

ATTACHMENT G

**DARLING HARBOUR CATCHMENT
FLOODPLAIN RISK MANAGEMENT
PLAN (FINAL DRAFT REPORT)**

DARLING HARBOUR CATCHMENT FLOODPLAIN RISK MANAGEMENT PLAN

FINAL DRAFT





Level 2, 160 Clarence Street
Sydney, NSW, 2000

Tel: 9299 2855
Fax: 9262 6208
Email: wma@wmawater.com.au
Web: www.wmawater.com.au

DARLING HARBOUR CATCHMENT FLOODPLAIN RISK MANAGEMENT PLAN

FINAL DRAFT REPORT

MAY 2016

| | | | |
|---|-----------------------------|---|-------------|
| Project Darling Harbour Catchment Floodplain Risk Management Plan | | Project Number 114095 | |
| Client City of Sydney | | Client's Representative Sean Howie | |
| Authors Felix Taaffe Steve Gray | | Prepared by TO BE SIGNED FOR FINAL REPORT | |
| Date May 2016 | | Verified by TO BE SIGNED FOR FINAL REPORT | |
| Revision | Description | Distribution | Date |
| | | | |
| 3 | Final Draft | Sean Howie | May 2016 |
| 2 | Draft for Public Exhibition | | Jan 2016 |
| 1 | Draft Plan | | Nov 2015 |

DARLING HARBOUR CATCHMENT FLOODPLAIN RISK MANAGEMENT PLAN

TABLE OF CONTENTS

| | PAGE |
|--|-----------|
| FOREWORD | i |
| EXECUTIVE SUMMARY | ii |
| 1. FINDINGS OF FLOODPLAIN RISK MANAGEMENT STUDY | 1 |
| 1.1. Background | 1 |
| 1.2. Flood Hazard Classification | 1 |
| 1.3. Economic Impact of Flooding | 3 |
| 2. RECOMMENDED MANAGEMENT MEASURES | 4 |
| 2.1. Timeframe for Implementation | 4 |
| 2.2. Flood Modification Measures | 4 |
| 2.2.1. Drainage Upgrade – Commonwealth Street (FM – DH01) | 5 |
| 2.2.2. Drainage Upgrade – Elizabeth Street (FM – DH02) | 5 |
| 2.2.3. Drainage Upgrade – Elizabeth Street to Outlet (FM – DH05) | 5 |
| 2.2.4. Drainage Upgrade – Pyrmont Street to Outlet (FM – DH06) | 6 |
| 2.2.5. Drainage Upgrade – Black Wattle Place (FM – DH07) | 6 |
| 2.2.6. Data Collection – Catchment Specific Flood Damages Assessment (FM – DH08) | 6 |
| 2.3. Response Modification Measures | 7 |
| 2.3.1. Flood Warning and Evacuation (RM – DH01) | 7 |
| 2.3.2. Flood Emergency Management (RM – DH02) | 7 |
| 2.3.3. Public Information and Raising Flood Awareness (RM – DH03) | 7 |
| 2.4. Property Modification Measures | 8 |
| 2.4.1. Flood Planning Levels (PM – DH01) | 8 |
| 2.4.2. Development Control Planning (PM – DH02) | 8 |
| 2.4.3. Flood Proofing (PM – DH03) | 9 |
| 2.4.4. Property Modification – Feasibility Study for City of Sydney Flood Proofing (PM – DH04) | 9 |
| 2.5. Recommended Management Measures – Table | 9 |
| 3. ACKNOWLEDGEMENTS | 13 |
| 4. REFERENCES | 14 |

LIST OF TABLES

| | |
|---|----|
| Table 1: Hazard Classification..... | 2 |
| Table 2: Estimated Combined Flood Damages for Darling Harbour Catchment | 3 |
| Table 3: Recommended Management Measures..... | 11 |

LIST OF FIGURES

| |
|---|
| Figure 1: Study Area |
| Figure 2: Peak Flood Depth - 1% AEP Design Flood Event |
| Figure 3: Peak Flood Depth - PMF Event |
| Figure 4: Hazard Categories - 1% AEP Design Flood Event |
| Figure 5: Hazard Categories - PMF Event |
| Figure 6: Short Term Flood Risk Mitigation Options |
| Figure 7: Long Term Flood Risk Mitigation Options |

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 Darling Harbour Catchment Floodplain Risk Management Plan constitutes the third stage of this management process. This plan has been prepared by WMAwater for the City of Sydney (Council) under the guidance of Council's floodplain management committee (Committee). This plan provides the basis for the future management of those parts of the Darling Harbour catchment which are flood liable.

EXECUTIVE SUMMARY

The recommended Floodplain Risk Management Plan for the Darling Harbour catchment has been prepared in accordance with the NSW Floodplain Development Manual (Reference 1) and:

- Is based on a comprehensive and detailed evaluation of all factors that affect and are affected by the use of flood prone land; and
- Provides a long-term path for the future development of the floodplain.

The Darling Harbour catchment is located in Sydney's inner city suburbs of Haymarket, Surry Hills and parts of Pyrmont, Ultimo and Sydney, in the City of Sydney Local Government Area (LGA). The 307 hectare catchment is fully urbanised, with runoff in the catchment draining to Darling Harbour via the area's pit and pipe stormwater system. There are significant overland flowpaths in the catchment, which are active when the capacity of the pit and pipe network is exceeded. Flood liability exists across the area, including several locations where overland flow is trapped by unrelieved depressions in the catchment topography.

The Darling Harbour Catchment Floodplain Risk Management Study (Reference 2) undertook a detailed assessment of flood risk in the catchment. The assessment included a description of flood hazard in the catchment, as well as an estimate of the economic impact of flooding. The study gave a description of the flood emergency response arrangements in the area, as well as a review of the flood planning level and flood planning area.

The floodplain risk management study also included an investigation of possible options for the management of flood risk in the area. These included structural works, such as drainage upgrades and overland flowpaths, as well as planning measures and SES-related actions. The measures were assessed for their ability to reduce flood risk while also considering their economic, social and environmental impact. A multi-criteria matrix assessment was used to directly compare the options. Of the options investigated, 13 were recommended for implementation, with a priority and time frame assigned to each.

The Study and Plan were publicly exhibited from the 8th of March to the 11th of April 2016. Several submissions were received from community groups and individuals and have been summarised in the Study.

1. FINDINGS OF FLOODPLAIN RISK MANAGEMENT STUDY

1.1. Background

The Darling Harbour catchment is located in Sydney's inner city suburbs of Haymarket, Surry Hills and parts of Pyrmont, Ultimo and Sydney (refer Figure 1). This region lies within the City of Sydney Local Government Area (LGA) and has been fully developed for urban and commercial usage which provides little opportunity for water to infiltrate due to the high degree of impervious surfaces. Land use is predominantly high-density housing and commercial development, with some areas of open space including parts of Hyde Park. The catchment also includes the large development sites of the Sydney Entertainment Centre, Sydney Exhibition Centre and University of Technology, Sydney.

The catchment covers an area of approximately 307 hectares which drains into Sydney Harbour at various locations, with the main drainage outlets at Darling Harbour. The drainage network includes open channels, covered channels, in-ground pipes, culverts and pits. The majority of the trunk drainage is owned by Sydney Water Company and City of Sydney.

A number of locations within the catchment are flood liable, and flooding is known to occur in some areas for all rainfall events greater than the 0.5 EY. 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 where sub-surface systems are running at capacity. This creates a significant drainage/flooding problem in many areas throughout the catchment, with roads and pedestrian areas forming major flow paths, with associated high velocities and flood depths.

The Darling Harbour Catchment Flood Study (2014) was carried out to define existing flood behaviour for the catchment in terms of flood levels, depth, velocities, flows, hydraulic categories and provisional hazard. The 1% AEP peak flood depth is shown on Figure 2, while Figure 3 shows the Probable Maximum Flood (PMF). As can be seen on Figure 2, there is significant overland flow in large flood events, with over 1.0 m of water in several areas, including the unrelieved depressions in Commonwealth Street, Pyrmont Street, Hay Street and parts of Darling Harbour. Figure 4 and Figure 5 show the hazard categories for the 1% AEP and PMF events respectively. Areas of high hazard in the catchment generally correspond to the major overland flowpaths, with the majority of high hazard along the central flowpath in the catchment.

1.2. Flood Hazard Classification

Classification of flood hazard in the catchment was based on a combination of the provisional flood hazard categories and a range of other factors that are not captured by the provisional categories. These factors include, but are not limited to: rate of rise of floodwater, duration of flooding, community awareness and effective warning time. A qualitative assessment of these

factors was undertaken, the results of which are summarised in Table 1. The provisional hazard categories complement this assessment, as they delineate areas of the floodplain where the depth or velocity of floodwaters is considered hazardous.

Table 1: 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 | High | 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 | High | 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 | Medium | 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 Darling Harbour catchment

Detailed description of the flood hazard classification is given in Section 3 of the Darling Harbour Catchment Floodplain Risk Management Study.

1.3. Economic Impact of Flooding

The economic impact of flooding in Darling Harbour catchment was assessed as part of the floodplain risk management study. Damages were calculated for residential and commercial/industrial properties, based on a floor level survey of properties inundated in the 1% AEP event. The flood damages estimate does not include the cost of restoring or maintaining public services and infrastructure. It should be noted that damages calculations have only a very approximate damages estimate to any basements or cellars.

The damages assessment found that 193 properties within the catchment are liable to over floor inundation in the 100 year ARI event, while 86 properties are liable in the 5 year ARI event. The assessment estimated the average annual damage to be approximately \$3.7 million for the catchment. Table 2 gives the estimated tangible damages for the catchment (both residential and commercial/industrial properties).

Table 2: Estimated Combined Flood Damages for Darling Harbour Catchment

| Event (ARI) | Number of Properties Flood Affected | No. of Properties Flooded Above Floor Level | Total Tangible Flood Damages | Average Tangible Damages Per Flood Affected Property |
|-------------------------------------|-------------------------------------|---|------------------------------|--|
| 2 | 74 | 56 | \$ 3,739,000 | \$ 50,500 |
| 5 | 118 | 86 | \$ 5,211,800 | \$ 44,200 |
| 10 | 174 | 123 | \$ 11,732,400 | \$ 67,400 |
| 20 | 224 | 155 | \$ 15,014,800 | \$ 67,000 |
| 50 | 246 | 173 | \$ 17,893,900 | \$ 72,700 |
| 100 | 274 | 193 | \$ 21,443,100 | \$ 78,300 |
| 500 | 332 | 235 | \$ 29,940,600 | \$ 90,200 |
| PMF | 437 | 299 | \$ 73,470,600 | \$ 168,100 |
| Average Annual Damages (AAD) | | | \$ 3,723,800 | \$ 8,500 |

Detailed description and results of the damages assessment is given in Section 5 of the Darling Harbour Catchment Floodplain Risk Management Study.

2. RECOMMENDED MANAGEMENT MEASURES

The Darling Harbour Catchment Floodplain Risk Management Study made a full assessment of the existing flood risk in the catchment. Based on this assessment of flood risk, the study investigated a range of management measures for the area, which can be categorised as Response Modification Measures, Property Modification Measures and Flood Modification measures, as per the NSW Floodplain Development Manual (Reference 1). Measures were assessed for their efficacy across a range of criteria, which allowed them to be compared against one another and their overall effectiveness ranked. Measures which improved the management of flood risk in the catchment were selected and form the primary content of this Plan.

The measures have been categorised by their type (Response, Flood or Property) and given a priority ranking. The ranking is based upon a combination of reduction in flood risk, ease of implementation, cost/funding implications and outcomes based on the multi-criteria matrix assessment (refer Section 9.6 of the Study). More information on each measure is available in the Floodplain Risk Management Study, including discussion of its implementation and its effect on the existing flood behaviour.

2.1. Timeframe for Implementation

Floodplain management measures recommended by this Plan have been assigned a timeframe for implementation, in order to form short term and long term strategies for the area's floodplain management. Use of different timeframes ensures that priority is given to those measures which can be undertaken in the near future, while also retaining less feasible options for long term implementation.

Short term measures are those that are able to be implemented in the next 1-10 years, and are comprised of response modification and property modification measures, while long term measures are those that have greater constraints (usually financial or logistical) and are therefore planned to be implemented in the next 20-50 years. As discussed in the floodplain risk management study, the structural options for the Darling Harbour catchment have numerous technical constraints and mostly do not have favourable benefit-cost ratios. For this reason, the options should be undertaken in conjunction with other infrastructure works (for example, road upgrades) that mitigate their constraints.

The following section includes both a priority and a designated timeframe for each recommended management measure. Short term measures are shown on Figure 6, while Figure 7 shows the long term measures.

2.2. Flood Modification Measures

The following sections detail the flood modification measures recommended for implementation in the catchment. Figure 7 shows the location of the measures in the catchment.

2.2.1. Drainage Upgrade – Commonwealth Street (FM – DH01)

Option FM – DH01 describes a pit and pipe upgrade at Commonwealth Street and Elizabeth Street in order to address property flooding at Commonwealth Street. The measure, which involves additional pit and feeder pipe capacity at Commonwealth Street and an additional pipe at Elizabeth Street, has been shown to reduce the flood level on Commonwealth Street to below 0.1 m in a 5% AEP event, which corresponds to reduced flooding for around 13 properties.

Although the measure produces a range of benefits to the area's flood risk, it is prohibitively expensive and involves very large capacity pipes that may not be technically feasible, due to the high density development that already exists in the area. The benefit-cost ratio of the option is 0.6.

The measure has been given a medium priority in the Floodplain Risk Management Plan, based on its financial feasibility, benefit cost ratio and associated technical issues. The measure is recommended to be implemented by City of Sydney in the long term.

2.2.2. Drainage Upgrade – Elizabeth Street (FM – DH02)

Option FM-DH02 involves a large-scale drainage upgrade for Elizabeth Street aimed at alleviating the road flooding at the location. The measure, which involves large-scale pipe upgrades at Elizabeth Street and also downstream at Quay Street, has been shown to reduce flooding on Elizabeth Street to below 0.1 m in the 10% AEP event. As with FM – DH01, the measure involves large-scale stormwater drainage that is prohibitively expensive and faces significant technical challenges to incorporate into the existing urban environment.

The measure has been given a low priority in the Floodplain Risk Management Plan, based on its financial feasibility, improved road flooding and associated technical issues. The measure is recommended to be implemented by City of Sydney in the long term.

2.2.3. Drainage Upgrade – Elizabeth Street to Outlet (FM – DH05)

Option FM – DH05 consists of a large-scale stormwater drain from Elizabeth Street to Darling Harbour and is aimed at mitigating the flood affectation at Elizabeth Street, along Hay Street and in the Darling Harbour area. The new drainage line, which consists of a 1.8 m diameter pipe with all inlet pits at Elizabeth Street, was shown to reduce flooding at Elizabeth Street and Hay Street upstream of George Street, while having less impact downstream of George Street and in Darling Harbour. This corresponds to improved road serviceability and some reduction in property flooding. The main constraints of the measure are incorporating its design into the high density of services which already exists along Hay Street. The benefit-cost ratio of the measure is 0.1.

The measure has been given a low priority in the Floodplain Risk Management Plan, based on its financial feasibility, benefit cost ratio and associated technical issues. The measure is

recommended to be implemented by City of Sydney in the long term.

2.2.4. Drainage Upgrade – Pyrmont Street to Outlet (FM – DH06)

Option FM – DH06 describes a pit and pipe upgrade on Pyrmont Street and Jones Bay Road aimed at alleviating inundation on Pyrmont Street. The upgrade consists of additional feeder pits at the low point on Pyrmont Street and upgrades to the trunk system downstream on Jones Bay Road. The additional drainage removes the ponding on Pyrmont Street in a 10% AEP event, improving the road's serviceability. There is minimal change to property affectation. As with other drainage upgrades, the required drainage is very large and incorporating the design into the existing services would be a large constraint.

The measure has been given a low priority in the Floodplain Risk Management Plan, based on its reduction in hazard and technical issues. The measure is recommended to be implemented by City of Sydney in the long term.

2.2.5. Drainage Upgrade – Black Wattle Place (FM – DH07)

Option FM – DH07 consists of a drainage upgrade on Black Wattle Place and Harbour Street with the goal of reducing flooding around the substation at the location. The upgrade, which consists of additional pit capacity and two 0.6 m diameter pipes crossing to the existing trunk drainage, which discharges to Darling Harbour, removes the ponding around the building in a 5% AEP event. There is also benefit to Harbour Street's serviceability. The drainage upgrade is small relative to other options tested, but will likely still face significant construction constraints. Furthermore, it is not known whether the reduced affectation will result in change in above floor flooding to the substation, as its internal features are not known.

The measure has been given a low priority in the Floodplain Risk Management Plan, based on its reduction in property affectation and technical issues. The measure is recommended to be implemented by City of Sydney in the long term.

2.2.6. Data Collection – Catchment Specific Flood Damages Assessment (FM – DH08)

Option FM-DH08 consists of a specialised flood damages assessment of property in the Sydney CBD. The damages assessment involves estimating damage costs for different building types in the area and reassessing the damage cost/benefit assessments for all flood modification measures. It will allow much greater confidence in the economic damages assessment which will in turn improve the economic assessment of flood modification measures.

The measure has been given a high priority in the Floodplain Risk Management Plan, based on its benefit to assessing other mitigation measures. The measure is recommended to be implemented by City of Sydney in the short term.

2.3. Response Modification Measures

2.3.1. Flood Warning and Evacuation (RM – DH01)

Very limited flood warning is possible in the catchment; however, there is an opportunity to issue warnings through social media and other methods. The nature of the catchment means that flood-producing rainfall is difficult to forecast, and there is negligible time between the rainfall occurring and the flood peak being reached. This prevents the implementation of conventional flood warning systems where a flood height is predicted and an evacuation order or other measures can be undertaken. Given this constraint, it is recommended that warnings be issued as the flood is occurring, through the EMPLAN process. There may also be opportunity to issue warnings as SMS alerts or through online social media and existing electronic signage.

The measure has been given a high priority in the Floodplain Risk Management Plan, based on its positive effect on SES operations, and its financial feasibility. The measure is recommended to be implemented by all relevant authorities in the short term.

2.3.2. Flood Emergency Management (RM – DH02)

Emergency response arrangements during a flood can be formalised in a Local Emergency Management Plan (LEMPAN) and Consequent Management Guide (Flood) for the area, including the recommended evacuation arrangements. A LEMPLAN should be developed by the Local Emergency Management Committee to identify evacuation centres for the area, use of Variable Message Signs during a flood, and description of the flood behaviour, including vulnerable buildings, facilities and roads. It is recommended that wherever possible, evacuation in the catchment should involve moving from a ground or below ground floor to a higher floor in the building, given that virtually all buildings have higher floors, there is no risk of structural failure, and most flooding is short-lived (less than one hour).

The measure has been given a medium priority in the Floodplain Risk Management Plan, based on its positive effect on SES operations. The LEMPLAN should be developed by the Local Emergency Management Committee, likely as part of other emergency response arrangements.

2.3.3. Public Information and Raising Flood Awareness (RM – DH03)

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.

The measure has been given a medium priority in the Floodplain Risk Management Plan, based on its positive effect on SES operations and risk to life. The measure is recommended to be implemented by City of Sydney in the short term.

2.4. Property Modification Measures

2.4.1. Flood Planning Levels (PM – DH01)

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.

The measure has been given a high priority in the Floodplain Risk Management Plan, based on its positive effect on long term floodplain risk management in the catchment, and its economic merits. A review of the FPLs put forward by Council in their *Interim Floodplain Management Policy* (Reference 4) was carried out as part of the Floodplain Risk Management Study and it was recommended that case studies be provided to illustrate how these levels could be applied to individual developments to assist in development applications.

2.4.2. Development Control Planning (PM – DH02)

Within the Darling Harbour 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.

The measure has been given a high priority in the Floodplain Risk Management Plan, based on its positive effect on long term floodplain risk management in the catchment, and its community acceptance and financial feasibility. Recommendation for an update of the planning documents (i.e. Sydney DCP 2012 and Sydney LEP 2012) has been discussed in the Floodplain Risk Management Study in order to inform of the development controls as published in the Interim Floodplain Management Policy (Reference 4). Inclusion of these provisions would ensure that the controls can be enforced which also take into consideration the potential impact of climate change. The update is recommended to be implemented within City of Sydney in the short term.

2.4.3. Flood Proofing (PM – DH03)

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.

The measure has been given medium priority in the Floodplain Risk Management Plan, based on the number of properties it can benefit and its economic merits. The measure is recommended to be implemented by local business owners/ home owners in the short term.

2.4.4. Property Modification – Feasibility Study for City of Sydney Flood Proofing (PM – DH04)

Flood proofing for residential properties in the catchment may be undertaken by City of Sydney when the property is put up for sale. As described in the previous measure, flood proofing can be a cost effective means of preventing over-floor inundation of a property. For residential properties, this may be done via City of Sydney purchasing the property and re-selling it after modifications have been made. Further assessment should be undertaken to ascertain the depth of ponding that flood proofing can protect against, what types of properties can be flood-proofed, the variation in cost for different cases, where responsibility lies for carrying out and funding the works, and any associated risks with the approach.

The measure has been given medium priority in the Floodplain Risk Management Plan, based on the number of properties it can benefit and its economic merits. Investigation is recommended to be undertaken by City of Sydney in the short term.

2.5. Recommended Management Measures – Table

The recommended measures described in the previous sections are summarised in Table 3 in order of priority. The table provides a reference point for the Plan's recommendations, and represents one of the main outcomes of the floodplain risk management process for the Darling Harbour catchment.

Through the flood mitigation option development process, at some locations more than one option has been tested for the mitigation of flood risk. These will tend to have some variance in

their impact, so for example Elizabeth Street flooding is reduced by both FM – DH02 and FM-DH05, with the latter having larger benefit along Hay Street. Nevertheless, in most cases it may be that one of these options is preferred for implementation rather than both.

However, given the scale of these works and the fact that their feasibility and eventual cost will be significantly impacted by existing services, further analysis is required prior to a decisive selection being made. This analysis should focus specifically on feasibility of construction and if feasible, cost estimates should then be estimated by a quantity surveyor. It is recommended that the further feasibility analysis is carried out when appropriate capital is available for the works.

DRAFT

Table 3: Recommended Management Measures

| REF ¹ | MEASURE | PURPOSE | PRIORITY | RESPONSIBILITY | TIME FRAME | COST |
|------------------|---|--|-----------------|---|------------|---|
| PM-DH02 | Update Sydney DCP 2012 and LEP 2012 based on FRMS&P outcomes and to inform of Council's Interim Floodplain Management Policy. (Section 9.4.2) | Prevent development occurring in high hazard areas or impacting existing flood behaviour | High Priority | City of Sydney | Short term | Internally within Council |
| PM-DH01 | Review FPLs following completion of FRMS&P for Darling Harbour catchment. (Section 9.4.1) | Reduce the damages of flood affected properties by having elevated floor level | High Priority | City of Sydney | Short term | Internally within Council |
| RM-DH01 | Review flood warnings on Council website or social media. Investigate feasibility of flood warning systems. (Section 9.4.5) | Improve public awareness during a flood event, reduce number of vehicles entering hazardous ponding. | High Priority | City of Sydney and RMS | Short term | Internally within Council and RMS |
| FM-DH08 | Carry out a catchment specific flood damages assessment for the Sydney CBD and remainder of Darling Harbour catchment (Section 9.3.8) | Allow for an improved cost-benefit analysis of the flood modification options. | High Priority | City of Sydney | Short term | Internally within Council |
| RM-DH03 | Develop ongoing flood awareness and public information programmes for the area. (Section 9.4.7) | Increase community's awareness during and after a flood event to reduce damages and risk to life | Medium Priority | City of Sydney | Short term | Internally within Council |
| RM-DH02 | REMPAN + LEMPLAN (Section 9.4.5) | Minimise the risk associated with evacuations, determine when evacuation is required | Medium Priority | Regional and Local Emergency Management Committee | Short term | Internally within Council |
| PM-DH03 | Initiate flood proofing for frequently flood affected properties. (Section 9.4.3) | Reduce the damages of flood affected properties by preventing ingress of floodwaters. | Medium Priority | Property owners | Short term | Internally within Council |
| PM-DH04 | Investigate the feasibility of a voluntary purchase scheme that includes flood proofing affected properties. (Section 9.4.4) | Reduce the damages of flood affected properties via flood proofing. | Medium Priority | City of Sydney | Short term | Internally within Council |
| FM-DH01 | Drainage Upgrade – Commonwealth Street. (Section 9.3.1) ² | Reduce the damages of flood affected properties | Medium Priority | City of Sydney and Sydney Water Corporation | Long Term | Approx. \$1,200,000 capital, \$12,540 ongoing (annual) |
| FM-DH05 | Drainage Upgrade – Elizabeth Street to Outlet. (Section 9.3.5) ² | Reduce hazardous overland flowpath, reduce the damages of flood affected | Low Priority | City of Sydney and Sydney Water Corporation | Long Term | Approx. \$10,454,900 capital, \$12,810 ongoing (annual) |

| | | | | | | |
|----------------|---|---|--------------|---|-----------|---|
| | | properties, improve FPL requirements | | | | |
| FM-DH07 | Drainage Upgrade – Black Wattle Place. (Section 9.3.7)² | Reduce the damages of flood affected properties | Low Priority | City of Sydney | Long Term | Approx. \$894,500 capital, \$1,730 ongoing (annual) |
| FM-DH06 | Drainage Upgrade – Pyrmont Street to Outlet. (Section 9.3.2)² | Reduce hazardous ponding | Low Priority | City of Sydney and Sydney Water Corporation | Long Term | Approx. \$3,897,500 capital, \$4,860 ongoing (annual) |
| FM-DH02 | Drainage Upgrade – Elizabeth Street. (Section 9.3.2) | Reduce hazardous road flooding | Low Priority | City of Sydney and Sydney Water Corporation | Long Term | Approx. \$8,096,900 capital, \$4,920 ongoing (annual) |

¹Reference of measure in the Darling Harbour Catchment Floodplain Risk Management Study

²Further investigation is required should this be implemented

DRAFT

3. 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 and business operators of the Darling Harbour catchment. This study was jointly funded by the City of Sydney Council and the NSW Government. The cover page image is used courtesy of Wikimedia Commons user Adam.J.W.C.

DRAFT

4. REFERENCES

1. NSW Government (2005) Floodplain Development Manual – the Management of Flood Liable Land, Department of Infrastructure, Planning and Natural Resources
2. WMAwater (2015), Darling Harbour Catchment Floodplain Risk Management Study
3. BMT-WBM (2014), Darling Harbour Catchment Flood Study
4. City of Sydney (2014), Interim Floodplain Management Policy

DRAFT



Figures

FIGURE 1
STUDY AREA
DARLING HARBOUR CATCHMENT

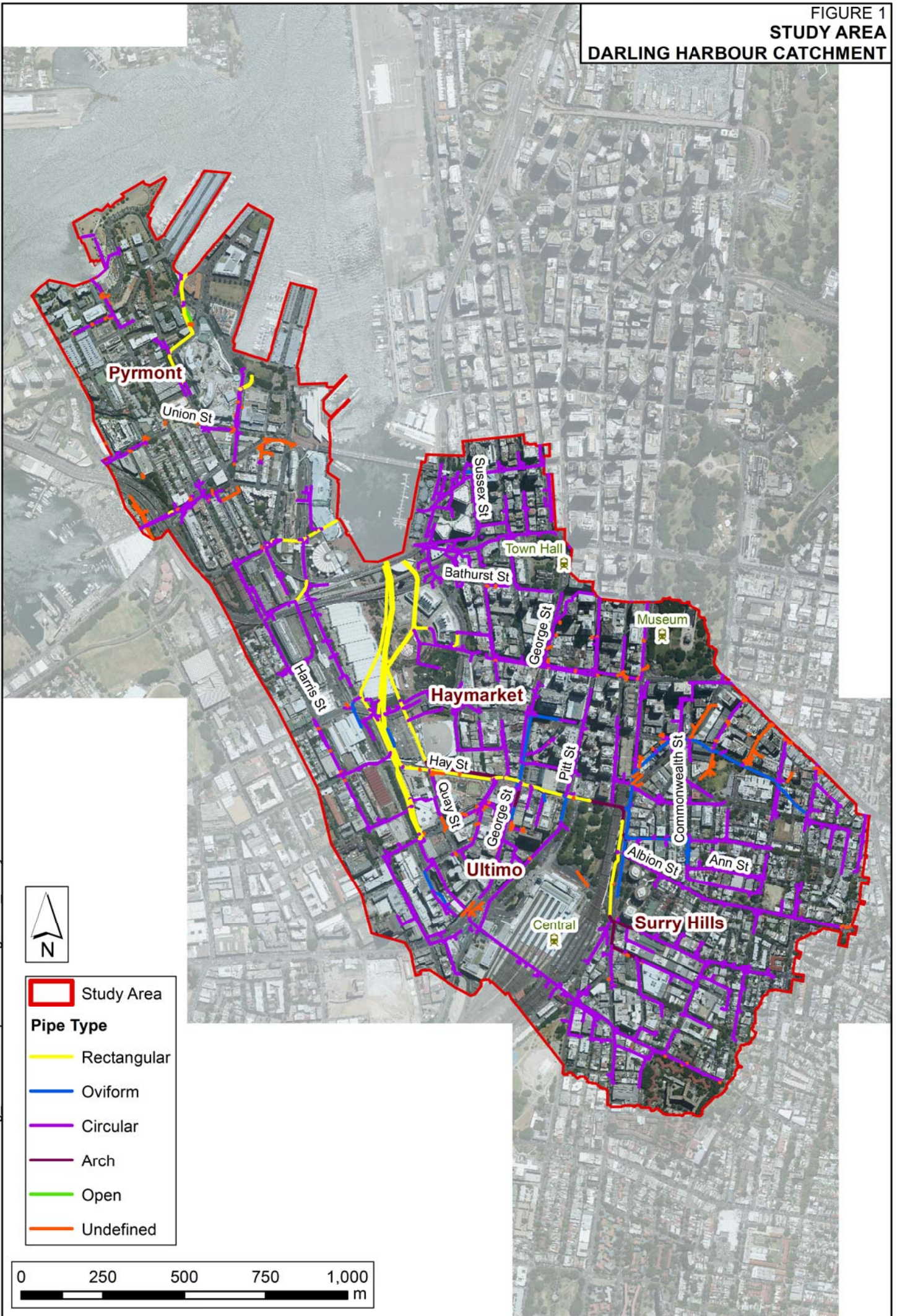
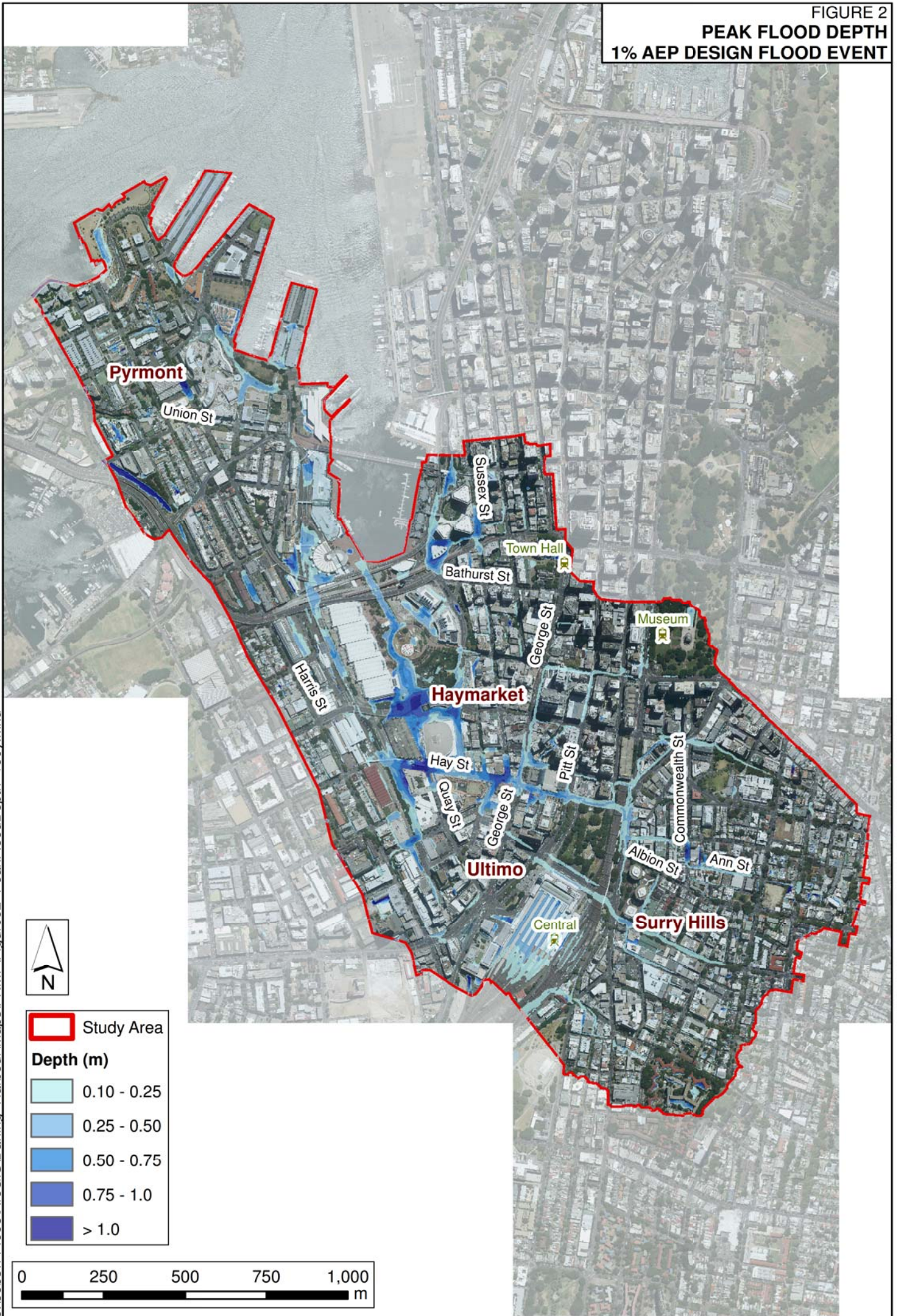








FIGURE 2
PEAK FLOOD DEPTH
1% AEP DESIGN FLOOD EVENT



J:\Jobs\114095\ArcGIS\Darling_Harbour\Maps\FRMP\Figure02_PeakFloodDepth_100y.mxd



| | |
|---|-------------|
|  | Study Area |
| Depth (m) | |
|  | 0.10 - 0.25 |
|  | 0.25 - 0.50 |
|  | 0.50 - 0.75 |
|  | 0.75 - 1.0 |
|  | > 1.0 |

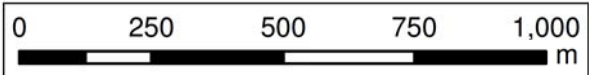


FIGURE 3
PEAK FLOOD DEPTH
PMF DESIGN FLOOD EVENT

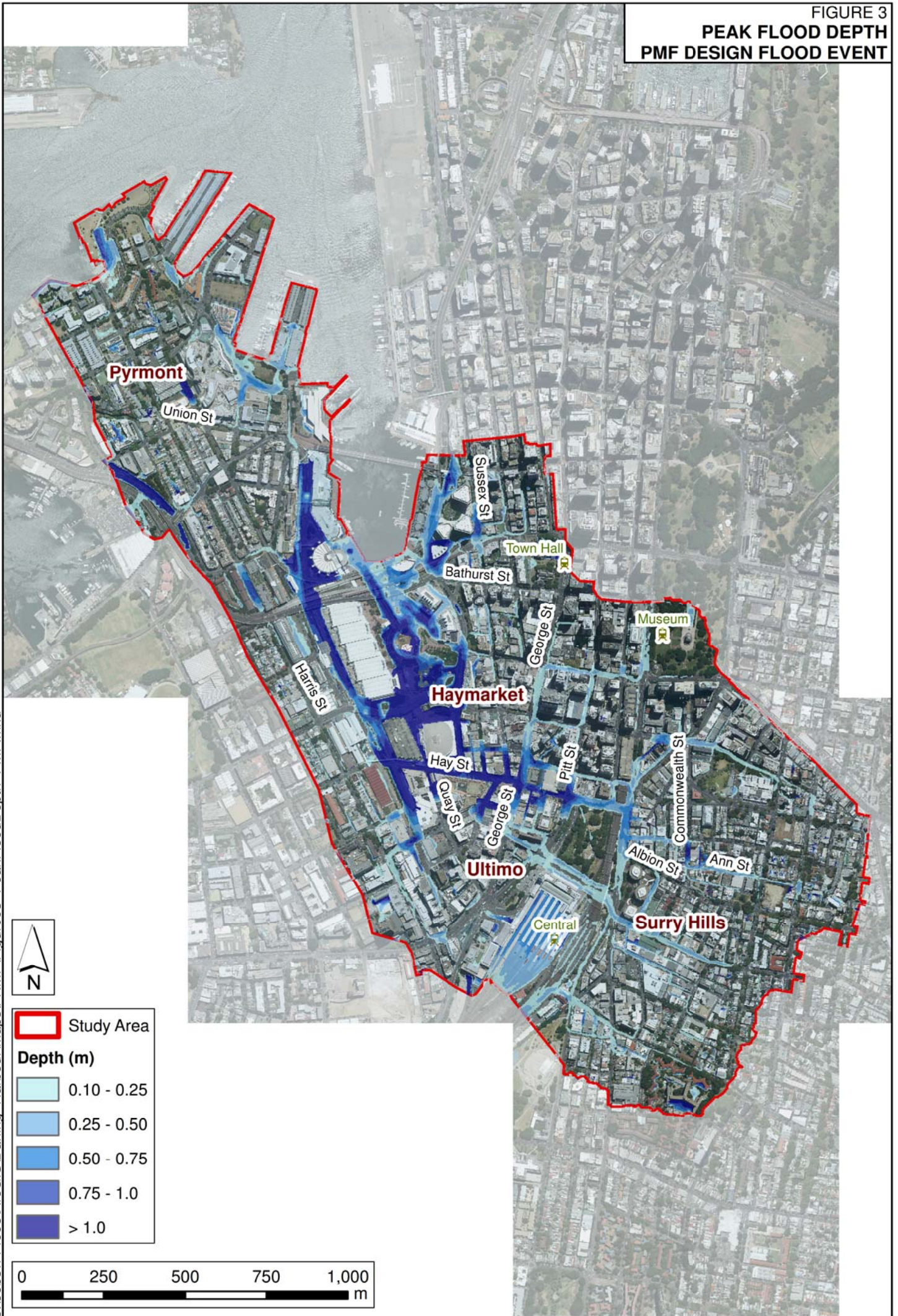


FIGURE 4
HAZARD CATEGORIES
1% AEP DESIGN FLOOD EVENT

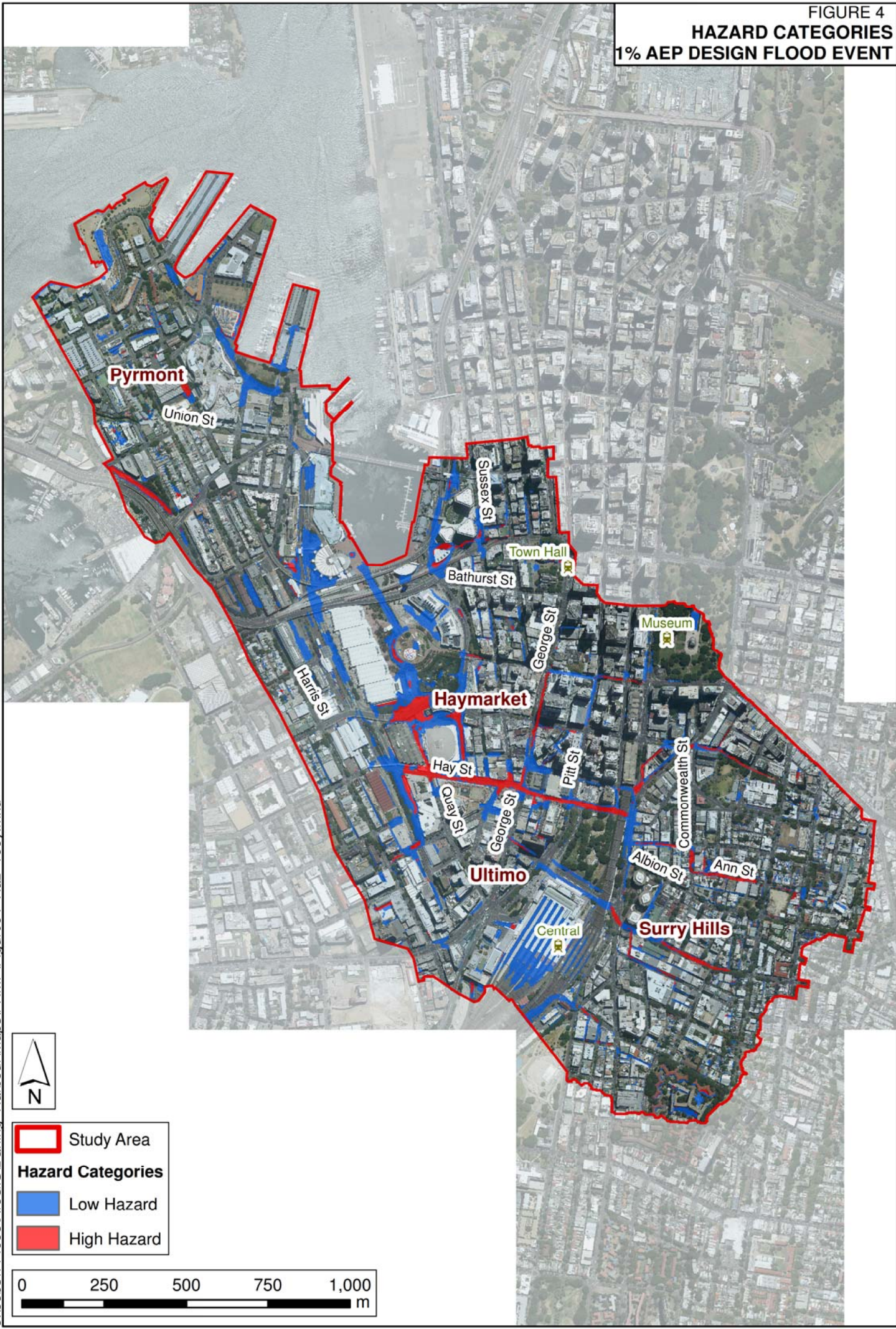


FIGURE 5
HAZARD CATEGORIES
PMF DESIGN FLOOD EVENT

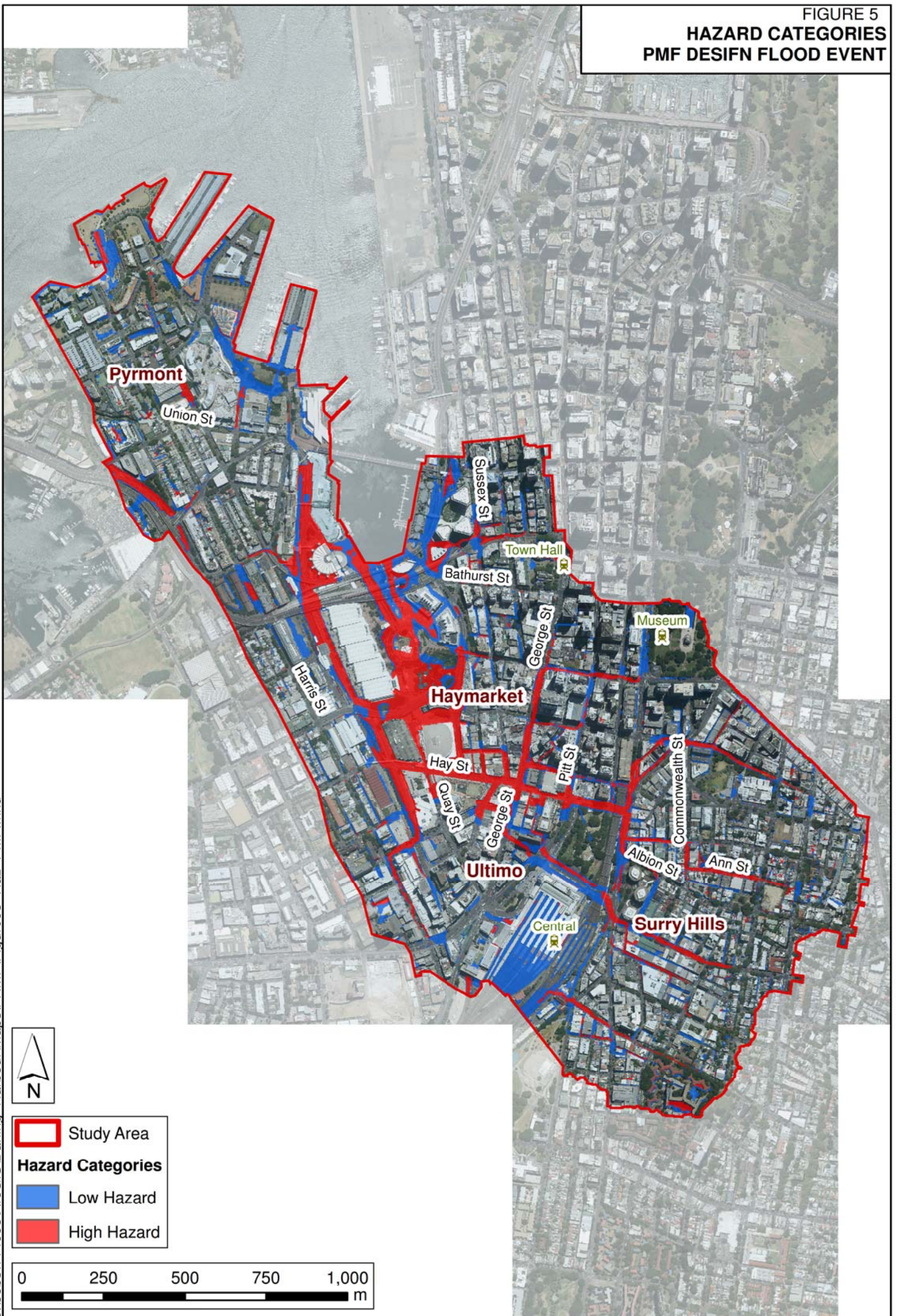
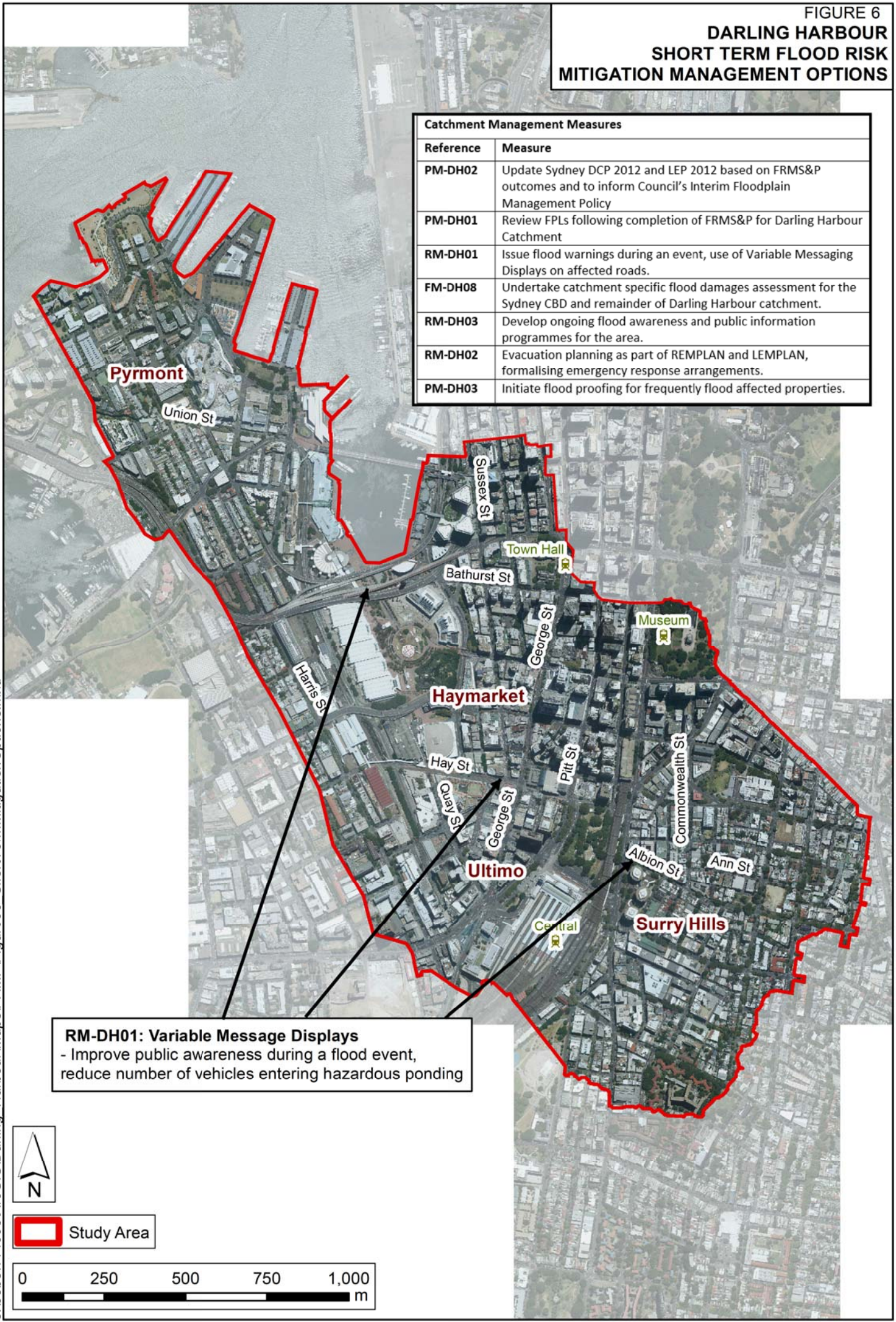


FIGURE 6
**DARLING HARBOUR
 SHORT TERM FLOOD RISK
 MITIGATION MANAGEMENT OPTIONS**

| Catchment Management Measures | |
|-------------------------------|---|
| Reference | Measure |
| PM-DH02 | Update Sydney DCP 2012 and LEP 2012 based on FRMS&P outcomes and to inform Council's Interim Floodplain Management Policy |
| PM-DH01 | Review FPLs following completion of FRMS&P for Darling Harbour Catchment |
| RM-DH01 | Issue flood warnings during an event, use of Variable Messaging Displays on affected roads. |
| FM-DH08 | Undertake catchment specific flood damages assessment for the Sydney CBD and remainder of Darling Harbour catchment. |
| RM-DH03 | Develop ongoing flood awareness and public information programmes for the area. |
| RM-DH02 | Evacuation planning as part of REMPLAN and LEMPLAN, formalising emergency response arrangements. |
| PM-DH03 | Initiate flood proofing for frequently flood affected properties. |



RM-DH01: Variable Message Displays
 - Improve public awareness during a flood event,
 reduce number of vehicles entering hazardous ponding



 Study Area

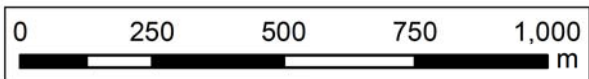
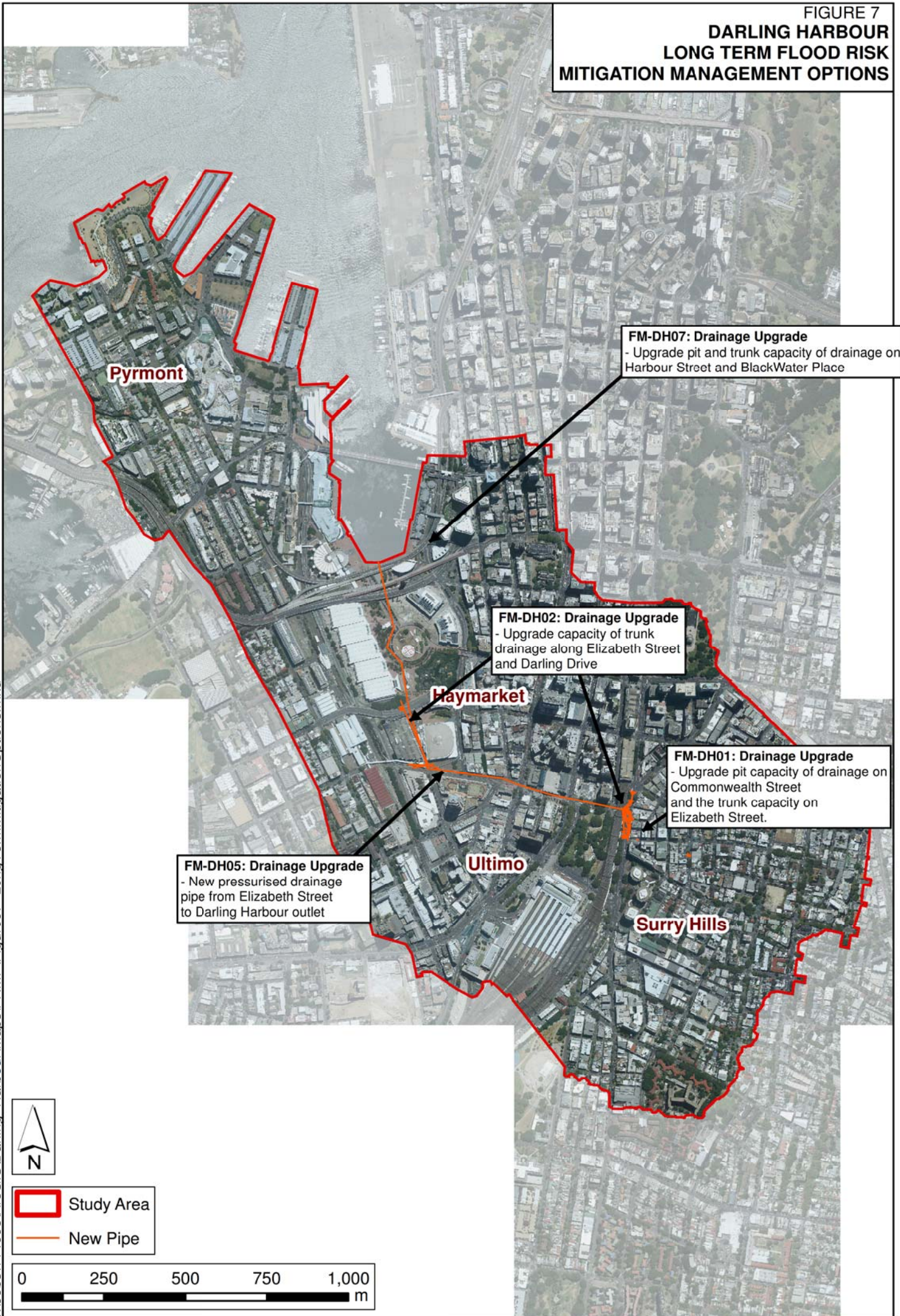


FIGURE 7
**DARLING HARBOUR
LONG TERM FLOOD RISK
MITIGATION MANAGEMENT OPTIONS**



-  Study Area
-  New Pipe

