ATTACHMENT I

CENTENNIAL PARK CATCHMENT FLOODPLAIN RISK MANAGEMENT STUDY (DRAFT REPORT)

CITY OF SYDNEY

CENTENNIAL PARK FLOODPLAIN RISK MANAGEMENT STUDY

DRAFT REPORT

wma water

APRIL 2015

Level 2, 160 Clarence Street
Sydney, NSW, 2000

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

CENTENNIAL PARK CATCHMENT FLOODPLAIN RISK MANAGEMENT STUDY

DRAFT REPORT

MAY 2015

Project Centennial Park Catchment Floodplain Risk Management Study	**Project Number** 114014
Client City of Sydney	**Client's Representative** Shah Alam
Authors Felix Taaffe Isabelle Testoni Steve Gray	**Prepared by** TO BE SIGNED FOR FINAL REPORT
Date 14 May 2015	**Verified by** TO BE SIGNED FOR FINAL REPORT

Revision	Description	Date
4	Draft Report - Revised	Apr 15
3	Draft Report	Feb 15
2	Stage 2 Report	Nov 14
1	Stage 1 Report	Jun 14

CENTENNIAL PARK CATCHMENT FLOODPLAIN RISK MANAGEMENT STUDY

TABLE OF CONTENTS

LIST OF APPENDICES

LIST OF TABLES

LIST OF FIGURES

FOREWORD

The NSW State Government's Flood 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 Policy, the management of flood liable land remains the responsibility of local government. The State Government subsidises flood mitigation works to alleviate existing problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities.

The Policy provides for technical and financial support by the Government through four sequential stages:

1. Flood Study

- Determine the nature and extent of the flood problem.

2. Floodplain Risk Management

- 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 Draft Centennial Park Catchment Floodplain Risk Management Study and Draft Plan constitute the second and third stages of this management process. This study has been prepared by WMAwater for 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 Centennial Park catchment which are flood liable and within the City of Sydney Local Government Area.

1. INTRODUCTION

1.1. Study Area

The Centennial Park catchment is located in Sydney's inner city suburbs of Paddington, Moore Park and Centennial Park and is shown on Figure 1. The catchment lies within the City of Sydney Local Government Area (LGA) and has been extensively developed for urban usage. It covers an area of approximately 150 hectares and drains to Sydney Water Corporation's (SWC) major trunk drainage systems. When the pipe drainage is at capacity, water flows overland along streets and other open space. A number of locations in the area are flood liable, mainly as a result of the area's topography, which includes several unrelieved depressions, both in residential areas and around Moore Park. This creates a significant drainage/flooding problem in many areas in the catchment. Detailed description of the study area is given in Section 2.1.

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;
- Draft Floodplain Risk Management Plan; and
- Plan Implementation.

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

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

- Review the current Draft Centennial Park Catchment Flood Study (2013) and update the hydraulic model to accommodate recent changes in the catchment;
- Acquire any additional floor level survey required;
- Review Council's existing environmental planning policies and instruments, identify modifications required to current policies;
- Identify residential flood planning levels;
- Identify and assess works, measures and controls 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).
- Investigate flood mitigation options for flood affected streets and areas as identified in the revised Flood Study.

Phase II – Draft 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 flood hazard now and in the future. The Plan consists of prioritised and costed measures for implementation.

1.3. Relevant Studies

Limited studies have been undertaken regarding flooding and stormwater in the Centennial Park catchment. Two flood studies have been undertaken for the catchment, the first covering the part of the catchment in the Randwick LGA and a second study covering the part in the City of Sydney LGA. Both are summarised in the following section.

1.3.1. Kensington – Centennial Park Flood Study, WMAwater, April 2013

The study (Reference 3) defined existing flood behaviour for design flood events up to the Probably Maximum (PMF) for the Centennial Park catchment within Randwick City Council's LGA. The study modelled the catchment hydrology using two models, MIKE-STORM and DRAINS and assessed hydraulic behaviour using a 1D/2D TUFLOW model. Two flood events in November 1984 were used as calibration and validation events for the models.

The study characterised the catchment as having a number of trapped low points, where the existing drainage was not sufficient to convey flows away from the depression. These include sections of Aboud Avenue, Cottenham Avenue, Barker Street, Market Street, Clovelly Road and Wentworth Street.

1.3.2. Centennial Park Catchment Draft Flood Study

The draft Flood Study report (Reference 2) which preceded the current study in the floodplain risk management process being undertaken for the area, defined existing flood behaviour for the Centennial Park catchment within City of Sydney's LGA. Flood behaviour was described as flood levels, depths, velocities, flows and extents for a range of design events up to the PMF. A 1D/2D TUFLOW hydraulic model was used in conjunction with a DRAINS hydrologic model. Insufficient data was available for a full model calibration and so only verification was carried out, which entailed comparing model results to anecdotal reports of flooding to several historical events and to various descriptions of flooding behaviour in the catchment. The study defined flood behaviour for the 2, 5, 10, 20, 50 and 100 year ARI as well as the PMF. Preliminary hydraulic hazard was determined for the 10, 20 and 100 year ARI flood events and the PMF,

while hydraulic categories were determined for the 100 year ARI event. Hotspots were not identified by the study, but some description is given to trapped low points in the area. A floor level survey and damages assessment were carried out, of which the latter identified 29 properties that would be flooded above floor level in a 100 year ARI event.

The study found that the urbanisation of the catchment, particularly in the past 100 years, significantly altered the drainage characteristics of the catchment. For example, development on Leinster Street, Stewart Street, at Fox Studios and on Lang Road all block or impede natural flow paths, causing ponding that cannot be effectively drained by the subsurface drainage network. Similarly, low points on Driver Avenue and Lang Road are not efficiently drained by overland flowpaths and tend to store water in flood events.

The study identified a number of trapped low points in the catchment. This was taken into consideration along with properties' inundation and five hotspots were examined. The hotspots are shown on Figure 2 and were as follows:

1. Poate Road
2. Stewart Street and Leinster Street
3. Driver Avenue
4. Lang Road near Driver Avenue
5. Lang Road near Darvall Street

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. Generally speaking, each incremental 10% increase in flow results in a 0.02 m to 0.05 m increase in peak flood levels at most of the locations analysed. A 30% increase in rainfalls would therefore not exceed the typical freeboard for most residential properties. Sea level rise was not relevant as none of the study area is tidal.

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.

1.3.3. Centennial Park Flood Study Review and Update

The draft Centennial Park Flood Study (Reference 2) was reviewed as part of this Management Study, to incorporate any recent changes to the catchment which had occurred. Three minor updates were made. Firstly, at the hotspot along Lang Road near Darvall Street pits were upgraded and a pipe was added, in line with a recent drainage upgrade in the area. This resulted in a reduction of 0.05 m in the 1% AEP event in the immediate vicinity of the upgrade.

Secondly, the inverts of several nodes along the trunk drainage line were re-estimated using

updated interpolation techniques (no invert data was available). The amendment caused a reduction of 0.1 m in the 1% AEP event flood depth at Driver Avenue and some small increases and decreases within Moore Park.

Finally, two small changes to building outlines were made. These were updated when the flow paths between buildings were examined in more detail. The impacts of flood levels around the change were minimal.

2. CATCHMENT CHARACTERISTICS

2.1. Study Area

The Centennial Park catchment is located in Sydney's inner city suburbs of Paddington, Moore Park and Centennial Park. The catchment lies within the City of Sydney Local Government Area (LGA) and has been extensively developed for urban usage. Land use is predominantly medium to high-density housing as well as commercial and industrial developments, with some large open recreational spaces and facilities that include Moore Park, Sydney Cricket Ground, Sydney Football Stadium, Fox Studios and Heritage Park.

The catchment covers an area of approximately 150 hectares draining to Sydney Water Corporation's (SWC) major trunk drainage systems (known as SWC 58, 59 and 89) to route flows from the upper regions of the catchment. The trunk drainage system is linked to Council's local drainage system consisting of covered channels, in-ground pipes, culverts and kerb inlet pits. When these systems reach capacity, flow cannot enter the subsurface network and passes overland along streets and other open space. The drainage system is shown on Figure 3.

The topography of the catchment is steep with the greatest relief occurring at the top of the catchment along Oxford Street at elevations of 60 to 70 mAHD which slopes south to the Fox Studios site with grades of approximately 4%. Anzac Parade, extending along the western side of the study area, has a grade of approximately 1% from north to south. The downstream end of the study area is also the flattest part of the catchment; within the Parklands Tennis club, which has a relatively gentle ground gradient of 1% draining south towards Anzac Parade.

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 some 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 is exacerbated by the relatively flat terrain in the lower section of the catchment (broadly, the area south of Moore Park Road and west of Cook Road), which results in a lack of flood gradient in this area. This lack of gradient, as well as insufficient pipe drainage causes localised flooding in several areas in the catchment.

Future development in this area is likely to be in the form of landuse changes in the SCG/SFS/Fox Studios/Moore Park area, as well as urban consolidation in the area's limited residential land. Around half of the land in the catchment is part of the Centennial Parklands and is managed by the Centennial Park and Moore Park Trust, a NSW Government agency. The Trust released a 'strategic land use vision' (Reference 4) in mid-2013 that includes increased commercialisation of parts of its park, including an underground car park under Moore Park and redevelopment of ES Marks Fields, at the southern tip of the catchment. Construction recently began on Tibby Cotter Bridge, a pedestrian bridge over Anzac Parade linking Moore Park West

to Driver Avenue.

2.1.1. Land Use

The land use zones as identified in the Sydney LEP 2012 are shown in Figure 4. The land usage within the study area is a mix of urban residential development, parkland, commercial area and sporting grounds. Urban residential development is located on the northern and eastern sides of the catchment, with Paddington in the north having mostly two-storey terrace houses and Centennial Park to the east having a mix of apartment buildings and large, heritage-listed houses. Fox Studios, the Entertainment Quarter and two sports stadiums occupy the centre of the area, which have a mix of commercial and industrial use. The remainder of the land, in the south and west of the study area, is used for public recreation, and includes sports fields, tennis courts, and parklands.

2.1.2. Social Characteristics

Understanding the social characteristics of the area can help in ensuring that the floodplain risk management practices adopted are aligned with the communities at risk. For example, 'stable' communities (characterised by a high proportion of homeownership and low frequency of residents moving into or out-of the area) are more like to have a better understanding of the flood risks within the area.

Social characteristic data were obtained from the 2011 census (http://www.abs.gov.au/) for the study area. The census data shows that a significant number of households speak a language other than English at home (12%), for example Spanish (1.9%) and French (1.5%), which should be considered when organising flood awareness education or when issuing evacuation orders. 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 35% of the residents, and around 50% of residents are staying in a rented property. This suggests a high frequency of change of residents in the area, which may indicate a need for more frequently occurring flood awareness/community education programmes.

The catchment has a small dwelling size of only 1.8 people, and a high portion of single person dwellings (47.3% compared to the NSW average of 24.2%). This may need to be considered in any evacuation planning as it may indicate a higher than usual number of properties relative to population. There is also a small average number of motor vehicles per dwelling, with 23.3% of households having no motor vehicles (compared to a NSW average of 10.4%), which might need to be considered in any assumptions regarding evacuation routes (i.e. that they should be traversable by foot rather than vehicle as due to the small proportion of vehicle owners in the catchment).

Demographically, the catchment has a lower than average portion of greater than 65 year olds (9.9% compared to 14.7% for NSW), and a lower than average portion of under 14 year olds (9.3% compared to 19.2% for the state), which suggests demographics shouldn't have a significant influence on the consideration of mitigation measures.

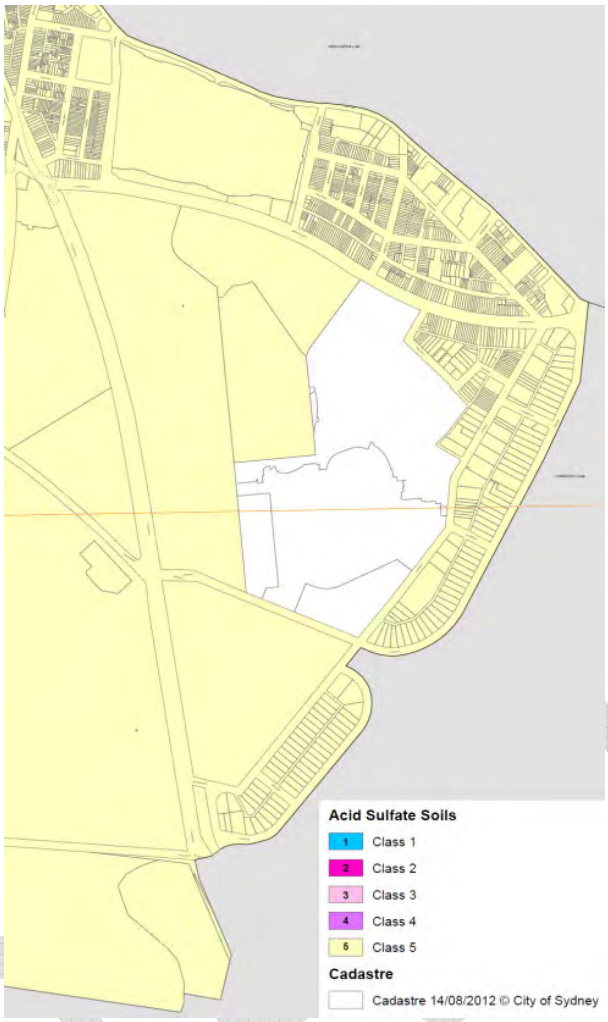
2.1.3. Environmental Features

Centennial Park catchment is developed and urbanised and therefore has limited areas of natural environment, other than some parkland and urban forests. Furthermore, the drainage system has been highly modified and is now completely man-made.

City of Sydney aspires to protect and expand the LGA's urban forest. This includes a list of protected Significant Trees, of which there are a significant number in the area, including the well-known Port Jackson and Moreton Bay Fig trees on Anzac Parade, Driver Avenue, Lang Road and Moore Park Road. These trees are well established and are unlikely to be affected by flood behaviour in the catchment. Mitigation measures assessed by this study will consider the value that is placed upon trees in the catchment when there is a potential impact.

Other environmental features of interest in the catchment are:

- The catchment is classified as a general conservation area with a number of conservation buildings identified. No aboriginal heritage sites have been identified in the catchment
- there are no Record of Notices of contaminated land in the catchment area.
- A large portion of the Centennial Park catchment has an Acid Sulphate Soils classification of 5 (works within 500m adjacent of an area classified 1 -4 and likely to reduced groundwater levels by 1m or more are likely to present an environmental risk). Maps of the Acid Sulphate Soils classification have been taken from the Sydney LEP (Reference 6) and are presented here.



Sheets ASS_024 and ASS_023 from Sydney LEP 2012

2.1.4. Historical Flood Events

The drainage characteristics of the catchment have been significantly altered as a result of urbanisation, particularly in the past 100 years.

Frequent flooding occurs in areas of the catchment including along Lang Road at localised depression storages which collect excess overland flow which is unable to be transported by the underground drainage network.

Historical records indicate flooding within the catchment at many locations for events in excess of the 1 in 20 year ARI. June 1949, November 1961, March 1975, November 1984, January 1991 and February 2001 were some of the major storm events in which the catchment experienced extensive flooding. Community consultation and City of Sydney's database provide information on events as early as November 1984. Multiple occurrences of flooding at Moore Park Road properties are reported for this period, while Driver Avenue, Stewart Street, Lang Road and Robertson Road experienced a combination of property and road inundation.

3. EXISTING FLOOD ENVIRONMENT

The existing flood risk for the Centennial Park catchment is defined by the design flood affection in the Flood Study (Reference 2). The design flood information is then used to determine the Hydraulic categories, Hazard classification and the Flood Emergency Response categories (the latter is detailed in Section 6.4). It also enables the identification of any key flood risk areas or 'hotspots' in the catchment. An overview of the previously undertaken climate change analysis is also given.

3.1. Hydraulic Categories

The 2005 NSW Government's Floodplain Development Manual (Reference 1) defines three hydraulic categories which can be applied to different areas of the floodplain; namely floodway, flood storage or flood fringe. Floodway describes areas of significant discharge during floods, which, if partially blocked, would cause a significant redistribution of flood flow. Flood storage areas are used for temporary storage of floodwaters during a flood, while flood fringe is all other flood prone land.

There is no single definition of these three categories or a prescribed method to allocate the flood prone land into them. Rather, their categorisation is based on knowledge of the study area, hydraulic modelling and previous experiences. Based on analysis of similar catchments, as well as literature review (Reference 9), 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 the 5% AEP, 1% AEP and PMF events, are shown on Figure 6 to Figure 8. In the 5% AEP event there are significant flood storage areas on Driver Avenue, Poate Road and Lang Road and smaller storages on Leinster Street, as well as floodways on Errol Flynn Boulevard (the entrance to Fox Studios off Lang Road) and the southern section of Anzac Parade. In the 1% AEP event flood storage locations are generally similar, while the floodway is more pronounced, starting at Fox Studios, crossing Lang Road and Parklands tennis courts, continuing down Anzac Parade.

3.2. 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. These hazard categories do not consider other factors which may influence the flood hazard (Figure L2 of the Floodplain Development Manual); hence they are a

provisional 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 9 to Figure 16 show the flow hazard classification throughout the catchment for the 50%, 20% 10%, 5%, 2%, 1% and 0.2% AEP and PMF events. As shown in the figures, hazard is quite consistent between the events, with the largest areas of high hazard at Driver Avenue, Poate Road and Lang Road. Of these, Lang Road and Driver Avenue are not adjacent to residential areas, but are transport thoroughfares (Lang Road more so) and present a flood risk to vehicles. Smaller sections of high hazard are on Stewart Street and Leinster Street, which will present a flood issue to residents in the area. There is some high hazard flow on Anzac Parade but it is generally not across the road, and would not affect more than one lane of traffic in either direction.

To assess the true flood hazard, all adverse effects of flooding have to be considered. This includes the provisional (hydraulic) hazard, 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

The classification is a qualitative assessment, which results in two categorisations:

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.*

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	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	Medium	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	Low	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 Centennial Park catchment

Larger flood events in the catchment are associated with increased depths and velocities, however, this is largely accounted for by the provisional hazard criteria being considered over a range of events. Furthermore, the nature of flooding in the catchment results in only small increases in flood levels between design events.

Floodwaters have hazardous depth and velocity in frequent flood events, with overland flow passing down several roads in the catchment. There are associated risks of persons being swept into floodwaters, as well as cars being destabilised in areas with greater depth, such as Lang Road and Leinster Street. However, this component does not warrant more attention than others, as the risk posed by high hazard depths and velocities is already well-described by the provisional hydraulic hazard.

The concept of rate of rise of flood waters is more applicable to mainstream flooding scenarios, where a fast rate of rise can leave residents unaware of the flood event, and they can become stranded. However, the rate of rise in this catchment is very fast (up to 1.5-2 m/hour in the 5% AEP and 2-2.5 m/hour in the 1% AEP) and flood prone areas will become inundated soon after the rainfall event begins. If evacuation is required in the catchment, the fast rate of rise will likely mean it is undertaken after the peak flood level.

Flood awareness in the community appears to be moderate, with 63% of questionnaire respondents aware of flooding in the catchment (Reference 2) (this is likely to exaggerate the awareness, as aware residents are presumably more likely to respond). Given that only 10% of those surveyed responded, the confidence interval on the estimate is around 15% (i.e. the number of aware respondents is likely between 45 and 75%). The estimate is also complicated by the bias in the respondents, with those residents who are aware of flooding more likely to respond. Although it may be assumed that frequently flood-affected properties are aware of flooding, the high number of renters in the area means this awareness could too be exaggerated. Experience in similar urban catchments indicates residents are generally sceptical of the possibility of large floods and therefore may not ascribe the appropriate level of risk to floodwaters when they are encountered.

Effective warning and evacuation time in the catchment is relatively low, as the flooding is likely to be sudden, with a fast rate of rise. For a resident without additional warning or forecast, flood events will initially resemble more benign (but still heavy) storms, with awareness of the flood coming from direct experience of it. However, effective access, which refers to an exit route that remains trafficable for sufficient time to evacuate people and possessions, is likely to be available to the majority of affected residents, as the flood extents are not wide. The areas where access is an issue are those areas identified as having high hydraulic hazard, shown on Figure 14 for the 1% AEP event. The vehicular and pedestrian access routes are all along sealed roads and present to unexpected hazards if the roads have been adequately maintained.

At depths of 0.3 m wading should be possible for most mobile adults, but could be problematic for children, elderly or disabled people. The majority of flood prone properties in the catchment do have access with flood depths of 0.3 m or less. Areas that do have depths of 300 mm or more in the 1% AEP include:

- Stewart Street south of Alexander Street
- Leinster Street east of Oatley Road
- Leinster Road west of Furber Road
- Poate Road west of Furber Road
- Cook Road north of Darvall Street
- Lang Road north of Darvall Street

At depths of 300mm, larger vehicles can easily travel through water at this depth and aid evacuation. 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 harm's 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. It would impact the time of inundation as waters would take longer to recede, however as the duration of the flooding is generally short across the catchment this is not considered significant. Figure 17 shows the length of inundation taken at each of the drainage pit inlets in the 1% AEP, 1 hour event. This shows that the duration of flooding is typically less than 1 hour except in the known trapped depressions on Grand Drive

and Driver Avenue, where it may take up to four hours to drain, assuming the piped network is operating efficiently (i.e. without blockages).

3.3. Hotspots

Hotspots in the area are defined as those locations where there is a known flood issue. They are identified by considering accounts of previous floods, and by examining the flood behaviour as defined by the Flood Study (Reference 2). The latter involves identifying areas of high hazard flow where flooding of property occurs, and through consideration of subsurface drainage capacity.

The Flood Study (Reference 2) informally identified several such hotspots, which the current study then re-examined. Floor level survey undertaken as part of the current study gave further information on flood affectation of property in the catchment. Similarly, a community questionnaire and newsletter gave new information on residents' experience of flooding (see Section 4.1.2). Description of each hotspot in the following sections refers to depths of hydraulic hazard, which is shown on Figure 9 to Figure 16, duration of flooding (Figure 17) and overfloor inundation (Figure 19).

3.3.1. Poate Road

The section of Poate Road parallel to Poate Lane has a topographic depression that acts as a storage in a flood event. The depression is caused by the street sloping towards the south-west, and the masonry wall that blocks the natural gradient of the area. The pit and pipe network in the area drains the depression but its capacity is exceeded in frequent flood events. The road has a depth of 2.08 m in a 10% AEP event, while in the 1% AEP event has depths of up to 2.38 m. Figure 22 shows the hotspot in detail, including the areas where runoff accumulates and the area's drainage.

The large depths of inundation that occur in the hotspot result in significant areas of high hydraulic hazard across the range of design events. In a 50% AEP event, the eastern end at the elbow of the road has high hazard ponding, while in the 1% AEP event the high hazard area extends up to 120 m west along Poate Road. The area has a long duration of flooding relative to the rest of the catchment (though a shorter duration than other hotspots), but can still be expected to drain within 2 hours in a 1% AEP, 1 hour duration event, given the trunk drainage is functioning.

The hotspot has moderate property inundation and is not a pedestrian or vehicle thoroughfare. Three properties are flooded above floor in the 10% AEP event, and an additional property is first inundated in a 1% AEP event. Other properties on the street are relatively high above street level and flooding is limited to front yards. There is a risk of damage to cars parked on the street as depths are significant.

3.3.2. Stewart Street and Leinster Street

The topographic depressions on Stewart Street and Leinster Street detain a significant volume of runoff in a flood event and act as flood storages. As with Poate Road, the pit and pipe network drain the depressions, however, it has limited capacity and is exceeded in events larger than a 50% AEP event. At their lowest points, Stewart Street and Leinster Street have a depth of 0.84 m and 1.28m respectively in a 10% AEP event, while in the 1% AEP event they have depths of up to 1.18 m and 1.54 m respectively. Figure 25 shows the hotspot in detail, including the areas where runoff accumulates and the area's drainage.

The large depths of inundation that occur in the hotspot result in significant areas of high hydraulic hazard across the range of design events. In a 50% AEP event, Leinster Street has high hazard ponding, while in the 1% AEP event the high hazard area covers an 80 m section of Leinster Street and 40 m of Stewart Street. As with Poate Road, the area has a long duration of flooding relative to the rest of the catchment and storm duration. Stewart Street can still be expected to drain within an hour with Leinster Street taking more than 2 hours in a 1% AEP, 1 hour duration event, given the trunk drainage is functioning.

The hotspot has major property inundation but does not contain any pedestrian or vehicle thoroughfares. Stewart Street has 7 properties inundated in the 50% AEP event increasing to 17 properties in the 1% AEP event. As properties only back onto Leinster Street significant inundation of property is limited to flooded garages and yards. There is a risk of damage to cars within these garages.

3.3.3. Driver Avenue

The grading of Driver Avenue creates an unrelieved depression that acts as a flood storage area in flood events. The conveyance downstream is entirely through the pipe network system as the road slopes upwards from the depression. This drainage network is at capacity upstream of the hotspot, even in more frequent events such as the 50% AEP. The road has a depth of around 1.04 m in the 10% AEP event; while the 1% AEP event has depths of up to 1.4 m. Figure 30 shows the hotspot in detail, including the areas where runoff accumulates and the area's drainage.

The large depths of inundation that occur in the hotspot result in significant areas of high hydraulic hazard across the range of design events. In a 50% AEP event, the gutters in the area have high hazard ponding, while in the 1% AEP event the high hazard area covers a 180 m section of Driver Avenue and the park to the west. The area has a long duration of flooding relative to the rest of the catchment and hotspots, but can still be expected to drain within 3 hours in a 1% AEP, 1 hour duration event, given the trunk drainage is functioning.

The hotspot has no property inundation but does cut off a vehicle or pedestrian thoroughfare (Driver Avenue). Traffic in the area is highly variable, with high volumes during an event at Hordern Pavilion, the Entertainment Quarter, the cricket ground or the football stadium. There is a risk of damage to cars parked along the street, though there is limited parking.

3.3.4. Lang Road near Driver Avenue

There is a topographic depression at the intersection of Lang Road and Driver Avenue which detains runoff in frequent flood events. Runoff into the depression is from Lang Road itself, and from Driver Avenue and the parkland to the north. Piped drainage is relied on to transmit flow from the area, as the topography slopes up from the area (up Driver Avenue and along Lang Road), creating an unrelieved depression. The road has a depth of 0.84 m in the 10% AEP event in the centre; while the 1% AEP event has depths of up to 0.93 m. Figure 33 shows the hotspot in detail, including the areas where runoff accumulates and the area's drainage.

The large depths of inundation that occur in the hotspot result in significant areas of high hydraulic hazard across the range of design events. In a 50% AEP event, the gutters in the area and the parkland to the south have high hazard ponding, while in the 1% AEP event the high hazard area covers a 75 m section of Lang Road and the parkland to the south. The area has a long duration of flooding relative to the rest of the catchment and hotspots, but can still be expected to drain within 3 hours in a 1% AEP, 1 hour duration event, given the trunk drainage is functioning.

The hotspot has no property inundation but does inundate a vehicle and pedestrian thoroughfare, posing a significant risk in most flood events. The frequency of inundation of the area (there is typically ponding multiple times in a year) means that larger events may resemble the less hazardous frequent events, and people will attempt to cross the inundated section.

3.3.5. Lang Road near Darvall Street

A minor depression exists on Lang Road near Darvall Street where water ponds before discharging into Centennial Park. The local pit and pipe network drains the depression to the east into Centennial Park. The road has a depth of around 0.46 m in the 10% AEP event at the centre of the road; while the 1% AEP event has depths of up to 0.57 m. Figure 28 shows the hotspot in detail, including the areas where runoff accumulates and the area's drainage.

The depth of inundation that occur in the hotspot does not result in areas of high hydraulic hazard across the range of design events except in the PMF event. The area has a short duration of flooding relative to the rest of the catchment and hotspots, and can still be expected to drain in less than an hour in a 1% AEP, 1 hour duration event, given the local drainage is functioning.

The hotspot has no overfloor property inundation but does affect a vehicle and pedestrian thoroughfare. The area poses risk to both vehicles and pedestrians in frequent events such as the 50% AEP event and a significant risk in larger events.

Mitigation measures for the hotspots are discussed in Section 9.3.

3.4. Impact of Climate Change

The impact of climate change on flood behaviour has been assessed as part of the Flood Study (Reference 2) through a sensitivity analysis of rainfall increase due to climate change. The assessment followed NSW State Government guidelines, which require testing of rainfall increases of 10, 20 and 30%. Table 2 gives the results of the analysis.

Table 2: Results of Climate Change Analysis - 1% AEP Event Depths (m)

ID	Location	100 Year ARI Peak Flood Depth (m)	Rainfall Increase 10%	Rainfall Increase 20%	Rainfall Increase 30%
			Difference with 100 Year ARI Base Case (m)		
1	Stewart Street	0.9	0.05	0.09	0.12
2	Leinster Street	1.4	0.04	0.08	0.12
3	Poate Road	1.7	0.06	0.11	0.16
4	Driver Avenue	1.5	0.07	0.14	0.20
5	John Hargraves Ave	0.6	0.10	0.17	0.24
6	Erol Flynn Boulevard	0.4	0.03	0.05	0.06
7	Lang Road / Driver Ave	0.9	0.03	0.06	0.09
8	Parklands adjacent Lang Road / Driver Ave	0.9	0.03	0.06	0.09
9	Lang Road adjacent 62	0.6	0.02	0.03	0.05
10	Anzac Parade	0.5	0.02	0.05	0.07

The table shows that 1% AEP peak flood depths across the catchment will increase by around 0.05 m in a 10% rainfall increase, while a 30% rainfall increase will correspond to depth increases of around 0.1 m. The most sensitive areas are on John Hargraves Avenue, Driver Avenue and Poate Road.

4. STAKEHOLDER 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 consists of:

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

4.1.1. Previous Consultation

As part of the Flood Studies (Reference 2), community questionnaire surveys were undertaken during October-November 2012 to gather historical data for model calibration. 560 surveys were distributed to residents within the Centennial Park catchment. 47 responses were received, which equates to a return rate of 8%. The most frequently recalled flood was the June 2007 storm, although other events were also mentioned by a significant number of respondents. Approximately 75% of respondents are aware of flooding or have some knowledge of flooding in the study area. Of the property areas flooded, one respondents reported flooding above floor, while others reported flooding of yard or garage.

4.1.2. Consultation as Part of This Study

Further community questionnaire survey work was undertaken during June-July 2014 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. 557 copies of the newsletters and questionnaires were printed and delivered to the owners of properties likely to be aware of flooding issues. In total 57 responses were received constituting a 10% return rate and the results are as shown in Figure 18. The newsletter and questionnaire is shown in Appendix B.

37% of the respondents experienced some form of flooding within the catchment and three respondents reported floodwaters entering their houses or businesses. Of the three respondents, two reported flooding in the Stewart/Leinster Street hotspot, while the third was an SCG building on Driver Avenue. The responses confirmed the existence of hotspots at Stewart/Leinster Street, Driver Avenue, Poate Road and Lang Road, all of which contain topographic depressions that trap runoff.

Several residents identified blocked pits and pipes as a flooding-related issue in the catchment, with various respondents commenting that litter and leaves were frequently blocking the drainage. One respondent recommended trees be removed that are blocking drainage.

Among the preferred management options for managing flood risks within the catchment: pit and pipe upgrades, improved flow paths and retarding basins were the most popular, while levee banks, community education and flood forecasting were the least preferred.

The Sydney Cricket Ground and Sports Ground Trust were also contacted as part of the study. As operators of the SCG and SFS, experience of prior floods was provided, as well as information of their emergency response arrangement (described in Section 6.2.3.1)

4.1.3. Community Information Session

Yet to be hosted.

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

Workshops with internal stakeholders were held to gather feedback on the management measures being assessed for the study. The workshops, which were held in December 2014, consisted of presentation of the various measures, including their cost and impact on flooding and property affectation. Attendees included representatives from City of Sydney, OEH, SES and Sydney Water, and each provided input on the feasibility and suitability of the measures, as well as possible variations to the measures presented.

4.4. Public Exhibition

Following approval by the Committee, this Floodplain Risk Management Study and draft Plan draft report will be put on public exhibition. This will be the opportunity for the community to examine the report and the study outcomes and make any comments or suggestions. Formal submissions from the community will be considered by Council and the Committee before finalisation of the report.

5. ECONOMIC IMPACT OF FLOODING

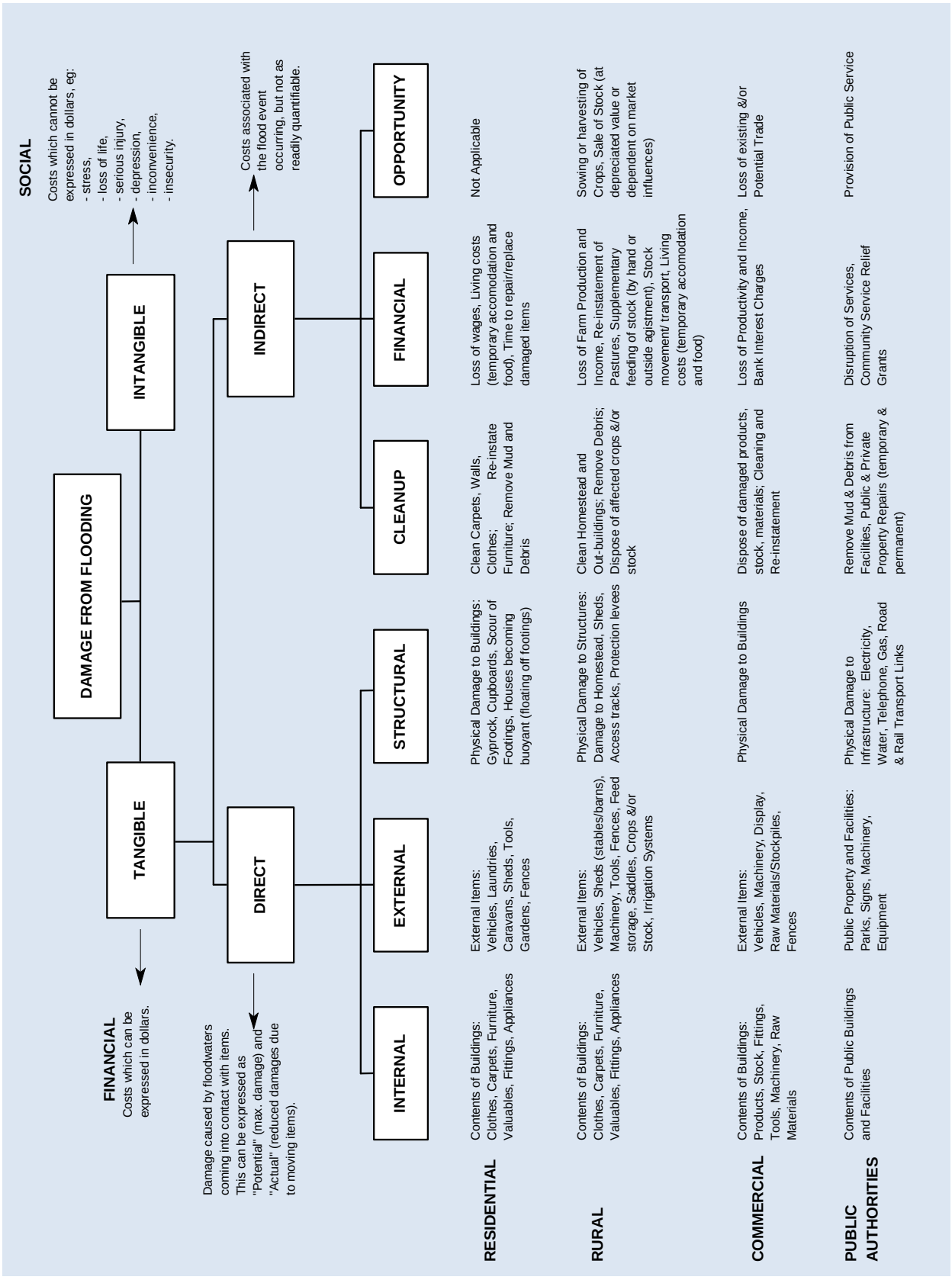
The impact of flooding can be quantified through the calculation of flood damages. Flood damage calculations do not include all impacts associated with flooding. They do, however, provide a basis for assessing the economic loss of flooding and also a non-subjective means of assessing the merit of flood 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 19.

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



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. Flood damages estimates are also useful when studying the economic effectiveness of potential 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 slightly underestimated.

The floor level survey used as part of this study is given in Appendix E.

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 10) 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.

Centennial Park has a small catchment size (150 hectares) that limits the volume of runoff that occurs in a rainfall event. This limited volume, combined with the relatively short duration of the flood event (typically a few hours), means there is limited opportunity for floodwaters to enter premises. This is especially true of basement flats - flats where the entry is below the level of the footpath. For example, a basement flat may have a floor level two metres below the design flood level, but will not experience two metres of depth throughout the dwelling, due to the limited runoff volume. To account for this, the maximum depth of inundation in the damages calculation for each property is 0.5 m.

Similarly, the damages calculation was augmented so as to avoid designating these basement flats as being flooded over floor in frequent flood events. This change was made after detailed assessment of the properties in question, as well residents' experiences via the questionnaire, suggested that these basement flats were typically not flooded in frequent flood events (e.g. a 1 in 2 year ARI event). The damages calculation was augmented by not designating properties as flooded overfloor when the depth on the footpath is less than 0.15 m. This is not to say that a depth of 0.15 m cannot inundate a low-lying property. Rather, that without this threshold, the flood affectation is overestimated, and so the threshold improves the estimate of the affectation.

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 Centennial Park 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
PMF	90	57	$ 3,540,500	$ 39,300
0.2%	86	37	$ 2,427,900	$ 28,200
1%	84	28	$ 1,850,100	$ 22,000
2%	80	25	$ 1,668,600	$ 20,900
5%	77	23	$ 1,511,100	$ 19,600
10%	71	19	$ 1,287,300	$ 18,100
20%	64	13	$ 914,700	$ 14,300
50%	55	9	$ 612,900	$ 11,100
Average Annual Damages (AAD)			**$ 650,800**	**$ 7,800**

Section 9.3.6 presents results of the damages assessment undertaken for the potential mitigation options which were compared against the existing scenario so that the feasibility of the options can be determined.

5.1.1. Residential Properties

The flood damages assessment for residential development was undertaken in accordance with OEH guidelines (Reference 10). 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 $33,750 occurring at a depth of 0.5 m above the building floor level (and linearly proportioned between the depths of 0 to 0.5 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 Centennial Park 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 Centennial Park 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
PMF	86	57	$ 3,532,400	$ 41,100
0.2%	83	37	$ 2,422,200	$ 29,200
1.0%	81	28	$ 1,844,800	$ 22,800
2.0%	77	25	$ 1,663,600	$ 21,600
5.0%	75	23	$ 1,506,300	$ 20,100
10.0%	69	19	$ 1,282,600	$ 18,600
20.0%	62	13	$ 910,100	$ 14,700
50.0%	53	9	$ 608,700	$ 11,500
Average Annual Damages (AAD)			**$ 647,400**	**$ 7,800**

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 be 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 $95,625 since the building contents are of higher value whilst loss of rent was set at $1,000 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 Centennial Park catchment is provided in Table 6. AAD for the surveyed commercial/industrial properties is less than that for

residential properties but there are no flood affected properties above floor level for the commercial/industrial properties.

Table 6: Estimated Commercial and Industrial Flood Damages for Centennial Park 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
PMF	4	0	$ 8,100	$ 2,000
0.2%	3	0	$ 5,700	$ 1,900
1.0%	3	0	$ 5,300	$ 1,800
2.0%	3	0	$ 5,100	$ 1,700
5.0%	2	0	$ 4,900	$ 2,400
10.0%	2	0	$ 4,700	$ 2,300
20.0%	2	0	$ 4,500	$ 2,300
50.0%	2	0	$ 4,300	$ 2,100
Average Annual Damages (AAD)			**$ 3,300**	**$ 1,100**

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 Centennial Park catchment area, the high hazard areas include Driver Avenue and trapped low points with high flood depths, i.e. at Lang Road, Poate Road, Leinster and Stewart Street. 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 Centennial Park catchment is characterised by overland flow. The critical duration is between 30 and 60 minutes across the catchment, with the peak of the flood reached approximately 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. Assessment of evacuation and emergency response arrangements is given in Sections 9.4.2 and 9.4.4.

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 property 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 Centennial Park catchment are discussed as follows.

6.2.1. DISPLAN

The Centennial Park catchment is located within the Sydney East 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 East 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 East Metropolitan District Emergency Operations Controller and Local Emergency Operations Controllers within the East 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 Centennial Park 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 Centennial Park 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 Centennial Park 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 Centennial Park Flood Study (Reference 2) should be transferred to the Security and Emergency Management Centre.

6.2.3.1. Sydney Cricket Ground and Sydney Football Stadium

There is a separate emergency response arrangement for the Sydney Cricket Ground and Sydney Football Stadium, which are operated by the Sydney Cricket and Sports Ground Trust. In the event of a flood in the catchment, the grounds' Emergency Control Organisation will assess the risk to patrons and determine whether it is safe for people to leave. The risk is concentrated to patrons who may attempt to cross floodwaters in the Driver Road hotspot (described in Section 3.3.3). If there is an evacuation path available, the route will be regulated by emergency wardens. There is no hazardous inundation in the stadiums themselves, meaning they can be used as refuges if need be.

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 Centennial Park 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 Centennial Park 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.).

6.3. 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

The catchment area has two arterial roads (Moore Park Road and Anzac Parade) and one main

road (Lang Road) that are flood affected, and a smaller road (Driver Avenue) where traffic will be impeded in a flood event. Both arterial roads connect the CBD to the eastern suburbs and convey a significant volume of vehicle traffic. Moore Park Road has little upstream catchment and, in frequent events, only has significant inundation in the gutters and adjoining area, the depths of which are listed in Table 7. As shown in the table, the Anzac Parade bus lane has around 0.3 m in frequent events and up to 0.5 m in the 1% AEP event. On Lang Road, there is up to 1 m of water in frequent events, while Driver Avenue has around the same depth.

Table 8 lists the rate of rise in metres per hour for the same locations listed in Table 7, for the 1 hour duration storm. It should be noted that the rate of rise will vary with other event durations, and therefore the values presented are only to give a general approximation of rate of rise and how it varies in the catchment. Also, the five locations (except for Driver Avenue) reach their peak depth within one hour of the vent occurring, hence the rates of rise are greater than the peak flood depths. Rate of rise is around 1 m/hour in frequent events, except for on Anzac Parade which is around 0.4 m/hour.

Table 7: Major Road Peak Flood Depths (m) for Various Events

ID	Road Location	2 year ARI	5 year ARI	10% AEP	5% AEP	2% AEP	1% AEP	0.2% AEP	PMF
1	Lang Road near Driver Avenue	1.0	1.0	1.1	1.1	1.1	1.2	1.3	1.6
2	Driver Avenue near SCG	1.0	1.3	1.4	1.5	1.6	1.7	1.7	2.8
3	Lang Road near Darvall Street	0.3	0.5	0.5	0.6	0.6	0.7	0.7	0.9
4	Anzac Parade bus lane near Robertson Road Fields	0.2	0.3	0.3	0.4	0.4	0.5	0.5	1.0
5	Moore Park Road near Driver Avenue	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7

Table 8: Major Road Flooding Rate of Rise (m/hour) for Various Events (1 hour duration event)

ID	Road Location	2 year ARI	5 year ARI	10% AEP	5% AEP	2% AEP	1% AEP	PMF
1	Lang Road near Driver Avenue	1.2	1.6	1.7	1.9	1.9	2.0	2.2
2	Driver Avenue near SCG	1.0	1.3	1.4	1.5	1.5	1.6	3.4
3	Lang Road near Darvall Street	0.7	1.0	1.1	1.2	1.4	1.5	1.9
4	Anzac Parade bus lane near Robertson Road Fields	0.4	0.3	0.4	0.5	0.6	0.7	1.4
5	Moore Park Road near Driver Avenue	1.1	1.2	1.3	1.3	1.4	1.3	1.9

For the 1% AEP flood event, roads cut (as per Figure 20) are shown in Table 9.

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

Road Location	Description
Lang Road near Driver Avenue	Flood depths are up to 2 m and a depth of greater than 0.3 m will persist for up to 4 hours given the critical storm modelled (1 hour)
Driver Avenue near SCG	Flood depths are up to 1.6 m and a depth of greater than 0.3 m will persist for up to 4 hours given the critical storm modelled (1 hour)
Lang Road near Darvall Street	Flood depths of up to 1.5 m and persist for up to 1 hour for the critical storm modelled (1 hour)
Anzac Parade bus lane near Robertson Road Fields	Flood depths of up to 0.7 m and persist for up to 1 hour for the critical storm modelled (1 hour)
Moore Park Road near Driver Avenue	Flood depths of up to 0.6 m and persist for up to 30 minutes for the critical storm modelled (1 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.

6.4. 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 8) 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 8). The ERP classification can identify the type and scale of information needed by the SES to assist in emergency response planning (refer to Table 10).

Table 10: 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, with the additional criteria of flood depths being greater than 0.1 m. If only the flood extent was used in the Centennial Park catchment, areas surrounded by less than 0.1 m would be classified as flood islands, when in reality, people could move through this water without concern. Therefore, all flood depths of less than 0.1 m were removed from the PMF flood extents prior to classification. The ERP classifications for the study area are shown in Figure 5.

This figure shows that a large proportion of the study area has been classified as high flood island due to the reasonably high depths that would occur in road reserves surrounding properties, prior to inundation of the properties themselves. Adjacent to this are several rising road access areas which allow access out of the flood affected area.

7. POLICIES AND PLANNING

7.1. Legislative and Planning Context

The NSW State Government's Flood 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 Policy, the management of flood liable land remains the responsibility of local government. Furthermore, Section 117(2) of the 1979 Environmental Planning and Assessment Act Direction 15 states that Council must ensure development is appropriate in regard to flood risk and that furthermore it does not cause impacts on adjoining property.

Councils have a number of planning tools available to them in order to fulfil this role, including the Local Environment Plan (LEP) and Development Control Plans (DCPs). Detail of the specific planning documents relevant to Centennial Park is provided below.

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.

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.

Interim Floodplain Management Policy

This interim Policy (Reference 7) was adopted in May 2014 and 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 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 in the area:

- 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:

- 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 7). 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 7); 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 7).

8. FLOOD PLANNING

8.1. 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 Centennial Park 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.

8.1.1. Likelihood of Flooding

As a guide, Table 11 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 11 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 11: 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

8.1.2. 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 7).

8.1.3. 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 waves from vehicles);
    - Blockage of drainage network; and
    - Climate change (affecting rainfall).

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 (0.02 m to 0.24 m, mean 0.08 m, as per Centennial Park Flood Study (2013))
- Sensitivity of the model +/-0.05 m.

Based on this analysis, the total sum of the likely variations is between 250 mm and 500 mm, depending on climate change, which has a varying effect across the catchment. Based on this range, the freeboard recommended in the Interim Floodplain Management Policy (Reference 7) is suitable for the catchment. 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 two times the depth of flow with a minimum of 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.

8.1.4. Current FPL as Adopted by Council

FPL requirements have been outlined by Council in their Interim Floodplain Management Policy (Reference 7). 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 12.

Table 12: Adopted Flood Planning Levels in CoS Interim Floodplain Management Policy (Reference 7)

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 Centennial Park 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

9.1. General

The NSW Government's Floodplain Development Manual (2005) separates floodplain management measures into three broad categories:

Flood modification measures modify the flood's physical behaviour (depth, velocity) and include flood mitigation dams, retarding basins and levees.

Property modification measures modify land use including development controls. This is generally accomplished through such means as flood proofing (house raising or sealing entrances), planning and building regulations (zoning) or voluntary purchase.

Response modification measures modify the community's response to flood hazard by educating flood affected property owners about the nature of flooding so that they can make 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.

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. The B/C is the ratio of the net present worth of the reduction in flood damages (benefit) compared to the cost of the works. Generally, the ratio only expresses the reduction in tangible damages as it is difficult to accurately include intangibles (such as anxiety, risk to life, ill health, etc.).

The potential environmental or social impacts of any proposed flood mitigation measure are of great concern to society and these cannot be evaluated using the classic 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. The public consultation program has ensured that identifiable social and environmental factors were considered in the decision making process for the Centennial Park catchment.

A summary of the measures considered for the catchment and at the specific hotspot locations is provided in Table 13 below and discussed in the following sections.

Table 13: Flood Affected Areas and Investigated Management Options

Hotspot	Flooding issues	Investigated Measures	Measures Reference
Poate Road	Inundation with high depth or velocity, flooding of major roads, many properties flooded above floor	Trunk drainage upgrade from corner of Poate Road to SCG under Fox Studios	FM - CP01

Leinster Street	Localised inundation with high depth, many properties flooded above floor	Trunk drainage upgrade on Leinster and Stewart to Oatley Road and down to More Park Road.	FM - CP02
Lang Road near Darvall Street	Localised inundation with moderate depth, flooding of major roads	Drainage upgrade on Lang road for pipes into Centennial Park.	FM - CP03
Driver Avenue outside the SCG	Localised inundation with high depth, flooding of major roads	Regrade Driver Avenue to allow water to flow down the road rather than pooling in the low point	FM - CP04
Lang Road at Driver Avenue intersection	Localised inundation with high depth, flooding of major roads	Trunk drainage upgrade from Lang Road through a park down Anzac parade to the outlet in Centennial Park.	FM - CP05
Catchment-wide	General flood risk, inundation of major roads	Variable Message Display on Major Roads	RM-CP01
		Evacuation Planning	RM-CP02
		Public Information and Raising Flood Awareness	RM-CP03
		Local Flood Plan and DISPLAN	RM-CP04
		Flood Planning Levels	PM-CP01
		Flood Proofing of Affected Properties	PM-CP02
		Voluntary Purchase	PM-CP03
		Development Control Planning	PM-CP04

9.2. Measures Not Considered Further

During the early phase of this study a review of all possible floodplain management measures and their application in the Centennial Park catchment was undertaken. The measures not taken forward for further consideration, and the reasons for their exclusion, are summarised in the following sections.

9.2.1. Flood Modification - Dams and Retarding Basins

Flood mitigation dams and their smaller urban counterparts termed retarding basins have frequently been used in NSW to reduce peak flows downstream. However, dams are rarely used as a flood mitigation measure for existing development on account of the:

- high cost of construction,
- high cost of land purchase,
- risk of failure of the dam wall,
- likely low B/C ratio,
- lack of suitable sites as a considerable volume of water needs to be impounded by the dam in order to provide a significant reduction in flood level downstream.

This measure was not considered further for the above reasons.

9.2.2. Flood Modification - Levees, Flood Gates and Pumps

Levees are built to exclude previously inundated areas of the floodplain from the river up to a certain design events, and are commonly used on large river systems (e.g. Hunter and Macleay Rivers), but can also be found on small creek systems in urban areas.

Flood gates allow local waters to be drained from the leveed area when the external level is low, but when the river is elevated, the gates prevents floodwaters from entering.

Pumps are also generally associated with levee designs. They are installed to remove local floodwaters from behind levees when flood gates are closed or there are no flood gates.

These measures were not considered further due to the absence of a defined channel or river in the catchment area.

9.2.3. Response Modification – Catchment-Wide Flood Warning

During a major flood it may be necessary for some residents to evacuate their homes. Whilst not all will have their house floors inundated, it is possible that their power, water and sewerage systems could be affected. The amount of evacuation time depends on the available warning time. Providing sufficient warning time has the potential to reduce the social impacts of the flood as well as reducing the strain on emergency services.

The effectiveness of a flood warning systems 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,
- the flood awareness of the community responding to a warning.

At present there is no flood warning system in place for the Centennial Park catchment area. This is a result of the short time from the start of the rainfall to the flood peak (around 1 hour for the critical storm duration), which would not allow sufficient time for evacuation to occur prior to the flood event. Furthermore, flood risk in the catchment is concentrated at several separate locations, meaning a warning system would not benefit the majority of the area. This option was not considered further for these reasons.

9.2.4. Property modification - House raising

House raising has been widely used throughout NSW to eliminate inundation from habitable floors. However, it has limited application as it is not suitable for all building types. It is also more common in areas where there is a greater depth of inundation that in the Centennial Park catchment.

House raising is suitable for most non-brick, single storey buildings on piers and is particularly

relevant to those houses situated in low hazard areas of the floodplain. The benefit of house raising is that it eliminates inundation to the height of the floor, and consequently reduces the flood damages.

Due to the nature of development and the heavily urbanised city catchment, it is considered highly unlikely that any of the flood affected buildings would be suitable for house raising. As such, this measure has not been considered further.

9.3. Site Specific Management Options

Site specific management options involve specific works aimed at managing the flood risk in a particular part of the catchment. Modifying the flood behaviour at a particular location involves either detaining runoff or improving the drainage capacity. Retarding basins were considered for the area around Lang Road but were discarded after producing limited benefit (see Section 9.3.7).

Measures to increase the capacity or efficiency of the existing piped drainage network include upgrading pipe capacity; re-profiling the pipe network; removing fixed blockages or impediments to flow and improved maintenance. This type of measure was assessed in detail for a number of flood affected areas within the catchment. An overview of the flood affected areas and assessed mitigation options are provided in Table 14 and shown in Figure 21. These options are discussed in detail in Sections 9.3.1 to 9.3.5.

Table 14: Flood Modification Measures

Suburb	Flood Affected Streets/Areas	Proposed Mitigation Options	Ref
Centennial Park	Poate Road adjacent to Fox Studios	Trunk drainage upgrade from corner of Poate Road to SCG under Fox Studios	FM - CP01
Paddington	Leinster and Stewart Street	Trunk drainage upgrade on Leinster and Stewart to Oatley Road up to Moore Park Road.	FM - CP02
Centennial Park	Lang Road near Darvall Street	Drainage upgrade on Lang road for pipes into Centennial Park.	FM - CP03
Moore Park	Driver Avenue outside the SCG	Regrade Driver Avenue to relieve topographic depression	FM - CP04
Moore Park	Lang Road at Driver Avenue intersection	Trunk drainage upgrade up to Centennial Park	FM - CP05

9.3.1. Trunk Drainage Upgrade – Poate Road (FM - CP01)

Option Description

Option FM – CP01 describes a trunk drainage upgrade of the pipe relieving the depression in Poate Road. The upgrade extends approximately 200 m from Poate Road to adjacent to the Sydney Football Stadium, and consists of a 1.5 m diameter replacing the current 525 mm diameter pipe. The upgrade would also involve upgrading the pits and feeder pipe on Poate Road to ensure the upgraded trunk element is at capacity in a 5% AEP event. It should be noted that the location of the existing pipe proposed for upgrade was based on incomplete survey, and that its size and location should be confirmed before any further work is carried out.

Modelled Impacts

The upgrade achieves a significant reduction in the peak flood level in the hotspot; however, it

also increases the peak flood level downstream, through the SCG precinct and on Errol Flynn Boulevard and Lang Road. Figure 23 shows the location of the upgrade and its impact on the 5% AEP peak flood level, while Figure 24 shows the change in hazard in the same event. The reduction in peak flood level is over 1 m in the event shown, and parts of the north side of the street are no longer flooded. Relieving the ponding in this area (via the upgraded pipe) transfers the runoff to the downstream area, where impacts are around 0.3 m around the stadiums, and less than 0.05 m on Lang Road and Driver Avenue. In a 5% AEP event, the option reduces the ponding on Poate Road to low hydraulic hazard, while there is a minimal area that is newly high hazard immediately downstream of the upgraded section.

Evaluation

The option is unlikely to be feasible, based on its significant downstream impact, however, it does demonstrate that the Poate Road flood issue can be largely resolved via a pit and pipe upgrade. The downstream impact affects parts of Fox Studios, the Entertainment Quarter and the SCG precinct, as well as an existing hotspot at Lang Road. These impacts are the direct result of the reduced flooding at Poate Road, and can only be managed with a detention basin in the area (of which there appears to be no opportunity for) or a much longer pipe upgrade, past the Lang Road/Driver Avenue hotspot, which would likely be prohibitively expensive.

9.3.2. Trunk Drainage Upgrade – Stewart and Leinster Street (FM - CP02)

Option Description

Option FM – CP02 describes a trunk drainage upgrade on Leinster Street, Stewart Street and Oatley Road. The upgrade consists of new pits and pipes on Leinster Street and Stewart Street, which drain to the network on Oatley Road, which has also been upgraded. The upgraded pipes have the following dimensions:

- Upgrade of Stewart Street pipes to one 1.2 m diameter pipe;
- Upgrade of Oatley Road pipes to one 2.4 m diameter pipe;
- Upgrade of Leinster Street pipes to two 3.0 m diameter pipes;

The upgraded pipe capacities are designed to transmit the 5% AEP flood. New pipes, rather than using the existing system, were used to avoid the high cost associated with upgrading pipes below properties; however, upgrading of the existing system could also produce similar reductions in flood level.

Modelled Impacts

The upgrade achieves a significant reduction in peak flood level at both Stewart Street and Leinster Street. Figure 26 shows the location of the upgraded and new pipes, and their impact on the 5% AEP peak flood level, while Figure 27 shows the change in hazard in the same event. The reduction in peak flood level is up to 1.2 m on Leinster Street and up to 0.9 m on Stewart Street, with many properties backyards on Leinster Street no longer flooded. As shown on Figure 26, the reduced flood level results in 11 properties no longer being flooded above floor in a 5% AEP event. The upgrade reduces the ponding on both streets to a depth that is categorised as low hazard, and under the option there are no areas of high hazard in the 5% AEP event.

Evaluation

The option produces significant benefit with regards to overfloor flooding and reduction in high hazard flooding, as well having negligible downstream impacts; however, the required drainage elements are exceptionally large and may not be economically or technically feasible. As previously described, the benefit to the area is well defined, with 11 properties no longer being flooded overfloor in a 5% AEP event, and no high hazard inundation in the area in the same event. To achieve these benefits, pipes with a cross-sectional area of up to 14 m^2 are required, which are both very expensive to construct, and technically difficult to design. Section 9.3.6 has further assessment of the option's economic feasibility.

9.3.3. Drainage Upgrade – Lang Road North (FM - CP03)

Option Description

Option FM – CP03 describes a drainage upgrade on Lang Road near Darvall Street, discharging into Centennial Park. The upgrade consists of upgrading a single pipe beneath Lang Road to have a diameter of 900 mm (currently 450 mm), as well any pit upgrades to ensure they are not restricting flow into the pipe. The upgrade was designed to mitigate a 10% AEP flood event.

Modelled Impacts

The upgrade achieves a localised benefit to the depression on Lang Road, by increasing discharge from the area into Centennial Park. Figure 29 shows the location of the upgrade and its impact on the 5% AEP peak flood level. The figure shows that a large section of Lang Road is no longer flooded, while the remainder has a decrease of 0.2 – 0.5 m in peak flood level. The improved drainage of the area causes an impact of around 0.05 m in Centennial Park, which is considered acceptable.

Evaluation

The option relieves the existing flood issue on Lang Road near Darvall Street, but is difficult to justify due to the cost of works. The reduction in flood level is significant, with an associated reduction in the flood risk to vehicles and pedestrians along the road. In addition, the two properties on Lang Road that are adjacent to the hotspot are no longer flooded in their front yards. However, as these properties are not flooded above floor level in current conditions, there is minimal economic cost associated with the existing flood issue. As a result, the cost of the works will outweigh their limited economic benefit. It is not recommended that the option be carried out for this reason. Nuisance flooding of the properties' front yards may be better managed via flood proofing (see Section 9.4.6).

9.3.4. Trunk Drainage Upgrade – Driver Avenue (FM – CP04)

Option Description

Option FM – CP04 describes a regrading of Driver Avenue, between the Sydney Cricket Ground and Lang Road. The regrading removes the topographic depression on Driver Avenue, increasing the conveyance to the downstream area. As shown on Diagram 1, the option would lower Driver Avenue by up to 3 m, and would require large-scale earth works.

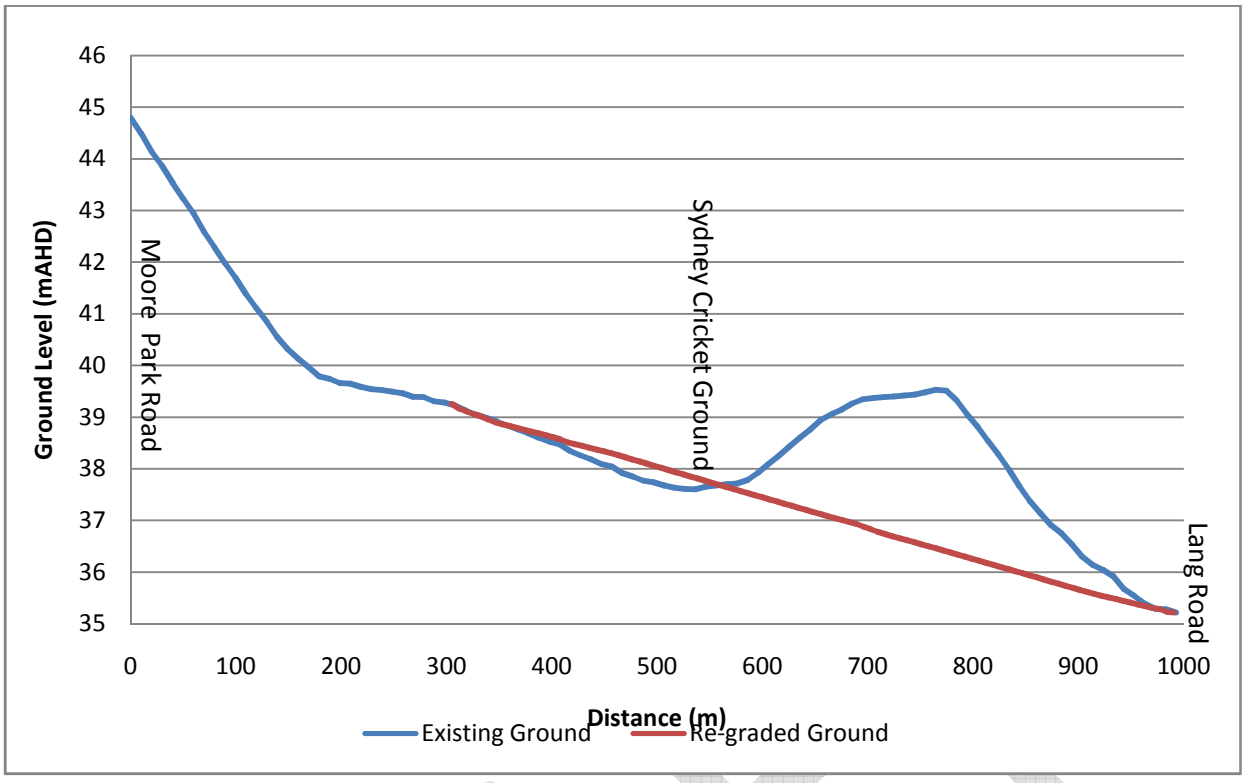


Diagram 1: FM - CP04 Driver Avenue Long Section

Modelled Impacts

The regrading results in a significant reduction of peak flood level on Driver Avenue; however, it also has adverse impacts downstream at Lang Road and Anzac Parade. Figure 31 shows the location of the regrading and its impact on the 10% AEP peak flood level, while Figure 32 shows the change in hazard in the same event. The reduction in flood level is up to 2.4 m on Driver Avenue, while the downstream has an increase of 0.06 m at the Lang Road hotspot, 0.1 m on the Robertson Road Sports Fields, and up to 0.16 m on Anzac Parade. The lowered flood level on Driver Avenue reduces the flooding adjacent to the SCG to low hazard; however, there are new areas of high hazard at the Lang Road hotspot, and on parts of Anzac Parade.

Evaluation

The reduction of flood affectation at the Driver Avenue hotspot directly impacts the downstream flood issue at Lang Road, making the option difficult to justify under most criteria. At present, the depression on Lang Road stores runoff that would otherwise pond at Lang Road. Given that Lang Road is a traffic thoroughfare and Driver Avenue is not, it is not desirable to pass the flood risk downstream to Lang Road. Under an economic assessment, the reduction at Driver Avenue has little economic benefit, as there are no flood affected properties in the hotspot. As the hotspot currently benefits the downstream area, it is recommended that no works be undertaken, and the existing flood hazard is warned of via a depth marker or similar signage (see Section 9.4.1)

9.3.5. Trunk Drainage Upgrade – Lang Road (FM - CP05)

Option Description

Option FM – CP05 describes a trunk drainage upgrade on Lang Road and underneath Robertson Road Sport Fields up to the trunk outlet into Kensington Ponds in Centennial Park. The upgrade consists of increased pit and pipe capacity on Lang Road at the hotspot, and the trunk drain increased to transmit the runoff in a 10% AEP event. Due to the flat grading between Lang Road and Centennial Park, the trunk drain has a grading of around 0.6%, which results in a very large pipe being required to convey the runoff. To mitigate the ponding in the 10% AEP event, a flow of 17.9 m^3/s is required to leave the area. This discharge requires drainage with cross-sectional area of up to 26 m^2, due to the grading of the area.

Modelled Impacts

The upgrade achieves a significant reduction in the 10% AEP peak flood level, with a decrease of up to 0.75 m at Lang Road (down from 0.84 m in the existing case). Figure 34 shows the location of the upgrade and the flood level impact in the 10% AEP event. As shown on the figure, the area of beneficial impact is extensive, with flooding in the hotspot relieved, as well as a large area on the tennis courts, netball courts and playing fields downstream that is no longer flooded. There is a minimal decrease on Anzac Parade of around 0.05 m, while there is an increase of 0.28 m in Centennial Park.

Evaluation

The reduction in peak flood level provided by the upgrade is only possible with exceptionally large pipe sizes, which are not economically feasible. The flat grading of this lower part of the catchment places a large constraint on the design of any additional drainage to service the area. Given that no economic costs are associated with the current flood issue (as no properties are flooded), the high cost of the upgrade cannot be compared to any estimated cost of flooding. For this reason, it is unlikely that the option will be recommended for implementation. More information on the option's costing is given in Section 9.3.6.

9.3.6. Economic Assessment of Site Specific Options

The cost effectiveness of the site specific management options in reducing flood liability within the catchment was determined using the benefit/cost (B/C) approach. A costing was estimated for each option and this was compared, where appropriate, to the option's reduction in AAD. Where no significant benefit to AAD was found, the option's cost effectiveness was assessed qualitatively.

Costing

Detailed cost estimates have been prepared for each option and these are summarised in Table 15, with detailed costing in Appendix C. 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. For FM-CP02, the very large capacity of the upgrade's pipes meant that the width of the upgrade was comparable to the width of the available area (i.e. roadway and footpaths). Such a large upgrade would incur additional costs due to the re-location of existing services, and this has been accounted for by a higher contingency multiplier in the costing estimates.

Table 15: Costings of Management Options

SUMMARY	Capital	Maintenance per year
FM – CP01 - Trunk drainage upgrade from corner of Poate Road to SCG under Fox Studios	$2,001,700	$2,100
FM – CP02 - Trunk drainage upgrade on Leinster and Stewart to Oatley Road and down to Moore Park Road.	$8,863.300	$3,600
FM - CP03 - Drainage upgrade on Lang Road for pipes into Centennial Park.	$108,500	$200
FM - CP04 - Regrade Driver Avenue to allow water to flow down the road rather than pooling in the low point	$5,769,200	$0
FM - CP05 - Drainage upgrade on Lang Road through the park to ANZAC Parade.	$24,176,000	$8,700

Table 15 shows that the trunk drainage upgrade from Lang Road to the outlet (FM – CP05) is the most costly. This option, along with the upgrades on Poate Road and Leinster/Stewart Street, entails significant pipe upgrades and all three are costly to implement. Re-grading Driver Avenue is also costly, due to the volume and area of excavation involved.

Damage Assessment

The total damage costs were also evaluated for FM – CP02 (Drainage upgrade for Leinster/Stewart Street). 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, and was then compared to the same assessment under existing conditions. FM – CP02 was found to have an annual average damages cost of $371,900, which is a reduction of $282,700 from the existing AAD.

Damages calculations for other management options were not assessed, as they either produced significant downstream impact or only benefited flooded roads, which are not included in the damages assessment.

Benefit Cost Ratio of Options

Following estimation of the option's cost and AAD, the benefit/cost ratio (B/C) of FM – CP02 was calculated. The B/C is the ratio of the net present worth of the reduction in flood damages (benefit) compared to the cost of the works and is used to compare the economic worth of a set of works to others in the area. The net present worth (NPW) of the AAD reduction was calculated to be $4,174,736, based on a lifespan of 50 years and a 7% discount rate, while the NPW of the cost of the option (capital + maintenance costs) was calculated to be $8,916,198. This gives the option a B/C of 0.5, which indicates the economic benefit of the option is approximately half of its cost. The damages estimation under the option is given in detail in Appendix D.

The analysis does not consider social factors, environmental factors and risk to life which cannot be quantified in monetary terms but would have been a net contributor to the benefits that could be gained from these management options.

9.3.7. Other Site Specific Management Options Considered

Each hotspot had a range of management options that were assessed to manage the flood risk

in the area. Of these options, those that were determined to have the greatest benefit, or were the most technically or economically feasible, were assessed in detail. For the Centennial Park catchment, these are the previously described options, FM – CP01 to FM - CP05. Other options were assessed in the hotspots that were discarded, and these are presented in Table 16. The table also lists why the option was not considered further. For example, purchasing land and removing a house on Stewart Street does not relieve the topographic depression, as the house is not preventing runoff leaving the depression.

Table 16: Other Site Specific Management Options Considered

Hotspot	Option	Reason Discarded
Poate Road	Regrading the road so flow doesn't accumulate in the unrelieved corner (existing issue)	Too large a regrade is required (> 1 m), would also impact on Fox Studios overland flow.
Stewart/Leinster Street	Establish a new flowpath by removing a house on Moore Park Road (via voluntary purchase)	New flowpath does not relieve the depression as Leinster Street depression is lower than Moore Park Road
Lang Road near Darvall Street	Upgrade the pit capacity without changing pipes	Lowered park has limited storage capacity, drainage achieves benefit, only addresses in Palmer Street in isolation
Lang Road near Driver Avenue	Establish an overland flowpath above the trunk drainage line	Significant benefit, but very localised – does not extend south of Bland Street.
Driver Avenue	Detention basin on park land adjacent to Hordern Pavilion, and, upgrading pipe system along Driver Avenue	Both options relieve Driver Avenue issue, but exacerbate flooding at Lang Road. Same issues as FM – CP04

9.4. Catchment Wide General Management Measures

9.4.1. Response Modification – Variable Message Display (RM-CP01)

DESCRIPTION

Although a catchment wide flood warning system has been excluded as described in Section 9.2.3, there may be an opportunity to develop localised warning and notifications to alert the community during a flood to areas that are flooded or will be in the near future. Variable message displays on main roads in the area would be able to warn drivers not to enter floodwaters. Lang Road and Moore Park Road are the main roads in the area, with the flood affectation concentrated at Lang Road (minor ponding has been reported on Moore Park Road near Driver Avenue). The displays would likely be operated by Roads and Maritime Services (RMS).

DISCUSSION

Variable Message Displays on major roads, such as Lang Road near Driver Avenue, would reduce the flood risk associated with vehicles entering floodwaters and becoming stranded. The Lang Road low point has up to 0.8 m in the 10% AEP event and is therefore capable of disabling a vehicle that drives through the ponding. At present, there is a variable message sign at the hotspot that could be used as a flood warning. The nature of urban areas means vehicles or

pedestrians may underestimate flood hazard, and unknowingly try to cross the floodwaters. For example, in October 2014, a small flood inundated part of Parramatta Road in Summer Hill, and people became stranded in their cars and required SES assistance. The written warnings would aim to avoid this scenario by communicating the risk to people in the area and suggesting an alternative route.

EVALUATION

The measure is inexpensive relative to other options and it has the ability to manage the risk associated with people and vehicles entering floodwaters. However, people do not always heed flood warnings. Consideration should also be given to possible diversion routes and how traffic in a flood can be managed.

9.4.2. Response Modification - Evacuation Planning (RM – CP02)

DESCRIPTION

Significant property inundation in a rare flood may force residents to evacuate their homes. Residents will either leave of their own accord, as they feel their property is uninhabitable, or they will be issued an evacuation order. The SES has responsibility for evacuating people due to flooding. The sudden nature of flooding in the catchment means little to no warning is available for a flood event, and so the evacuation would almost certainly take place during or after the storm event.

DISCUSSION

The main issues with all flood evacuations are:

- they must be carried out quickly and efficiently,
- they are hazardous for both rescuers and evacuees,
- residents are generally reluctant to leave their homes, causing delays and placing more stress on the rescuers,
- people do not appreciate the dangers of crossing floodwaters.

The nature of flooding in Centennial Park creates additional issues for evacuation. These include:

- The short duration of flooding in the catchment means that the evacuation itself will be of comparable time to remaining indoors and waiting for the flood to recede.
- The limited warning time means that many residents may evacuate at the same time, creating gridlock and placing them in a more dangerous situation than not evacuating. Furthermore, areas that require evacuation the most (i.e. where significant depths occur) will likely not be accessible in a standard vehicle, forcing residents to leave on foot.

EVALUATION

Evacuation of residents in the catchment has significant associated risks and may increase the flood risk in the brief time (typically, hours) that residents are flood affected. Furthermore, the more widespread the evacuation is, the greater the risk of gridlock and people becoming stranded. In general, evacuation should not be undertaken, unless there is exceptionally hazardous flooding at a property.

9.4.3. Response Modification - Public Information and Raising Flood Awareness (RM – CP03)

DESCRIPTION

A community with high flood awareness will suffer less damage and disruption during and after a flood because people are knowledgeable about the flood and what is required of them. The success of any flood warning system and the evacuation process depends on:

Flood Awareness: How aware is the community to the threat of flooding? Has it been adequately informed or educated?

Flood Preparedness: How prepared is the community to react to the threat? 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? How will the evacuation be done, where will the evacuees be moved to?

DISCUSSION

In catchments 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. The level of trauma or anxiety may be reduced as people have "survived" previous floods and know how to handle both the immediate emergency and the post rehabilitation phase in a calm and efficient manner.

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*. A major flood causing a high degree of flood damage in relatively recent times will increase flood awareness. If no floods have occurred, or there have been a number of small floods which cause little damage or inconvenience, then the level of flood awareness may be low. In Centennial Park, there is little experience of flooding that has caused major disruption to residents (e.g. overfloor flooding). There are, however, localised hotspots that have a high awareness of flooding, for example in Victoria Street.

- *History of residence.* Families who have owned properties for a long time will have established a considerable depth of knowledge regarding flooding and a high level of flood awareness. A community which consists predominantly of short lease rental homes will have a low level of flood awareness. As discussed in Section 4.1.2, a high portion of residents have only recently moved into the catchment and the most residents live in rented accommodation.

- *Whether an effective public awareness has been implemented.* It is understood that no large scale awareness program has been implemented in the catchment. However, flooding information is available via the publicly available Flood Study (Reference 2) completed for the catchment, and residents are well informed of the floodplain risk management process through newsletters sent out as part of each study.

For flood 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 information and levels of awareness diminishes as the time since the last flood increases. Often a major hurdle is convincing residents that major floods, larger than those previously experienced, will occur in the future. Table 17 lists tools that can be used to promote public awareness of flooding in an area.

Table 17: Public Information Tools

Method	Comment
Letter/Pamphlet from Council	These may be sent annually or biannually with the rate notice or separately. The pamphlet can inform residents of subsidies, changes to flood levels or any other relevant information.
School Project or Local Historical Society	This provides an excellent means of informing the younger generation about flooding. It may involve talks from various authorities and can be combined with topics relating to the natural environment, etc.
Displays at Libraries / community centres	This is an inexpensive, passive, way of informing the community and may be combined with related information.
Historical Flood Markers	Signs or marks can be prominently displayed on telegraph poles or such like to indicate the level reached in previous floods. Depth indicators advice of potential hazards.
Articles in Local Newspapers	Ongoing articles in newspapers will ensure that the problem is not forgotten. Historical features and remembrance of the anniversary of past events make good copy.
Collection of Data from Future Floods	Collection of data 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	Council may wish to advice interested parties on the flood information currently available and how it can be obtained at cost when they inquire during the property purchase process.
Establishment of Flood Affectation Database	A database would provide information on (say) which houses require evacuation, which public structures will be affected (e.g. telephone or power cuts). This database should be reviewed after each flood event.
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, led by the SES would ensure that the community is adequately prepared.
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. Residents have a responsibility to advice Council if they see a problem such as potential debris blockage.

EVALUATION

A program aimed at raising flood awareness in the catchment is a cost-effective measure that will reduce the flood risk in the area. There is generally little perception of the risk of high hazard flooding in the area. In similar studies in urban areas that are not perceived as having a flood issue, photos of historical floods communicate well the possible floods that can occur.

9.4.4. Response Modification – Local Flood Plan and DISPLAN (RM – CP04)

DESCRIPTION

As described previously, it may be necessary for a small number of residents to evacuate their homes in a major flood. This would usually be undertaken under the authority of the lead agency under the DISPLAN, the SES. Based on the duration of flooding in the catchment (typically, hours) and the risks associated with evacuation, it may be that evacuation is undertaken on a case by case basis. 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 preparation of a flood emergency response plan aims to minimise the risk associated with evacuations (described in Section 9.4.2) by providing information regarding evacuation routes, refuge areas, and generally what processes should be followed in a flood. It is the role of the SES to develop this plan for flood-affected communities.

DISCUSSION

As recommended in Section 6.2, a DISPLAN should be prepared for the Sydney East Emergency Management District (of which Centennial Park 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 East Metropolitan District Emergency Operations Controller and Local Emergency Operations Controllers within the 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 SES prepare a Local Flood Plan in conjunction with the City of Sydney (who shall supply the necessary data) 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 (specifically recommended in Section 9.4.1).
- 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 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 be prepared for the Sydney East Emergency Management District, and Council, with the help of the SES should prepare a Local Flood Plan 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.

9.4.5. Property Modification - Flood Planning Levels (PM – CP01)

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 7) 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.

EVALUATION

A review of the FPLs put forward by Council in their *Interim Floodplain Management Policy* (Reference 7) 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.

9.4.6. Property Modification - Flood Proofing (PM – CP02)

DESCRIPTION

Flood Proofing involves the sealing of entrances, windows, vents, etc., to prevent or limit the ingress of floodwaters. It is only suitable for brick buildings with concrete floors and can prevent ingress for outside depths of approximately one metre. Greater depths may cause collapse of the structure unless water is allowed to enter.

DISCUSSION

In general, flood proofing requires sealing of doors (new frame, seal and door); sealing and re-routing of ventilation gaps in brickwork; sealing of all underfloor entrances and checking of brickwork to ensure that there are no gaps or weaknesses in the mortar. It will not reduce the flood hazard, and in fact may increase the true hazard if residents stay in their houses and a large flood eventually inundates the building. A typical benefit/cost ratio is high and there are no significant environmental and social problems.

An assessment of the variation in types of flood proofing, the flood depths to which can be protected, and the costs involved, is required before the option can be fully recommended. Past experience indicates that some types of flood proofing are affordable relative to the cost of flooding, for example, in some cases, an existing house could be sealed for approximately $20,000. In the case of a new house of extension, the cost of flood proofing would be less if included as part of the construction. There is also variation in the types of property that can be proofed, for example, it is easier to apply to commercial premises where there are only one or two entrances, and maintenance and operation procedures can be better enforced.

EVALUATION

Preliminary assessment has indicated that flood proofing is a good solution to reducing flood risk to commercial and industrial properties. Based on previous experience, the option can be cost-effective relative to drainage upgrades or other structural works, and easier to implement. 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.

9.4.7. Property Modification – Feasibility Study for City of Sydney Flood Proofing (PM – CP03)

DESCRIPTION

As discussed in the previous option, flood proofing involves modifications to a building's exterior in order to prevent the ingress of floodwater. Where flood proofing is not undertaken by property owners, it may be possible for City of Sydney to undertake mitigation works if the property is put up for sale. That is, for a severely flood affected properties, City of Sydney may purchase the property so that works on it can be undertaken, and then the property is put up for sale soon after. Such a scheme would be most suited to areas with significant overfloor flood affectation where structural measures (for example, drainage upgrades) are not feasible.

DISCUSSION

A Council-led program that involves the purchase, renovation and selling of flood-affected land is a straightforward variation on other Council-led property modification measures, and will provide benefit to properties that do not have other available options. The nature of the flood issue in Centennial Park is that although there is significant overfloor flood affectation, it is concentrated in several localised areas. This makes structural options difficult to justify, and it is possible that a property's flood risk will remain indefinitely.

As the option can only be implemented when an affected property is put on sale, such a program's implementation would be very gradual and would be undertaken over a long period of time. In this sense, the option is an extension of Council's FPL policy, whereby minimum floor levels are required when a flood-affected property is re-developed. A Council-led flood proofing program would account for the flood affected properties that are not re-developed and therefore would not otherwise have their floor levels raised.

Although such a program has some similarity to a voluntary purchase scheme, it would be markedly less obtrusive and would not reduce the number of dwellings in the catchment. Voluntary purchase involves returning severely-affected land on a floodway to the floodplain, whereas in Centennial Park, affected properties are not necessarily on a floodway and restoring an area's natural flowpath (for example, in a trapped depression) would adversely impact downstream properties and may impact an area's streetscape and character. Most significantly, a flood proofing program would only involve properties that are available for purchase, meaning there would be no disruption to the existing property market. This would be further ensured by having no publicly available information on which properties would be targeted by such a program.

EVALUATION

A flood proofing program undertaken by the City of Sydney could significantly alleviate property affectation and give Council an alternative to drainage upgrades in areas where they are prohibitively expensive and not cost-effective. It would also allow Council to extend their

objective of raising flood affected properties (via an FPL) to affected properties by improving properties that may not otherwise have their floor level raised. Although such a program has several apparent benefits, its feasibility should be investigated further to determine whether it can be cost-effective (based on the cost of purchasing, flood-proofing and re-selling a property compared to the existing economic cost of flooding) and what social impacts may exist.

9.4.8. Property Modification - Development Control Planning (PM – CP04)

DESCRIPTION

The catchment's location in inner Sydney means 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 7) 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 7.1.2. 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 7). 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. Assessment Matrix

Multi-variate decision matrices are recommended in the Floodplain Development Manual (Reference 1) and therefore it is also a recommendation of this report that multi-variate decision matrices be developed for specific management areas, allowing detailed benefit/cost estimates, community involvement in determining social and other intangible values, and local assessment of environmental impacts.

The criteria assigned a value in the management matrix are:

- Risk to life;
- Impact on flood behaviour (reduction in flood level, hazard or hydraulic categorisation)

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;
- Long term performance;
- Environmental and ecological benefits;
- Impacts on the State Emergency Services;
- 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 18 and largely relates to the impacts in a 1% AEP event. The matrix below 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 18: 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	minor	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

A draft assessment matrix has been included in the following section. It will be updated for the final report with the results of the community consultation.

9.5.1. Results

The assessment matrix is given in Table 19, with each of the assessed management options

scored against the range of criteria. ‘Community Acceptance’ has not been scored at this time, as the community information session is yet to be held (the matrix will be updated when the information is available). Also, 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 is rather for the purpose of providing an easy framework for comparing the various options on an issue by issue basis which stakeholders can then use to make a decision. For the same reason, the total score given to each option, and the subsequent rank, is only an indicator to be used for general comparison.

Table 19: 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-CP01	Trunk Drainage Upgrade - Poate Road	9.3.1	5%	3	2	-3	N/A*	-1	-2	0	1	-3	1	2	0	10=
FM-CP02	Trunk Drainage Upgrade - Stewart and Leinster Street	9.3.2	5%	3	3	-3	N/A	-3	-3	0	2	-1	1	2	1	8=
FM-CP03	Drainage Upgrade - Lang Road North	9.3.3	10%	2	1	0	N/A	-2	-1	-1	1	0	1	0	1	8=
FM-CP04	Trunk Drainage Upgrade - Driver Avenue	9.3.4	10%	3	1	-3	N/A	-3	-2	-1	2	-1	1	1	-2	12=
FM-CP05	Trunk Drainage Upgrade - Lang Road	9.3.5	10%	3	0	-3	N/A	-2	-3	-1	2	-1	1	2	-2	12=
Response Modification Measures																
RM-CP01	Variable Message Display	9.4.1	N/A	0	0	2	N/A	2	2	0	2	1	0	1	10	2
RM- CP02	Evacuation Planning	9.4.2	N/A	0	0	-1	N/A	0	2	0	1	2	0	1	5	7
RM-CP03	Public Information and Raising Flood Awareness	9.4.3	N/A	0	0	1	N/A	1	2	0	2	1	-2	1	6	6
RM-CP04	Local Flood Plan and DISPLAN	9.4.4	N/A	0	0	0	N/A	2	2	0	2	2	1	2	11	1
Property Modification Measures																
PM-CP01	Flood Planning Levels	9.4.5	N/A	0	0	0	N/A	2	2	0	1	0	3	1	9	5
PM-CP02	Investigate Flood Proofing	9.4.6	N/A	0	0	0	N/A	1	3	0	1	2	2	1	10	2
PM-CP03	Voluntary Purchase	9.4.7	N/A	0	0	-2	N/A	1	-1	0	1	-2	2	1	0	10
PM-CP04	Development Control Planning	9.4.8	N/A	0	0	0	N/A	2	2	0	1	1	3	1	10	2

*'Community Acceptance' will be completed following a community information session as part of the Public Exhibition

As shown in the matrix, the structural measures score lowly on economic merit, as they do not have favourable B/C ratios, and on financial feasibility, as all require a large capital outlay. In addition, they have technical feasibility issues, either relating to the potential issues in the design of the required drainage (except for Lang Road North, which is relatively straightforward), or due to their adverse downstream impacts. Low scores in these three categories result in a much lower score than most of the response modification and property modification measures.

The five highest ranking measures scored between 9 and 11, which indicates that they are all generally equivalent under this assessment. They all require relatively little financial outlay, and will lower the economic cost of flooding in the catchment. Public information and flood awareness also scores well, but ranks lower due to its limited long term performance, an issue also associated with evacuation planning. Voluntary purchase is difficult to justify as it is has issues with its technical feasibility, in that it would be very different to a typical VP scheme, and the political/administrative issues associated with buying flood-affected houses.

Based on the matrix, the options for future implementation are ranked in the order as tabulated in Table 20.

Table 20: Ranking of Management Options

Rank	Ref	Options	Score
1	RM-CP04	Local Flood Plan and DISPLAN	11
2=	PM-CP02	Investigate Flood Proofing	10
2=	RM-CP01	Variable Message Display	10
2=	PM-CP04	Development Control Planning	10
5	PM-CP01	Flood Planning Levels	9
6	RM-CP03	Public Information and Raising Flood Awareness	6
7	RM-CP02	Evacuation Planning	5
8=	FM-CP02	Trunk Drainage Upgrade - Stewart and Leinster Street	1
8=	FM-CP03	Drainage Upgrade - Lang Road North	1
10=	PM-CP03	Voluntary Purchase	0
10=	FM-CP01	Trunk Drainage Upgrade - Poate Road	0
12=	FM-CP04	Trunk Drainage Upgrade - Driver Avenue	-2
12=	FM-CP05	Trunk Drainage Upgrade - Lang Road	-2

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

Of the 13 management options presented here, 11 have been recommended for implementation as part of the Centennial Park Catchment Floodplain Risk Management Plan. The two discarded options are FM-CP01 and FM-CP04. Both options were found to produce significant adverse impacts downstream of the works, at Lang Road in the case of FM-CP04 and through the SCG precinct in the case of FM-CP01. Both downstream impacts are unacceptably large and mean the options cannot be recommended.

10. REFERENCES

1. NSW Government
Floodplain Development Manual
April 2005

2. WMAwater
Centennial Park Flood Study
Draft Report, June 2013

3. WMAwater
Kensington – Centennial park Flood Study
Final Report, April 2013

4. Centennial Parklands
Strategic Land Use Vision
http://www.centennialparklands.com.au/about/planning/strategic_land_use_vision
Accessed June 2014

5. Sydney Water Corporation
City Area SWC 30 Capacity Assessment
Sydney Water Corporation, July 1996

6. City of Sydney
Sydney Local Environmental Plan 2012
2012

7. City of Sydney
Draft Interim Floodplain Management Policy
July 2013

8. NSW Department of Environment and Climate Change
Flood Emergency Response Classification of Communities
October 2010

9. Howells *et. al.*
Defining the Floodway – Can One Size Fit All?
2004

10. NSW Department of Environment and Climate Change
Floodplain Risk Management Guideline – Residential Flood Damages
October 2007

Figures

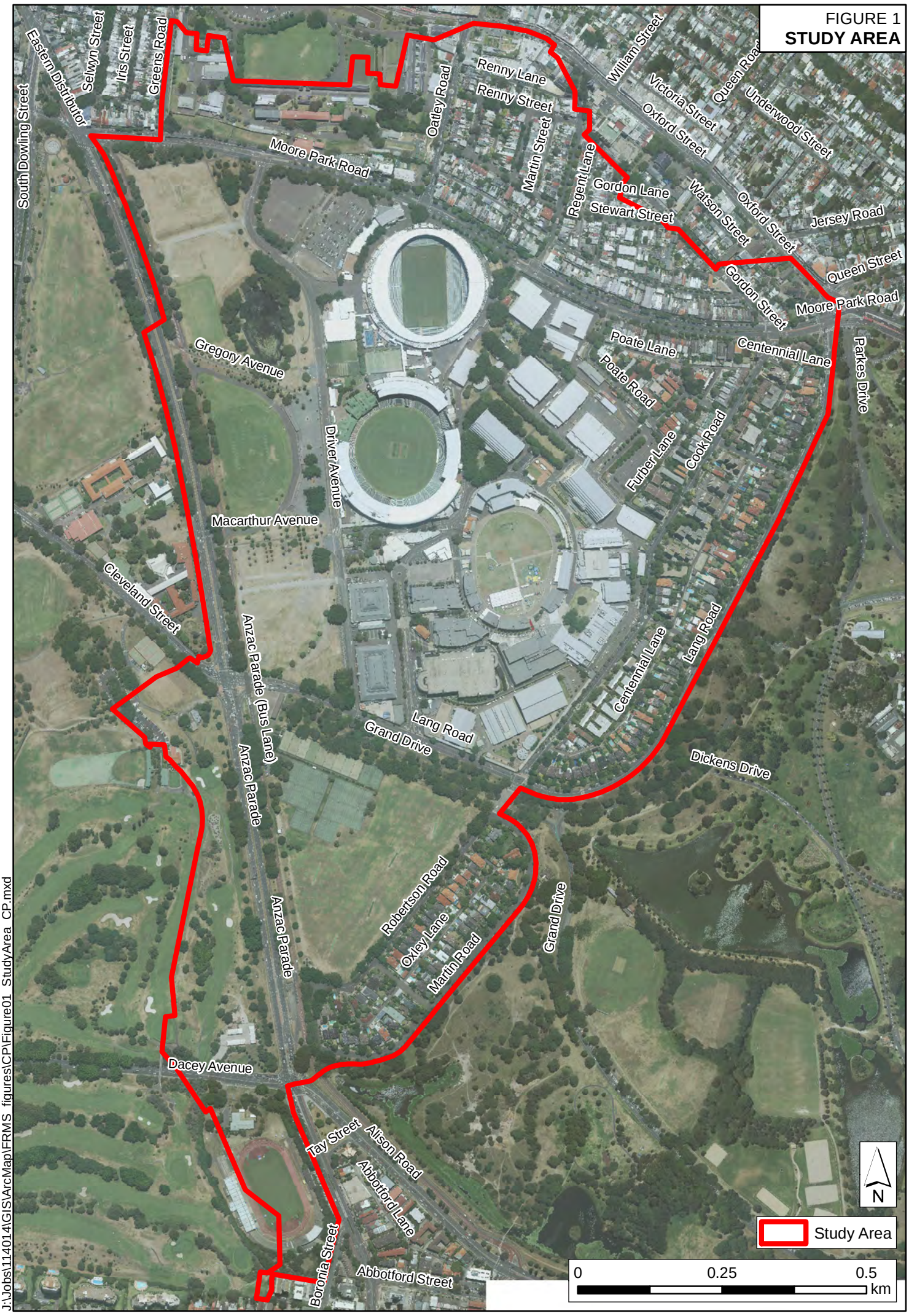


FIGURE 1
STUDY AREA
Eastern Distributor
Selwyn Street
Iris Street
Greens Road
South Dowling Street
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
William Street
Victoria Street
Oxford Street
Queen Road
Underwood Street
Regent Lane
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Parkes Drive
Gregory Avenue
Poate Lane
Poate Road
Centennial Lane
Furber Lane
Cook Road
Driver Avenue
Macarthur Avenue
Cleveland Street
Anzac Parade (Bus Lane)
Anzac Parade
Lang Road
Centennial Lane
Grand Drive
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Dacey Avenue
Tay Street
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS_figures\CP\Figure01_StudyArea_CP.mxd

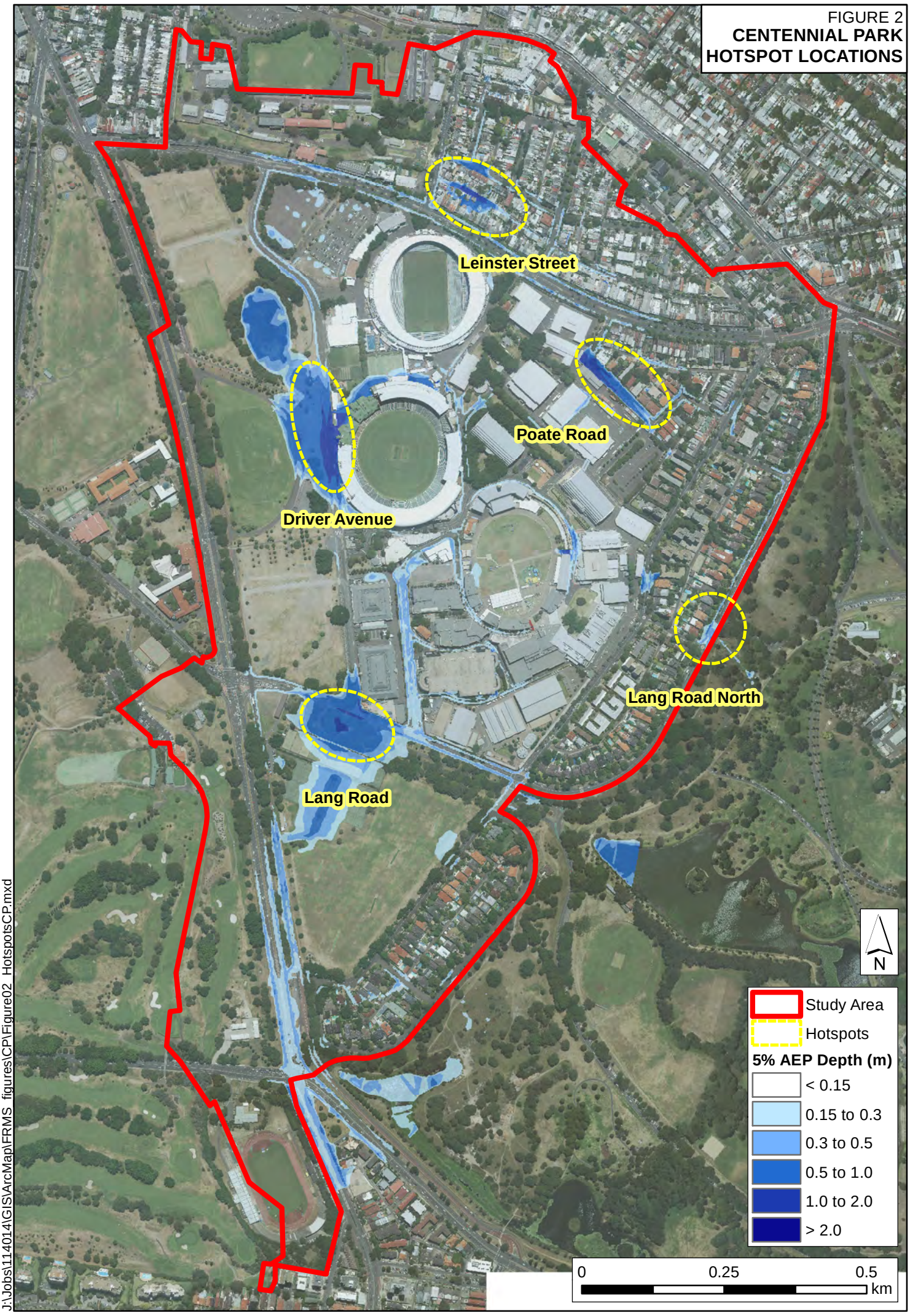


FIGURE 2
CENTENNIAL PARK
HOTSPOT LOCATIONS
Leinster Street
Poate Road
Driver Avenue
Lang Road North
Lang Road
N
Study Area
Hotspots
5% AEP Depth (m)
< 0.15
0.15 to 0.3
0.3 to 0.5
0.5 to 1.0
1.0 to 2.0
> 2.0
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure02 HotspotsCP.mxd

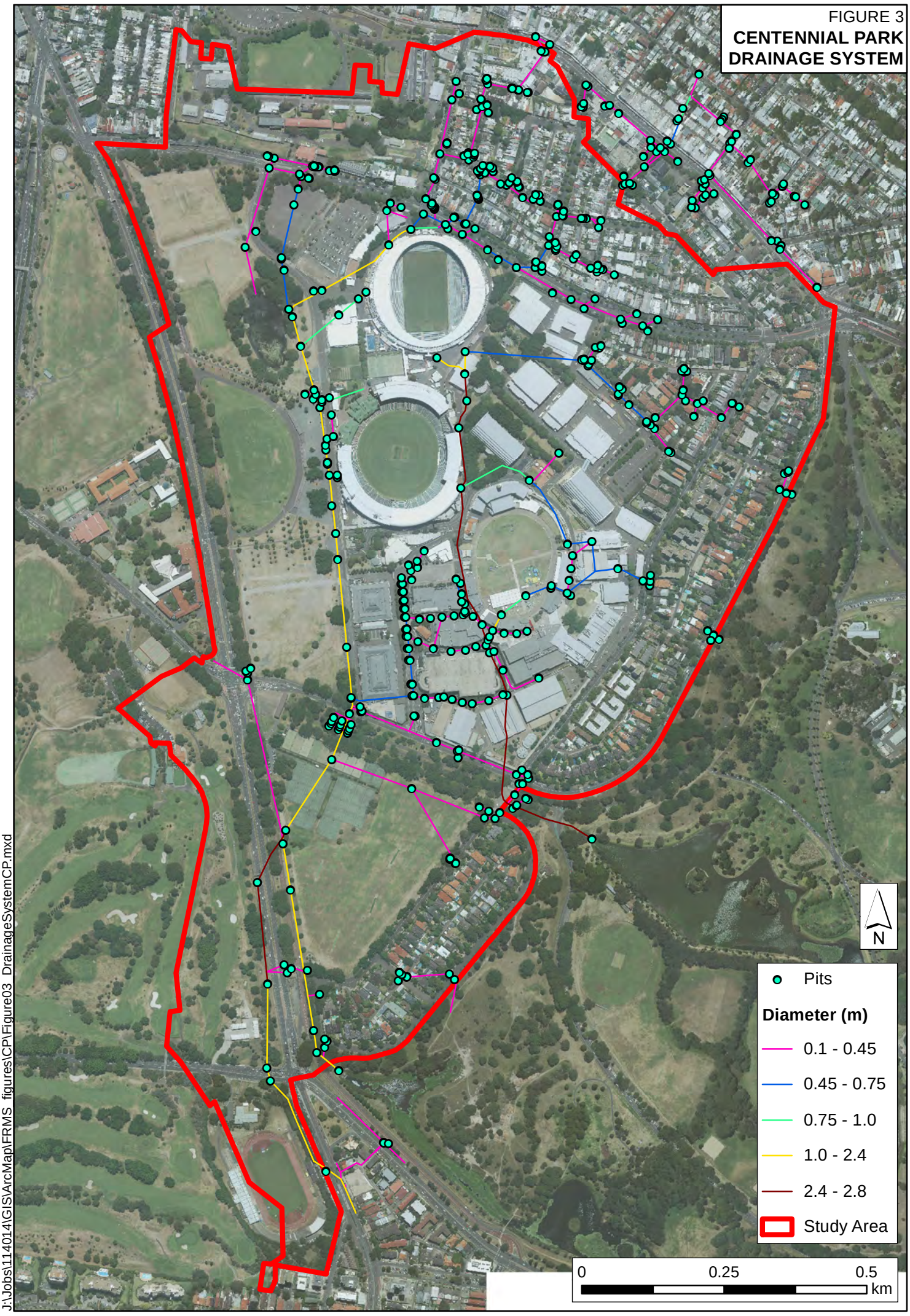


FIGURE 3
CENTENNIAL PARK
DRAINAGE SYSTEM
N
Pits
Diameter (m)
0.1 - 0.45
0.45 - 0.75
0.75 - 1.0
1.0 - 2.4
2.4 - 2.8
Study Area
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure03 DrainageSystemCP.mxd

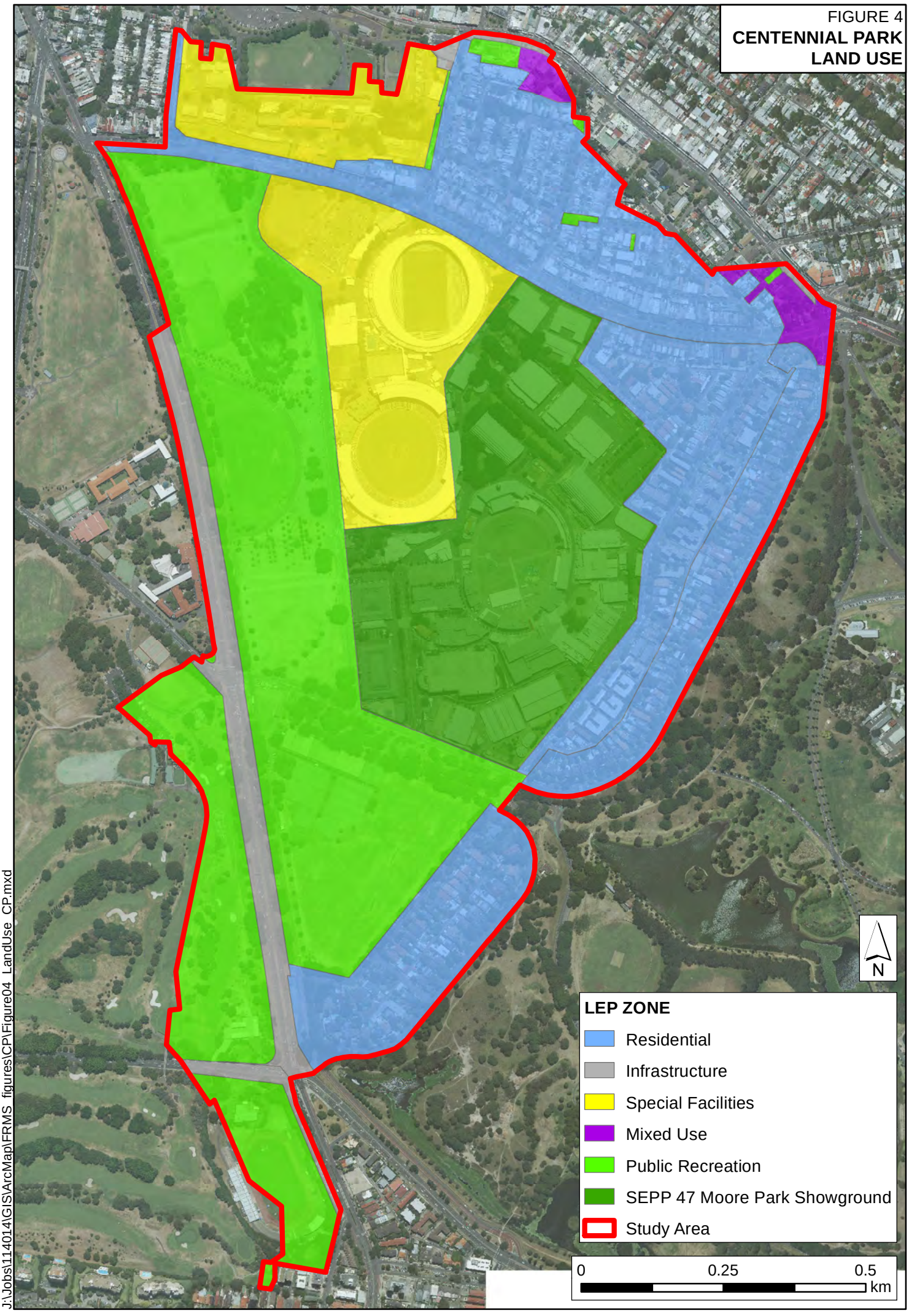


FIGURE 4
CENTENNIAL PARK
LAND USE
N
LEP ZONE
Residential
Infrastructure
Special Facilities
Mixed Use
Public Recreation
SEPP 47 Moore Park Showground
Study Area
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS_figures\CP\Figure04_LandUse_CP.mxd

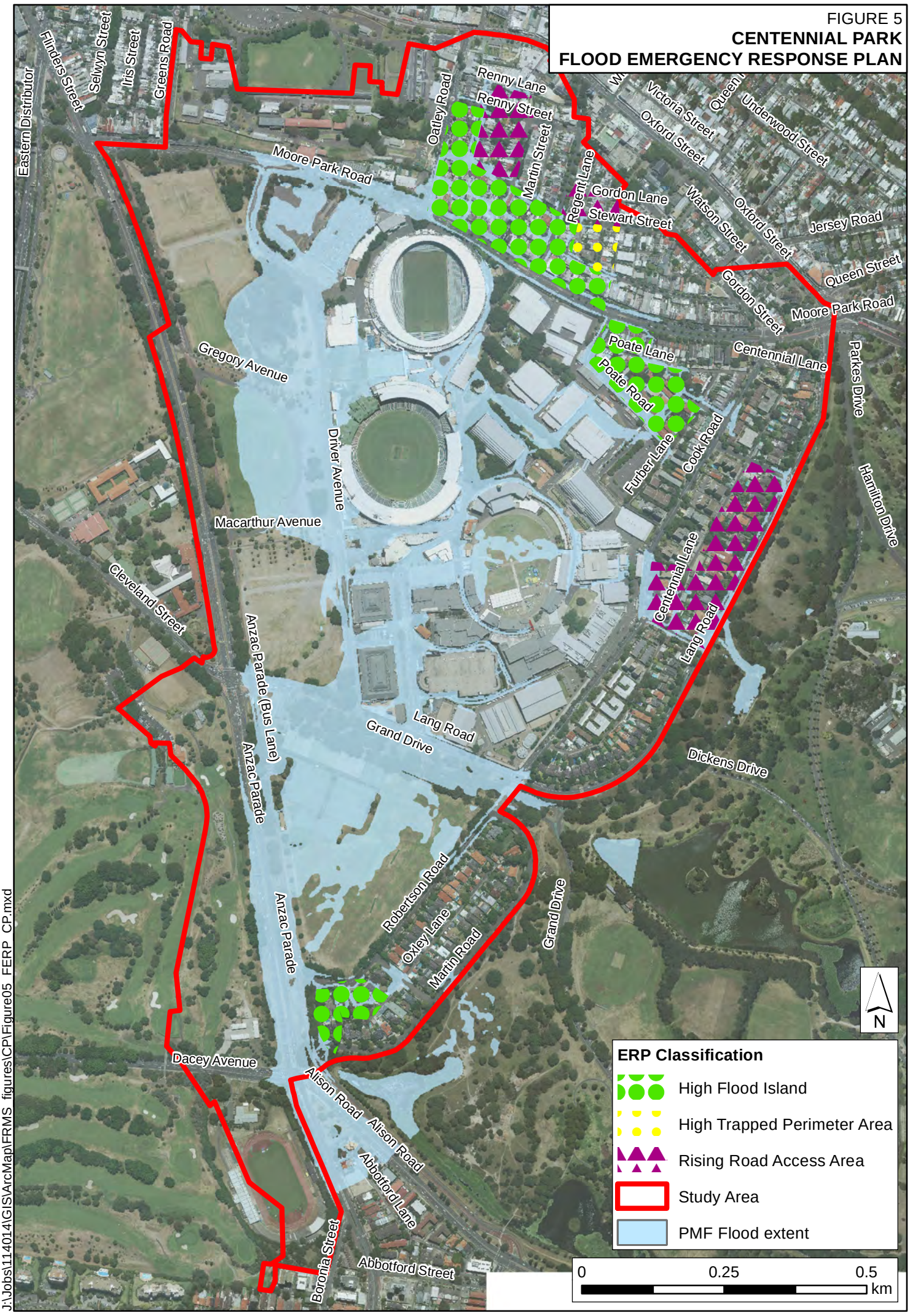


FIGURE 5
CENTENNIAL PARK
FLOOD EMERGENCY RESPONSE PLAN
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
Regent Lane
Gordon Lane
Stewart Street
Victoria Street
Oxford Street
Queen
Underwood Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Gregory Avenue
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Centennial Lane
Lang Road
Anzac Parade (Bus Lane)
Anzac Parade
Lang Road
Grand Drive
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Anzac Parade
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
ERP Classification
High Flood Island
High Trapped Perimeter Area
Rising Road Access Area
Study Area
PMF Flood extent
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure05 FERP CP.mxd

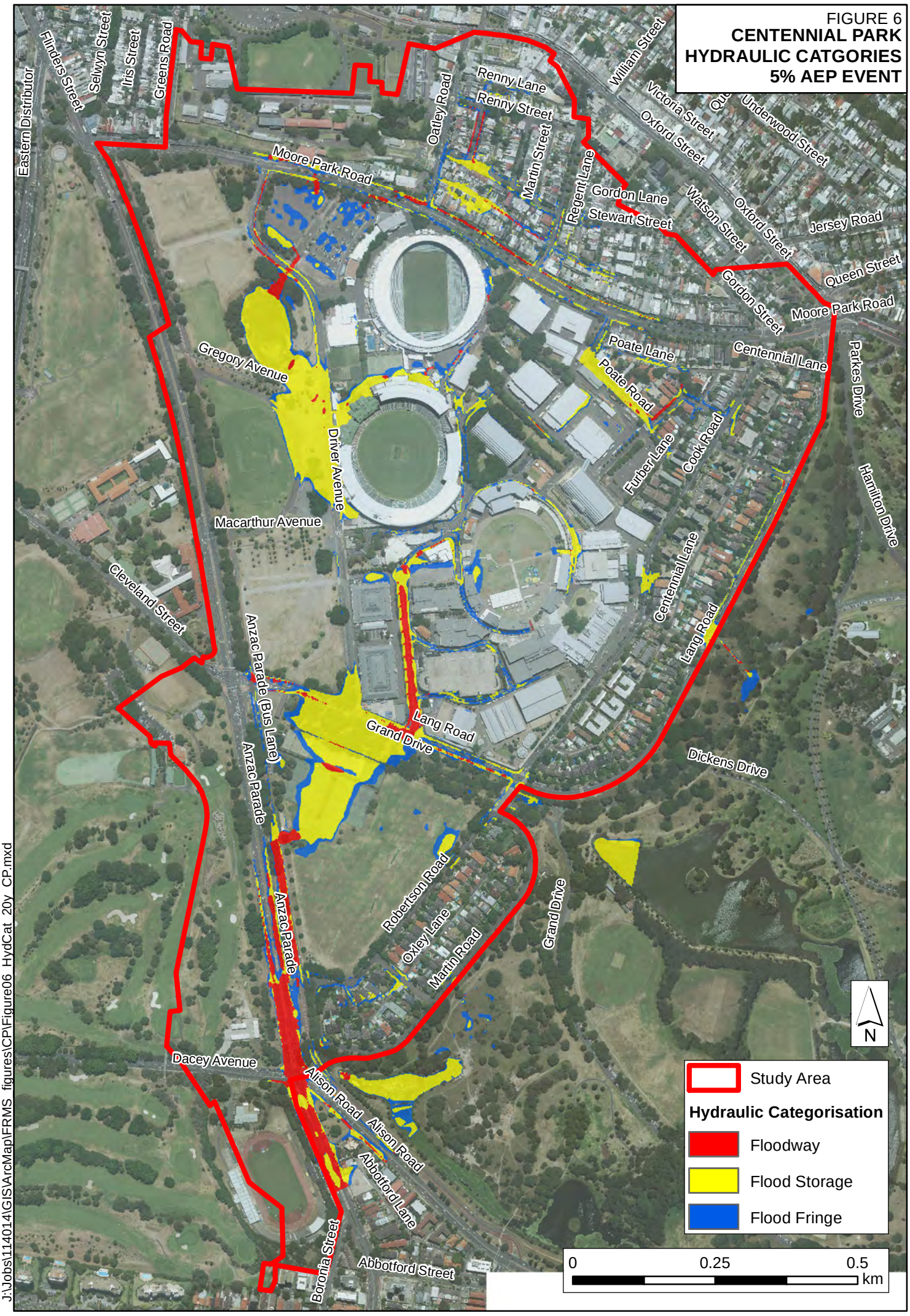
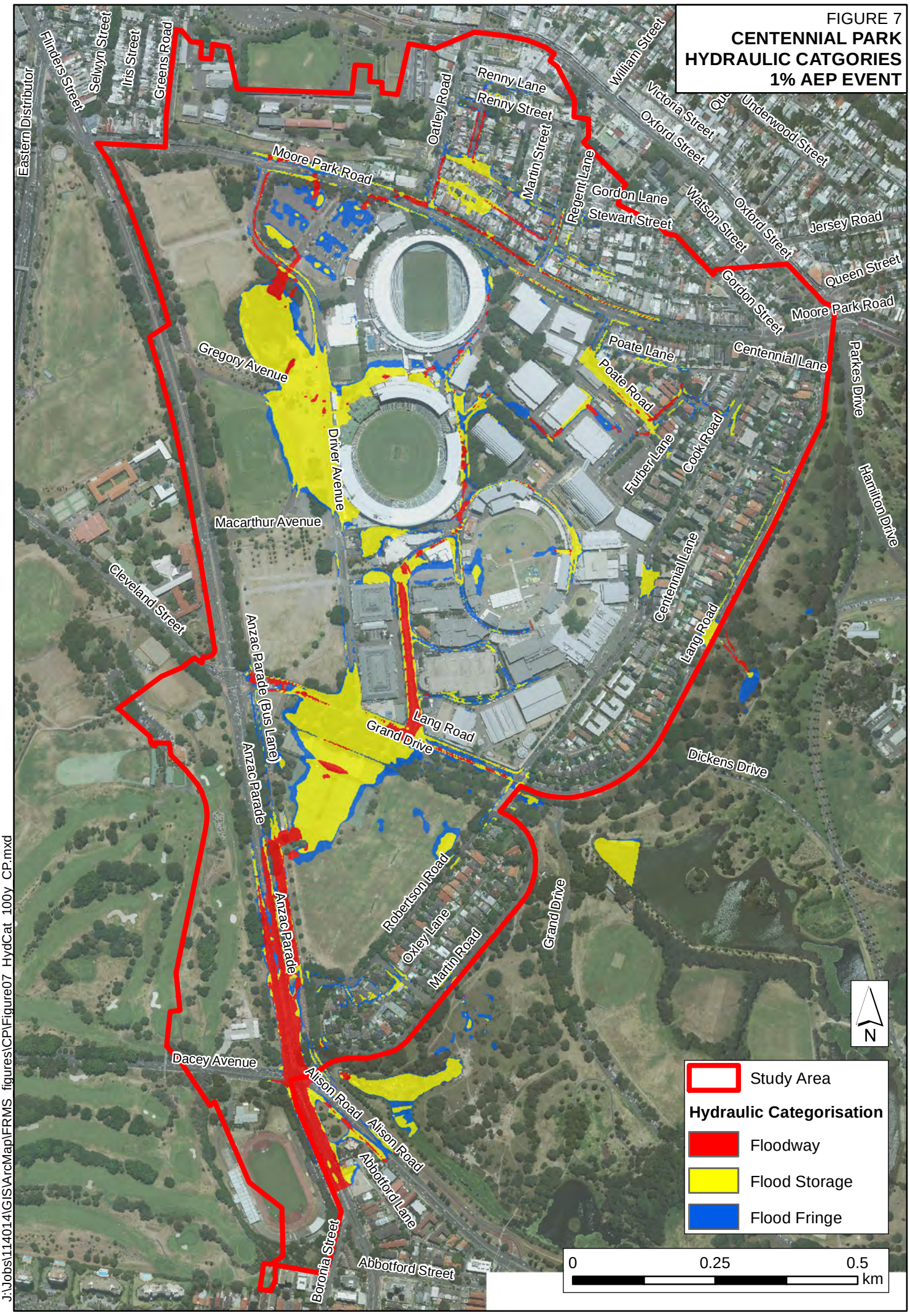


FIGURE 6
CENTENNIAL PARK
HYDRAULIC CATGORIES
5% AEP EVENT
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
William Street
Victoria Street
Oxford Street
Underwood Street
Regent Lane
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Gregory Avenue
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Anzac Parade (Bus Lane)
Anzac Parade
Lang Road
Grand Drive
Centennial Lane
Lang Road
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure06 HydCat 20y CP.mxd



J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure07 HydCat 100y CP.mxd

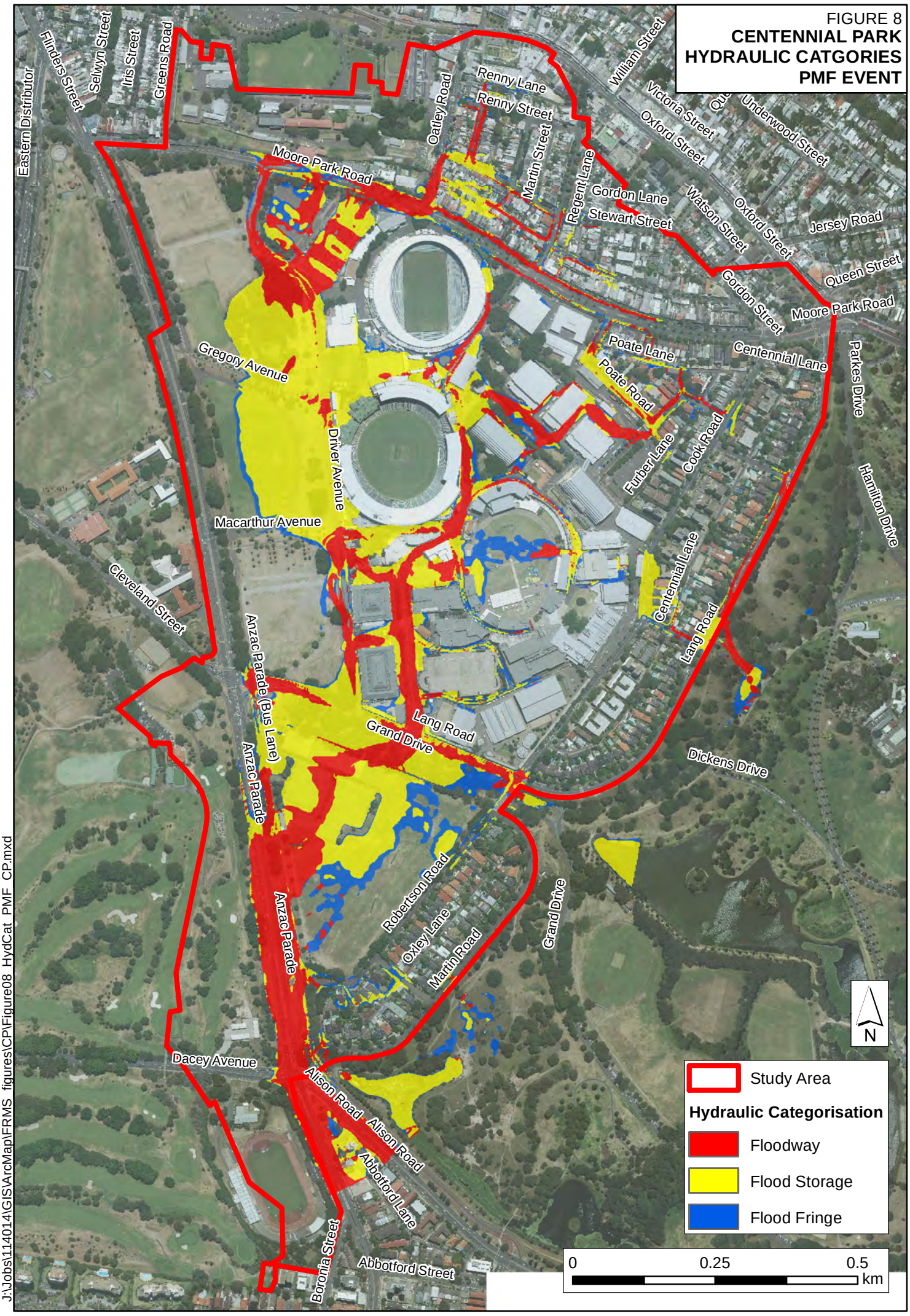


FIGURE 8
CENTENNIAL PARK
HYDRAULIC CATGORIES
PMF EVENT
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Oatley Road
Renny Lane
Renny Street
William Street
Victoria Street
Oxford Street
Underwood Street
Martin Street
Regent Lane
Moore Park Road
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Gregory Avenue
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Centennial Lane
Lang Road
Anzac Parade (Bus Lane)
Grand Drive
Lang Road
Dickens Drive
Anzac Parade
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Anzac Parade
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
Hydraulic Categorisation
Floodway
Flood Storage
Flood Fringe
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure08 HydCat PMF CP.mxd

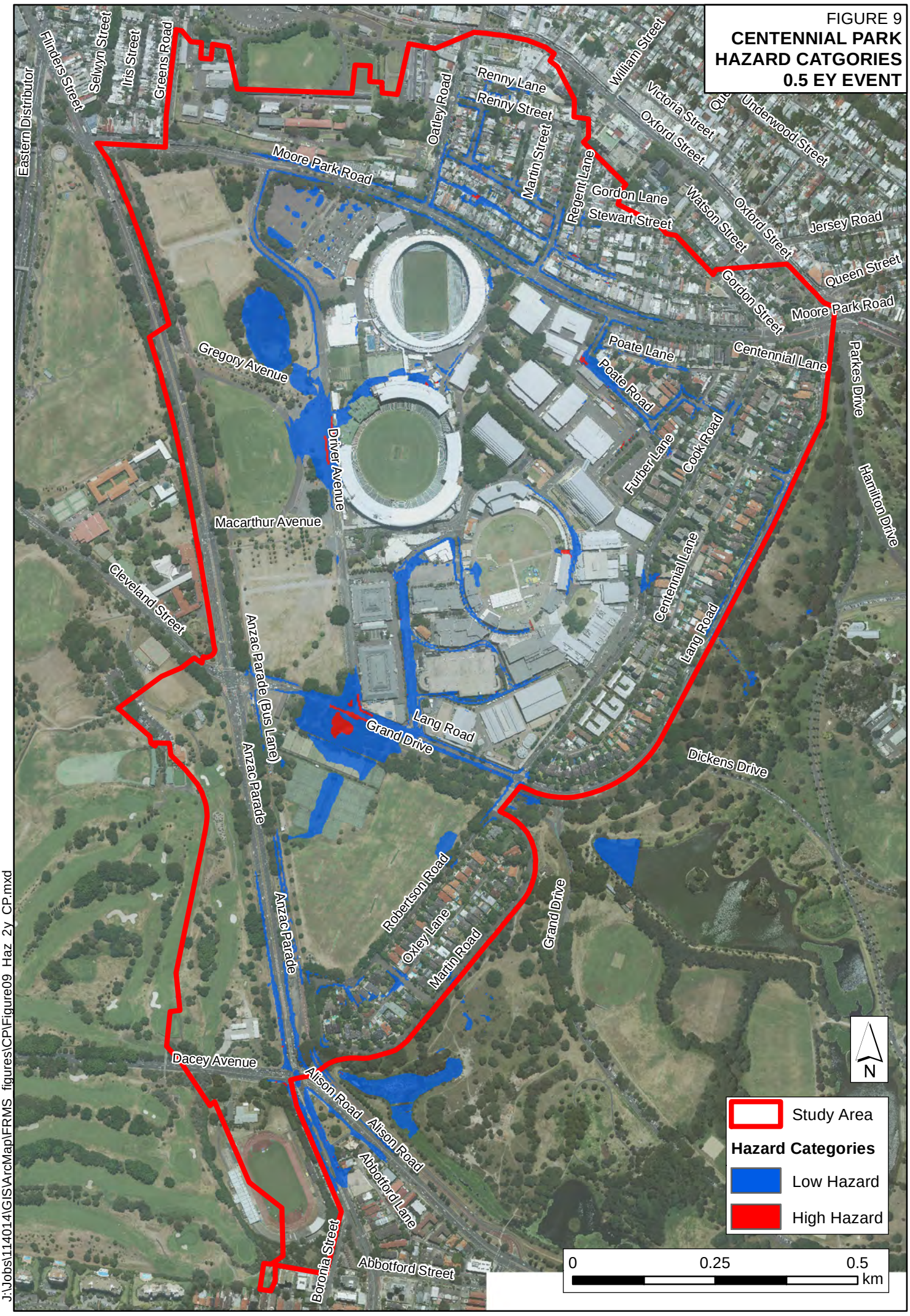


FIGURE 9
CENTENNIAL PARK
HAZARD CATGORIES
0.5 EY EVENT
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
William Street
Victoria Street
Oxford Street
Underwood Street
Regent Lane
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Gregory Avenue
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Centennial Lane
Lang Road
Anzac Parade (Bus Lane)
Grand Drive
Lang Road
Dickens Drive
Anzac Parade
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
Hazard Categories
Low Hazard
High Hazard
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure09 Haz 2y CP.mxd

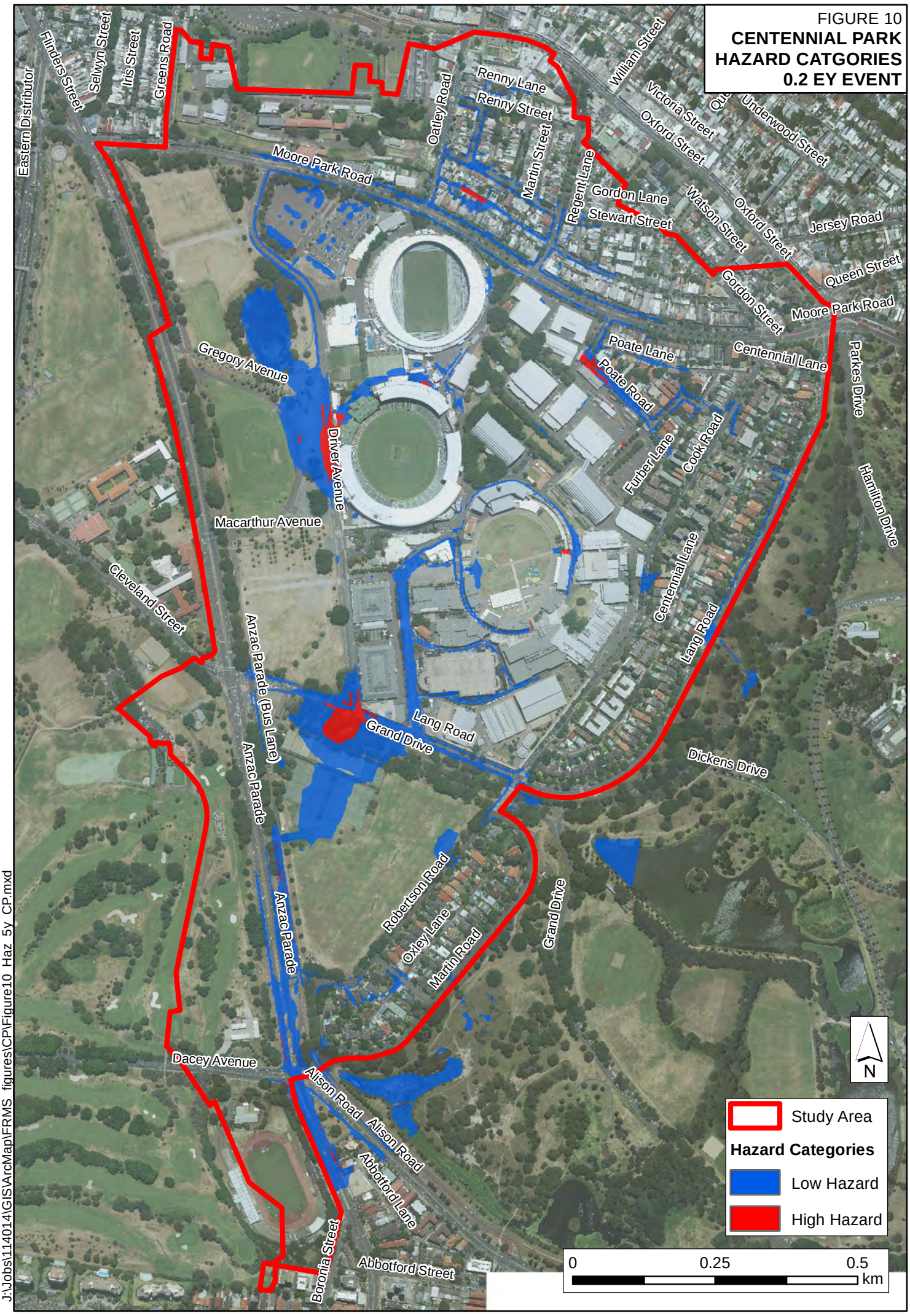


FIGURE 10
CENTENNIAL PARK
HAZARD CATGORIES
0.2 EY EVENT
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
William Street
Victoria Street
Oxford Street
Underwood Street
Regent Lane
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Gregory Avenue
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Anzac Parade (Bus Lane)
Anzac Parade
Centennial Lane
Lang Road
Grand Drive
Lang Road
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Anzac Parade
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
Hazard Categories
Low Hazard
High Hazard
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure10 Haz 5y CP.mxd

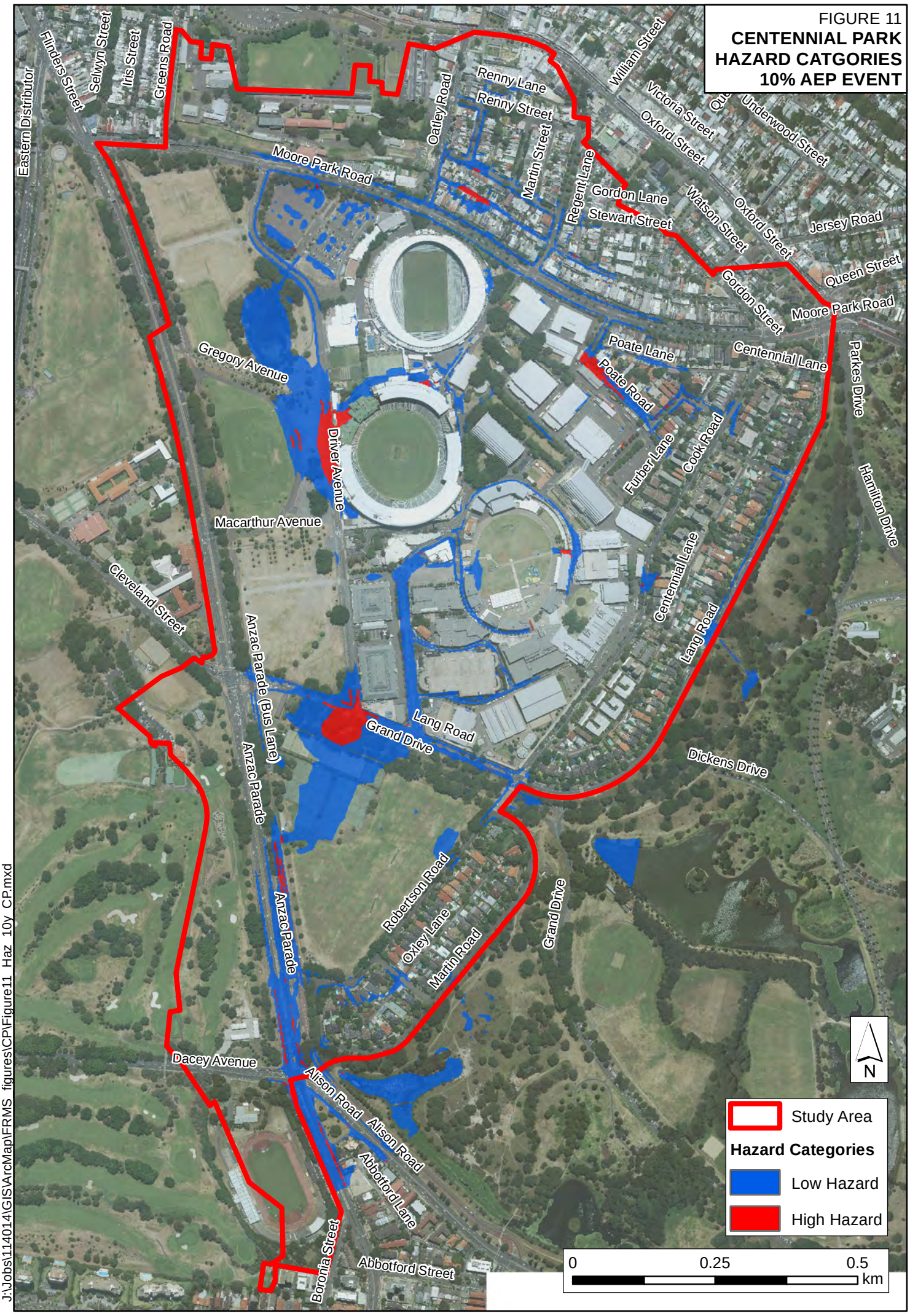


FIGURE 11
CENTENNIAL PARK
HAZARD CATGORIES
10% AEP EVENT
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
William Street
Victoria Street
Oxford Street
Underwood Street
Regent Lane
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Gregory Avenue
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Anzac Parade (Bus Lane)
Anzac Parade
Centennial Lane
Lang Road
Grand Drive
Lang Road
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Anzac Parade
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
Hazard Categories
Low Hazard
High Hazard
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure11 Haz 10y CP.mxd

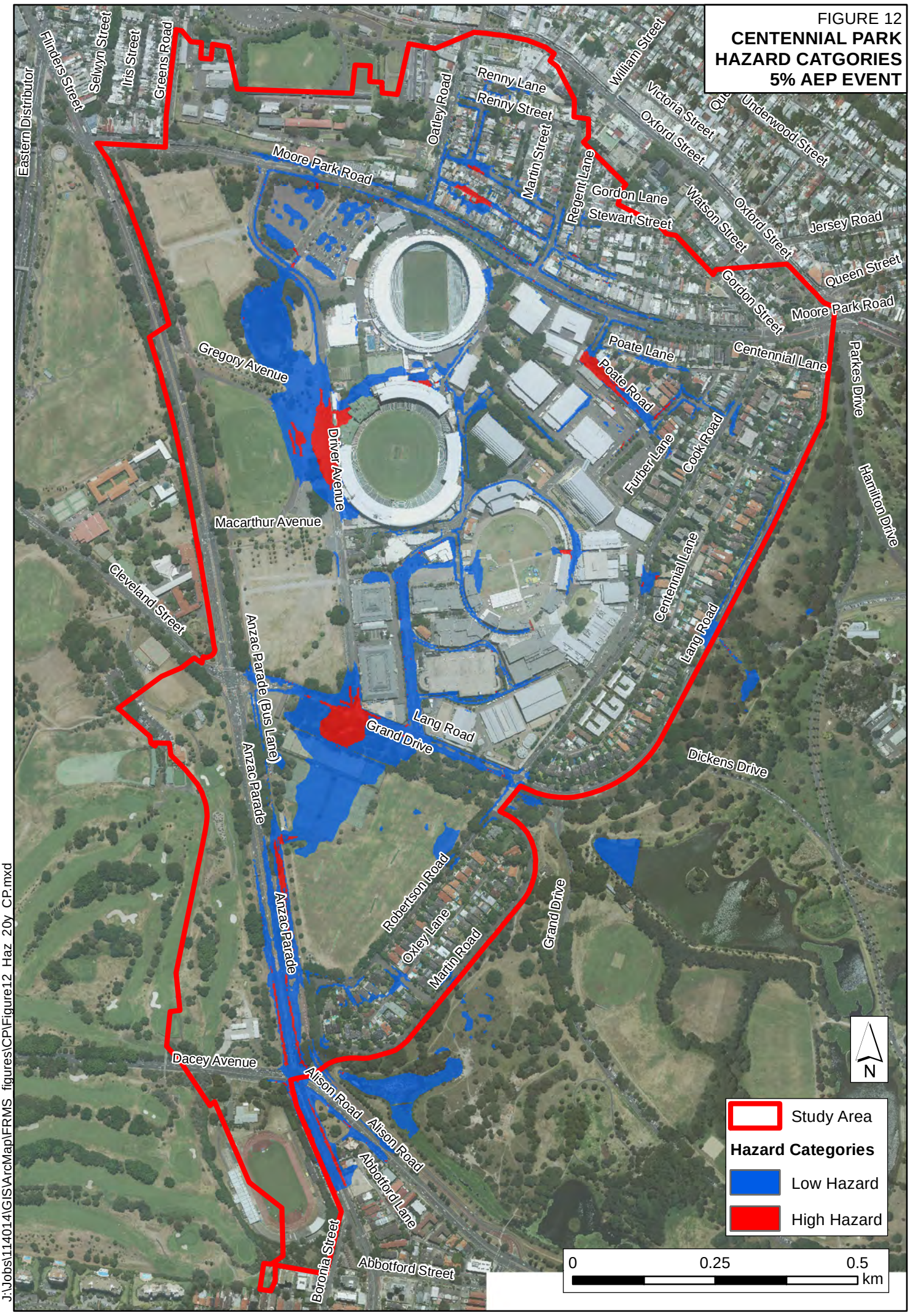


FIGURE 12
CENTENNIAL PARK
HAZARD CATGORIES
5% AEP EVENT
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
Regent Lane
William Street
Victoria Street
Oxford Street
Underwood Street
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Gregory Avenue
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Anzac Parade (Bus Lane)
Anzac Parade
Centennial Lane
Lang Road
Grand Drive
Lang Road
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Anzac Parade
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
Hazard Categories
Low Hazard
High Hazard
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure12 Haz 20y CP.mxd

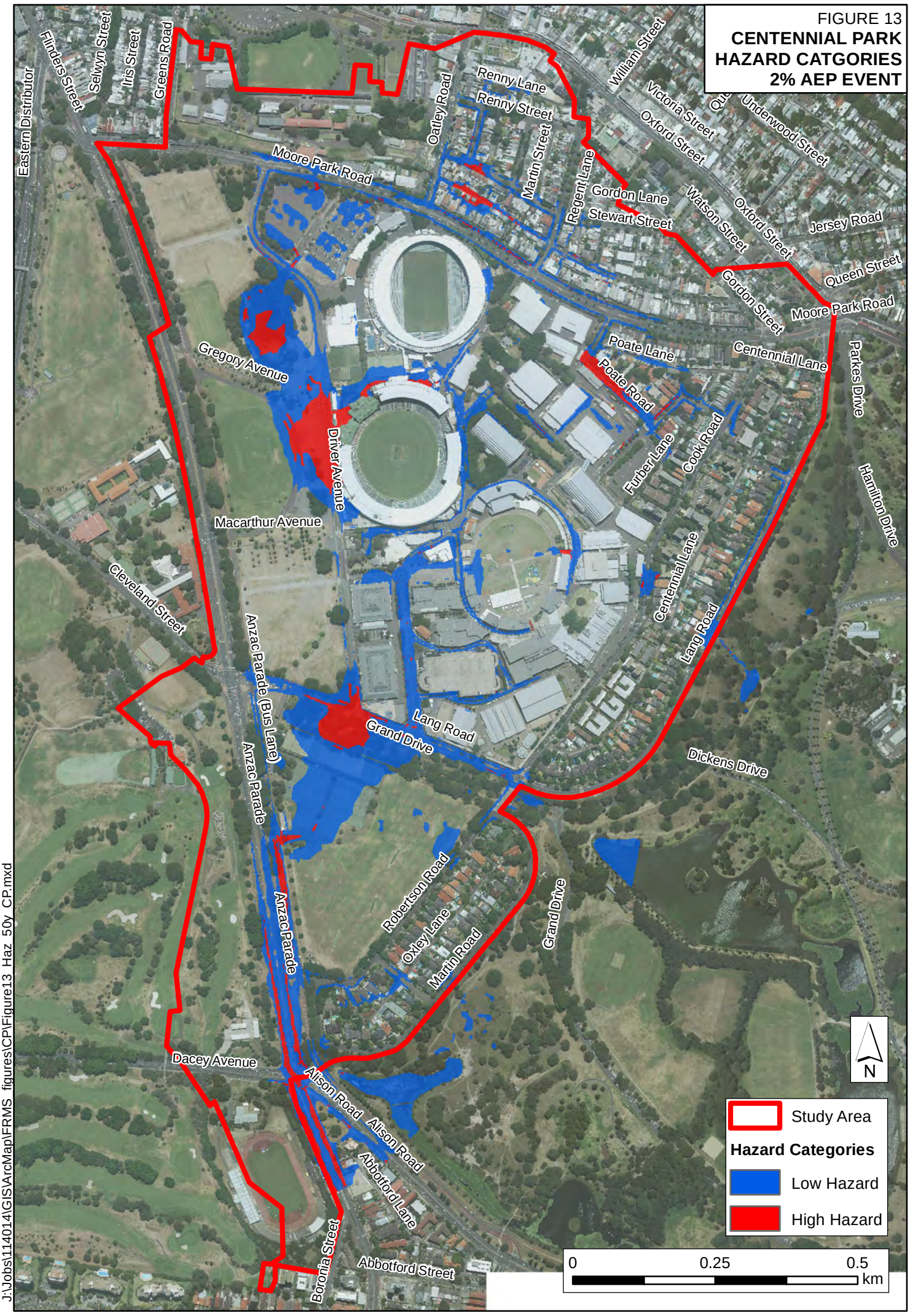


FIGURE 13
CENTENNIAL PARK
HAZARD CATGORIES
2% AEP EVENT
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
Regent Lane
William Street
Victoria Street
Oxford Street
Underwood Street
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Gregory Avenue
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Anzac Parade (Bus Lane)
Anzac Parade
Centennial Lane
Lang Road
Grand Drive
Lang Road
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Anzac Parade
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
Hazard Categories
Low Hazard
High Hazard
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure13 Haz 50y CP.mxd

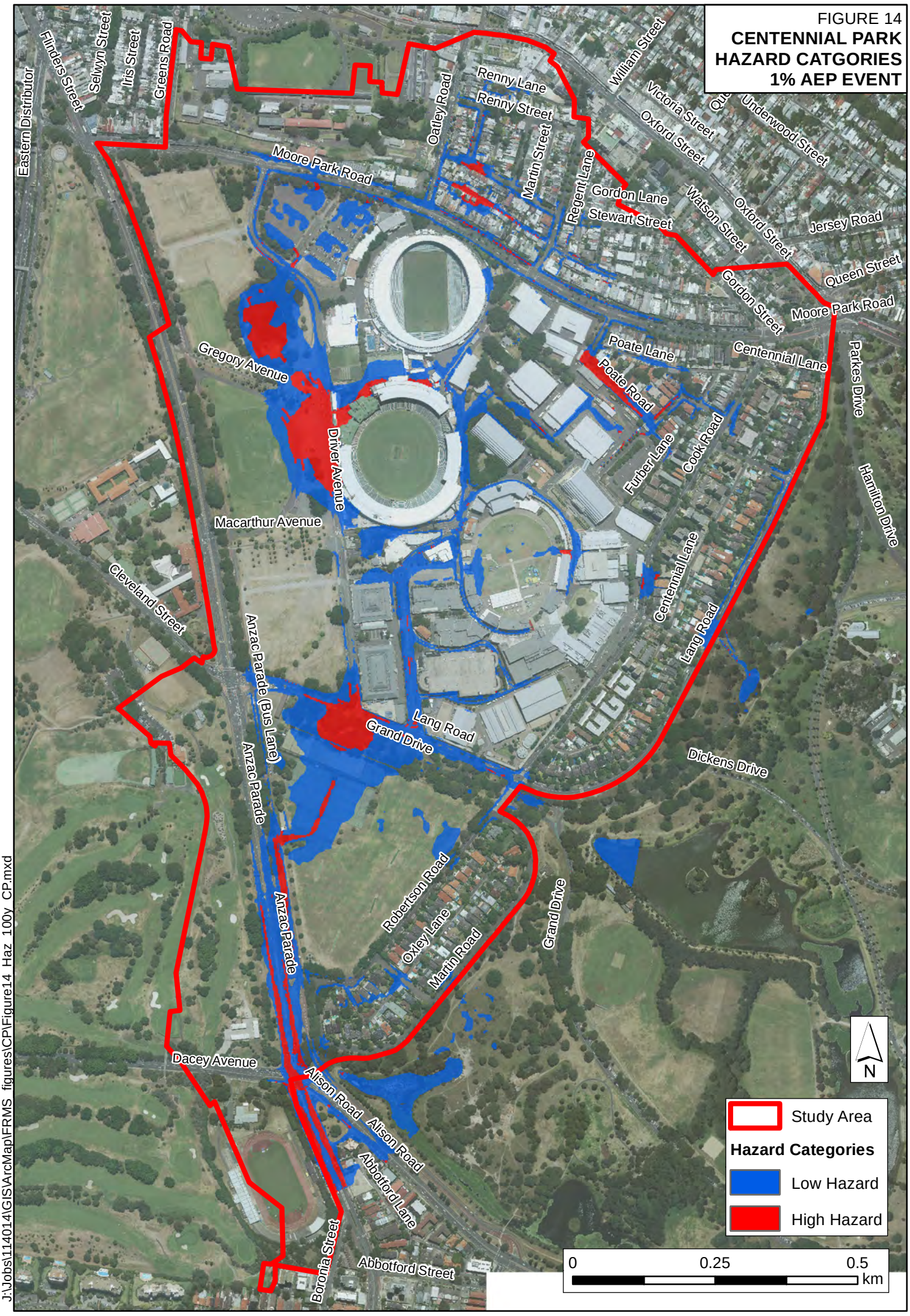


FIGURE 14
CENTENNIAL PARK
HAZARD CATGORIES
1% AEP EVENT
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
William Street
Victoria Street
Oxford Street
Underwood Street
Regent Lane
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Gregory Avenue
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Anzac Parade (Bus Lane)
Anzac Parade
Lang Road
Grand Drive
Centennial Lane
Lang Road
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
Hazard Categories
Low Hazard
High Hazard
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure14 Haz 100y CP.mxd

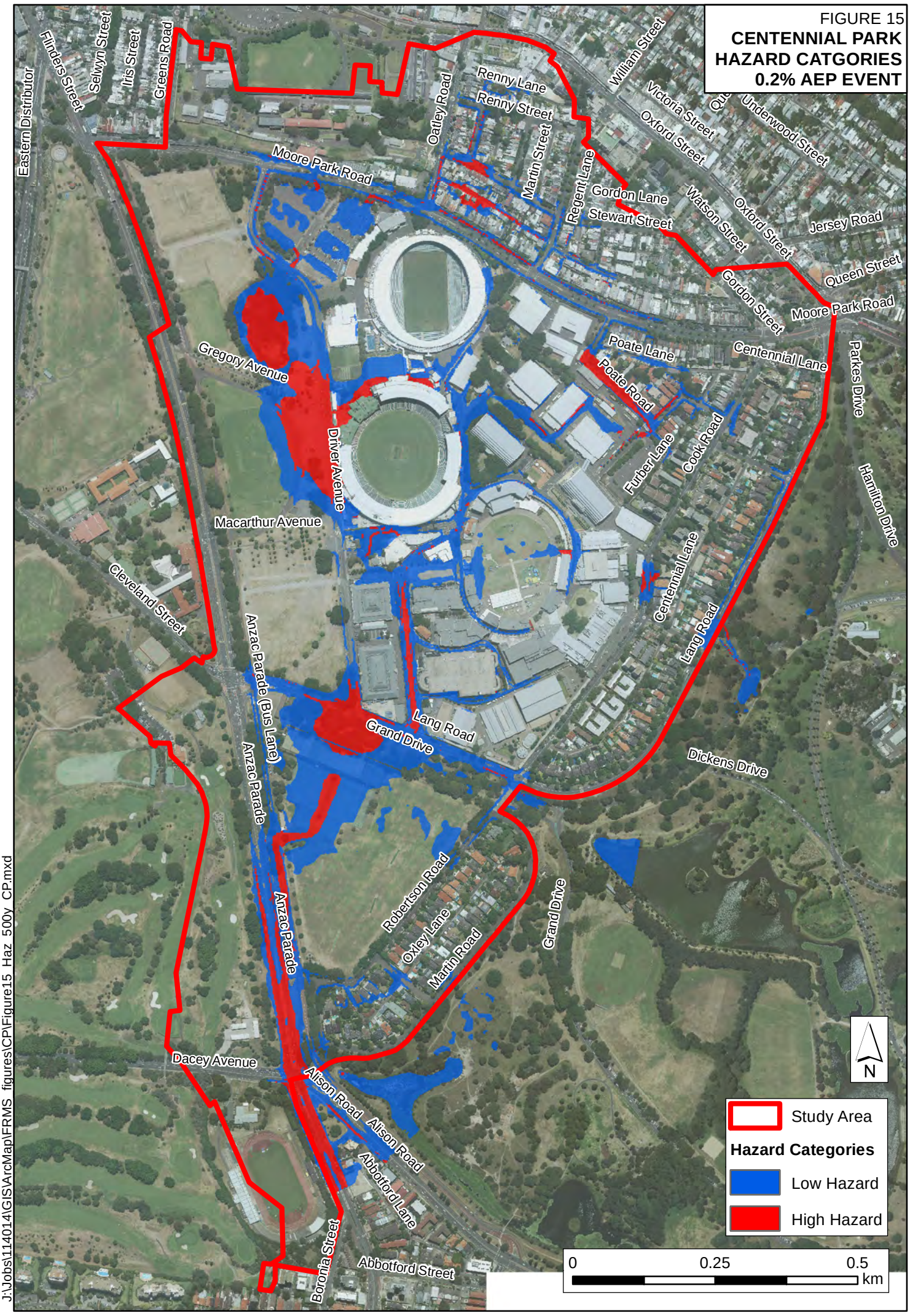


FIGURE 15
CENTENNIAL PARK
HAZARD CATGORIES
0.2% AEP EVENT
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
William Street
Victoria Street
Oxford Street
Underwood Street
Regent Lane
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Gregory Avenue
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Anzac Parade (Bus Lane)
Anzac Parade
Centennial Lane
Lang Road
Grand Drive
Lang Road
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Anzac Parade
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
Hazard Categories
Low Hazard
High Hazard
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure15 Haz 500y CP.mxd

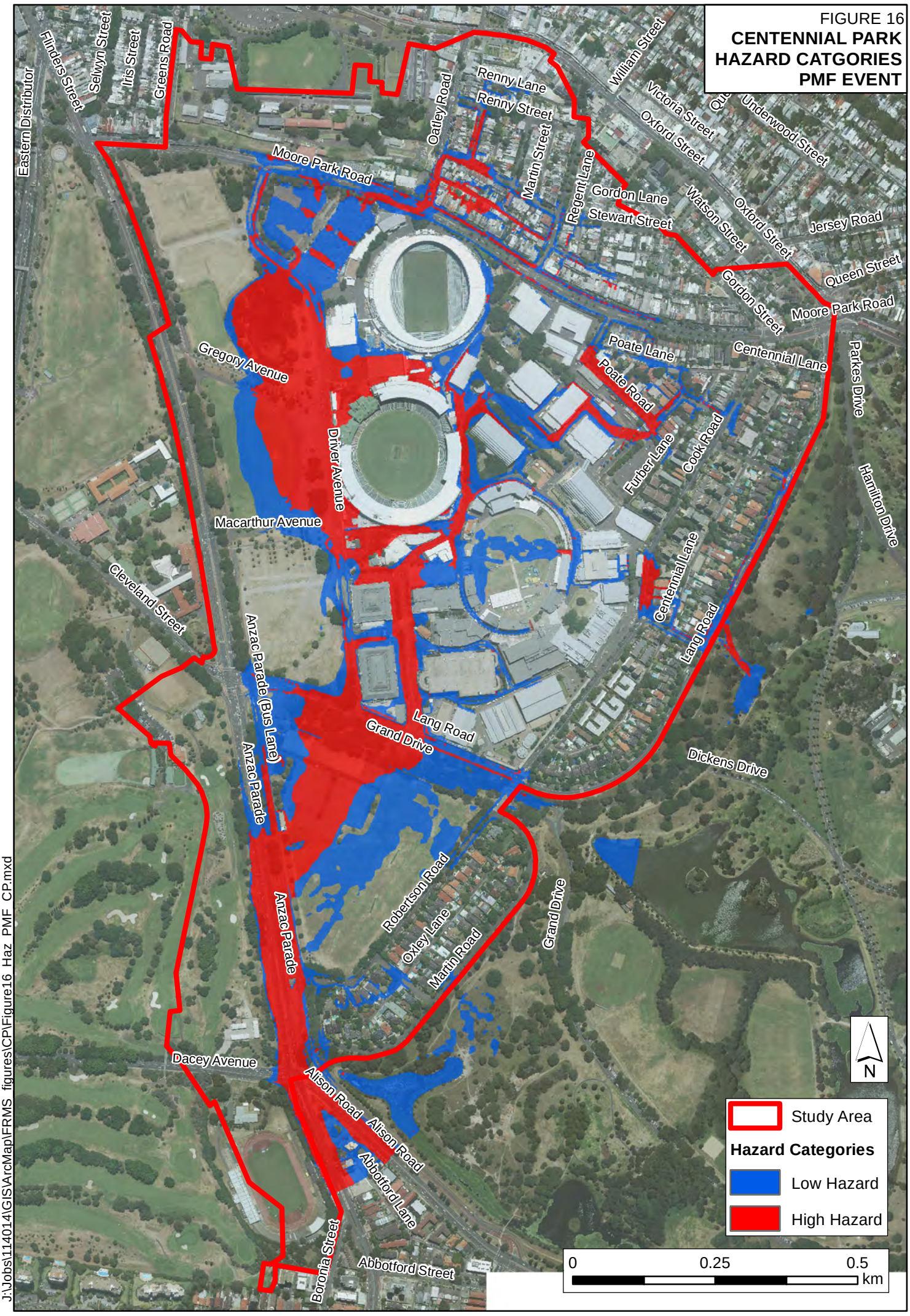


FIGURE 16
CENTENNIAL PARK
HAZARD CATGORIES
PMF EVENT
Eastern Distributor
Flinders Street
Selwyn Street
Iris Street
Greens Road
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
William Street
Victoria Street
Oxford Street
Underwood Street
Regent Lane
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Poate Lane
Poate Road
Centennial Lane
Parkes Drive
Gregory Avenue
Driver Avenue
Furber Lane
Cook Road
Hamilton Drive
Macarthur Avenue
Cleveland Street
Centennial Lane
Lang Road
Anzac Parade (Bus Lane)
Anzac Parade
Grand Drive
Lang Road
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Grand Drive
Anzac Parade
Dacey Avenue
Alison Road
Alison Road
Abbotford Lane
Boronia Street
Abbotford Street
N
Study Area
Hazard Categories
Low Hazard
High Hazard
0
0.25
0.5
km
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure16 Haz PMF CP.mxd

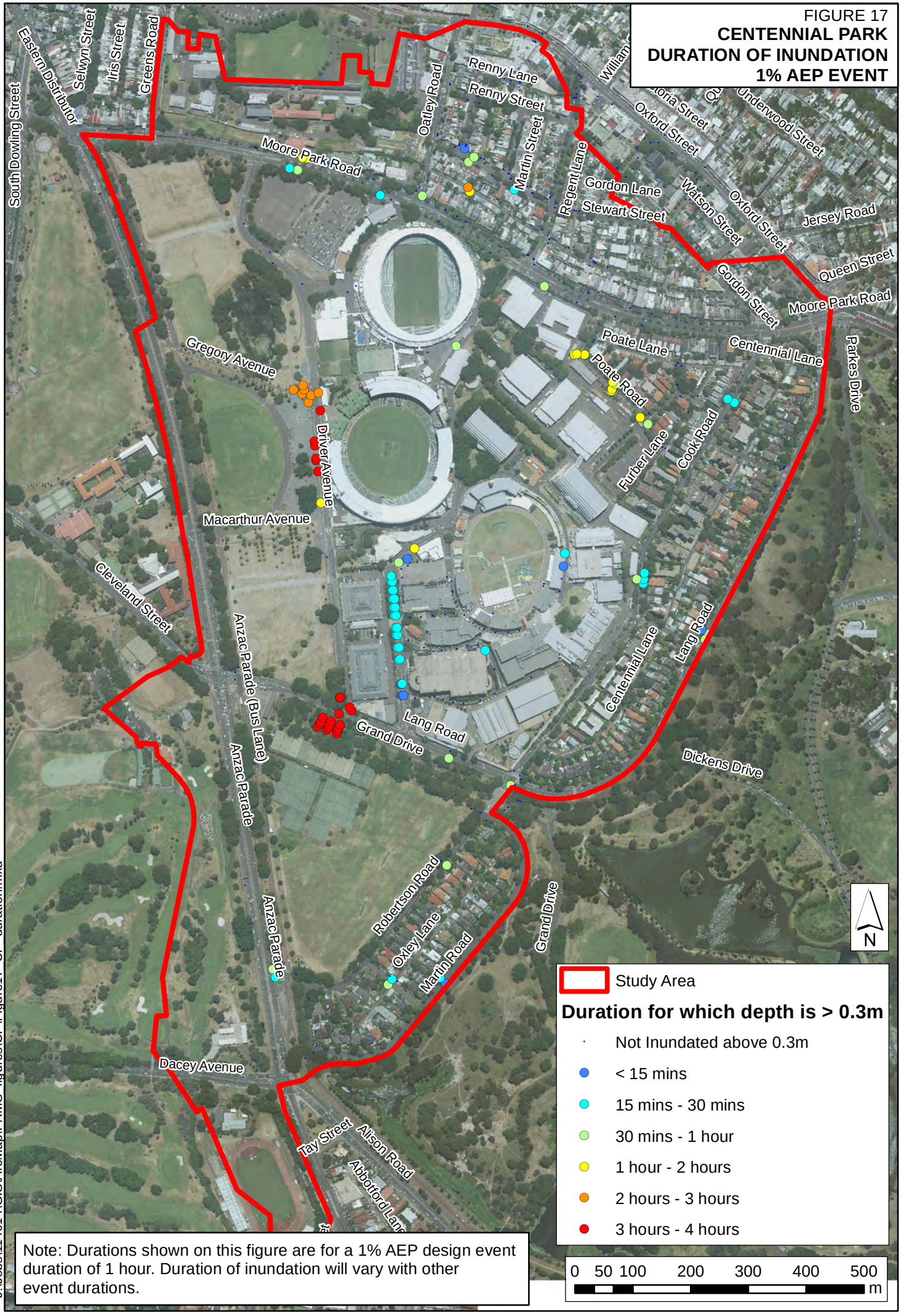


FIGURE 17
CENTENNIAL PARK
DURATION OF INUNDATION
1% AEP EVENT
Eastern Distributor
Selwyn Street
Iris Street
Greens Road
South Dowling Street
Moore Park Road
Oatley Road
Renny Lane
Renny Street
Martin Street
Regent Lane
Gordon Lane
Stewart Street
Watson Street
Oxford Street
Underwood Street
Jersey Road
Queen Street
Gordon Street
Moore Park Road
Parkes Drive
Centennial Lane
Poate Lane
Poate Road
Furber Lane
Cook Road
Gregory Avenue
Driver Avenue
Macarthur Avenue
Cleveland Street
Anzac Parade (Bus Lane)
Anzac Parade
Lang Road
Grand Drive
Dickens Drive
Robertson Road
Oxley Lane
Martin Road
Dacey Avenue
Tay Street
Alison Road
Abbotford Lane
N
Study Area
Duration for which depth is > 0.3m
Not Inundated above 0.3m
< 15 mins
15 mins - 30 mins
30 mins - 1 hour
1 hour - 2 hours
2 hours - 3 hours
3 hours - 4 hours
0 50 100 200 300 400 500
m
Note: Durations shown on this figure are for a 1% AEP design event duration of 1 hour. Duration of inundation will vary with other event durations.
J:\Jobs\114014\GIS\ArcMap\FRMS figures\CP\Figure17_CP_duration.mxd