ATTACHMENT C

ALEXANDRA CANAL FLOODPLAIN RISK MANAGEMENT STUDY (DRAFT REPORT)

Floodplain Risk Management Study

Alexandra Canal Floodplain Risk Management Study and Plan

W4948

Prepared for
City of Sydney

12 September 2013

Document Information

Prepared for	City of Sydney
Project Name	Alexandra Canal Floodplain Risk Management Study and Plan
File Reference	R001-W4948-Alex Canal FPRMSv4.docx
Job Reference	W4948
Date	12 September 2013

Contact Information

Cardno (NSW/ACT) Pty Ltd
ABN 95 001 145 035

Level 9, The Forum, 203 Pacific Highway
St Leonards NSW 2065
PO Box 19 St Leonards NSW 1590

Telephone: 02 9496 7700
Facsimile: 02 9439 5170
International: +61 2 9496 7700

sydney@cardno.com.au
www.cardno.com

Document Control

Version	Date	Author	Reviewer
Preliminary Draft	4th June 2013	Andrew Reid Emma Maratea Bala Kilaparty Tina Fang	Rhys Thomson
Draft	25 June 2013	Andrew Reid, Emma Maratea, Bala Kilaparty, Tina Fang	Rhys Thomson
Revised Draft	6 August 2013	Andrew Reid	Rhys Thomson
Draft for Exhibition	12 September 2013	Andrew Reid	Rhys Thomson

Foreword

The NSW Government Flood Prone Land Policy is directed towards providing solutions to existing flood problems in developed areas and ensuring that 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 prone land is the responsibility of Local Government. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist Councils in the discharge of their floodplain management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain management measures.

The Policy identifies the following floodplain management 'process' for the identification and management of flood risks:

1. Formation of a Committee -

   Established by a Local Government Body (Local Council) and includes community group representatives and State agency specialists.

2. Data Collection -

   The collection of data such as historical flood levels, rainfall records, land use, soil types etc.

3. Flood Study -

   Determines the nature and extent of the flood problem.

4. Floodplain Risk Management Study –

   Evaluates floodplain management measures for the floodplain in respect of both existing and proposed development.

5. Floodplain Risk Management Plan –

   Involves formal adoption by Council of a management plan for the floodplain.

6. Implementation of the Plan –

   Implementation of actions to manage flood risks for existing and new development.

This Alexandra Canal Catchment Floodplain Risk Management Study is developed from the previous Flood Study, prepared by Cardno for the City of Sydney Council.

Executive Summary

Cardno were commissioned by the City of Sydney to undertake a Floodplain Risk Management Study and Plan (FRMSP) for the Alexandra Canal Catchment. This FRMSP has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible management options to reduce flood damage and risk. The tasks were undertaken alongside community consultation to ensure that community concerns were addressed.

The overall objective of this study is to develop a FRMSP that addresses the existing, future and continuing flood problems, taking into account the potential impacts of climate change, in accordance with the NSW Government's Flood Policy, as detailed in the Floodplain Development Manual (NSW Government, 2005).

The total catchment area is approximately 1,141ha and includes the suburbs of Alexandria, Rosebery, Erskineville, Beaconsfield, Zetland, Waterloo, Redfern, Newtown, Eveleigh, Surry Hills and Moore Park. It is generally bounded by the Eastern Distributor and Moore Park in the east, Gardeners Road in the south, Sydney Park and Newton in the west and Albion Street in the north-east. The majority of the trunk drainage system is owned by Sydney Water Corporation, while the feeding drainage systems are primarily owned by Council.

The majority of the catchment is fully developed and consists predominantly of medium to high-density housing, commercial and industrial development with some large open spaces.

A draft flood study has been prepared by Cardno (2013) to define the flood behaviour in the study area, including both mainstream and overland flooding. The Flood Study determined the flood behaviour for the 100 year ARI, 20 year, 10 year, 5 year, 2 year and 1 year Average Recurrence Interval (ARI) events together with the Probable Maximum Flood (PMF). The primary flood characteristics reported for the design events considered include depths, levels and velocities. The study has also defined the Provisional Flood Hazard for flood-affected areas. An assessment of the impact of blockages of culverts and pits was also undertaken for the flood study.

The community consultation undertaken as part of the FRMS built on the consultation undertaken as part of the Flood Study (Cardno, 2013). The purpose of the Flood Study (Cardno, 2013) consultation was to inform the community about the study and gain an understanding of the communities experience with historical flooding in the catchment. The purpose of the more recent consultation undertaken as part of this FRMS was to inform the community about the study, identify community concerns and attitudes, to gather information from the community on potential options for the floodplain and to develop and maintain community confidence in the study results.

The community consultation consisted of:

- A community brochure and survey;
- A press release; and
- Public meetings (to be undertaken during the public exhibition period).

Provisional flood hazard was defined as part of the Flood Study (Cardno, 2013) based on velocity and depth of flood waters for the PMF, 100 and 5 Year ARI events. The additional hazard factors outlined in the Floodplain Development Manual were considered as part of a true hazard assessment undertaken in this FRMS.

Flooding is likely to cause significant social and economic damages to the community. A flood damage assessment for the existing catchment and floodplain conditions has been undertaken as part of the current study. The assessment is based on damage curves that relate the depth of flooding on a property to the potential damage within the property. Average Annual Damage (AAD) is calculated on a probability approach using the flood damages calculated for each design event. The average annual damage estimated for the Alexandra Canal floodplain under existing conditions is approximately **$13.0 million** (excluding GST).

The majority of flooding within the Alexandra Canal catchment is characterised by overland flow. The critical duration is between 1 and 3 hours across the catchment, with the peak of the flood reached approximately 30 minutes to 1 hour after the start of the storm. This is considered short duration “flash” flooding. The short time period until flooding occurs does not allow sufficient time to evacuate residents from their properties. A review of the current emergency response arrangements has been undertaken considering the nature of flooding within the catchment.

Floodplain management is primarily employed through development controls and other planning measures. A review of the relevant state and local planning instruments has been undertaken with regards to floodplain management within Alexandra Canal Catchment. The outcomes of this review have been incorporated into the proposed floodplain risk management options.

A key component of development controls relating to floodplain management is the adoption of a flood planning level. The Sydney LEP 2012 currently defines the flood planning level as the 100 year ARI event plus a freeboard of 0.5m. The suitability of this level for planning purposes in the Alexandra Canal Catchment has been review based on flood behaviour and land use types.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. Various options for flood risk management have been identified and assessed. These options can be broadly defined into three categories:

- **Flood modification measures** – Flood modification measures are aimed at preventing / avoiding or reducing the likelihood of flood risks. These options reduce the risk by modifying the flood behaviour in the catchment.
- **Property modification measures** – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than necessarily modify the flood behaviour, these options aim to modify properties (both existing and future) so that there is a reduction in flood risk.
- **Emergency response modification measures** – Emergency response modification measures aim to reduce the consequences of flood risks. These measures generally aim to modify the behaviour of people during a flood event.

It is possible to quantitatively assess the economic benefits of some of the options, namely those that were hydraulically modelled, and those with known benefits. For those options, a benefit-cost ratio can be calculated. Where a desktop assessment was utilised for options (as opposed to hydraulic modelling), a detailed economic analysis was not undertaken. In these cases a judgement on the likely economic benefits of the options was made.

A multi-criteria matrix assessment approach has been adopted for the comparative assessment of all options identified using a similar approach to that recommended in the Floodplain Development Manual (2005). This approach uses a subjective scoring system to assess the merits of various options against economic, social and environmental criteria. The principal merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition, it makes the assessment of alternatives “transparent” (i.e. all important factors are included in the analysis). However, this approach does not provide an absolute “right” answer as to what should be included in the plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned. Each option is given a score according to how well the option meets specific considerations.

The outcome of the multi-criteria matrix assessment is a ranked list of potential floodplain risk management options for implementation in the floodplain. The following measures were highly ranked and should be considered for further assessment and / or implementation:

Non-Structural Measures-

- FM15 Liveable Green Network
- FM23 Increased pit cleaning and maintenance
- EM1 Information Transfer to SES
- EM2 Preparation of District DISPLAN
- EM3 Preparation of Local Flood Plan
- PM3 Opportunities related to Large Scale Future Development
- PM2 Development Controls and Policies
- EM5 Public awareness and education
- PM1 LEP Update
- EM6 Flood warning signs at critical locations
- PM9 Flood Proofing Guidelines
- EM4 Flood Warning System and Temporary Refuge

Structural Measures-

- FM9 Link Road to Alexandra Canal Upgrade – Maddox Street Alignment
- FM6 Additional pipes from Macdonald Street and Coulson Street to Alexandra Canal (alternatively FM21 Detention Basin in Sydney Park – Offset Storage from Macdonald Street)
- FM7 Detention basins in Redfern Park.
- FM18 Additional Drainage Network at Harcourt Parade to Gardeners Road
- FM17 Detention basin in Turruwul Park
- FM20 Sheas Creek Channel Flood Walls

The implementation strategy for recommended floodplain risk management measures is outlined in a Floodplain Risk Management Plan.

The next stage of the study is for this draft Floodplain Risk Management Study to be reviewed by stakeholders and the community during the public exhibition period. It should be noted that the outcomes of this study may alter as a result of this process.

Table of Contents

Appendices

Tables

Figures

Glossary

Annual Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large. The 1% AEP event is equivalent to the 1 in 100 year Average Recurrence Interval event.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random. That is, an event of a certain magnitude may occur several times within its estimated return period.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1 in 1 year ARI or 100% AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.

Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood-prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood-prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood-prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard

	flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks;

	able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
NPER	National Professional Engineers Register. Maintained by Engineers Australia.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a more detailed explanation see Annual Exceedance Probability.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.

Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

Abbreviations

1D	One Dimensional
2D	Two Dimensional
AHD	Australian Height Datum
ARI	Average Recurrence Interval
BoM	Bureau of Meteorology
DCP	Development Control Plan
DECCW	Department of Environment, Climate Change & Water (now OEH)
FPL	Flood Planning Level
FRMP	Floodplain Risk Management Plan
FRMS	Floodplain Risk Management Study
FRMSP	Floodplain Risk Management Study & Plan
km	kilometres
km^2	Square kilometres
LEP	Local Environment Plan
LGA	Local Government Area
m	metre
m^2	Square metres
m^3	Cubic metres
mAHD	Metres to Australian Height Datum
mm	millimetres
m/s	metres per second
NSW	New South Wales
OSD	On-site Detention
OEH	Office of Environment and Heritage
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SES	State Emergency Service
SWC	Sydney Water Corporation

1 Introduction

Cardno were commissioned by the City of Sydney to undertake a Floodplain Risk Management Study and Plan (FRMSP) for the Alexandra Canal Catchment. This FRMSP has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible management options to reduce flood damage and risk. The tasks were undertaken alongside community consultation to ensure that community concerns were addressed.

The total catchment area is approximately 1,141ha and includes the suburbs of Alexandria, Rosebery, Erskineville, Beaconsfield, Zetland, Waterloo, Redfern, Newtown, Eveleigh, Surry Hills and Moore Park. It is generally bounded by the Eastern Distributor and Moore Park in the east, Gardeners Road in the south, Sydney Park and Newton in the west and Albion Street in the north-east. The majority of the trunk drainage system is owned by Sydney Water Corporation, while the feeding drainage systems are primarily owned by Council.

The majority of the catchment is fully developed and consists predominantly of medium to high-density housing, commercial and industrial development with some large open spaces.

A draft flood study was prepared in 2012 by Cardno to define the flood behaviour in the study area, including both mainstream and overland flooding. An updated version of the draft report (Cardno, 2013) has subsequently been provided to Council in conjunction with this study, following a review and some minor changes to the flood modelling that was undertaken.

Models were calibrated and verified against four historical storm events that occurred in November 1984, January 1991, April 1998 and February 2001. November 1984 was approximately larger than a 100 year Average Recurrence Interval (ARI) event, while April 1998 was in the order of a 10 year ARI event. The other two events were smaller, with January 1991 roughly a 5 – 10 year ARI event, and February 2001 less than a 1 year ARI event. Using the established models, the flood study determined the flood behaviour for the 100 year ARI, 20 year, 10 year, 5 year, 2 year and 1 year ARI events together with the Probable Maximum Flood (PMF). The primary flood characteristics reported for the design events considered include depths, levels and velocities. The study has also defined the Provisional Flood Hazard for flood-affected areas.

An assessment of the impact of blockages of culverts and pits was also undertaken for the flood study. The results found that the catchment is particularly sensitive to these factors and are therefore considered further in this FRMSP for evaluation of flood planning levels.

A number of flood management options have been examined as part of this Floodplain Risk Management Study to manage flooding within the Alexandra Canal catchment. The identification and examination of these options was done in accordance with the NSW Floodplain Development Manual: The Management of Flood Liable Land ("the Manual") (NSW Government, 2005).

1.1 Study Context

The Floodplain Management process progresses through 6 stages, in an iterative process:

1) Formation of a Floodplain Management Committee;
2) Data collection;
3) Flood Study;
4) Floodplain Risk Management Study;
5) Floodplain Risk Management Plan; and

6) Implementation of the Floodplain Risk Management Plan.

This report represents Stage 4.

1.2 Study Objectives

The overall objective of this study is to develop a FRMSP that addresses the existing, future and continuing flood problems, taking into account the potential impacts of climate change, in accordance with the NSW Government's Flood Policy, as detailed in the Manual (NSW Government, 2005).

This FRMSP was undertaken in two phases:

- Phase 1 – Floodplain Risk Management Study where management issues are assessed, management options are investigated and recommendations are made, and
- Phase 2 – Floodplain Management Plan detailing how flood prone land within the study area is to be managed.

Specific objectives for Phase 1 included:

- Review of the current Flood Study (Cardno, 2013) and (if necessary) re-assess the design flood discharges, velocities, flood levels, hydraulic categories and other relevant flood information for any changes that may have occurred in the Study Area since the flood study was undertaken. Up to date information is required for the full range of potential flood events i.e. up to the PMF or an appropriate extreme flood.
- Review of Council's existing environmental planning policies and instruments including Council's long term planning strategies for the study area, particularly in the light of the potential impact of climate change.
- Identify residential flood planning levels and flood planning area.
- Identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events and taking into account the potential impacts of climate change. Council's aim is to have innovative solutions to the management of the flood hazards within the study area and aims to have effective community consultation and participation throughout the Study.
- To assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future and taking into account the potential impacts of climate change.
- Assess whether the proposed works and measures might produce adverse effects (environmental, social, economic, or flooding) in the floodplain and whether they can be minimised.
- In terms of the Department of Planning Circular PS 07-003 and "Guideline on Development Controls on Low Flood Risk Areas – Floodplain Development Manual", determine if and where exceptional circumstance are appropriate for flood related development controls on residential development on land outside the residential flood planning area.
- Review the local flood plan, identify deficiencies in information and address the issues identified in the DECCW (now OEH) Guideline "SES Requirements from the FRM Process."
- Examination of the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's developments and disaster planning requirements.

- Examine ways in which the floodplain environment may be enhanced without having a detrimental effect on flooding.
- Identification of modifications required to current policies in the light of investigations
- Council identified the following areas / precincts for redevelopment to accommodate future needs:
  - Midblock Precinct
  - Epsom Park Precinct
  - Green Square Precinct
  - Green Square Town Centre
  - Ashmore Street Estate

The majority of these areas are affected by flooding and to allow redevelopment of these areas flood management solutions are to be investigated. Some individual investigations have already been carried out but these have been reviewed and management solutions assessed for incorporating in the Floodplain Risk Management Plan.

- The City has developed the Liveable Green Network (LGN) Strategy and Master Plan (draft April 2011). Specific flood management measures to be developed based on the LGN strategy and Master Plan.
- Provide flood management strategies to the flood affected areas summarised in **Table 1-1**.

Table 1-1 Flood Affected Areas

Suburb	Flood Affected Streets and Areas
Alexandria	▪ Bourke Road / Doody Street / Ralph Street ▪ Bowden Street ▪ McEvoy Street ▪ Huntley and Coulson Streets ▪ Maddox street ▪ Sydney Park Road ▪ Euston Road ▪ Burrow Road ▪ O'Riordan Street ▪ Botany Road / Wyndham Street/ Buckland Street / Wellington Street
Beaconsfield	▪ Botany Road / Collins Street ▪ Victoria Street and Victoria Lane ▪ Queen Street ▪ Reserve Street
Erskineville	▪ MacDonald Street, ▪ Erskineville Oval and Copeland Street ▪ Ashmore Street ▪ Burren Street ▪ Charles Street ▪ Erskineville Road ▪ Coulson Street and Mitchell Avenue
Eveleigh	▪ Newton Street and Renwick Street ▪ Burren Street ▪ Holdsworth Street ▪ Henderson Street and Mitchell Street
Newtown	▪ Macdonaldtown and Holdsworh Street ▪ Burren Street and Copeland Avenue
Redfern	▪ Boronia Street and Marriott Street ▪ Boronia Street/ Bourke Street/ South Dowling Street ▪ Phillip Street and Baptist Street ▪ Chalmers Street ▪ Phillip Street / Elizabeth Street ▪ Phillip Street / Walkers Street
Rosebery	▪ Morley Avenue / Botany Road / Jones Lane ▪ Cressy Street / Botany Road ▪ Hayes Road / Dunning Avenue / Botany Road ▪ Harcourt Parade / Dunning Avenue / Botany Road ▪ Harcourt parade / Dalmeny Avenue / Tweedmouth Avenue/ Gardeners Road
St Peters	▪ Burrows Road
Surry Hills	▪ Arthur Street / Bourke Street / Nobbs Street / South Dowling Street
Waterloo	▪ Phillip Street and Walker Street ▪ Powell Street and young Street ▪ Phillip Street / Elizabeth Street ▪ Young Street / Danks Street ▪ Elizabeth Street / Wellington Street

Suburb	Flood Affected Streets and Areas
Zetland	▪ Joynton Avenue ▪ Epsom Park ▪ Green square ▪ South Dowling Street

Specific objectives for Phase 2 include:

- Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk (taking into account the potential impacts of climate change).
- Reduce private and public losses due to flooding.
- Protect and where possible enhance the floodplain environment.
- Be consistent with the objectives of relevant State policies, in particular, the Government's Flood Prone Land and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act, 1979.
- Ensure that the Floodplain Risk Management Plan is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act, 1993 and has the support of the local community.
- Ensure actions arising out of the draft plan are sustainable in social, environmental, ecological and economic terms.
- Ensure that the draft floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans.
- Establish a program for implementation which should include priorities, staging, funding, responsibilities, constraints, and monitoring.

2 Catchment Description

The Alexandra Canal catchment covers 1,141ha or 43% of City of Sydney Local Government area, including suburbs of Alexandria, Beaconsfield, Erskineville, Eveleigh, Moore Park, Redfern, Rosebery, Surry Hills, Waterloo and Zetland. Approximately 93% of the total catchment area is within the City of Sydney, with the remaining 7% being shared with the City of Botany Bay, Marrickville and Randwick Councils.

The catchment and study area are shown in Figure 2-1.

Drainage systems consisting of open channels, covered channels, in-ground pipes, culverts and pits convey runoff from the catchment to Alexandra Canal which discharges into the Cooks River. The majority of the trunk drainage system is owned by Sydney Water Corporation, with the feeding drainage systems primarily owned by Council.

The majority of the catchment is fully developed and consists predominantly of medium to high-density housing, commercial and industrial development with some large open spaces that include Moore Park Playing Fields, Moore Park Golf Course, The Australian Golf Course, Sydney Park, Redfern Park, Waterloo Park and Alexandria Park.

Flooding throughout the catchment is a combination of overland flow and mainstream flooding. Mainstream flooding issues tend to occur around Alexandra Canal and the open channels in the study area. Examples of this type of flooding occur at the channel that runs between Alexandra Canal and Bowden Street, the channel near Euston Road and the channel at South Sydney Corporate Park. Elsewhere, flooding is primarily a result of overland flow and the capacity of the stormwater network and overland flowpaths.

A feature of the catchment is the prevalence of 'trapped' low points. These areas, due to topographical and development constraints, result in significant ponding and flooding of properties and roads. In a number of these locations, the only way for water to escape is via the pit and pipe system. Examples of these ponding areas include the Coulson Street sag, Joynton Avenue and the ponding upstream of Erskineville Oval.

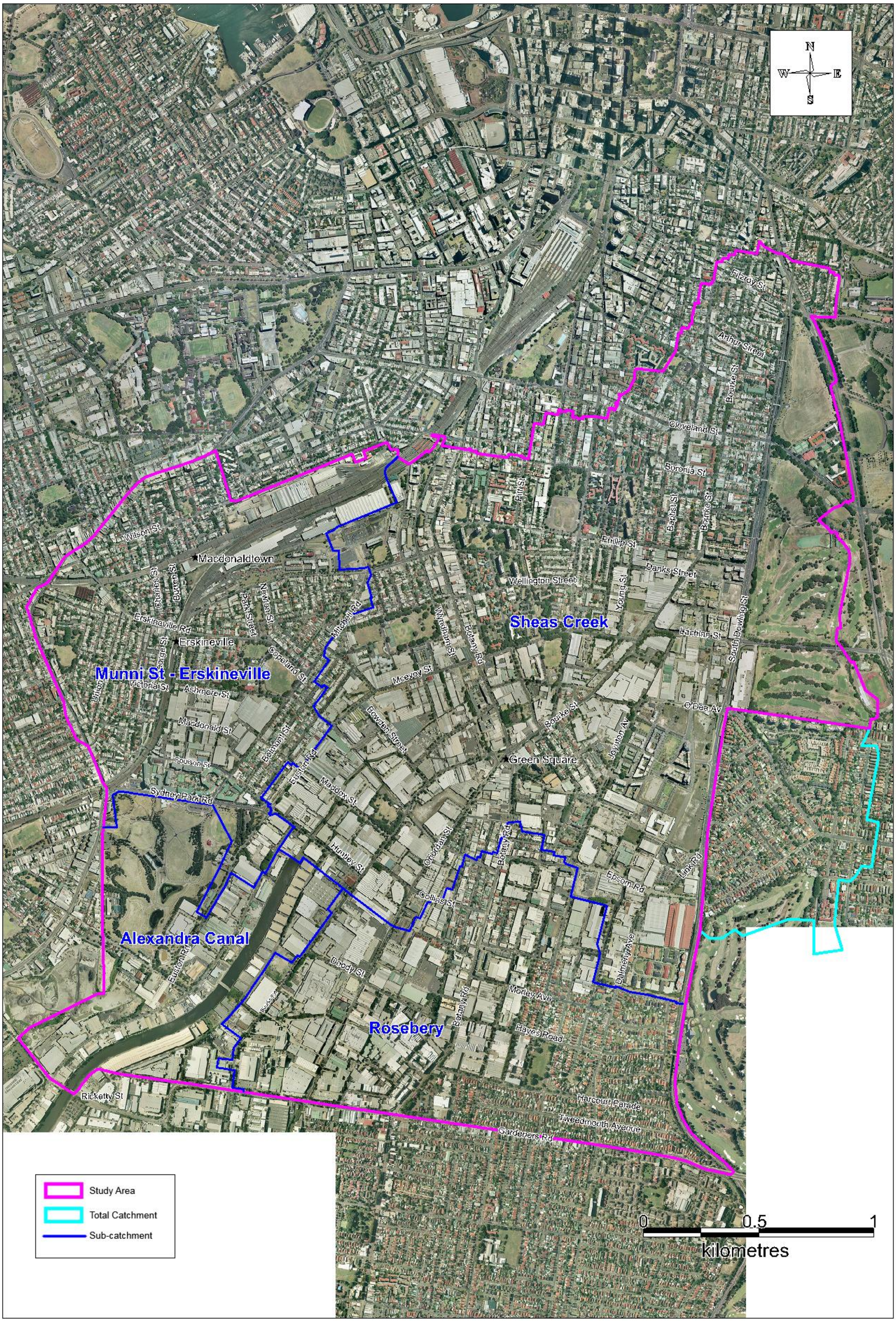


Figure 2-1 Study Area

3 Available Data

3.1 Previous Studies and Reports

3.1.1 Alexandra Canal Catchment Flood Study

The draft Alexandra Canal Catchment Flood Study (Cardno, 2013) is the key input study to the FRMSP. The primary objective of this study was to define the flood behaviour in the study area, including both mainstream and overland flooding. An extensive data compilation and review was undertaken for the study and included a review of a number of previous studies, together with collection of available rainfall records and survey data.

A detailed 1D/2D flood model was established to describe the flooding behaviour throughout the study area. This model incorporates all pits and pipes from data provided by the City of Sydney and has a 4 metre grid resolution. Hydrological modelling was undertaken through the application of the Direct Rainfall methodology.

The models were calibrated and verified against four historical storms; November 1984, January 1991, April 1998 and February 2001. The results of the calibration and verification showed that the model was capable of reproducing the observations from those events, providing confidence in the overall modelling results.

Using the established models, the study has determined the flood behaviour for the 100 year ARI, 20 year, 10 year, 5 year, 2 year and 1 year ARI events as well as the Probable Maximum Flood (PMF). The primary flood characteristics reported for the design events considered include depths, levels and velocities. The study has also defined the Provisional Flood Hazard for flood-affected areas.

Following a review that was undertaken in conjunction with this study, some minor updates were undertaken to the modelling for the flood study, and a revised draft was provided to Council. The key changes that occurred in the modelling are:

- Modification of the terrain in the model between Nobbs Lane and Parkham Lane. This localised area was under construction at the time that the LiDAR was collected, and therefore did not suitably represent the storage in this area.
- Model terrain at Erskineville railway station was revised to refine the representation of overland flowpaths in the vicinity.
- Refinement of hydraulic parameters along Sheas Creek concrete drainage channel.

The above changes were made and incorporated into the updated draft. It is noted that these resulted in only minor localised changes to flood model results to the previous draft.

3.1.2 Green Square – West Kensington Floodplain Risk Management Study & Plan

The relevant documents from the Green Square West Kensington Study are:

- Green Square – West Kensington Floodplain Risk Management Study, Public Exhibition Draft, February 2011, by WMA Water
- Green Square Catchment Floodplain Risk Management Plan, Final Draft, May 2013, by WMA Water

These two documents overlap a part of the study area for the current project, incorporating the eastern part of the Sheas Creek Catchment, inclusive of the Green Square redevelopment area.

The studies identified a number of options for floodplain management and prioritised these options for implementation into a plan. This is similar to the current process undertaken for the study.

Whereas the Green Square West Kensington Studies focused on a portion of the catchment, the current study overviews a much larger study area within the City of Sydney LGA. The measures identified in the Green Square West Kensington studies have been reviewed in conjunction with the identification of options in the current study.

3.1.3 Additional Studies

A number of additional studies have been conducted regarding the Alexandra Canal Catchment. These studies were completed prior to the undertaking of the Flood Study (Cardno 2013) and were reviewed and incorporated into the Flood Study (where relevant). These studies include:

- Green Square Town Centre Flood Mitigation Option Report, 16 July 2008 by Cardno
- Green Square Town Centre Flood Mitigation Option Report Addendum, 12 July 2012 by Cardno
- Green Square Town Centre Floodplain Risk Management Plan, 13 July 2012 by Cardno
- The Liveable Green Network:
  - Volume 1 - Liveable Green Network Strategy and Master Plan Report, draft April 2011
  - Volume 2 – Network Development Assessment, draft April 2011
  - Volume 3 – Background Research and Case Studies, draft April 2011
- Ashmore Precinct Structure Plan Flooding and WSUD Assessment, February 2006 by Cardno
- Ashmore Street Masterplan Flood Assessment, 16 October 2008 by Cardno

3.2 Survey Information

Council provided aerial laser scanning (ALS) ground levels surveyed in 2007 and 2008 for the entire catchment. Generally, the accuracy of the ALS data is +/- 0.15m to one standard deviation on hard surfaces.

Additional field survey was undertaken as part of the Flood Study (Cardno, 2013) by Cardno's surveyors to provide additional detail for the development of the flood model. This included cross-sections of some open-channels, bathymetry of Alexandra Canal, and historical flood level observations.

3.2.1 Floor Level Survey

Detailed survey of building floor levels within the flood inundation extent was conducted in March-April 2013. A total of 1820 floor levels were surveyed:

- 429 by Council in St Peters, Alexandria, Beaconsfield, Rosebery and Zetland; and
- 1391 by Cardno in St Peters, Erskineville, Waterloo, Redfern, and Surry Hills.

This information has been provided separately to Council for privacy reasons and is thus not included in this Report.

3.3 GIS Data

City of Sydney Council provided Geographic Information System (GIS) data for preparing the Alexandra Canal Catchment Flood Study model and reporting. The data included:

- Pit and pipe data
- Cadastre
- 1m and 2m Land Information Centre (LIC) contours
- Aerial photography (2006)
- Road centrelines

Field survey of more than 4500 pits and over 4000 pipes was undertaken by Cardno's surveyors (separate to this study) to provide a detailed database of the locations and dimensions of all Council's pits and pipes within the entire LGA. Invert and surface levels of pits was determined from airborne laser scanning (ALS) levels and details measured directly during survey. This information was collated during the Flood Study (Cardno, 2013).

3.4 Site Inspections

Detailed site inspections of the study area were conducted on numerous occasions during the Flood Study as well for the FRMSP and during the assessment for GSTC and individual developments. The site visits provided the opportunity to review flood issues identified as part of the Flood Study (Cardno, 2013) and identify and review the feasibility of potential flood management strategies.

4 Consultation

4.1 Community Consultation

The community consultation undertaken as part of the FRMS built on the consultation undertaken as part of the Flood Study (Cardno, 2013). The purpose of the Flood Study (Cardno, 2013) consultation was to inform the community about the study and gain an understanding of the community's experience with historical flooding in the catchment.

The purpose of the more recent consultation undertaken as part of this FRMS was to inform the community about the study, identify community concerns and attitudes, to gather information from the community on potential options for the floodplain and to develop and maintain community confidence in the study results.

The community consultation consisted of:

- A community brochure and survey;
- A press release; and
- Public meetings.

4.1.1 Community Brochure and Survey

A community information brochure and questionnaire was prepared and distributed in April 2013 as attached in **Appendix A**. The questionnaire sought information on people's recollection of flooding in the catchment and feedback on potential flood management options. It was mailed to 5,893 properties identified as within the floodplain extent (PMF). An email with the questionnaire was also sent to 165 of the respondents from the questionnaire of the Alexandra Canal Flood Study (Cardno, 2013). An online version of the questionnaire was included on Council's website for public access.

A total of 461 responses were received, primarily as return posted forms, representing a return of approximately 8% of the direct mailed quantity. Of these responses, 402 (88%) were from residents and 53 (11%) were from business. Four respondents did not specify their status.

Property Information

The majority of respondents to the questionnaire are from owner occupied residential properties as summarised in **Table 4-1**. Properties are occupied by a tenant in about 19% of the responses and business accounted for approximately 8%. Some respondents selected multiple descriptions for their property.

Table 4-1 Property Ownership

	All Responses	Residential Responses
Owner Occupied	329 (72%)	318
Occupied by a tenant	88 (19%)	76
Business	37 (8%)	6
Not Specified	4 (1%)	2

A high proportion of respondents live within apartments or freestanding houses, about 46% and 39% respectively, as listed in **Table 4-2**. The catchment has particular property types that dominate particular areas, for example apartment buildings are predominant in the new redevelopment areas and industrial / commercial properties may be concentrated in the lower reaches of the catchment. Potentially apartment blocks would likely provide refuge from floodwaters at the higher levels within the building.

Table 4-2 Property Description

Structure Description	All Responses	
Apartment	213	46.4%
Dual Occupancy	4	0.9%
Dual Occupancy & Commercial	2	0.4%
Freestanding house	179	39.0%
Industrial & Commercial	57	12.4%
Not Specified	4	0.9%

The amount of time that respondents have lived or worked in the catchment is important to evaluate their experience of flood events. Awareness of flooding is dependent on whether a flood event has occurred recently and its magnitude as well as the respondent's location within the floodplain. For this Study, there have been some recent storm events resulting in some flooding and the questionnaire distribution was focussed on properties within the main flood extents.

Of the residents who responded, 60% had resided at their current address less than 10 years, whilst 35% had occupied their current residences greater than 10 years. Fifty-five percent of business respondents had occupied their property less than 10 years, whilst 41% had been there longer than 10 years.

Figure 4-1 shows the proportion of respondents within ranges for their years within the catchment at their current address.

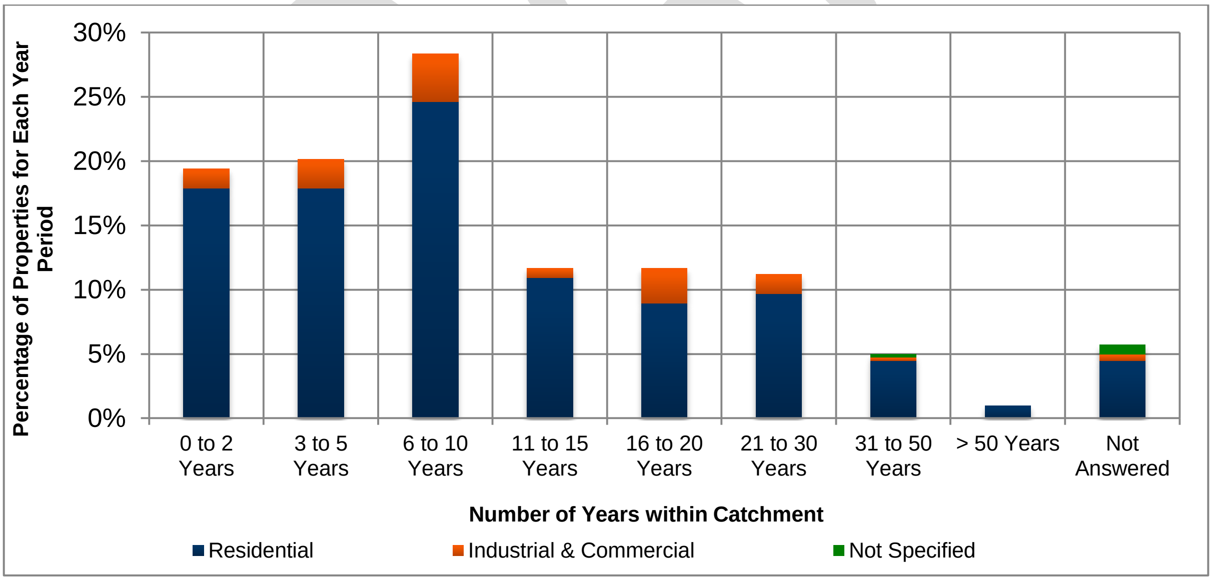


Figure 4-1 Years of Residence

Demographic Information

The age and languages of people within the catchment is important for flood planning within the catchment. Education and potential evacuation plans would take into consideration the age of residents noting potential mobility issues and languages used to provide effective communication. Respondents to the questionnaire may not be a true representation of the whole but does indicate a cross-section of the community. This information should be used in conjunction with the general demographic review undertaken in **Section 7**.

Based on the 461 responses, the number of people working or residing was advised as 1790 comprising 954 residents, 833 related to businesses and three unspecified. The average number of residents per residential property is about two, whereas for businesses the average number of occupants is 16. The predominant age group is between 15 and 64 years as shown in **Figure 4-2** and summarised in **Table 4-3**. This age group represents generally able-bodied persons who may not require assistance in case of evacuation. Of those residents who responded, 93% stated English as their main language at home, whilst 6% of respondents spoke a language other than English such as Chinese (6%), Greek (2%) and French (2%), noting 1% of respondents did not specify.

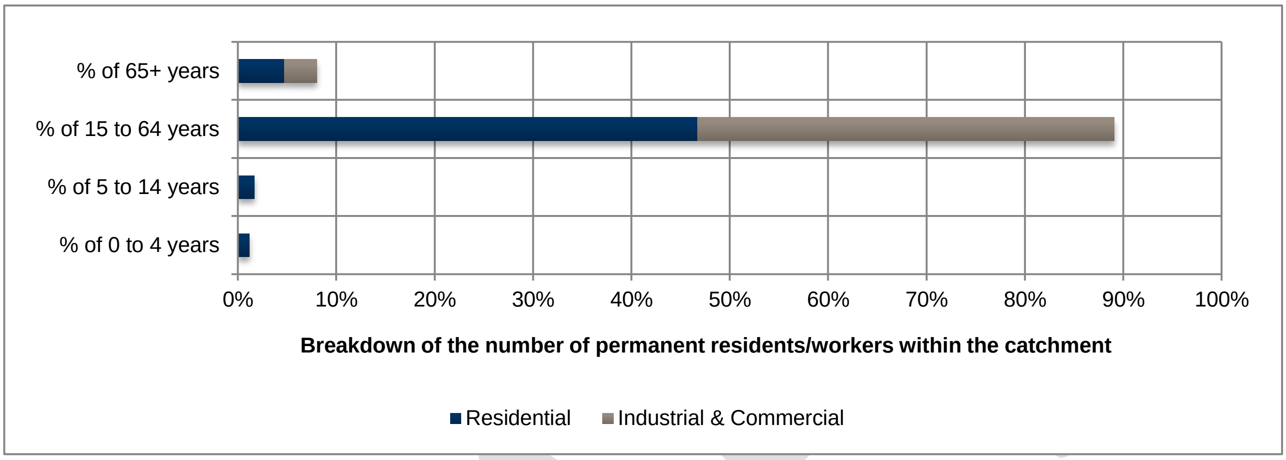


Figure 4-2 Age Groups

Table 4-3 Summary of Age Groups

	Residential	Industrial and Commercial	Total
0 to 4 years	19 (1%)	0	19
25 to 14 years	28 (2%)	0	28
15 to 64 years	783 (46%)	722 (43%)	1505
65+ years	79 (5%)	55 (3%)	136

Flooding Experience and Awareness

About 49% of the 461 respondents indicated they had not experienced flooding as summarised in **Table 4-4**. Of these 224 responses that had not experienced flooding, 213 occupied apartments. Inundation of houses or business was reported for 95 properties, 83 residential and 12 industrial / commercial. Of those who had experienced flooding within their house or business, 53 were residents occupying freestanding houses, 27 occupied apartments, 2 occupied dual occupancies and the remaining 12 were businesses.

Table 4-4 Flood Affectation of Respondents

	Total Responses	Residential Responses	Industrial/Commercial Responses
Yes, floodwaters entered my house/business	95	83	12
Yes, floodwaters entered my yard/surrounds of my business	97	84	13
Yes, the road was flooded and I couldn't get to my car	86	74	12
Yes, other parts of my neighbourhood were flooded	135	124	11
No, I haven't experienced flooding	224	195	29
No Specified	5	2	3

Respondents noted locations where they had witnessed localised flooding, including:

- Buckland Street, Alexandria;
- Maddox Street, Alexandria;
- Brandling Street, Alexandria;
- O'Riordan Street, Alexandria;
- Intersection of Mitchell Road and Huntley Street, Alexandria;
- Pleasant Avenue, Erskineville;
- Smiths Lane, Erskineville;
- George Street, Erskineville;
- Boronia Street Redfern;
- Chalmers Street, Redfern;
- Botany Road, Waterloo;
- Joynton Avenue, Zetland; and
- Marshall Street, Surry Hills.

Historical flooding was noted to have occurred in Alexandria in 1998, Waterloo in 2003, and localised flooding in Redfern (2010 and 2013) and Rosebery (2007).

Photographs of flooding in the catchment provided by residents are shown in **Appendix A**.

Flood Management

Nine approaches to flood management were presented in the questionnaire for respondents to list a preference rating for each approach. A rating of 1 to 5 was presented, with 5 being the most preferred and 1 being least preferred. Of the 461 respondents, 407 were from residential properties and 54 from commercial / industrial properties.

Figure 4-3 shows the flood management approaches in order of preference based on the average of the response ratings. Also shown are the extents of the 25th percentile and 75th percentile scores which show the range within which at least half of the ratings were given.

Table 4-5 summarises the average preference rating of all responses as well as the rating with the highest individual response and the amount that did not specify a preference rating.

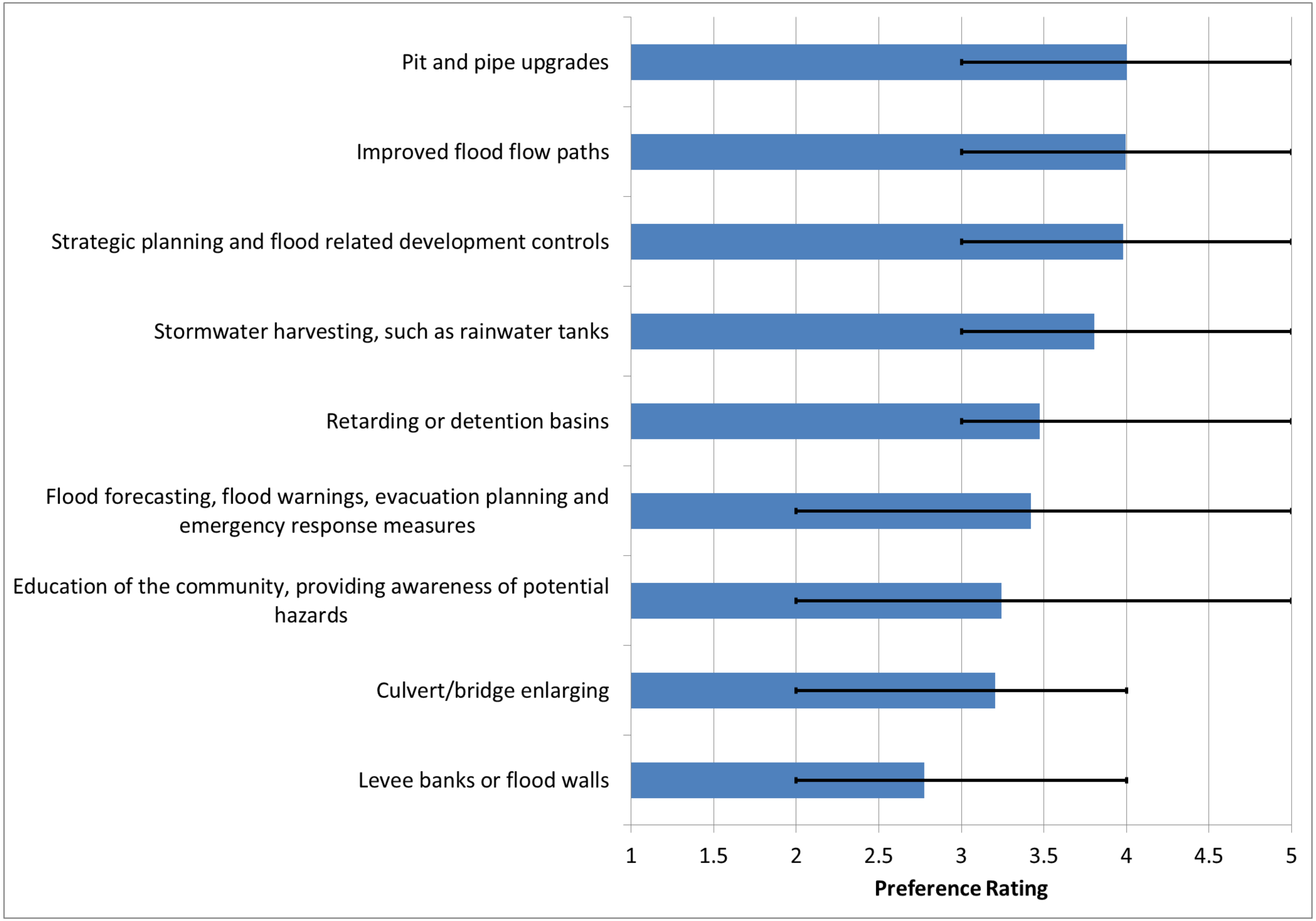


Figure 4-3 Average Rating for Flood Management Approaches

Table 4-5 Flood Management Approach Rating Summary

Flood Management Approach	All Responses	Residential Responses	
	Average Rating	Rating with Highest Response	Not Answered
Pit and pipe upgrades	4.0	5 (31%)	153 (38%)
Improved flood flow paths	4.0	5 (18%)	154 (38%)
Strategic planning and flood related development controls	4.0	5 (26%)	175 (44%)
Stormwater harvesting, such as rainwater tanks	3.8	5 (31%)	131 (33%)
Retarding or detention basins	3.5	5 (18%)	153 (38%)
Flood forecasting, flood warnings, evacuation planning and emergency response measures	3.4	5 (17%)	176 (44%)
Education of the community, providing awareness of potential hazards	3.2	5 (14%)	175 (44%)
Culvert/bridge enlarging	3.2	3 (17%)	179 (45%)
Levee banks or flood walls	2.7	3 (16%)	177 (44%)

The two highest rated approaches; pit / pipe upgrades and improved flowpaths, both aim to reduce the potential inundation of roads and properties by constructing additional capacity to convey flood water to the Canal. Strategic planning and development controls is the highest rated non-structural approach.

Stormwater harvesting approaches may have limited impact on flood inundation within the catchment. The potential advantages are minor due to the relative volume of runoff during a flood event compared to the available storage capacity. Similarly, storages for harvesting may be kept full following an event to provide water for alternative uses but this does not leave free capacity for a follow-up storm event.

Levee banks / flood walls and culvert / bridge enlarging are the least favoured approaches, potentially as other approaches are preferred which would more efficiently convey runoff from the catchment. These approaches may also reduce the visual amenity of the area. Similarly retarding / detention basins were not highly favoured, potentially due to visual impact and loss of open space.

Flood forecasting and education approaches were ranked as sixth and seventh based on the mean rating, however they had a wider range of ratings generally indicating that some respondents were more strongly in favour (or not in favour) of these approaches. The responses do not indicate the reasons for ratings, however it may be summised that these are ranked lower as they are not considered to provide a tangible improvement to flood inundation.

The approaches with the highest percentage for ratings of '5' (being most preferred) were pit / pipe upgrades, strategic planning and stormwater harvesting. Approaches with the highest proportion of no response, potentially indicating they were not favoured, are non-structural measures and culvert / bridge enlarging, and levee banks / flood walls.

Approximately 22% of the total respondents recommended other flood management approaches, most common being maintenance of drains and guttering (litter and debris removal) and improving stormwater drainage capacity (noting that this is the outcome of several of the presented approaches).

Generally, responses to the questionnaire potentially indicate a preference for flood management approaches that will result in tangible reductions to flood inundation in the catchment, such as improved pit and pipe drainage.

4.1.2 Public Meetings

Public meetings will be held during the public exhibition period (described in **Section 4.3**).

4.2 Floodplain Committee and Stakeholder Consultation

The floodplain committee provides an important role in assisting Council in the development and implementation of the Floodplain Management Plan. It comprises of various agency and community representatives. The Cardno project team have reported to the committee and undertaken workshops with the committee and additional stakeholders at key stages of the study.

- Inception Meeting (15th March 2012): An overview of the project purpose, scope and methodology was presented to the Committee. Key issues and ideas regarding the direction of the study were raised by the committee for consideration by Cardno and Council.
- Floodplain Management Committee Meeting (6th June 2012): An overview of the risk management study and plan to date including previous studies conducted by Cardno. A list of management and identifiable options were presented by Cardno for consideration by the committee.
- Floodplain Management Committee Meeting (5th December 2012): This meeting outlined the floodplain risk management process including tasks to be conducted and the results from this study. An extensive and detailed list of processes was provided by Cardno to be considered by the committee.
- Council Internal Workshop (15th April 2013): A workshop was conducted by Cardno with several Council staff providing details of project stakeholders, identification of additional options and the proposed Multi-Criteria Assessment.
- Floodplain Management Committee Workshop (29th April 2013): This workshop was undertaken as a follow-up meeting from the previous Council internal workshop. The workshop further reviewed potential floodplain management options, the results of preliminary options assessments and further developed the Multi-Criteria Assessment.

The outcomes of the workshops on the 14th and 29th April are included in **Appendix B**.

4.3 Public Exhibition

Following approval by the Committee, this Draft Floodplain Risk Management Study and Plan will be put on public exhibition for a minimum of four weeks. During the public exhibition period the community and interested parties will be able to review the draft study and submit comments on the study and its outcomes. These submissions will be considered in the preparation of the finalisation of the FRMSP.

5 Existing Flood Behaviour

5.1 Flood Study

A detailed 1D/2D flood model was established as part of the Flood Study (Cardno, 2013) to describe the flooding behaviour throughout the study area. This model incorporated all pits and pipes from data provided by the City of Sydney and had a 4 metre grid resolution. Hydrological modelling was undertaken through the application of the Direct Rainfall methodology.

The models were calibrated and verified against four historical storms; November 1984, January 1991, April 1998 and February 2001. November 1984 was approximately larger than a 100 year ARI event, while April 1998 was in the order of a 10 year ARI event. The other two events were smaller, with January 1991 roughly a 20 – 50 year ARI event, and February 2001 less than a 1 year ARI event. The calibration events were chosen through a combination of both their magnitude, together with the quantity of flood observations from the storm.

The results of the calibration and verification showed that the model was capable of reproducing the observations from those events, providing confidence in the overall modelling results. The models were further verified against the previous studies that have been undertaken within the catchment.

Using the established models, the study has determined the flood behaviour for the 100 year ARI, 20 year, 10 year, 5 year, 2 year and 1 year ARI events together with the Probable Maximum Flood (PMF). The primary flood characteristics reported for the design events considered include depths, levels and velocities. The study has also defined the Provisional Flood Hazard for flood-affected areas.

The 100 Year ARI and PMF extents are shown in **Figures 5-1 and 5-2**. The flooding behaviour across the catchment is described in the following section with regards to each of the sub-catchments as shown in **Figure 5-3**.

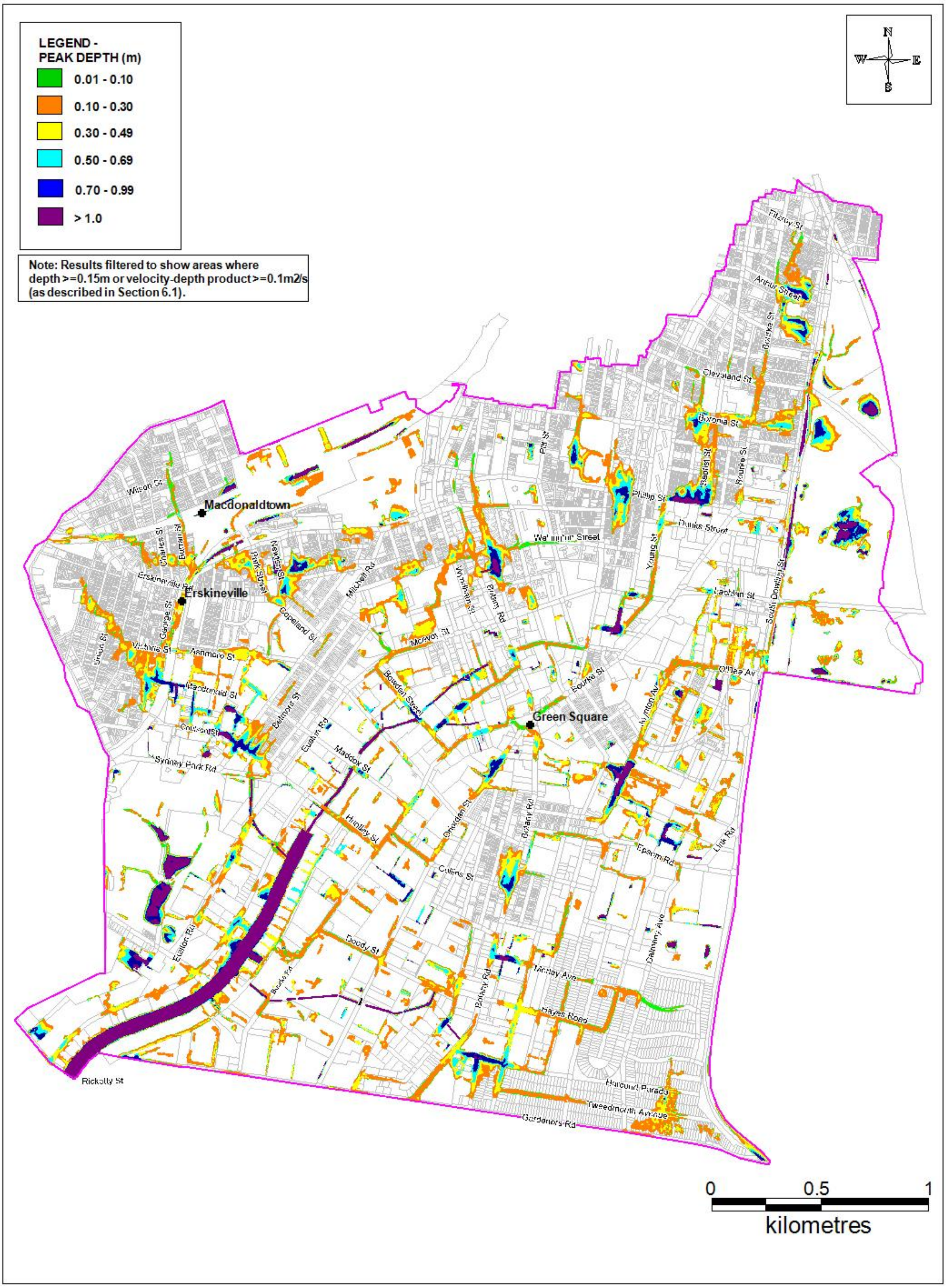


Figure 5-1 100 Year ARI Peak Flood Depths

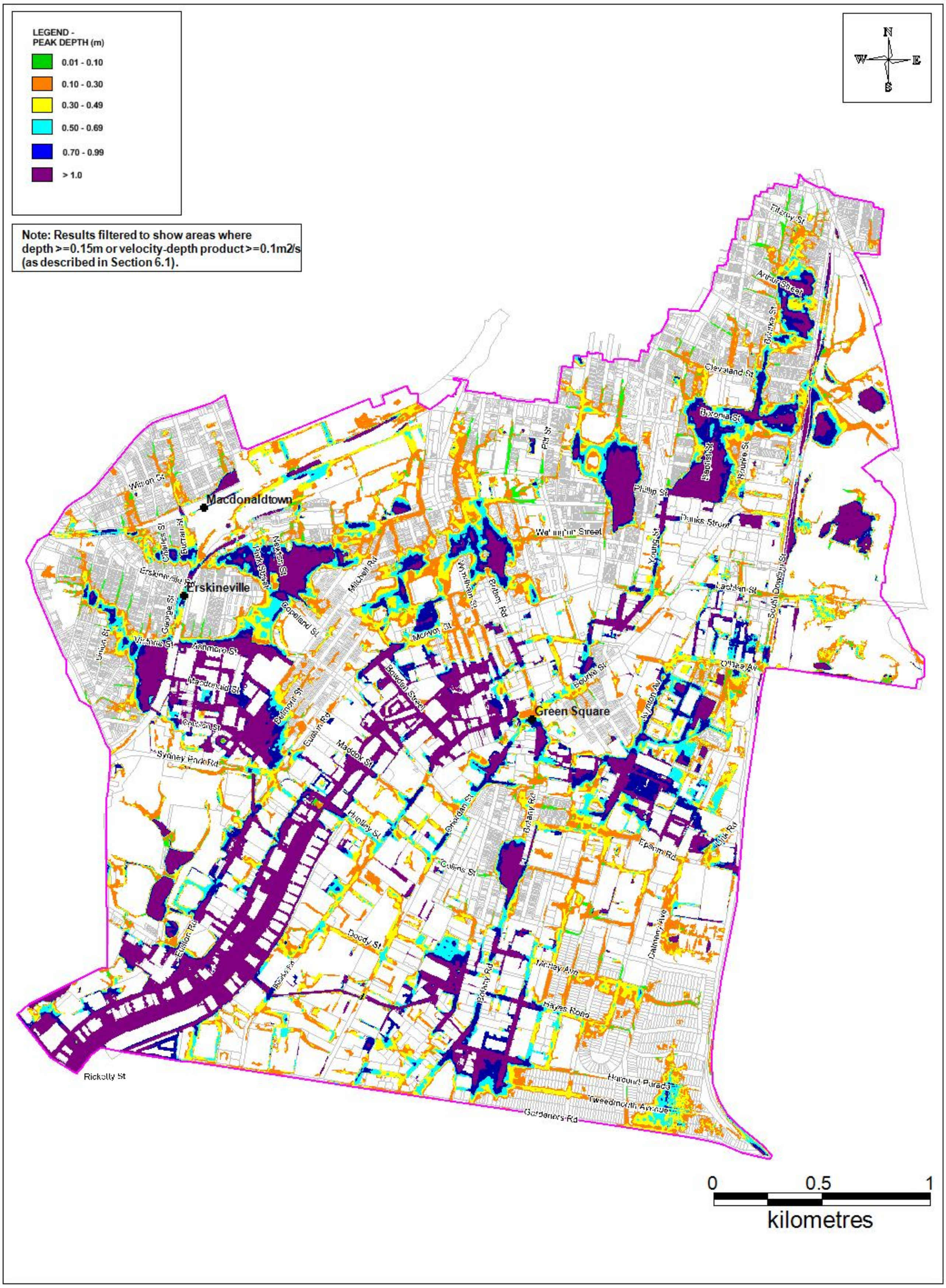


Figure 5-2 PMF Peak Flood Depths

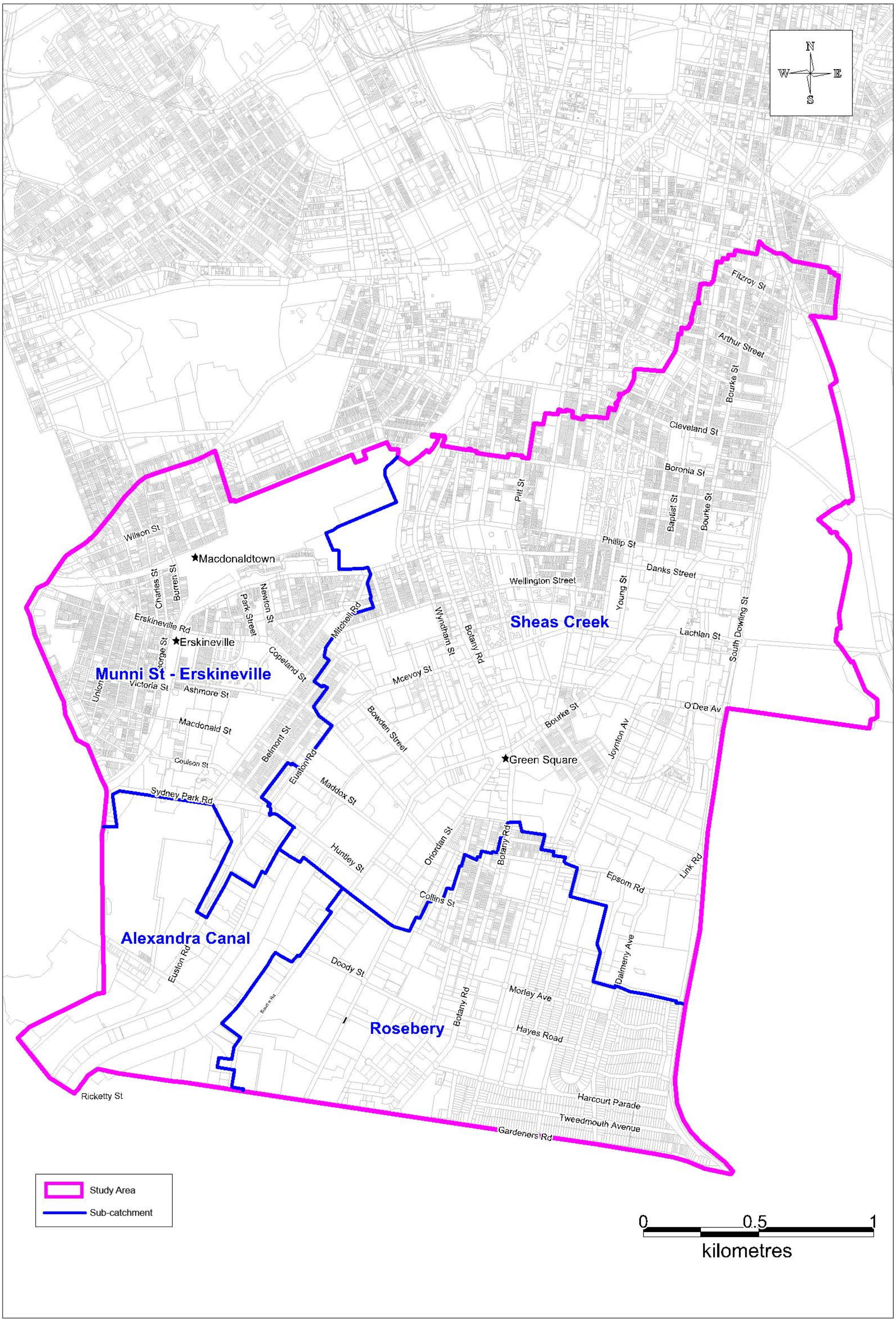


Figure 5-3 Sub-Catchments

5.2 Flooding Behaviour

5.2.1 Munni Street Sub-Catchment

The Munni Street catchment discharges into Alexandra Canal through a concrete channel near Burrows Road. The catchment incorporates a mix of residential and industrial.

The upper parts of the catchment are primarily residential and townhouses. The flowpaths in the upper portions are primarily overland flow, and proceed between the houses and across the roads in these areas. Some ponding occurs north of Macdonaldtown Station and the rail line, due to the obstruction that the rail line creates in this area on Holdsworth Street. Ponding in this area is in the order of 1.7 metres in the 100 year ARI event.

To the west of the Illawarra and Eastern suburbs rail line, an overland flow path forms a ponding and backwater area on Macdonald Street due to the control of the rail underpass on Macdonald Street. Ponding in this area is in the order of 0.8 metres in the 100 year ARI event.

A significant isolated ponding area occurs north of Erskineville Oval and Copeland Street. This area is controlled by the high point and limited capacity of Fox Avenue, as well as from the obstruction of the oval itself. Ponding upstream of this area reaches depths in excess of 1 metre in a 100 year ARI event and affects a number of residential properties.

The industrial area in the centre of the Munni Street catchment is inundated by overland flowpaths which arrive from Macdonald Street (to the west of the rail line) and from the north of Ashmore Street. This overland flow accumulates at a trapped low point at the intersection of Coulson Street and Mitchell Avenue. At this location, the estimated 100 year ARI depths are in the order of 0.9 metres, and increase to around 1.3 metres further west of the intersection on Coulson Street. This ponding area is controlled by the high point which runs between Sydney Park Road and Huntley Street.

5.2.2 Sheas Creek Sub-Catchment

The Sheas Creek catchment drains to a main open channel at Bowden Street conveying runoff to Alexandra Canal south of Huntley Street. Three subsections of the catchment drain toward Bowden Street – Alexandria and Macdonaldtown Branch, Main Branch, and Victoria Branch.

Lowpoints in the roads of the Alexandria and Macdonaldtown Branch result in ponding at Cope Street near Wellington Street, Buckland Street near Gerard Street and at Park Road.

In the Main Branch subsection, a series of lowpoints in roads show ponding of runoff in frequent storm events. These include Phelps Street, Arthur Street, Boronia Street near Marriott Street, along Baptist Street to Phillip Street, Phillip Street near Walker Street, Chalmers Street and Hunter Street. In a larger storm event, runoff flows out of these ponded areas primarily along roads from the north-east of the study area to the open channel at Wyndham Street.

The upstream areas of the Victoria Branch are located outside the study area in West Kensington to the east of South Dowling Street. Runoff is conveyed generally towards Joynton Avenue where box culverts are located to convey water through the area of the proposed Green Square Town Centre towards Mandible Street. Ponding occurs in lowpoints in roadways during frequent ARI events at Joynton Avenue, Botany Road near Bourke Street and O'Riordan Street near Johnson Street. In a larger storm event, a relatively contiguous flowpath along roads is evident from Lachlan Street and South Dowling Street along Joynton Avenue and O'Riordan Street to the open channels.

5.2.3 Rosebery Sub-Catchment

Rosebery sub-catchment is comprised of several sections which drain either to Alexandra Canal or out of the study area south of Gardeners Road. A relatively small portion in the south-eastern corner of the study area, bounded by Dalmeny Avenue and Asquith Avenue, drains toward the south across Gardeners Road. The portion of the catchment bounded by Birmingham Street, Gillespie Avenue and Botany Road also drains across Gardeners Road into the City of Botany Bay LGA.

The majority of the Rosebery sub-catchment comprises the Doody Street drainage area and drains towards the open channel located between properties from Doody Street to Bourke Road. Ponding of runoff is particularly evident at lowpoints in the road at Botany Road near Collins Street, Morley Avenue near Jones Lane, Harcourt Parade near Durdans Avenue, and Ralph Street near Shirley Street.

5.2.4 Alexandra Canal Sub-Catchment

Rainfall on Sydney Park is conveyed to the ponds within the Park and excess runoff may flow towards Euston Road in large ARI events. This sub-catchment generally drains towards Burrows Road which has several lowpoints along its length that are drained by pit and pipe systems. Ponding of runoff occurs in the lowpoints of Euston Road and Burrows Road. In large ARI events, inundation to properties may result from overland flows from upstream areas and or elevated levels in Alexandra Canal itself.

5.3 Historical Flooding

Several significant flooding events have occurred within the Alexandra Canal Catchment. Rainfall analysis would indicate that the most significant flood events occurred in the 1980s and 1990s. However, the majority of the respondents to the community survey undertaken as part of the Flood Study (Cardno, 2013) had only resided in the catchment for less than 10 years. Therefore, little information relating to historical flood events is available as a result of the survey.

Rainfall analysis identified the following key historical events in the catchment as summarised in **Table 5-1**:

- 8 November 1984 (Approximately 100 Year ARI);
- 26 January 1991 (Approximately 20 to 50 Year ARI);
- 10 April 1998 (Approximately 10 to 20 Year ARI); and
- 1 March 28 February 2001 (Approximately 1 Year ARI).

Table 5-1 Approximate ARI of Historical Rainfall Events (Observatory Hill – 66062)

Storm Event	Details	Duration				
		30 mins	60 mins	90 mins	2 hour	3 hour
8th November 1984	Intensity (mm/h)	180	119	104	90	64
	Approx. ARI	*>100y*	*>100y*	*>100y*	*>100y*	*>100y*
26th January 1991	Intensity (mm/h)	120	65	43	32	20
	Approx. ARI	*~50y*	*10-20y*	*5-10y*	*2-5y*	*1-2y*
10th April 1998	Intensity (mm/h)	84	67	48	37	35
	Approx. ARI	*5-10y*	*10-20y*	*~10y*	*5-10y*	*~20y*
28th February 2001	Intensity (mm/h)	44	22	15	11	8
	Approx. ARI	*<1y*	*<1y*	*<1y*	*<1y*	*<1y*

5.4 Flood Hazard

Flood hazard can be defined as the risk to life and limb caused by a flood. The hazard caused by a flood varies both in time and place across the floodplain.

5.4.1 Provisional Flood Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters (Figure L2, NSW Government, 2005). The Floodplain Development Manual (2005) defines two categories for provisional hazard - High and Low.

The provisional flood hazard was defined as part of the Flood Study (Cardno, 2013) using an in-house developed program, which utilises the model results of flood depths and velocity. Provisional flood hazard mapping was prepared for the PMF, 100 Year ARI and 5 Year ARI events as shown in **Figures 5-4 to 5-6**.

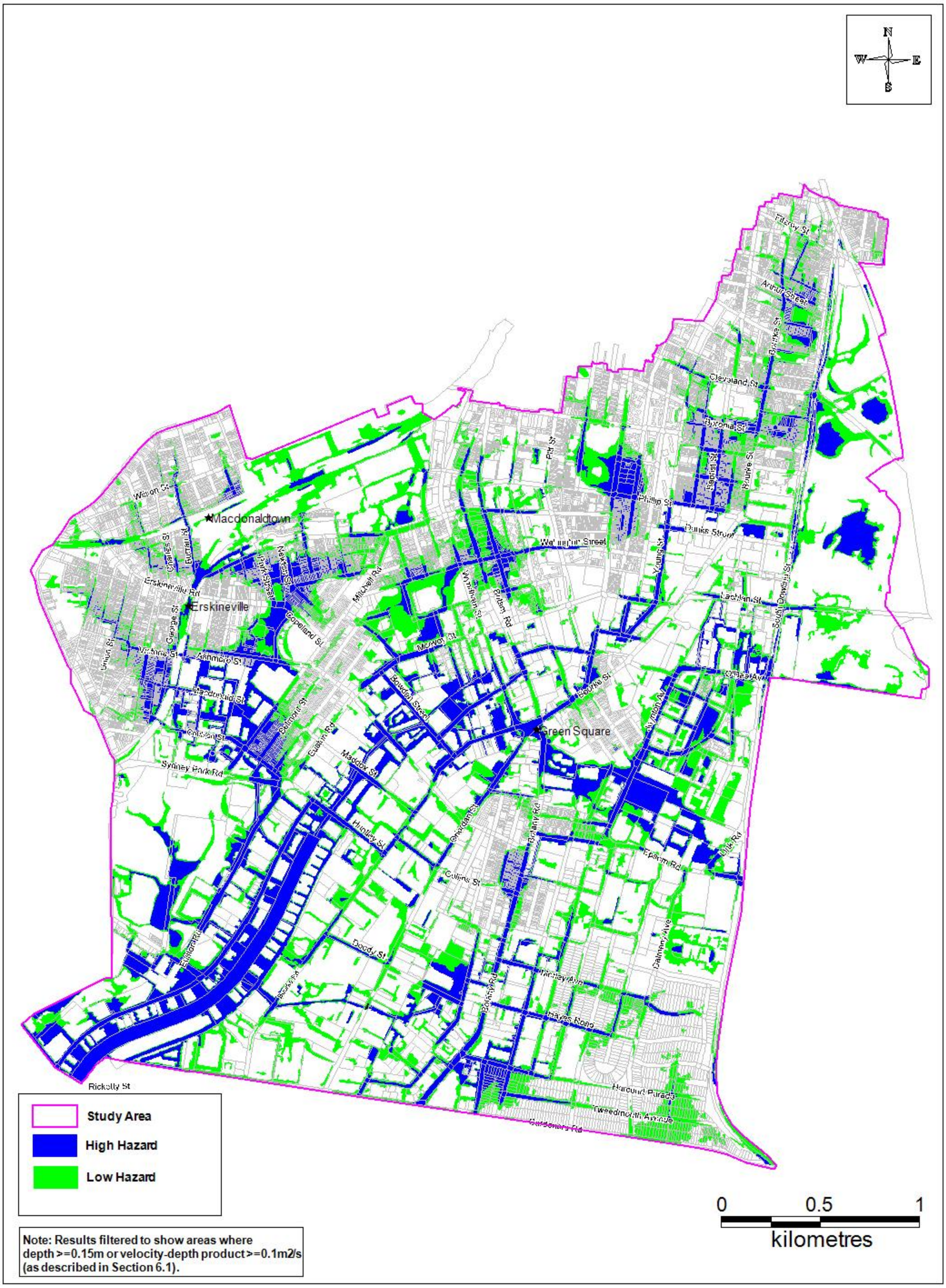


Figure 5-4 PMF Provisional Flood Hazard

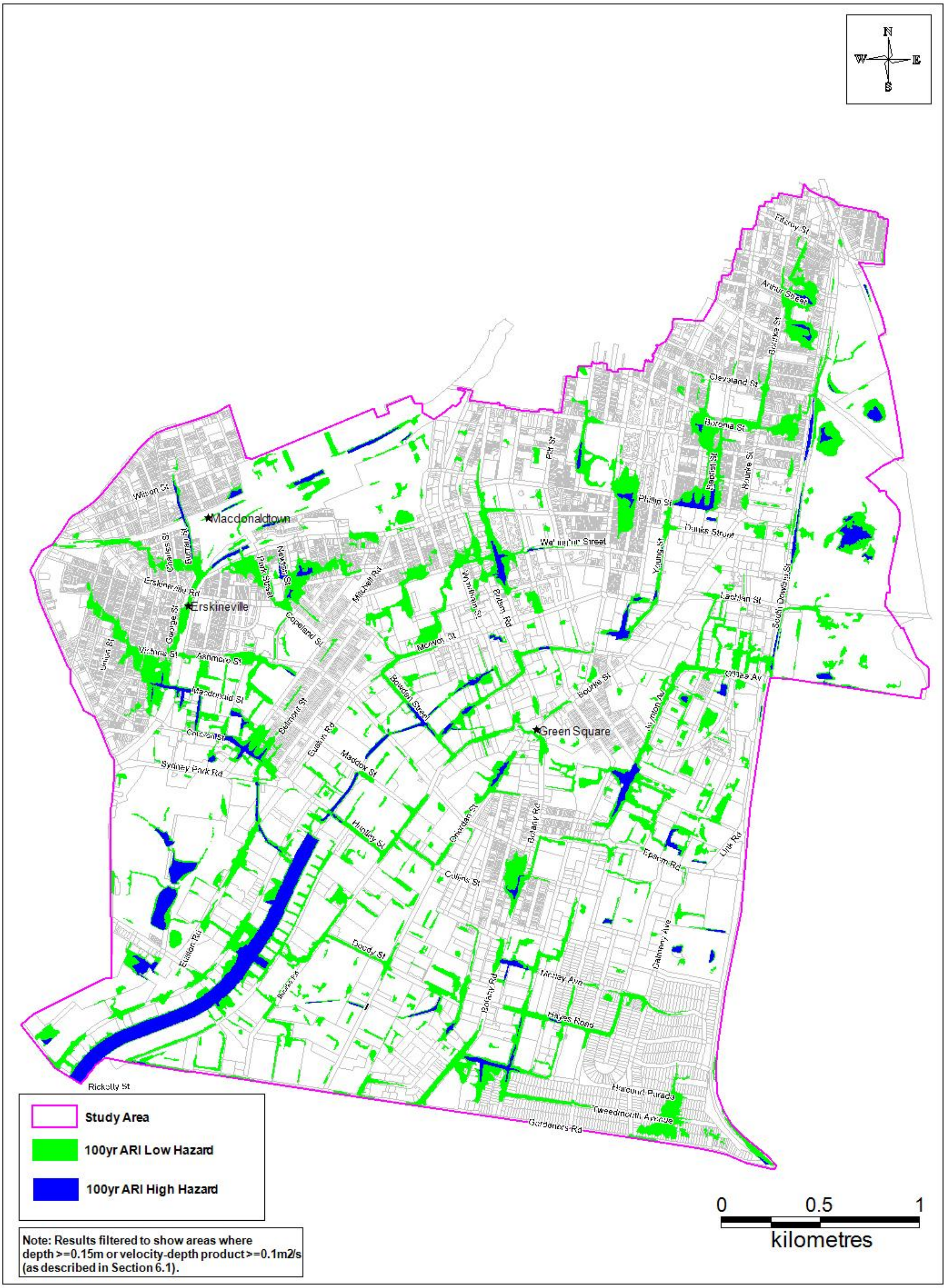


Figure 5-5 100 Year ARI Provisional Flood Hazard

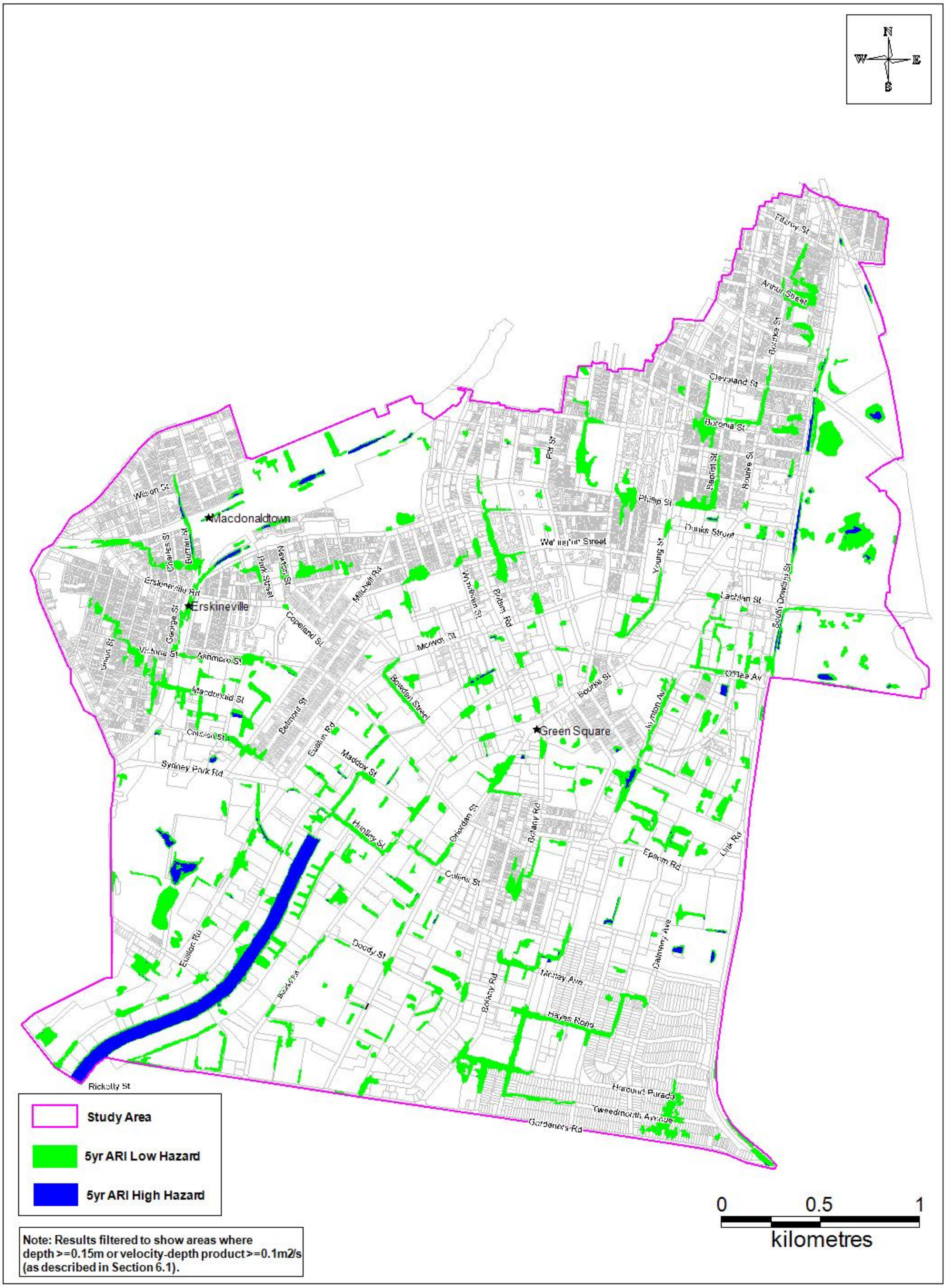


Figure 5-6 5 Year ARI Provisional Flood Hazard

5.4.2 True Flood Hazard

Provisional flood hazard categorisation is based around a function of velocity and depth, and does not consider a range of other factors that influence the "true" flood hazard. In addition to water depth and velocity, other factors contributing to the true flood hazard include:

- Size of the flood,
- Effective warning time,
- Flood readiness,
- Rate of rise of floodwaters,
- Duration of flooding,
- Ease of evacuation,
- Effective flood access, and
- Type of development in the floodplain.

The flood hazard in areas both within the floodplain and those areas outside of the floodplain impacted by flooding have been reviewed against the above listed factors. True Flood Hazard mapping has been undertaken for the 5 Year ARI, 100 Year ARI and the PMF flood event.

Size of Flood

The size of a flood and the damage it causes varies from one event to another. For the purposes of this Floodplain Risk Management Study, provisional flood hazard has been assessed for the 5 Year, 100 Year ARI and PMF events which produce the peak water levels in the floodplain. True hazard has also been assessed for the 5 and 100 Year ARI events as well as the PMF event.

Effective Warning Time

The effective warning time can also be described as the actual time for people to undertake appropriate actions (such as lift or transport belongings and/or evacuate). This time is generally always less than the total warning time available to emergency agencies. This is because of the time needed to alert people to the imminence of flooding and to have them begin effective property protection and/or evacuation procedures.

The critical duration storm for the study area is generally a 60 minute duration event for the 100 year ARI. The peak duration for the PMF event is approximately a 15 minute duration event.

The peak of the flow would therefore generally occur at various locations within the catchment within15 minutes to 2 hours from the start of the rainfall. Therefore, there is little to no warning time throughout the catchment.

However, it is noted that all areas within the catchment are exposed to similar flood response times, and therefore it can be considered that no area within the catchment is any more at risk than another.

The exception to this is overfloor flooding. Due to the critical durations within the catchment, if a property experiences overfloor flooding this will occur within a very short timeframe. This is considered to pose a hazard to these properties, and these should be included in the True Hazard Mapping. As summarised in **Table 6-5**, there are 580 residential properties and 71 commercial properties and 54 industrial properties with overfloor flooding in the 100 year ARI event. Note that these have not been shown on the mapping for privacy reasons, but this data has been provided to Council separately.

Flood Readiness

Flood readiness can greatly influence the time taken by flood-affected residents and visitors to respond in an effective fashion to flood warnings. In communities with a high degree of flood readiness, the response to flood warnings is generally prompt, efficient and effective.

Flood readiness is generally influenced by the time elapsed since the area last experienced severe flooding. The major flood events occurred in the catchment were in November 1984 which was roughly equivalent to a 100 Year ARI event, January 1991 which is approximately 20 to 50 Year ARI event and April 1998 which is approximately 10 to 20 Year ARI event.

Based on the responses from the resident survey (**Section 4**), approximately 5-10% of respondents has been living in the catchment at the time of the 1984 flood event and 1991 flood event.

The responses from the resident survey suggest that around 49% of the residents are not aware of flooding in the catchment. This can be both a function of the understanding of overland flooding, which is commonly associated with stormwater flooding. Furthermore, the short duration of flooding in the catchment may mean that the flooding occurs when the residents are not at home.

It is assumed that flood awareness of larger floods is likely to be relatively low and no particular part of the catchment is likely to be any more prepared for a flood than another, thus flood readiness has not been considered in the preparation of hazard extents.

Rate of Rise of Floodwaters

The rate of rise of floodwaters affects the consequences of a flood. Situations where floodwaters rise rapidly are potentially far more dangerous and cause more damage than situations where flood levels increase slowly. Both the catchment and floodplain characteristics affect the rate of rise.

A rate of rise of 0.5 m/hr has been adopted as indicative of hazardous conditions. However, it is important to note that a rate of rise greater than 0.5 m/hr on its own is not necessarily hazardous. For instance, if the rate of rise is very high but flood depths only reach 200 mm, this is not considered to pose any greater hazard than slowly rising waters. Therefore, peak flood depths were considered in conjunction with the rate of rise in identifying hazardous areas.

A flood depth of 500 mm, combined with a rate of rise greater than 0.5 mm/hr was selected as the trigger depth to identify hazardous conditions. A 500 mm flood depth is well within the range of available information as to when vehicles become unstable even with no flow velocity (Figure L1; NSW Government, 2005).

The mapping provided in **Figure 5-8 to Figure 5-10,** show there are few properties with flow behaviour of these constraints for the 100 and 5 Year ARI events which are not already selected by the provisional high hazard criteria. These areas should be considered with regards to flood planning end emergency response in the catchment.

Duration of Flooding

The duration of flooding or length of time a community, suburb or single dwelling is cut off by floodwaters can have a significant impact on the costs and disruption associated with flooding. Flooding durations are generally less than a couple of hours, and as such this is not considered as a key issue for Alexandra Canal Catchment. **Figure 5-7** shows the critical duration for the catchment in a 100 Year ARI flood event.

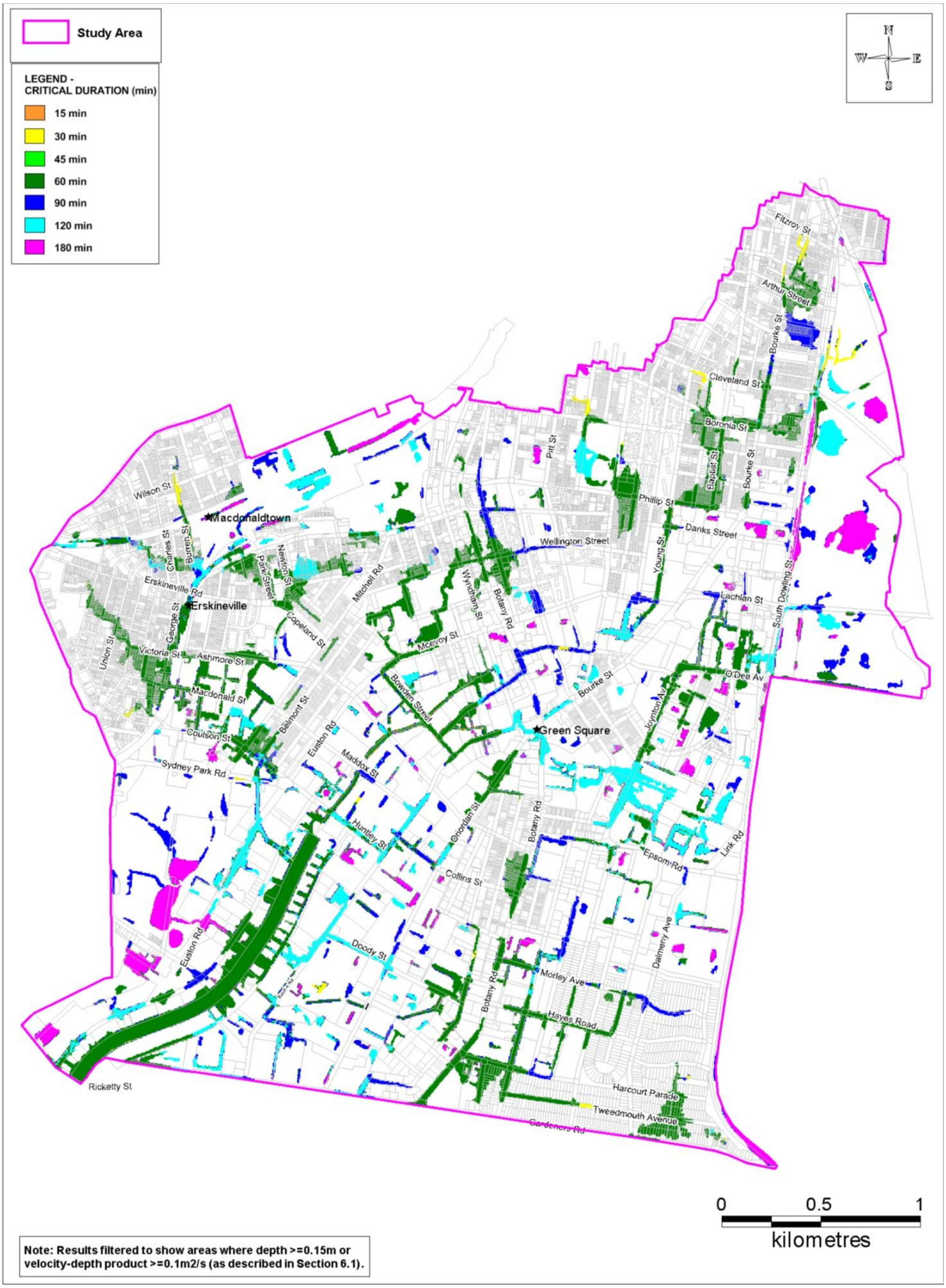


Figure 5-7 100 Year ARI Critical Duration

Ease of Evacuation

The levels of damage and disruption caused by a flood are also influenced by the difficulty of evacuating flood-affected people and property. Evacuation may be difficult because of a number of factors, including:

- The number of people requiring assistance;
- Mobility of people;
- Time of day; and
- Lack of suitable evacuation equipment.

The duration of flooding in the catchment is short, as noted above. Therefore, evacuation issues for the majority of the catchment are not considered to be an issue in a 100 Year ARI. Considering the factor of the number of people requiring assistance and mobility of people, the Waterloo Public School and Alexandria Park Community School are mapped in PMF event because the flood free access are cut off by flood waters.

Effective Flood Access

The availability of effective access routes from flood prone areas can directly influence personal danger and potential damage reduction measures. Effective access means an exit route that remains trafficable for sufficient time to evacuate people and possessions.

Flood access issues vary across the catchment. For the purposes of this assessment properties were identified as being in one of these flood access categories:

- Site is flooded and evacuation required through a high hazard flooded roadway,
- Site is flooded and evacuation is required through a flooded roadway,
- Site is flood free, however all road access is impeded by floodwaters.

The effective flood access mapping shown in **Figure 5-8 to Figure 5-10** identify that there are significant areas within the catchment which do not have effective flood access. In these areas, for the duration of the flooding, evacuation is generally not recommended. In this type of short duration flooding, residents are as likely to put themselves in harms way by evacuating rather than staying indoors.

Type of Development in the Floodplain

The degree of hazard to be managed is also a function of the type of development and resident mobility. This may alter the type of development considered appropriate in new development areas and modify management strategies in existing development areas.

The land-use in the Study Area is a mix of residential, commercial and industrial. No schools, community use buildings, nursing homes or child care centres were identified in a flood inundated area in a 100 Year ARI event.

5.4.2.2 Outcome of True Hazard Assessment

The outcomes of the true hazard assessment has been mapped in **Figure 5-8 to Figure 5-10** for the PMF, 100 year ARI and 5 year ARI flood event.

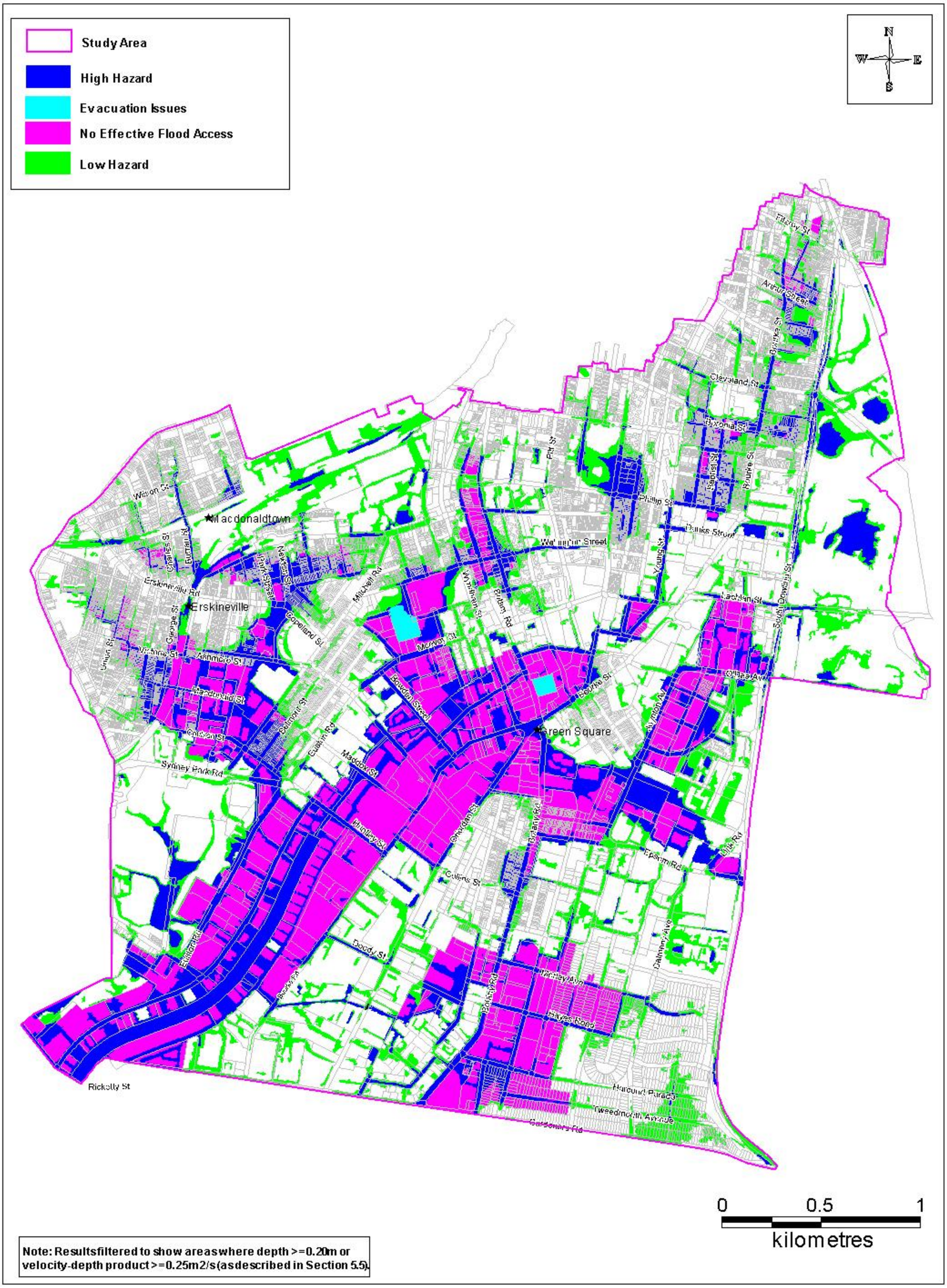


Figure 5-8 PMF True Hazard

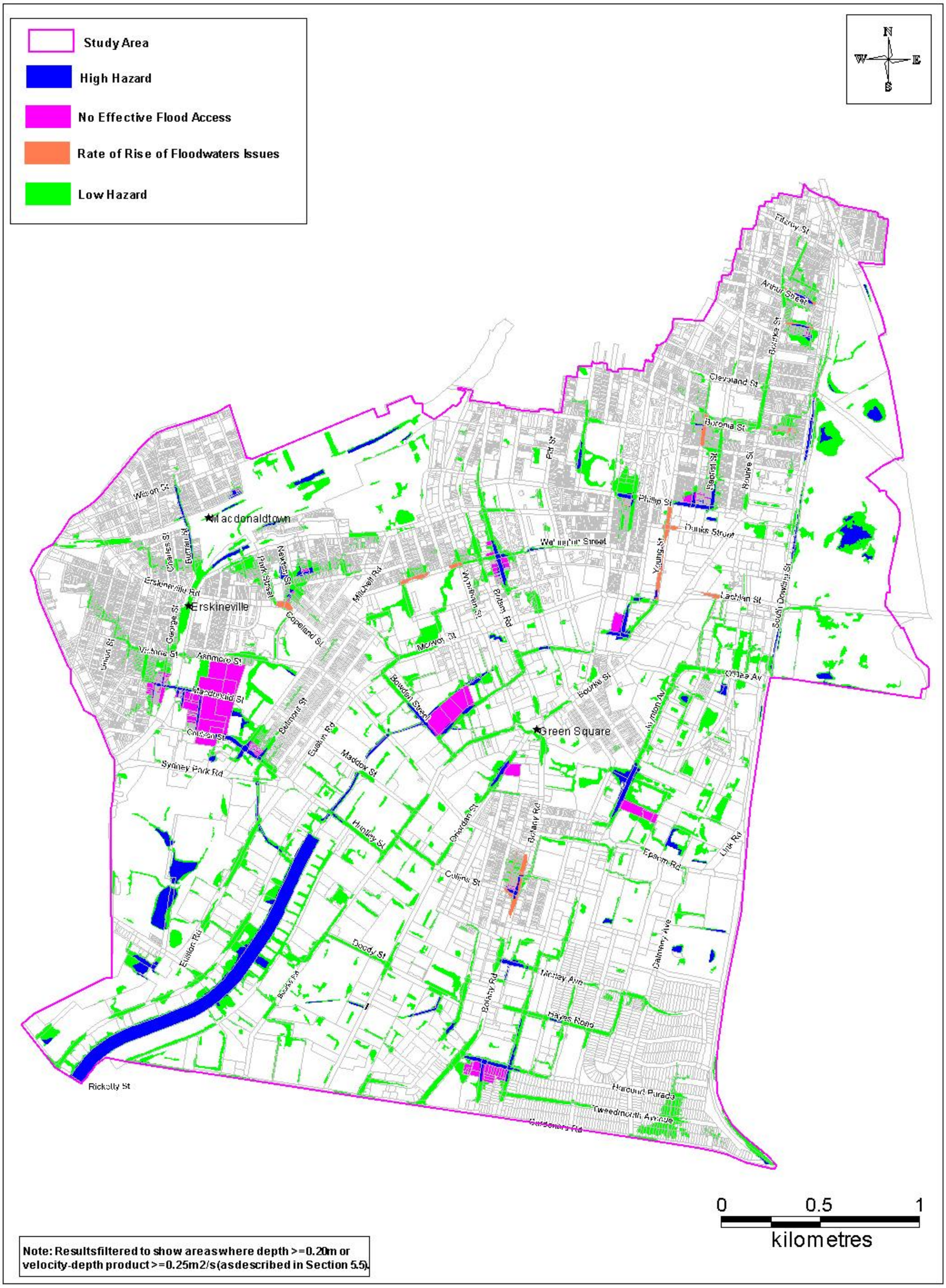


Figure 5-9 100 Year ARI True Hazard

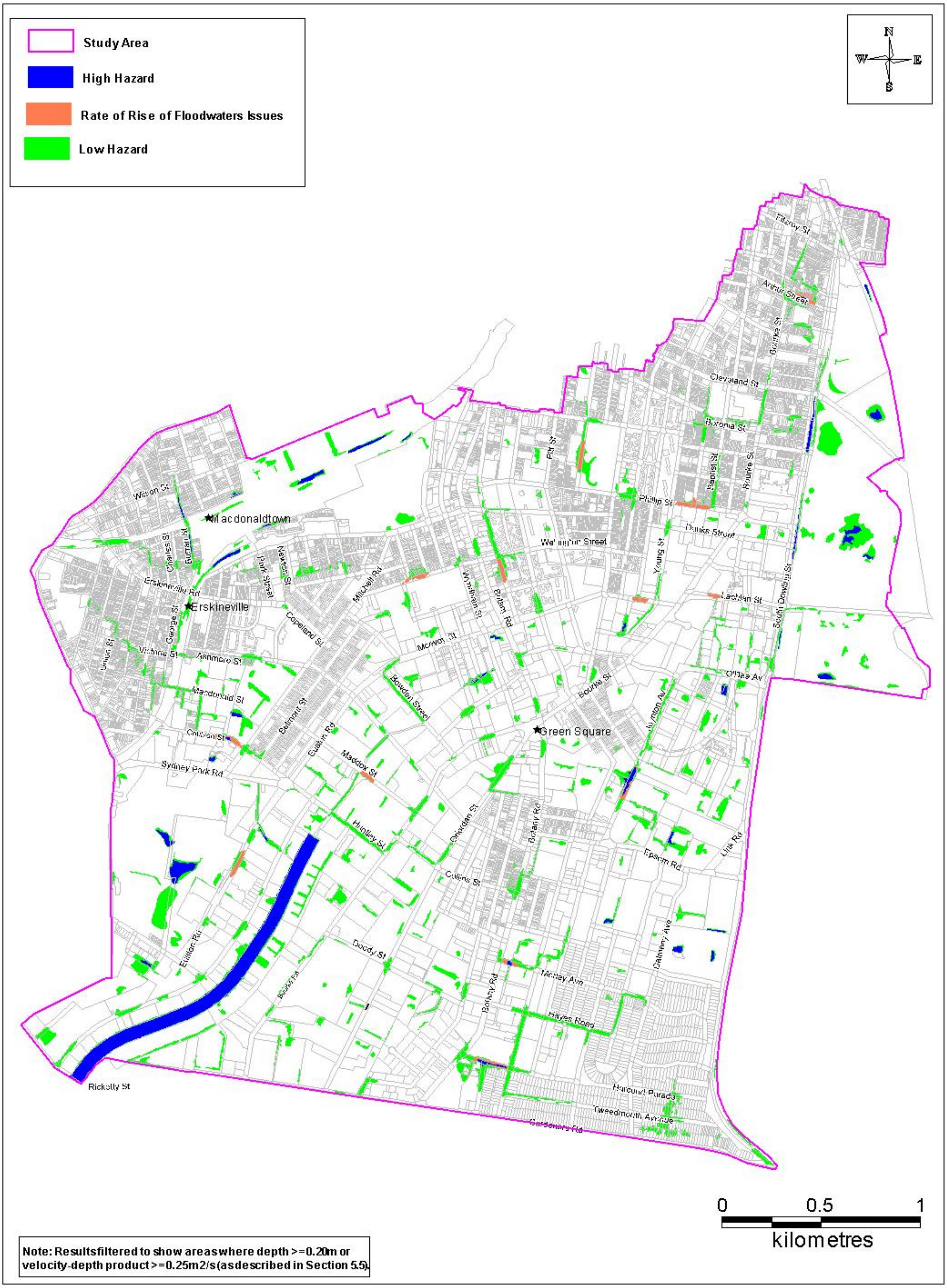


Figure 5-10 5 Year ARI True Hazard

5.5 Hydraulic Categorisation

While Flood Hazard (described in the sections above) relates to the impact of flooding on development and people, Hydraulic Categorisation is used to reflect the impact of development activity on flood behaviour. The Floodplain Development Manual (2005) defines flood prone land to be one of the following three hydraulic categories:

- **Floodway –** Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas.
- **Flood Storage –** Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10 percent.
- **Flood Fringe –** Remaining area of flood prone land after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

Hydraulic categorisation mapping has been undertaken for the 5 and 100 Year ARI together with the PMF using the results from the Draft Flood Study (Cardno, 2013).

The criteria used to define floodways and flood storage is described below (based on Howells et al, 2003). It provides a framework for the FRMSP and guides planning for properties potentially requiring a detailed assessment for future development.

As a minimum, the floodway was assumed to follow the channels from bank to bank. In addition, the following depth and velocity criteria were used to define a floodway:

- Velocity x Depth product must be greater than 0.25 m^2/s and velocity must be greater than 0.25 m/s; OR
- Velocity is greater than 1 m/s.

Flood storage was defined as those areas outside the floodway, which if completely filled would cause peak flood levels to increase by 0.1 m and/or would cause peak discharges to increase by more than 10 percent. The criteria were applied to the model results as described below.

Previous analysis of flood storage in 1D cross sections assumed that if the cross-sectional area is reduced such that 10 percent of the conveyance is lost, the criteria for flood storage would be satisfies. To determine the limits of 10 percent conveyance in a cross-section, the depth was determined at which 10 percent of the flow was conveyed. This depth averaged over several cross-sections was found to be 0.2m (Howells et al, 2003). Thus the criteria used to determine the flood storage is:

- Depth greater than 0.2m; AND
- Not classified as floodway.

The hydraulic categories are shown in **Figure 5-11 to Figure 5-13**.

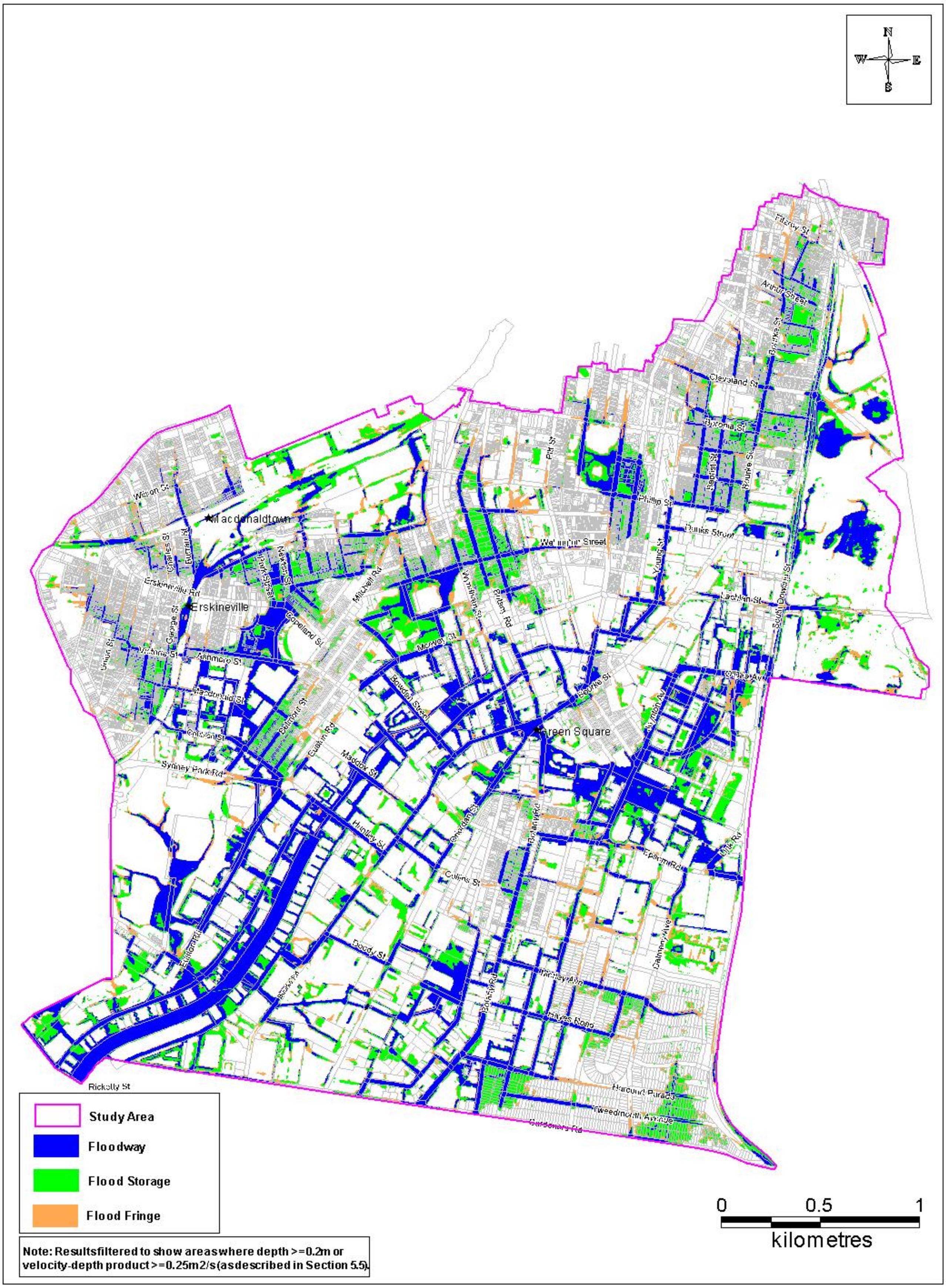


Figure 5-11 Hydraulic Categories – PMF

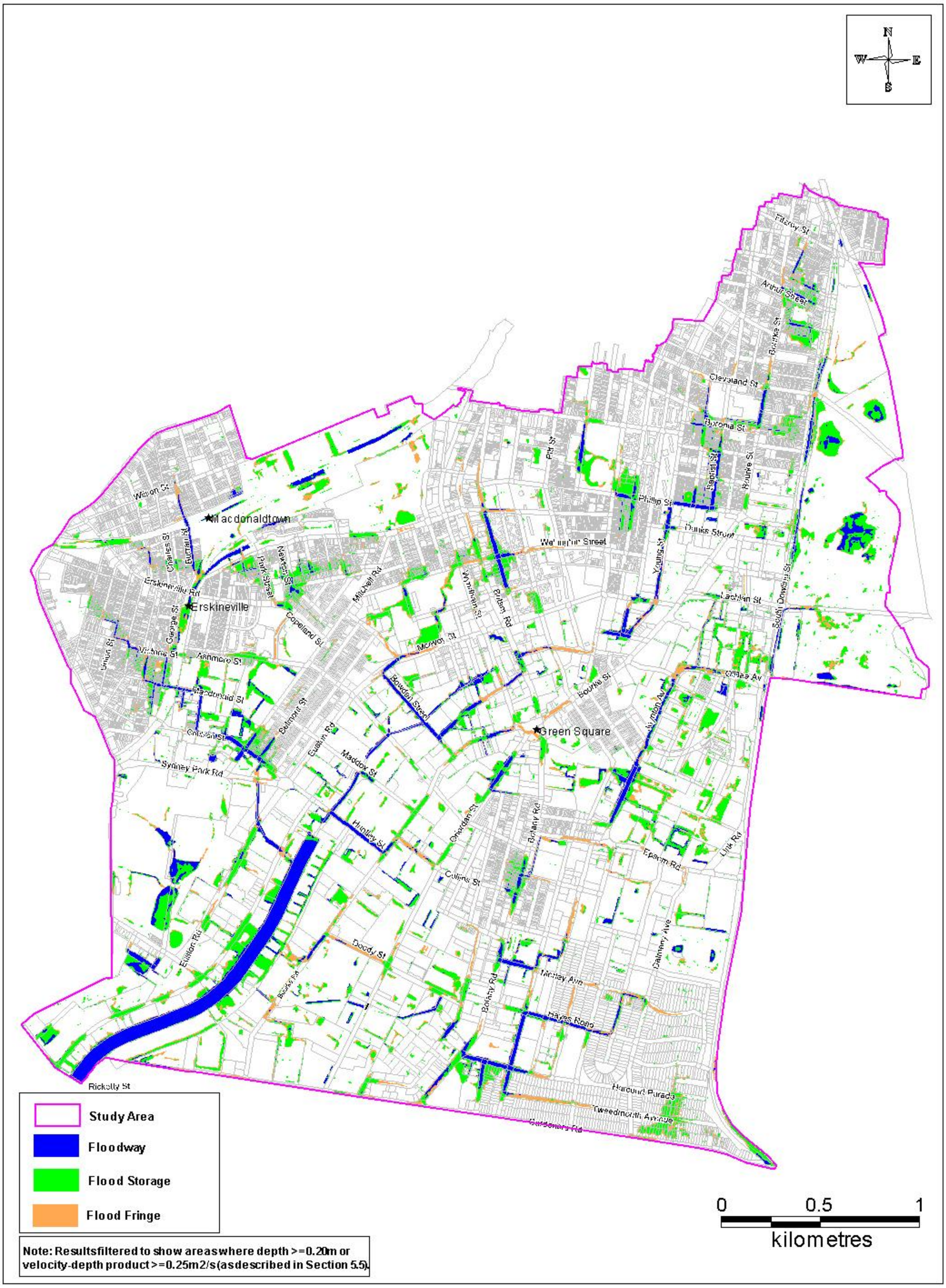


Figure 5-12 Hydraulic Categories – 100 Year ARI

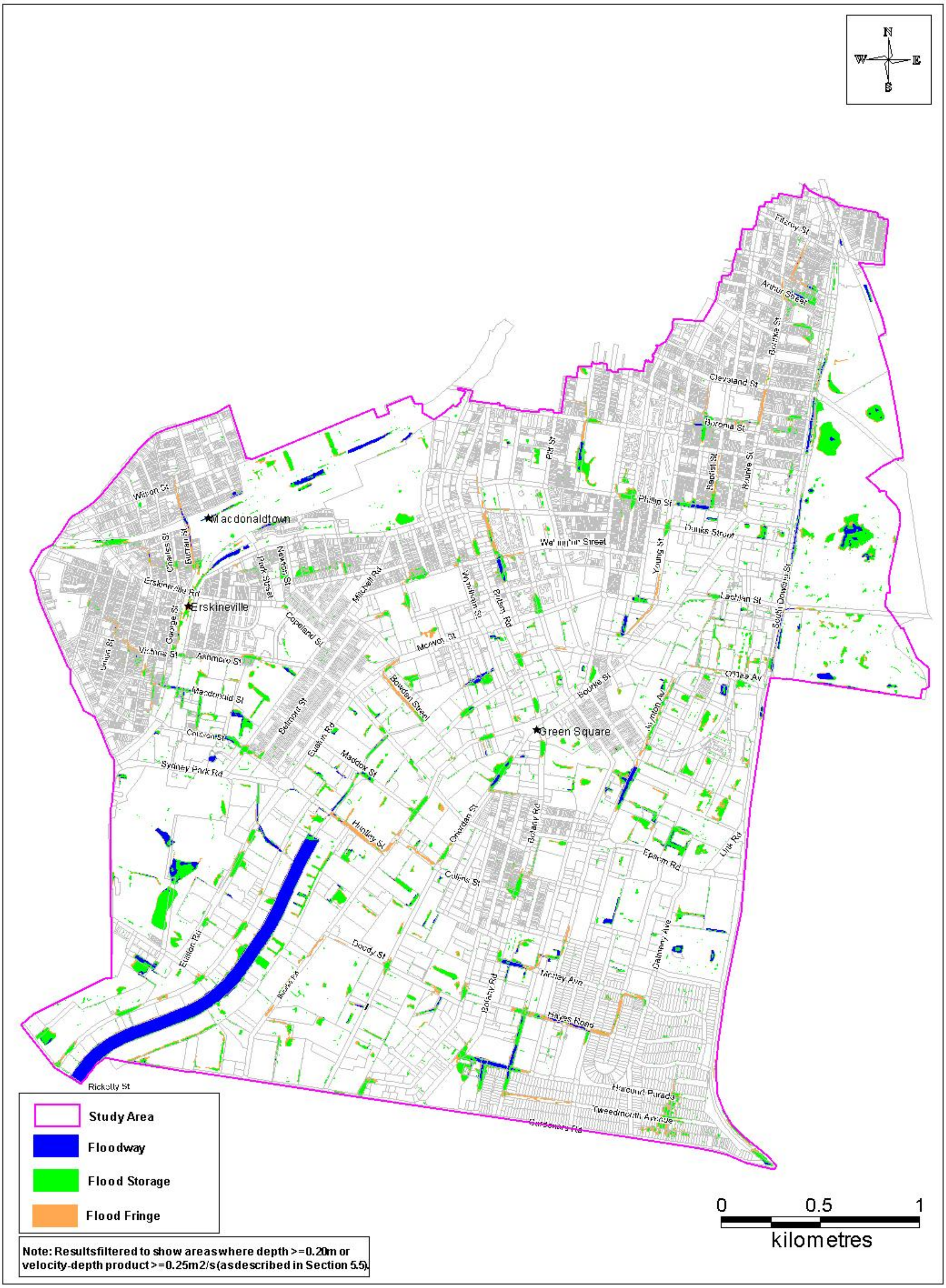


Figure 5-13 Hydraulic Categories – 5 Year ARI

6 Current Economic Impact of Flooding

6.1 Background

Flooding is likely to cause significant social and economic damages to the communities. The flood damages are classified into different categories, which are summarised in **Table 6-1**.

Table 6-1 Flood Damages Categories

Type of Flood Damage	Description
Direct	Building contents (internal) Structure (building repair and clean) External items (vehicles, contents of sheds etc)
Indirect	Clean-up (immediate removal of debris) Financial (loss of revenue, extra expenditure) Opportunity (non-provision of public services)
Intangible	Social – increased levels of insecurity, depression, stress General inconvenience in post-flood stage

The direct damage costs, as indicated in the above table, are just one component of the entire cost of a flood event. There are also indirect costs. Both direct and indirect costs are referred to as 'tangible' costs. In addition to this there are also 'intangible' costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

Flood damages can be assessed by a number of methods including the use of computer programs such as FLDAMAGE or ANUFLOOD or via more generic methods using spreadsheets. For the purposes of this project, generic spreadsheets have been used with assistance from OEH (formerly DECCW) Damage Curves on the adoption of appropriate damage curves.

6.2 Floor Level and Property Survey

A combined floor level and property survey data utilised for the flood damage estimation consists of survey data from the following sources:

- A detailed floor level and property survey undertaken by Cardno surveyors;
- Two floor level and property survey spreadsheets provided by Council;
- Data interpolated for properties based on the survey data provided by Cardno and Council; and
- A floor level and property survey data from Green Square West Kensington Flood Study (WMA, 2011).

A detailed floor level and property survey was undertaken by Cardno surveyors in February 2013, including 1344 properties. The survey results were provided by Cardno surveyors in GIS format.

Council provided two floor level and property survey spreadsheets, which include 540 survey samples. The Council's survey spreadsheets were converted into GIS layers based on coordinates of the survey locations provided in these spreadsheets.

Some modifications were made to floor levels for calculation of the flood damages.

6.3 Damage Analysis

A flood damage assessment for the existing catchment and floodplain conditions has been undertaken as part of the current study. The assessment is based on damage curves that relate the depth of flooding on a property, to the potential damage within the property.

Ideally, the damage curves should be prepared for the particular catchment for which the study is being carried out. However, damage data in most catchments is not available and recourse is generally made to damage curves from other catchments. OEH has carried out research and prepared a methodology (draft) to develop damage curves based on state-wide historical data. This methodology is only for residential properties and does not cover industrial or commercial properties.

The OEH methodology is only a recommendation and there are currently no strict guidelines regarding the use of damage curves in NSW. However, correspondence at the outset of this project with OEH (then Department of Natural Resources (DNR)) confirmed that the use of OEH curves was appropriate.

The following sections set out the methodology for the determination of damages within Alexandra Canal floodplain.

6.3.1 Residential Damage Curves

The draft DNR (now OEH) Floodplain Management Guideline No. 4 Residential Flood Damage Calculation (2004) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet program that determines damage curves for three types of residential buildings:

- Single storey, slab-on-ground;
- Two storey, slab-on-ground; and
- Single storey, high-set (i.e. on piers).

Two types of these properties were adopted for this study, including the single storey slab-on-ground and the two storey slab-on-ground. No single storey high-set houses, apartment buildings or townhouses were identified in the survey therefore no additional costs were apportioned based on these land uses.

Damages are generally incurred on a property prior to any over-floor flooding. The OEH curves allow for a damage of $10,720 (November 2012 dollars) to be incurred when the water level reaches the base of the house (the base of the house is determined by 0.3m below the floor level for slab on ground). Damages of this type are generally direct external damages (sheds, gardens), direct structural damages (foundational damage) or indirect damages (garden amenity and debris clean-up). According to the damage curves this amount of damage remains constant from the base of the house to the floor level of the house.

Given some of the inconsistencies in the data set, the following was assumed:

- When the depth of flooding on the property exceeded 0.3 metres, a nominal $1000 of garden damage was assumed since the majority of residential properties are terrace houses; and
- When the flood level is a 0.1 metres below the floor level, then a damage of $10,720 is incurred, as per the OEH damage curves.

There are a number of input parameters required for the OEH curves, such as floor area and level of flood awareness. The following parameters were adopted:

- Based on interrogation of the aerial photos a value of 200m^2 was adopted as a conservative estimate of the floor area for residential dwellings for the floodplain. With a floor area of 200m^2, the default contents value is $50,000 (November 2001 dollars).
- The effective warning time has been assumed to be zero due to the absence of any flood warning systems in the catchment. A long effective warning time allows residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches).
- The Alexandra Canal catchment is within a large metropolitan area, and as such is not likely to cause any post-flood inflation. These inflation costs are generally experienced in remote areas, where re-construction resources are limited and large floods can cause a strain on these resources.

6.3.2 Average Weekly Earnings

The OEH curves are derived for late 2001, and were updated to represent November 2012 dollars. General recommendations by OEH are to adjust values in residential damage curves by Average Weekly Earnings (AWE), rather than by the inflation rate as measured by the Consumer Price Index (CPI). OEH proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data for AWE from the Australian Bureau of Statistics at the time of the assessment was for November 2012. Therefore all ordinates in the residential flood damage curves were updated to November 2012 dollars.

While not specified, it has been assumed that the curves provided by OEH were derived in November 2001, which allows the use of November 2001 AWE statistics (issued quarterly) for comparison purposes. November 2001 AWE is shown in Table D1 of the DECC guidelines, and November 2012 AWE were taken from the Australian Bureau of Statistics website (www.abs.gov.au), as shown in **Table 6-2.**

Table 6-2 CPI Statistics for Residential Damage Curves

Month	Year	AWE
November	2001	$676.40
November	2012	$1081.30
Change	60%	

Consequently, all ordinates on the damage curves were increased by 60%. GST is not included in these values.

6.3.3 Commercial Damage Curves

Commercial damage curves have been adopted from the FLDamage Manual, Water Studies Pty Ltd (1992). FLDamage allows for three types of commercial properties:

- Low value commercial;
- Medium value commercial; and
- High value commercial.

In determining these damage curves, it has been assumed that the effective warning time is approximately zero, and the loss of trading days as a result of the flooding has been taken as 10 days.

These curves are determined based on the floor area of the property. The floor level survey provides an estimate of the floor area of the individual properties. For some commercial properties without the surveyed floor area, the floor area was estimated from aerial photographs.

The Consumer Price Index (CPI) was used to bring the 1990 data to March 2013 dollars (this data was obtained from the Australian Bureau of Statistics website (www.abs.gov.au). The CPI data is shown in **Table 6-3**.

The commercial properties were not classified into different value categories (low, medium, or high) in the survey data. Medium value was assumed for all commercial properties.

Table 6-3 CPI Statistics for Commercial Property Damage Estimation

Month	Year	CPI
June	1990	102.50
March	2013	183.60
Change	79%	

Consequently, damages have been increased by 79%. GST is not included in these values.

6.3.4 Industrial Damage Curves

Cardno, as a part of the Allans Creek Floodplain Management Study, conducted a survey of industrial properties in 1998 for Wollongong City Council (Cardno Lawson Treloar, 2006). The damage curves derived from this survey are more recent than those presented in FLDamage and have been used in a number of previous studies. Therefore, these damage curves are considered appropriate for use in this study.

The curves were prepared for three categories:

- Low value industrial (e.g. small factories and workshops);
- Medium value industrial (e.g. large industrial properties in the corner of Castlereagh Road and Railway); and
- High value industrial (e.g. BHP steelworks in Wollongong).

Within the catchment, there are no properties considered to be representative of high value industrial properties, and hence these curves were not used.

The survey conducted only accounts for structural and contents damage to the property. Clean up costs and indirect financial costs were estimated based on FLDamage Manual. Actual internal damage could be estimated, along with potential internal damage, using various factors within FLDamage. Using both the actual and potential internal damages, estimation of both the cleanup costs and indirect financial costs could be made. The values were adjusted to March 2013 dollars using the CPI statistics shown in **Table 6-4**.

The industrial properties were not classified into different value categories (low, medium, or high) in the survey data. Medium value was assumed for all industrial properties.

Table 6-4 CPI Statistics for Industrial Property Damage Estimation

Month	Year	CPI
June	1998	121.00
March	2013	183.60
Change	51%	

Consequently, damages have been increased by 51%. GST is not included in these values.

6.4 Adopted Damage Curves

The adopted damage curves are shown in **Figure 6-1**. The commercial and industrial damage curves are for a property with a floor area of 100m^2.

To normalise the damages for property size, the curves have been factored to account for floor area. For the commercial\industrial properties, the floor area was estimated from aerial photographs.

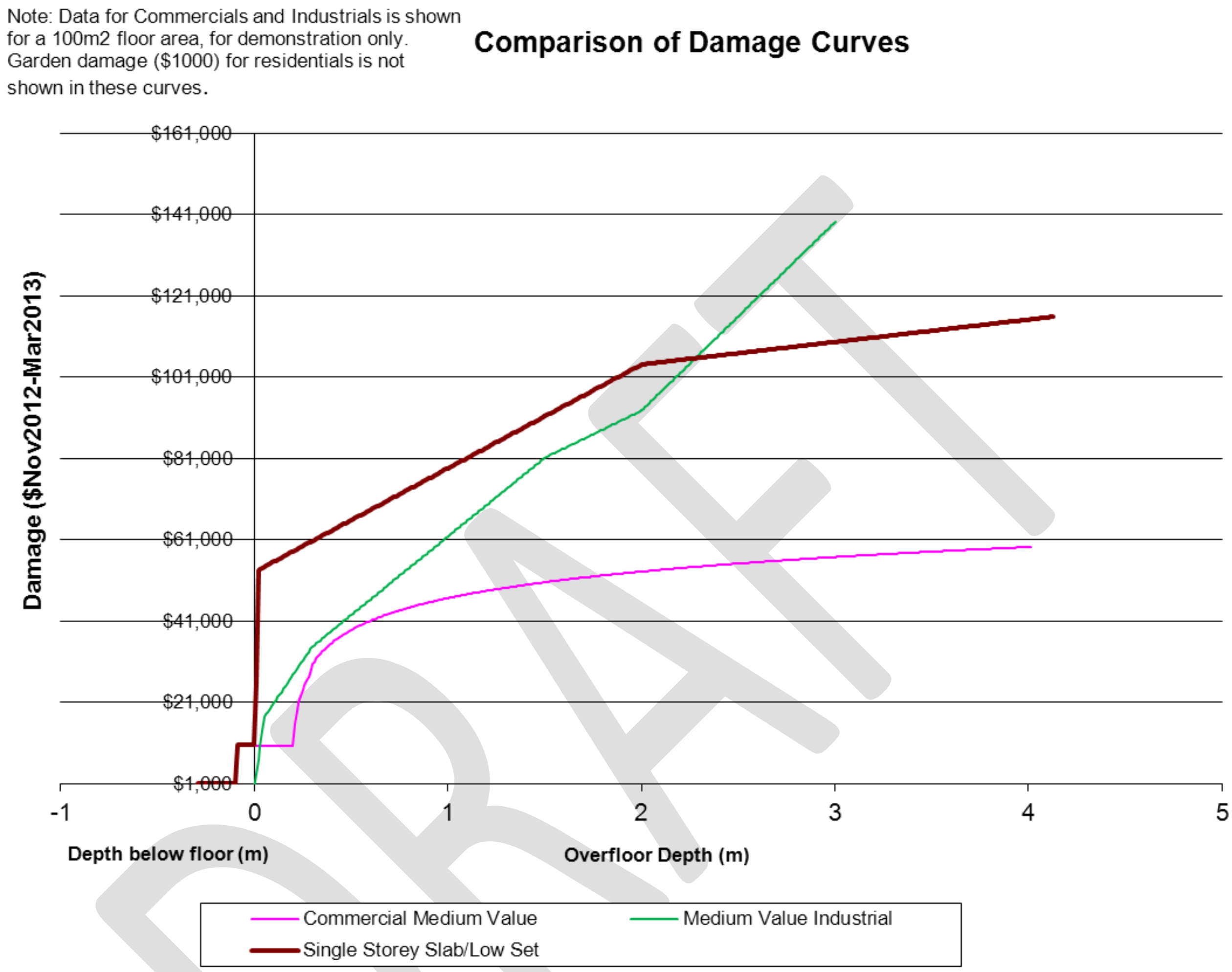


Figure 6-1 Damage Curves Developed for Alexandra Canal Catchment

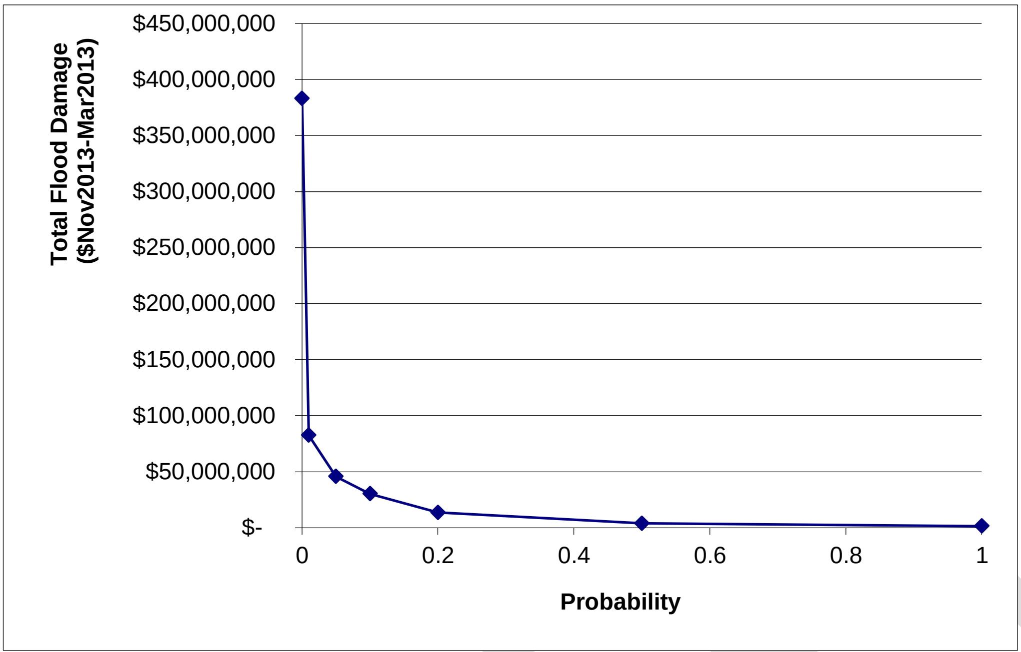
6.5 Average Annual Damage

Average Annual Damage (AAD) is calculated on a probability approach, using the flood damages calculated for each design event.

Flood damages (for a design event) are calculated by using the 'damage curves' described in the sections above. These damage curves define the damage experienced on a property for varying depths of flooding. The total damage for a design event is determined by adding all the individual property damages for that event.

AAD attempts to quantify the flood damage that a floodplain would receive on average during a single year. It does this using a probability approach. A probability curve is drawn, based on the flood damages calculated for each design event (**Figure 6-2**). For example, the 100 year ARI design event has a probability of occurring of 1% in any given year, and as such the 100 year ARI flood damage is plotted at this point on the AAD curve (**Figure 6-2**). AAD is then calculated by determining the area under this curve.

Further information on the calculation of AAD is provided in Appendix M of the Floodplain Development Manual (NSW Government, 2005).



Note: The probability of the PMF occurring is assumed as 0.0001%

Figure 6-2 Average Annual Damage Curve for Alexandra Canal Catchment

6.6 Results

Table 6-5 shows the results of the flood damage assessments. Based on the analysis described in **Section 6.3**, the average annual damage estimated for the Alexandra Canal floodplain under existing conditions is approximately **$13 million** (excluding GST).

The average annual damage reflects of the likelihood of each design flood event in one year and the damages likely to occur as a result of that event. Whilst this is a useful tool for evaluating the benefit of flood management options and assessing the flood damage to an area over a long period of time, it is also important to note the actual damages estimated to occur as a result of each design flood event. The cost to the community of flood damage is not incurred as an average annual amount. The costs will be borne at one time by the damage incurred by a specific flood event.

Financial and community attitude surveys and analysis undertaken in other areas of Sydney (e.g. the Hawkesbury Nepean Valley) (Gillespie et al, 2002) suggests that many people would have real difficulties dealing with the cost of recovering from severe flooding.

Table 6-5 Flood Damage Assessment Summary

Property Type	Properties with Overfloor Flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Properties with Overground Flooding	Total Damage ($Nov 2012-Mar 2013) (ex. GST)
PMF					
Residential	1263	0.78	3.26	1345	$91,800,740
Commercial	196	0.71	2.95	207	$97,607,569
Industry	125	0.99	3.16	131	$193,627,407
Total	1584			1683	$383,035,716
100 Year ARI					
Residential	580	0.23	1.51	988	$30,121,637
Commercial	71	0.30	0.96	110	$19,240,425
Industrial	54	0.31	1.58	89	$33,190,832
Total	705			1187	$82,552,895
20 Year ARI					
Residential	271	0.19	0.74	602	$16,236,372
Commercial	42	0.20	0.60	76	$9,928,007
Industrial	35	0.25	0.96	60	$19,491,268
Total	348			738	$45,655,647
10 Year ARI					
Residential	175	0.16	0.55	439	$10,272,581
Commercial	26	0.18	0.43	50	$6,163,448
Industry	29	0.21	0.52	43	$13,817,069
Total	230			532	$30,253,098
5 Year ARI					
Residential	106	0.16	0.39	338	$6,262,566
Commercial	8	0.19	0.29	27	$2,485,745
Industry	16	0.19	0.43	35	$4,889,260
Total	130			400	$13,637,570
2 Year ARI					
Residential	30	0.11	0.29	132	$1,653,255
Commercial	3	0.10	0.24	14	$1,397,261
Industry	6	0.17		15	$856,874
Total	39			161	$3,907,389
1 Year ARI					
Residential	1	0.11	0.19	29	$71,664
Commercial	2	0.13	0.20	8	$1,016,841
Industry	3	0.11		6	$371,364
Total	6			0	$1,459,869

6.7 Discussion

The results of the damage calculation indicate that 6 properties are exposed to overfloor flooding in a 1 year ARI event and 130 properties are exposed to overfloor flooding in a 5 year ARI event. These numbers would appear relatively high. However, there are a few key points to note:

- The average and maximum overfloor flooding depths in these events is relatively low. For example, the average overfloor flooding in a 5 year ARI event is 0.15 metres. Depending on localised factors (such as localised obstructions inside of properties, whether the front door was closed etc), the actual extent of inundation within the building may be lower than indicated;
- Further to the above, the rapid response of this type of overland flow, where in general the flood may only be at its peak for a short period of time, may result in doors and other obstructions providing some protection; and,

- There may also be localised obstructions within the property which result in slightly different water levels than indicated by the modelling.

Another consideration is the experience of property owners within the catchment. Approximately 20% of the responses (95 responses in total) from the resident survey (described in **Section 4**) identified that floodwaters had entered their house or business. Of all residential responses, around 60% have resided in the catchment for less than 10 years.

As described in **Section 5.3**, the Cardno (2013) Flood Study identified that the largest storm event in the period 2001 to 2010 was in 2001 corresponding roughly to a 1 year ARI event. April 1998 was the largest event within the last 15 years with an estimated return period of between 10 and 20 years. Therefore, there is unlikely to have been significant experience of very large events within the catchment. Based on responses listed in **Section 4**, only around 15% of the total respondents would have experienced the 1984 event, which was roughly equivalent to a 100 year ARI event.

Considering the above and that 20% of responses observed floodwaters in their house or business, potentially this type of flooding behaviour occurs for even relatively frequent events. This would tend to correspond with the outcomes of the damages analysis.

7 Environmental and Social Characteristics

Environmental and social characteristics of the study area may influence the type and extent of flood management options able to be implemented. Environmental characteristics, such as habitats, threatened species, topography and geology are constraints of structural flood modification sites.

Social characteristics such as housing and demographics may impact the community's response to flooding and therefore affect the type of flood management options proposed.

The following environmental and social characteristics have been considered in the assessment:

- Geology, Soils, Geomorphology and Groundwater;
- Demographic Characteristics;
- Flora and Fauna; and
- Aboriginal and Non-Aboriginal Cultural Heritage.

The detailed environmental and social assessment is provided in **Appendix C**.

Environmental and social issues to be considered in the development of floodplain management strategies for the Alexandra Canal Catchment include:

- The soil types that are present may potentially pose issues related to earth movement and construction due to erosion risk, low soil fertility, poor soil drainage and high permeability.
- The area adjacent to Alexandra Canal has a high probability of Acid Sulfate Soils, within 1m of the ground surface (severe environmental risk if ASS materials are disturbed by activities such as shallow drainage, excavation or clearing).
- There are 28 contaminated sites and three Protection of the Environment and Operations Act 1997 licenced premises within the catchment.
- The Alexandra Canal Catchment is located on the Botany Sand Beds aquifer. The aquifer is highly vulnerable to contamination due to the permeability of the sands and the generally shallow water table. The Botany Sands Beds Aquifer plays an important role in the Decentralised Water Master Plan 2012 – 2030. Flood management options may provide opportunities to align with the Master Plan.
- Almost a third of people living in the Alexandra Canal catchment are within the 25-34 year age bracket. In fact, 72% of the population are aged below 55 years. This indicates a community which may be primarily able-bodied, able to evacuate effectively and/or assist with evacuation procedures.
- English was the only language spoken in approximately 62% of homes in the Alexandra Canal catchment. The most common languages spoken at home other than English are Greek, Chinese languages, Indo-Aryan languages, South-east Asian languages, Russian and Spanish.
- Most of the plant species found within the catchment are introduced species or species that are not indigenous to the Sydney Area. Only the *Syzygium paniculatum* (Magenta Lilly Pilly) is known to occur within the immediate catchment area.

- Only a small number of threatened or endangered fauna species have been recorded within the immediate catchment area. This included the endangered Green and Golden Bell Frog.
- Only one Aboriginal heritage site (the Wynyard Station Midden) was identified within the vicinity of the study area.
- 31 non-Aboriginal heritage items are found within or surrounding the catchment area which have been listed by the Heritage Council under the NSW Heritage Act 1977. A further 825 items were found within or surrounding the catchment area which have been listed by local council and state government agencies.

8 Flood Emergency Response Arrangements

8.1 Flood Emergency Response

The majority of flooding within the Alexandra Canal catchment is characterised by overland flow. The critical duration is between 1 and 3 hours across the catchment, with the peak of the flood reached approximately 30 minutes to 1 hour after the start of the storm. This is considered short duration “flash” flooding.

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

The short duration until flooding occurs does not allow sufficient time to evacuate residents from their properties. In these situations, evacuation is generally not recommended as the response during a flood event as it is likely to be hurried and uncoordinated, which can expose evacuees to a hazardous situation. As such, the preferred response to flooding in flash flooding catchments, is for people to remain within the property, preferably within the upper levels, if available. The suitability of the shelter-in-place approach should be considered in consultation with the State Emergency Service for the preparation of a Local Flood Plan (Section 8.2.2).

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.

8.2 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 management flooding in the Alexandra Canal Catchment are discussed below.

8.2.1 DISPLAN

The Alexandra Canal Catchment is located within the Sydney East Emergency Management District. Flood emergency management for the Alexandra Canal Catchment is organised under the New South Wales State Disaster Plan (DISPLAN) (2010). 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 South West Metropolitan District Emergency Operations Controller and Local Emergency Operations Controllers within the South West Metro EM District.
- Detail the responsibilities for the identification, development and implementation of prevention and mitigation strategies.
- Detail the responsibilities of the District & 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.
- Detail the arrangements for the review, testing, evaluation and maintenance of the Plan.

8.2.2 Local Flood Plan

A local flood plan has not been prepared for the local area containing the Alexandra Canal 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:

a) The State of New South Wales;

b) Each SES Region; and

c) 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 which 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 road subject to flooding.

8.3 Emergency Service Operators

The emergency response to any flooding of the Alexandra Canal 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 that 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 Alexandra Canal 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 Alexandra Canal Catchment Flood Study (Cardno, 2013) should be transferred to the Security and Emergency Management Centre.

8.4 Flood Warning Systems

The critical duration and response times for the Alexandra Canal floodplain 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 flash flood catchments (such as Alexandra Canal 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.

Flood Warnings Issued by BoM

Alexandra Canal 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 Alexandra Canal

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.

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 minimise 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 stormwater 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.).

Management of the Public Domain

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

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

8.5 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.

8.5.1 Access Road Flooding

Table 8-1 provides a summary of road flooding in the Alexandra Canal Catchment.

It is recommended that permanent flood depth markers be installed on either side of roads which are subject to significant inundation to provide an indication to motorists of water levels at these locations when the road is flooded. Locations inundated in the 1 Year ARI event and which exceed 0.3m depth in any event up to the 100 Year ARI have been identified in **Table 8-1** and depth markers are recommended at these locations (this may also include adjacent intersections and low points).

Table 8-1 Access Road Flooding

ID	Location of Road Flooding (As shown on Map)	Depth Marker	Depth of Flooding (m)					
			1 Year ARI	2 Year ARI	5 Year ARI	20 Year ARI	100 Year ARI	PMF
1	Charles Street	N	0.00	0.24	0.34	0.44	0.52	1.05
2	Burren Street	N	0.00	0.20	0.25	0.33	0.41	0.90
3	Park Street	N	0.00	0.00	0.21	0.36	0.45	1.24
4	Newton Street	N	0.00	0.00	0.31	0.68	1.00	2.08
5	Copeland Street	N	0.00	0.00	0.29	0.53	0.73	1.34
6	Ashmore Street	N	0.00	0.16	0.25	0.34	0.45	1.79
7	Union Street	N	0.00	0.17	0.25	0.34	0.44	1.03
8	George Street/Macdonald Street	N	0.00	0.00	0.33	0.59	0.80	2.00
9	Coulson Street	Y	0.33	0.50	0.82	1.20	1.41	2.59
10	Mitchell Road / Coulson Street	N	0.00	0.23	0.38	0.76	0.97	2.16
11	Arthur Street	Y	0.43	0.65	0.82	0.95	1.06	1.59
12	Nobbs Street	Y	0.21	0.26	0.37	0.54	0.78	1.44
13	Cleveland Street	N	0.00	0.00	0.14	0.19	0.26	0.90
14	Charles Street	N	0.00	0.19	0.35	0.48	0.60	1.31
15	Bourke Street	N	0.00	0.00	0.23	0.34	0.43	1.29
16	Boronia Street	Y	0.17	0.32	0.48	0.60	0.70	1.26
17	Baptist Street	N	0.00	0.24	0.13	0.23	0.33	1.74
18	Phillip Street	Y	0.24	0.38	0.72	1.05	1.27	2.63
19	Chalmers Street	Y	0.54	0.64	0.73	0.80	0.86	1.12
20	Walker Street	Y	0.22	0.32	0.46	0.67	0.90	2.10
21	Young Street	N	0.00	0.23	0.28	0.39	0.62	1.64
22	Mcevoy Street	Y	0.34	0.51	0.66	0.75	0.80	1.04
23	Powell Street	N	0.00	0.21	0.40	0.79	1.45	2.95
24	Botany Road	Y	0.24	0.33	0.48	0.61	0.72	1.66
25	Wellington Street/ Cope Street	Y	0.15	0.18	0.26	0.59	0.77	1.41
26	Cope Street	Y	0.20	0.32	0.65	1.00	1.19	1.82
27	Wyndham Street/ Wellington Street	N	0.00	0.00	0.27	0.37	0.51	1.08
28	Buckland Street	Y	0.51	0.59	0.67	0.72	0.77	1.36
29	Mcevoy Street	Y	0.19	0.21	0.26	0.32	0.44	1.61
30	Lachlan Street	N	0.00	0.39	0.57	0.67	0.73	1.05
31	O'Dea Avenue	N	0.21	0.22	0.25	0.29	0.31	0.42
32	Joynton Avenue	Y	0.53	0.86	1.34	1.75	1.87	2.66
33	Botany Road (near Green Square)	Y	0.20	0.28	0.37	0.45	0.53	1.57
34	O’Riordan Street	Y	0.37	0.51	0.69	0.84	0.93	1.46
35	Bourke Road (near Bowden Street)	Y	0.15	0.18	0.33	0.55	0.67	2.45
36	Mandible Street	Y	0.24	0.32	0.45	0.69	0.89	3.08
37	Bowden Street	Y	0.30	0.33	0.37	0.47	1.02	3.62
38	Maddox Street	Y	0.63	0.76	0.81	0.85	0.88	2.71
39	Huntley Street	N	0.00	0.27	0.11	0.14	0.35	2.09
40	Harcourt Parade	Y	0.18	0.21	0.26	0.31	0.36	0.71

ID	Location of Road Flooding (As shown on Map)	Depth Marker	Depth of Flooding (m)					
			1 Year ARI	2 Year ARI	5 Year ARI	20 Year ARI	100 Year ARI	PMF
41	Tweedmouth Avenue	Y	0.26	0.30	0.35	0.40	0.45	0.75
42	Botany Road/Collins Street	Y	0.21	0.31	0.43	0.63	0.82	1.64
43	Morley Avenue	Y	0.40	0.58	0.77	1.00	1.17	1.73
44	Hayes Road	Y	0.20	0.27	0.35	0.46	0.56	1.22
45	Tweedmouth Avenue	N	0.00	0.00	0.22	0.29	0.40	1.13
46	Harcourt Parade/Durdans Avenue	Y	0.56	0.66	0.78	0.90	1.01	1.73
47	Botany Road\Harcourt Parade	N	0.00	0.17	0.26	0.37	0.48	1.18
48	Doody Street	Y	0.18	0.23	0.28	0.33	0.37	0.64
49	Euston Road	Y	0.42	0.47	0.55	0.63	0.74	1.68

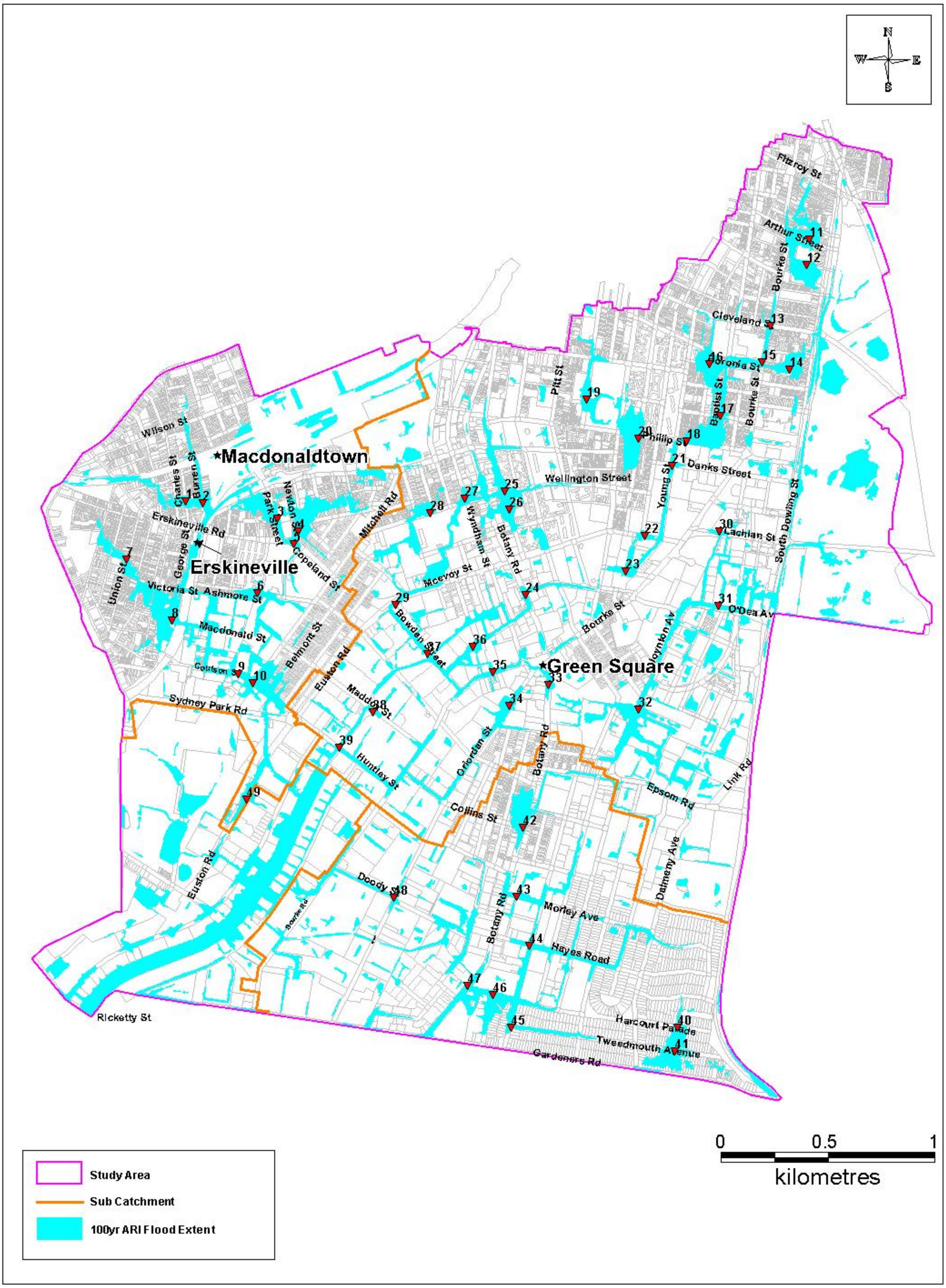


Figure 8-1 Access Road Flooding

8.5.2 Evacuation Centres

Several flood free locations have been identified in **Table 8-2** and **Figure 8-2** that may be suitable to function as evacuation centres during and following a flood event. Council and the SES should liaise with the owners and / or managers of the venues identified to determine appropriate evacuation centres. The selected locations should be identified in a local flood plan when it is prepared.

Table 8-2 Possible Evacuation Centres

ID*	Name of Venue	Address
1	Newtown High School of the Performing Arts	350 King Street Newtown NSW 2042
2	Newtown Public School	Norfolk Street Newtown NSW 204
3	St Mary's Primary School	54 Swanson Street Erskineville NSW 2043
4	Erskineville Public School	Swanson Street Sydney NSW 2043
5	Wunanbiri Pre-School	Belmont Street Alexandria NSW 2015
6	Alexandria Park Community Centre / Alexandria Park Community School	Power Avenue Alexandria NSW 2015
7	Surry Hills Neighbourhood Centre	405 Crown Street Surry Hills NSW 2010
8	Bourke Street Public School	590 Bourke Street Surry Hills NSW 2010
9	Sydney Boys High School	Cleveland Street Moore Park NSW 2021
10	Sydney Girls High School	Cleveland Street Moore Park NSW 2021
11	Moore Park Gardens Preschool & Long Day Care Centre	4/780 Bourke Street Redfern NSW 2016
12	SDN Redfern Children's Education and Care Centres	141-145 Pitt Street Redfern NSW 2016
13	The Factory Community Centre	67 Raglan Street Waterloo NSW 2017
14	Shop Women & Childrens Centre/ The Waterloo Girl's Centre	133 Morehead Street Waterloo NSW 2017
15	Our Lady of Mount Carmel	2-6 Kellick Street Waterloo NSW 2017
16	Taylors College	965 Bourke Street Waterloo NSW 2017
17	Waterloo Public School	237 Botany Road Waterloo NSW 2017
18	KU James Cahill Preschool	7 Raglan Street Waterloo NSW 2017

*ID as shown on Figure 8-2

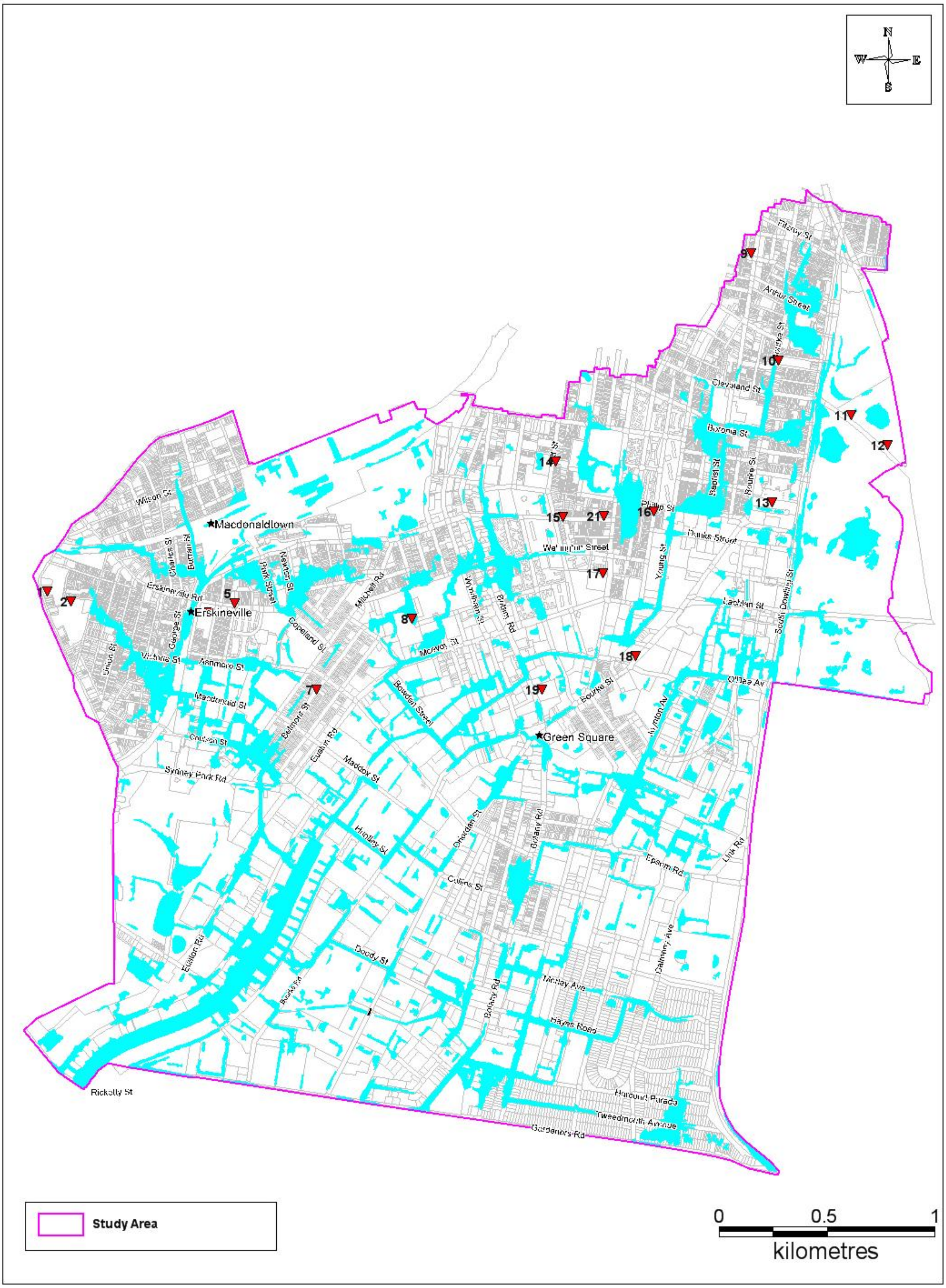


Figure 8-2 Locations of Possible Evacuation Centres

8.6 Flood Emergency Response Planning Classifications

To assist in the planning and implementation of response strategies the State Emergency Service (SES) classifies communities according to the impact flooding has on them. Flood affected communities are 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. The classifications adopted by the SES are (DECC, 2007):

- **Flood Islands.** These are inhabited or potentially habitable areas of high ground within a floodplain linked to the flood-free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. Flood islands can be further classified as:
  - High Flood Island (the flood island contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground).
  - Low Flood Island (the flood island does not have enough flood free land to cope with the number of people in the area or the island will eventually become inundated by flood waters).
- **Trapped Perimeter Areas.** These would generally be inhabited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through flood prone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped Perimeter Areas are further classified according to their evacuation route:
  - High Trapped Perimeter (the area contains enough flood free land to cope with the number of people in the area or there is opportunity for people to retreat to higher ground).
  - Low Trapped Perimeter (the area does not have enough flood free land to cope with the number of people in the area or the island will eventually become inundated by flood waters).
- **Areas Able to be Evacuated.** These are inhabited areas on flood prone ridges jutting into the floodplain or on the valley side that are able to be evacuated.
  - Areas with Overland Escape Route (access roads to flood free land cross lower lying flood prone land).
  - Areas with Rising Road Access (access roads rise steadily uphill and away from the rising floodwaters).
- **Indirectly Affected Areas.** These are areas which are outside the limit of flooding and therefore will not be inundated nor will they lose road access. However, they may be indirectly affected as a result of flood damaged infrastructure or due to the loss of transport links, electricity supply, water supply, sewage or telecommunications services and they may therefore require resupply or in the worst case, evacuation.
- **Overland Refuge Areas.** These are areas that other areas of the floodplain may be evacuated to, at least temporarily, but which are isolated from the edge of the floodplain by floodwaters and are therefore effectively flood islands or trapped perimeter areas.

The flood emergency response planning classifications for the floodplain are shown in **Figure 8-3**.

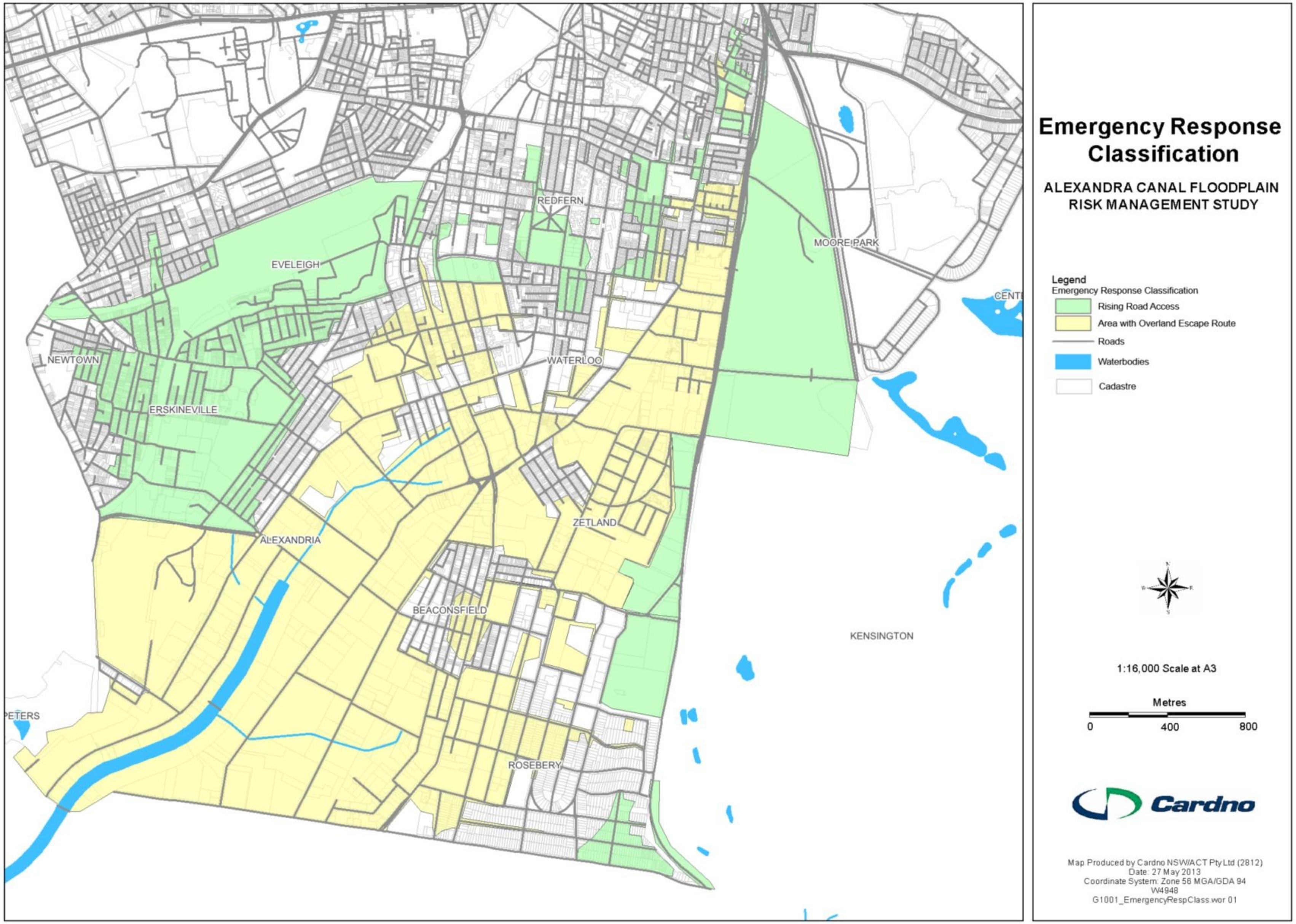


Figure 8-3 Emergency Response Classification Map

The flood affected areas of Alexandria, Beaconsfield, Zetland and Waterloo are primarily classified as "Areas with Overland Escape Routes". These areas have access roads to flood free land which cross lower lying flood prone land. Evacuation can take place by road only until access roads are closed by floodwater. Escape from rising floodwater is possible but by walking overland to higher ground. Anyone that requires assistance during a flood event that is not able to walk out will require specialised access by SES or other emergency services.

The flood affected areas of Erskineville, Eveleigh, Redfern, Moore Park and the outskirts of Zetland and Beaconsfield are primarily classified as "Areas with Rising Road Access". These areas have access roads rising steadily uphill and away from the rising floodwaters. The community cannot be completely isolated before inundation reaches its maximum extent (in the 100 Year ARI). Evacuation can take place by vehicle or on foot along the road as floodwater advances. People should not be trapped unless they delay their evacuation from their homes. For example people living in two storey homes may initially decide to stay but reconsider after water surrounds them.

Table 8-3 outlines the response recommended in the *Flood Risk Management Guideline* (DECC, 2007) for different flood emergency response planning classifications. It is noted that although evacuation is recommended in these guidelines for both of the emergency response classifications identified in the catchment. However, the catchment is primarily affected by short duration "flash" flooding and evacuation may not always be possible or safe in these circumstances. The classification should be used by emergency response providers to identify that these areas will potentially be isolated for a short period of time and appropriate response to this situation is required.

Table 8-3 Emergency Response Requirements (as recommended in DECC, 2007)

Classification	Response Required		
	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

**note that in this catchment is primarily affected by "flash" flooding and evacuation may not always be safe or appropriate in these circumstances.*

9 Policies and Planning

9.1 Planning Instruments / Policy

The Alexandra Canal Catchment is located in the City of Sydney LGA where development is controlled through the Sydney Local Environment Plan (LEP) 2012 and Development Control Plans (DCP). The LEP is a planning instrument which designates land uses and development in the LGA, which the DCPs regulates development with specific guidelines and parameters. Management policies and plans are often used to provide additional information regarding development guidelines and parameters.

This section reviews flood controls covered by the LEP, relevant DCPs, policies and plans.

9.2 Sydney Local Environmental Plan 2012

9.2.1 Flood Controls

Section 7.15 Flood Planning of the LEP outlines control and objectives for land below the flood planning level (100 Year ARI + 0.5m). The objectives of this section are:

- 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,
- to avoid significant adverse impacts on flood behaviour and the environment.

It is stated that development consent must not be granted to development on land to which this clause applies unless the consent authority 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.

Several other state planning instruments also apply to specific areas within the catchment. **Table 9-1** provide a summary of the relevant flood related objectives and controls contained within those instruments.

Table 9-1 State Planning Controls

Planning Control	Flood Management Objectives and Controls
South Sydney LEP 114	The Council shall not grant consent to the erection of a building or the carrying out of works on land to which this plan applies if, in the opinion of the Council: (a) the land is within a floodway, and (b) the carrying out of the development is likely: (i) to adversely impede the flow of flood waters on that land or land in its immediate vicinity, or

Planning Control	Flood Management Objectives and Controls
	(ii) to imperil the safety of persons on that land or land in its immediate vicinity in the event of those lands being inundated with flood waters, or (iii) to aggravate the consequences of floodwaters flowing on that land or land in its immediate vicinity with regard to erosion or siltation, or (iv) to have an adverse effect on the water table of that land or of land in its immediate vicinity. This plan does not apply to land to which South Sydney Local Environmental Plan 1998 applies.
South Sydney Local Environmental Plan 1998	The Council must not consent to development on land within the Green Square Town Centre unless it is satisfied that the development: (a) will not adversely affect flood behaviour, including: (i) the flood peak at any point upstream or downstream of the proposed development, and (ii) the flow of floodwater on adjoining lands, and (b) will not significantly increase any flood hazard or the likelihood of flood damage to any property, and (c) will not restrict the capacity of any floodway, and (d) will not increase the risk to the lives or personal safety of members of the public or emergency services and rescue personnel, and (e) incorporates any freeboard levels and other flood proofing measures adopted by the Council in any relevant floodplain risk management policy. Without limiting the subclause above, the Council must not consent to development on land situated on the southern corner of Botany Road and O'Riordan Street, unless it is satisfied that: (a) the development is consistent with any relevant floodplain risk management policies and local flood plans that have been adopted by the Council, and (b) on completion of the development, the land will achieve a low hazard categorisation for a 100 Year ARI flood event, having regard to the design of the development, including flood proofing and flood modification measures, and (c) the development does not create or materially contribute to a significant risk to the safety of persons in a probable maximum.
SEPP Major Development 2005	The objectives of the flood related clauses are: (a) to minimise the flood risk to life and property associated with the use of land, (b) to allow development on land that is compatible with the land's flood hazard, taking into account projected changes as a result of climate change, (c) to avoid significant adverse impacts on flood behaviour and the environment. The flood related clause applies to land at or below the flood planning level. Development consent must not be granted to development on land to which this clause applies unless the consent authority is satisfied that the development: (a) is compatible with the flood hazard of the land, and (b) will not significantly adversely affect flood behaviour resulting in detrimental increases in the potential flood affectation of other development or properties, and (c) incorporates appropriate measures to manage risk to life from flood, and (d) will not significantly adversely affect the environment or cause avoidable erosion, siltation, destruction or riparian vegetation or a reduction in the stability of river banks or watercourses, and (e) is not likely to result in unsustainable social and economic costs to the community as a consequence of flooding. In this clause: flood planning level means the level of a 1:100 ARI (average recurrent interval) flood event plus 0.5m freeboard.

9.2.2 Current Land Use and Zoning

The Alexandra Canal Catchment is primarily comprised of a combination of urban zones with some areas of open space.

The land use within the Alexandra Canal Catchment is controlled by the Sydney LEP 2012. The zoning of the study area is shown in **Figure 9-1**, and these zones and the flood affected areas within each zone are described in **Table 9-2**.

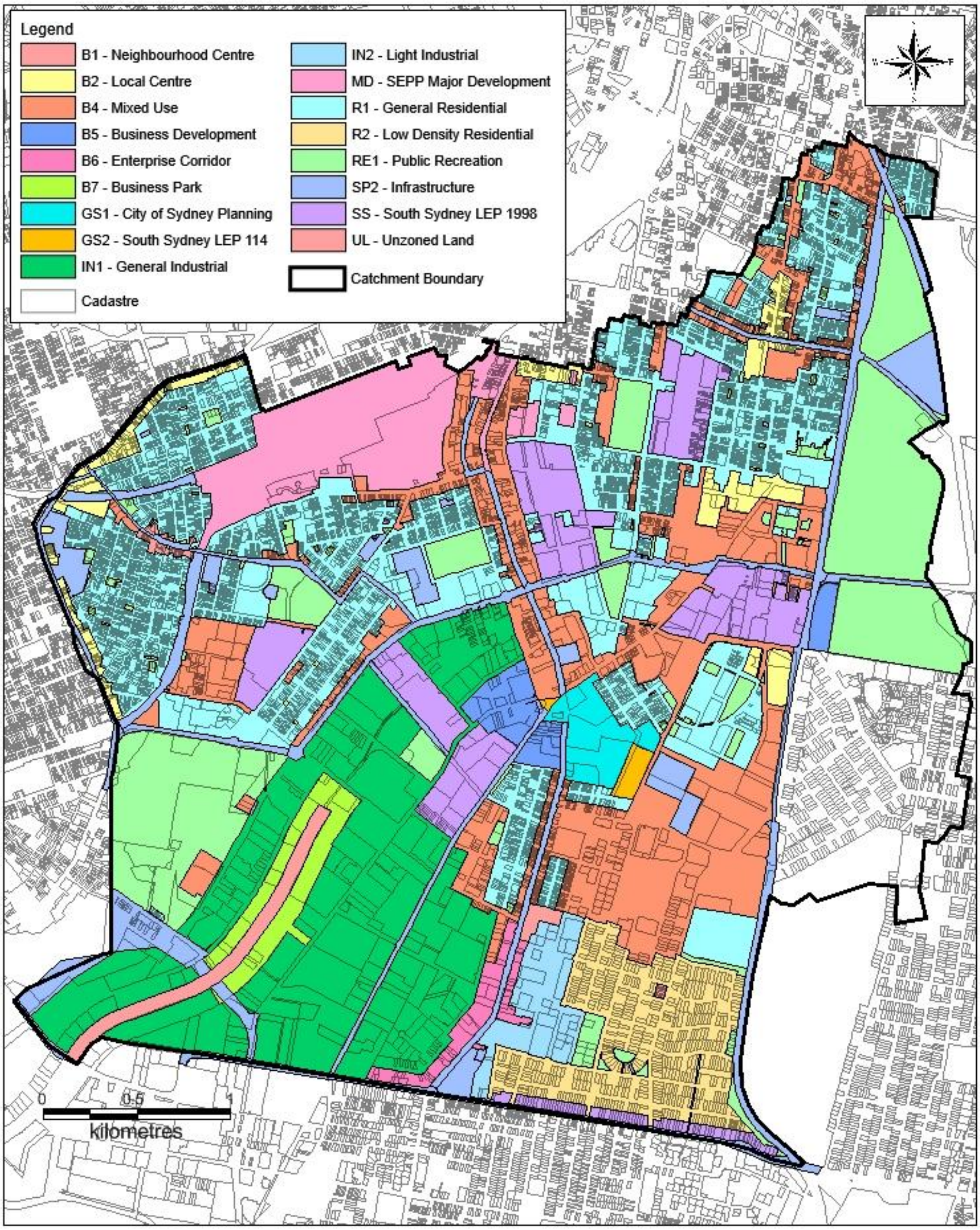


Figure 9-1 LEP Zones

Table 9-2 Alexandra Canal Catchment Land Uses

Zone	Land Use	Description	Area Affected by PMF (ha)	Area Affected by 100 Year ARI (ha)
Business	B1 Neighbourhood Centre	To provide a range of small-scale retail, business and community uses that serve the needs of people who live or work in the surrounding neighbourhood. To allow appropriate residential uses so as to support the vitality of neighbourhood centres.	3.18	0.2
	B2 Local Centre	To provide a range of retail, business, entertainment and community uses that serve the needs of people who live in, work in and visit the local area. To encourage employment opportunities in accessible locations. To maximise public transport patronage and encourage walking and cycling. To allow appropriate residential uses so as to support the vitality of local centres.	24.4	1.2
	B4 Mixed Use	To provide a mixture of compatible land uses. To integrate suitable business, office, residential, retail and other development in accessible locations so as to maximise public transport patronage and encourage walking and cycling. To ensure uses support the viability of centres.	177.6	21
	B5 Business Development	To enable a mix of business and warehouse uses, and bulky goods premises that require a large floor area, in locations that are close to, and that support the viability of, centres. To encourage employment opportunities. To enable other land uses that provide facilities or services to meet the day to day needs of the community. To promote uses with active street frontages	13.4	1.8
	B6 Enterprise Corridor	To promote businesses along main roads and to encourage a mix of compatible uses. To provide a range of employment uses (including business, office, retail and light industrial uses). To maintain the economic strength of centres by limiting retailing activity. To provide for residential uses, but only as part of a mixed use development.	9.2	0.5
	B7 Business Park	To provide a range of office and light industrial uses. To encourage employment opportunities. To enable other land uses that provide facilities or services to meet the day to day needs of workers in the area. To ensure uses support the viability of nearby centres.	16	5.6
City of Sydney Planning	GS1	Green Square	12.2	1.76

Zone	Land Use	Description	Area Affected by PMF (ha)	Area Affected by 100 Year ARI (ha)
South Sydney LEP 114	GS2 – Zone 5 (a) Special Uses Zone South Sydney Hospital	The objective is to identify land which is currently used by public authorities, institutions, organisations or for Council to provide certain community facilities, services or utilities.	2.6	0.5
Industrial	IN1 General Industrial	To provide a wide range of industrial and warehouse land uses. To encourage employment opportunities. To minimise any adverse effect of industry on other land uses. To support and protect industrial land for industrial uses. To ensure uses support the viability of nearby centres.	165.8	23.4
	IN2 Light Industrial	To provide a wide range of light industrial, warehouse and related land uses. To encourage employment opportunities and to support the viability of centres. To minimise any adverse effect of industry on other land uses. To enable other land uses that provide facilities or services to meet the day to day needs of workers in the area. To support and protect industrial land for industrial uses.	17.7	3.4
Major Development	MD SEPP Major Development	Redfern-Waterloo Authority Sites	55.4	6.4
Residential	R1 General Residential	To provide for the housing needs of the community. To provide for a variety of housing types and densities. To maintain the existing land use pattern of predominantly residential uses To enable other land uses that provide facilities or services to meet the day to day needs of residents.	266	• • • • 36.2
	R2 Low Density Residential	To provide for the housing needs of the community within a low density residential environment. To enable other land uses that provide facilities or services to meet the day to day needs of residents.	56	6.8
Recreation	RE1 Public Recreation	To enable land to be used for public open space or recreational purposes. To provide a range of recreational settings and activities and compatible land uses. To protect and enhance the natural environment for recreational purposes. To provide links between open space areas. To retain and promote access by members of the public to areas in the public domain including recreation facilities and waterways and other natural features.	143.4	16.4

Zone	Land Use	Description	Area Affected by PMF (ha)	Area Affected by 100 Year ARI (ha)
Special Purpose Zones	SP2 Infrastructure	To provide for infrastructure and related uses. To prevent development that is not compatible with or that may detract from the provision of infrastructure.	104	17.3
South Sydney LEP	SS – Zone No.2 (b) Residential (medium density)	to enhance the amenity of existing medium density residential areas, and to nominate those localities which are primarily residential and where future residential development is likely to occur, and to ensure that building form including alterations and additions, is in character with the surrounding built environment and does not detract from the amenity enjoyed by nearby residents or the existing quality of the environment, and to provide limited opportunities for non-residential development which provides goods, services or employment for residents and is of a type and scale that is compatible with existing or planned residential development and does not detract from the amenity enjoyed by nearby residents or the existing quality of the environment, and to facilitate a higher density and diverse forms of residential development on appropriate sites, and to facilitate opportunities for small scale local business activity which is compatible with existing residential areas.	74	9
	SS – Zone No.10 (b) Mixed Uses	to provide urban housing and a range of compatible vibrant non-residential uses, such as shops, offices, retail and studio-type workshops, and to promote mixed use planning by encouraging the location of facilities such as housing, places of employment and shops in close proximity to each other and so as to be accessible by public transport, and to allow up to 25% non-residential use of the total floorspace proposed for each development site, and to ensure non-residential uses are environmentally compatible with residential uses, and do not adversely affect residential amenity, within the zone, and to minimise any adverse impact, including social impact, on residential amenity by devising appropriate design assessment criteria and applying specific impact mitigation requirements by the use of development control plans, and to ensure that the nuisance generated by non-residential development, such as is caused by operating hours, noise, loss of privacy, vehicular and pedestrian traffic or other factors, is controlled, so as to preserve the quality of life for residents in the area, and to ensure that development contributes to a sustainable, vibrant community, and reflects equal and integrated consideration of social, economic and environmental design issues, and to enhance and enliven Green Square through the implementation of public art where appropriate.		

Zone	Land Use	Description	Area Affected by PMF (ha)	Area Affected by 100 Year ARI (ha)
South Sydney LEP	SS – Zone No.10 (d) Mixed Uses	to establish a predominantly employment based zone while allowing not more than 15% residential use of the total floorspace proposed for each development site, but only if it supports those employment uses, and to encourage appropriate business activities which contribute to economic growth and employment opportunities within the Green Square area, and to promote the vitality of the public domain by encouraging the location of active retail and entertainment uses at ground and first floor levels, particularly in areas fronting the Green Square Railway Station, and to ensure through the design of a high quality public domain that a high level of amenity is provided for pedestrians, shoppers and workers within the zone, and to minimise any adverse impact, including social impact, on residential amenity by devising appropriate design assessment criteria and applying specific impact mitigation requirements by the use of development control plans, and to ensure that existing and future development on land zoned industrial under this plan is preserved and promoted so as to protect the existing employment within South Sydney, and to ensure that development within the zone contributes to a sustainable, vibrant community, and reflects equal and integrated consideration of social, economic and environmental design issues, and to enhance and enliven Green Square through the implementation of public art where appropriate.		
South Sydney LEP	SS – Zone No.10 (e) Mixed Uses	to establish a predominantly employment-based zone while allowing residential use on appropriate development sites, and to allow for appropriate business activities which contribute to economic growth and employment opportunities within the Green Square area, provided they are environmentally compatible in terms of design and operational requirements with residential development, and to allow residential development within the zone, provided it is designed so as to be compatible with other non-residential uses and will not adversely affect the operations of existing lawfully operating industrial uses, and to minimise any adverse impact, including social impact, on residential amenity by devising appropriate design assessment criteria and applying specific impact mitigation requirements by the use of development control plans, and to ensure that development within the zone contributes to a highly sustainable, vibrant community, and reflects equal and integrated consideration of social, economic and environmental design issues.		

Zone	Land Use	Description	Area Affected by PMF (ha)	Area Affected by 100 Year ARI (ha)
South Sydney LEP	SS – Zone No.11 (a) Green Square Town Centre	to establish the Green Square Town Centre as the major commercial, retailing, cultural and entertainment centre for Green Square, and to allow for a mix of land uses that will: (i) ensure that there is an appropriate balance between residential, retail, commercial and other land uses within the Green Square Town Centre, and (ii) encourage the provision of a range of services and facilities to help meet the needs of the population and users of the Green Square Town Centre, and (iii) generate employment in the Green Square Town Centre, and to facilitate the development of buildings and works that are of a scale, character and design quality consistent with the other objectives of the zone, and to encourage development that is compatible with the surrounding heritage conservation areas and heritage items, and to ensure that the public domain of the Green Square Town Centre is fronted by high-quality buildings having a scale and alignment that both define, and contribute positively to the amenity of, the public spaces (including parks, plazas and streets) they adjoin, and to protect the amenity of parks and community places by protecting access to sunlight, providing shelter from the rain and minimising wind speeds, and to provide active frontages to streets and other identified public spaces (including parks and plazas), and to promote the vitality of the public domain by encouraging the location of active retail, food and beverage and entertainment uses, and of community and cultural facilities, at ground level (particularly at the edges of public plazas), and to accommodate and integrate the management of stormwater (including floodwater) into the function and design of buildings in the Green Square Town Centre.		
Unzoned Land	UZ	N/A	10.2	10

9.3 Development Control Plans

A development control plan (DCP) is a non-legal document that supports the LEP with more detailed planning and design guidelines. Several DCPs are in place in the City of Sydney LGA, the key document within the Alexandra Canal Catchment being the Sydney DCP 2012.

The flood related objective of the Sydney DCP 2012 is to:

- 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.

Whilst the objective is clearly defined in the Sydney DCP 2012, no specific development controls are provided to achieve this objective (except for those relating to on-site detention).

The DCP outlines the requirements for site specific flood studies. However, there seems to be some inconsistency between the DCP and the LEP, as the DCP states that site specific flood studies may be required by Clause 7.17 of the Sydney LEP 2012. There is no mention of flood management in Clause 7.17 and no reference as to when a site specific flood study may be required in Sydney LEP 2012.

Development within the Green Square Town Centre is managed under the Green Square Town Centre DCP 2012. The objectives of the flood related provisions in this DCP are to:

- Ensure that new development is not subjected to undue flood risk, nor exacerbates the potential for flood damage or hazard to existing development and to the public domain both during and after the event.
- Ensure that flood risk management within the Green Square Town Centre addresses public safety and protection from flooding.

The Green Square Town Centre DCP 2012 requires all development application to be prepared in accordance within the Green Square West Kensington Flood Study and Flood Risk Management Study and Plan (WMA, 2011).

The DCP also provides guidance on preparing site specific flood studies, and outlines key flood management principals which development must adhere to (e.g. incorporation of flow paths, detention areas and upgraded culverts).

Specific flood planning levels (FPLs) are documented for various development types. Further details are provided on this in **Section 10**.

9.4 Relevant Policies and Plans

9.4.1 Floodplain Management Policy

Council is currently preparing a Floodplain Management Policy. The purpose of the policy is to ensure the flood related objectives of the Sydney LEP 2012 are met and to provide specific development principals, controls and guidance not available in the LEP or DCP.

A review of the current (in preparation) Floodplain Management Policy identifies the following components contained within:

- Development application requirements and inclusions;
- Performance criteria;
- Allowances for concessional development;
- Specific controls relating to residential and industrial / commercial development, fencing, car parking, filling, on-site sewer management and storage hazardous substances.

- Flood planning levels (FPLs) are provided for various development types and components.
- Details regarding flood compatible materials.

9.4.2 Decentralised Water Master Plan 2012 - 2030

The Decentralised Water Master Plan 2012–2030 has been prepared by City of Sydney Council to position the city to deliver 30 per cent of the city's water demand from recycled water by 2030. Floodplain management in Alexandra Canal needs to consider the objectives of the Master plan, primarily to look for opportunities to achieve the dual outcomes of flood risk reduction and alternative water delivery (e.g. detention and retention storage, groundwater recharge). However, floodplain management planning also needs to consider the constraints imposed by the Master Plan such as coordinating flood works and decentralised water works within large scale development. The compatibility of floodplain risk management options with the Master Plan has been considered in the multi-criteria matrix assessment (**Section 13**).

Guidelines for on-site detention (OSD) are provided in Stormwater Drainage Connection Information (City of Sydney, 2006). The policy requires all development sites in the LGA greater than 250 m^2 and less than 1000 m^2 to incorporate OSD to reduce the 100 Year ARI post-development site runoff to the 5 Year ARI site run off.

9.5 Planning Recommendations for Alexandra Canal Floodplain

Based on the review of the documents presented in the previous sections, the following recommendations have been made. Additional details are provided in **Section 11.4**.

- Whilst the Sydney LEP 2012 is the primary state planning document relating to the catchment the South Sydney LEP 114, South Sydney LEP 1998 and the SEPP Major Development 2005 are also relevant to specific areas or development types in the catchment. These other documents contain more detailed consideration of flood management than the Sydney LEP 2012. Council may wish to consider updating the Sydney LEP 2012 to be consistent with the flood related clauses in these other documents.
- There was 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.
- The requirements for a site specific flood study are provided in the Sydney DCP 2012. However, 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.
- The Sydney DCP 2012 outlines the objective of the DCP with regards to flooding and the requirements for a site specific flood study. However, no specific flood related development controls are provided. It is understood that Council is currently preparing a *Floodplain Management Policy*, which will include more detailed controls and requirements for flood planning. 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.
- The flood management provisions in the Sydney DCP 2012 do not provide consideration of the impacts of climate change on flooding and how that should be responded to in development. The DCP should be updated to identify Council's current position on climate change and floodplain management. Alternatively, this information could be included in the Floodplain Management Policy.
- It is recommended that the Floodplain Management Policy should include controls relating to the following:

  - Impacts of climate change on flooding and how this should be considered in development and planning.
  - Consideration of the flood planning levels recommended in **Section 10**.
  - Consideration of emergency response provisions in new development with regards to short duration flooding in the catchment.
- Council may wish to consider using the outcomes of the Alexandra Canal Flood Study (Cardno, 2013) to develop OSD requirements specific to the catchment requirements. In particular, there may be areas in the catchment where OSD should not be incorporated, as it may adversely impact on downstream areas. Any such changes should also be considered as part of the implementation of the Decentralised Water Master Plan.
- 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 Floodplain Management Policy.
- No local controls specific to Alexandra Canal have been identified for inclusion in the LEPs, DCPs or Floodplain Management Policy.