dry higher ground. The vehicular and pedestrian access routes are all along sealed roads and present no unexpected hazards if the roads have been adequately maintained.

At depths of 0.3 m wading should be possible for most mobile adults. This obviously could be more of an issue for children, elderly or disabled people. The majority of flood prone properties in the catchment do have access with flood depths of 300mm or less. Larger vehicles can easily travel through water at this depth and aid evacuation. As can be seen on Figure 11, areas of greater than 0.3 m depth in the 1% AEP are limited to the main flowpaths (Lillie Bridge Branch and Orphan School Creek), as well as some small, localised areas elsewhere. This central flowpath, which has velocities between 0.5 and 2.5 m/s in that event, affects only a small part of the catchment and has numerous access roads leading away from it that are relatively dry. Nevertheless, for areas within the catchment without effective flood access, evacuation is generally not recommended considering the short duration of flooding experienced as residents are more likely to put themselves in harms way by evacuating.

The impact of debris is unlikely to be a significant factor due to the low flood depths and/or velocities for large parts of the catchment. Debris can block drains and subsequently severely exacerbate flooding in an area; however, this is very unlikely in the catchment as the drains are not exposed. There is some risk of debris blocking a bridge structure and exacerbating flooding nearby, for example a bridge near Coneill Place; however, the catchment is relatively small, and so there are few areas debris can originate from.

In floods greater than the 1% AEP the hazard will increase as the depth increases. For the majority of areas, the flood level will increase gradually, and as such, residents will be able to evacuate to higher ground. However, in a PMF event there are likely to be areas of high hazard where evacuation could become difficult due to flood depths and velocities (Figure 18). Flood Emergency Response Planning classifications are considered in Section 6.4.

4. CONSULTATION

4.1. Community Consultation

One of the central objectives of the FRMS process is to actively liaise with the community throughout the process, keep them informed about the current study, identify community concerns and gather information from the community on potential management options for the floodplain. The consultation programme consisted of:

- Distribution of brochure and questionnaire survey;
- Media release; and
- Public meetings.

4.1.1. Previous Consultation

As part of the Flood Study (Reference 2), a community questionnaire survey was undertaken during June 2011 to gather historical data for model calibration. 6,500 surveys were distributed to residents within the Johnstons Creek catchment study area and 59 responses were received, which equates to a return rate of 0.9%. Unfortunately no flood levels or depths were provided although the reported flood marks were able to be used as a means of model verification. It was found that there was not one historic event in particular that the residents within the study area identified as being significant. However, it was noted that over 80% of respondents (out of the 59 who replied) are aware of flooding or have some knowledge of flooding in the study area. Further, almost half of the respondents reported flooding on roads, which serve as formalised overland flow paths in this catchment as the sub-surface drainage system is overwhelmed by the runoff volume associated with more extreme events.

4.1.2. Consultation as Part of This Study

Further community questionnaire survey was undertaken during September 2013 to inform residents of the next stage of the floodplain management process as well as to gather flood information and community's preferred options of managing flood risks within the catchment. With assistance from Council, 2,933 copies of the newsletters and questionnaires were printed and delivered to the owners of properties located within the PMF extents as identified in the 2012 Flood Study (Reference 2). 151 responses were received constituting a 5% return rate and the results are as shown in Figure 6A to C.

Of interest is the period of residency/property ownership of the respondents within the catchments with the large majority being less than 10 years. Generally residents who have lived in the same place for many years will have a better understanding of the existing flood risks within the area. About 33% of the respondents experienced some form of flooding within the catchment and 12 respondents reported floodwaters entering their houses or businesses, which is relatively significant. Many residents expressed concerns in regards to the maintenance of the drainage assets within the study area whereby leaves and debris have not been sufficiently cleared from the entry points resulting in local nuisance flooding and exacerbation of existing flood problems.

Among the preferred management options for managing flood risks within the catchment, stormwater harvesting was found to be most popular though this option presents minimal benefits in terms of reducing major flooding. It was suggested that this scheme be carried out at the precinct-wide level rather than at individual lots. The other popular options are improvements to flood flow paths and strategic planning as well as introduction of flood related development controls. One resident proposed that a levee bank is a practical option in managing flooding from Johnstons Creek as a result of high tide and heavy rainfall. The preferred use of public grounds as a retarding basin during a flood event was also mentioned.

4.1.3. Community Information Session

A community information session was held as part of Council's community barbeque on the 9th of March 2014. Information about the current study was provided on a series of posters as well as having representatives from WMAwater and Council on hand to answer questions from local residents. The posters gave information on the floodplain risk management process, both in general and in the study area, as well as on historical flooding in the catchment and the mitigation options currently being considered. Residents were invited to ask questions about the information presented, and to fill out a short questionnaire that rated their support for the different management options.

Residents who attended the session were generally keen to learn about flooding in the area, and to ask questions about the proposed mitigation options. Some were surprised at the magnitude of flooding that was on display; for example, depths of over 1 m flowing down nearby streets, and were interested in photos of historical flooding that showed such depths. There was a general interest in sea level rise and how it would affect flooding in the area, as well as what different levels of risk signified; for example, the likelihood of a 1% AEP flood. On the whole, only a few people had strong opinions on the choice between the different mitigation options, as can be seen from the feedback received from the survey distributed on that day (Figure 6D).

A second community information session was held to inform residents of the options being proposed and to gather feedback. The session was held on the 26th of October 2014 and again was part of a community barbeque. The information presented was largely identical to the March session, with some minor changes to the naming of the mitigation options. As with the previous session, posters described the floodplain risk management process, historical flooding in the catchment and the measures being proposed by the current study.

Public response was similar to the previous session, with residents showing interest in the mitigation options and the area's historical flooding. Of the residents that attended, there was general interest in mitigation options involving structural works and some provided feedback on the options proposed. Around 30 people attended the information stand over the course of the barbeque.

4.2. Floodplain Committee Meetings

The Floodplain Management Committee (FMC) oversees and assists with the floodplain risk management process being carried out within the Council LGA. The committee is comprised of representatives from various stakeholders, including local Councillors, emergency services, Sydney Water Corporation and community representatives. Progress on the current study has been regularly presented to the committee at FMC meetings (every 3 months), at which point questions or feedback from the various representatives was taken.

4.3. Internal Stakeholders Workshop

A workshop attended by internal stakeholders (i.e. representatives from Council, OEH, SES, Sydney Water) was conducted on the 18th December 2013 by WMAwater to provide details and preliminary assessment outcomes of the proposed flood mitigation options. Valuable feedback on the feasibility and suitability of the options presented was obtained and additional options were identified throughout the course of the workshop for further investigation.

4.4. Public Exhibition

Draft reports of the Floodplain Risk Management Study and draft Plan were placed on Public Exhibition in November 2014 in order to present the findings of the study to the public. The exhibition period was from November 10th to December 8th and included advertisements in four newspapers, a letter sent to property owners within the PMF flood extent, publicly available hard copies of the reports and online versions. Community members were invited to make comment on the report either in writing or via the sydneyyoursay.com website. There was also a community information session on October 26th (described in Section 4.1.3). A submission was received from Sydney Water Corporation, who requested more information on the proposed pipe upgrades and acknowledgement of when drainage upgrades use Sydney Water assets. One resident made a submission, requesting more information on flooding around Minogue Crescent.

5. ECONOMIC IMPACT OF FLOODING

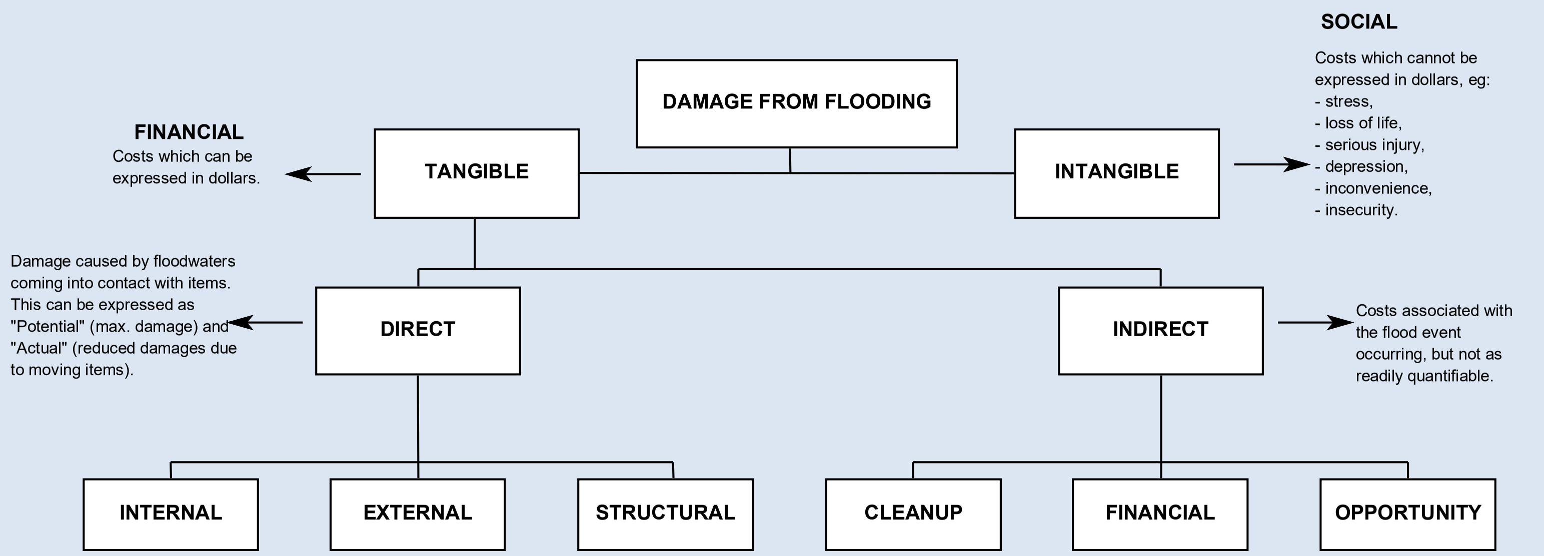
Flood impact can be quantified in the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding. They do, however, provide a basis for assessing the economic loss of flooding and also a non-subjective means of assessing the merit of flood mitigation works such as retarding basins, levees, drainage enhancement etc. The quantification of flood damages is an important part of the floodplain risk management process. By quantifying flood damage for a range of design events, appropriate cost effective management measures can be analysed in terms of their benefits (reduction in damages) versus the cost of implementation. The cost of damage and the degree of disruption to the community caused by flooding depends upon many factors including:

- The magnitude (depth, velocity and duration) of the flood;
- Land use and susceptibility to damages;
- Awareness of the community to flooding;
- Effective warning time;
- The availability of an evacuation plan or damage minimisation program;
- Physical factors such failure of services (sewerage), flood borne debris, sedimentation; and
- The types of asset and infrastructure affected.

The estimation of flood damages tends to focus on the physical impact of damages on the human environment but there is also a need to consider the ecological cost and benefits associated with flooding. Flood damages can be defined as being tangible or intangible. Tangible damages are those for which a monetary value can be easily assigned, while intangible damages are those to which a monetary value cannot easily be attributed. Types of flood damages are shown in Table 3.

The assessment of flood damages not only looks at potential costs due to flooding but also identifies when properties are likely to become flood affected by either flooding on the property or by over floor flooding as shown on Figure 4.

Table 3: Flood Damages Categories (including damage and losses from permanent inundation)



	INTERNAL	EXTERNAL	STRUCTURAL	CLEANUP	FINANCIAL	OPPORTUNITY
RESIDENTIAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Laundries, Caravans, Sheds, Tools, Gardens, Fences	Physical Damage to Buildings: Gyprock, Cupboards, Scour of Footings, Houses becoming buoyant (floating off footings)	Clean Carpets, Walls, Clothes; Re-instate Furniture; Remove Mud and Debris	Loss of wages, Living costs (temporary accomodation and food), Time to repair/replace damaged items	Not Applicable
RURAL	Contents of Buildings: Clothes, Carpets, Furniture, Valuables, Fittings, Appliances	External Items: Vehicles, Sheds (stables/barns), Machinery, Tools, Fences, Feed storage, Saddles, Crops &/or Stock, Irrigation Systems	Physical Damage to Structures: Damage to Homestead, Sheds, Access tracks, Protection levees	Clean Homestead and Out-buildings; Remove Debris; Dispose of affected crops &/or stock	Loss of Farm Production and Income, Re-instatement of Pastures, Supplementary feeding of stock (by hand or outside agistment), Stock movement/ transport, Living costs (temporary accomodation and food)	Sowing or harvesting of Crops, Sale of Stock (at depreciated value or dependent on market influences)
COMMERCIAL	Contents of Buildings: Products, Stock, Fittings, Tools, Machinery, Raw Materials	External Items: Vehicles, Machinery, Display, Raw Materials/Stockpiles, Fences	Physical Damage to Buildings	Dispose of damaged products, stock, materials; Cleaning and Re-instatement	Loss of Productivity and Income, Bank Interest Charges	Loss of existing &/or Potential Trade
PUBLIC AUTHORITIES	Contents of Public Buildings and Facilities	Public Property and Facilities: Parks, Signs, Machinery, Equipment	Physical Damage to Infrastructure: Electricity, Water, Telephone, Gas, Road & Rail Transport Links	Remove Mud & Debris from Facilities, Public & Private Property Repairs (temporary & permanent)	Disruption of Services, Community Service Relief Grants	Provision of Public Service

5.1. Tangible Flood Damages

Tangible flood damages are comprised of two basic categories; direct and indirect damages (refer Table 3). Direct damages are caused by floodwaters wetting goods and possessions thereby damaging them and resulting in either costs to replace or repair or in a reduction to their value. Direct damages are further classified as either internal (damage to the contents of a building including carpets, furniture), structural (referring to the structural fabric of a building such as foundations, walls, floors, windows) or external (damage to all items outside the building such as cars, garages). Indirect damages are the additional financial losses caused by the flood for example the cost of temporary accommodation, loss of wages by employees etc.

Given the variability of flooding and property and content values, the total likely damages figure in any given flood event is useful to get a feel for the magnitude of the flood problem, however it is of little value for absolute economic evaluation. However, damages estimates are useful when studying the economic effectiveness of proposed mitigation options. Understanding the total damages prevented over the life of the option in relation to current damages, or to an alternative option, can assist in the decision making process.

The standard way of expressing flood damages is in terms of average annual damages (AAD). AAD represents the equivalent average damages that would be experienced by the community on an annual basis, by taking into account the probability of a flood occurrence. This means the smaller floods, which occur more frequently, are given a greater weighting than the rare catastrophic floods.

In order to quantify the damages caused by inundation for existing development a floor level survey was undertaken. As part of this floor level survey work an indicative ground level was recorded for use in the damages assessment. This was used in conjunction with the flood level information for design events as established in the Flood Study (Reference 2) and amended as part of this Study to take into account the recent changes in the floodplain. Damages calculations were carried out for all properties within the 1% AEP flood extent, and floor level survey was undertaken for these properties. It should be noted that by including only those properties in the 1% AEP extent, properties that are inundated in rarer events have not been accounted for. Therefore damage calculations for the PMF event are likely to be underestimated.

It was not considered viable to survey all properties within the PMF extent for the purpose of damage calculations. The selection of all properties in the 1% AEP extent would be expected to include all properties that have overfloor flooding in the PMF, given the relatively small difference in the 1% AEP and PMF flood level across the catchment.

A flood damages assessment was undertaken as part of the Flood Study (Reference 2) for existing development in accordance with current OEH guidelines (Reference 8) and the Floodplain Development Manual (Reference 1). As additional properties floor levels were surveyed as part of this study, the estimated flood damages were revised. The damages were calculated using a number of height-damage curves which relate the depth of water above the floor with tangible damages. Each component of tangible damages is allocated a maximum value and a maximum depth at which this value occurs. Any flood depths greater than this allocated value do not incur additional damages as it is assumed that, by this level, all potential damages have already occurred.

Damages were calculated for residential and commercial\industrial properties separately and the process and results are described in the following sections. The combined results are provided as Table 4. This flood damages estimate does not include the cost of restoring or maintaining public services and infrastructure. It should be noted that damages calculations do not take into account flood damages to any basements or cellars, hence where properties have basements damages can be under estimated.

Table 4: Estimated Combined Flood Damages for Johnstons Creek Catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
5 year ARI	111	38	$ 3,281,700	$ 29,600
10% AEP	127	61	$ 4,311,900	$ 34,000
5% AEP	138	75	$ 5,358,000	$ 38,900
2% AEP	148	82	$ 6,080,100	$ 41,100
1% AEP	159	94	$ 7,027,200	$ 44,200
PMF	180	139	$ 14,320,800	$ 79,600
		Average Annual Damages (AAD)	**$ 2,277,900**	**$ 12,700**

Section 10.2 presents results of the damages assessment undertaken for the proposed mitigation options which were compared against the existing scenario so that the feasibility of the proposed mitigation options can be determined.

5.1.1. Residential Properties

Flood damages assessment for residential development was undertaken in accordance with OEH guidelines (Reference 8). For residential properties, external damages (damages caused by flooding below the floor level) were set at $6,700 and additional costs for clean-up as $4,000. For additional accommodation costs or loss of rent a value of $220 per week was allowed assuming that the property would have to be unoccupied for up to three weeks. Internal (contents) damages were allocated a maximum value of $37,500 occurring at a depth of 2 m above the building floor level (and linearly proportioned between the depths of 0 to 2 m). Structural damages vary on whether the property is slab/low set or high set. For the purpose of this study, any property with a floor level of 0.5 m or more above ground level was assumed to be high set. For two storey properties, damages (apart from external damages) are reduced by a factor of 70% where only the ground floor is flooded as it is assumed some contents will be on the upper floor and unaffected and that structural damage costs will be less. In some instances external damage may occur even where the property is not inundated above floor level and therefore tangible damages include external damages which may occur with or without house floor inundation.

A summary of the residential flood damages for the Johnstons Creek catchment is provided in Table 5. Overall, for residential properties in the catchment there is little difference in the average tangible damages per property for all the design events analysis up to the 1% AEP event. This is reflective of the relatively small differences in flood levels between the design flood events. Average damage per property increases at events larger than the 1% AEP when more properties become flooded above floor level. Note that the terminology used refers to a property or lot being the land within the ownership boundary. Flooding of a property does not necessarily mean flooding above floor level of a building on that property/lot.

Table 5: Estimated Residential Flood Damages for Johnstons Creek Catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
5 year ARI	97	32	$ 1,910,700	$ 19,700
10% AEP	114	54	$ 2,696,100	$ 23,700
5% AEP	124	66	$ 3,220,700	$ 26,000
2% AEP	134	73	$ 3,715,200	$ 27,800
1% AEP	145	84	$ 4,322,200	$ 29,900
PMF	166	125	$ 8,700,600	$ 52,500
		Average Annual Damages (AAD)	**$ 1,351,900**	**$ 8,200**

5.1.2. Commercial and Industrial Properties

The tangible flood damage to commercial and industrial properties is more difficult to assess. Commercial and industrial damage estimates are more uncertain and larger than residential damages. Commercial and industrial damage estimates can vary significantly depending on:

- Type of business – stock based or not;
- Duration of flooding – affects how long a business may be closed for not just whether the business itself if closed but when access to it becomes available;
- Ability to move stock or assets before onset of flooding - some large machinery will not

be able to moved and in other instances there may be no sufficient warning time to move stock to dry locations; and

- Ability to transfer business to a temporary location.

Costs to business can occur for a range of reasons, some of which will affect some businesses more than others dependent on the magnitude of flooding and the type of businesses. Common flood costs to businesses are:

- Removal and storage of stock before a flood if warning is given;
- Loss of production – caused by damaged stock, assets and availability of staff;
- Loss of stock and/or assets;
- Reduced stock through reduced or no supplies;
- Trade loss – by customers not being able to access the business or through business closure;
- Cost of replacing damages or lost stock or assets; and
- Clean-up costs.

No specific guidance is available for assessing flood damages to non-residential properties. Therefore for this Study, commercial and industrial damages were calculated using the methodology for residential properties but with the costs/damages increased to a value which is consistent with commercial/industrial development. For example, the maximum value of internal (contents) damages was increased to $250,000 since the building contents are of higher value whilst loss of rent was set at $3,000 per week to account for the loss of business through having to close for a period. Flooding below floor level uses the same damages curve as the residential properties.

Though the original OEH guidelines for flood damages calculations are not applicable to non-residential properties, they can still be used to create comparable damage figures. The damages value figure should not be taken as an actual likely cost rather it is useful when comparing potential management options and for benefit-cost analysis.

A summary of the commercial/industrial flood damages for the Johnstons Creek catchment is provided in Table 6. AAD for the surveyed commercial/industrial properties is slightly less than that for residential properties but the number of flood affected properties for the latter is 7 to 10 times more than that of the former. This reflects the higher costs that businesses would incur compared to residential dwellings when flooded above floor level. On a per property basis the AAD is approximately 8.1 times higher when comparing the commercial/industrial properties against the residential properties.

Table 6: Estimated Commercial and Industrial Flood Damages for Johnstons Creek Catchment

Event	Number of Properties Flood Affected	No. of Properties Flooded Above Floor Level	Total Tangible Flood Damages	Average Tangible Damages Per Flood Affected Property
5 year ARI	14	6	$ 1,371,000	$ 98,000
10% AEP	13	7	$ 1,615,800	$ 124,300
5% AEP	14	9	$ 2,137,300	$ 152,700
2% AEP	14	9	$ 2,365,000	$ 169,000
1% AEP	14	10	$ 2,705,000	$ 193,300
PMF	14	14	$ 5,620,300	$ 401,500
Average Annual Damages (AAD)			**$ 926,100**	**$ 66,200**

5.2. Intangible Flood Damages

The intangible damages associated with flooding, by their nature, are inherently more difficult to estimate in monetary terms. In addition to the tangible damages discussed previously, additional costs/damages are incurred by residents affected by flooding, such as stress, risk/loss to life, injury, loss of sentimental items etc. It is not possible to put a monetary value on the intangible damages as they are likely to vary dramatically between each flood (from a negligible amount to several hundred times greater than the tangible damages) and depend on a range of factors such as the size of flood, the individuals affected, and community preparedness. However, it is still important that the consideration of intangible damages is included when considering the impacts of flooding on a community.

Post flood damages surveys have linked flooding to stress, ill-health and trauma for the residents. For example the loss of memorabilia, pets, insurance papers and other items without fixed costs and of sentimental value may cause stress and subsequent ill-health. In addition flooding may affect personal relationships and lead to stress in domestic and work situations. In addition to the stress caused during an event (from concern over property damage, risk to life for the individuals or their family, clean up etc.) many residents who have experienced a major flood are fearful of the occurrence of another flood event and the associated damage. The extent of the stress depends on the individual and although the majority of flood victims recover, these effects can lead to a reduction in quality of life for the flood victims.

During any flood event there is the potential for injury as well as loss of life due to causes such as drowning, floating debris or illness from polluted water. Generally, the higher the flood velocities and depths the higher the risk. Within the Johnstons Creek catchment area, the high hazard areas include Johnstons Creek and trapped low points with high flood depths, i.e. at Larkin Street upstream of Pyrmont Bridge Road. However, there will always be local high risk (high hazard) areas where flows may be concentrated around buildings or other structures within low hazard areas.

6. FLOOD EMERGENCY RESPONSE ARRANGEMENTS

6.1. Flood Emergency Response

The majority of flooding within the Johnstons Creek catchment is characterised by overland flow. The critical duration is between 30 minutes and 2 hours across the catchment, with the peak of the flood reached approximately 30 minutes to 1 hour after the start of the storm. This is considered short duration “flash” flooding.

Due to the short interval between the start of the storm and the peak of the flood, there is little in the way of warning that can be provided. Any warning provided would be for immediate safety precautions such as temporary refuge (if available nearby or onsite), raising of items off the ground and accounting for people on site.

The short duration until flooding occurs does not allow sufficient time to evacuate residents from their properties. In these situations, evacuation is generally not recommended as the response during a flood event as it is likely to be hurried and uncoordinated, which can expose evacuees to a hazardous situation. As such, the preferred response to flooding in flash flooding catchments is for people to remain within the property, preferably within the upper levels if available. The suitability of the shelter-in-place approach should be considered in consultation with the State Emergency Service (SES) for the preparation of a Local Flood Plan.

It is important that residents are aware of signs that will signal an approaching flood, and are aware of the correct response such that the small time period before the flood arrives may be used as effectively as possible to move people and belongings to a close, safe location.

The nature of the flood problem in the study area does not lend itself to a managed flood response. The issues undermining a planned response are as follows:

- Lack of effective warning time;
- Flood issue is distributed rather than aggregated;
- Difficulty with vehicle movement during an event; and finally
- The flash nature of the flooding. Note that where rainfall exceeds 5 year ARI intensity generally speaking vehicle movement will be limited by visibility.

As such, and given the lack of a specific response plan at this time, it is reasonable to suggest that SES response will be ad hoc and demand based. Arguably then the most critical element of SES response will be flexibility.

The largest impediment to operational flexibility is likely to be vehicle movement. As such in looking at improving flood risk via enhanced flood emergency response the study has focussed on the roads that may be cut in the event of flooding.

Given the relatively low risk nature of most flooding it is reasonable to assume that flooded roads will be one of the highest risk areas during flooding. As such road locations subject to inundation must be a priority for management.

6.2. Flood Emergency Responses Documentation

Flood emergency measures are an effective means of reducing the costs of flooding and managing the continuing and residual risks to the area. Current flood emergency response arrangements for managing flooding in the Johnstons Creek catchment are discussed as follows.

6.2.1. DISPLAN

The Johnstons Creek catchment is located within the Sydney West Emergency Management District. Flood emergency management for the study area is organised under the NSW Disaster Plan (2010) (DISPLAN). No district DISPLAN has been prepared for this district.

The DISPLAN details emergency preparedness, response and recovery arrangement for NSW to ensure the coordinated response to emergencies by all agencies having responsibilities and functions in emergencies.

The DISPLAN has been prepared to coordinate the emergency management measures necessary at State level when an emergency occurs, and to provide direction at District and Local level.

The plan is consistent with district plans prepared for areas across NSW and covers the following aspects at a state level:

- Roles and strategies for prevention of disasters;
- Planning and preparation measures;
- Control, coordination and communication arrangements;
- Roles and responsibilities of agencies and officers;
- Conduct of response operations; and
- Co-ordination of immediate recovery measures.

The DISPLAN states that:

"*Each District and Local Emergency Management Committee is to develop and maintain its own District / Local Disaster Plan, with appropriate Supporting Plans and Sub Plans, as required by*

Functional Area Coordinators and Combat Agency Controllers at the appropriate level. Supporting plans are to be the exception at local level and their development must be approved by District Functional Area Coordinators."

It is recommended that a DISPLAN be prepared for the Sydney West Emergency Management District to outline emergency response arrangement specific to the district. In particular the purpose of a District DISPLAN is to:

- Identify responsibilities at a District and Local level in regards to the prevention, preparation, response and recovery for each type of emergency situation likely to affect the district;
- Detail arrangements for coordinating resource support during emergency operations at both a District and Local level;
- Outline the tasks to be performed in the event of an emergency at a District and Local level;
- Specifies the responsibilities of the West Metropolitan District Emergency Operations Controller and Local Emergency Operations Controllers within the West Metro EM District;
- Detail the responsibilities for the identification, development and implementation of prevention and mitigation strategies;
- Detail the responsibilities of the District and Local Emergency Management Committees within the District;
- Detail agreed Agency and Functional Area roles and responsibilities in preparation for, response to and recovery from, emergencies;
- Outline the control, coordination and liaison arrangements at District and Local levels;
- Detail arrangements for the acquisition and coordination of resources;
- Detail public warning systems and responsibility for implementation;
- Detail public information arrangements and public education responsibilities;
- Specifies arrangements for reporting before, during and after an operation; and
- Detail the arrangements for the review, testing, evaluation and maintenance of the Plan.

6.2.2. Local Flood Plan

A local flood plan has not been prepared for the local area containing the Johnstons Creek catchment. As such, the New South Wales State Flood Sub-plan (2008) is used to set out the arrangements for the emergency management of flooding.

The State Flood Sub-plan is a sub-plan to the state DISPLAN. The Sub-plan sets out the emergency management aspects of prevention, preparation, response and initial recovery arrangements for flooding and the responsibilities of agencies and organisations with regards to these functions.

There is a requirement for the development and maintenance of a Flood Sub-plan for:

- The State of New South Wales;
- Each SES Region; and
- Each council area with a significant flood problem. In some cases the flood problems of more than one council area may be addressed in a single plan or the problems of a single council area may be addressed in more than one.

Annex B of the Sub-plan lists the Local Flood Sub Plans that exist or are to be prepared in New South Wales and indicates which river, creek and/or lake systems are to be covered in each plan.

The City of Sydney is not listed in Annex B. However, it may be useful for the City of Sydney to prepare a Local Flood Plan in conjunction with the SES to outline the following details:

- Evacuation centres in close proximity to the floodplain which allow flood free access to the centres and are flood free sites;
- Inclusion of a description of local flooding conditions;
- Identification of potentially flood affected vulnerable facilities; and
- Identification of key access roads subject to flooding.

6.2.3. Emergency Service Operators

The emergency response to any flooding of the Johnstons Creek catchment will be coordinated by the lead combat agency, the SES, from their Local Command Centre located at Erskineville. However, the City of Sydney Security and Emergency Management Centre located at Town Hall is on the notification list for SES flood warning alerts and direct liaison between the SES and the Security and Emergency Management Centre may be conducted via a dedicated radio frequency.

The Manager - Security and Emergency Management may then pass on the flood warnings to any affected Council or Community Building within the Johnstons Creek catchment.

The Security and Emergency Management Centre will continue to receive regular updates from the SES throughout a flood event.

The relevant flood information from the draft Johnstons Creek Catchment Flood Study (Reference 2) should be transferred to the Security and Emergency Management Centre.

6.2.4. Flood Warning Systems

The critical duration and response times for the catchment limit the implementation of a flood warning system. The short duration flooding experienced in local systems is not well suited to flood warning systems. However, for areas prone to flash flood within the catchment, the BoM provides general warning services, including:

- Severe Thunderstorm Warnings
- Severe Weather Warnings
- Flood Watches

These services are typically issued for a much larger region, or catchment, that includes the local flash flood site. This information can sometime be used at a local level as discussed below.

6.2.4.1. Flood Warnings Issued by BOM

The Johnstons Creek catchment is affected by flash flooding (i.e. floods where the warning time is less than 6 hours). As such it is difficult to provide any flood warning in advance of floods. Where possible, the Bureau of Meteorology (BoM) will issue a severe weather / flood warning to the Regional SES headquarters in Bankstown. Where that alert is relevant to the Johnstons Creek catchment, the SES Regional Command will pass the BoM's warning on to the Local Command based in Erskineville. In some cases, 2-3 days advanced notice may be available (e.g. where an East Coast Low develops off Sydney). However, at other times it may only be possible to issue a flood warning a few hours in advance, if at all.

6.2.4.2. Activation of Local SES Command

SES staff are advised and placed on alert when the SES Local Command has been issued with a flood warning by the BoM. The BoM's flood warning is also forwarded by SMS to the relevant individuals and organisations, including the City of Sydney Security and Emergency Management Centre located at Town Hall.

It is noted that the SES is the designated lead combat agency in an emergency such as a flood event. However, local authorities may wish to act on the advice provided by the SES to minimize the level of risk in the lead up to the flood event. Depending on the amount of lead time provided, Council may undertake any relevant priority works, such as cleaning out storm water pits to reduce the risk of blockage. In addition, Council's Rangers are placed on standby and report any issue directly to the SES (e.g. cars parked in overland flow paths, etc.).

6.2.4.3. Management of the Public Domain

A number of open, public areas are located within the Johnstons Creek catchment. This includes the parkland near the catchment outlet (Jubilee Park, Bicentennial Park and part of the Harold Park development), which are all flood liable, and the various ovals in University of Sydney. Two of these ovals (St. Johns Oval and Sydney University Oval 2, shown on Figure 1) are largely flood free in the 1% AEP event, and could provide temporary refuges which can be accessed in a few minutes. A small warning time may provide the public with sufficient time to seek refuge. The provision of rapid flood warnings within the catchment may be delivered through an automated process that triggers a warning (e.g. with the installation of water level sensors placed in trapped depression areas). The warning itself could be delivered through the use of suitably located electronic information boards at key locations.

Another option is to have a public address system, which can relay a recorded message. The system could be similar to what the City of Sydney has already installed to manage emergencies in the busy streets of the City. An example of this system can be found near the main entrance of the Council building at Town Hall Square, where the public address speakers are installed on a traffic light pole. Similarly, Variable Message Displays may be used at inundated roads to give warning during a flood event.

6.3. Access and Movement During Flood Events

Any flood response suggested for the study area must take into account the availability of flood free access, and the ease with which movement may be accomplished. Movement may be evacuation from flood affected areas, medical personnel attempting to provide aid, or SES personnel installing flood defences.

6.3.1. Access Road Flooding

Parramatta Road is one of the main road linkages from the city to the Western Suburbs. At the intersection of Parramatta Road and Larkin Street events with rainfall intensities as low as 5 year ARI intensities can potentially cause significant inundation. Excessive flooding of this road could potentially inhibit traffic and result in significant impacts on traffic flows throughout the region. During a significant flood event it is likely that emergency service vehicles would be required in the affected area, though access may be severely hindered by the possibility of major road closures. A summary of flood depths on Parramatta Road (near Larkin Street) is provided in Table 7, while Table 8 gives the rate of rise at the same locations. Locations described in the table are shown on Figure 25, which also shows the 1% AEP flood depth for several access roads in detail. Note that inundation duration may vary significantly although given the limited catchment area overall, duration of an hour or less will be typical.

Table 7: Major Road Peak Flood Depths (m) and Rate of Rise (m/hour) for Various Events

ID	Road Location	5 year ARI	10% AEP	5% AEP	2% AEP	1% AEP	PMF
1	Parramatta Road (St Johns Oval)	0.8	0.9	0.9	1.0	1.0	2.3
2	Pyrmont Bridge Road	0.1	0.1	0.1	0.2	0.2	1.3
3	Bridge Road (Abbey)	0.5	0.5	0.6	0.6	0.6	0.8
4	St Johns Road	0.6	0.6	0.6	0.7	0.7	0.9
5	Mallet Street & Parramatta Road	0.1	0.1	0.1	0.1	0.2	0.2
6	Minogue Crescent	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
7	Chapman Road	0.3	0.4	0.6	0.7	0.7	1.2

Table 8: Major Road Flooding Rate of Rise (m/hour) for Various Events (2 hour duration event)

ID	Road Location	5 year ARI	10% AEP	5% AEP	2% AEP	1% AEP	PMF
1	Parramatta Road (St Johns Oval)	0.5	0.6	0.7	0.8	0.9	1.5
2	Pyrmont Bridge Road	0.5	0.5	0.5	0.5	0.5	0.3
3	Bridge Road (Abbey)	0.7	0.7	0.8	0.9	0.9	0.3
4	St Johns Road	0.6	0.6	0.7	0.7	0.8	0.3
5	Mallet Street & Parramatta Road	0.2	0.2	0.2	0.2	0.2	0.1
6	Minogue Crescent	0.1	0.1	0.1	0.1	0.1	<0.1
7	Chapman Road	0.9	1.0	1.2	1.3	1.4	0.5

For the 1% AEP flood event, roads cut (as per Figure 25) are shown in Table 9 (in order of importance).

Table 9: Major Roads Cut in the 1% AEP Event

Road Location	Description
Parramatta Road at north-western extent of University of Sydney	Flood depths are up to 1.0 m and persist for a period of one hour given the critical storm modelled (2 hour)
The Crescent near the Trafalgar Street intersection	Flood depths up to 0.8 m can be expected and persist for a period of one hour
St Johns Road opposite Mt Vernon Lane	Flood depths of up to 0.8 m depth which will persist for short periods (less than one hour)
Wigram Road immediately upstream of the new Harold Park development	Minor flooding, depths are less than 0.5 m and will not persist for long (less than one hour)

Following a review of this information revised SES plans might allot responsibility for management of these road closures. Note SES involvement is likely to be required given the presumable limited mobility of Council employees in the event of a severe flood event.

6.3.2. Evacuation Centres

Given the lack of effective warning time in the catchment evacuation will likely occur as a reaction to flooding rather than as a preventive action prior to flooding. On this basis, and given difficulties in moving around the catchment during flooding, it seems that evacuation in most cases will be opportunistic and involve buildings that are flood free proximate to flooded homes.

Across the catchment as a whole, the following can be said in regards to evacuation:

- Flood affectation generally doesn't warrant evacuation. Due to the limited catchment and the overland flow nature of the flooding in the main flow paths, flood flows and depths will not increase dramatically for events of low probability of occurrence. This reduces the need for evacuation as in most cases, even where property is flooded, the property is not exposed to high hazard/floodway flow; and
- In most cases should a resident seek to leave an inundated property, safe egress will be relatively straightforward as most flood affected areas can be categorised as "Rising Road Access" (see Section 6.4 for further details).

Several flood free locations have been identified in Table 10 and Figure 26 that may be suitable to function as evacuation centres during and following a flood event, if required. Council and the SES should liaise with the owners or managers of these venues identified to ascertain their suitability to function as evacuation centres. The selected location should be identified in a local flood plan when it is prepared.

Table 10: Possible Evacuation Centres

ID[1]	Name of Venue	Address
1	PCYC	2-4 Minogue Crescent Glebe NSW 2037
2	St James Catholic Primary School	2 Woolley Street Glebe NSW 2037
3	St James' Catholic Church	2 Woolley Street Glebe NSW 2037
4	Forest Lodge Public School	Bridge Road Forest Lodge NSW 2037
5	The Salvation Army Glebe	9 Ross Street Forest Lodge NSW 2037
6	University of Sydney School of Geosciences	Madsen Building (F09) Eastern Avenue Camperdown NSW 2006
7	University of Sydney School of Public Health	Edward Ford Building (A27),University of Sydney/Fisher Road Sydney NSW 2206
8	University of Sydney School of Psychology	Brennan MacCallum Building A18 Manning Road Camperdown NSW 2050

9	University of Sydney School of Letters, Art and Media	Parramatta Road Camperdown NSW 2050
10	Royal Prince Alfred Hospital	Missenden Road Camperdown NSW 2050
11	University of Sydney Nursing School	88 Mallett Street Camperdown NSW 2050

[1] Refer to Figure 26

6.4. Flood Emergency Response Classifications

To assist in the planning and implementation of response strategies, the SES in conjunction with OEH has developed guidelines to classify communities according to the impact that flooding has upon them. These Emergency Response Planning (ERP) classifications (Reference 9) consider flood affected communities as those in which the normal functioning of services is altered, either directly or indirectly, because a flood results in the need for external assistance. This impact relates directly to the operational issues of evacuation, resupply and rescue. Based on the guidelines, communities are classified as either; Flood Islands; Road Access Areas; Overland Access Areas; Trapped Perimeter Areas or Indirectly Affected Areas and when used with the SES Requirements Guideline (Reference 9). The ERP classification can identify the type and scale of information needed by the SES to assist in emergency response planning (refer to Table 11).

Table 11: Emergency Response Planning Classifications of Communities

	Response Required		
Classification	**Resupply**	**Rescue/Medivac**	**Evacuation**
High flood island	Yes	Possibly	Possibly
Low flood island	No	Yes	Yes
Area with rising road access	No	Possibly	Yes
Area with overland escape routes	No	Possibly	Yes
Low trapped perimeter	No	Yes	Yes
High trapped perimeter	Yes	Possibly	Possibly
Indirectly affected areas	Possibly	Possibly	Possibly

Key considerations for flood emergency response planning in these areas include:

- Cutting of external access isolating an area;
- Key internal roads being cut;
- Transport infrastructure being shut down or unable to operate at maximum efficiency;
- Flooding of any key response infrastructure such as hospitals, evacuation centres, emergency services sites;
- Risk of flooding to key public utilities such as gas, power, sewerage; and
- The extent of the area flooded.

Flood liable areas within the study area have been classified according to the ERP classification above. As the classifications take account of flood extents and do not regard flood depths it was seen as unsuitable to use the full flood extent for the Johnstons Creek catchment where, using the above classification, areas surrounded by less than only 0.1 m of water could be classified as flood islands when in reality most people could move through this water without problem. Therefore before assessing the ERP classifications flood depths less than 0.1 m were removed from the PMF flood extents. ERP classifications for the study area are shown in Figure 27.

7. POLICIES AND PLANNING

7.1. Legislative and Planning Context

The Johnstons Creek catchment is located within the City of Sydney LGA where development is controlled through the Sydney Local Environment Plan (LEP) 2012 and Sydney Development Control Plan (DCP) 2012. The LEP is a planning instrument which designates land uses and development in the LGA while the DCP regulates development with specific guidelines and parameters. Management policies and plans are often used to provide additional information regarding development guidelines and parameters. This section reviews flood controls covered by the LEP, DCP, and other relevant policies and plans.

7.1.1. NSW Flood Prone Land Policy

The primary objective of the NSW Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property and reduce public and private losses resulting from floods whilst utilising ecologically positive methods wherever possible.

The NSW Floodplain Development Manual (Reference 1) relates to the development of flood liable land for the purposes of Section 733 of the Local Government Act 1993 and incorporates the NSW Flood Prone Land Policy.

The Manual outlines a merits based approach to floodplain management. At the strategic level this allows for the consideration of social, economic, cultural, ecological and flooding issues to determine strategies for the management of flood risk. The Manual recognises differences between urban and rural floodplain issues. Although it maintains that the same overall floodplain management approach should apply to both, it recognises that a different emphasis is required for each type of floodplain.

7.1.2. Existing Council Policy

With regards to flood risk management, Councils use Local Environment Plans (LEP) and Development Control Plans (DCP) to set policies and development controls. City of Sydney recently adopted the Sydney Local Environmental Plan 2012 and Sydney Development Control Plan 2012 and these are discussed in the following sections in relation to flood risk and management. Council has also prepared an Interim Floodplain Management Policy that will operate until Council completes floodplain risk management plans for its entire LGA and then integrates these outcomes into planning controls.

Sydney LEP 2012

This planning instrument provides overall objectives, zones and core development standards, including provisions related to "flood planning" applicable to land at or below the flood planning level. Clause 7.15 of the Plan states the following objectives in relation to flood planning:

- To minimise the flood risk to life and property associated with the use of land;
- To allow development on land that is compatible with the land's flood hazard, taking into consideration projected changes as a result of climate change; and
- To avoid significant adverse impacts on flood behaviour and the environment.

The Clause stipulates that consent will not be granted to development on land to which this Clause applies unless Council is satisfied that the development:

- Is compatible with the flood hazard of the land;
- Is not likely to significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties;
- Incorporates appropriate measures to manage risk to life from flood;
- Is not likely to significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and
- Is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding.

Under this Clause, the flood planning level is defined as the level of a 1% AEP flood event plus 0.5 metres freeboard.

The LEP contains a number of land use zones as shown in Figure 2. For each zone, the LEP specifies development which may be carried out with or without consent, prohibited development and objectives for development. For the Harold Park redevelopment, the Sydney LEP (Harold Park) 2011 applies. Several other state planning instruments also apply to specific areas within the catchment including:

- Sydney Regional Environmental Plan (SREP) No. 26 City West; and
- Sydney Regional Environmental Plan (SREP) Sydney Harbour Catchment 2005.

Sydney DCP 2012

The purpose of this plan is to supplement the LEP and provide more detailed provisions to guide development. It came into effect on the same day as the LEP and must be read in conjunction with the provision of the LEP.

Prescriptive planning controls are provided in Section 3.7 of the document. The objectives of these planning controls are to:

- Ensure an integrated approach to water management across the City through the use of water sensitive urban design principles;
- Encourage sustainable water use practices;
- Assist in the management of stormwater to minimise flooding and reduce the effects of stormwater pollution on receiving waterways;
- Ensure that development manages and mitigates flood risk, and does not exacerbate the potential for flood damage or hazard to existing development and to the public domain; and
- Ensure that development above the flood planning level as defined in the Sydney LEP 2012 will minimise the impact of stormwater and flooding on other developments and the public domain both during and after the event.

Whilst these objectives are clearly defined in the Sydney DCP 2012, no specific development controls are provided to achieve these objectives (except for those relating to-site detention). Requirements for site specific flood studies are also outlined in the document but there seems to be some inconsistency between this document and the LEP, as the DCP states that site specific flood studies may be required by Clause 7.17 of the Sydney LEP 2012. There is no mention of flood management in Clause 7.17 and no reference as to when a site specific flood study may be required in the LEP.

Sydney DCP (Harold Park) 2011
This DCP applies to Harold Park and was adopted by Council in 2011. It complements the provisions of the Sydney LEP (Harold Park) 2011 as well as Sydney DCP 2012. The DCP provides more detailed provisions than those in the LEP for development on the site.

The objective of this plan in regards to stormwater and water sensitive urban design is to ensure an integrated approach to water cycle management through the use of water sensitive urban design principles and that new development is not subjected to undue flood risk nor exacerbate the potential for flood damage or hazard to existing development and to the public domain. With regards to flooding, Section 6.3.3 designated that the development of the site shall:

a) not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties;
b) incorporate appropriate measures to manage risk to life from flooding;
c) not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses; and
d) is not likely to result in unsustainable social and economic costs to the community as a

consequence of flooding.

The requirements for flood planning levels for this development are also provided in this document.

Interim Floodplain Management Policy (2014)

This interim Policy (Reference 11) provides direction with respect to how floodplains are managed within the LGA of the City of Sydney. This Policy has been prepared having regard to the provisions of the NSW Flood Policy and NSW Floodplain Development Manual (Reference 1) and is to be read in conjunction with the provisions of the LEP and DCP. The draft Policy was on exhibition in September and October 2013, and adopted by Council in May 2014.

The Policy outlines Council responsibilities in managing floodplains and it provides controls to facilitate a consistent, technically sound and best practice approach for the management of flood risk within the LGA. This interim policy will be withdrawn once Council complete Floodplain Risk Management Plans for the entire LGA and then integrate outcomes from these plans into planning controls.

The document provides general requirements for proposed development on flood prone land, Flood Planning Level requirements for different development types and guidelines on flood compatible materials. It makes the following requirements of new development on flood prone land:

- It stipulates the information that is to be provided with a development application relevant to the various controls, for example building layouts and floor plans;
- It gives a criterion that must be satisfied in the case of a development not meeting the relevant Prescriptive Provisions in Sydney DCP 2012. These criteria include the development being compatible with established flood hazard of the land, not impacting flood behaviour so that other properties' affectation is worsened and incorporating appropriate measures to manage risk to life from flood;
- Concession is made to minor additions being made to existing properties, as these additions are acknowledged to not present an unmanageable risk to life. The concession can be given to dwelling additions of up to 40 m^2 and commercial industrial/commercial additions of up to 100 m^2 or 20% of Gross Floor Area. The concession is granted no more than once per development;
- It gives general requirements for development on flood prone land, including design requirements for fencing, minimum floor level, car parking, filling of flood prone land and the impact of climate change;
- It sets flood planning levels to be adhered to by various types of development. For example habitable rooms affected by mainstream flooding are to be at or above the 1% AEP flood level + 0.5 m. Other levels are given for properties affected by local drainage

flooding (as per the Policy's definition), industrial/commercial development, car parks and critical facilities; and

- It specifies flood compatible materials for various components of a development, for example use of concrete slab-on-ground monolith construction or suspended reinforced concrete slab for flooring.

7.2. Planning Recommendations

Based on the review of the planning documents presented in the previous sections, the following recommendations have been made:

- Though the Sydney LEP 2012 is the primary state planning document relating to the catchment, other documents like the Sydney LEP (Harold Park) 2011 are also relevant to specific areas or development types in the catchment. These other documents contain more detailed consideration of flood management than the Sydney LEP 2012. Council may wish to consider updating the Sydney LEP 2012 to be consistent with the flood related clauses in these other documents;
- There is a lack of consistency between the Sydney LEP 2012 and the Sydney DCP 2012. It is recommended that either the LEP or the DCP or both are updated to ensure accurate cross referencing between the two documents. Also the requirements for a site specific flood study are provided in the Sydney DCP 2012. Though the DCP notes that the Sydney LEP 2012 outlines when a site specific flood study is required, the LEP does not contain this information. Either the LEP or the DCP or both should be updated to ensure this information is provided;
- Flood related development controls and requirements are provided in the Interim Floodplain Management Policy (Reference 11). Reference to this policy should be included in the DCP or the key controls outlined in the Policy could also be included in the DCP. Council's current position on climate change requirements should also be informed in the DCP as outlined in the Policy;
- Consideration of emergency response provisions in new development with regards to short duration flooding in the catchment should also be included in the Interim Floodplain Management Policy (Reference 11); and
- There may be opportunities to incorporate flood management measures into new developments as a condition of consent, Section 94 contribution offsets or government related funding. The nature of the flood controls implemented will be dependent on the location of the development, the flooding behaviour and the type of development. However, allowance and / or requirements for these works could be identified through amendments to the Sydney DCP 2012 or the Interim Floodplain Management Policy (Reference 11).

8. FLOOD PLANNING AREA AND LEVEL REVIEW

8.1. Flood Planning Area (FPA)

The Flood Planning Area (FPA) is an area within Council's LGA to which flood planning controls are applied. It is important to define the boundaries of the FPA to ensure flood related planning controls are applied where necessary and not to those lots unaffected by flood risk. It is also important to define the FPA on criteria as per the NSW Floodplain Development Manual (Reference 1).

Note that the FPA can be composed of mainstream and overland flow elements. Typically different criteria are used to generate the mainstream and overland flow FPA extents and then these are combined. Since the Johnstons Creek catchment is subject to both mainstream and overland flow flooding, both elements were considered.

The FPA extent defines those properties subject to Section 149 (2) notification under the 1979 EP&A Act. Section 149(2) notification denotes that a land owner is subject to flood related development controls.

Whilst for mainstream flooding the FPA can be defined simply as the 1% AEP event plus freeboard (typically 0.5 m), such a method is sometimes not appropriate for areas subject to overland flow flooding which often do not reach the depths that could occur from mainstream flooding and additionally, where depths do not tend to increase significantly for rarer events. This is particularly an issue in urban areas such as the Johnstons Creek catchment where the 1% AEP flood level plus 500 mm freeboard is consistently higher than the PMF flood level in areas of overland flow.

The provisional FPA is shown in Figure 28. As can be seen use of the 1% AEP flood level with 500 mm freeboard (for overland flow) results in a FPA that encompasses much of the catchment.

Clearly however it would be overly conservative to define a FPA that was significantly larger than the PMF as this would effectively impose flood risk related planning controls on properties not subject to any flood risk.

Therefore an alternative approach to define a reasonable FPA is being considered by Council. This is being considered in the context of LGA wide flood affectation and as such no FPA has been finalised as part of the work herein. A recommendation for defining the overland flow component of the FPA is provided as follows.

Due to the nature of flooding in the Johnstons Creek catchment area it is recommended that Council consider adoption of an alternate method of establishing the FPA for areas affected by overland flow rather than the current 1% AEP plus 0.5 m freeboard. The following methodology is proposed for defining the FPA as a composite of mainstream and overland flow flooding:

- Mainstream flooding: Defined as the peak flood level within the open channel section of Johnstons Creek plus a 0.5 m freeboard, with the level extended perpendicular to the flow direction; and
- Overland flow flooding: Greater than or equal to 10% of the "active" cadastral area is affected by the 1% AEP peak flood depth of greater than 0.15 m. The "active" cadastral area is considered to be the cadastral area excluding the building area (modelled as impermeable).

In situations where a cadastral lot is subject to both mainstream flooding and overland flow flooding, the mechanism that produces the highest Flood Planning Level (FPL) is given precedence.

A further step is to then ground truth the overland flow property set. This process facilitates a check of the "tagged" properties and ensures that significant on-ground features haven't been missed in the modelling process. Generally properties tagged due to scattered ponding as opposed to a flow path will be eliminated from the tagged property set.

8.2. Flood Planning Level (FPL)

The FPL is the height at which new building floor levels should be built. Due to the mixture of residential and commercial development in the Johnstons Creek catchment, a variety of FPLs may be applicable depending on where in the catchment development is being considered and also based on the type of development being proposed.

A variety of factors need to be considered when calculating the FPL for an area. A key consideration is the flood behaviour and resultant risk to life and property. The Floodplain Development Manual (Reference 1) identifies the following issues to be considered:

- Risk to life;
- Long term strategic plan for land use near and on the floodplain;
- Existing and potential land use;
- Current flood level used for planning purposes;
- Land availability and its needs;
- FPL for flood modification measures (levee banks etc);
- Changes in potential flood damages caused by selecting a particular flood planning level;

- Consequences of floods larger than that selected for the FPL;
- Environmental issues along the flood corridor;
- Flood warning, emergency response and evacuation issues;
- Flood readiness of the community (both present and future);
- Possibility of creating a false sense of security within the community;
- Land values and social equity;
- Potential impact of future development on flooding;
- Duty of care.

8.2.1. Likelihood of Flooding

As a guide, Table 12 has been reproduced from the NSW Floodplain Development Manual 2005 to indicate the likelihood of the occurrence of an event in an average lifetime to indicate the potential risk to life.

Analysis of the data presented in Table 12 gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 100 Year ARI (1% AEP) event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1% AEP flood event as the basis for the FPL. Given the social issues associated with a flood event, and the non-tangible effects such as stress and trauma, it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to at least one flood of a 200 Year ARI (0.5% AEP) magnitude over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the PMF) as the flood planning level for some types of development.

Table 12: Likelihood of given design events occurring in a period of 70 years

Likelihood of Occurrence in Any Year (ARI)	Probability of Experiencing At Least One Event in 70 Years (%)	Probability of Experiencing At Least Two Events in 70 Years (%)
10	99.9	99.3
20	97	86
50	75	41
100	50	16
200	30	5

8.2.2. Land Use and Planning

The hydrological regime of the catchment can change as a result of changes to the land-use, particularly with an increase in the density of development. The removal of pervious areas in the catchment can increase the peak flow arriving at various locations, and hence the flood levels and flood hazards can be increased.

A potential impact on flooding can arise through the intensification of development on the floodplain, which may either remove flood storage or impact on the conveyance of flows. The Sydney DCP 2012 currently outlined controls relating to the installation of onsite detention to manage increased impervious area. No provisions exist within the current DCP 2012 or LEP 2012 to limit development within floodway or areas or limit filling in storage areas. Provisions to these issues, however, have been included in the Interim Floodplain Management Policy (Reference 11).

8.2.3. Freeboard Selection

A freeboard ranging from 0.3 – 0.5 metres is commonly adopted in determining the FPL. The freeboard accounts for uncertainties in deriving the design flood levels and as such should be used as a safety margin for the adopted FPL. The freeboard may account for factors such as:

- Changes in the catchment;
- Changes in flowpath vegetation;
- Accuracy of the model inputs (e.g. ground survey, design rainfall inputs for the area);
- Model sensitivity:
    - Local flood behaviour (due to local obstructions);
    - Wave action (e.g. wind induced waves or was from vehicles);
    - Culvert blockage; and
    - Climate change (affecting both rainfall and ocean levels).

The various elements factored into a freeboard can be summarised as follows:

- Afflux (local increase in flood levels due to small local obstructions not accounted for in the modelling) (+0.1 m);
- Local wave action (trucks and other vehicles) (allowance of +0.1 m is typical);
- Climate change impacts on rainfall (0.01 m to 0.79 m, mean 0.12 m, as per Johnstons Creek Flood Study (2012))
- Climate change impacts on sea level rise (0.0 m to 0.17 m, mean 0.02m, as per Johnstons Creek Flood Study (2012)); and
- Sensitivity of the model +/-0.05 m.

Based on this analysis, the total sum of the likely variations is between 260 mm and 1200 mm, depending on climate change, which has a varying effect across the catchment. This range, however, exaggerates the effect of climate change, as the maximum impact is localised to the Sparkes Street and Larkin Street depression (0.79 m impact under 30% rainfall increase), which acts as a flood storage area.

Based on this range, the freeboard recommended in the Interim Floodplain Management Policy (Reference 11) is suitable for the catchment, except for in the Sparkes Street and Larkin Street depression, where a higher freeboard of around 1000 mm should be considered. The policy specifies a freeboard of 500 mm, except for in areas with local drainage flooding. In the policy, local drainage flooding refers to where there the 1% AEP depth is less than 0.25 m and the area is not in, or influenced by, a trapped low point. In these areas, the flood planning level is the minimum of two times the depth of flow and 0.3 m. Given the difference in flood depth between the 1% AEP and the PMF in the catchment, this freeboard is suitable for local drainage flooding.

When applied to design events less than the PMF, the freeboard may still result in the FPL being higher than the PMF in certain cases.

8.2.4. Current FPL as Adopted by Council

FPL requirements have been outlined by Council in their Interim Floodplain Management Policy (Reference 11). This policy was tested each time a development application was received. The policy provides further details regarding flood planning levels for various types of development within the floodplain and these are outlined in Table 13.

Table 13: Adopted Flood Planning Levels in CoS Interim Floodplain Management Policy (Reference 11)

Development		Type of flooding	Flood Planning Level
Residential	Habitable rooms	Mainstream flooding	1% AEP flood level + 0.5 m
		Local drainage flooding	1% AEP flood level + 0.5 m or Two times the depth of flow with a minimum of 0.3 m above the surrounding surface if the depth of flow in the 1% AEP flood is less than 0.25 m
		Outside floodplain	0.3 m above surrounding ground
	Non-habitable rooms such as a laundry or garage (excluding below-ground car parks)	Mainstream or local drainage flooding	1% AEP flood level

Industrial or Commercial	Business	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of 1% AEP flood level
	Schools and child care facilities	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of 1% AEP flood level + 0.5m
	Residential floors within tourist establishments	Mainstream or local drainage flooding	1% AEP floor level + 0.5 m
	Housing for older people or people with disabilities	Mainstream or local drainage flooding	1% AEP flood level + 0.5 m or a the PMF, whichever is the higher
	On-site sewer management (sewer mining)	Mainstream or local drainage flooding	1% AEP floor level
	Retail Floor Levels	Mainstream or local drainage flooding	Merits approach presented by the applicant with a minimum of the 1% AEP flood. The proposal must demonstrate a reasonable balance between flood protection and urban design outcomes for street level activation.
Below-ground garage/ car park	Single property owner with not more than 2 car spaces.	Mainstream or local drainage flooding	1% AEP floor level + 0.5 m
	All other below-ground car parks	Mainstream or local drainage flooding	1% AEP flood level + 0.5 m or the PMF (whichever is the higher)
	Below-ground car park outside floodplain	Outside floodplain	0.3 m above the surrounding surface
Above ground car park	Car parks	Mainstream or local drainage flooding	1% AEP flood level
	Open car parks	Mainstream or local drainage	5% AEP flood level
Critical Facilities	Floor level	Mainstream or local drainage flooding	1% AEP flood level + 0.5m or the PMF (whichever is higher)
	Access to and from critical facility within development site	Mainstream or local drainage flooding	1% AEP flood level

In the policy, Council also provided clarity in the definition of local drainage flooding as opposed to mainstream flooding as follows:

1. Local drainage flooding occurs where:

- The maximum cross sectional depth of flooding in the local overland flow path through and upstream of the site is less than 0.25 m for the 1% AEP flood; and
- The development is at least 0.5 m above the 1% AEP flood level at the nearest downstream trapped low point; and
- The development does not adjoin the nearest upstream trapped low point; and
- Blockage of an upstream trapped low point is unlikely to increase the depth of flow past the property to greater than 0.25 m in the 1% AEP flood.

2. Mainstream flooding occurs where the local drainage flooding criteria cannot be satisfied.
3. A property is considered to be outside the floodplain where it is above the mainstream and local drainage flood planning levels including freeboard.

The establishment of the flood planning levels in conjunction with the publication of the Interim Floodplain Management Policy is a positive step forward for Council in setting development controls for new developments within the Johnstons Creek catchment. Nevertheless, it could be helpful to provide several case studies to illustrate how these levels could be applied to individual developments to assist in development applications.

9. FLOODPLAIN RISK MANAGEMENT MEASURES

The FRMS aims to identify and assess risk management measures which could be put in place to mitigate flooding risk and reduce flood damages. The risk management measures should be assessed against the legal, structural, environmental, social and economic conditions or constraints of the local area. The 2005 NSW Government's Floodplain Development Manual separates risk management measures into three broad categories.

9.1. Risk Management Measures Categories

Flood modification measures modify the physical behaviour of a flood including depth, velocity and redirection of flow paths. Typical measures include flood mitigation dams, retarding basins, on-site detention, channel improvements, levees or floodways. Pit and pipe improvement and even pumps may also be considered in some cases.

Property modification measures modify the existing land use and development controls for future development. This is generally accomplished through such means as flood proofing, house raising or sealing entrances, strategic planning such as land use zoning, building regulations such as flood-related development controls, or voluntary purchase.

Response modification measures modify the response of the community to flood hazard by educating flood affected property owners about the nature of flooding so that they can make better informed decisions. Examples of such measures include provision of flood warning and emergency services, improved information, awareness and education of the community and provision of flood insurance.

Table 14 below provides a summary of floodplain risk management measures that are considered for the Johnstons Creek catchment.

Table 14: Flood Risk Management Measures

Flood Modification	Property Modification	Response Modification
Retarding basins	Land zoning	Community awareness/preparedness
Channel modifications	Voluntary purchase	Flood warning
Levees	Building & development controls	Evacuation planning
Temporary defences	Flood proofing	Evacuation access
Drainage Capacity Enhancement	House raising	Flood plan / recovery plan
	Flood access	Flood insurance

9.1.1. Relative Merits of Management Measures

A number of methods are available for judging the relative merits of competing measures. The benefit/cost (B/C) approach has long been used to quantify the economic worth of each option enabling the ranking against similar projects in other areas. A B/C ratio is the benefits expressed in monetary terms, compared to the actual likely cost of achieving those benefits. It is a standard method for using the time value of money to appraise long-term projects of the reduction in flood damages (benefit) compared to the cost of the works. Generally the ratio expresses only the reduction in tangible damages as it is difficult to accurately include intangibles.

The potential environmental or social impacts of any proposed flood mitigation measure must be considered in the assessment of any management measure and these cannot be evaluated using the classical B/C approach. For this reason a matrix type assessment has been used which enables a value (including non-economic worth) to be assigned to each measure.

Multi-variate decision matrices are recommended in the Floodplain Development Manual and therefore it is also a recommendation herein that multi-variate decision matrices be developed allowing detailed benefit/cost estimates, community involvement in determining social and other intangible values, and local assessment of environmental impacts.

9.1.2. Management Matrix

The criteria assigned a value in the management matrix are:

- Risk to life;
- Impact on flood behaviour (reduction in flood level or hazard) over the range of flood events;
- Number of properties benefited by measure;
- Technical feasibility (design considerations, construction constraints, long-term performance);
- Community acceptance and social impacts;
- Economic merits (capital and recurring costs versus reduction in flood damages);
- Financial feasibility to fund the measure;
- Environmental and ecological benefits;
- Impacts on the State Emergency Services (SES);
- Political and/or administrative issues; and
- Long-term performance given the potential impacts of climate change.

The scoring system for the above criteria is provided in Table 15 and largely relates to the impacts during the implementation time frame. The following matrix is designed to set out a general scheme to illustrate how a local matrix might be developed. These criteria and their relative weighting may be adjusted in the light of community consultations and local conditions.

Tangible costs and damages are also used as the basis of B/C analysis for some measures.

Table 15: Matrix Scoring System

SCORE:	-3	-2	-1	0	1	2	3
Impact on Flood Behaviour	>100mm increase	50 to 100mm increase	<50mm increase	no change	<50mm decrease	50 to 100mm decrease	>100mm decrease
Number of Properties Benefited	>5 adversely affected	2-5 adversely affected	<2 adversely affected	none	<2	2 to 5	>5
Technical Feasibility	major issues	moderate issues	minor issues	neutral	moderately straight-forward	Straight-forward	no issues
Community Acceptance	majority against	most against	some against	neutral	some	most	majority
Economic Merits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Financial Feasibility	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Environmental & Ecological Benefits	major disbenefit	moderate disbenefit	minor disbenefit	neutral	low	medium	high
Impacts on SES	major disbenefit	moderate disbenefit	minor disbenefit	neutral	minor benefit	moderate benefit	major benefit
Political / Administrative Issues	major negative	moderate negative	minor negative	neutral	few	very few	none
Long Term Performance	major disbenefit	moderate disbenefit	minor disbenefit	neutral	positive	good	excellent
Risk to Life	major increase	moderate increase	minor increase	neutral	minor benefit	moderate benefit	major benefit

9.2. Management Objectives in City of Sydney

To align with the floodplain risk management activities within the other parts of the LGA the following objectives were set:

- **Long term goal (20–50 years)**: to identify and upgrade all trunk drainage up to 5% AEP capacity;
- **Short term goal (10-20 years)**: where possible, to improve localised flooding;

Flood modification measures discussed in the following sections were developed in view of these objectives.

It should be noted that limited description of the effects of each flood modification measure in the 1% AEP event is given in the following section. Although the 1% AEP event is of principle interest under the NSW Floodplain Risk Management Process, the reliance on pit/pipe drainage systems, which typically have capacities in the order of 2 to 20 year ARI, in the Johnstons Creek catchment means more frequent events were focussed upon. For pit/pipe based drainage to have a significant effect in the 1% AEP event, it would entail non-economic upgrades to the pit and pipe system.

9.3. Flood Modification Measures

The purpose of flood modification measures is to modify the behaviour of the flood itself by reducing flood levels or velocities by excluding water from areas under threat. A number of flood affected areas within the catchment have been identified in the Flood Study and specific flood mitigation options are investigated to alleviate flood risk in these areas. An overview of the flood affected areas and proposed mitigation options are provided in Table 16 and shown in Figure 29. These options are discussed in detail in Section 9.4.

Table 16: Flood Affected Areas and Proposed Mitigation Options

Suburb	Flood Affected Streets/Areas	Proposed Mitigation Options	Ref
Camperdown	Parramatta Road, Sparkes Street and Larkin Street trapped low points	Detention basin upstream of Parramatta Road at University of Sydney's St Johns Oval	FM - JC01
Camperdown	Depression upstream of Pyrmont Bridge Road (Larkin Street)	Trunk drainage upgrade (from Larkin Street to Johnstons Creek channel confluence) and Johnstons Creek channel works	FM - JC02
Glebe	Glebe Gardens/Hereford Street	Pipe upgrade and pit inlet capacity enhancement (along Hereford Street) and detention basins at John Street and Arthur Gray Reserves	FM - JC03
Forest Lodge	Minogue Crescent and Coneill Place	Regrade Hogan Park (Leichhardt Council LGA) and widen walkway under The Crescent bridge	FM - JC04
Forest Lodge	Johnstons Creek	Raise bridges along Johnstons Creek to designated design level (i.e. 1% AEP peak flood level + freeboard)	FM - JC05

The aforementioned mitigation options have been assessed on their viability to mitigate flooding and reduce flood damages using the hydraulic model from the Flood Study that is updated to include changes to the floodplain since its completion. All options were assessed using a range of design flood events in order to ascertain the impacts on flood levels. Benefit/cost analysis was then carried out for each option and reported herein.

A number of other options were also tested for the catchment that were either discarded for not being feasible, or modified to become the options investigated in more detail (shown in Table 16). These other options are listed in Appendix F.

9.3.1. Drainage Capacity Enhancement

DESCRIPTION

Increasing the flow conveyance capacity of a drainage structure typically involves an increase to the effective flow area of the structure via installation of larger or more pipes/culverts. This generally reduces flood levels upstream of the area where the modifications are made. The resulting increase in flow to downstream areas can cause increases to flood levels and inundation frequency downstream of the modifications, if the increased capacity is not matched throughout the downstream drainage system. In this regard, increases to structure conveyance can produce opposite effects to detention basins, which reduce discharge to downstream areas at the expense of increased storage of floodwaters within the basin and potentially surrounding areas.

It is generally impractical and uneconomical to design drainage systems that have the capacity to convey flows up to the 1% AEP magnitude. Urban drainage systems are typically designed to convey the 5 year ARI or 10% AEP discharge without surcharging or overtopping of the main drainage path. Regardless of the drainage system capacity, management of flows that exceed the design flow should be considered and managed appropriately.

DISCUSSION

Most areas within the catchment are already developed, with residential units located adjacent to Johnstons Creek downstream in addition to public parklands. Increases to flood levels downstream are therefore unlikely to be acceptable unless channel works are carried out concurrently to alleviate these adverse impacts.

Upgrading of the existing sub-surface drainage system within the study area would be a very expensive undertaking as it would involve closure of major roads owned by the Roads and Maritime Services (RMS) for long period of time. Careful consideration should be given to the feasibility of carrying out such drainage works and addressing potential adverse impacts generated downstream.

OUTCOME

Major focus has been placed on exploring the drainage upgrade option for mitigating flood risks at the identified hot spots, which is also in line with Council's long term vision to upgrade trunk drainage capacity to convey the 5% AEP discharge.

9.3.2. Channel Modifications

DESCRIPTION

Channel modifications are usually undertaken to either increase the capacity of the channel and/or improve the conveyance of floodwaters, which in turn will reduce peak flood levels. Channel modifications encompass a broad range of measures and include amplification, straightening, concrete lining, removal of structures, dredging and vegetation clearing. In some instances 'naturalising' the channel upstream can reduce peak level downstream by slowing flows and making better use of flood storage.

DISCUSSION

The only open channel within the catchment is Johnstons Creek which starts as an open channel at Salisbury Road and then runs through the Federal, Jubilee and Bicentennial Parks before discharging into Rozelle Bay. This channel is tidal and its capacity is exceeded in events less than the 5 year ARI (depending on downstream tailwater assumptions). Applicable methods of increasing channel capacity and conveyance are primarily channel widening, removal of bridge piers along the channel and raising the bridges to above a designated design level (i.e. usually the 1% AEP level).

Widening Johnstons Creek would increase the capacity of the creek system and reduce the frequency with which floodwaters overtop the banks. Nevertheless, constraints are found along the channel in the form of major road crossings, i.e. Wigram Road and The Crescent, which limit the width the channel can be extended to. Hence it is unlikely that the existing capacity of the channel can be greatly increased with this method. Other measures like channel straightening, concrete lining and vegetation clearing do not apply since the existing channel is concrete lined, relatively straight and free of vegetation.

Review of the August 1998 North Wollongong and June 2007 Newcastle storms highlighted the significant effects blockage of structures can have on flood levels. Evidence from the North Wollongong event indicates that there is the potential for hydraulic structures with openings less than 6 m width to be partially or fully blocked during a flood. Some of the bridges along Johnstons Creek have piers located within the channel and bridge deck soffit that is lower than the 5 year ARI channel peak flood level. Historical photos obtained as part of the 2012 Flood Study have shown that debris and trash get trapped behind these structures which would have exacerbated existing flood problems. Redesigning these structures by removing the piers or raising the bridge decks would reduce the probability of blockage and improve conveyance for Johnstons Creek.

OUTCOME

Modelling was undertaken to investigate the effect of raising bridge decks and removing piers. This option was also considered in conjunction with the drainage upgrade from the Larkin Street depression.

9.3.3. Levees, Flood Gates and Pumps

DESCRIPTION

Levees are a means of excluding floodwaters from areas that would otherwise be inundated up to a designated design level (with a freeboard allowance of typically 0.5 m) and have been widely used for this purpose. They are commonly used on large river systems but can also be found on small creeks in urban areas. Levee banks are generally made of compacted earth and can usually be successfully landscaped to produce minimal visual impact. Where there is limited space or other constraints levees can be replaced by concrete walls.

Flap gates can be constructed as part of the levee design to allow local drainage through the levee. Flood valves could allow local catchment runoff to drain through the levee into the downstream creek/channel, but during times of elevated creek/channel flows, they can prevent floodwaters from entering (or exiting). If a levee system was built to protect the properties adjacent to Johnstons Creek from backwater flooding for instance, it is likely local drains/pipes discharging to the creek would require the installation of flap gates.

Pumps are sometimes also associated with levee designs, as levees can sometimes create trapped depressions which cannot be drained by gravity. Pumps may be installed to remove local floodwaters behind levees when flood gates are closed or there are no flood gates. They are generally only suitable where there is a small contributory catchment upstream of the areas contained by the levee, and thus only a small volume of water needs to be discharged. However pumps are costly to operate and have a high likelihood of failure (due to loss of power, lack of maintenance etc.).

Further, flap gates and pumps require ongoing maintenance to ensure their continued successful operation. Vandalism, corrosion, damage or vegetation growth can all result in failure at critical times. Some form of ongoing maintenance program is therefore required. Ensuring the power supply for pumps remains operable during times of flood can also be problematic.

It is also vital to note that levees and associated structures may provide a false sense of security and make residents less flood aware, or less resilient to flood events greater than the protection level of the structure.

DISCUSSION

Due to the significance of local catchment flood mechanisms at the study area, and the potential for local flooding to be exacerbated by the introduction of a levee/gate system, these measures were considered with due regard for impacts on local catchment flows. Suitable locations considered for the construction of the levee system along Johnstons Creek include the rear end of the properties on Coneill Place as well as the western side of the channel downstream of The Crescent bridge up to the Tram bridge. Preliminary model runs, nevertheless, have shown that the benefits gained from stopping mainstream flooding from Johnstons Creek would be lost by the accumulation of local runoff behind the levee even with ample provision of flood gates.

OUTCOME

In view of the limited benefit that can be obtained from implementing the levee/flap gate system, this option has not been explored further.

9.3.4. Retarding/Detention Basins

DESCRIPTION

Retarding basins are often used in developing catchments. These measures are appropriate for use in controlling flooding in small catchments or to mitigate the effects of increased runoff caused by development. Retarding basins store runoff temporarily and then release it at a slower rate. Although they do not reduce the total volume of runoff significantly, they do reduce the rate at which runoff occurs, thus reducing downstream flood levels. Communal retarding basins are generally used in conjunction with large scale development to allow for communal mitigation of runoff. They can also be used in general urban drainage systems for example, some Councils use playing fields for retention of flows during flood events.

One of the major impediments in their use as a flood mitigation measure for existing development is the lack of suitable sites. For new “green fields” developments there is the opportunity to incorporate the retarding basins into site design which is not possible for existing development. Retarding basins can also provide some water quality benefits, though in a heavily built up urban environment it is difficult to maintain these systems for this purpose.

DISCUSSION

These systems are easier to implement as new development comes forward when Council can place the responsibility on the developer to provide drainage systems appropriate to the development. Nevertheless it is still possible for existing systems to be retrofitted by utilising park lands and playing fields within the catchment. In order to be effective at reducing peak flood flows, the location of the basins should be on well defined flow paths and covering a significant footprint, which could lead to loss of previously useable land (parks). The basin construction costs will be high in the urban environment particularly with the additional costs incurred with alterations to services (gas, electricity, sewerage, roads etc.) that are within or close proximity to the proposed basin.

Like the rest of the drainage system basins have maintenance requirements. Regular checks and maintenance will be required by Council. Large retarding basins can also be a safety hazard particularly when full. Appropriate safety controls such as fencing and signage should be included as part of the overall asset and should also be subject to routine checks and maintenance.

OUTCOME

Limited park lands exist within the catchment which could be converted into retarding basins, i.e. John Street and Arthur Gray reserves. The potential for utilising the playing fields at the upstream part of the catchment within the University of Sydney campus for flood storage was also investigated herein. Lowering/regrading of Hogan Park to provide additional bank storage for Johnstons Creek was also considered in conjunction with other proposed channel works.

9.4. Management Options

9.4.1. Detention Basin – St Johns Oval (FM - JC01)

Description

Option FM – JC01 is proposed to mitigate flooding in the vicinity of the Parramatta Road/Larkin Street intersection as well as reducing the volume of floodwaters which will get trapped eventually at the trapped low point upstream of Pyrmont Bridge Road. The purpose of this mitigation option is two fold: to reduce the likelihood of flooding on Parramatta Road which is a major access road and to reduce the flood liability for the residential properties located on the Larkin Street low point. Referring to Figure 30, this option comprises provision of detention storage with 14,400 m^3 capacity (area approximately 7,000 m^2 with depth up to 2 m) in St Johns Oval by excavating existing ground to the indicated invert level.

Results

Figure 30 shows significant reduction in the 10% AEP peak flood levels by up to about 0.28 m at the Larkin Street low point and 0.18 m at the trapped low point on Parramatta Road. Time of inundation of Parramatta Road remains largely unchanged from existing conditions but the peak discharge crossing Parramatta Road reduced from 3.4 m^3/s to 1.5 m^3/s.

Over floor flood liability will reduce by 20 properties (primarily those located near the Larkin Street low point) for the 10% AEP flood event which helps reduce the AAD by $267,000.

More importantly, with the reduction in peak flood depths at the Larkin Street low point and Parramatta Road, some of the areas previously categorised as high hazard are now downgraded to low hazard meaning the risk to life is reduced as a result of this proposed basin.

Discussion

St Johns Oval falls under the jurisdiction of the University of Sydney and as such any proposed works within the campus would have to be in line with the University long term strategic planning. The availability of playing fields within the University presents opportunities for multi purpose use of the same facilities for storage of floodwaters which is not an uncommon occurrence. The basin would have minimal environmental impact, as the area is currently cleared of vegetation. The long term performance of the basin may be slightly impaired by its location, as City of Sydney have limited influence on mitigation works on the campus.

9.4.2. Drainage Upgrade – Sparkes Street to Johnstons Creek (FM – JC02)

Description

Option FM – JC02 is proposed to alleviate flood risk at the unrelieved depression upstream of Pyrmont Bridge Road. The severity of flooding for some properties in this area can be reduced with the upgrade of the Sydney Water-owned trunk drainage system to the 5% AEP capacity all the way to the confluence with Johnstons Creek, as shown in Figure 31. Works have to be undertaken to enhance the capacity of the surrounding pits to facilitate the transfer of floodwaters from above surface to the sub-surface drainage system. The required capacity upgrades are as follows:

- For the 240 m section between Sparkes Street and Bridge Road, beginning at Sparkes Street;
  - 58 m of 1 x 2.4 m x 1.5 m culvert
  - 35 m of 1 x 2.7 m x 1.5 m culvert
  - 50 m of 2 x 3.0 m x 1.5 m culvert
  - 97 m of 1 x 2.1 m x 1.8 m culvert
- For the 385 m section between Bridge Road and Johnstons Creek;
  - 385 m of 1 x 3.3 m x 1.8 m culvert
- All pits and feeder pipes in the Larkin Street area upgraded to efficiently drain the 5% AEP runoff, which includes pipes of up to 2.4 m diameter near the north end of Larkin Street
- Grading of the proposed upgrade has not been changed from the existing drainage network.

Results

Figure 31 shows significant reduction in the 5% AEP peak flood extent and levels by up to about 2.4 m at the depression upstream of Pyrmont Bridge Road. Some areas are shown to be no longer flooded. The increase in flows in the trunk drainage system (by up to almost 3 times that of existing conditions) as a result of the capacity upgrade could lead to adverse impacts on the peak flood levels downstream if further works are not undertaken along Johnstons Creek to improve conveyance of this additional flow to Rozelle Bay.

Over floor flood liability will reduce by 24 properties (primarily those located near the depression) for the 5% AEP flood event which helps reduce the AAD by $703,000. The reduced peak flood depths also resulted in majority of the depression area now re-categorised as low hazard, as can be seen from Figure 32. The figure has been presented as it is indicative of the upper limit of hazard reduction that can be achieved in the Larkin Street hotspot. Similar hazard reduction is possible with other options, such as FM – JC01.

Discussion

This mitigation option should only be undertaken after works have been undertaken to improve the conveyance of Johnstons Creek due to the increased flows discharged from upstream. These channel works can be in the form of removal of obstacles such as bridge piers along the channel (part of Option FM – JC05). Other potential constraints which may hamper the feasibility of this option include the significant excavation required along the Orphan School

Creek nature reserve, which has environmental value in the area, and the relocation of services during the upgrade and crossings of Pyrmont Bridge Road. As the option involves significant changes to the Sydney Water-owned trunk drain, approval must be granted from Sydney Water before any works are proposed. This would be sought via an extensive consultation process.

9.4.3. Drainage Upgrade – Hereford Street and Detention Basins – John Street and Arthur (Paddy) Gray Reserves (FM – JC03)

Description

The premise of Option FM – JC03 is to reduce flooding on Bridge Road, Hereford Street and their surrounds. This involves upgrading the Sydney Water-owned trunk drainage starting from Reuss Street all the way to Wigram Lane, downstream of Glebe Gardens to the 5% AEP capacity. To provide additional flood storage, two detention basins are proposed utilising existing parklands, i.e. John Street and Arthur (Paddy) Gray Reserves. The excavation volume required for these basins is about 4,200 m^3 (area approximately 1,700 m^2 with depth up to 3 m) and 11,700 m^3 (area approximately 3,700 m^2 with depth up to 4 m) respectively. Also, works have to be undertaken to enhance the capacity of the surrounding pits to facilitate the transfer of floodwaters from above surface to the sub-surface drainage system. The required pit and pipe upgrades are as follows:

- For the 166 m section between Reuss Street and John Street, beginning at Reuss Street;
  - 58 m of 2 x 2.1 m diameter pipes
  - 108 m of 2.1 m diameter pipe
- For the 295 m section between Woolley Lane and Wigram Lane, beginning at Woolley Lane;
  - 30 m of 1.8 m diameter pipe
  - 41 m of 2.4 m diameter pipe
  - 176 m of 2.1 m diameter pipe
  - 48 m of 2 x 2.1 m diameter pipe
- All pits and feeder pipes in the area upgraded to efficiently drain the 5% AEP runoff, which includes pipes of up to 0.9 m diameter on Hereford Street
- Grading of the proposed upgrade has not been changed from the existing drainage network.

Results

Referring to Figure 33, accessibility of the roads in this area would be improved upon this upgrade as peak flood depths reduce by up to 0.5 m on Bridge Road and 0.3m on Hereford Street in the 5% AEP flood event. Some areas are shown to be no longer flooded such as Clare Street with flood flows now within the trunk drainage system. The detention basins proposed managed to offset the potential adverse impacts on the peak flood levels downstream as a result of increased flows in the trunk drainage system.

Over floor flood liability will reduce by 11 properties for the 5% AEP flood event which helps reduce the AAD by $180,000.

Discussion

This option could lead to limiting the recreational use of John Street and Arthur (Paddy) Gray Reserves depending on the configuration of the detention basins proposed as well as vegetation removal. The vegetation removal would have significant impact on the environmental value that is placed on the two parks. Further, the proximity of the drainage upgrade corridor to residential properties means there will be significant amounts of services to be relocated. The detention basins may have limited long term performance, given the role of open space in an area will often change over time, especially in a heavily urbanised area.

As the option involves significant changes to the Sydney Water-owned trunk drain, approval must be granted from Sydney Water before any works are proposed. This would be sought via an extensive consultation process.

9.4.4. Lowering of Hogan Park and Widening of Walkway - The Crescent (FM – JC04)

Description

Option FM – JC04 is proposed to provide additional flood storage area in order to alleviate to some extent the flood risk presented by mainstream Johnstons Creek flooding as well as reduce over floor flood liability for properties on Coneill Place and The Crescent. The 2012 Flood Study has shown that floodwaters overtop the channel bank for events less than the 5 year ARI and lowering Hogan Park (for the area indicated in Figure 34) would provide an additional 16,200 m^3 of storage (area approximately 17,500 m^2 with depth up to 2 m) that would reduce the peak flood levels of Johnstons Creek and its surrounds. As floodwaters are discharged downstream through The Crescent bridge for in-bank flows and through the pedestrian walkway underneath the bridge for over-bank flows, widening the walkway would create additional conveyance capacity for this “secondary outlet” for major event flows coming from upstream.

Results

Figure 34 shows a decrease in the 5% AEP peak flood levels in Johnstons Creek upstream of The Crescent as well as Hogan Park as a result of the proposed work. The peak flood levels drop by about 0.18 m in the area just upstream of The Crescent bridge and 0.5 m reduction in peak flood levels further upstream of bridge no. 2 (refer Figure 35). As a result, 2 residential properties on Coneill Place are no longer flooded in the 5% AEP flood event, which translates to a $10,000 reduction in the AAD. No adverse impact is found downstream as a result of this proposed work.

Discussion

Hogan Park is located within the Leichhardt Municipal Council LGA and any proposed work here would require both councils (City of Sydney and Leichhardt Municipal Council) to come on board in addressing issues related to flood risks, financing, and environmental concerns. The option may impact on the natural environment in Hogan Park, which includes mature trees around the park boundary.

9.4.5. Bridge Raising – Johnstons Creek (FM – JC05)

Description

As part of Option FM – JC05, bridges along Johnstons Creek which have soffit levels below the 1% AEP channel peak flood level (bridges no. 2, 4, 6, 7, 9 (refer Figure 35)) are raised to a new designated design level, preferably above the 1% AEP peak flood level plus freeboard. In addition, bridges no. 6 and no. 7 would be reconstructed to eliminate the need for piers which would effectively improve conveyance within the concrete lined channel. The increased discharge to Rozelle Bay would reduce peak flood levels for the over-bank areas stretching from Wigram Road to Bicentennial Park. Here, the cumulative impacts are determined for this option together with Option FM – JC04.

Results

Figure 36 shows peak flood level profiles along Johnstons Creek for existing conditions as well as post-works conditions (bridge raising and piers removed). Reduction by up to 0.65 m of the 5% AEP peak flood level can be expected in the vicinity of bridge no. 2 (refer Figure 35) with the decrease in levels becoming less significant when approaching the Bay area. Despite the improvements observed, the relatively low level of over-floor flood liability of properties adjacent to Johnstons Creek means that the benefit gained in the reduction of the AAD is only $6,000.

Nevertheless, there would be negative impacts (increase in the 5% peak flood levels) by up to about 50 mm which are confined to the Bicentennial Park area due to the increased flow downstream with the improved channel conveyance.

Discussion

The bridges identified for raising/reconstruction primarily serve pedestrian traffic and as such would not result in road closures or traffic disruption. This option can be undertaken in conjunction with Option FM – JC02 and FM-JC-04 to augment the benefits that can be gained just with the individual mitigation option alone. The option will have negligible impact on the area’s environment, as the bridge structures already exist and the additional approach ramps have a small footprint.

9.5. Property Modification Measures

9.5.1. Flood Planning Levels (PM – JC01)

DESCRIPTION

The flood planning level (FPL) is used to define land subject to flood related development controls and is generally adopted as the minimum level to which floor levels in the flood affected areas must be built. The FPL includes a freeboard above the design flood level. It is common practice to set minimum floor levels for residential buildings, garages, driveways and even commercial floors as this reduces the frequency and extent of flood damages. Freeboards provide reasonable certainty that the reduced level of risk exposure selected (by deciding upon a particular event to provide flood protection for) is actually provided.

DISCUSSION

The main aim of the FPLs is to reduce the damages experienced by the property owner during a flood. Elevating a house floor level above the FPL will ensure that flood damages are significantly reduced. Council have specified FPL requirements in their *Interim Floodplain Management Policy* (Reference 11) prior to the completion of the Floodplain Risk Management Plans for the entire LGA and we endorse this move. It is important that the same requirements are applied throughout the LGA to new development or redevelopments regardless of whether the Floodplain Risk Management Plan have been completed for the catchment or not. A review of the suitability of the FPLs adopted is discussed in Section 8.2.4.

OUTCOME

A review of the FPLs put forward by Council in their *Interim Floodplain Management Policy* (Reference 11) was carried out as part of this study. In order to ensure consistency throughout the LGA, the same principle for FPLs should be applied regardless of whether a Floodplain Risk Management Plan have been completed for the catchment or not. The only exception would be if the Floodplain Risk Management Plan proposes a change to these FPLs.

9.5.2. Development Control Planning (PM – JC02)

DESCRIPTION

Within the Johnstons Creek catchment there is continuing pressures for both redevelopments of existing buildings as well as for new developments. The strategic assessment of flood risk can prevent development occurring in areas with a high hazard and/or with the potential to have significant impacts upon flood behaviour in other areas. It can also reduce the potential damage to new or redeveloped properties likely to be affected by flooding to acceptable levels.

DISCUSSION

The Interim Floodplain Management Policy (Reference 11) provides general requirements for new developments on flood liable land within the catchment, Flood Planning Level requirements for different development types and guidelines on flood compatible materials. This document serves as an interim policy for managing floodplain within the Council LGA which will be withdrawn once Council complete Floodplain Risk Management Plans for the entire LGA and then integrate outcomes from these plans into planning controls. A review of this document as well as the Sydney LEP 2012 and Sydney DCP 2012 has been undertaken and discussed in Section 7.1. Nevertheless the success of these policies can only be determined once implemented and specific problems/issues addressed as they arise.

OUTCOME

Recommendation for an update of the planning documents (i.e. Sydney DCP 2012 and Sydney LEP 2012) has been discussed in Section 7.2 in order to inform of the development controls as published in the Interim Floodplain Management Policy (Reference 11). Inclusion of these provisions would ensure that the controls can be enforced which also take into consideration the potential impact of climate change.

9.5.3. House Raising

DESCRIPTION

House raising has been widely used throughout NSW to eliminate or significantly reduce flooding of habitable floors particularly in lower hazard areas of the floodplain, albeit in limited overall numbers. However it has limited application as it is not suitable for all building types being more suitable for non-brick single storey buildings. This measure only becomes economically viable when above flood inundation occurs frequently (say in a 10% AEP flood event or less).

DISCUSSION

The benefit of house raising is that it eliminates above floor flooding and consequently reduces flood damages. House raising also provides a safe refuge during a flood, assuming that the building is suitably designed for the water and debris loading. However the potential risk to life is still present if residents choose to enter floodwaters or are unable to leave the house during a medical emergency, or larger floods than the design flood occurs particularly in high hazard areas.

Property raising is not an option for any commercial or industrial properties as most are brick on concrete structures. Many of the residential properties in the Johnstons Creek catchment are brick structures and therefore difficult to raise. It may be possible to raise some houses of timber construction or non-brick single storey buildings on piers however other measures for flood proofing are considered more cost effective due to the shallow depths of flooding occurring for most design events up to and including the PMF.

OUTCOME

House raising is not considered to be the most cost effective option for the type of flooding in the Johnstons Creek catchment. Flood proofing is more appropriate and cost effective for flooding at shallow depths. In addition many of the flood affected properties are brick construction and therefore difficult to raise. It is not viable to raise commercial properties in the catchment due to their construction, the street scene setting/character and access requirements.

Current planning controls are in place that stipulate any new residential development should be above the flood planning level (1% AEP flood level plus 0.5 m) to ensure community flood risk is not increased in the future. Planning controls are also in place setting floor levels for commercial property (see Section 8.2.4).

9.5.4. Flood Proofing (PM – JC03)

DESCRIPTION

An alternative to house raising for buildings that are not compatible or not economically viable, is flood proofing or sealing off the entry points to the building. This measure has the advantage that it is generally less expensive than house raising and causes less social disruption. Flood proofing requires sealing of doors and possibly windows (new frame, seal and door); sealing and re-routing of ventilation gaps in brick work; sealing of all underfloor entrances and checking of brickwork to ensure there are no gaps or weaknesses in mortar. It is generally only suitable for brick buildings with concrete floors and it can prevent ingress from outside depths of up to one meter. Greater depths may cause structural problems (buoyancy) unless water is allowed to enter. Generally an existing house can be sealed for approximately $10,000. New development and extensions allow the inclusions of flood appropriate materials and designs meaning the actual cost of flood proofing can be significantly less when compared to buildings requiring retro-fitting of flood proofing measures.

Flood proofing should also consider suitable electrical installation to as to avoid the risk of electrocution. A minimum aim should be to have all properties in flood hazard areas to, at least, be fitted with a circuit breaker although ideally for all new development all unsealed electrical circuits should be at the Flood Planning Level (FPL).

Additionally, flood proofing can involve the raising of easily damage/high cost items such as commercial stock, equipment and machinery. New buildings should have floor levels above the flood planning level.

Alternatively, temporary flood proofing can also be achieved by the use of sandbags in conjunction with plastic sheeting or private flood gates which fit over doors, windows and vents and are deployed by the occupant before the onset of flooding (see Photo 5).

Photo 5: Flood gate at front door of residential property

DISCUSSION

Permanent flood proofing measures are more suitable for commercial and industrial buildings where there are only limited entry points and aesthetic considerations are less of an issue. Also there are issues of compliance with other regulations such as fire safety and maintenance issues as well as access issues. However flood compatible building or renovating techniques should be employed for extensions or renovations where appropriate. Council have provided a list of suitable flood compatible materials in Reference 11.

The use of temporary measures such as flood gates which occupants fit over their doors and other possible water inlets can be useful in areas where there is frequent shallow flooding. These methods are better used when flooding is of short duration otherwise people may become stranded in their homes. Alternatively they can be used to make a property more flood resistant before evacuation. However, temporary flood proofing measures rely on sufficient warning time to be effective so that they can be installed before the onset of flooding. If used, it could be recommended that temporary measures could be deployed following a BoM flood watch being issued for the region. However the effectiveness relies on the user understanding how and when to deploy.

Minimising the chance of electrocution by turning off the electricity supply during a flood should be standard practice for both residents and commercial owners during floods. The risk of electrocution can also be reduced by installing electrical circuits above, at least, the flood planning level.

OUTCOME
Flood proofing is a good solution to reducing flood risk to commercial and industrial properties. Flood proofing techniques, be they permanent or temporary, could be utilised for the properties in the industrial area. They are more likely to be effective for the more frequently flooded properties as infrequency of use will lead to the system being poorly maintained leading to a greater chance of failure during a flood event. Temporary flood proofing techniques may be deployed in the commercial areas like those on The Crescent although lack of warning time may limit their efficiency. This is a good technique to use where stock, machinery or other goods cannot be moved before the onset of flooding and also suitable where flood depths may be shallow but have potential to cause significant damages.

9.5.5. Minor Property Adjustments (PM – JC04)

DESCRIPTION
In overland flow areas minor property adjustments can be made to manage overland flow passing through private property. Such adjustments can include amendments to fences, construction of fences which act as deflector levees, modifying gardens, changing easements etc all of which can affect the local continuity of overland flow paths.

DISCUSSION
Property adjustments can be used to manage overland flows through private property and minimise impacts on dwellings by helping to divert local overland flows away from dwellings and access points. For most of the upstream areas of the Johnstons Creek catchment this option will have negligible benefits due to the shallow and diffuse nature of flooding.

It is also difficult for Council to enforce property adjustments and furthermore the issue can be complicated by requirements of S149 certificates (Note: this corresponds to 'Political/Admin Issues' in

Table 21). In addition, adjustments on one property may have knock on effects on adjoining properties, or require modifications on neighbouring properties to be effective.

OUTCOME
Although minor property adjustments can have localised benefits, it is not recommended that Council specifically encourage or become involved in this. With the distributed nature of the overland flooding benefits are likely to be minor and the complexity of Council managing such as scheme can outweigh the benefits.

9.5.6. Voluntary House Purchase

DESCRIPTION

Voluntary purchase involves the acquisition of flood affected residential properties (particularly those frequently inundated in high hazard areas) and demolition of the residence to remove it from the floodplain. Generally the land is returned to open space, however there may be an opportunity for a new house to be built at a higher floor level, either on fill or on a higher part of the property.

DISCUSSION

Voluntary purchase is mainly implemented in high hazard areas over a long period as a means of removing isolated or remaining buildings and thus freeing both residents and potential rescuers from the danger and cost of future floods. It also helps to restore the hydraulic capacity of the floodplain (storage volume and waterway area).

Voluntary purchase has no environmental impacts although the economic cost and social impacts can be high. Many residents do not accept voluntary purchase because it would have significant impact on their community and way of life. Among these concerns are:

- It can be difficult to establish a market value that is acceptable to both the State Valuation Office and the resident;
- In many cases residents may not wish to move for a reasonable purchase price;
- Progressive removal of properties may impose stress on the social fabric of an area; and
- It may be difficult to find alternative equivalent priced housing in the nearby area with similar aesthetic values or features.

A voluntary purchase scheme is not considered necessary in the Johnstons Creek catchment given that no properties are at extreme risk of high velocities or loss of life. However, voluntary purchase should be maintained as an option where the purchase of a house is required to build flood mitigation works. The inclusion of properties in a voluntary purchase scheme requires careful consideration and discussion between the affected residents and Council.

OUTCOME

A voluntary purchase scheme is not considered necessary in the Johnstons Creek catchment given that no properties are at extreme risk of high velocities or loss of life. This option should only be considered if the houses need to be removed to restore flow paths.

9.6. Response Modification Measures

9.6.1. Flood Warning and Evacuation (RM – JC01)

DESCRIPTION

Flood warning can significantly reduce damages and risk to life and studies have shown that flood warning systems generally have high benefit/cost ration if sufficient warning time is provided.

Flood warning and the implementation of evacuation procedures by the SES are widely used throughout NSW to reduce flood damages and protect lives. The Bureau of Meteorology (BoM) is responsible for flood warnings on major river systems and the SES is disseminating these warning to the local community. Adequate warning gives residents time to move goods and cars above the reach of floodwaters and to evacuate from the immediate area to designated evacuation points or flood free ground. The effectiveness of a flood warning scheme, known as the effective flood warning time, depends on;

- The maximum potential warning time before the onset of flooding;
- The actual warning time provided before the onset of flooding. This depends on the adequacy of the information gathering network and the skill and knowledge of the operators; and
- The flood awareness of the community responding to a warning.

DISCUSSION

For overland flow flooding providing a flood warning is more difficult than for area impacted by mainstream floods. For river systems, predictions of potential peak flood height and timing are possible with a high degree of reliability afforded by upstream gauges. However, predicting urban overland flow peak flood levels is not necessarily practicable. Overland flooding usually occurs soon after, or at the same time, as intense rainfall. Spatial differences in the rainfall patterns may go undetected by the sparse rainfall gauge network. Furthermore the extent of flood levels can vary over the study area. Therefore, weather warnings are often more useful with regard to providing warning to residents and businesses. Weather warnings issued by BOM can advise if flooding is expected.

This Study has found that over floor flooding does occur for some properties. Furthermore, there are some properties that may not be directly affected by flooding but will become flood islands during flooding (refer Figure 27) and therefore a decision needs to be made whether to evacuate these people or allow them to remain in their homes.

The greatest improvement in the accuracy of any flood warning predictions generally only occurs following major flood events. It is imperative therefore that a post flood assessment report be prepared following each future flood event.

There may be some opportunity to connect in with the City of Sydney Emergency Response Centre. This may provide some limited warning, as well as a more coordinated response to a flood event. Given the speed with which floods can occur a more realistic system may be the additional service of communication of flood risk via SMS alerts or online social media, i.e. Twitter, Facebook etc.

A number of open, public areas are located within the Johnstons Creek catchment. The provision of temporary refuges which can be accessed in a few minutes, even a small warning time may provide the public with sufficient time to seek refuge. The provision of rapid flood warnings within the Johnstons Creek catchment may be delivered through an automated process that triggers a warning (e.g. with the installation of water level sensors placed in trapped depression areas). The warning itself could be delivered through the use of suitably located electronic information boards at key locations.

Another option is to have a public address system, which can relay a recorded message. The system could be similar to what the City of Sydney has already installed to manage emergencies in the busy streets of the City. An example of this system can be found near the main entrance of the Council building at Town Hall Square, where the public address speakers are installed on a traffic light pole.

OUTCOME

Due to the nature of flooding in the study area flood warnings are difficult. In addition there would be little time for evacuation. Severe weather warnings should be used as a caution to potential onset of flooding. These are available through BOM and can also be made available on Council's website and through SMS alerts or online social media, i.e. Twitter, Facebook etc. Investigation should also be carried out on the feasibility of installing warning systems at key locations within the catchment.

9.6.2. Flood Emergency Management (RM – JC02 and RM – JC03)

DESCRIPTION

As mentioned previously, it may be necessary for some residents to evacuate their homes in a major flood. This would usually be undertaken under the direction of the lead agency under the DISPLAN, the SES. Some residents may choose to leave on their own accord based on flood information from the radio or other warnings, and may be assisted by local residents. The main problems with all flood evacuations are;

- They must be carried out quickly and efficiently;
- There can be confusion about 'ordering' evacuations, with rumours and well-meaning

advice taking precedence over official directions which can only come from the lead agency, the SES;

- They are hazardous for both rescuers and the evacuees;
- Residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers, and
- People (residents and visitors) do not appreciate the dangers of crossing floodwaters.

For this reason, the preparation of a flood emergency response plan helps to minimise the risk associated with evacuations by providing information regarding evacuation routes, refuge areas, what to do/not to do during floods etc. It is the role of the SES to develop this plan for vulnerable communities.

DISCUSSION

As recommended in Section 6.2, a DISPLAN should be prepared for the Sydney West Emergency Management District (of which Johnstons Creek catchment is part of) to outline emergency response arrangement specific to the district. In particular the purpose of a District DISPLAN is to:

- Identify responsibilities at a District and Local level in regards to the prevention, preparation, response and recovery for each type of emergency situation likely to affect the district;
- Detail arrangements for coordinating resource support during emergency operations at both a District and Local level;
- Outline the tasks to be performed in the event of an emergency at a District and Local level;
- Specifies the responsibilities of the West Metropolitan District Emergency Operations Controller and Local Emergency Operations Controllers within the West Metro EM District;
- Detail the responsibilities for the identification, development and implementation of prevention and mitigation strategies;
- Detail the responsibilities of the District and Local Emergency Management Committees within the District;
- Detail agreed Agency and Functional Area roles and responsibilities in preparation for, response to and recovery from, emergencies;
- Outline the control, coordination and liaison arrangements at District and Local levels;
- Detail arrangements for the acquisition and coordination of resources;
- Detail public warning systems and responsibility for implementation;
- Detail public information arrangements and public education responsibilities;
- Specifies arrangements for reporting before, during and after an operation; and
- Detail the arrangements for the review, testing, evaluation and maintenance of the Plan.

Further, it is recommended that the City of Sydney to prepare a Local Flood Plan in conjunction with the SES to outline the following details:

- Evacuation centres in close proximity to the floodplain which are flood free sites with flood free access;
- Organise use of Variable Message Signs for use during a flood event for flood affected roads.
- Inclusion of a description of local flooding conditions;
- Identification of potentially flood affected vulnerable facilities; and
- Identification of key access road subject to flooding.

Details of access road flooding, evacuation centres and recommended inclusions for the flood plan are provided in Section 6.

Although flood warning is limited, a local disaster plan should be continually updated to include the latest information on design flood levels and details on roads, properties, and other facilities which would be flood affected.

OUTCOME
The SES should ensure that a DISPLAN (Option RM – JC02) be prepared for the Sydney West Emergency Management District (of which Johnstons Creek catchment is part of) and Council with the help of the SES should prepare a Local Flood Plan (Option RM – JC03) for the study catchment. This should also take into account those properties not directly flood affected but which may have had access cut and become flood islands. These plans should be regularly kept up to date and should include feedback from recent major flood events and the recommendations of this Study once finalised.

9.6.3. Community Awareness Programme (RM – JC04)

DESCRIPTION
The success of any flood warning system and the evacuation process in reducing flood losses and damages depends on:

- *Flood Awareness*: How aware is the community of the flood threat? Has it been adequately informed and educated?
- *Flood Preparedness*: How prepared is the community to react to the threat of flooding? Do they (or the SES) have damage minimisation strategies (such as sand bags, raising possessions) which can be implemented?
- *Flood Evacuation*: How prepared are the authorities and the residents to evacuate

households to minimise damages and the potential risk to life during a flood? How will the evacuation be done, where will the evacuees be moved to?

Public information and the level of public awareness are keys in reducing flood damages and losses. A more aware community will suffer less losses and damage than an unprepared community.

DISCUSSION

The level of flood awareness within a community is difficult to evaluate. It will vary over time and depends on a number of factors including frequency and impact of previous floods, history of residence, and whether an effective community awareness program has been implemented.

Families who have owned properties for a long time will have established a considerable depth of knowledge regarding flooding and a relatively high level of flood awareness. A community which consists predominantly of short lease rental homes will have a low level of flood awareness. Also it is very likely that new residents will be aware from advice at the time of their property purchase (Section 149 certificate) or from neighbours after they move in.

Generally community awareness will decline as the time since the last flood increases. Community awareness can be raised as a result of community flood or climate change awareness programs albeit temporarily and without the same consensus an actual flood brings. A community with high flood awareness will suffer less damage and disruption during and after a flood because people are aware of the potential of the situation. On river systems which regularly flood, there is often a large, local, unofficial warning network which has developed over the years and residents know how to effectively respond to warnings by raising goods, moving cars, lifting carpets, etc. Photographs and other sentimental or non-replaceable items are generally put in safe places. In more frequently flooded areas, some residents may have developed storage facilities which are flood compatible. However, this is generally not the case within the Johnstons Creek catchment urban area.

A major hurdle is often convincing residents that major floods will occur in the future. Many residents hold the false view that once they have experienced a large flood then another will not occur for a long time thereafter. History shows that, in contrast, actual flood events tend to cluster into a period of several years over 20-50 year cycles. Residents should be made aware that within the Johnstons Creek catchment, significant damage can occur even in the smaller, more frequent flood events.

Community information can simply be provided in an information brochure mailed to residents for them to keep available. This would include such things as identifying the risk, the procedures to be followed in an emergency evacuation, details of the local evacuation centre and evacuation routes telephone numbers etc. Further community awareness options are detailed in Table 17.

Table 17: Community Flood Awareness Methods

Method	Comment
Letter/pamphlet from Council	These may be sent (annually or biannually) with the rate notice or separately. A Council database of flood liable properties/addresses makes this a relatively inexpensive and effective measure. The pamphlet can inform residents of ongoing implementation of the Risk Management Plan, changes to flood levels, climate change or any other relevant information.
Council website	Council should continue to update and expand their website to provide both technical information on flood levels as well as qualitative information on how residents can make themselves flood aware. This would provide an excellent source of knowledge on flooding as well as on issues such as climate change. It is recommended that Council's website continue to be updated as and when required.
Community Working Group	Council should initiate a Community Working Group framework which will provide a valuable two way conduit between the local residents and Council.
School project or local historical society	This provides an excellent means of informing the younger generation about flooding and climate change. It may involve talks from various authorities and can be combined with topics relating to water quality, estuary management, etc.
Historical flood markers and flood depth markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advise of potential hazards, particularly to drivers. These are inexpensive and effective but in some flood communities not well accepted as it is considered that they affect property values.
Articles in local newspapers	Ongoing articles in the newspapers will ensure that the flood and climate change issues are not forgotten. Historical features and remembrance of the anniversary of past events are interesting for local residents.
Collection of data from future floods	Collection of data (including photographs and recorded flood levels) assists in reinforcing to the residents that Council is aware of the problem and ensures that the design flood levels are as accurate as possible.
Types of information available	A recurring problem is that new owners consider they were not adequately advised that their property was flood affected on the 149 Certificate during the purchase process. Council may wish to advise interested parties, when they inquire during the property purchase process, regarding flood information currently available, how it can be obtained and the cost. This information also needs to be provided to all visitors who may rent for a period. Some Councils have conducted "briefing" sessions with real estate agents and conveyancers.
Establishment of a flood effects database and post flood data collection program	A database would provide information on a number of issues such as which houses require evacuation, which public structures will be affected (eg. telephone or power cuts). This database should be reviewed after each flood event. This database should be updated following each flood with input from the community.
Flood preparedness program	Providing information to the community regarding flooding helps to inform it of the problem and associated implications. However, it does not necessarily adequately prepare people to react effectively to the problem. A Flood Preparedness Program would ensure that the community is adequately prepared. The SES would take a lead role in this.
Develop approaches to foster community ownership of the problem	Flood damages in future events can be minimised if the community is aware of the problem and takes steps to find solutions. The development of approaches that promote community ownership should therefore be encouraged. For example residents should be advised that they have a responsibility to advise Council if they see a problem such as blockage of drains or such like. This process can be linked to water quality or other water related issues including estuary management. The specific approach can only be developed in consultation with the community.

Following flooding it is important to collect available information but to also let the community know that Council is aware of the problems and are managing it. Council staff should meet with affected community members following flooding, particularly those properties in the identified hot spots like Coneill Place and Sparkes Street. Ongoing post flood data collection by Council in conjunction with the SES should occur after every flood event to enable improved understanding of the flooding situation and ensure data is always the most recent to allow better decision making for flood management.

OUTCOME

For risk management to be effective it must become the responsibility of the whole community. It is difficult to accurately assess the benefits of an awareness program but it is generally considered that the benefits far outweigh the costs. The perceived value of the information and level of awareness diminishes as the time since the last flood increases.

As time passes since the last significant flood, the direct experience of the community with historical floods will diminish. It is important that a high level of awareness is maintained through implementation of a suitable Flood Awareness Program that would include Floodsafe brochures as well as advice provided on Council's and SES's websites. These need to be updated on regular basis.

Table 17 provides examples of possible further education methods that may be developed and supported by Council. The specific flood awareness measures that are implemented will need to be developed by Council taking into account the views of the local community, funding considerations and other awareness programs within the LGA. The details of the exact measures would need to be developed in consultation with affected communities.

10. ASSESSMENT OF MITIGATION MEASURES

The cost effectiveness of the identified works and measures from Section 9.4 in reducing flood liability within the catchment was determined using the benefit/cost (B/C) approach. Each management option was assessed by considering the reduction in the amount of flood damage incurred by a range of design events and comparing this value with the cost of implementing the option.

10.1. Costing of Options

Detailed cost estimates have been prepared for each option and these are summarised in Table 18. The details are provided in Appendix E. It is important to note that these are estimates and should be revised prior to the detailed design phase of the options to obtain a more accurate costing.

Table 18: Costings of Management Options

Options	Capital Cost	Ongoing (Annual) Costs
FM - JC01 Detention Basin at St Johns Oval	$3,385,000	$10,000
FM - JC02 Drainage Upgrade – Sparkes Street to Johnstons Creek	$10,727,000	$28,000
FM - JC03 Drainage Upgrade – Hereford Street & Detention Basins at John Street & Arthur Gray Reserves	$9,011,000	$16,000
FM - JC04 Lowering Hogan Park & Walkway Widening	$4,575,000	-
FM - JC05 Johnstons Creek Bridge Raising	$629,000	$20,000

Table 18 shows that the drainage capacity upgrade options (FM – JC02 and FM – JC03) are generally more costly and would involve more disruption to the community.

10.2. Damage Assessment of Options

The total damage costs were also evaluated for each of the management option and compared against the existing base case, as shown in Table 19. The assessment was carried out in accordance with OEH guidelines utilising data obtained from the flood level survey and height-damage curves that relate the depth of water above the floor with tangible damages. The damages were evaluated for a range of design events from the 5 year ARI up to the PMF.

Table 19: Average Annual Damage Reduction of Management Options

Options	AAD	Reduction in AAD due to Option
FM - JC01 Detention Basin at St Johns Oval	$2,011,000	$267,000
FM - JC02 Drainage Upgrade – Sparkes Street to Johnstons Creek	$1,575,000	$703,000
FM - JC03 Drainage Upgrade – Hereford Street & Detention Basins at John Street & Arthur Gray Reserves	$2,098,000	$180,000
FM - JC04 Lowering Hogan Park & Walkway Widening	$2,268,000	$10,000
FM - JC05 Johnstons Creek Bridge Raising	$2,264,000	$6,000

The results show that Option FM – JC02 which provides significant relief of the flood issues at the depression upstream of Pyrmont Bridge Road has the largest reduction in AAD whilst Options FM – JC04 and FM – JC05 which only impact on limited properties adjacent to Johnstons Creek has the smallest reduction in AAD.

10.3. Benefit Cost Ratio of Options

As part of the economic evaluation of each management option proposed, the reduction of average annual damage (AAD) calculated for each option needs to be evaluated against the capital and ongoing costs in order to ascertain the benefit cost ratio. The existing condition ('do nothing' option) was used as the base case to compare the performance of the various options modelled. Table 20 provides a summary of the costs, reduction in damages and benefit/cost ratio for the options.

Table 20: Benefit/Cost Ratio for Management Options

		Benefit		Cost Estimate				
Options	AAD	Reduction in AAD	NPW of AAD Reduction*	Capital	Maintenance (Annual)	NPW of Costs*	B/C Ratio	Rank
FM - JC01	$2,011,000	$267,000	$3,935,000	$3,385,000	$10,000	$3,532,000	1.11	1
FM - JC02	$1,575,000	$703,000	$10,378,000	$10,727,000	$28,000	$11,130,000	0.93	2
FM - JC03	$2,098,000	$180,000	$2,656,000	$9,011,000	$16,000	$9,235,000	0.29	3
FM - JC04	$2,268,000	$10,000	$139,000	$4,575,000	-	$4,575,000	0.03	5
FM - JC05	$2,264,000	$6,000	$98,000	$629,000	$20,000	$924,000	0.11	4

* NPW: Net present worth calculated over 50 years at 7%

Annual expenses in the form of maintenance were included in the cost estimates but these are generally insignificant compared to the capital costs.

The benefit/cost ratio provides an insight into how the damage savings relate to the construction and maintenance costs of an option, whereby:

- A ratio of greater than 1 indicates the economic benefits are greater than the cost of implementing the option;
- A ratio of less than 1 but greater than 0 indicates there is still an economic benefit from implementing the option but the cost of implementation outweighs the economic benefit;
- A ratio of 0 indicates there is no economic benefit from implementing the option; and
- A negative ratio indicates there is a negative economic impact of implementing the option.

From the benefit/cost analysis, it can be seen that all options have a ratio of less than 1 with the exception of FM – JC01, which is not unusual for this type of analysis. Option FM – JC05 is found to have minimal impact on over-floor flood liability though it has the lowest capital cost. On the other hand, implementing Option FM – JC02 results in the highest reduction of AAD in excess of $10 million over the period of 50 years though the capital cost is of the same order of magnitude.

The analysis does not consider social factors, environmental factors and risk to life which cannot be quantified in monetary terms but would have contributed to the benefits that could be gained from these management options. Nevertheless, these factors are considered as part of the multi-criteria matrix assessment (refer Section 10.4).

10.4. Multi-Criteria Matrix Assessment

The relative merits of each proposed management options in Section 9 are evaluated by developing a multi-variate decision matrix (discussed in Section 9.1.1) and using the scoring framework outlined in Section 9.1.2. The matrix is shown as

Table 21. Each option is subjectively scored for a range of criteria considering the background information on the nature of the catchment as well as outcomes from the stakeholder and community workshops. It is important to note that the approach undertaken does not provide an absolute "right" answer as to what should be included in the Management Plan but rather to provide an easy framework for comparing the various options on an issue by issue basis which stakeholders can then use to make a decision.

Based on the matrix, the options for future implementation are ranked in the order as tabulated in Table 22.

Table 21: Multi-Criteria Assessment of Management Options

Ref	Options	Section in Report	Design Event (AEP)	Impact on Flood Behaviour	Number of Properties Benefited	Technical Feasibility	Community Acceptance	Economic Merits	Financial Feasibility	Environmental/Ecological Benefits	Impact on SES	Political/Admin Issues	Long Term Performance	Risk to Life	Total Score	Rank (Total)
Flood Modification Measures																
FM – JC01	Detention Basin at St Johns Oval	9.4.1	10%	3	3	-1	2	1	-1	-1	2	-2	-1	2	7	9
FM – JC02	Drainage Upgrade – Sparkes Street to Johnstons Creek	9.4.2	5%	3	3	-3	1	0	-2	-3	2	-3	0	2	0	11
FM – JC03	Drainage Upgrade – Hereford Street & Detention Basins at John Street & Arthur Gray Reserves	9.4.3	5%	3	3	-2	-2	-1	-2	-2	2	-1	-1	1	-2	13
FM – JC04	Lowering Hogan Park & Walkway Widening	9.4.4	5%	3	2	-2	-1	-2	-1	-1	1	-2	1	1	-1	12
FM – JC05	Johnstons Creek Bridge Raising	9.4.5	5%	3	2	2	2	-1	3	0	1	-1	2	1	14	1
Property Modification Measures																
PM - JC01	Review FPLs following completion of FRMS&P, provide case studies to assist DA.	9.5.1	N/A	0	0	0	2	2	0	0	1	1	2	1	9	7
PM - JC02	Update Sydney DCP 2012 and LEP 2012 based on FRMS&P outcomes and to inform of Council's Interim Floodplain Management Policy	9.5.2	N/A	0	0	0	2	1	2	0	1	1	2	1	10	4=
PM - JC03	Investigate flood proofing techniques for flood affected commercial/industrial properties	9.5.4	N/A	0	2	2	0	2	1	0	0	-1	1	1	8	8
PM - JC04	Investigate potential for property adjustments to manage overland flow at flooding hot spots	9.5.5	N/A	0	2	1	0	2	1	-1	0	-1	1	1	6	10
Response Modification Measures																
RM - JC01	Make available flood warnings on Council's website or social media, investigate feasibility of installing flood	9.6.1	N/A	0	0	0	3	1	1	0	2	1	0	2	10	4=

	warning systems at key locations															
RM - JC02	Prepare DISPLAN for the Sydney West Emergency Management District (SES)	9.6.2	N/A	0	0	0	3	1	1	0	3	1	0	2	11	2=
RM - JC03	Prepare Local Flood Plan to inform evacuation centres, identify vulnerable facilities and evacuation routes	9.6.2	N/A	0	0	0	3	1	1	0	3	1	0	2	11	2=
RM - JC04	Develop ongoing flood awareness programmes for the community	9.6.3	N/A	0	0	0	3	1	1	0	2	1	0	2	10	4=

Table 22: Ranking of Management Options

Rank	Ref	Options	Score
1	FM-JC05	Raise footbridges along Johnstons Creek to above the 1% AEP level	14
2=	RM-JC02	Prepare DISPLAN for the Sydney West Emergency Management District (SES)	11
2=	RM-JC03	Prepare Local Flood Plan to inform evacuation centres, identify vulnerable facilities and evacuation routes	11
4=	PM-JC02	Update Sydney DCP 2012 and LEP 2012 based on FRMS&P outcomes and to inform of Council's Interim Floodplain Management Policy	10
4=	RM-JC01	Make available flood warnings on Council's website or social media, investigate feasibility of installing flood warning systems at key locations	10
4=	RM-JC04	Develop ongoing flood awareness programmes for the community	10
7	PM-JC01	Review FPLs following completion of FRMS&P for Johnstons Creek catchment. Provide case studies to assist DA	9
8	PM-JC03	Investigate flood proofing techniques for flood affected commercial/industrial properties	8
9	FM-JC01	Detention basin in part of St Johns Oval, University of Sydney	7
10	PM-JC04	Investigate potential for property adjustments to manage overland flow at flooding hot spots	6
11	FM-JC02	Drainage upgrade between Sparkes Street to Johnstons Creek & downstream channel works	0
12	FM-JC04	Regrade Hogan Park & widen walkway under The Crescent	-1
13	FM-JC03	Drainage upgrade near Hereford Street & detention basins in John Street & Arthur Gray Reserves	-2

Note: ‘=’ denotes equal position. E.g. ‘3=’ refers to equal third rank.

11. ACKNOWLEDGEMENTS

WMAwater wish to acknowledge the assistance of the City of Sydney Council staff and the Floodplain Management Committee in carrying out this study as well as the NSW Government (Office of Environment and Heritage) and the residents of the Johnstons Creek catchment. This study was jointly funded by the City of Sydney Council and the NSW Government.

12. REFERENCES

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6. Sydney Water (1995), Johnstons Creek (SWC 17) Capacity Assessment

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9. NSW Government (2010), Flood Emergency Response Classification of Communities, NSW Department of Environment and Climate Change

10. WMAwater (2012), Blackwattle Bay Catchment Flood Study, Draft Report

11. City of Sydney (2014), Interim Floodplain Management Policy

12. Howells *et. Al.* (2004), Defining the Floodway – Can One Size Fit All?, FMA NSW Annual Conference, Coffs Harbour, February 2004

Figures

FIGURE 1
STUDY AREA
JOHNSTONS CREEK CATCHMENT

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FIGURE 2
LAND USE MAP
JOHNSTONS CREEK CATCHMENT

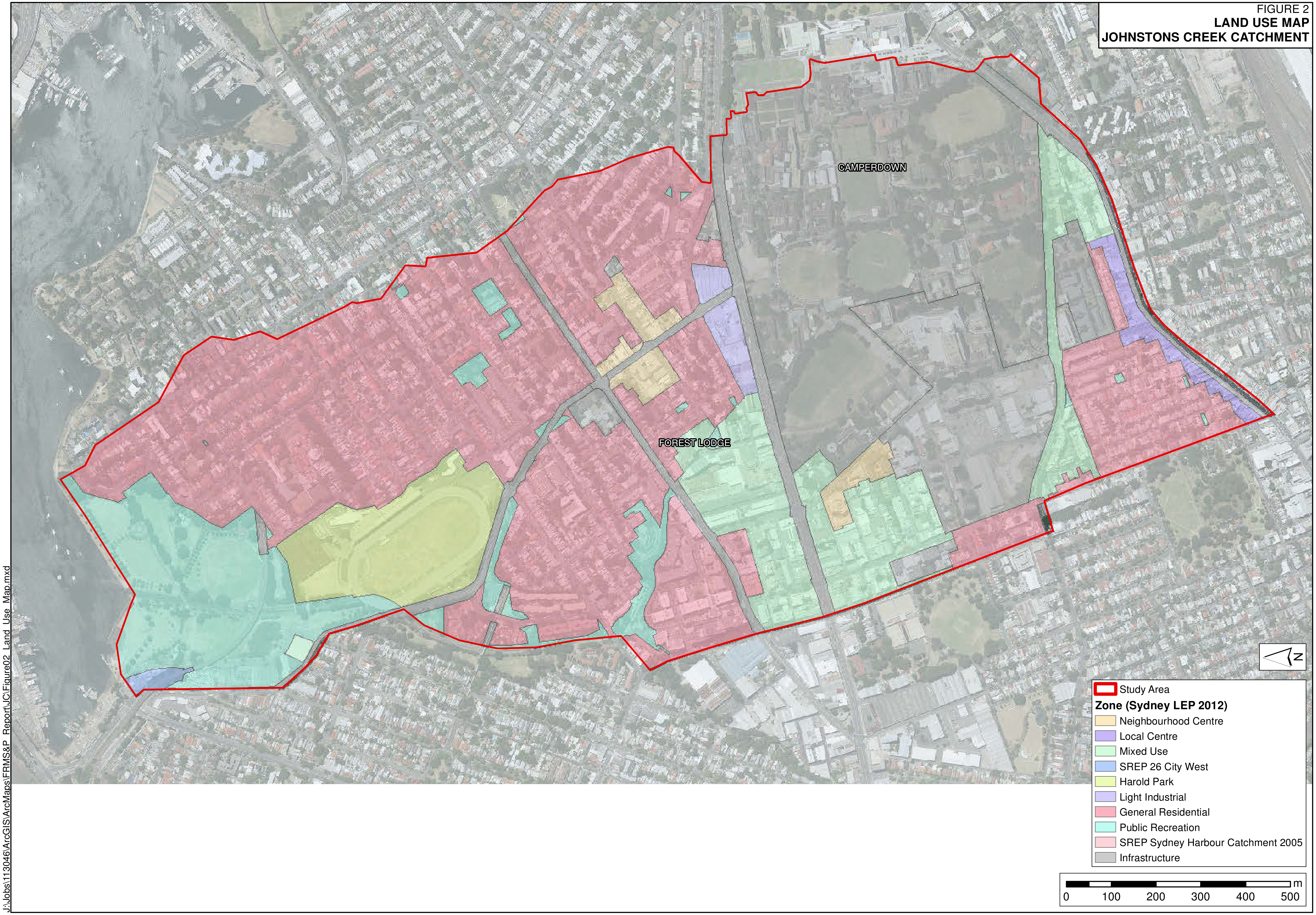

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FIGURE 3
DRAINAGE CAPACITY ASSESSMENT
JOHNSTONS CREEK CATCHMENT

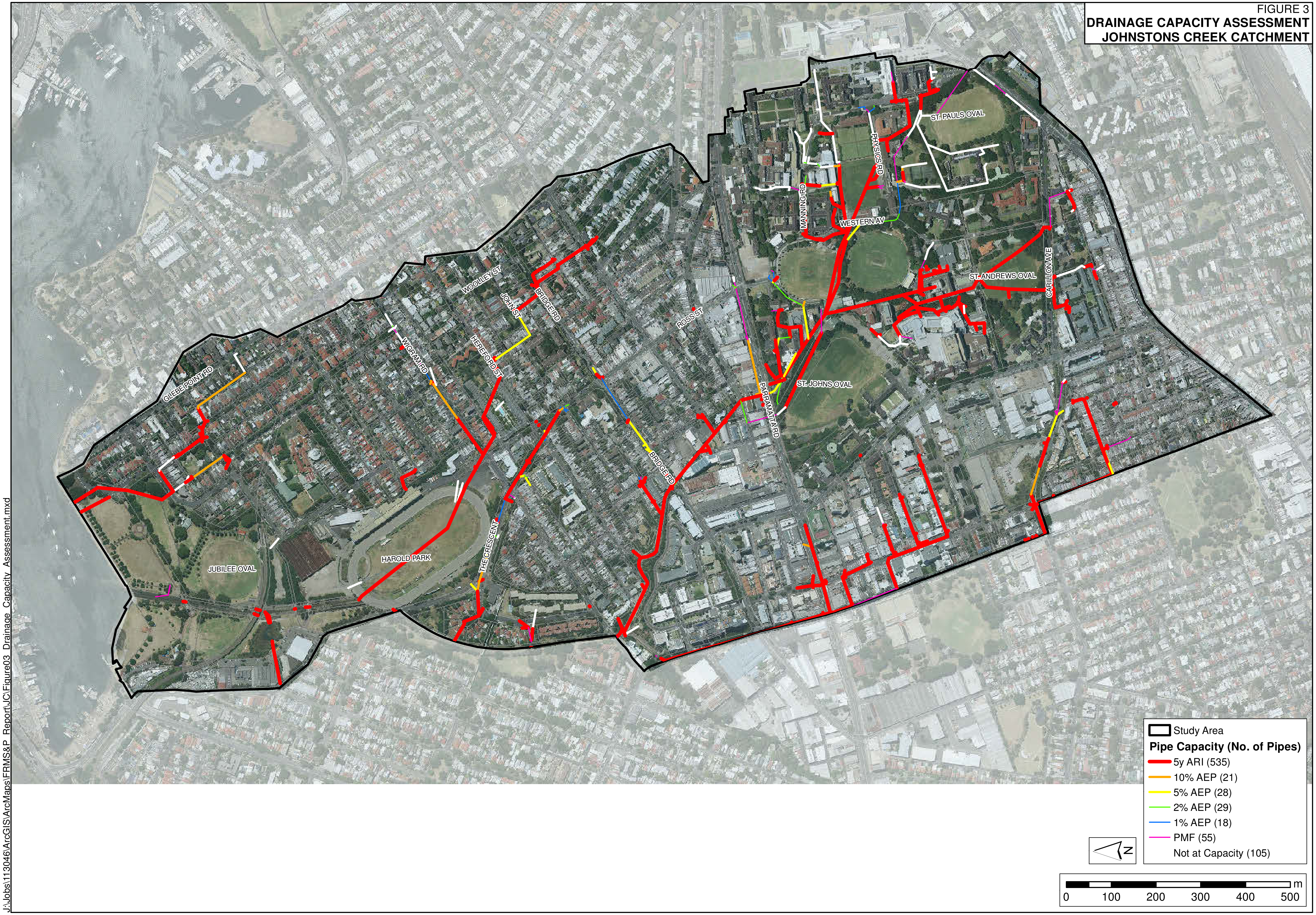

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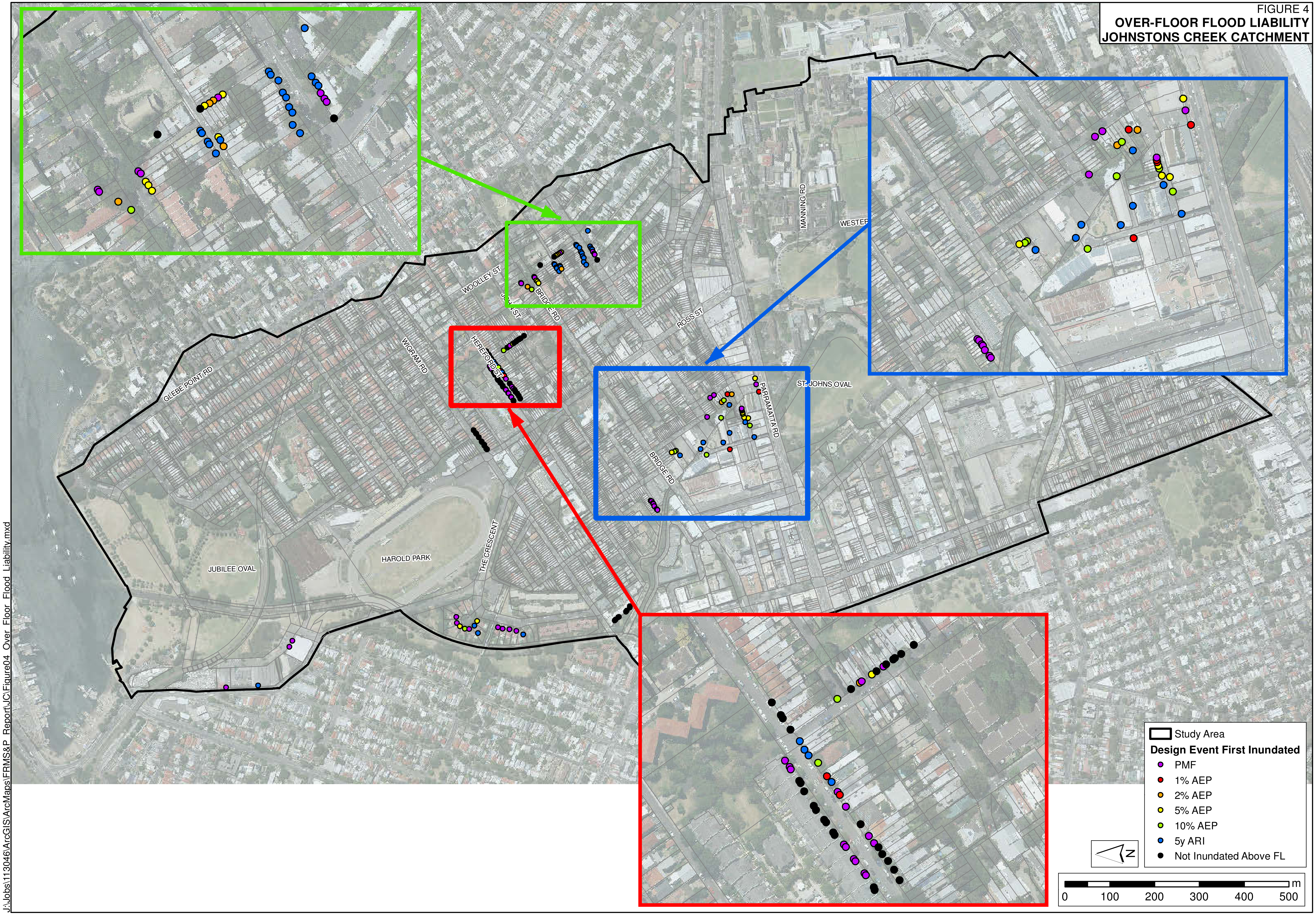
FIGURE 4
OVER-FLOOR FLOOD LIABILITY
JOHNSTONS CREEK CATCHMENT



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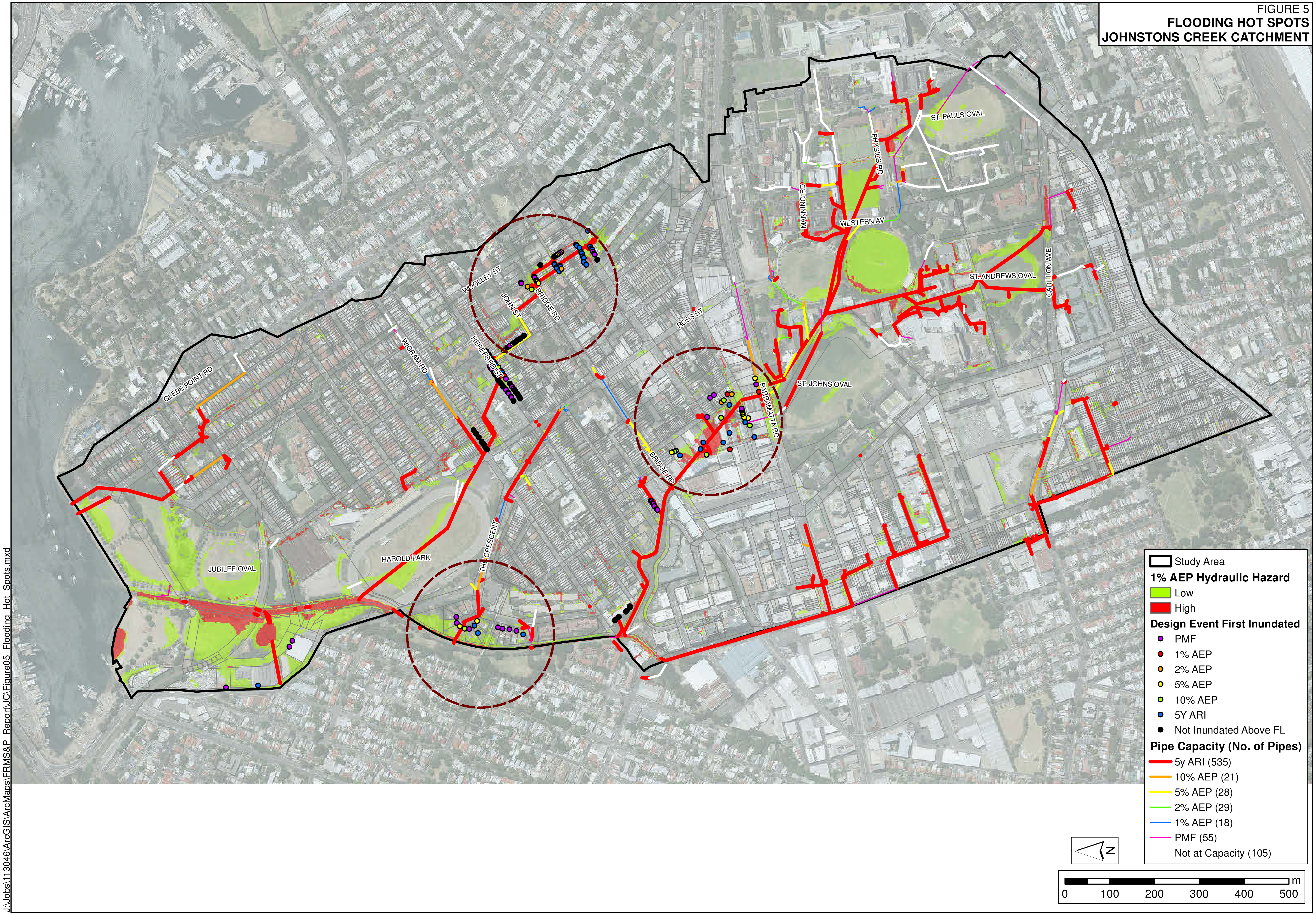

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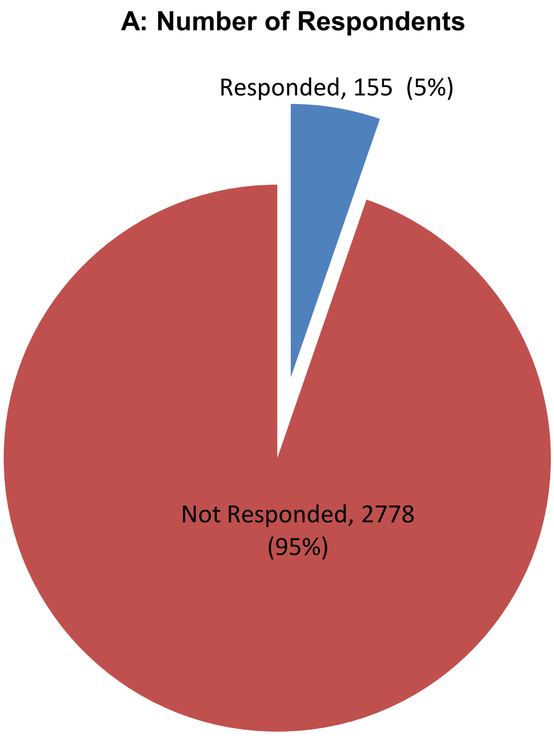
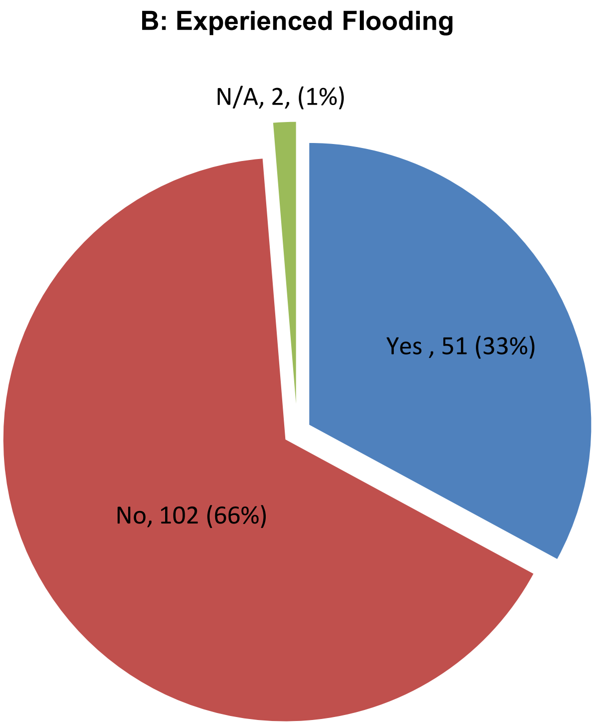
FIGURE 6A
COMMUNITY CONSULTATION RESULTS
JOHNSTONS CREEK CATCHMENT
SEPTEMBER 2013 MAILOUT

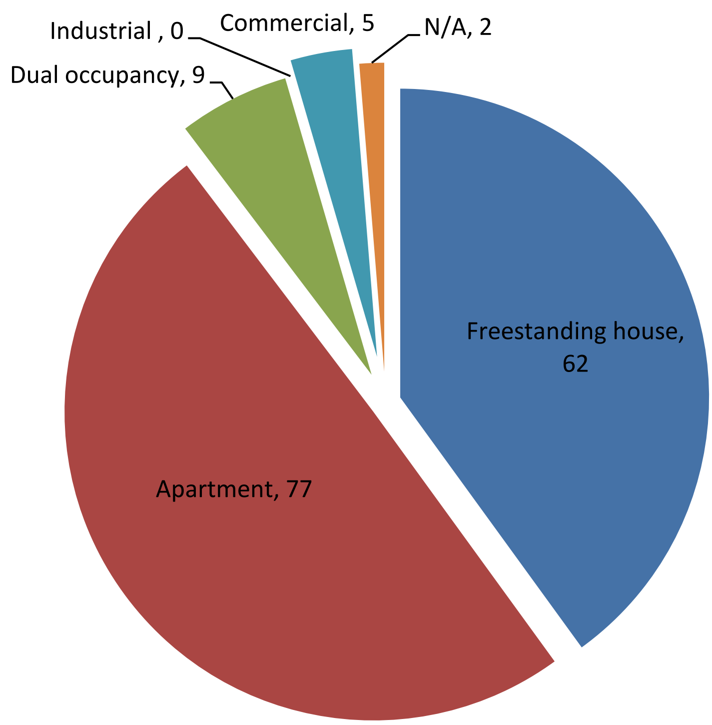




J:\Jobs\113046\Admin\Community_Consultation\Results\Questionnaire_Blackwattle&Johnstons.xlsx

FIGURE 6B
COMMUNITY CONSULTATION RESULTS
JOHNSTONS CREEK CATCHMENT
SEPTEMBER 2013 MAILOUT

C: Property Type



D: Period of Living/Working/Owning Property

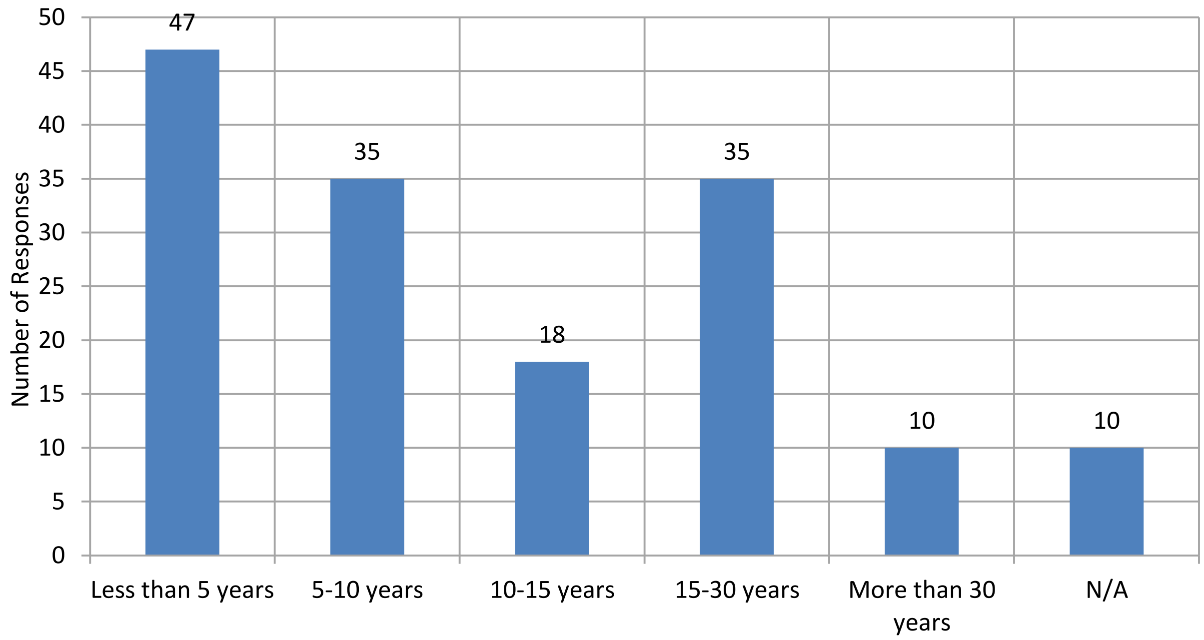


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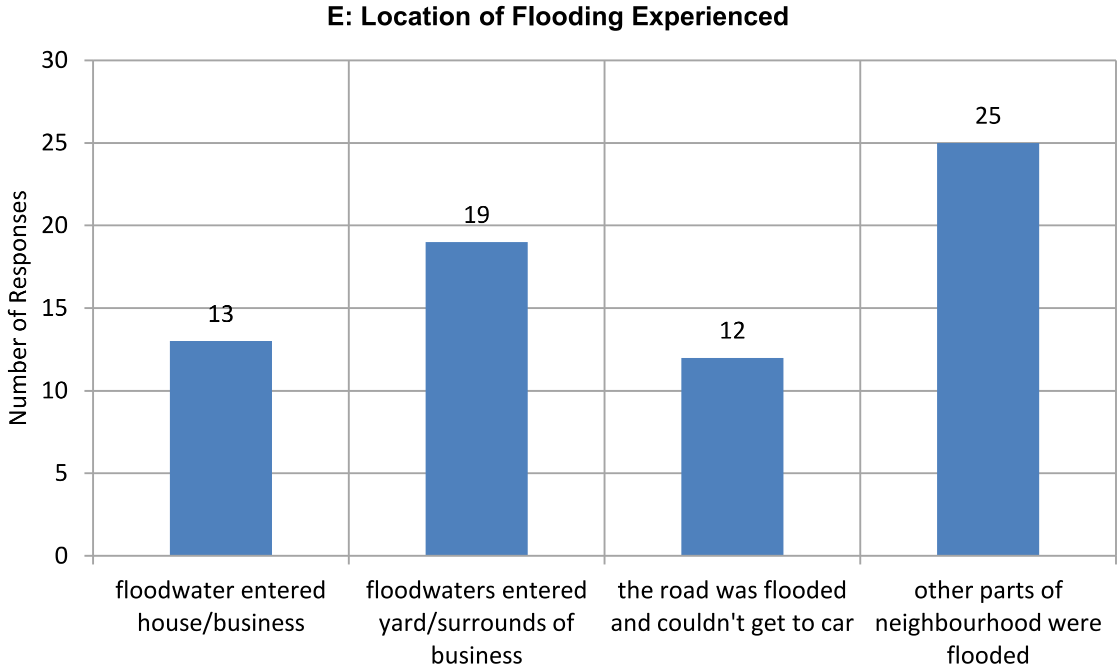
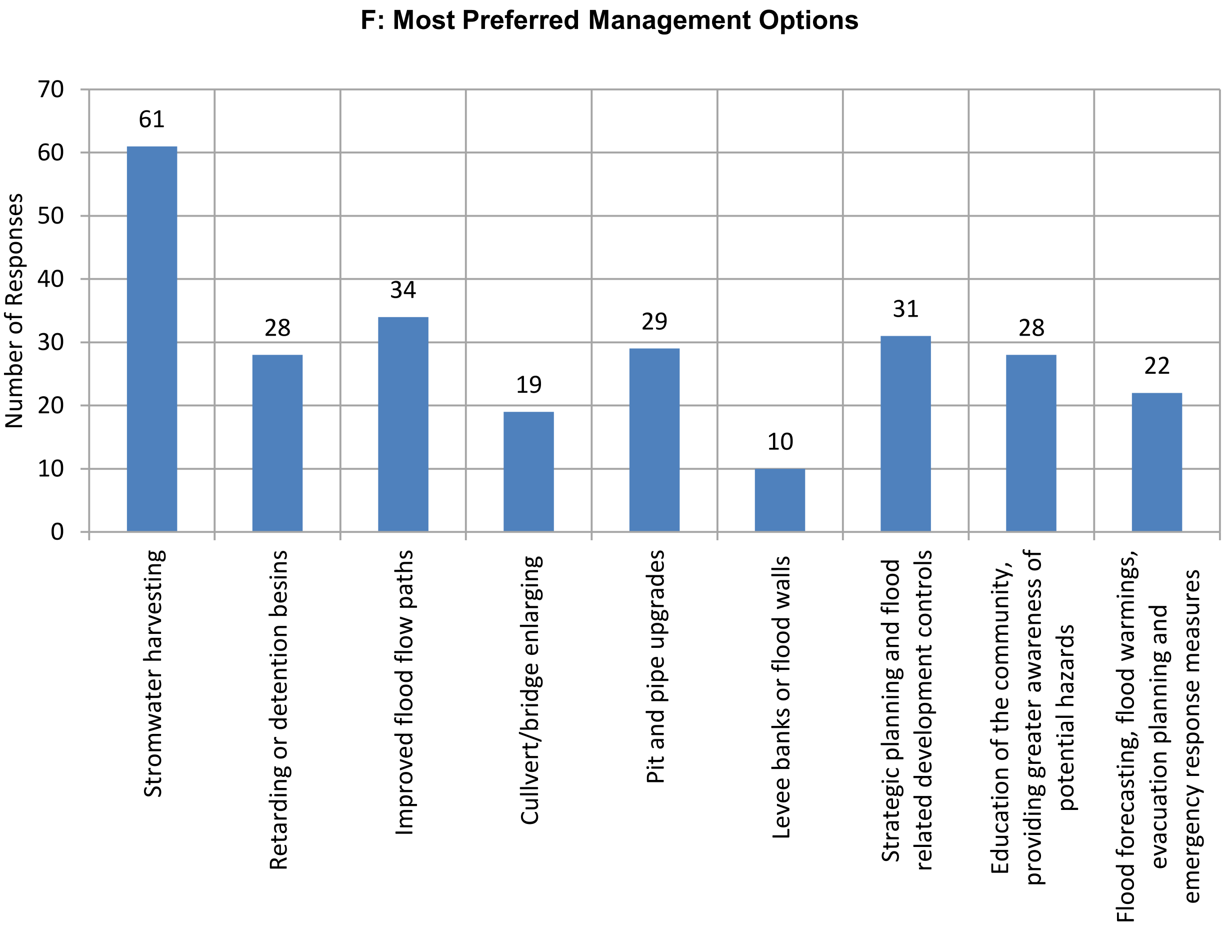
FIGURE 6C
COMMUNITY CONSULTATION RESULTS
JOHNSTONS CREEK CATCHMENT
SEPTEMBER 2013 MAILOUT





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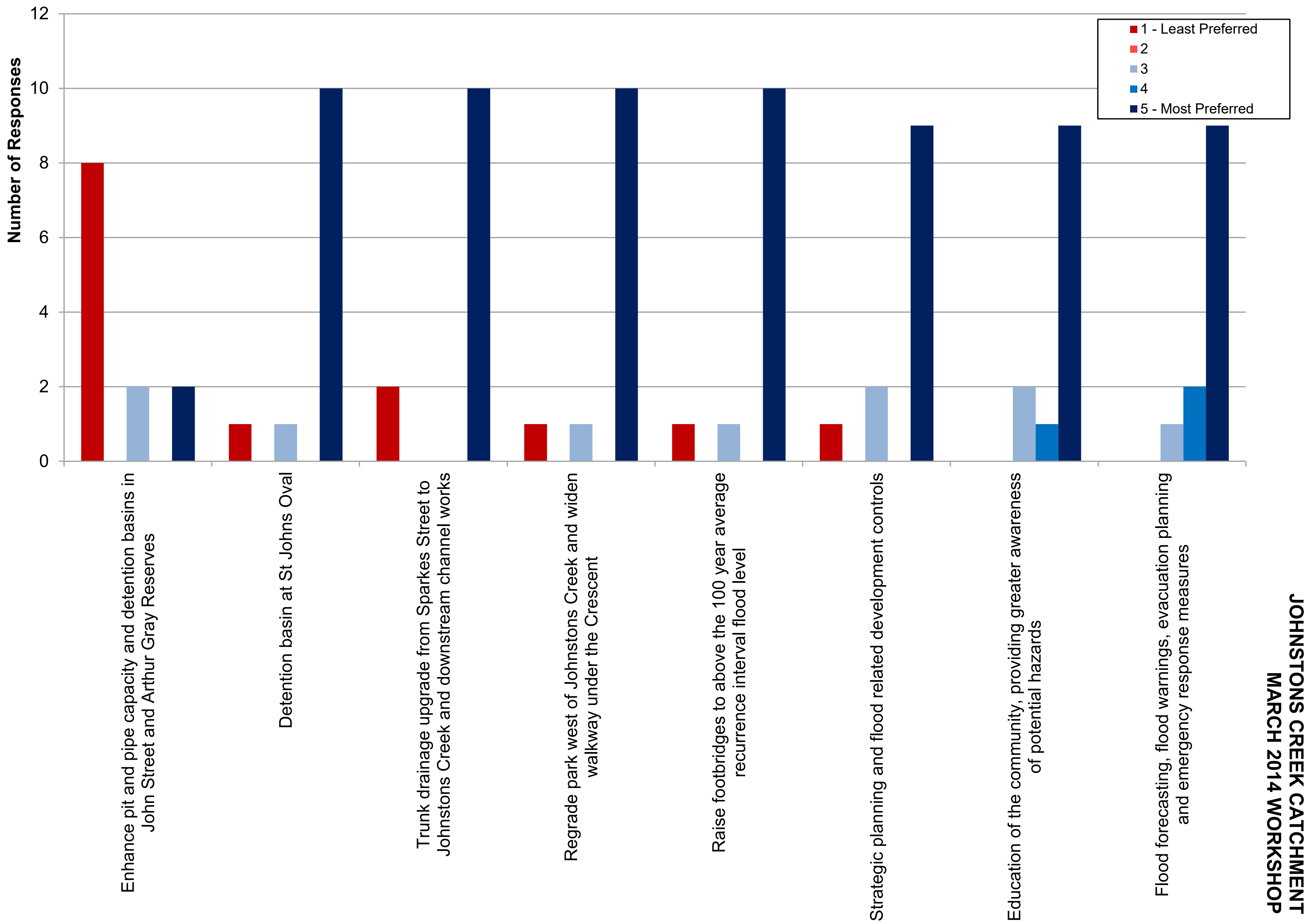

FIGURE 6D

COMMUNITY CONSULTATION RESULTS
JOHNSTONS CREEK CATCHMENT
MARCH 2014 WORKSHOP

FIGURE 7
PEAK FLOOD DEPTH
5Y ARI DESIGN FLOOD EVENT

Study Area

Depth (m)

- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- >1

0 100 200 300 400 500 m

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Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

Note: Flood depths modelled as less than 0.1m are not displayed

FIGURE 8
PEAK FLOOD DEPTH
10% AEP DESIGN FLOOD EVENT

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Study Area

Depth (m)

- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- >1

0 100 200 300 400 500 m

Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

Note: Flood depths modelled as less than 0.1m are not displayed

FIGURE 9

PEAK FLOOD DEPTH

5% AEP DESIGN FLOOD EVENT

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N

Study Area

Depth (m)

- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- >1

0 100 200 300 400 500 m

Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

Note: Flood depths modelled as less than 0.1m are not displayed

FIGURE 10
PEAK FLOOD DEPTH
2% AEP DESIGN FLOOD EVENT

Study Area

Depth (m)

- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- >1

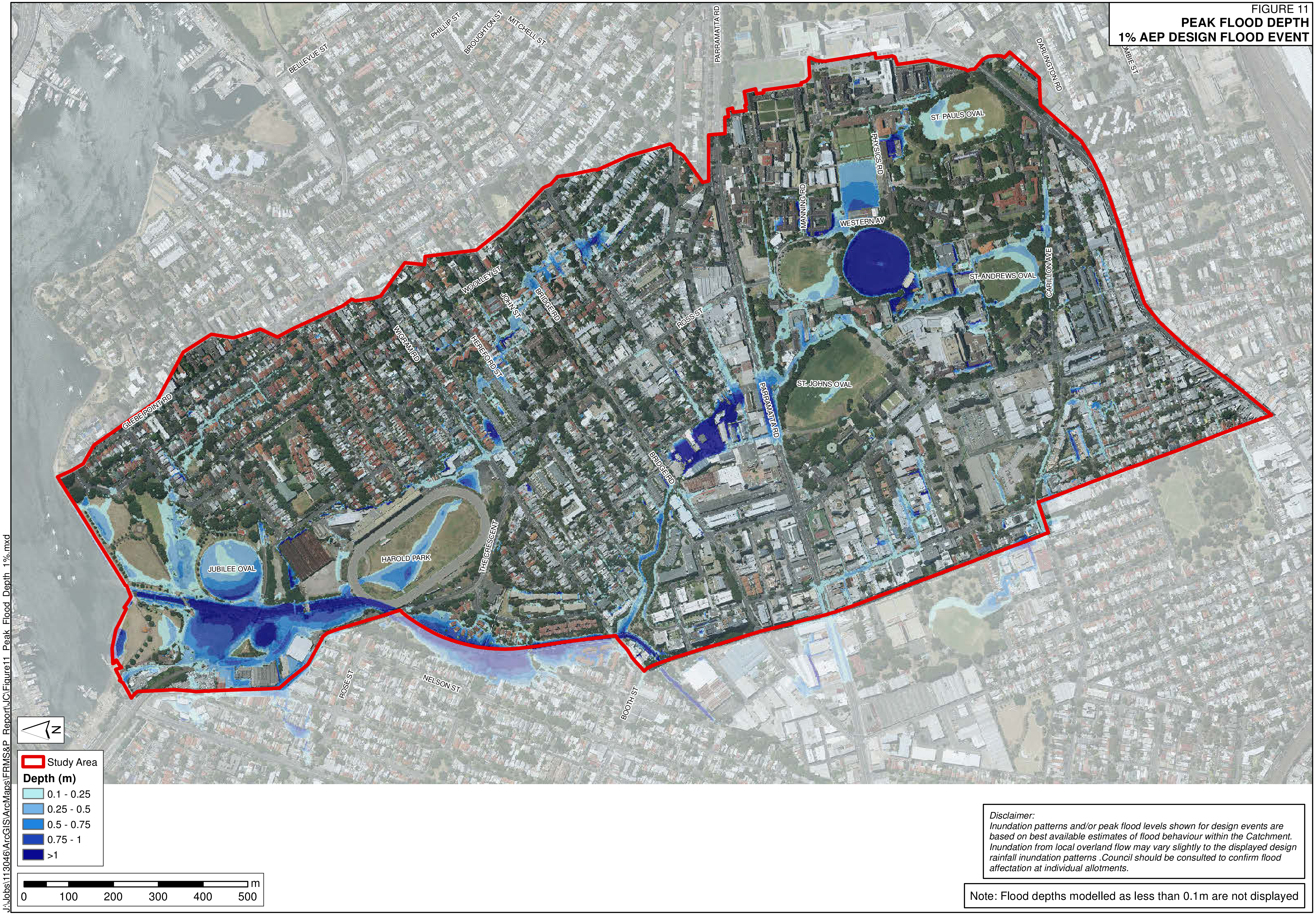
0 100 200 300 400 500 m

Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

Note: Flood depths modelled as less than 0.1m are not displayed

J:\Jobs\113046\ArcGIS\ArcMaps\FRMS&P Report\JC\Figure10_Peak_Flood_Depth_2%.mxd

FIGURE 11
PEAK FLOOD DEPTH
1% AEP DESIGN FLOOD EVENT



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Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

Note: Flood depths modelled as less than 0.1m are not displayed

FIGURE 12
PEAK FLOOD DEPTH PMF EVENT

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Study Area

Depth (m)

- 0.1 - 0.25
- 0.25 - 0.5
- 0.5 - 0.75
- 0.75 - 1
- >1

0 100 200 300 400 500 m

Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

Note: Flood depths modelled as less than 0.1m are not displayed

FIGURE 13
HAZARD CATEGORIES
5 YEAR ARI DESIGN FLOOD EVENT

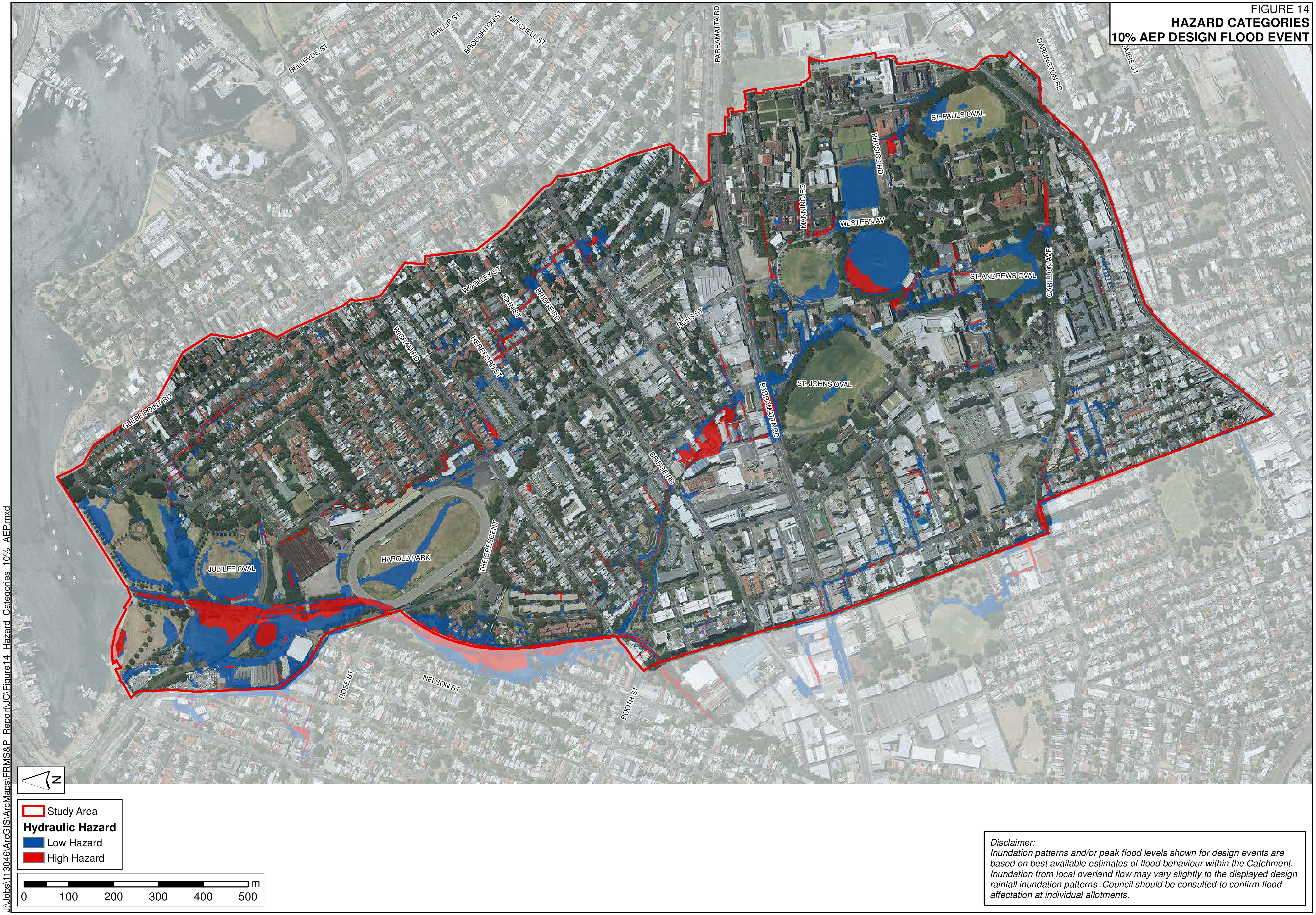
Study Area
Hydraulic Hazard
Low Hazard
High Hazard

0 100 200 300 400 500 m

Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

J:\Jobs\113046\ArcGIS\ArcMaps\FRMS&P Report\JC\Figure13_Hazard_Categories_5Y_ARI.mxd

FIGURE 14
HAZARD CATEGORIES
10% AEP DESIGN FLOOD EVENT



J:\Jobs\113046\ArcGIS\ArcMaps\FRMS&P Report\JC\Figure14_Hazard_Categories_10%_AEP.mxd

Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

FIGURE 15
HAZARD CATEGORIES
5% AEP DESIGN FLOOD EVENT

Study Area
Hydraulic Hazard
Low Hazard
High Hazard

0 100 200 300 400 500 m

J:\Jobs\113046\ArcGIS\ArcMaps\FRMS&P Report\UC\Figure15 Hazard Categories 5% AEP.mxd

Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

FIGURE 16

HAZARD CATEGORIES

2% AEP DESIGN FLOOD EVENT

Study Area

Hydraulic Hazard

Low Hazard

High Hazard

m

0 100 200 300 400 500

Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

J:\Jobs\111021\GIS\ArcMaps\JC\Report Figures 20120323\Figure26 Provisional Hazard Categories 20% AEP.mxd

FIGURE 17
HAZARD CATEGORIES
1% AEP DESIGN FLOOD EVENT

Study Area
Hydraulic Hazard
Low Hazard
High Hazard

0 100 200 300 400 500 m

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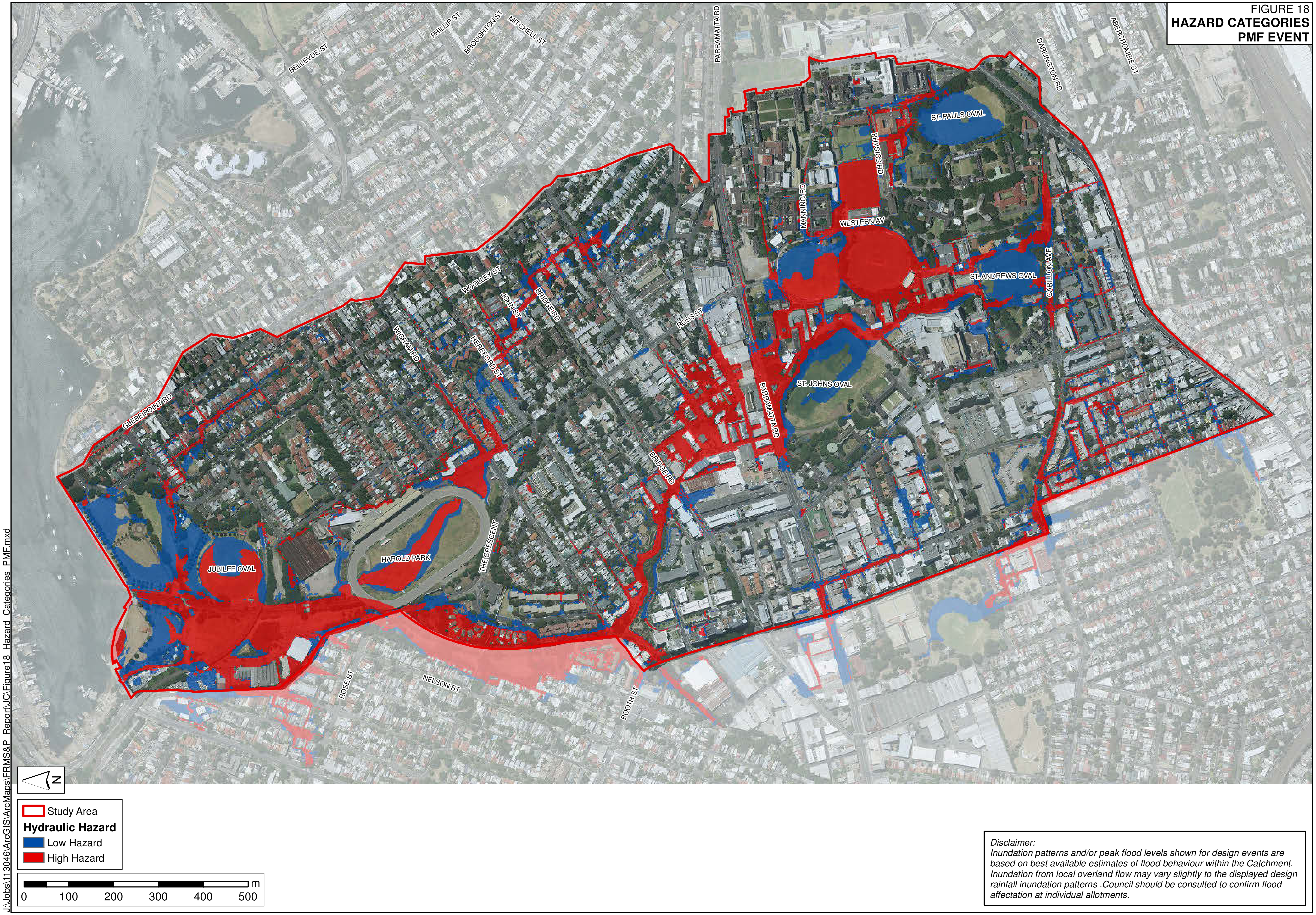
Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.

FIGURE 18
HAZARD CATEGORIES
PMF EVENT



J:\Jobs\113046\ArcGIS\ArcMaps\FRMS&P Report\JC\Figure18 Hazard Categories PMF.mxd

Disclaimer:
Inundation patterns and/or peak flood levels shown for design events are based on best available estimates of flood behaviour within the Catchment. Inundation from local overland flow may vary slightly to the displayed design rainfall inundation patterns .Council should be consulted to confirm flood affectation at individual allotments.