Final Floodplain Risk Management Study

Marrickville Valley Floodplain Risk Management Study and Plan

59915195

Prepared for
Inner West Council

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Cardno
Shaping the Future

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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 modification 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 Marrickville Valley Floodplain Risk Management Study is developed from the previous Flood Study, adopted by Council in 2013.

Executive Summary

Cardno were commissioned by Inner West Council to undertake a Floodplain Risk Management Study (FRMS) and Floodplain Risk Management Draft Plan (FRMP) for the Marrickville Valley catchment.

This FRMS has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible mitigation options to reduce flood damages and risks. The tasks were undertaken together with stakeholder and community consultation to ensure that their concerns were addressed.

The overall objective of this study is to develop a FRMP that address 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).

The Marrickville Valley catchment comprises a 7.9 km^2 catchment which ultimately drains into the Cooks River via four outfalls:

> Eastern Channel –This Channel drains approximately 345 hectares or 44% of the Marrickville Valley. It also receives pumped flows from the low lying areas and the Central Channel.

> Central Channel – This channel starts at Sydenham Road near Fraser Park and alternates between an open channel and closed box culvert. Two pumping stations are located within the catchment of this channel.

> Western Channel – This Channel starts at Malakoff Street with the upper reaches discharging flows into Malakoff Tunnel. The channel alternates between an open concrete channel and a concrete box culvert.

> Malakoff Tunnel (Western Channel Amplification) – This is a closed box culvert which starts at Malakoff Street. It extends to Cooks River and discharges below Warren Park.

A distinguishing factor for the Marrickville Valley catchment is that there are three existing pump stations in the catchment to help reduce flooding. These pumps are run by Sydney Water and are located in Sydenham, Mackey Park and the northern end of Carrington Road.

A flood study was completed by WMAwater in 2013 to define the flood behaviour in the study area. As part of this study the flood model was updated to account for the following:

> A more recent Airborne Laser Survey (ALS) data set was used for the model terrain grid;

> New drainage works that had been undertaken since the Flood Study was completed and availability of new information;

> The modelling of the existing pump systems in the TUFLOW hydraulic model did not accurately represent the pump system operation; and

> The inlet pit and pipe set-up was changed to use inlet rating curves and no blockages in pipes greater than 300mm diameter.

There have been some changes to flood levels as a result of model updates (**Section 5.1**), however, flood levels remain similar and these changes do not impact the outcomes of the identification of flood affected properties that Council undertook based on the 2013 Flood Study results.

The number of properties vulnerable to overfloor flooding in the Marrickville Valley catchment ranges from 198 for the 2 year ARI event to 933 for the 1% AEP event. Based on a total damage assessment using residential, commercial and industrial damage curves, the average annual damage for the Marrickville Valley floodplain under existing conditions is expected to be approximately $21,264,981 with the contributions of the various design flood events summarised in the following table.

Design Event	Properties with Overfloor Flooding	Total Damage ($)
PMF	2214	145,574,007
1% AEP	933	54,486,966
10% AEP	499	34,322,087
20% AEP	366	29,830,250
2 year ARI	198	21,467,788
Average Annual Damage (AAD)		21,264,981

A number of flood mitigation options have been examined as part of this FRMS to manage flooding within the study area. 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).

A range of flood risk management options were considered to reduce the flood risk including flood modification, emergency response modification and property modification.

Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These measures reduce the risk through modification of the flood behaviour in the catchment. Sixty-nine possible flood modification measures were identified and forty options were assessed across the study area. A summary of all options assessed is provided in **Section 9** of this Floodplain Risk Management Study. Hydraulic modelling and an economic analysis (option cost verses reduction in flood damages) was undertaken for each of the flood modification option assessed.

Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than modifying the flood behaviour, these measures aim to modify properties so that there is a reduction in flood risk. Property modification assessed for the study area included opportunities to improve the flood compatibility of at risk properties.

Emergency response modification measures aim to reduce the consequences of flood risks, by modifying the behaviour of people during a flood event. A range of emergency response options were assessed including actions to improve public awareness of flood risk, local evacuation measures and improved response to flooding.

A number of structural options assessed were not considered viable where the cost benefit ratio indicated the cost of implementing the option was much higher than the resultant reduction in flood damages. All of the viable flood risk management options were assessed using a Multi-Criteria Assessment (MCA). This assessment provided for a triple bottom line approach to account for the performance of the various options with respect to economic, social and environmental criteria. The outcomes of this ranking process of the options have been used to guide the implementation strategy which is the primary component of the Floodplain Risk Management Plan.

The highest ranking flood modification options identified by the MCA include:

> FM 5.6 – Upgrade pipes along Illawarra Rd, York St and Shepherd St;

> FM 11.1 & 11.2 – Construction of an overland flowpath along the north-eastern and south-western boundary of Tillman Park;

> FM 5.3 & 5.4 – New drainage pits and pipe in Addison Road between Park Rd and Gordon Ln and raised road levels at the intersections of Park St, Neville St and Essex St with Addison Rd;

> FM 6.4 – New pipes and inlet pits along England Ave, Agar St and Wemyss St; and

> FM 11.3 – New pipes along Unwins Bridge Rd and Terry St.

The highest ranking property and emergency response modification options identified by the MCA include:

> EM 2 – Information transfer to SES;

> EM 6 – Interactive flood mapping;

> EM 5 – Flood awareness and education;

> EM 3 – Flood response for vulnerable properties; and

> EM 7 – Education and awareness of littering.

The overall recommendations of this study find that it is impractical to eliminate all flood risks from the study are. Instead, the aim of the recommendations of this FRMS is to ensure that existing and future development is exposed to a reduced level of risk.

The key findings of this FRMS is that although there is a significant flood risk within the study area, the potential for this flood behaviour to be managed through on ground works (such as drainage upgrades) is limited without significant cost. This is due to the highly urbanised catchment and high density population.

However, due to the relatively short period of flooding, flood risk can be effectively managed through the implementation of emergency response measures.

The recommendations resulting from this Floodplain Risk Management Study (FRMS) and the proposed implementation strategy is outlined in the *Marrickville Valley Floodplain Risk Management Plan (FRMP)*. The FRMP is provided separately to this FRMS document.

Table of Contents

Appendices

Tables

Figures

Glossary and Abbreviations

Australian Height Datum (AHD)	A standard national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The long-term average period between occurrences equalling or exceeding a given value. For example a 20 year ARI flood would occur on average once every 20 years.
Annual Exceedance Probability (AEP)	The probability of an event occurring or being exceeded within a year. For example, a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided. AEP – ARI: 63.2 % – 1 year 39.3 % – 2 year 18.1 % – 5 year 10 % – 10 year 5 % – 20 year 2 % – 50 year 1 % – 100 year 0.5 % – 200 year 0.2 % – 500 year
Acid Sulfate Soils (ASS)	Acid sulfate soils (ASS) are naturally occurring sediments and soils containing iron sulfides (mostly pyrite). When these sediments are exposed to the air by excavation or drainage of overlying water, the iron sulfides oxidise and form sulphuric acid. ASSs are widespread among low lying coastal areas of NSW, in estuarine floodplains and coastal lowlands.
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% 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 control lot	A lot to which flood related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).
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 (FPLs)	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.
Overland Flow	The term overland flow is used interchangeably in this report with “flooding”.
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood (PMF)	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 AEP and Average Recurrence Interval.

1 Introduction

Cardno (NSW/ACT) Pty Ltd ('Cardno') was commissioned by Inner West Council (formerly Marrickville Council) to undertake a Floodplain Risk Management Study and Plan (FRMS&P) for the Marrickville Valley catchment. This FRMS&P process 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 future flood risk has also been considered through the assessment of potential impacts of changes in sea level rise and rainfall on flood behaviour. The tasks were undertaken alongside community and stakeholder consultation to ensure that community and stakeholder concerns were addressed.

1.1 Study Context

Inner West Council has commissioned the preparation of a comprehensive Floodplain Risk Management Plan for Marrickville Valley in accordance with the *NSW Floodplain Development Manual: The Management of Flood Liable Land (NSW Government, 2005)*.

The initial key stage of the process has been undertaken with the completion of the *Marrickville Valley Flood Study* (WMAwater, 2013) which was adopted by Council in 2013. Cardno has been commissioned to prepare the next key stage of the process, the Floodplain Risk Management Study and the preparation of a Floodplain Risk Management Plan.

The NSW 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.

1.2 Study Objectives

The overall objective of this study is to develop a Floodplain Risk Management Plan for the Marrickville Valley study area to reduce the impacts of flooding and improve flood preparedness by addressing the existing, future and continuing flood problems, taking into account the potential impacts of climate change.

1.2.1 Floodplain Risk Management Study

The objectives of the Floodplain Risk Management Study are to:

- Review the current Marrickville Valley Flood Study and, only if necessary, re-assess the design flood discharges, velocities, flood levels and other relevant flood information for the Study Area;
- Review Council's existing environmental planning policies and instruments including Councils long-term planning strategies for the study area, particularly in light of the potential impacts of climate change;
- Identify works, measures and controls 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;
- Assess the effectiveness of these works and measures for reducing the effects of flooding on the community and development, both existing and future, taking into account the potential impacts of climate change;
- Consider whether the proposed works and measures might produce adverse effects (environmental, social, economic or worsened flooding) in the floodplain and whether they can be minimised taking into account the potential impacts of climate change;
- 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 any deficiencies in information and address the issues;
- Examine the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's development and disaster planning requirements;
- Examine ways in which the river and floodplain environment may be enhanced without having a detrimental effect on flooding; and
- Identify modifications that are required to current policies in light of the investigations.

1.2.2 Floodplain Risk Management Plan

The objectives of the Floodplain Risk Management Plan are to:

- Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk (taking into account the potential impacts of climate change);
- Reduce private and public losses due to flooding;
- Where possible, protect and enhance the creek and floodplain environment;
- Be consistent with the objectives of relevant state policies, in particular, the Government's Flood Prone Lands and State Rivers and Estuaries Policies and satisfy the objectives and requirements of the Environmental Planning and Assessment Act 1979;
- Be consistent with the objectives of Marrickville Strategy for a Water Sensitive Community and Stormwater Assets Management Plan;
- Ensure actions arising out of the draft plan are sustainable in social, environmental, ecological and economic terms;
- Ensure that the floodplain risk management plan is fully integrated with the local emergency management plan (flood plan) and other relevant catchment management plans; and
- Establish a program for implementation and mechanism for the funding of the plan which should include priorities, staging, funding, responsibilities, constraints, and monitoring.

1.3 Context of this Report

This report provides the following information:

- Study area description - **Section 2;**
- A review of the available data - **Section 3**;
- A summary of consultation undertaken with the community and stakeholders - **Section 4;**
- A flood behaviour summary for the Marrickville Valley floodplain, including assessment of high hazard areas, local flooding problems and flood affected critical and vulnerable developments – **Section 5**;
- The economic impacts of flooding (flood damages assessment) – **Section 6**;
- Review of the emergency response provisions available and possible within the area – **Section 7**;
- Review of flood-related policies and planning – **Section 8**;
- Preliminary identification of flood modification options for the Marrickville Valley floodplain – **Section 9**.

2 Study Area Description

The following sections provide a summary of the physical characteristics and social and environmental considerations of the study area that can be utilised to inform the floodplain management option identification and assessment process. Data and information on the following has been collated:

> Catchment description;
> Topography, soils, and contamination;
> Threatened flora and fauna;
> Demographic and social characteristics; and,
> Cultural heritage.

All of these factors help to define the Study Area and are important considerations in the assessment of floodplain risk management options within this FRMS&P.

2.1 Catchment Description

The Marrickville Valley catchment is shown in **Figure 2-1**. It comprises a 7.9 km^2 catchment that ultimately drains into the Cooks River via four outfalls:

> Eastern Channel –This Channel drains approximately 345 hectares or 44% of the Marrickville Valley. It also receives pumped flow from the low lying areas and the Central Channel.
> Central Channel – This channel starts at Sydenham Road near Fraser Park and alternates between an open channel and closed box culvert. Two pumping stations are located within the catchment of this channel.
> Western Channel – This Channel starts at Malakoff Street with the upper reaches discharging flows into Malakoff Tunnel. The channel alternates between an open concrete channel and a concrete box culvert.
> Malakoff Tunnel (Western Channel Amplification) – This is a closed box culvert which starts at Malakoff Street. It extends to Cooks River and discharges below Warren Park.

The catchment is bounded to the north by New Canterbury Road and Stanmore Rd, east by Princes Highway and south by Cooks River. The area is heavily urban and primarily comprises of high density residential and light industrial developments. The catchment is divided into nine subcatchments, each of which drains to one of the four outfalls. The catchment areas of the nine subcatchments are provided in **Table 2-1**. The location of the various subcatchments is shown in **Figure 2-1**.

Table 2-1 Approximate Catchment Sizes (Source: WMAwater, 2013)

Catchment	Catchment Size (ha)
Eastern Channel North (ECN)	136
Eastern Channel East (ECE)	131
Eastern Channel West (ECW)	75
Eastern Channel South (ECS)	43
Central Channel (CC)	71
Eastern Channel 2 (EC2)	52
Western Channel (WM)	81
Malakoff Tunnel (MT)	59
Malakoff Street (MK)	141
TOTAL	**790**

2.2 Study Area

The Study Area for this FRMS&P is shown in **Figure 2-1**. It comprises a 6.5km^2 catchment which does not encompass the entire Marrickville Valley Catchment. Eastern Channel East Subcatchment which drains into the Eastern Channel has been excluded from this study. Flood behaviour and flood modification options for this subcatchment has been previously assessed as part of the *EC East Subcatchment Management Plan – Volume 1* (Golder Associates, 2011). Further details on this study is provided in **Table 3-1**.

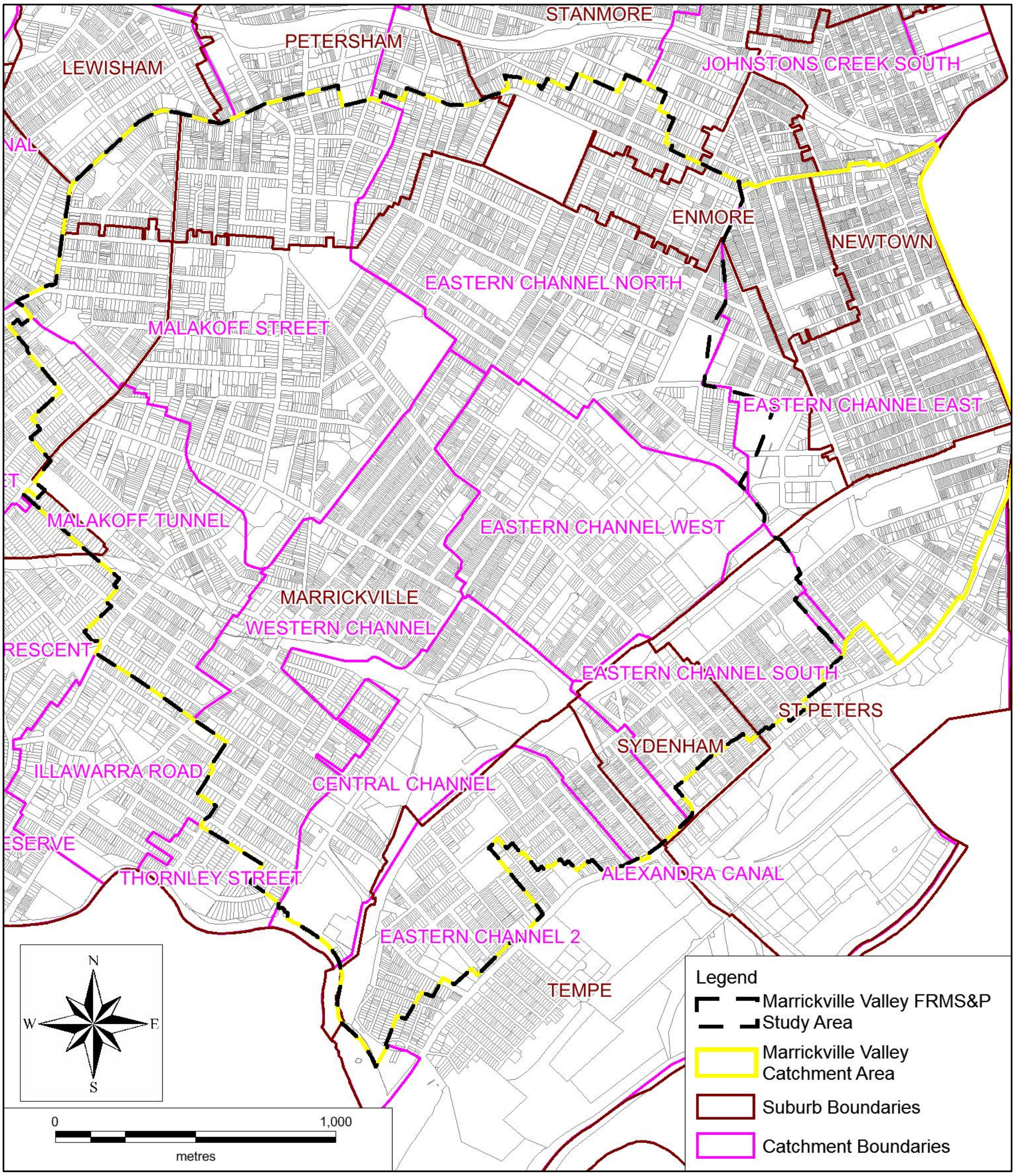


Figure 2-1 **Marrickville Valley Study Area and Catchments**

The low-lying land in the centre of the Marrickville Valley starting from Addison Rd was previously part of the Gumbramorra Swamp which has had a long history of flooding. The size of this brackish and freshwater swamp varied depending on the season and rainfall and could double in size during wet periods.

2.3 Topography and Soils

2.3.1 Topography

The Marrickville Valley area has relatively gentle slopes from north-west to south-east, with some undulating terrain along the western border of the study area. The topography of the Marrickville Valley is shown in **Figure 2-2**.

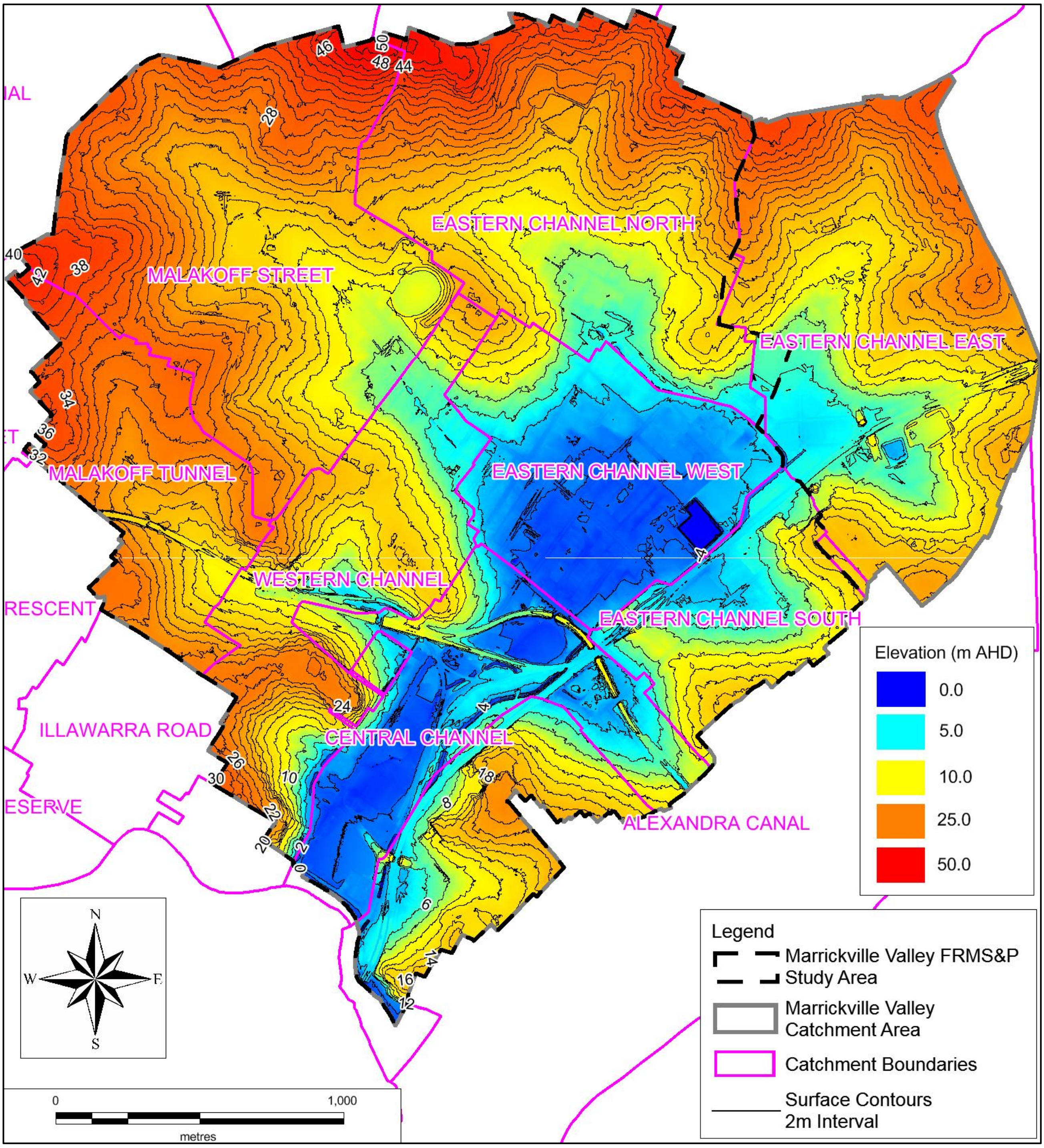


Figure 2-2 **Topography of Marrickville Valley**

The ridgeline that forms the upper boundary of the catchment runs along the northern (near Stanmore Road) and western (near New Canterbury Road) edges of the catchment and has elevations between approximately 35 – 50m AHD. The eastern boundary of the study area is another ridgeline of comparatively lower elevation (20 – 25m AHD) close to the Princes Highway. This eastern ridgeline separates the Marrickville Valley from the Alexandra Canal catchment to the east.

From these upper catchment areas the area has relatively gentle slopes grading to the lower portion of the floodplain, in the centre of the Valley. These low lying portions of the Valley grade in a southern direction towards the Cooks River adjacent to Mackey Park.

There are a range of distinguishing man made features of the study areas topography including embankments for the various rail lines that run through the study area, as well as the Sydenham detention basin which is a large area of detention significantly lower than the surrounding topography.

2.3.2 Soil Erosion Potential

A review of the Soil Landscapes of the Sydney 1:100,000 Sheet indicates that Marrickville Valley is located on several soil landscape groups, and some limitations to development may be present. Some of the key soil landscapes underlying the area are outlined in **Table 2-2** below.

The soil landscapes for the study area are shown in **Figure 2-3**.

Table 2-2 Soil Type Summary

Soil Landscape	Geomorphic Process	General Location	Erosion Hazard	
			Concentrated Flows	Non Concentrated Flows
Birrong	Alluvial	South-eastern boundary of Marrickville suburb	Low-moderate	
Blacktown	Residual	Northern portion of the study area and Sydenham and St Peters.	Moderate-high	Slight-moderate
Gymea	Erosional	Generally following Illawarra Road	High-extreme	High-very high (generally moderate – extreme)
Hawkesbury	Colluvial	A small area near Cooks River	Very high	High-extreme
Oxford Falls	Transferral	Southernmost point of the study area		

Included in **Table 2-2** is a summary of the limitations of these soil landscapes which may need to be considered during floodplain risk management options development and design. Of particular concern would be the erosion hazard associated with soil types Gymea and Hawkesbury.

2.3.3 Acid Sulfate Soils

Acid Sulfate Soil (ASS) is the common name for soils that contain metal sulfides. The presence of these soils is more likely in generally low-lying areas of the floodplain. In an undisturbed and waterlogged state, acid sulphate soils generally pose no or low risk. However, when disturbed, an oxidation reaction occurs to produce sulfuric acid which can negatively impact on the surrounding environment in a number of ways such as a reduction in water quality, fish kill and plant death. Sulfuric acid produced by the soils can also corrode and weaken certain structures and building foundations. Part 6.1 of the *Marrickville LEP 2011* outlines general provisions for development near ASS.

Potential ASS within Marrickville Area of Inner West Council LGA are classified into five land classes with each land class indicating the depth where potential acid sulphate soils may occur. Development consent is required for work in those five classes as described in **Appendix A**, Table A1.

The majority of the study area is mapped as Class 5 acid sulphate soils (ASS) according to Council’s LEP 2011 mapping. Class 3 ASS soils are present through the low-lying portion of Marrickville (varying between 200-500m in depth). Class 4 ASS are also present generally along the northern half of Sydenham Road. The location of acid sulfate soil classes for the study area is shown in **Figure 2-4**.

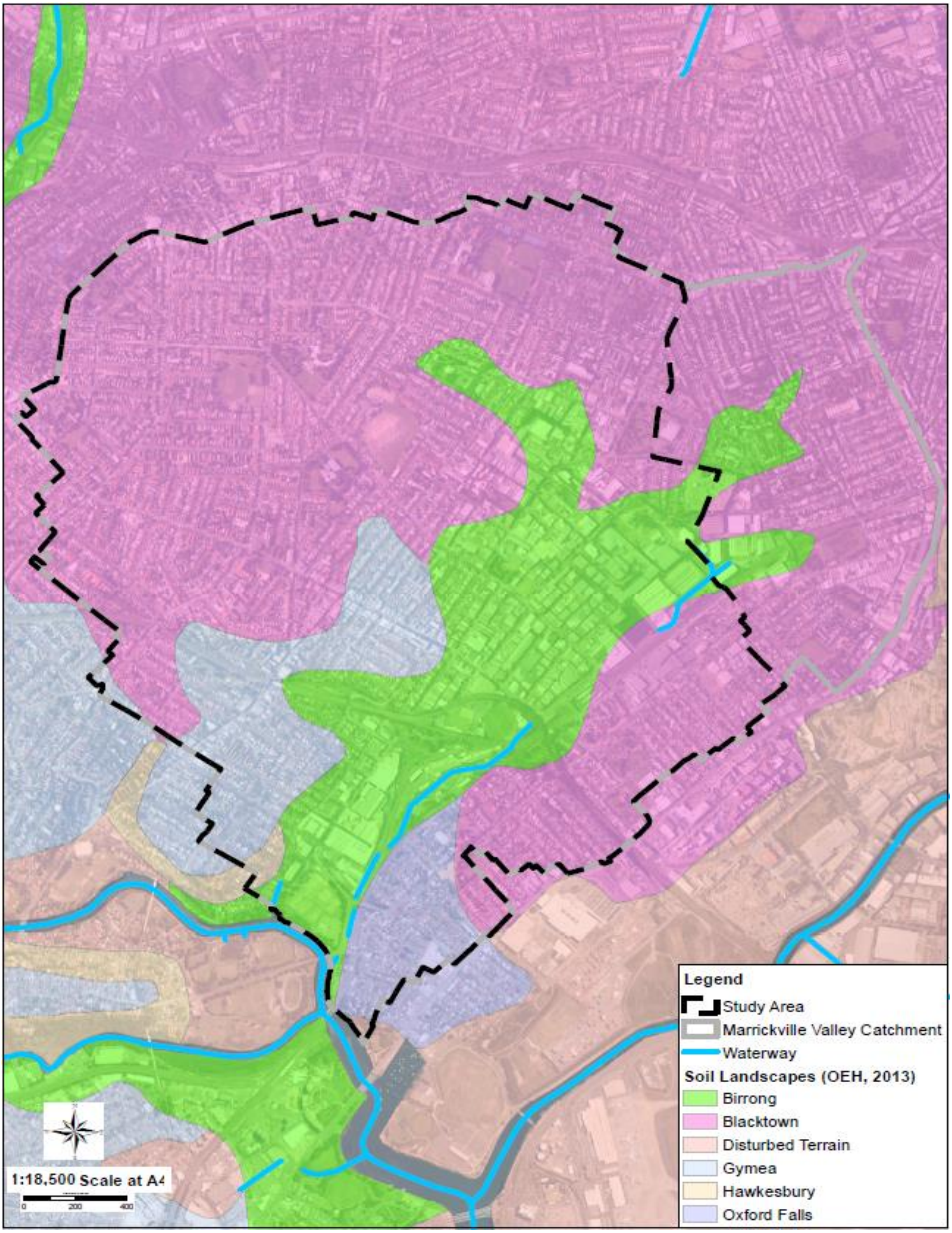


Figure 2-3 **Soil Landscapes**

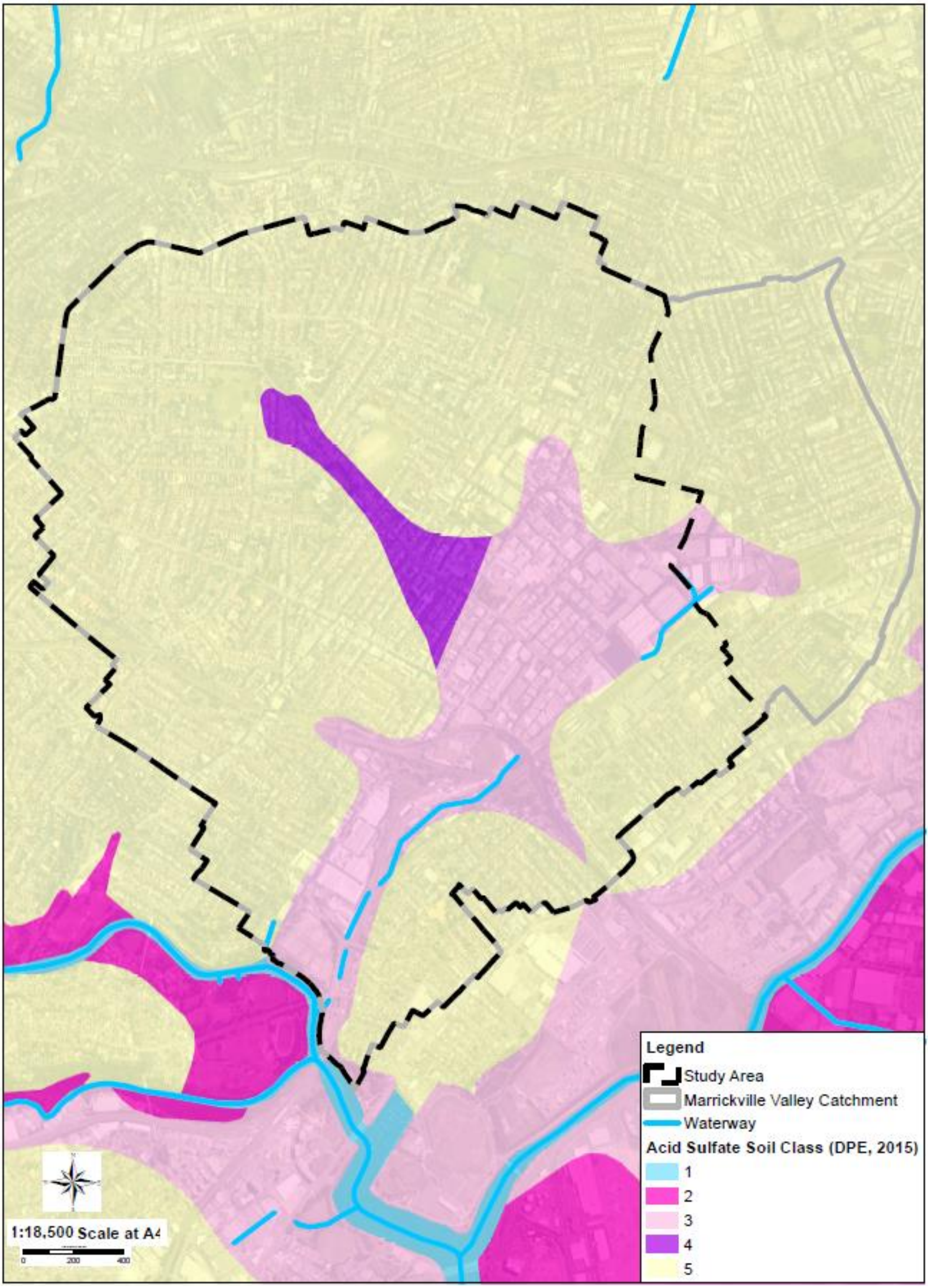


Figure 2-4 **Acid Sulfate Soil Classes**

2.4 Contaminated Land and Licensed Discharges

Contaminated land refers to any land which contains a substance at such concentrations as to present a risk of harm to human or environmental health, as defined in the *Contaminated Land Management Act 1997*. Contamination issues need to be considered at the flood management options development and design stage.

The NSW Office of Environment and Heritage (OEH) regulates contaminated land sites and maintains a record of written notices issued by the Environment Protection Authority (EPA) in relation to the investigation or remediation of site contamination. Searches were undertaken of the online OEH Contaminated Land Record and the List of NSW Contaminated Sites notified to the EPA on 4 February 2016. A total of eight premises were listed within the study area, and these are provided in **Appendix A** (Table A2). It was determined that six of these sites do not require regulation under the *Contamination Land Management Act 1997*. It is important to note that there are limitations to the registers and there may be contaminated sites that are not listed.

A search of the *Protection of the Environment Operations Act 1997* (PoEO Act) licensed premises public register on 4 February 2016 identified no premises in the study area that have current or previous pollution discharge licences.

2.5 Flora and Fauna

There are no national parks or reserves in the study area. The nearest nationally listed nature reserve is Towra Point Nature Reserve, a wetland of international importance (Ramsar wetland), located approximately 8km to the south of the study area. The nearest National Park is Kamay Botany Bay National Park which is located approximately 10km to south-east, and the Royal National Park which located approximately 15km to the south.

A search of the Australian Department of the Environment's Protected Matters Search Tool (DotE, 2015a) undertaken on 4 February 2016 indicated that four threatened ecological communities are likely to occur in the area, namely:

> Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion (Endangered)

> Coastal Upland Swamps in the Sydney Basin Bioregion (Endangered)

> Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion (Critically Endangered)

> Western Sydney Dry Rainforest and Moist Woodland on Shale (Critically Endangered)

The search also indicated that a total of 47 threatened species and 40 migratory species are known, likely or may occur in the area (refer **Appendix A** Table A3).

A search of OEH (2015a) Bionet database was undertaken to assess relevant biodiversity features within the Marrickville Area of Inner West Council LGA. Fifty-four threatened flora species have recorded in the LGA (**Appendix A**, Table A4). Seventy-eight threatened and migratory fauna sightings have been recorded in the LGA, consisting of five amphibian species, four reptile species, 51 bird species, 16 mammal species and 2 gastropod species (**Appendix A**, Table A5).

Twenty one threatened ecological communities listed under the *Threatened Species Conservation Act 1995* are known to occur in the LGA, thirteen of which are also listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (**Appendix A**, Table A6). The relatively large number of threatened communities and species that occurs or has the potential to occur within the study area should be considered in the development and implementation of any proposed flood modification options or flood protection works. Species type, abundance and distribution should be considered, and further investigation may be required if impacts are anticipated.

2.6 Demographic Profile

Knowledge of the demographic character of an area assists in the preparation and evaluation of floodplain management options that are appropriate for the local community. For example, in the consideration of emergency response or evacuation procedures, information may need to be presented in a range of languages and/or additional arrangements may need to be made for less mobile members of the community.

Demographic data for the Marrickville area, sourced primarily from the Australian Bureau of Statistics (ABS), was reviewed to gain an appreciation of the social characteristics of the area. The most recent Australian Census was undertaken by ABS in 2011, so this data has been used in the assessment.

The study area comprises the majority of the Marrickville Area of Inner West Council LGA. All, or part, of the following suburbs are located within the study area:

- Dulwich Hill;
- Enmore;
- Lewisham;
- Marrickville;
- Petersham;
- Stanmore;
- St Peters;
- Sydenham; and
- Tempe.

Census data showed that the population of the Marrickville area in 2011 was approximately 76,500, with a median age of 36 years, which is lower than the median for NSW (38). Approximately two thirds of the people living in the Marrickville area are aged between 15-54 years, which suggests that the community is likely to be generally able-bodied and able to evacuate effectively. However, very young children (0-4 years) and the elderly (>75) make up approximately 11% of the population (approximately 8,600 people) so it is important to consider these members of the community in flood risk management planning.

English was the only language spoken in nearly two-thirds (62%) of homes in the Marrickville area. Other languages spoken at home included Greek (5.5%), Vietnamese (3.7%), Arabic (2.3%), Portuguese (2%) and Cantonese (1.7%). This suggests that language barriers (e.g. during evacuation, or for flood education) have the potential to be an issue for some households. The inclusion of multi-lingual brochures and personnel may be required in this instance.

More detailed Census data has been tabulated in **Appendix B** (Tables B1 and B2).

Consideration of house prices in Marrickville Area of Inner West Council LGA may assist in the calculation of economic damages incurred during a flood event. According to data from realestate.com.au (APM, 2015) the average median property prices across the study area are approximately $1,214,000 for houses and $672,000 for units.

2.7 Cultural Heritage

2.7.1 Aboriginal Heritage

'Traditional Custodians' is the term to describe the original Aboriginal or Torres Strait Islander people who inhabited an area (DLG, n.d). Traditional custodians today are descendants of the original inhabitants and have ongoing spiritual and cultural ties to the land and waterways where their ancestors lived. Marrickville Valley is situated on the traditional land of the Cadigal Wangal clans of the Eora Nation. Cadigal land lies south of Port Jackson and stretches from South Head to Petersham with part of the southern boundary lying on the Cooks River. On the western border lies the territory of the Wangal clan, which extends along the southern shore of the Parramatta River to Parramatta (Inner West Council, n.d).

A number of sites of Aboriginal archaeological and heritage significance are known (at least seven sites recorded based on a search of the Aboriginal Heritage Information Management System). According to the Marrickville Development Control Plan 2011, an Aboriginal Site Survey has identified places of Aboriginal heritage significance with the Marrickville Area of Inner West Council LGA. Therefore, there is potential for Aboriginal objects to exist across the study area even though they have not been formally recorded.

All Aboriginal sites are protected under the *National Parks and Wildlife Act 1974* (NPW Act) and therefore any management options that will impact upon Aboriginal sites must include this in their design. Known Aboriginal sites should be left undisturbed if possible, however if a management option requires damage of an item, an Aboriginal Heritage Impact Permit (AHIP) must be sought from OEH. Under the NPW Act it is a requirement that any developments show "due diligence" with regard to Aboriginal heritage in the area.

In addition, the Marrickville Development Control Plan 2011 outlines provisions and provides guidance on conservation of Aboriginal heritage.

2.7.2 Non-Indigenous Heritage

Non-Indigenous heritage can be classified into three statutory listing classifications based on significance, namely Commonwealth, State and local. The significance of an item is a status determined by assessing its historical, scientific, cultural, social, archaeological, architectural, natural or aesthetic value.

A desktop review of non-Indigenous heritage was undertaken for the Marrickville Area of Inner West Council LGA. Searches were undertaken of the following databases:

- Australian Heritage Database which incorporates World Heritage List; National Heritage List; Commonwealth Heritage List (DotE, 2016b);
- State Heritage Register (OEH, 2016b); and
- Local Council Heritage as listed on the *Marrickville Local Environmental Plan 2011* (Marrickville Council, 2011a).

Within the study area, one Commonwealth heritage items was recorded (refer **Appendix C**, Table C1).

Based on a search of the State Heritage Register (OEH, 2016b) a total of 27 heritage items were identified as being listed under the NSW *Heritage Act 1977*, with an additional 65 identified as being listed by State Agencies under Section 170 of the Act (**Appendix C**, Table C2 and Table C3).

There are 305 items of local significance and 36 Heritage Conservation Areas listed on the *Marrickville Local Environmental Plan 2011.*

Where alteration of a heritage item or undertaking development in a heritage conservation area is proposed, the proponent must refer to the *Marrickville Local Environmental Plan 2011* and Part 8 of the *Marrickville Development Control Plan 2011* for heritage provisions and development guidelines.

Depending on the nature of any structural floodplain risk management works proposed, a more detailed heritage assessment may be required to assess potential impacts on these features.

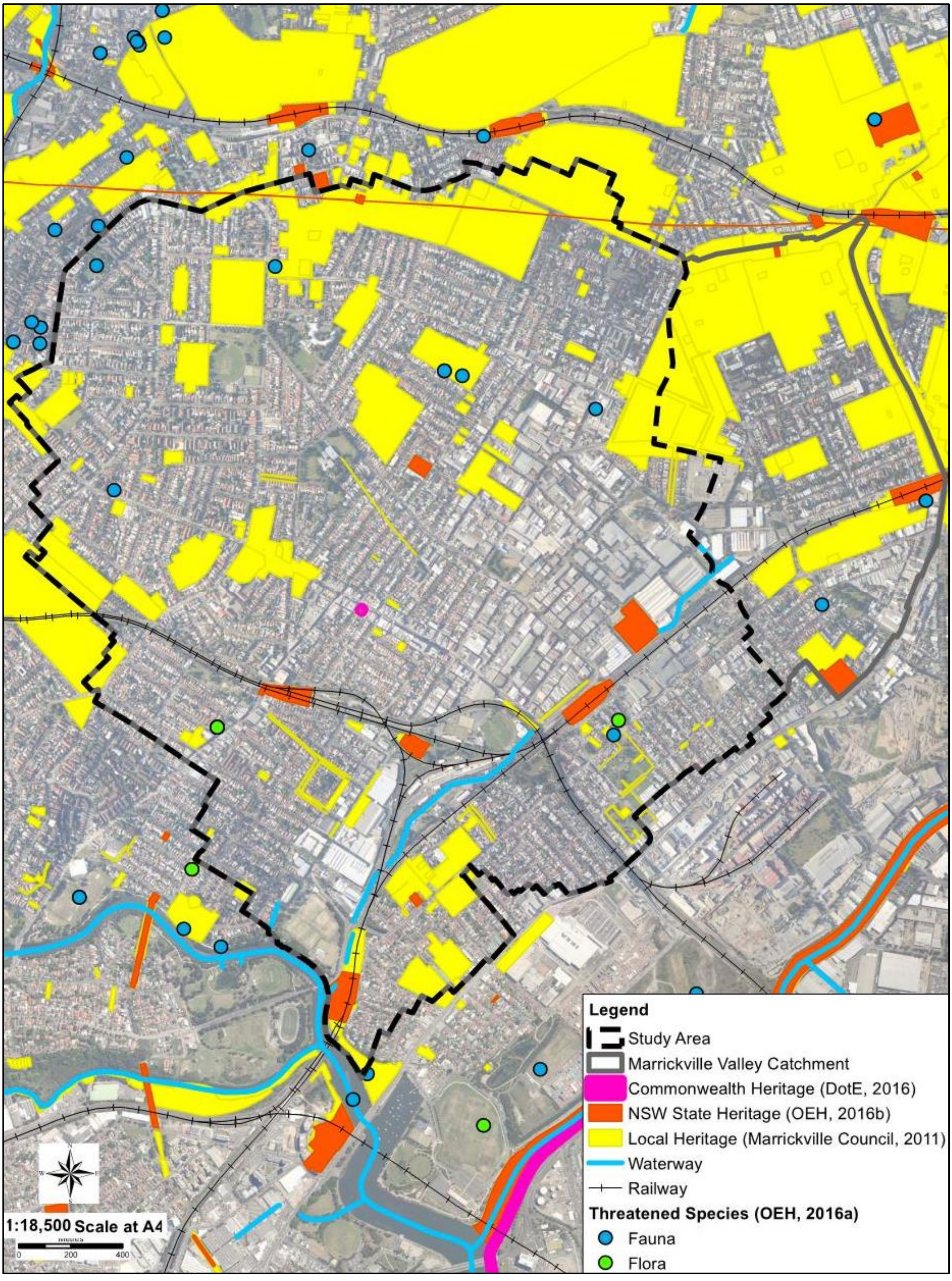


Figure 2-5 **Mapping of Marrickville Valley Social and Environmental Considerations**

2.8 Future Planning and Major Developments

Sydney Metro City and Southwest is one of the major future projects that will be undertaken in the Marrickville Valley catchment area. The project extends from Chatswood to Bankstown with Sydenham being one of the key stations. As part of this project stormwater infrastructure will be provided which could potentially alleviate flooding at the following key locations:

> Sydenham Station;

> Marrickville Station;

> Bolton St; and

> McNeily Park.

The Chatswood to Sydenham Environmental Impact Statements (EIS) is complete and the Sydenham to Bankstown EIS is currently underway. This EIS will provide additional information on management in the area.

3 Review of Available Data

3.1 Marrickville Valley Flood Study

3.1.1 Overview

The *Marrickville Valley Flood Study* was prepared by WMAwater with the objective of defining the existing flood behaviour, forming the basis for the preparation of this FRMS&P. Specifically the intention of the Flood Study was to provide the following:

- Define flood behaviour in terms of flood levels, depths, velocities, flows and flood extents within the study area;
- Prepare provisional flood hazard which was provided within the Flood Study based on provisional hazard definitions defined within the *Floodplain Development Manual* (NSW Government, 2005);
- To consider the potential effects of a climate change induced increase in design rainfall intensities and sea level rise in accordance with the current NSW Government climate change guidelines.

The Flood Study defined flood behaviour in the catchment under existing conditions for the 2 year ARI[1], 20% AEP, 10% AEP, 1% AEP events and the Probable Maximum Flood (PMF). The Flood Study was placed on public exhibition by Council from May to June 2012, with two community workshops held during this time, and three submissions received from the public that were generally supportive of the Study.

Following the public exhibition period the Flood Study report was finalised and adopted by Council in April 2013.

3.1.2 Modelling Methodology

3.1.2.1 Hydrologic Modelling

The hydrologic modelling adopted within the Flood Study was conducted using the ILSAX component of DRAINS modelling software. Design rainfall intensities were applied using the methods to estimate IFD curves from AR&R (2001). The hydrology model details are:

- The Flood Study DRAINS model was adapted from the *Marrickville Industrial Area (MIA) Drainage Study* (GHD 2002) (see **Section 3.2** for further details). This original model accounted for 7 of the 9 catchments in the study area (refer **Section 2.1**). Hydrology of the two outstanding catchments, Malakoff Tunnel and Eastern Channel South, were added to the DRAINS model as part of the Flood Study.
- The ILSAX approach to rainfall losses was applied with a soil type of 3 used to define antecedent moisture condition equivalent to 12.5 – 25 mm of rain in the 5 days prior to the design event. The initial losses were assumed to be 1 mm and 5 mm for paved and grassed surfaces respectively.
- An overall imperviousness of 82% has been assumed throughout the study area, with imperviousness being variable for each subcatchment in the model based on aerial photography and land use.
- The critical duration throughout the study area is the 2 hour duration storm for the 2 year ARI, 20%, 10%, and 1% AEP events. The 60 minute storm duration was found to be critical for the PMF event.
- The Flood Study DRAINS model has a total of 1,030 subcatchments (misreported as 1,185 in the Flood Study report) corresponding to the catchments upstream of surveyed inlet pits in the study area. The assumption within the routing is that all properties drain to the street and all street flows are routed to the nearest inlet pit.

3.1.2.2 Hydraulic Modelling

Hydraulic modelling for the Flood Study was conducted using a detailed 1D / 2D TUFLOW model. The TUFLOW version adopted within the study was version 2010-10-AA. The hydrology inputs to the model was

[1] In the Flood Study the Average Recurrence Interval (ARI) notation has been used to describe the 2 year ARI event, instead of the AEP notation as for events less than a 20% AEP event the theoretical relationship between partial and annual series diverges significantly.

in the form of flow hydrographs from the DRAINS subcatchments input into the TUFLOW model at the equivalent inlet pit. Details of the 1D component of the TUFLOW model include:

> Stormwater pit and pipe network was included within the TUFLOW model as a 1D network:
  - The hydraulic capacity of inlet pits has not been assessed in the TUFLOW model with unlimited capacity assumed for all inlet pits.
  - Pipe and culvert capacity has been assessed using the geometry of the pipe, with the TUFLOW model adopting Mannings equation in the assessment of pipe capacity. Pipes with a diameter less than 300 mm were assumed to have negligible impact on flood behaviour and were not modelled.
  - Design blockage was applied to a selection of enclosed pipes and culverts, with the blockage factor for the selected pipes being 50%. No blockage applied to overland flow channels in the catchment.

> A number of overland flow channels were also modelled within the 1D domain using variable channel cross sections as the 2D grid was assumed to not represent these channels in sufficient detail.

The details of the 2D component of the hydraulic model are as follows:

> A 3m x 3m 2D grid size was applied using a Digital Elevation Model (1 metre raster file) supplied by Council based on the 2007 ALS data available at the time of the Study.

> The downstream boundary of the hydraulic model was the length of Cooks River that the study area discharges to. A downstream boundary condition of standing water at 0.625 m AHD was applied for all design events corresponding to the Mean High Water Spring (MHWS) level.

> Hydraulic roughness of the surface was accounted for in the 2D domain using variable Mannings roughness values based on assigned land use. Mannings roughness values range from 0.04 for open space areas and 0.12 for areas of dense vegetation.

> Existing building polygons were excluded from the hydraulic model as it was assumed that the buildings would provide no floodplain storage and represent a complete blockage of overland flow.

A distinguishing factor for the Marrickville Valley catchment is that there are three existing pump stations in the catchment to help reduce flooding. These pumps are run by Sydney Water and are located in Sydenham, Mackey Park and the northern end of Carrington Road. Further details on the pumping stations are provided in **Section 3.6**.

These pumps have been modelled using a pump rating curve within TUFLOW based on pump performance data provided by Sydney Water.

3.1.2.3 Sensitivity Analysis

A series of sensitivity analyses were conducted within the TUFLOW model using the 1% AEP design flood event as the base case, with the impact on flood levels used as the basis for assessment. The assumptions made within the DRAINS hydrology model were assessed to determine the sensitivity of the hydrology model:

> An increase in rainfall losses (soil type 2), and a decrease in rainfall losses (soil type 4);

> An increase in routing lag of 20%, and a decrease of 20%;

A range of sensitivity analyses were also conducted for model assumptions within the TUFLOW hydraulic model, including:

> An increase in Manning's roughness value for the 2D domain of 20%, as well as a decrease by 20%;

> An increase of pipe/culvert blockage to 75%, and a decrease to 25% blockage.

The outcome of all four sensitivity analyses showed that the model was insensitive to either increases or decreases of rainfall losses, routing lag in the DRAINS model, hydraulic roughness, or pipe blockage factors, with water level increases / decreases not exceeding 0.1 metres difference to design flood levels.

3.1.2.4 Climate Change Assessment

The impact of climate change on flood behaviour was also assessed within the TUFLOW model using the 1% AEP as the basis for assessment. The effects of climate change have been assessed in two ways:

> Sea Level Rise: Flooding of low lying coastal floodplains is expected to be affected by potential sea level rise in the future;

> Rainfall Increase: In NSW, it is common for rainfall intensity increases to be modelled resulting from climate change.

For these two types of climate change impacts there are a range of different conditions that the NSW State Government recommends for considerations. This has resulted in a total of 8 climate change scenarios being assessed within the Flood Study:

> 0.4m rise in tailwater level in the Cooks River;

> 0.9m rise in tailwater level in the Cooks River,

> 10% increase in design rainfall intensity,

> 20% increase in design rainfall intensity,

> 30% increase in design rainfall intensity,

> 10% increase in design rainfall intensity plus a 0.4m rise in tailwater level in the Cooks River,

> 10% increase in design rainfall intensity plus a 0.9m rise in tailwater level in the Cooks River,

> 30% increase in design rainfall intensity plus a 0.4m rise in tailwater level in the Cooks River.

The results indicate that a 0.4m sea level rise will increase the 1% AEP flood levels by a maximum of 0.1m and a 0.9m sea level rise by a maximum of 0.2m. These increases are confined to the lower parts of the catchment.

The increase in the design rainfalls result in a more general increase in flood levels across the entire catchment. The 10%, 20%, and 30% rainfall increases result in approximate maximum increases of 0.1m, 0.2m, and 0.3m respectively throughout the catchment.

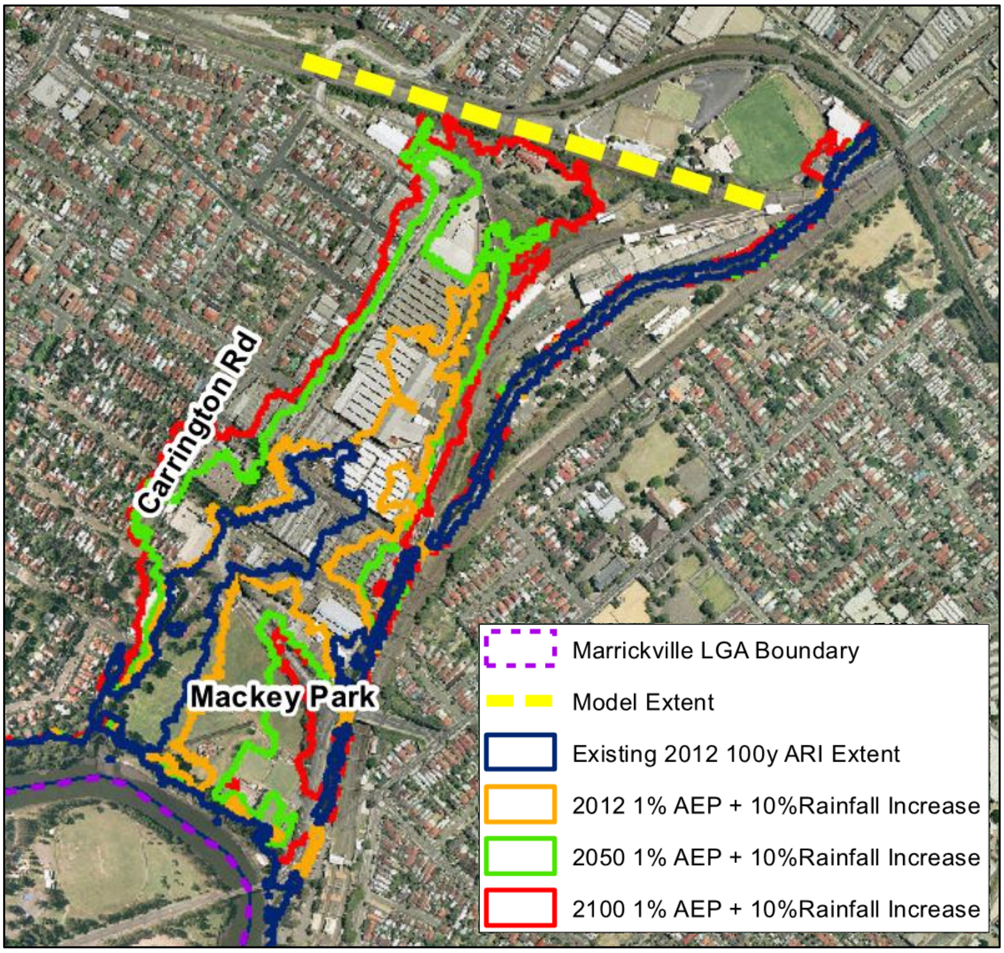
The combinations of a rainfall increase and sea level rise increase indicated the similar results to the addition of the individual rainfall and sea level rise scenario increases.

3.2 Other Reports and Studies

In addition to the *Marrickville Valley Flood Study* (WMAwater, 2013), a number of other previous studies and assessment have been undertaken for the Marrickville Valley catchment and surrounds. These studies were reviewed and a summary is outlined in **Table 3-1**.

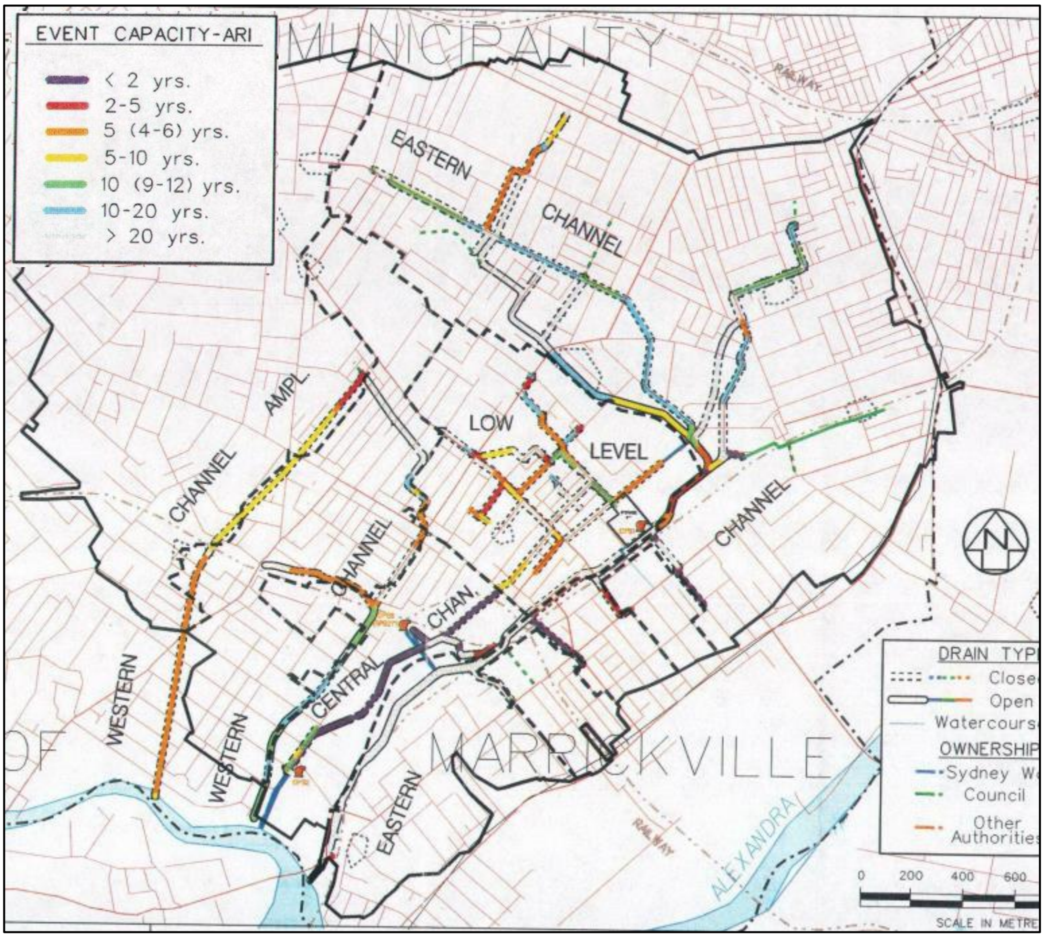
Table 3-1 Review of Previous Flood Related Studies for Marrickville Valley and Surrounds

Study / Report	Description
Cooks River Floodplain Risk Management Study and Plan (WMAwater 2015)	Inner West Council commissioned the investigation of floodplain risk management options for mainstream flooding along the Cooks River, excluding overland flow areas flowing to the River. The study utilises flood behaviour modelling established for Cooks River in the 2009 Flood Study (see below) for the 2yr ARI, 5%, 1% and 0.5% AEP and PMF events. Tailwater conditions from the Flood Study were updated to represent coincident flooding in accordance with NSW Government recommendations and climate change runs were also prepared based on sea level rise (SLR) and rainfall increase. In addition Flood Planning Levels (1% AEP plus 0.5m freeboard) and Flood Planning Areas were prepared for the Cooks River. One structural option was recommended within the Marrickville Valley Study Area; an audit of the existing Mackey Park levee. The existing 1% AEP level in Cooks River at Mackey Park is 2.5m AHD and the crest of the existing levee is 2.5 - 2.8m AHD. The study recommends a detailed review with scope to raise the levee height to improve existing freeboard above the 1% AEP event and to protect for future climate change scenarios, as the 1% AEP level for 2100 SLR is 3.0m AHD.

Study / Report	Description
	Also recommended are a range of non-structural options which are relevant for consideration in this study, including review of Marrickville DCP flood provisions, updating of S149 certificates, and a range of flood emergency provisions. The Cooks River modelling extends into the Marrickville Valley as far as the rail crossings in Fraser Park, see below. 
EC East Subcatchment Management Plan – Volume 1 (Golder Associates, 2011)	Golder Associates on behalf of Inner West Council has completed a subcatchment management plan for the Eastern Channel (EC) East subcatchment located in the north east of the Marrickville Valley catchment. The plan includes recommended management options for the subcatchment for both water quality treatment and floodplain risk management. The nine water quality treatment options include a range of bio-retention measures on existing public land throughout the subcatchment as well as proposals for rainwater tanks and gardens for future development sites of the subcatchment. Three water quality measures were recommended for adoption based on MCA results. There are 10 floodplain modification measures that were assessed for the subcatchment including 3 detention basins, 4 proposed locations of pit and pipe installation, two options for increasing of existing trunk drainage and one option creating an overland flowpath. Following the MCA only one is recommended for adoption, the drainage upgrade at corner of Campbell Street and May Street. Also assessed are a range of property modification measures and emergency response measures. The non-structural options recommended for adoption are: > Update of Councils OSD Policy

Study / Report	Description
	> Update Local Flood Plan in association with SES > Public awareness campaign in association with SES > Provision of flood markers > Flood data collection It was envisaged that the EC East Subcatchment Management Plan will be used as a template for preparing integrated plans for the remaining six subcatchments in the valley. Due to the comprehensive assessment of options for the EC East subcatchment within this report, this subcatchment has been excluded from the Study Area for this FRMS&P.
Cooks River Flood Study (PB / MWH, 2009)	Sydney Water commissioned a flood study of the Cooks River as part of Sydney Waters Cooks River Bank Naturalisation Project in 2009. A WBNM hydrologic model and two dimensional TUFLOW hydraulic model utilising aerial laser scanning (ALS) data have been established for the Cooks River to provide a more accurate picture of mainstream flood behaviour, particularly in the Carrington Road area and taking into account climate change scenarios. The flood study establishes flood behaviour for the 2yr ARI, 5%, and 1% AEP and PMF events. Sufficient data was not available to conduct a full model calibration but the model was verified against historical flood events from November 1961 and March 1983.
Marrickville Industrial Area (MIA) Drainage Study (GHD 2002)	A 1D DRAINS hydrologic / hydraulic model was established for Marrickville Valley in order to assess and recommend works to resolve drainage issues, primarily in the MIA in the EC West subcatchment. Complex drainage elements such as the basin, siphons, pumping stations and diversions were either simplified or excluded from the model. A total of 285 properties were found to be affected by above-ground and above-floor flooding in the modelled 100 year ARI event. It was concluded that this represented a significant flooding problem and recommended further more detailed investigations. Three basic options were adopted to reduce the risk of flooding and maximise the efficiency of the existing drainage system: > Option 1 - For each subcatchment, determine where additional pits are required so that the existing pipe system is flowing at maximum capacity. The purpose of this option is to ensure that Council's drainage system is being used at maximum efficiency; > Option 2 - Provide additional pits and pipes so that the SWC trunk drainage lines are flowing at maximum capacity. Areas where overland flows were in excess of 2.5 m^3/s (considered to be in excess of a safe overland flow) received a higher priority. This option ensures that the SWC drainage assets are being used at their maximum efficiency; and > Option 3 - Individually assess each surveyed trapped low point for additional measures to reduce flooding. Typical measures include diversion pipes, additional pits, planning controls, permeable fencing and high water relief channels. This option attempts to alleviate flooding in areas where stormwater would pond to levels, which could potentially cause above ground or above floor level flooding of adjacent properties. No additional major trunk drainage lines were proposed for the study area due to space limitations and the cost of construction. Only one suitable site for a detention basin was found but was not pursued as a result of having a minimal impact in reducing downstream flooding.

Study / Report	Description
Marrickville Valley SWC 66 Capacity Assessment (Sydney Water Utilities Planning Services 1995)	The capacity of individual trunk drainage systems within the valley was estimated using the Rational Method for hydrological assessment and Manning Formula for hydraulic assessment. It was found that the majority (67%) of the Central Channel has capacity less than the 2 year ARI while the Western Amplification (Malakoff Tunnel) had the smallest length capable of conveying the 20 year ARI. The largest capacity being the Eastern Channel with over 50% of its length having capacity of greater than 20 year ARI.



Sub-System	Catchment (ha)[1]	Length rated (m)	Percent satisfying peak flow for			
			2yr ARI	5yr ARI	10yr ARI	20yr ARI
Eastern	345.3	10,878	94 %	88 %	78 %	51 %
Low Level	85.7[2]	4,076	100 %	81 %	55 %	43 %
Central	61.4	1,689	33 %	27 %	23 %	15 %
Western	93.1	2,583	100 %	77 %	61 %	35 %
Western Amp	193.2	1,964	98 %	88 %	2 %	2 %
Total	778.7	21,191	91 %	80 %	60 %	40 %

Study / Report	Description
Sydenham Stormwater Storage-Pit Pollutant Trap Study (Willing & Partners 1993)	Sydney Water engaged Willing & Partners (now Cardno) to investigate options for using Sydenham Detention Basin to improve water quality whilst simultaneously improving flood control. The flood performance of the basin was assessed using RAFTS-XP hydrologic modelling and EXTRAN-XP hydraulic modelling for the 1yr, 2yr, 5yr, 10yr, 20yr, 50yr, and 100yr ARI. The basin is located near the low level catchment within the Marrickville Valley. The study found that local drainage system in the low level catchment surrounding the basin had a 2yr ARI capacity, with the basin itself having a capacity equivalent to the 20yr

Study / Report	Description
	ARI. The study concludes the best way to improve flood control (up to 50yr ARI) would be to increase flood storage capacity in the basin by lowering the invert of the basin, however this may require significant increases in capacity of the existing three pumps in the basin.

3.3 Site Inspection

A site inspection was conducted by Cardno engineers and Inner West Council staff on 23 June 2015. During the site inspection flooding problem areas, stormwater channels and outfalls, and key hydraulic features were investigated across the study area, as well as the opportunity for flood risk mitigation options.

3.4 Aerial Laser Survey Data

Recent Aerial Laser Survey (ALS) data acquired by Inner West Council was supplied to assist in this FRMS&P. The ALS data was recorded by NSW Department of Land and Property Information (LPI) on 3 June 2013 (resource title L0106 Sydney North). The NSW LPI provided the following commentary on the ALS dataset:

> *The processed data has been manually edited to achieve LPI classification level 3 whereby the ground class contains minimal non-ground points such as vegetation, water, bridges, temporary features, jetties etc. The purpose of the data is to provide fit-for-purpose elevation data for use in applications related to coastal vulnerability assessment, natural resource management (especially water and forests), transportation and urban planning. This data has an accuracy of 0.3m (95 percentile confidence) horizontal with a minimum point density of one laser pulse per square metre.*

This ALS data was used to create an updated 1m terrain grid for the Marrickville Valley study area. This terrain was compared with the terrain adopted within the *Marrickville Valley Flood Study* (WMAwater, 2013), also based on 1m grid size. It is assumed that this data was not available at the time of the Flood Study.

The differences between the new ALS and the original Flood Study TUFLOW model DEM based on 2007 ALS data is shown in **Figure 3-1**. The comparison of the two data sources showed that a significant portion of the study area had survey level differences in excess of 20 cm, in the majority of instances the updated 2013 ALS data was higher than the Flood Study Digital Elevation Model (DEM). In addition there are specific areas in the study area that have far more significant differences most notably Port Botany Freight Line with the updated ALS being 700cm higher than the Flood Study DEM. Comparison of the updated ALS data and Flood Study DEM was conducted at a number of key locations within the study area:

> Marrickville Oval– Surface levels are increased up to 30cm at Marrickville Oval;
> Henson Park – Surface levels are increased up to 60cm at Henson Park and for properties along Holmesdale Street and Illawarra Road;
> Newington Road – Surface levels are increased up to 30cm at Newington College with increases in levels up to 50cm for properties between Wemyss Street and Tupper Street;
> Marrickville Station - Surface levels are increased up to 50cm in vicinity of Marrickville Station, mainly upstream and downstream of Illawarra Road; and
> Tillman Park – Surface levels are increased up to 50 cm in Tillman Park and surrounding areas.

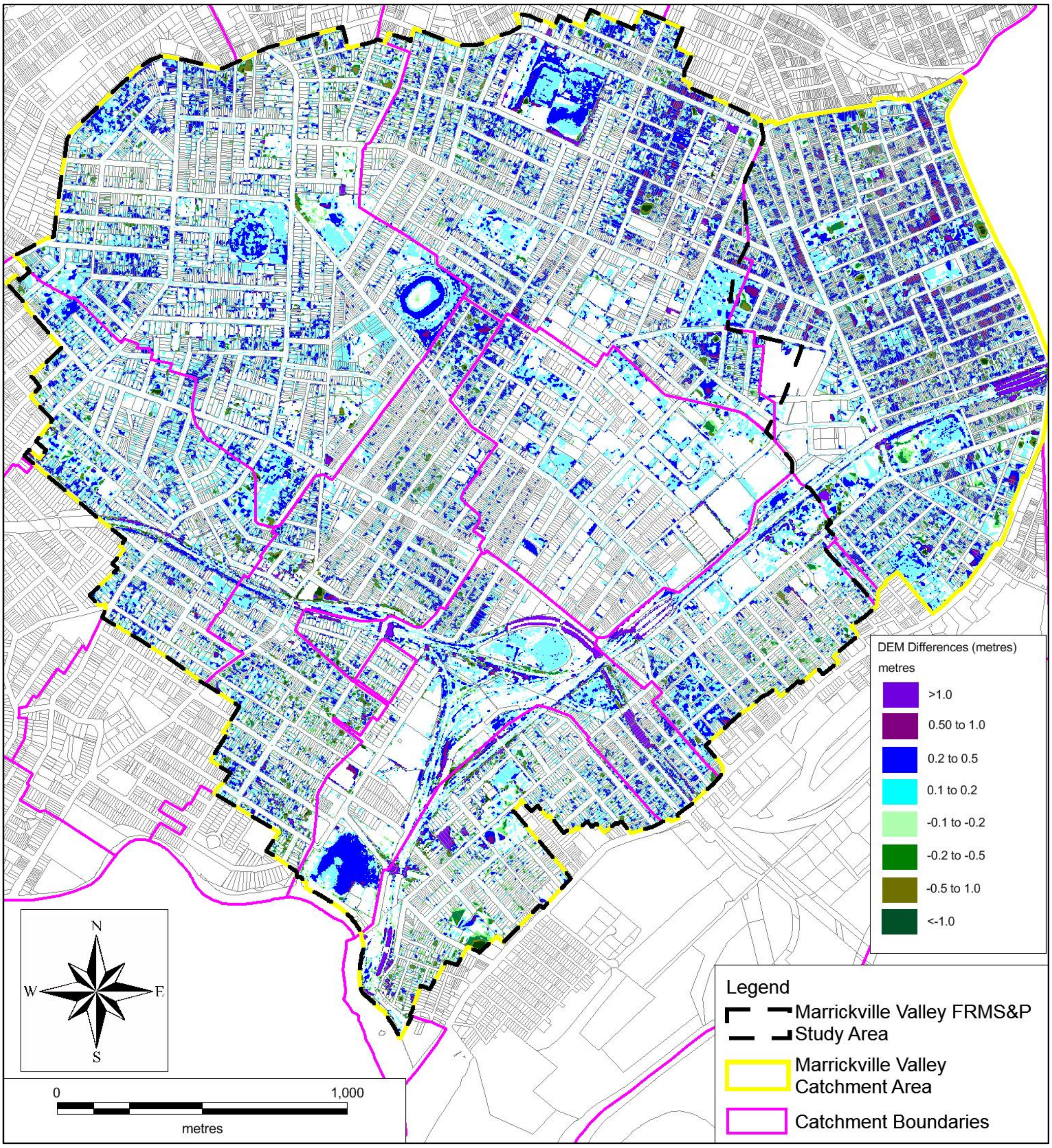


Figure 3-1 **Updated TUFLOW DEM Less Flood Study DEM**

3.4.2 Ground Truthing

Due to the discrepancies between the updated ALS data and the Flood Study DEM, a ground truthing process was undertaken to compare the updated ALS data with available ground survey data. The ground survey data was supplied by Inner West Council for a number of locations within the study area:

- Henson Park Survey
- Marrickville Oval Survey
- Wicks Park Marrickville
- Mackey Park
- Arthur St Marrickville

> College Lane Petersham

The ground survey levels were provided in Autocad (*.dwg) format. Henson Park ground survey were coordinated to Map Grid Australia (MGA) zone 56 and contained 3d levels, therefore it was possible to compare the ground survey surface to the updated ALS surface. For all other sites the data could not be established in a surface format so manual comparison of survey points was required.

The ground truthing process involved comparison of levels for the two survey types at a total of 33 points across the 6 sites. The location of the survey points and the survey levels for each of the points are included in **Appendix D**.

The outcomes of the ground truthing of the updated ALS data are summarised in **Table 3-2**. The results show that for 33 points across the 6 sites the ALS data is at most 0.42 metres higher and conversely 0.33 metres lower than the recorded ground survey. On average the updated ALS data was found to be 0.11 metres higher than the recorded ground survey data.

Table 3-2 Ground Truthing Results – Updated ALS Data Compared to Ground Survey

Location	Number of Ground Truthing Points	Updated ALS Less Ground Survey (metres)		
		Maximum Diff	Minimum Diff	Average Diff
Henson Park	5	+0.42	-0.22	+0.16
Marrickville Oval	7	+0.15	+0.01	+0.09
Wicks Park	8	+0.16	-0.33	+0.07
Mackey Park	5	+0.22	+0.08	+0.15
Authur Street, Marrickville	3	+0.15	+0.11	+0.13
College Lane, Petersham	5	+0.15	+0.03	+0.08
Total	**33**	**+0.42**	**-0.33**	**+0.11**

Assuming that recording errors in the ground survey are negligible and it is therefore accurate, these differences can be attributed to a number of different causes:

> Changes in terrain (typically through earthworks) between the time of recording of the two data sets;

> Triangulation issues, however this is not expected to be a significant issue as the updated ALS data is densely populated (average spacing of data points in the 1.57 metres); These are more likely in heavily vegetated or building footprints where data is thinned to remove these non-ground points.

The general accuracy of ALS data is typically stated as + / - 0.15 m vertically through various factors relating to recording through this method. The ground truthing results showing average differences to ground survey of 0.11 metres is seen as a preferable level of accuracy for the updated ALS data.

3.5 GIS Data

Council provided the Cardno study team with a range of relevant Geographic Information System (GIS) data from Council's spatial database, including:

> Cadastre;

> Building footprints;

> Aerial photography;

> Drainage network; and,

> Land use zoning.

3.5.1 Pit and Pipe Data

Inner West Council provided the Cardno study team with detailed stormwater pit and pipe information in GIS format. The information included in the pit and pipe layer included locations, asset identification, dimensions, inverts and levels, valuation data, and CCTV inspection data.

This data was compared to the stormwater network modelled within the DRAINS and TUFLOW models within the *Marrickville Valley Flood Study* (WMAwater, 2013). It was determined that there were a number of locations where there was discrepancies, including:

- Addison St and McCrae Rd – different pipe sizes;
- Wilkins School at Sydenham Road – different pipe configuration;
- Sydney Street – additional private box culverts in Council GIS pit and pipe data;
- Unwins Bridge Road and Hogan Avenue - different pipe configuration;
- Authur Street – additional pit and pipe network constructed not included in Flood Study data;
- Unwins Bridge Road and Gannon Street – different pipe configuration; and,
- McNeilly Park and Marrickville Train Station - different pipe sizes and different pipe configuration.

3.6 Pump Stations

There are three existing stormwater pumping stations located within the Marrickville Valley (DPS1, DPS2 and SPS271), which are all owned and managed by Sydney Water Corporation. The location of the three pumping stations is shown in **Figure 3-2**.

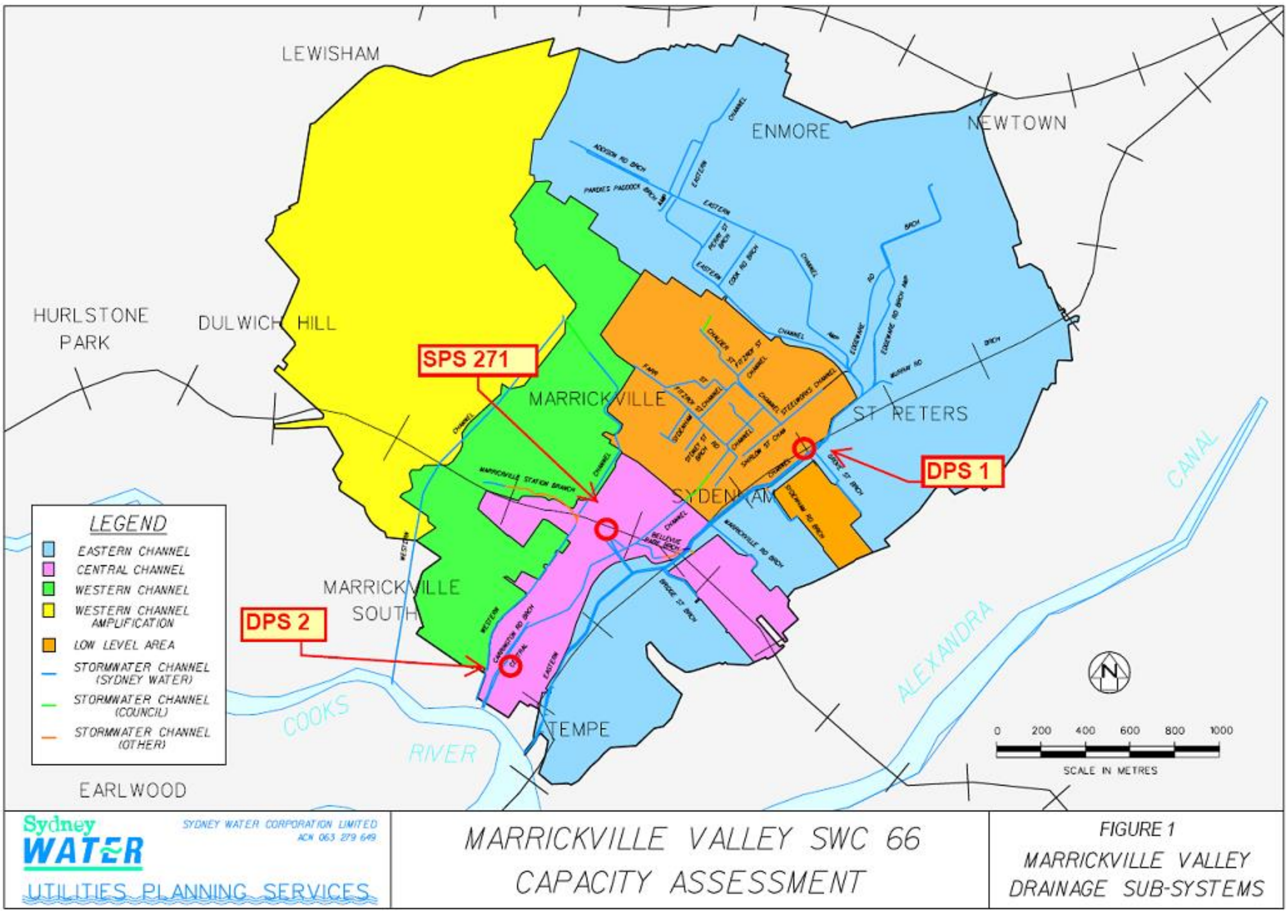


Figure 3-2 **Location of Pumping Stations within Marrickville Valley (Source: Sydney Water, 2011)**

The details of all of these pump stations has been guided by the report *Operational Interface Protocol: Stormwater Drainage Pumping Stations within Marrickville Valley Catchment* (SWC66) (Sydney Water, 2011) (Document Number IMS0085). Where information from this report was insufficient to review the Flood Study model set-up, such as for pump cut-in and cut-out levels, additional information was sourced from other Sydney Water reports provided by Council.

The details of the three pumping stations are described in the following sections. Additional pump station details are provided in **Appendix E**.

3.6.2 Drainage Pumping Station 1 (DPS1) – Sydenham Stormwater Storage Pit

The Sydenham Stormwater Pit receives flows from the Marrickville Valley low level area and during higher flow events also receives overflows from the Eastern Channel via syphons. DPS1 pumps elevate stormwater from the sump to the adjacent high-level system known as the Eastern Channel, with the invert of the channel being higher than the invert of the pit. The station has three main pumps, and operates under a Duty/Duty/Standby arrangement, with a maximum of two pumps running at any one time, with a combined capacity of 2.5 m^3/s.

3.6.3 Drainage Pumping Station 2 (DPS2) – Mackey Park

DPS2 is located at the northwest corner of Mackey Park and drains low-lying areas along the southern end of Carrington Road. Flows enter the pump wet well via an offtake from the Central Channel. The stormwater from the pump station is discharged via twin 800mm diameter rising main pipes along the western boundary of Mackey Park to the Cooks River. The pump station operates with two main pumps and a third minor sump pump, with a combined capacity of 2.84 m^3/s.

3.6.4 Sewage Pumping Station 271 (SPS271): Heritage Boiler House, Carrington Road

SPS271 is situated within the rail land between the freight rail and Bankstown passenger train lines and receives high flows that are diverted from the Central Channel at the northern end of Carrington Road. SPS271 station has pump stations for both stormwater and sewage discharge. The station has two drainage pumps (combined capacity 1.8m^3/s) that discharges the stormwater diverted from Central Channel into the Eastern Channel.

4 Consultation

4.1 Consultation Process

Consultation with the community and stakeholders is an important component in the development of a Floodplain Risk Management Study and Plan. Consultation provides an opportunity to collect feedback and observations from the community on problem areas and potential floodplain management measures. It also provides a mechanism to inform the community about the current study and flood risk within the study area and seeks to improve their awareness and readiness for dealing with flooding.

A consultation plan was developed in the preliminary stages of the project. Details of the plan are provided below in **Table 4-1**.

Table 4-1 Consultation Plan

Task	Description	Expected Outcome
Stakeholder Consultation – Council	Relevant Council staff attended the inception meeting to discuss various input to the study and the proposed study approach.	> All available information is utilised in the preparation of the flood study. > Modelling incorporates the high risk areas. > Council objectives are achieved by the study
	Cardno will undertake follow up consultation by phone throughout the duration of the study.	
Press Release	Cardno will draft a press release for Council's consideration and publication.	> Public awareness of the study. > Assist in engagement with the community through the newsletter/questionnaire, workshops and public exhibition. > Assist in the public acceptance of the study outcomes and implications for development and floodplain risk management in the future.
Community Newsletter and Questionnaire	Cardno will draft a newsletter and questionnaire for Council's consideration. Once finalised Cardno will print and distribute to flood affected properties within the catchment. The brochure and survey will also be made available online by Council.	> Inform the community about the study and provide background information. > Identify community concerns and awareness. > Gather information from the community on potential flood mitigation options. > Develop and maintain community confidence in the study results.
Website	Council will provide a web-based information gathering and mapping tool with pin drop and comment functionality. A link to the website would be provided on Council's website. Cardno will provide the relevant information to Council to upload onto the website.	> Collaborative community engagement process. > Provide community opportunities to provide input/feedback. > Provide key information to the community.
Stakeholder Consultation – Agencies	Cardno will contact relevant agency stakeholders via letter and follow up email and/or phone.	> Inform the agencies of the study. > Obtain relevant information. > Provide an opportunity for input from the relevant agencies.
Community Workshops	Cardno will prepare materials for and present at 3 community workshops. These workshops will be undertaken during Stage 2 of the study to get community feedback on the flood modification options.	> Provide the community with an understanding of the preliminary findings of the study and provide an opportunity for input prior to the preparation of the Draft FRMS&P.

Task	Description	Expected Outcome
Stakeholder Consultation – Floodplain Risk Management Committee	Cardno will undertake a meeting with the committee during Stage 3 of the study to discuss outcomes of the community consultation and flood mitigation options under consideration	> Update FMC on the FRMS&P process. > Provide an opportunity for input from the FMC on the mitigation options.
Public Exhibition Period	Cardno will draft a press release for Council's consideration and publication.	> Inform the community of the draft Study and Plan and invite submissions. > Inform the community of the workshop.
	Council will arrange for the public exhibition of the Draft Floodplain Risk Management Study and Plan.	> Provide an opportunity for the community to review and provide comment on the Draft Study and Plan.

The consultation plan identified that consultation was to be undertaken at key stages of the study. The main consultation elements for this study are:

> A press release and newsletter introducing the project to the community;

> An online questionnaire;

> A project website keeping the community informed about the project and its progress;

> A call for information from all affected stakeholders within the catchment;

> Community workshops during the study;

> Public Exhibition of Draft Floodplain Risk Management Study; and

> Collation and acknowledgement of written submissions during the public exhibition.

This process ensures that community participation is maximised during the development of the FRMS&P.

4.2 Agency Consultation

There are a large number of agencies with flood related interests in the LGA. To best approach them, a letter of introduction to the study was sent to the key stakeholder agencies and an invitation to be involved in the project. It also included requests for any relevant data or information that they may have. An example of the letter is provided in **Appendix F**.

The agencies contacted as part of the consultation are listed in **Table 4-2** with outcomes of the consultation.

Table 4-2 Agency Consultation

Agency	Outcome of Consultation
Office of Environment and Heritage (OEH)	Comment that they hold no relevant data
Roads and Maritime Service (RMS)	No response received
State Emergency Service (SES)	Acknowledgement of receipt of letter
Sydney Water	Request to be kept informed of the study progress

4.2.2 <u>Agency Workshop</u>

Agency input was sought to inform the development and assessment of the Flood Modification Options (**Section 9.3**), Property Modification Options (**Section 9.4**) and Emergency Management Modification Options (**Section 9.5**) through a meeting organised by Council.

The purposes of the meeting was to present the agencies an opportunity to inform their priorities, raise any concerns about the proposed options, identify any additional options and identify opportunities for possible future collaboration.

Representatives from the Office of Environment and Heritage (OEH), Sydney Water Corporation (SWC), Roads and Maritime Services (RMS) and State Emergency Services (SES) attended this meeting with Council staff.

The feedback received has been summarised in **Table 4-3**. Based on the feedback received, the property and emergency modification options will be revised.

Table 4-3 Agency Feedback Summary

Option	Feedback
Flood modification options	• Generally supportive of all options. • SWC capital program would typically allow joint funding for options related to their infrastructure. • RMS capital program would focus on state roads and will require feasibility studies and cost estimates to enable business case to be put forward to the Transport for NSW. • Flooding is some areas have not been adequately addressed. Council will approach OEH with additional options and refinement of some of the existing options to ensure flooding across all areas is addressed.
Property modification options	• Council to consider new planning control for High Density Residential Development in the flood planning area to ensure suitable for shelter in place.
Emergency response options	• Council depot is no longer the Emergency Operations Centre. • Amend proposed evacuation centres to exclude non-Council buildings. • Include new emergency management option to expand the existing Leichhardt Flood Mapping Tool or similar to increase flood awareness and access to information. • Council to consider amending the DCP to require site flood plans for vulnerable developments. • Radio and TV warning systems not useful in available timeframe as media releases typically take more than an hour to approve. Social media is the most useful within the available timeframe. • A flood education campaign was commenced with SES/Council and led by Council's communications team. • Council to consider amending its call centre on-hold message to include information on website rather than call SES first. • Council website flood page to link to SES floodsafe or stormsafe website and Marrickville SES Unit webpage for announcements.

4.3 Community Newsletter and Questionnaire

As part of the community consultation process, a newsletter about the study with a link to a questionnaire (available on Council's 'Have Your Say' webpage) was prepared to request feedback from the community (included in **Appendix F**). The survey was designed to gauge community awareness to flood related issues. The 'Have Your Say' webpage also allowed the community to pinpoint locations of flooding on an interactive map and to provide their flooding stories.

Council sent the newsletter to 12,000 properties within the study area and posted personalised letters to stakeholder groups and businesses in November 2015. In addition, questionnaires were sent to 1,765 property owners whose properties had been flood tagged within the study area. Consultation materials, including the newsletter and a media release, were uploaded to Council's 'Have Your Say' webpage.

At the close of the survey period on 20 November 2015, 12 survey submissions had been received via the online survey portal 'Have Your Say' plus seven stories and ten mapped locations. Council received an additional 13 letters / emails. This low response rate is likely to be attributed to the extensive community consultation that Council has undertaken over the past years for identification of flood affected properties. The locations from where the responses were received and areas of flooding identified are shown in **Figure 4-1**.

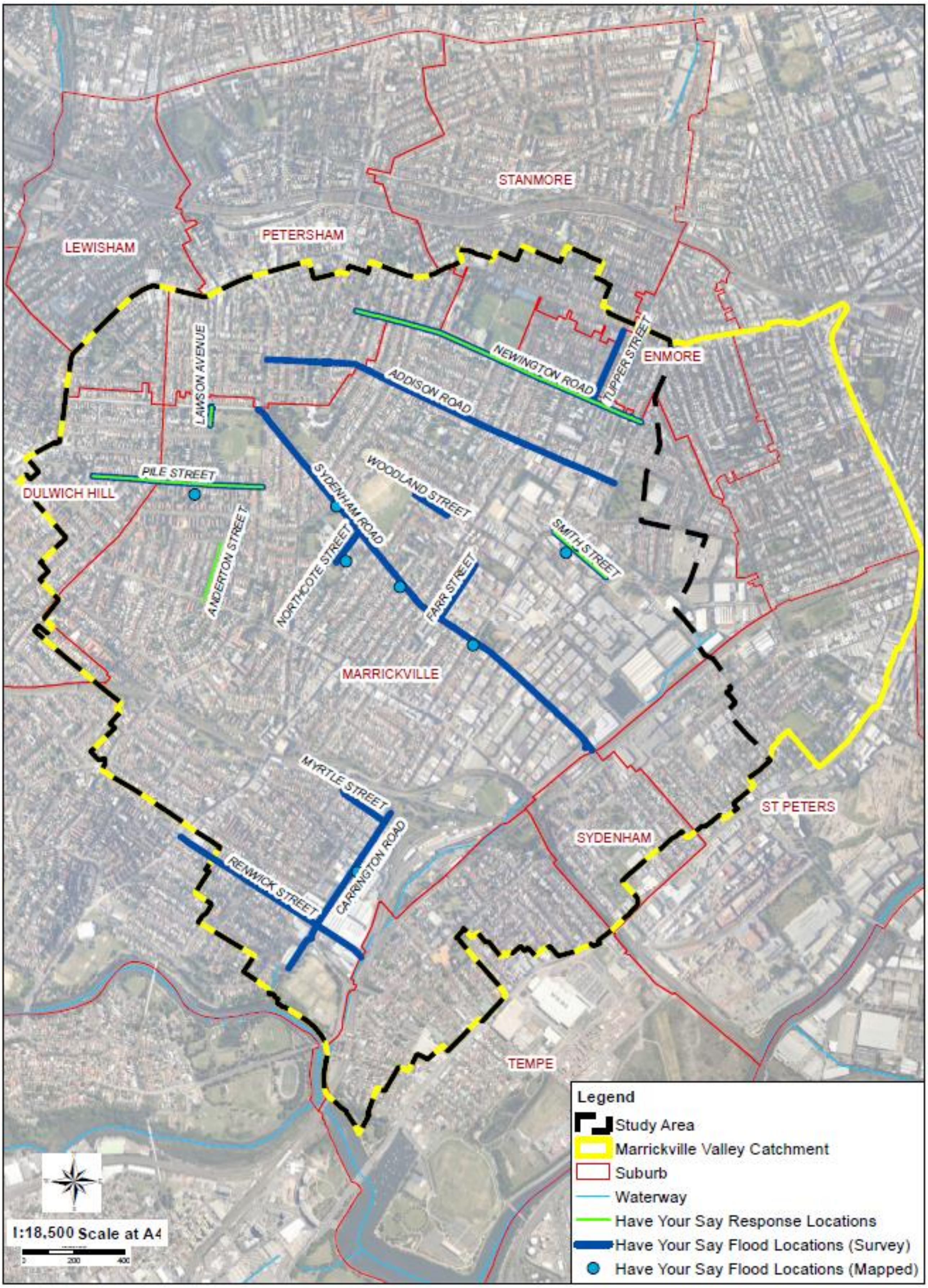
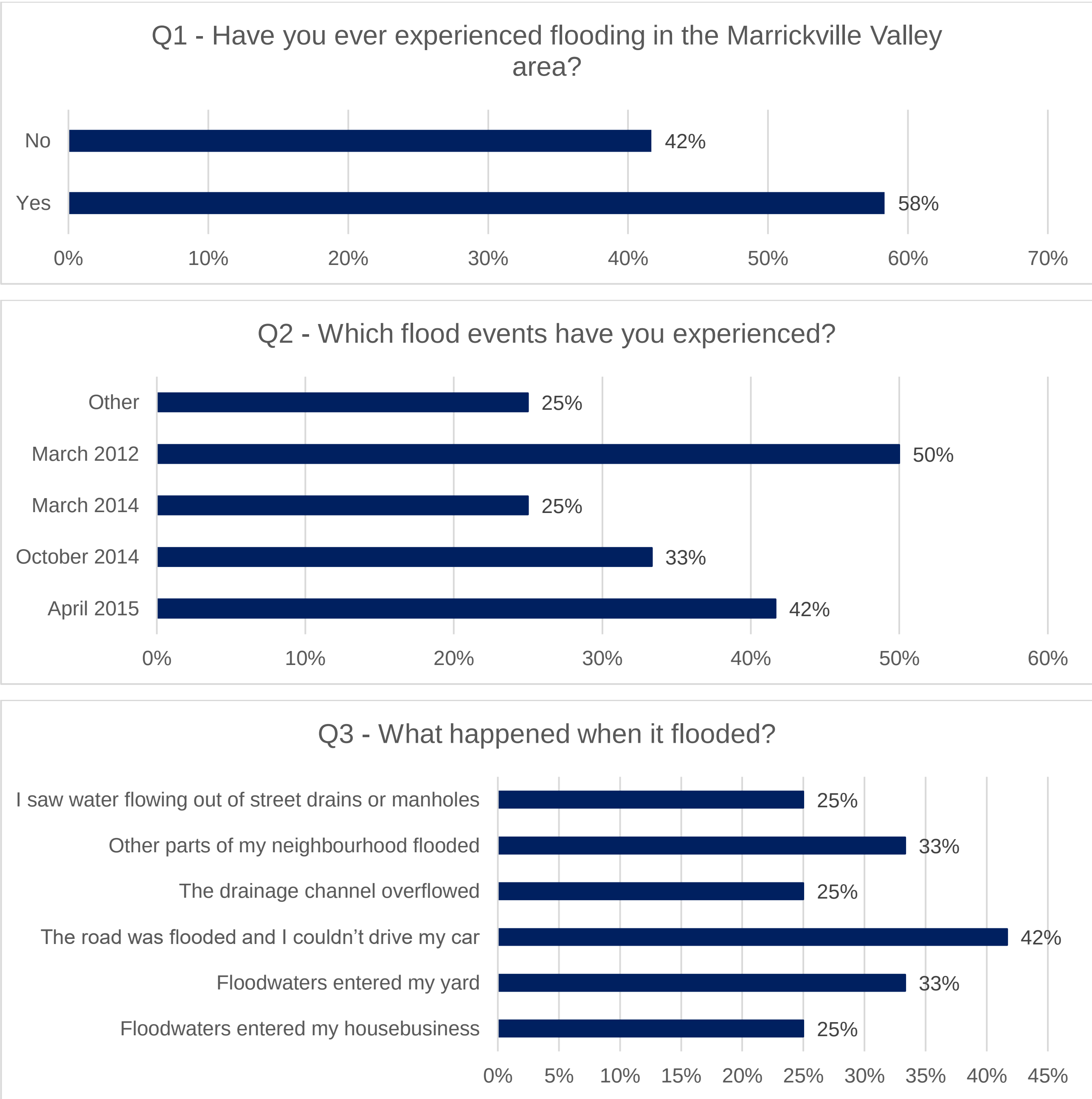
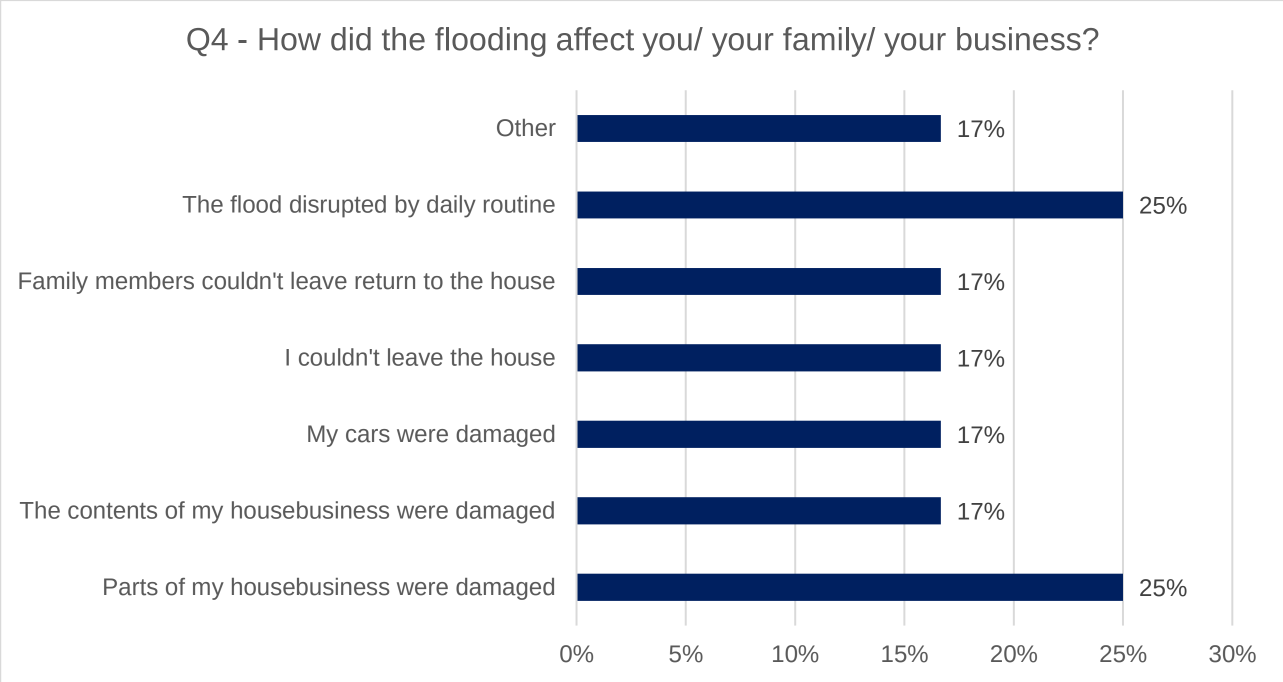


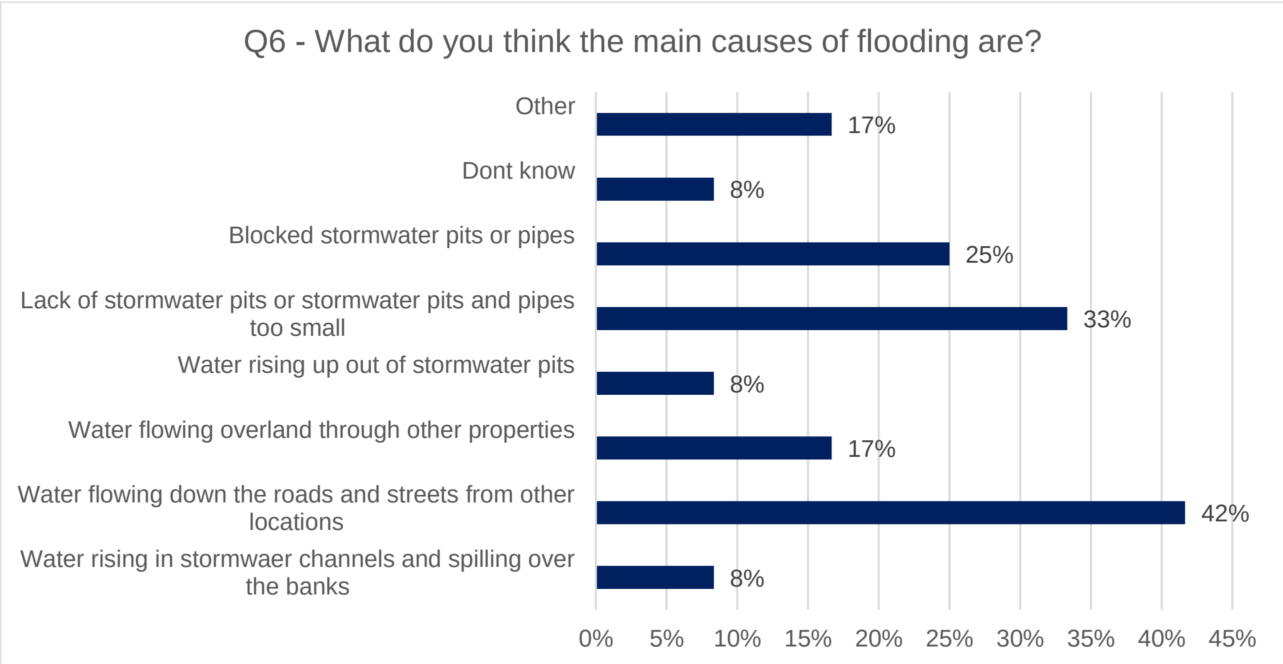
Figure 4-1 **Community Consultation Response Locations**

4.3.2 Survey Submission Results

A sample of the multiple submission results is shown in the charts below (**Figure 4-2**). **Appendix F** contains a sample of the questionnaire and brochure sent out as part of this information gathering process. Note that where percentages sum to greater than 100, respondents were able to provide multiple responses.







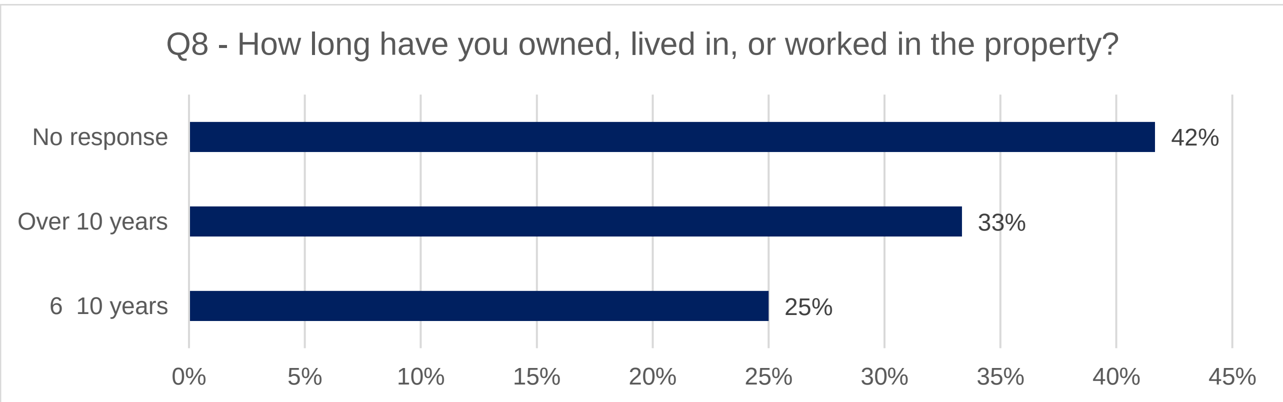


Figure 4-2 **Summary of Community Consultation Responses**

4.3.3 Flooding Locations

The 'Have Your Say' also enabled respondents to pinpoint the location of flooding in their area. Emails were also sent to members of Council's Subcatchment Working Groups. The locations noted as experiencing flooding are detailed below:

- Addison Road;
- Carrington Road and intersections with:
  - Myrtle Street,
  - Richardson Crescent;
- Lawson Avenue;
- Mackey Park
- Newington Road and Tupper Street or Short Street;
- Pile Street;
- Renwick Street;
- Smith Street and Victoria Road;
- Sydenham Road. Noted along its length, and at several intersections including:
  - Victoria Road,
  - Illawarra Road,
  - Northcote Street (and further to Yabsley Avenue and Carew Lane),
  - Farr Street,
  - Holmesdale Road; and
- Woodland Street.

Several reasons were provided for the flooding including inadequate drain sizes for the volume of water received, and blockage of drains by leaf litter and rubbish.

In addition the following locations, which are located outside of the study area, have also been noted as experiencing flooding:

- May Street and Campbell Street;
- Ness Avenue;
- Riverside Crescent and Dibble Avenue; and
- Riverview Road near Bass Road.

These locations have/will be considered in past/future studies.

4.3.4 Outcomes of Community Submissions

Based on the feedback provided within the completed questionnaires and email responses received the following key outcomes have been derived:

- There is a general consensus within the community that Marrickville Valley is subject to flooding;
- Streets around Sydenham Road were particularly noted as being liable to flooding;
- Respondents believe that flooding in their area is attributable to three main causes: water flowing down roads and streets from other locations, the lack of stormwater pipes and pipes being too small, and blocked stormwater pits and pipes.

These outcomes have been taken into account during the formulation and assessment of potential flood mitigation options.

4.4 Community Workshops

Community input was sought to inform the development and assessment of Flood Modification Options (**Section 9.3**) through a series of workshops. The workshops were held over three days, in various locations to best capture the interests of particular areas and ensure accessibility to those community members who wished to participate. The workshops undertaken were:

> Tuesday 4th April 6:30pm at Herb Greedy Hall, 79 Petersham Road, Marrickville;

> Wednesday 5th April 10:30am at SES Headquarters, 17 Railway Road, Sydenham; and

> Thursday 6th April 6:30pm at Addison Road Community Centre, 142 Addison Road, Marrickville.

The purpose of the workshops was to present the preliminary findings of the Flood Modification Options assessment and gain feedback on the community acceptance of those options, any possible modifications of those options and preferred options not already considered in the study.

The workshops did not present the proposed Property Modification Options (**Section 9.4**) and the Emergency Response Modification Options (**Section 9.5**). The community will have an opportunity to review these option types during the public exhibition of the Draft FRMS&P.

The workshops consisted of the following:

> Presentation by Cardno providing an overview of the study context, purpose and how the options were identified and assessed;

> Open forum questions; and

> Opportunity to undertake one on one discussions with the project team (both Cardno and Council representatives). These discussions were supported by flood maps showing the modelled benefits and impacts of the proposed options.

4.4.1 Feedback

Feedback was received from the workshops through the following avenues:

> Discussion directly with the project team;

> Submission of paper feedback forms at the workshops or sent to Council; and

> Online feedback forms (www.yoursayinnerwest.com.au).

Feedback was open for receipt until Sunday 9th April. Respondents were asked to identify their preferred options.

Twenty-eight (28) community members attended the workshops and the website was visited by 164 users. A total of 35 responses were received.

The outcome of this feedback identified strong support of options in the vicinity of Northcote Street (in particular Options FM3.1, FM3.2, FM 3.3 and FM3.4). Options near Wardell Road and Marrickville Oval (Options 1.1, 1.2, 2.1 and 2.3) and Addison Road and Illawarra Road (Options 5.3, 5.4, 5.6 and 6.4) were also given support. No negative feedback was received on the options presented although concern was raised by a significant number of community members regarding lack of options for Illawarra Road in the Marrickville Centre. It is anticipated further refinement to Option 9.1 will result in reduced flooding in this location.

Table 4-4 below summarises the outcome of the submissions. No submissions were received for the remainder options.

Table 4-4 Community Submissions Summary

Option ID	Total Submissions in support
FM 1.1	2
FM 1.2	2

Option ID	Total Submissions in support
FM 2.1	2
FM 2.3	2
FM 3.1	15
FM 3.2	17
FM 3.3	11
FM 3.4	4
FM 5.3 & 5.4	3
FM 5.6	3
FM 6.4	2
FM 9.1	7

Additional drainage upgrades were suggested that may improve local drainage issues in Northcote Street and Illawarra Road.

In addition to the feedback received via the feedback forms, general issues were raised by attendees and discussed with the project team. The discussion topics included:

> Existing stormwater pit blockage by debris was seen as the leading cause of flooding. Debris was noted from both fallen leaves and litter (e.g. bottles, cans and plastics). Increased public awareness through education and signage was supported as a strategy to address this. More regular street sweeping and drain clearing was also requested;

> Several attendees were concerned about the impact that inclusion of their property in the flood planning area would have on their property. Issues relating to insurance and property prices were discussed. Although this was not the subject directly of the workshops, attendees were informed that the reduction of flooding as a result of the proposed options would be assessed approximately every 10 years and this may result in changes to the flood planning area;

> Several attendees were concerned that their Streets/Lanes are not designed with adequate drainage to take overland flows;

> Some attendees enquired about the timeframes for the implementation of the preferred option; and

> A few attendees enquired about rezoning of Marrickville Industrial Area.

4.4.2 Outcomes

As an outcome of the workshops the Stakeholder and Community Support criteria in the multi-criteria assessment of the options (**Section 11**) will be revised. This will include increases in the scores for options where support of the options was noted in the feedback forms.

In addition, to the multi-criteria assessment scoring revisions, options have been included in this FRMS&P to address concerns raised. These options include the recommendation for increased street sweeping (PM5) and stormwater pit maintenance (PM6). A community education program has also been recommended to increase awareness of littering in public places (EM7).

4.5 Public Exhibition

The Draft Marrickville Valley Flood Risk Management Study and Plan was placed on public exhibition from 24 July 2017 to 27 August 2017. The plan was made available on Council's 'Your Say Inner West' webpage and the exhibition promoted through Council's e-newsletter. Community members were invited to view the plan and indicate the extent of their support for the plan. Community members were also able to provide comment on which options they support, which options they do not support and whether there were any other flood affected areas that had not been addressed in the plan.

During the exhibition period, the webpage was visited 201 times and the project documents were downloaded 78 times. Eight submissions were received through the website and one submission was received via email. Six survey submissions 75%) were received from residents of Marrickville, with one submission each from residents of St Peters and Dulwich Hill.

Of the eight submissions received through the website, four submissions strongly supported the draft plan, three submissions supported the plan, and one submission neither supported nor opposed the plan.

When asked to consider options they supported, half the submissions indicated their support for the options that alleviate flooding on Lawson Avenue. There were no specific options that were not supported, however, two submissions noted that not all options have been covered and raised suggestions for the dredging of Cooks River. Two submissions indicated that their properties were not addressed in the plan and concerns were raised about the flood impacts of new and proposed developments in the catchment.

An email submission from the Marrickville Croquet Club raised concerns about the impact to the club grounds as a result of the proposed option of regrading Lawson Avenue to direct flows into the park.

A summary of submissions received and responses to those submissions are provided in **Appendix F**. Based on the submissions received, any adjustment or further assessment to address issues raised were not warranted based on the outcomes of the public exhibition.

5 Flood Behaviour

5.1 Flood Study Model Review and Update

5.1.1 Model Review

For the *Marrickville Valley Flood Study* (WMAwater, 2013) a DRAINS hydrology model and TUFLOW 1D/2D hydraulic model were established for the Marrickville Valley, with a general summary of the modelling methodology provided in **Section 3.1.2**.

These models will form the basis for assessment of flood modification options within the floodplain as part of this FRMS&P. As a result a detailed review of both the hydrology and hydraulic models was conducted in order to confirm that the models appropriately represent the existing floodplain behaviour. For the most part the model set-up was assumed to be appropriate with the following exceptions:

> Due to new drainage works that had been undertaken since the Flood Study was completed and availability of new information, the DRAINS inflow subcatchments found that they did not accurately reflect the inlet pit configuration in a number of locations;

> The modelling of the existing pump systems in the TUFLOW hydraulic model did not accurately represent the pump system operation; and

> The inlet pits were modelled with unlimited capacity and 50% blockages applied for majority of the culverts and pipes resulting in majority of the pipes running full in the smaller events.

The updates to address these issues are discussed in the following sections.

5.1.1.1 Inflow Subcatchments

A review of the DRAINS inflow subcatchments was undertaken to compare with the updated stormwater pit and pipe data. Several catchments were identified that has to be divided into smaller subcatchments, to connect to the relevant inlet pit. An area analysis of the updated subcatchments is summarised in **Table 5-1**.

The DRAINS inflow subcatcments is shown in **Figure 5-1**.

Table 5-1 Updated Subcatchment Area Summary

Flood Study (WMAwater, 2013) DRAINS Model		Updated FRMS&P DRAINS Model	
Subcatchment ID	**Area (ha)**	**Subcatchment ID**	**Area (ha)**
cMT42	0.773	cMTA_3	0.459
		cMT42	0.314
ES64	3.115	ES64	0.441
		ES64a	1.238
		ES64b	0.699
		ES64c	0.746
cEC2_7	1.256	cEC2_7	0.509
		cEC2_7a	0.751
ES44	1.473	cES44	0.288
		cES44a	0.323
		cES44b	0.287
		cES44c	0.364
		cES44d	0.214
Cmk_116	0.092	cMK_116	0.060
		cMKA_5	0.032
cMK_128	6.959	cMK_128	5.944
		cMKA_1	0.731
		cMKA_2	0.283
MT534	0.426	MT534	0.121
		cMTA_1	0.305
cN166a	2.225	cN166a	1.114
		cN166b	0.844
		cN166c	0.268

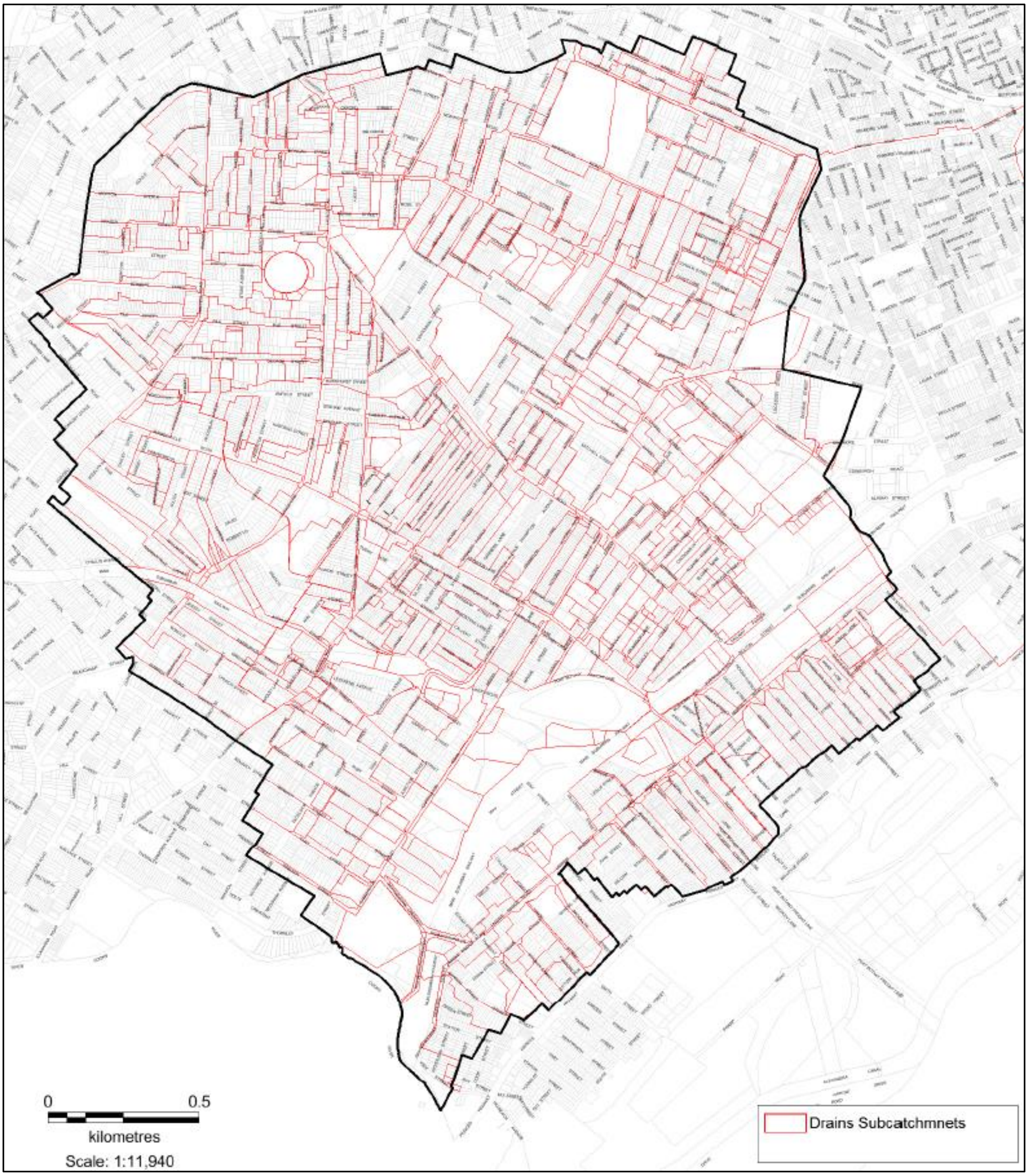


Figure 5-1 **DRAINS Inflow Subcatchments**

5.1.1.2 Existing Pump Stations Modelling

Review of the pump station setup in the flood study model identified some inconsistencies with the latest available information and it was agreed with Council to update the model setup in these locations. In the flood study model the inflows are directed to the wet wells with the pump outflows extracted from the model. Outflows from the pumps are represented in the model as a constant flow rate inserted as an inflow boundary at the receiving channel location. This setup is maintained as the version of the model software does not have full pump operation functionality.

However, the flood study model was seen to not appropriately represent the pump operating levels and actual outflow hydrographs. Hence, the wet well storage and variable pump outflows were not in line with the expected behaviour which affected the inflows to the wet wells. The model setup was changed to more accurately represent the latest available information such that the pumps achieve their primary purpose of removing flood storage from the wet wells making it available for continued flood storage.

As part of the FRMS&P TUFLOW model update, the pump systems have been reviewed and the model updated accordingly:

- Sydenham Storage Pit (DPS1) – Modelled as a two pump system, each with capacity of 1.42 m^3/s (combined capacity of 2.84 m^3/s) with cut-in elevations of -4.92m AHD and -4.52m AHD. The storage pit setup was changed to been modelled in the 2D domain of the TUFLOW model with 1d-2d boundary conditions for the inflows and pump outflows. The pump system was setup in the 1d component of the TUFLOW model as a boundary condition to extract flows from the 2d domain (the pit) and connect to 1d network in the Eastern Channel. The storage pit inflow setup and pump cut-in, cut-out levels were updated to reflect the provided information.
- Mackey Park (DPS2) – Modelled as a two pump system, each with capacity of 1.25 m^3/s (combined capacity of 2.5 m^3/s) with cut-in elevations of -3.61m AHD and -2.95m AHD This pump system has been modelled in the 1D component of the TUFLOW model. Pump wet well inflow setup and pump cut-in, cut-out levels were updated to reflect the provided information.
- SPS271 – Modelled as a two pump system, each with rated capacity of 1.00 m^3/s (maximum combined capacity of 1.8 m^3/s) with a single cut-in elevation of 0.45m AHD. The pump offtake and discharge outlet locations were updated to reflect the latest GIS information. Pump cut-in, cut-out levels were not able to be sourced from provided information and cut-in, cut-out levels in the existing model were adopted.

The pump station details in the updated TUFLOW model were based on information provided in *Operational Interface Protocol: Stormwater Drainage Pumping Stations within Marrickville Valley Catchment (SWC66)*, (Sydney Water, 2011), *Marrickville Valley SWC 66 Capacity Assessment* (Sydney Water, 1995) and *Contingency Plan – Drainage Pumping Station 1 Sydenham Stormwater Storage Pit* (Sydney Water, 1999).

5.1.1.3 Pit Set-up

Inlet capacity is one of the key factors that may constrain flows into the drainage system in urban hydraulic modelling. The capacity of inlets depends on the depth and velocity of approaching run-off and the configuration of the inlets.

The Marrickville Valley Flood Study model was set-up with all inlet pits modelled with unlimited capacity with large capture area (~10m) and flows applied to the base of the pit. The model then adopted a 50% blockage for the majority of culverts and pipes in the model as a surrogate for pit blockage, with the exception of the main channels (Eastern Channel, Central Channel, Western Channel and the Malakoff Tunnel). This approach effectively applies blockage to the entire network upstream rather than just the immediate upstream pit. This has resulted in the majority of pipes in the network running full in the 2 year ARI event and does not provide an accurate representation of the actual capacities of the pipe network (which became apparent in carrying out the pipe capacity assessment).

To address this issue, model set-up has been updated to have pipes below 300mm 100% blocked and all other pipes 0% blocked. All inlet pits were modelled at surface (kerb and gutter) using inlet rating curves.

Due to lack of detailed records of pit types, the majority of pits within the study area were replaced with a single most common pit type (e.g. NSW RMS SA2), with the exception of the Malakoff Tunnel inlet pits in Malakoff Street and surcharge pits in Marrickville Oval which are known special pits with a large inlet capacity. Three types of rating curve options for RMS-SA2 type pits were adopted: one sag curve and two on-grade curves (3% cross fall, 1% grade and 3% cross fall, 5% grade for flat and steep streets, respectively. A specific pit inlet rating curve for Malakoff Street and Marrickville Oval surcharge pits has also been adopted.

Pits were assigned an on-grade inlet capacity curve or a sag inlet capacity curve based on their position in the catchment. The 2d connection to the pit was limited to a single model grid cell of 3m X 3m (except specials which link to the appropriate number of cells). All the catchment flows from the hydrology model were applied at the inlet pit surface level rather than to the pipes inverts as in the current model set-up.

5.1.2 <u>Modelling of Additional Data</u>

As outlined within the data review section (**Section 2.8**) two additional pieces of information were made available by Inner West Council to inform this FRMS&P:

- Recent Aerial Laser Survey (ALS) data provided updated surface terrain information for the study area;
- Updated stormwater pit and pipe data in GIS format.

In consultation with Inner West Council and the Marrickville Valley Floodplain Risk Management Committee, and based on the review of the data it was agreed that the hydrology and hydraulic modelling would need to be updated to account for these data updates.

5.1.2.1 Updated ALS Data

As discussed in **Section 3.4** Inner West Council provided an updated ALS data that has been used to replace the Digital Elevation Model (DEM) used as the basis for 2D modelling in the TUFLOW model.

This change will impact flood behaviour throughout the model, particularly in locations where the updated DEM is most different to the Flood Study DEM.

5.1.2.2 Updated Pit and Pipe Data

As discussed in **Section 3.5.1** Council provided an updated stormwater pit and pipe layer which for the most part is reflective of the network adopted in the Flood Study. However, it was identified that there were notable differences at a number of locations including network configuration and pipe sizes. **Figure 5-2** shows the network updates that were undertaken.

The DRAINS and TUFLOW hydraulic models were revised to reflect these updated details of the stormwater pit and pipe network.

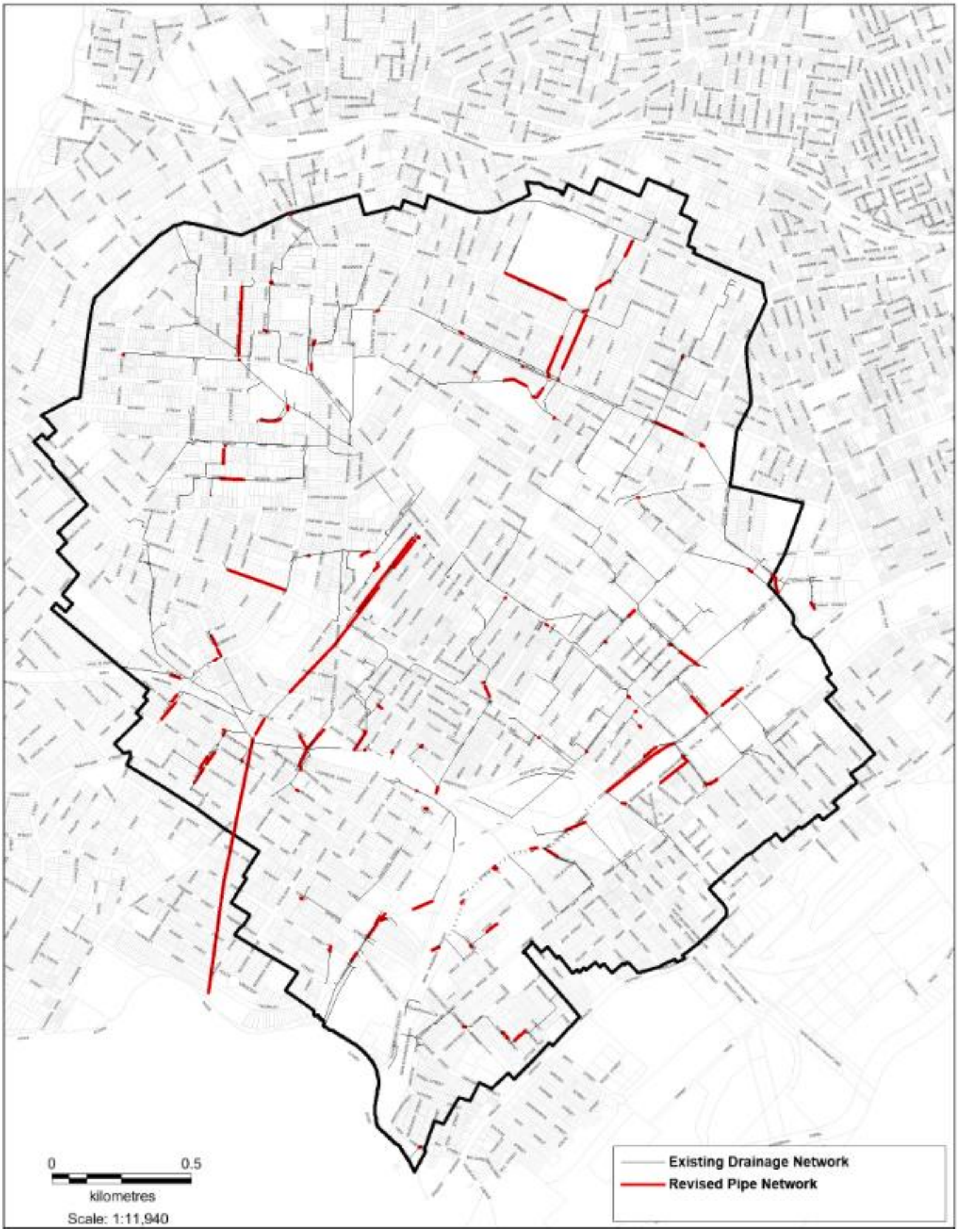


Figure 5-2 **Revised Drainage Network**

5.1.3 Model Results

Based on these updates the hydrology and hydraulic model were re-run for all design events: the 2 year ARI, 20%, 10%, and 1% AEP events and the PMF event. All events were only modelled for the critical durations identified within the Flood Study which is the 2 hour storm duration for all design events with the exception of the PMF for which the 60 minute storm is critical.

A set of figures showing flood extents, peak depth and peak velocity results for all design flood events for the updated existing scenario modelling has been included in **Appendix G**. The revised modelling now forms the existing scenario, or the base case for flood modification options assessment within this FRMS&P.

The updated model results were compared to the Flood Study (WMAWater, 2013) results. **Figure 5-3** shows the differences in peak water level for the 1% AEP event.

The results show a general increase of 0.1m to 0.2m across the study area. These increases can be attributed to the recent ALS data adopted which shows ground surface levels to be higher for the majority of the study area in comparison to the 2013 Flood Study terrain.

However, the results show reductions in water levels for the large parts of the study area, particularly adjacent to trunk drainage lines and in low lying areas. This is primarily due to the changes in the adopted pit and pipe model set-up. Applying inlet rating curves to the pits and removing 50% blockages that were previously applied to the pipes has increased the stormwater carrying capacity of the drainage system. This has resulted in reductions of surface overland flows. In addition, the changes to the pump station model set-up to more accurately represent the latest available information has further attributed to the reduction in water levels in adjacent areas.

The reductions observed in water surface levels are generally in the order of 0.1m to 0.5m. The reductions are observed at the following key locations are:

- Marrickville Industrial Area (up to 0.5m);
- Carrington Road (up to 0.3m);
- Mackey Park (0.1m to 0.3m);
- Marrickville Oval (up to 0.3m); and
- Addison Community Centre (0.1m to 0.5m).

The results also show increases in water surface levels at some locations in the study area. The increase in stormwater carrying capacity of the drainage system has resulted in water level increases in the downstream parts of networks, particularly in trunk drainage channels. This is due to additional flows entering the drainage system at the upstream end and supplying more flow to the trunk drainage pipes/channels resulting in increased water levels in these pipes/channels. In some cases, this is restricting the capacity to take more flows at the downstream end leading to increased water levels in adjacent areas.

In areas where there are increases in water surface levels these increases are observed to be approximately 0.1m to 0.5m. The increases are observed at the following key locations are:

- Western Channel (0.1m to 0.4m);
- Eastern Channel (up to 0.2m);
- Marrickville Station (0.1m to 0.5m);
- Lawson Avenue and Fraser Street (up to 0.2m); and
- Victoria Road (0.1m to 0.3m).

The majority of the changes in water levels observed in the study area are in the order of -0.2m and 0.2m. While these changes are important to better understand flood behaviour and plan for flood mitigation options, it should be noted that these differences are within reasonable bounds and will not impact the outcomes of the identification of flood affected properties that Council undertook based on the 2013 Flood Study results.

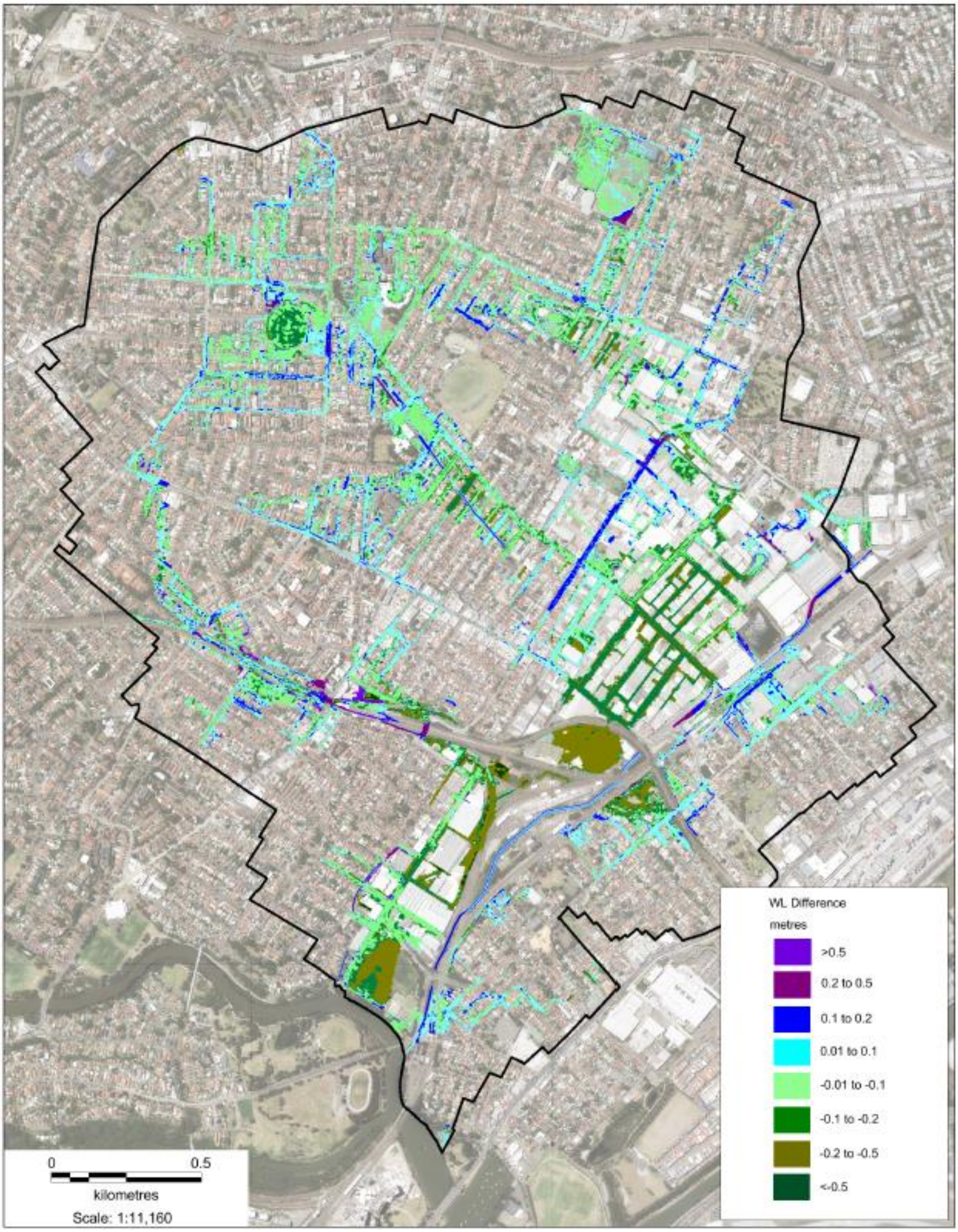


Figure 5-3 **1% AEP Peak Water Level Differences (Updated 2016 Model Results Less 2013 Flood Study Results)**

5.2 Hydraulic Categorisation

In accordance with the *Floodplain Development Manual* (NSW Government, 2005), hydraulic category mapping has been produced for the categories:

> Floodways are areas of the floodplain where a significant discharge of water occurs during floods that are often, but not always, aligned with naturally defined channels. They are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels.

> Flood Storage are parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood; and,

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

Hydraulic categories were determined using an in-house developed program which utilises model results from velocity and depth in addition to post processing to ensure categories are contiguous.

Hydraulic category mapping figures are shown in **Appendix H.**

5.3 Flood Timing

An important consideration in defining the flood behaviour of an area is an assessment of the timing of flooding which is a key factor in assessing flood risk. If the rate of rise of floodwaters is fast then the opportunity for emergency response is limited and the risk to life may be higher, while if there is a long duration of inundation then the risk may increase due to extended periods of isolation for flood affected residents. The actual risk associated with these scenarios is also dependant on the depth of floodwater. A detailed analysis of water level time series and the implications of the flood timing on emergency response provisions is discussed in further detail in **Section 7.9.9**.

In summary the peak of flooding occurs within 1 hour of the onset of rainfall for the 1% AEP critical event which is the 2 hour duration storm. For the PMF critical event, the peak of flooding occurs less than 30 minutes after the onset of rainfall. These fast times to peak flooding mean that flooding in the Marrickville Valley is flash flooding.

5.4 Pipe Capacity Assessment

An assessment of the stormwater network within the study area was undertaken for trunk drainage within the catchment and pipes greater than 600mm. Pipe attributes including diameter, slope, length and both upstream and downstream invert levels were extracted from the hydraulic model and pipe GIS dataset.

Using the Manning's equation, the theoretical pipe capacity was determined based on pipe grades and cross sectional area, calculating the maximum flow rate for pipe full flow with no downstream constraints.

The modelled pipe flows for each design event were extracted from the model and the design events at which the pipes are running full were determined.

By comparing the theoretical pipe capacity to the modelled pipe design flows and the event at which the pipes are running full, the pipe network was characterised as being either:

> Inlet Controlled – The pipe has additional unused capacity, but is limited by the inlet capacity of the pits;

> Outlet Controlled – The system is limited by the hydraulic performance of the outlet (this is due to downstream control such as smaller diameter pipe running at capacity or a tailwater from the receiving channel or creek);

> Capacity Controlled – The pipe is operating at maximum flow carrying capacity limited by its size; and

> Oversized – The pipe has capacity greater than the flows draining into it for all the design events.

The results of this assessment are provided in **Appendix I**.

The results show that majority of the pipes are running full in the 2-year event and much of the system is not operating at its theoretical capacity due to a downstream control within each network. This is predominantly due to downstream pipes running at full capacity and the relatively high 0.625m AHD tailwater level adopted in the Cooks River.

However, a number of pipes have also been identified as inlet controlled and have capacity to take additional flows during the smaller rainfall events if inlet capacity of pits was increased. These are evident along Addison Rd, downstream of Malakoff tunnel and along sections of the Eastern Channel.

5.4.1 Comparison with Marrickville Valley SWC 66 Capacity Assessment

In 1995, Sydney Water carried out a quantitative assessment of the following four major drainage systems owned by them:

> Eastern Channel;

> Central Channel;

> Western Channel; and

> Western Channel Amplification (Malakoff Tunnel).

The aim of the assessment was to assess the performance of the system in terms of the average recurrence design storm. The performance was estimated using the Rational Method for hydrological assessment and Manning Formula for hydraulic assessment.

A comparison of the pipe capacity assessment undertaken as part of this study with the Marrickville Valley SWC 66 Capacity Assessment highlighted the following:

- Both the studies confirm that the majority of the Central Channel has capacity less than the 2 year ARI event;
- Both the studies confirm that the upper reaches of the Western Channel has capacity less than 20% AEP;
- For Malakoff Tunnel, this study indicates that the upper reaches of the system has capacity less than 10% AEP event and the lower reaches has PMF capacity. The SWC 66 Capacity Assessment shows that the upper reaches has between 20% and 10% AEP capacity and the lower reaches has capacity less than 20% AEP event; and,
- For the Eastern Channel, this study indicates that the channel has capacity for up to 1% AEP event. The SWC 66 Capacity Assessment shows that it has capacity of greater than 5% AEP.

This comparison shows that the two studies are in general agreement, with the current study calculating slightly higher capacities in Malakoff Tunnel and Eastern Channel than the SWC 66 Assessment. This is likely due to the more detailed nature of the current study and greater consideration of catchment storage effects.

5.5 Climate Change

5.5.1 Climate Change Modelling for Marrickville Valley

Several climate change scenarios were modelled for the 1% AEP flood event as part of the *Marrickville Valley Flood Study* (WMAwater, 2013). The climate change runs were guided by the following documents which were the most relevant guides for impacts of climate change at the time:

> IPCC Fourth Assessment Synthesis Report - Summary for Policymakers (IPCC, 2007).

> NSW Sea Level Rise Policy Statement (NSW Government, 2009);

> Floodplain Risk Management Guideline: Practical Consideration of Climate Change (NSW Government, 2007);

The effects of climate change on flooding are typically incorporated in two ways, potential future sea level rise, and increases in rainfall for design storms. As part of the Flood Study the following climate change scenarios were analysed for the 1% AEP event:

> 0.4m rise in tailwater level in the Cooks River;

> 0.9m rise in tailwater level in the Cooks River;

> 10% increase in design rainfall intensity;

> 20% increase in design rainfall intensity;

> 30% increase in design rainfall intensity;

> 10% increase in design rainfall intensity PLUS a 0.4m rise in tailwater level in the Cooks River;

> 10% increase in design rainfall intensity PLUS a 0.9m rise in tailwater level in the Cooks River; and,

> 30% increase in design rainfall intensity PLUS a 0.4m rise in tailwater level in the Cooks River.

A comparison of the peak water level results for the various climate change scenarios and the current climate condition was conducted as part of Flood Study.

The results concluded that for the Marrickville Valley only the downstream edge of the catchment near Mackey Park is impacted by sea level rise. The results indicate that a 0.4m sea level rise will increase the 1% AEP flood levels by a maximum of 0.1m and a 0.9m sea level rise by a maximum of 0.2m for this one location.

The impacts of rainfall increase on flood behaviour is more significant with a general increase in flood levels across the entire catchment. A 10% rainfall increase in design rainfalls results in approximately a 0.1m maximum increase in peak levels, a 20% rainfall increase a 0.2m maximum increase in peak levels and a 30% rainfall increase a 0.3m maximum increase in peak levels.

For the coincident rainfall increase and sea level rise scenarios, the increases in water levels were in most instances directly equivalent to the addition of the individual impacts of the relevant sea level rise and rainfall increase scenarios. The peak water level increase for the 30% rainfall increase scenario and 0.4m sea level rise event was 0.4 metres at two locations, with water level increases at all other locations exceeding 0.3 metres.

5.5.2 Review of Modelled Sea Level Rise Scenarios

Since the finalisation of the *Marrickville Valley Flood Study* (WMAwater, 2013), revised projections have been released by the Intergovernmental Panel on Climate Change within the *IPCC Fifth Assessment Synthesis Report - Summary for Policymakers* (IPCC, 2014).

A graphical summary of projected sea level rise ranges are shown in **Figure 5-4** for four possible Representative Concentration Pathways (RCP's) that represent different future emissions reduction scenarios.

RCP2.6 is seen as a best case scenario for emissions reductions and RCP8.5 seen as a worst case scenario. For example, for the most severe RCP8.5, global mean sea level rise for 2081-2100 relative to 1986-2005 will likely be in the range of 0.45 to 0.98m.

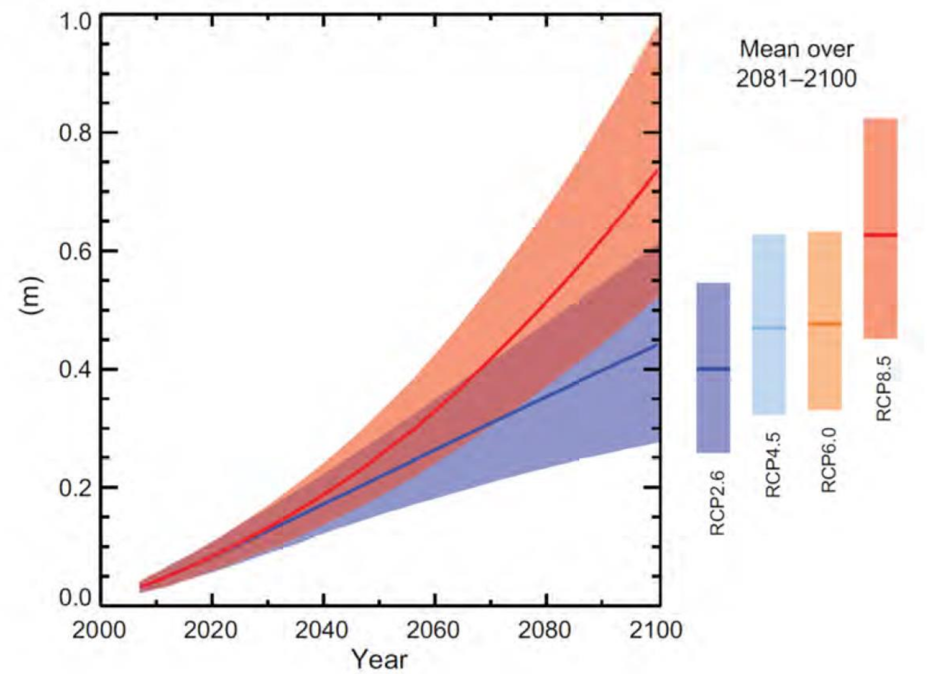


Figure 5-4 **Global mean sea level rise predicted to 2100 relative to 1986-2005 based on various representative concentration pathways (IPCC, 2014)**

Comparing the previous guidance around 2050 and 2100 benchmarks in the context of the latest IPCC data it can be seen that:

> The previous 0.9 metre 2100 sea level rise benchmark generally lies in the upper range of the upper bound RCP8.5 scenario for the year 2100, and therefore could be considered slightly conservative;

> The previous 0.4 metre 2050 sea level rise benchmark is the median of the range for the lower bound RCP2.6 scenario for the year 2100. In addition a sea level rise of 0.4 metres lies within the lower range of the two intermediate scenarios, RCP4.5 and RCP6.0. This 0.4 metre sea level rise value is therefore assumed to be more closely aligned with the sea level rise that may be anticipated by the year 2100.

5.5.3 Review of Modelled Rainfall Increases

Rainfall intensity is also predicted to alter, although there is less certainty around this on the basis of information published. The *Floodplain Risk Management Guideline: Practical Consideration of Climate Change* (NSW Government, 2007) recommends analysing a range of increases in rainfall between 10 and 30% for floodplain management assessments.

The most recent published information associated with the revision of the leading guide to flood estimation in Australia, *Australian Rainfall and Runoff*, suggests a 5% increase in intensity per degree Celsius of global warming (Engineers Australia, 2014). With a predicted mean temperature increase of 0.3 – 4.8 degree C at 2100 (IPCC, 2014) under a range of scenarios, this equates to an increase in intensity in the range 5 - 25%. As a consequence, the use of a 30% increase as an upper bound in rainfall intensity is a reasonable approach.

In relation to rainfall changes associated with climate change, it is anticipated that updated IFD information for climate change may become available as part of the *Australian Rainfall and Runoff* revision. In the meantime, however, the adopted percentage rainfall increase is seen as appropriate.

5.5.4 Summary

Based on a review of current information and guidelines relating to the impact of climate change on flood behaviour, the climate change scenarios that were modelled for the Marrickville Valley are assumed to be appropriate. In particular the modelled scenario of a 30% rainfall increase and 0.4 metre sea level rise is seen as a suitable event in assessing the impact climate change may have by the year 2100.

The significance of assessing the potential impacts of climate change for the year 2100 is that it represents a design life of over 80 years which has good congruence with current life expectancy. The potential incorporation of climate change within Flood Planning Level for the Marrickville Valley is discussed further in **Section 8.5.3**.

6 Economic Impact of Flooding

6.1 Background

The economic impact of flooding can be defined by what is commonly referred to as flood damages. Flood damages are generally categorised as either tangible (direct and indirect) or intangible damage types; these types are summarised in **Table 6-1**.

Table 6-1 Types of Flood Damages

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 **Table 6-1**, are just one component of the entire cost of a flood event. There are also indirect costs. Together, direct and indirect costs are referred to as tangible costs. In addition to tangible costs, there are 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 spread-sheets. For the purposes of this project, an in-house developed program has been used based on a combination of OEH residential damage curves and FLDamage processes.

A flood damage assessment for the existing catchment conditions has been completed as part of this study.

The assessment is based on damage curves that relate the depth of flooding on a property to the likely 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 as such, damage curves from other catchments, and available research in the area, is used as a substitute.

OEH has conducted 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.

6.2 Input Data

6.2.1 Floor Level Assessment

A desktop floor level assessment has been undertaken to assign average building heights for properties within the 1% AEP flood extents. Based on Council's Flood Planning Area map, a database was compiled of all flood affected streets. For each street Google Streetview was used to inform average building height (average number of steps to floor level). **Table 6-2** provides the average building height adopted for the flood affected streets. The building heights were then added to the ground levels for each property to generate a floor level.

Table 6-2 Average Building Heights Adopted

Street Name	Average number of steps	Floor height based on 150mm step
Illawarra Road	2	300
Despointes Street	2	300
Silver Street	2	300
Sydenham Road	2	300
Garners Avenue	3	450
Victoria Road	4	600
Malakoff Street	3	450
Northcote Street	3	450
Petersham Road	2	300
Brereton Ave	2	300
Livingstone Road	2	300
Addison Road	3	450
Agar Street	2	300
England Ave	2	300
Maria Street	3	450
Wardell Road	2	300
Jarvie Avenue	2	300
Frazer Street	4	600
Morton Avenue	1	150
Bishop Street	1	150
Lawson Avenue	3	450
Pile Street	1	150
George Street	1	150
Stanmore Road	5	750
Harrington Street	4	600
Edinburgh Road*	1	150
Bourne Street	1	150
Grove Street	2	300
Sutherland Street	1	150
Railway Road	6	900
Bridge Street	1	150
Terry Street	2	300
Union Street	2	300
Gannon Street	3	450
Arthur Street	7	150
Hollands Avenue	2	300
South Street	1	150

Street Name	Average number of steps	Floor height based on 150mm step
Warburton Street	1	150
O'Hara Street	4	600
Central Avenue	2	300
Calvert Street	1	150
Jersey Street	4	600
Marrickville Road	1	150
Harney Street	1	150
Byrnes Street	3	450
Cavey Street	1	150
Unwins Bridge Road	1	150
Park Road	1	150

For properties within the PMF flood extent which were not included in the floor level estimation, an indicative floor level was estimated by adding an average floor height of 300mm above ground to the ground level at that location. These properties are only impacted by the less frequent flood events and as such do not contribute a significant portion of the average annual damages. As such, the estimates are not critical to the outcomes of the damages.

6.2.2 Hydraulic Model Result Inputs

To inform the damages analysis summarised in **Section 6.3**, water level results are required to determine the depth of over-floor flooding and over-ground flooding for each flood affected lot. To inform this assessment, the flood level minus floor level for each building polygon was calculated and adopted as the inundation for that lot.

6.3 Damage Analysis Methodology

6.3.1 Residential Damage Curves

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 are not available and recourse is generally made to damage curves from other catchments. NSW Office of Environment and Heritage (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. OEH guidelines include a template spreadsheet program that determines damage curves for residential properties including:

> Single story, slab on ground;
> Two story, slab on ground; and
> Single story, high set.

Several input parameters are required to use the OEH curves, such as floor area and level of flood awareness. The following parameters were adopted in developing the residential damage curves for the Marrickville Valley study area:

- Damages are generally incurred on a property prior to any over floor flooding. The OEH curves allow for a damage of $15,017 (May 2016 dollars) to be incurred when the water level reaches the base of the house. The base of the house has been assumed to be 0.1 m below the floor level for slab on ground. We have assumed that this remains constant until over floor flooding occurs. This may occur on steeper properties and larger properties where the garden and fences may be impacted, but the flood waters do not reach the house.

> A value of 150 m^2 was adopted as a conservative estimate of the floor area for residential dwellings in the floodplain. With a floor area of 150 m^2, the contents value is estimated at $37,500.

> All single storey properties have been classified as “slab-on ground”.

> The effective warning time has been assumed to be zero due to the nature of flooding and 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 and hence reducing the potential damages to household contents; and

> The Marrickville catchment is within a large metropolitan areas, and as such is not likely to cause any post flood inflation. These inflation costs are generally experienced in regional areas where re-construction resources are limited and large floods can cause a strain on these resources.

6.3.1.1 Average Weekly Earnings

OEH damage curves were derived for late 2001. To convert damages to today’s dollars, it is recommended that values in residential damage curves are adjusted by Average Weekly Earnings (AWE) rather than by the inflation rate as measured by the Consumer Price Index (CPI). AWE is considered a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home.

The most recent data from the Australian Bureau of Statistics website (www.abs.gov.au) at the time of this study is for May 2016. The November 2001 AWE is shown in Table D1 of the DECC guidelines. Both are shown in **Table 6-3**. Consequently, all ordinates in the residential flood damage curves were updated to May 2016 dollars. In addition, all damage curves include GST as per OEH recommendations.

Table 6-3 Average Weekly Earnings (AWE) Statistics for Residential Damage Curves

Month	Year	AWE
November	2001	$673.60
May	2016	$1,516.00*

**Source: Australian Bureau of Statistics (2016)*

6.3.2 Commercial Damage Curves

Commercial damage curves were 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.

For the purpose of this assessment all commercial properties have been classified as low value commercial, as no other information was available in the survey obtained for this project. 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.

These curves are derived assuming a property floor area of 100 m^2. The floor areas were estimated based on the building footprints provided by Council.

The Consumer Price Index (CPI) was used to bring the 1990 data to March 2016 dollars (**Table 6-4**), using data from the Australian Bureau of Statistics (2016). It was assumed that the FLDamage data was in June 1990 dollars.

Table 6-4 CPI Statistics for Commercial Damage Curves

Month	Year	CPI
June	1990	$102.50
March	2016	$193.40

6.3.3 Industrial Damage Curves

Cardno, as a part of a previous floodplain management study (Cardno, 1998), conducted a survey of industrial properties in 1998 for Wollongong City Council. The damage curves derived from that survey are more recent than those presented in FLDamage and have been used in several previous studies. Therefore, these damage curves are considered the most appropriate for use in this study.

The curves were prepared for three categories:

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

The Marrickville Valley study area comprises a large industrial area to the east of Victoria Rd extending from Addison Rd to Marrickville Rd. A low value industrial classification was applied to all the properties within the industrial area. The floor areas were estimated based on the building footprints provided by Council.

The survey conducted only accounts for structural and contents damage to the property. Clean-up costs and indirect financial costs were estimated based on the FLDamage Manual (Water Studies Pty Ltd, 1992). 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 clean-up costs and indirect financial costs could be made. The values were adjusted to March 2016 dollars using the CPI statistics shown in **Table 6-5**.

Table 6-5 CPI Statistics for Industrial Damage Curves

Month	Year	CPI
June	1998	$121.00
March	2016	$193.43

6.4 Adopted Damages Curves

The adopted damage curves are shown in **Figure 6-1** and **Figure 6-2**. For illustrative purposes the commercial and industrial damage curves are shown assuming a floor area of 100m^2, although the floor areas for each commercial or industrial property were used based on building footprints.

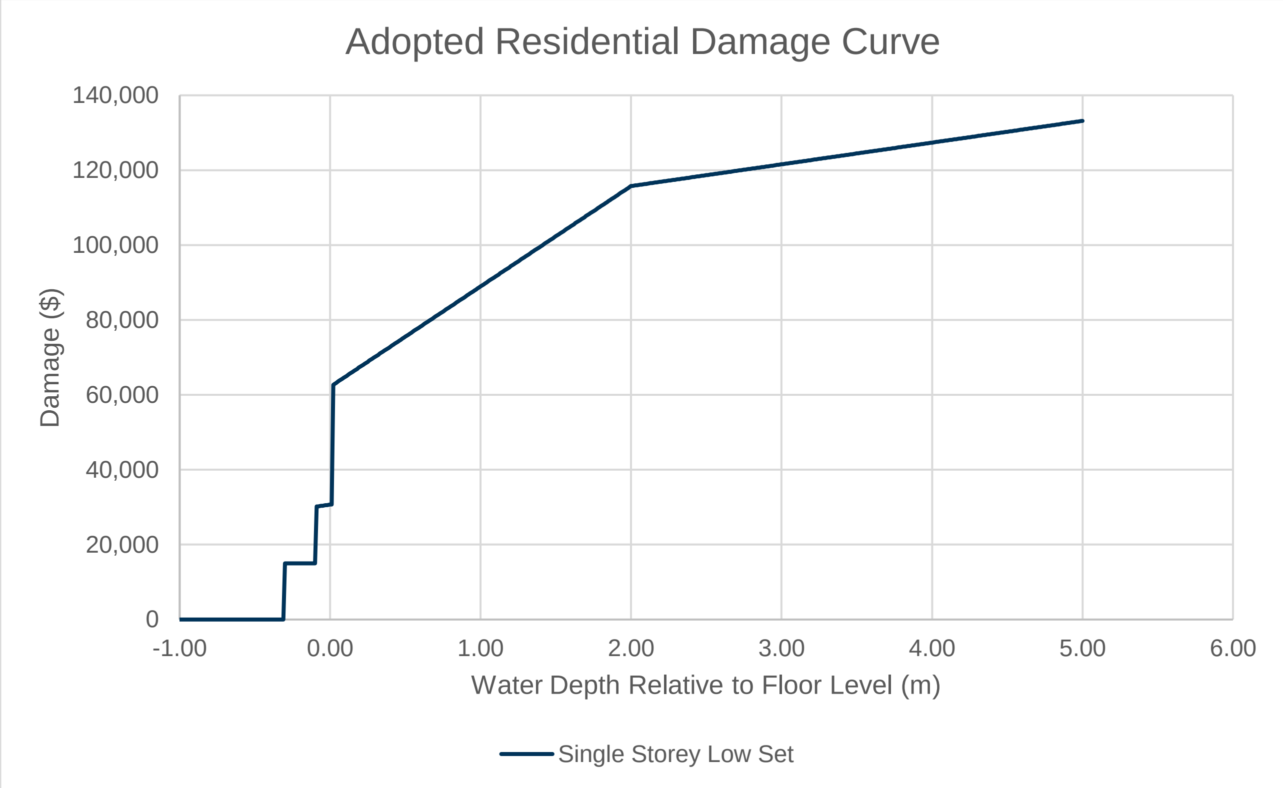


Figure 6-1 **Residential Damage Curve**

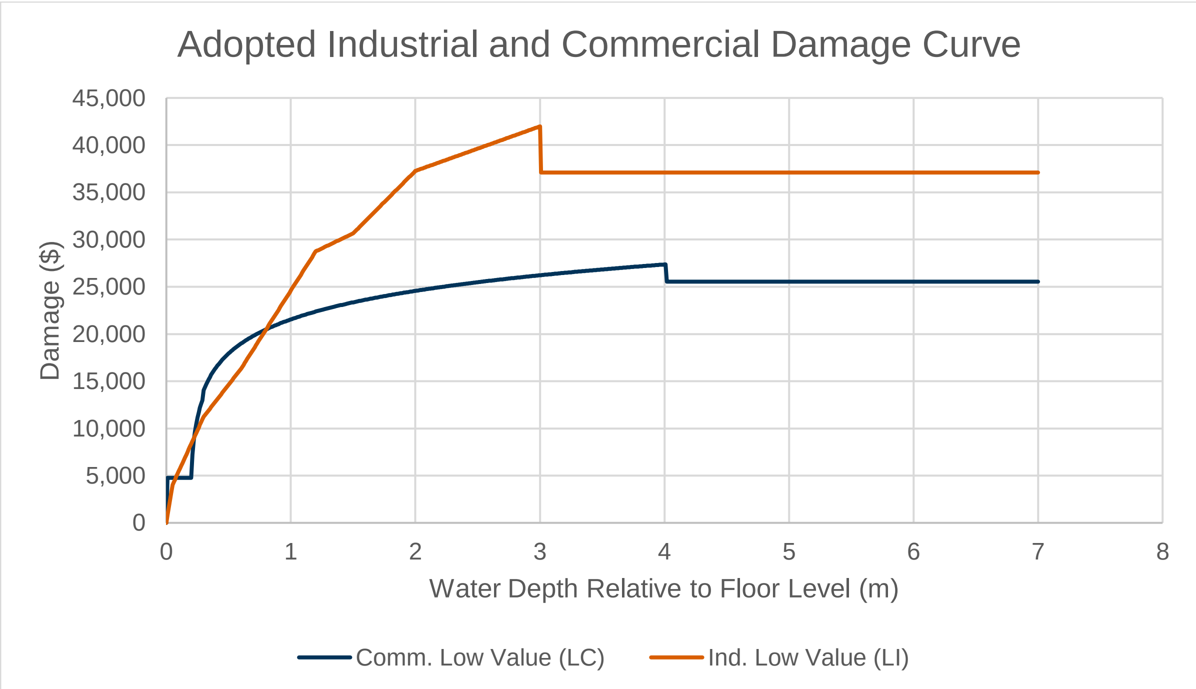


Figure 6-2 **Industrial and Commercial Damage Curves**

6.5 Damages Results

6.5.1 Total Damages

A summary of the damages results is shown in **Table 6-6**.

Table 6-6 Flood Damages Assessment Summary

Design Event	Properties with Overfloor Flooding	Total Damage ($)
PMF	2414	158,717,083
1% AEP	1140	68,093,894
10% AEP	662	44,252,172
20% AEP	531	39,447,127
2 year ARI	304	28,946,967
Average Annual Damage (AAD)		27,869,315

The impact of flooding across the catchment is significant, with the number of properties in the catchment that would be impacted by overfloor flooding in the 2 year ARI event being 304 properties. Economic impacts of flooding are also significant due to flooding over the floor level of both residential and commercial properties, as well as structural and garden damage for residential properties combining to represent a significant expense in flood events ranging from the 2 Year ARI to the PMF event. The Annual Average Damage for the catchment is expected to be approximately $28 million dollars with the contributions of the various design flood events summarised in **Table 6-6**.

6.5.2 Sensitivity Analysis

The significant number of properties in the catchment impacted by overfloor flooding co-relates to the floor levels adopted as part of the desktop assessment. Given a degree of uncertainty involved with the floor level estimation, a sensitivity analysis was undertaken to establish the sensitivity of the overfloor flooding properties to the changes in floor levels. The outcome of the analysis is presented in **Table 6-7**.

Table 6-7 Floor Level Sensitivity Analysis Results

Design Event	Properties with Overfloor Flooding		
	Desktop assessment floor levels	50mm increase in floor levels	100mm increase in floor levels
PMF	2414	2214	2050
1% AEP	1140	933	782
10% AEP	662	499	348
20% AEP	531	366	226
2 year ARI	304	198	118

As can be observed, the number of properties in the catchment that would be impacted by overfloor flooding is sensitive to the floor levels and significantly reduces with slight increase in floor levels for the smaller events. For the purpose of this study, a 50mm increase in floor levels has been adopted since this approach is considered to be within reasonable bounds of desktop floor level assessment sensitivity.

6.5.3 Adopted Total Damages

Based on the adopted 50mm increase in floor levels, a summary of the total damage results for Marrickville Valley catchment is shown in **Table 6-8** including:

> The number of residential, commercial, industrial and public properties with overfloor flooding;

> The average depth of overfloor flooding for residential, commercial, industrial and public properties;

> The maximum depth of overfloor flooding for residential, commercial, industrial and public properties; and

> Total damage value for the catchment.

The above results are listed for all design events; 2yr ARI, 20%, 10%, 1% AEP and the PMF event.

This result aligns with the summary of land uses for the catchment (**Section 8.4**) which shows the majority of the catchment area is residential land use with localised areas of commercial and industrial.

Table 6-8 Adopted Flood Damages Assessment Results

Property Type	Number of Properties	Properties with Overfloor Flooding	Average Overfloor Flooding Depth (m)	Maximum Overfloor Flooding Depth (m)	Total Damage ($May 2016)
PMF					
Residential	4384	1382	0.60	2.97	$121,867,236.81
Commercial	279	43	0.56	1.89	$1,202,224.62
Industrial	986	745	1.73	3.48	$21,762,171.72
Public	121	44	0.45	1.47	$742,373.59
Total	**5770**	**2214**			**$145,574,006.74**
1% AEP					
Residential	4384	473	0.19	1.28	$47,408,775.55
Commercial	279	20	0.25	1.2	$728,457.12
Industrial	986	425	0.35	1.37	$5,994,034.27
Public	121	15	0.25	0.55	$355,698.72
Total	**5770**	**933**			**$54,486,965.65**
10% AEP					
Residential	4384	263	0.15	0.65	$30,415,229.71
Commercial	279	20	0.17	1.08	$639,275.84
Industrial	986	206	0.16	0.97	$2,986,415.46
Public	121	10	0.16	0.09	$281,165.66
Total	**5770**	**499**			**$34,322,086.67**
20% AEP					
Residential	4384	210	0.14	1.28	$26,528,896.97
Commercial	279	20	0.14	1.2	$609,416.99
Industrial	986	128	0.14	1.37	$2,425,506.72
Public	121	8	0.15	0.55	$266,429.03
Total	**5770**	**366**			**$29,830,249.71**
2Year ARI					
Residential	4384	119	0.12	0.46	$18,750,270.81
Commercial	279	13	0.14	0.99	$546,749.48
Industrial	986	61	0.13	0.8	$1,927,913.03
Public	121	5	0.08	0.09	$242,854.73
Total	**5770**	**198**			**$21,467,788.05**

The existing scenario total damage curve for the Marrickville Valley catchment is shown in **Figure 6-3**.

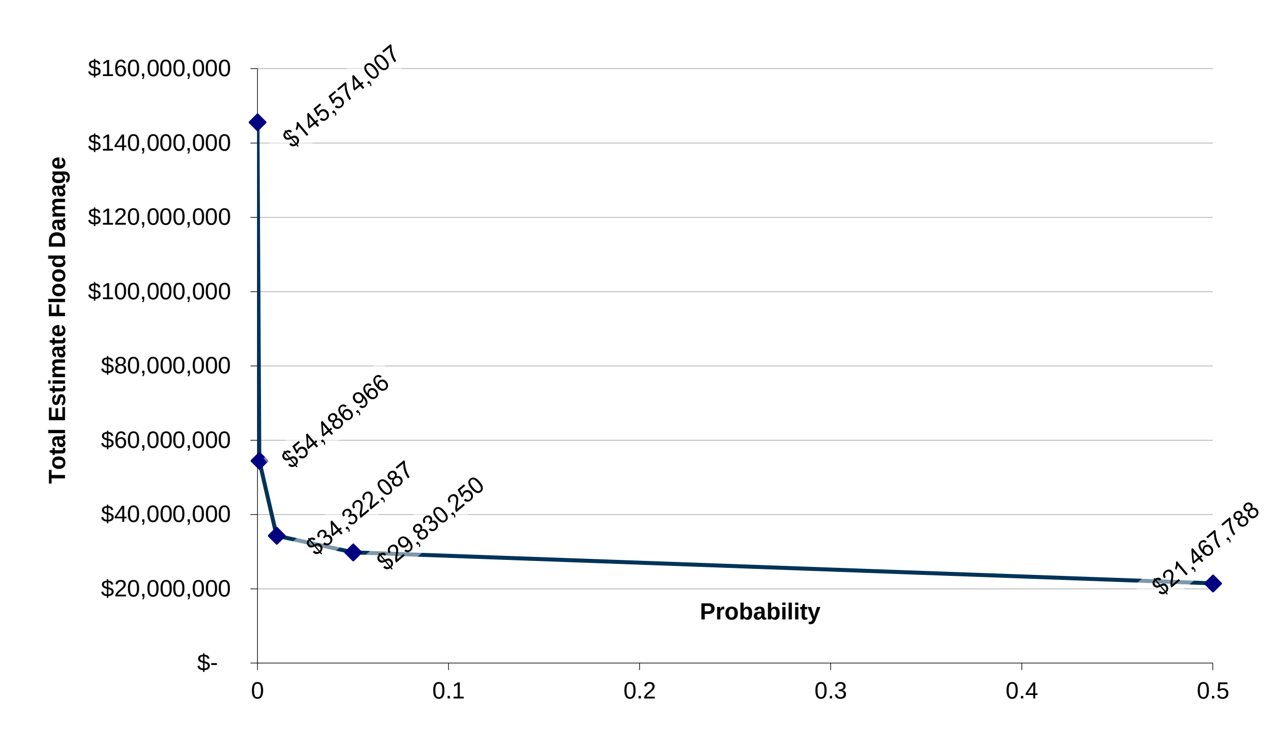


Figure 6-3 **Total Damage Curve (Existing Condition) for the Marrickville Valley Catchment**

6.5.4 Average Annual Damage

Average Annual Damage (AAD) is calculated using a probability approach based on the flood damages calculated for each design event. Flood damages (for a design event) are calculated by using the damage curves described above. These damage curves attempt to 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. For example, the 1% AEP design event has a probability of occurrence of 1% in any given year, and as such the 1% AEP flood damage is plotted at this point (0.01) on the AAD curve. AAD is then calculated by determining the area under the plotted curve.

While the PMF event has a theoretical probability of 0% of occurring, to inform the calculation of AAD a representative probability of 0.0001 (or 0.01%) has been adopted for the PMF event (equivalent to a 10,000 year ARI event). Through this method, the PMF accounts for extremely rare flood events in the AAD calculation.

Further information of the calculation of AAD can be found in Appendix M of the *Floodplain Development Manual* (NSW Government, 2005).

The total AAD for the Marrickville Valley study are is $21,264,981.

7 Emergency Response Review

7.1 Background

When determining the flood risk to life, the flood hazard for an area does not directly imply the danger posed to people in the floodplain. This is due to the capacity for people to respond and react to flooding, ensuring they do not enter floodwaters. This concept is referred to as flood emergency response.

To help minimise the flood risk to occupants of the floodplain, it is important that there are provisions for flood emergency response. There are two main forms of flood emergency response that may be adopted:

- Evacuation: The movement of occupants out of the floodplain before the property becomes flooded;
- Shelter-in-place: The movement of occupants to a building that provides vertical refuge on the site or near the site before their property becomes flood affected.

The emergency response provisions for a local area are outlined in documentation provided by the relevant emergency authority for New South Wales, the State Emergency Service (SES). The NSW SES typically prepare two documents relevant to flood emergency response; Emergency Management Plan (EMPLAN) (superseding the previous regional Disaster Plan (DISPLAN)), and a Flood Plan which is a sub-plan of the EMPLAN.

These documents are intended to provide information to SES coordinators and other authorities relating to identified responsible personnel and agencies, as well as evacuation centres, evacuation procedures and actions in the event of flooding. A summary of these relevant emergency management documents for the Marrickville Valley is summarised in **Section 7.2**.

While NSW SES do not have specific guidelines on the recommendations specifically for flash flooding, in lieu of state specific guidelines a review of national guidelines on flash flood emergency response has been provided in **Section 7.3**. In addition, discussion regarding selection of the relevant design flood event for emergency response is discussed in **Section 7.4**.

To assist NSW SES in the formulation of any regional or local emergency response documents, a review of the flood emergency response potential for the Marrickville Valley catchment is provided including critical and vulnerable developments (**Section 7.5**), potential evacuation centres (**Section 7.6**), suitable evacuation routes (**Section 7.7**), and flood warning systems (**Section 7.8**). In addition, an assessment has been undertaken of the evacuation timeline for the catchment (**Section 7.8**). A review of the potential for shelter-in-place refuge is provided in **Section 7.10**.

7.2 Flood Emergency Management Documentation

Emergency Management in NSW is run at three levels of scale, at a state-wide level, at a regional level, and a local level. Each subsequent level provides additional local detail in emergency management.

In 2012, the SES changed the Emergency Management Districts of NSW to Emergency Management Regions. The Marrickville Valley floodplain is located within the South West Metropolitan Emergency Management Region. This region encompasses 13 Local Government Areas of south-west Sydney bounded by Marrickville to the east and Wollondilly to the west.

The relevant local area with respect to SES emergency planning is the Marrickville Local Government Area (LGA), which includes not only the Marrickville Valley but also the suburbs of Dulwich Hill, Enmore, Lewisham, Petersham, Stanmore, St Peters, and parts of Camperdown, Newtown, and Hurlstone Park.

7.2.1 Local Flood Plan

In June 2015 the SES released the *Marrickville Flood Emergency Sub Plan* for the Marrickville Area of Inner West Council LGA, covering operations for flooding within the Inner West Council area.

In terms of key personnel and their responsibilities the Local Flood Plan outlines the following:

- SES Marrickville Local Controller is responsible for co-ordinating flood emergency response for the local area, focussing on the preparedness stage (pre-flood programs) such as maintaining local headquarters, training SES staff, develop a flood warning service, participate in floodplain risk management process, and co-ordinate community engagement program.

> An incident controller for the local area is to be identified by the local controller to manage the response in the event of flooding occurring including directing SES staff and supporting agencies in the following processes:
  - Flood rescue operations;
  - Evacuation of communities and provision of immediate welfare support for the displaced;
  - Provision of emergency food and medical supplies for isolated communities;
  - Assist in the repair and protection of levees and properties including sandbagging and movement of property; and,
  - Submit situation reports to the SES Sydney Southern Region Headquarters and keep the Local Emergency Operations Controller informed.

> Inner West Council has a number of responsibilities at all stages of emergency:
  - Preparedness: Council is to manage the Floodplain Risk Management Process (of which this FRMS document is a component), maintain Dam Safety Emergency Plans (DSEPs), develop plant and equipment list for SES, and work with SES on the development of a community engagement program and flood warning systems.
  - Response: At the request of the incident controller deploy personnel and resources, close and re-open Council roads notifying SES of road status, assist in protecting residents properties with sandbagging, provide back-up radio communications, and facilitating housing of domestic pets during flooding.
  - Recovery: Management of health hazards including removal of debris and waste, as well as ensuring premises are safe for re-occupation and storage of evacuee’s furniture.

The following local features within the Marrickville Valley are identified within the sub-plan:

> The SES Marrickville Operations Centre is located at 3-17 Railway Lane, Sydenham;

> The SES Marrickville Incident Response Centre is located at 3-17 Railway Lane, Sydenham;

> There are five active reconnaissance routes to confirm the occurrence of flooding with one of these being within the Marrickville Valley, Carrington Road, Carey Street, Richardsons Crescent, Renwick Street, Myrtle Street, and Mackey Park levee (UBD Ref: 274 Q2).

> Marrickville Oval is identified as the only flood detention system in the LGA noted as requiring a Dam Safety Emergency Plan (DSEP).

> No evacuation centres are identified to shelter evacuated residents. The primary advice to evacuated residents is to stay with friends or relatives, or else go to the nearest accessible evacuation centre, to be identified by the SES incident controller.

These local features have been discussed in this FRMS further within critical infrastructure and vulnerable development discussion in **Section 7.5**.

7.2.2 Regional EMPLAN and DISPLAN

Due to the changes in procedures in 2012, Regional Emergency Management Plans (EMPLANs) are being developed to supersede the previous Regional Disaster Plans (DISPLANs). The objective of both documents is to outline emergency management details at a regional level for all forms of emergency, not just flooding. Regional EMPLANs across the state are still under development, including the *South West Metropolitan Emergency Management Plan*, and until these documents are passed and available the regional DISPLANs remain in place.

Therefore the relevant regional plan for Marrickville Valley is the *South West Metropolitan Emergency Management District Disaster Plan* (2012). This regional document is supported by the *New South Wales State Emergency Management Plan* (EMPLAN) (2012) (see **Section 7.2.3** for further details).

The South West Metropolitan DISPLAN notes the following for the area:

> Major dams, weirs and rivers for the region, with the only major waterway close to Marrickville Valley being the Cooks River;
> Major roads in the area are listed and include New Canterbury Road and Victoria Road in the vicinity of Marrickville Valley;
> The plan notes rail lines through the district with almost all passing through Marrickville Valley. Major rail stations are noted as well, with Sydenham station included in the list however Marrickville is excluded.
> The South West Metropolitan Emergency Management District has eight (8) Major Hazard Facilities located within the district which are not identified within the publically available plan; and
> The plan notes regional and local evacuation centres which are not identified within the publically available plan.

7.2.3 State EMPLAN

The State Emergency Management Plan (EMPLAN) describes the New South Wales approach to emergency management, the governance and coordination arrangements and roles and responsibilities of agencies. The State EMPLAN was developed with a comprehensive approach to emergency management, and considers aspects of prevention, preparation, response and recovery with the aim of reducing the impacts of emergencies on communities in NSW.

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

> Relevant legislation for emergency management in NSW;
> The planning and policy framework including the State subplans and supporting plans;
> The roles and responsibilities of the various stakeholders in the emergency management process;
> State-wide emergency prevention, preparation, response and recovery procedures; and,
> State significant control and co-ordination centres.

7.3 Emergency Response Guideline for Flash Flooding

While the preferred method of emergency response throughout NSW is for evacuation to be assisted and directed by the SES, there are certain emergency situations where there is limited time available for SES to prepare and facilitate as preferred. One such example is flash flooding where the rate of rise of floodwaters is extremely fast and the ability for SES to co-ordinate a regional evacuation strategy is not possible. Although NSW SES do not currently have guidance, in 2013 the Australian Fire and Emergency Service Authorities Council (AFAC) released the *Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events*. This guideline for flash flood events provides a useful insight into the position of the national emergency services authorities' council, of which NSW SES is a member.

The guideline reflects a consensus on best practice for managing flash flooding, focussing on risk to life. The AFAC define flash flooding as:

> *Flash flooding may be defined as flooding that occurs within 6 hours or less of the flood-producing rainfall within the affected catchment. Flash flood environments are characterized by the rapid onset of flooding from when rainfall begins (often within tens of minutes to a few hours) and by rapid rates of rise and by high flow velocity.*

The discussion of flood timing for the Marrickville Valley (**Section 5.3**) shows the entire floodplain is flash flooding based on the above definition, making this guideline relevant to the catchment. The guideline provides the following comments relating to appropriate emergency response in relation to flash flooding:

> The safest place to be in a flash flood is well away from the affected area. Accordingly, pre-event planning for flash floods should commence with an assumption that evacuation is the most effective strategy, provided evacuation can be safely implemented;

> Evacuation too late may be worse than not evacuating at all because of the dangers inherent in moving through flood waters. The timescale at which flash floods occur may limit the feasibility of evacuation as a response measure;

> A structurally suitable building means a building which is strong enough to withstand lateral flood flow, buoyancy, and suction effects and debris impact load;

> In the absence of a more detailed engineering-based code the following observations can be made regarding structural suitability for shelter-in-place buildings:

- Single storey slab-on-ground dwellings, and relocatable homes and caravans are unlikely to be suitable;
- Reinforced concrete or steel-framed multi-level buildings are more likely to be suitable; and,
- Ideally the building should have sufficient area of habitable floor that will be flood free in a Probable Maximum Flood (PMF) event to accommodate the likely number of occupants (it should be noted that approval from the Minister of Environment will be required for planning controls that allow shelter in place refuges for levels above the flood planning levels);

> The pre-incident planning of evacuation must include operational contingency plans for the rescue of individuals who do not evacuate in a timely manner;

> Due to the nature of flash flood catchments, flash flood warning systems based on detection of rainfall or water level generally yield short lead times (less than 30 minutes) and as a result provide limited prospects for using such systems to trigger planned and effective evacuation;

> The dangers to be considered in relation to evacuation include evacuees being overwhelmed by floodwaters, and exposure to adverse weather such as lightning, hail, heavy rain, strong winds, flying debris, or falling trees and power lines;

> The dangers to be considered for shelter-in-place include risks resulting from:

- Their own decision making (drowning if they change their mind);
- Their mobility (not being able to reach the highest part of the building);
- Their personal safety within the building (fire and accident);
- Their health while isolated (pre-existing condition or sudden onset); and

> For these reasons, remaining in buildings likely to be affected by flash flooding is not low risk and should never be a default strategy for pre-incident planning. Where the available warning time and resources permit, evacuation should be the primary response strategy.

7.4 Emergency Response Design Event

Emergency response can be designed to cater for a range of flood events, from the more frequent flood events such as the 20% AEP event, through to the less frequent flood events up to the PMF Event. The more likely a flood event, the less likely it is to cause harm to people or property as its extent and hazard is less than rare events.

To determine the cumulative risk at any given location accounting for all flood events it is necessary to adopt a single design event upon which to derive emergency response provisions. The NSW Government's *Floodplain Development Manual* (2005) states the following:

> *"Response planning for the consequences of the PMF provides for effective management of smaller events, particularly those rarer than the flood event selected as the basis of the Flood Planning Level (FPL). For example, where 1% AEP flood is used as the basis for minimum floor levels or protection from a levee, a 0.5% AEP flood event will probably overwhelm these measures. This event, whilst smaller, but significantly more likely than the PMF, will have major consequences to people, property, and infrastructure and needs to be accounted for in emergency response planning."*
>
> *"An assessment of the full range of events therefore provides key information for flood response studies".*
>
> *"It is critical that relevant information on evacuation is provided on events up to the PMF".*

Whilst it is important to consider all available information of flood behaviour for a range of historical and modelled events when developing emergency response arrangements, the PMF has been adopted in this study for the purposes of emergency response assessments. This is an envelope approach as the risk associated with all flood events is encompassed within the consideration of the Probable Maximum Flood.

It is also noted that the Flood Planning Level is based on the 1% AEP event so the most significant risk to life and property is likely to occur in events greater than this. This supports the use of a large event such as the PMF for emergency response assessments.

7.5 Critical Infrastructure and Vulnerable Developments

In the event of flooding, public infrastructure can become critical in consideration of flood risk for the following reasons:

- **Vulnerable development** relates to the increased risk of loss of life to vulnerable people including children, the elderly and disabled in most of these land use types. These demographics have a significantly greater risk to life when exposed to flood hazard. In addition there is increased risk to life resulting from periods of isolation from medical emergency services due to pre-existing health conditions. Mobility of the related demographics is also compromised which will impede the effectiveness of both emergency response types. Included in these development types is:
  - Schools;
  - Preschools;
  - Childcare centres;
  - Aged care facilities;
  - Retirement villages;
  - Medical Centres.
- **Critical Infrastructure** are considered critical during flooding if the infrastructure is relied upon for emergency management on a regional scale or pose a significant hazard to surrounding areas, these include:
  - Hospitals;
  - Sewage facilities;
  - Sydney Water Stormwater Pumps (see Section 3.6 for further details);
  - Electricity substations;
  - Emergency services such as ambulance stations, fire stations, and police stations;
  - NSW SES facilities.

The vulnerable developments and critical infrastructure within the Marrickville Valley study area have been mapped in **Figure 7-1**. A summary of the number of critical and vulnerable sites within the Marrickville Valley Study Area (excluding East Channel East catchment) has been summarised in **Table 7-1**.

The assessment of the critical and vulnerable developments include:

- If a portion of the vulnerable development site or the critical infrastructure is affected by the 1% AEP or PMF event;
- For vulnerable developments it has been assessed if they do not have flood free access to the nearest hospital, Royal Prince Alfred. Further discussion of evacuation routes is included in **Section 7.7**. The significance of this for vulnerable developments is that medical emergencies are more likely for these development types so access to medical emergency services is important for these development types.

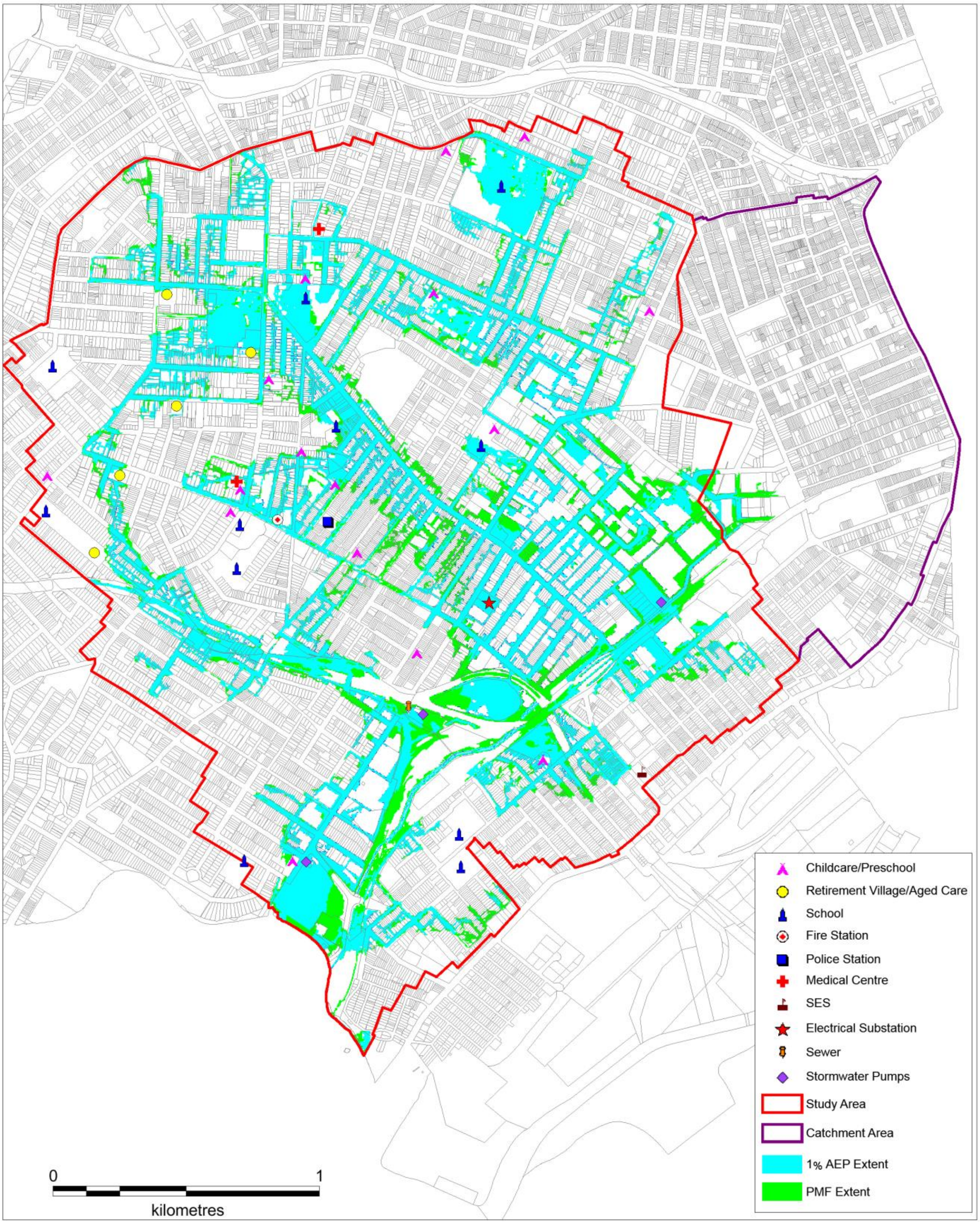


Figure 7-1 **Critical Infrastructure and Vulnerable Land Uses**

Table 7-1 Summary of Critical Infrastructure and Vulnerable Land Uses

Land Use	Number in Study Area	Number with 1% AEP Affectation	Number with PMF Affectation	Number without Access to RPA Hospital
Vulnerable Developments				
School	11	4	4	6
Preschool/ Childcare Centre	16	7	8	11
Retirement Village/ Aged Care Facility	5	1	2	4
Medical Centre	2	1	1	2
Critical Infrastructure				
Sewage Facilities	1	1	1	NA
Stormwater Pumps	3	3	3	
Electrical Substation	1	1	1	
Fire Station	1	1	1	
Police Station	1	0	0	
SES Facility	1	0	0	
Significant Dam Structure (Marrickville Oval)*	1	1	1	

*As identified within the *Marrickville Flood Emergency Sub Plan* (SES, 2015)

7.5.2 Emergency Coordination of Vulnerable Developments

In the event of flooding the *Marrickville Flood Emergency Sub Plan* (SES, 2015) outlines the response to be undertaken for childcare centres, preschools and schools:

> Childcare centres and preschools are to be contacted by the NSW SES and when notified the administrators of the sites should liaise with NSW SES and arrange for early release of children if possible, otherwise to assist with evacuation when required.

> For primary schools and high schools evacuation will be coordinated by school administration offices if they are not already closed at the time of flooding. In addition, the Plan notes if there is sufficient time SES will discuss with school administration the temporary closure of schools prior to flooding.

As discussed further in **Section 7.8**, the flash flooding nature of Marrickville Valley will make it difficult for SES to coordinate the evacuation of these vulnerable sites within the time available from the onset of rainfall.

It is therefore recommended that individual flood response plans are developed for the vulnerable developments that are affected by the 1% flood event.

7.6 Evacuation Centres

As mentioned in **Section 7.2.1**, there are no SES evacuation centres identified within the *Marrickville Flood Emergency Sub Plan* (SES, 2015), with the responsibility of selecting these sites left to the incident controller. In order to assist with this process, a number of potential sites within the Marrickville Valley have been identified in **Table 7-2** that may be suitable to function as evacuation centres during and following a flood event. The four locations are also shown in **Figure 7-2**.

The suitability of these centres has been defined by the following:

> Flood free in all flood events up to and including the PMF event;

> Accessible via flood free evacuation routes for the majority of the catchment;

> Publically owned space or a community space such as town halls;

> Accessible by Council at all times including after hours and at weekends; and,

> Site with sufficient indoor space to accommodate a large number of evacuees.

Table 7-2 Potential Evacuation Centres for Marrickville Valley

ID	Name of Venue	Address
1	Petersham Town Hall	Crystal St, Petersham 2049
2	Marrickville Town Hall	Marrickville Rd, Marrickville 2204
3	Annette Kellerman Aquatic Centre	Enmore Park, Black St, Marrickville 2204
4	St Peters Town Hall	Unwins Bridge Road, Sydenham 2044

7.7 Evacuation Routes

One of the key advantages of flood evacuation is intended to be the removal of flood isolation. Flood isolation can be considered in a number of ways:

> Isolation from medical services: In the event of a medical emergency; a pre-existing condition, injury, or sudden onset event such as heart attack, medical services may need to be accessed;

> Isolation from supplies: Isolation from drinking water, food, amenities, and communication lines.

It is assumed that for flash flooding (less than 6 hours) that isolation from medical services rather than isolation from supplies such as food and water poses a greater risk to life. Therefore if flood free land does not have access to a nearby hospital then the land may effectively be considered isolated.

Assessment of flood free land up to the PMF event in the Marrickville Valley catchment has been undertaken to determine which areas have road access to a public hospital (as private hospitals may not be able to assist all evacuees), which in this case the closest available hospital is Royal Prince Alfred (RPA) Hospital. Medical centres are assumed to be unsuitable to rely on as most are not open 24/7 and they are unlikely to have the medical emergency capabilities available at hospitals.

Royal Prince Alfred Hospital is located north-east of the Marrickville Valley in the suburb of Camperdown adjacent to the University of Sydney campus.

7.7.1 Modes of Evacuation

The *Marrickville Flood Emergency Sub Plan* (SES, 2015) under Section 3.18.23 notes the following with regards to modes of evacuation:

> *'The most desirable mode of evacuation is via road using private transport. This may be supplemented by buses for car-less people. However, other means of evacuation may also be available and as necessary (for example foot, rail, and air)'.*

Therefore in this analysis of evacuation routes only access through public roads for vehicles has been assessed, with rail, air, and boat options not taken into consideration.

7.7.2 Regional and Local Evacuation Routes

The *Marrickville Flood Emergency Sub Plan* (SES, 2015) under Section 3.18.25 notes the following with regards to evacuation routes:

> *'Evacuees will move under local traffic arrangements from the relevant communities via managed evacuation routes, and continue along the suburban / regional/ rural road network to allocated evacuation centres'.*

As discussed above the focus of this assessment is access to the RPA Hospital which is accessed by a 1.2 kilometre stretch of road along King Street and Missenden Road. This route along King Street acts as a ridgeline that separates the Alexandra Canal catchment to the east and Johnstons Creek catchment to the west. As the road is the upstream boundary of two stormwater catchments it is assumed to be flood free.

The east and west side of the Marrickville Valley can both access King Street via one of two flood free regional evacuation routes that approximately follow the ridgelines surrounding the Valley:

- On the eastern side of the Valley the Princes Highway is a major road which converges with King Street to the north. The Princes Highway is an ideal regional evacuation route due to its alignment with the catchment ridgeline which means it is predominantly flood free. In addition, it is one of the major roads in the area and is expected to have sufficient capacity for increased levels of traffic during evacuation. Importantly the Princes Highway can be accessed by the majority of the eastern portion of the Marrickville Valley via local roads directed eastwards.
- Along the western and northern side of the Valley the ridgeline generally follows a continuous major road network including New Canterbury Road, Stanmore Road and Enmore Road. The only detour from this major road is for a length of Stanmore Road that is marginally flood affected, where the proposed evacuation route diverts north to Cavendish Road before converging back with Stanmore Road via Cambridge Street.

The majority of the Marrickville Valley can access these regional evacuation routes via a range of local road routes throughout the Valley which are predominantly flood free. The regional and local evacuation routes for the Marrickville Valley are shown in **Figure 7-2**.

7.7.2.1 Suitability of Evacuation Routes

There is one proposed crossing, Surrey Street, Marrickville which has significant flood affectation, with up to 1.0 metres peak flood depths for the 1% AEP and PMF events. These flood depths represent a high hazard and this crossing cannot be traversed at the peak of either design storm. This crossing is the only evacuation route available for a community in Marrickville surrounded by Eastern Channel to the north and Sydenham Road to the south. The location of the Surrey Street crossing and the potentially isolated community is shown in **Figure 7-2**.

As discussed in **Section 5.3**, the duration of flooding at this Surrey Street crossing is likely to be less than 3.5 hours even in the PMF event as it is located in the upper catchment. Therefore the risk to life associated with the isolation of this Marrickville community during this short time of isolation is assumed to be minor. Nonetheless it is recommended that the upgrade of Surrey Street be considered to make it flood free meaning this community has no risk of isolation. Until such time that these works are undertaken, SES should be made aware of the road flooding issues in this location and the properties affected.

In addition there are five locations that have been identified with marginal affectation of the road network in the PMF event, likely to be not more than surface flows or ponding in roadside kerbs. These minor affected locations along nominated routes have been identified within **Figure 7-2**. These roads are considered suitable evacuation routes as the hazard for driving through these locations is assumed to be negligible due a combination of the following:

- The flood affectation does not exceed 0.3 metres depth for a significant portion of the road reserve, ponding is often confined to the kerbs meaning the crossings can be traversed at some section of road;
- Overland flow affected roads such as these were found to be affected for less than 1 hour duration in the PMF event (see **Section 7.9.2**). Even if these roads become inundated it will be for a short duration.

It is noted that the Alexandra Canal Draft Flood Study (WMAwater, 2017) has identified some localised flooding along Princes Highway at the intersection of Railway Rd and north of Campbell St. For the 1% AEP event the depth of flooding is up to 0.3m. It is recommended that these locations are considered for flood mitigation as part of the future Alexandra Canal FRMS&P.

7.7.3 <u>Flood Evacuation for Marrickville Industrial Area</u>

The area with the most concern in relation to evacuation is the Marrickville Industrial Area. As discussed further within **Section 7.9.2**, this location is significantly inundated within 30 minutes from the onset of rainfall in both the 1% AEP and PMF events. In addition the floodplain is relatively wider at this location than the majority of the floodplain, coupled with the fast rate of rise it is likely that occupants of the floodplain will not be able to evacuate the floodplain prior to flooding occurring. Therefore evacuation by either vehicle or on foot from this area will be incredibly difficult for affected occupants. SES and emergency access to the Marrickville Industrial Area during flooding will also be nearly impossible as it is the area of the floodplain with the most significant flood depths. Due to these problems for the Marrickville Industrial Area it is recommended that alternatives be investigated such as special shelter-in-place provisions or the methods to improve the evacuation timeline as discussed further in **Section 7.9.5**.

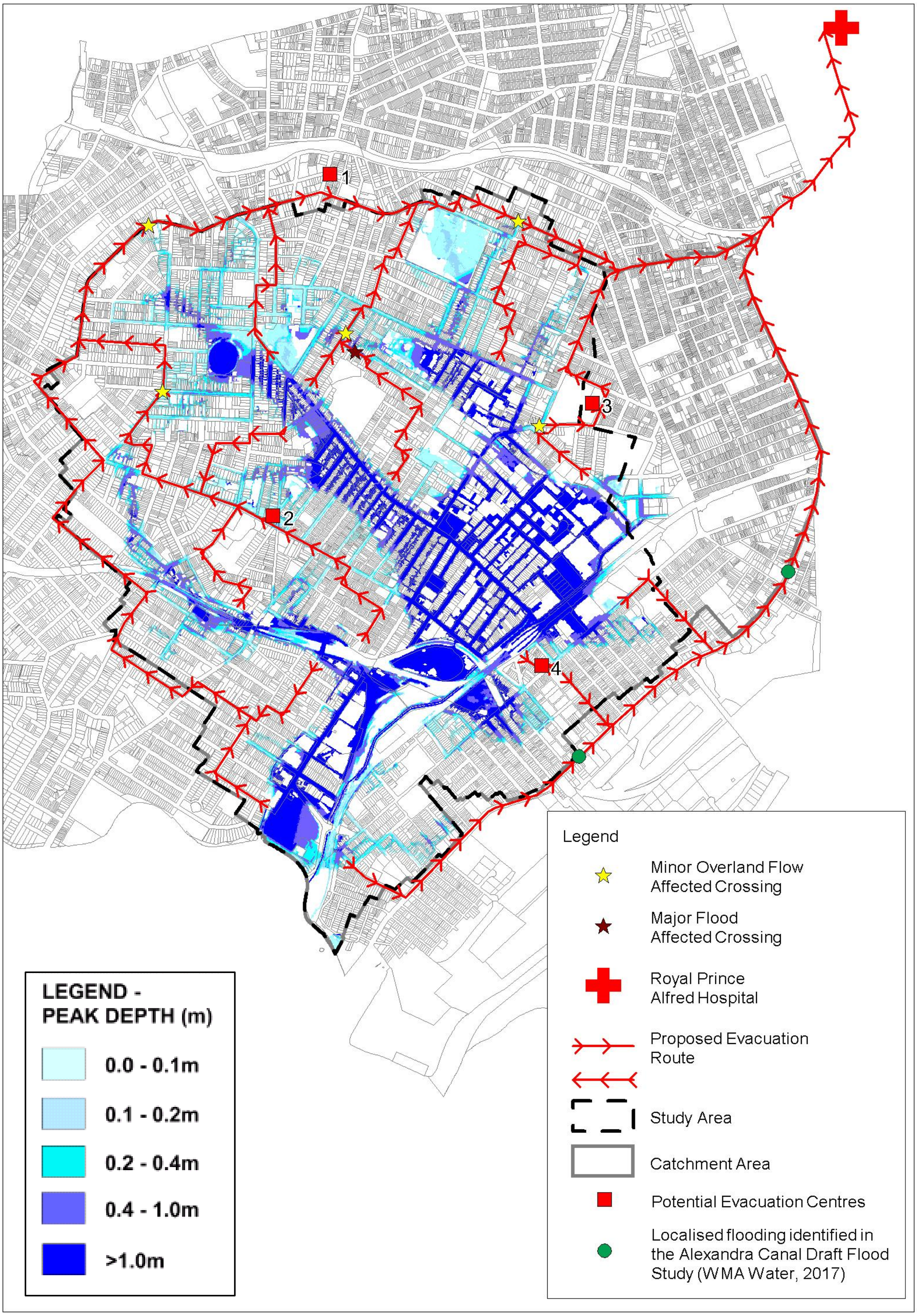


Figure 7-2 **Evacuation Routes to RPA Hospital and Potential Evacuation Centres**

7.8 Flood Warning Systems

The *Marrickville Flood Emergency Sub Plan* (SES, 2015) under Section 1.5.6 identifies as a key responsibility of both the NSW SES and Inner West Council to coordinate the development of warning services for catchments prone to flash flooding. There are two components to a flood warning system:

> Monitoring of weather and flood conditions to decide when emergency response is required;

> Disseminating this information to residents so that evacuation may commence.

These two components of a flood warning system are discussed for the Marrickville Valley in the following sections.

7.8.1 Forecast and Actual Rainfall Monitoring Phase

The *Marrickville Flood Emergency Sub Plan* (SES, 2015) under Section 3.3.2 notes that operations will begin upon receipt of one of the following:

> A number of Bureau of Meteorology warnings which are based on rainfall and flood forecasting. These flood warning options are discussed further in **Section 7.8.1.1**;

> Dam failure alert (applicable for Marrickville Oval) which is to have a Dam Safety Emergency Plan (DSEP) prepared in the future;

> When evidence leads to an expectation of flooding within the Council area. Section 3.8.4 of the Plan identifies active reconnaissance of local areas by SES team members which includes inspecting the Carrington Road area of Marrickville Valley.

The second and third forms of monitoring are based on observed flooding in the Marrickville Valley. As discussed in **Section 7.9.2**, this form of monitoring is unlikely to be suitable for Marrickville Valley as the observation of flooding for this catchment means that it is already too late to evacuate the most critical locations.

7.8.1.1 Flood Warnings Issued by BoM

Marrickville Valley floodplain is affected by flash flooding, and as such it is difficult to provide any warning in advance of floods. However, for flash flood catchments the BoM provides general warning services, including:

> Flood Watches – early appreciation of a developing weather system that could lead to flooding;

> Flood Warnings – water level readings from gauges;

> Severe Weather Warnings; and

> Severe Thunderstorm Warnings.

As part of its Severe Weather Warning Service, the Bureau also provides warnings for severe weather that may cause flash flooding. Where possible, the BoM will issue the severe weather warning to the Sydney Southern Regional SES headquarters as stated within the Local Flood Plan. Where that alert is relevant to the Marrickville Valley floodplain, the SES Regional Command will pass the BoM's warning on to the Local Command.

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.

While the general BoM warnings above can predict with relative confidence a potential flood event hours in advance, the level of confidence required to trigger an evacuation needs to be almost certain. The reason for this is if evacuation is triggered based on flood forecasting and no flooding occurs then community support for any flood evacuation will diminish and response to future evacuation messages will be minimal.

For catchments such as Marrickville Valley which need to rely on flood and rainfall forecasting, consideration should be given to developing a more specific forecasting tool that can provide greater certainty of the likelihood of flooding than the general BoM warnings listed above. This sort of tool would likely be based on rainfall gauge data rather than flow or water level data. However, it is noted that some portions of the floodplain can experience peak flood level in less than an hour from when the rainfall falls.

Such a system could be developed with the assistance of the BoM or other relevant authorities such as the NSW SES, Manly Hydraulics Lab (MHL) (a business unit of NSW Public Works), or Australian Rainfall and Runoff (AR&R) which have flood forecasting tools.

7.8.2 Dissemination of Flood Warning

Once an evacuation order has been decided upon by the SES incident controller for the area, there are a number of ways that the evacuation order can be disseminated to residents as identified within Section 3.18.16 of the Local Flood Plan:

- Doorknocking by emergency services personnel;
- Radio and television stations;
- Telephone based systems (including Emergency Alert);
- Internet and social media; and
- Public address systems (fixed or mobile).

The following section discusses the advantages and disadvantages of each of the above listed methods.

7.8.2.1 Doorknocking by Volunteers

This is the traditional method for distribution of evacuation orders for the SES, and involves a significant amount of SES staff participation and resources to issue the evacuation order. This is a major disadvantage of this method as at the time of a flood event it is likely that SES staff will be required assisting with other forms of emergency assistance such as fallen trees, wind damage to properties etc.

In addition, this method is very time consuming and the timeline assessment in **Section 7.9** shows that it would take as a minimum 2.5 hours to evacuate every property within the Marrickville Valley, meaning it is unlikely to be a feasible method of dissemination for the Marrickville Valley.

7.8.2.2 Radio and Television Stations

This method involves emergency messages being broadcast on commercial stations for both radio and television. This will require the cooperation of the various stations and pre-planning so that the evacuation message is ready to be broadcast when required.

The Standard Emergency Warning Signal (SEWS) is a nationally adopted distinctive sound which may be broadcast over radio or television immediately before an urgent public safety message. The SEWS is designed to attract the attention of the public to an urgent safety message. The NSW Government advises that

> *"Following the signal there will be a message, pay immediate attention, listen to the announcement, and follow any instructions given. As part of a coordinated national emergency plan, an audio signal has been adopted to alert the community to an urgent safety message relating to an identified emergency such as a flood, fire, or earthquake aftershocks."*

While this is an effective way to disseminate warnings to the public, the key disadvantage of this approach is that not all residents will have a radio or television on at the time of flooding, particularly if the flooding occurs at night, and the warnings issued are likely to be periodical and not constant. In addition, this method takes time to prepare and issue and it is unlikely to be a feasible method of dissemination for the Marrickville Valley.

7.8.2.3 Telephone Based Alerts

There may be an opportunity to provide improved flood warning for residents within the floodplain via SMS alerts or automated call alerts to landlines of pending storm events. The Australian Emergency Alert System could be used by the SES to disseminate telephone based flood warnings. This may be the most suitable mechanism to provide flood warnings in the Marrickville Valley catchment because, in addition to calling landlines in the affected area, it also captures mobile phone users:

- With a registered service address that falls within the area of interest; and
- Whose last known location for their handset at the time of emergency was in the area of interest.

In this way, the Alert System captures people visiting or travelling in the local area as well as residents. The NSW Government also describes the Emergency Alert telephone warning system as

> *"…one of a number of ways we can warn the community of NSW about an emergency threat or emergency situation. If a decision is made to issue a warning via telephone during an emergency, an Emergency Alert would be sent to landline telephones based on the location of the handset, and to mobile phones based on the billing address within an area defined as under threat or affected by the situation. Emergency Alerts will only be used as a complement to other existing warning mechanisms such as door-knocking, broadcasts via local media outlets such as television, radio and newspapers and public address systems."*

The disadvantage of this system is that it is reliant on all residents having a mobile phone or home phone switched on at the time of flooding, which should be the case for the vast majority of resident, but presumably not all. Mobile phones in particular are likely to be less effective at night when owners may turn them to off or silent.

7.8.2.4 Internet and Social Media

The increasing trend of accessing social media via computers and smartphones makes social media an effective method of disseminating information during flood events. Council would have the opportunity of directly contacting members of the community who are connected to Council's social media services. Such an alert would be sent to all members and not just those in the affected area. This is not necessarily a disadvantage, as it will also help in informing the wider community of the flood event, and discouraging people from entering the area for the duration of the flood event.

The advantage of social media is that warning and alerts issued by Council can be shared. This means that:

- Not all residents would be required to be connected via social media directly to Council, as they would also receive the message as it gets shared amongst their wider network; and,
- People would be given multiple chances to receive the message, as it would be shared and / or discussed multiple times amongst their wider network.

An alert via social media is likely to be more effective amongst a younger demographic who are more active across the social media platforms, compared with older residents.

Similar to TV and telephone based alerts, it requires people to both be a participating member of the media platform, and to be connected at the time of the warning. Messages issued at night are likely to be less effective as a result of people turning off their phones and computers. In addition this system requires access to internet and power. It should be noted that in the 2007 Newcastle flood, internet based warning system failed due to loss of power supply.

7.8.2.5 Public Address Systems

This approach involves the broadcasting of evacuation orders over a large area by an audible message from a Public Address system. This method effectively distributes evacuation orders in a way that should be able to reach almost all residents at risk as it is not reliant on residents incidentally having their phone, television, or radio switched on.

For the Marrickville Valley a public address system could be hindered by the extent of the floodplain. For example the length of floodplain from Marrickville Oval in the upper catchment to Mackey Park downstream is approximately 3.5 km with many affected neighbourhoods in the Valley. Therefore it is likely to be difficult to establish a PA system that can deliver an evacuation message to the entire Marrickville Valley floodplain.

Only Henson Park has a Public Address system installed, and it is not linked to telemetry, nor is it able to be activated remotely. As such, it would require a Council officer to physically attend the building during a flood event, which is not practical nor safe.

The Public Address system may be used if a sporting event is underway during a flood event, or the building is staffed, but it cannot be relied upon as a guaranteed emergency notification method.

Consequently, the use of PA systems is not considered a feasible option for the study area.

7.9 Evacuation Timeline

7.9.1 Background

The *NSW SES Timeline Evacuation Model* has been the de facto standard for evacuation calculations in NSW since it was first developed for evacuation planning in the Hawkesbury Nepean Valley. Though the guideline has not yet been released, the paper *Technical Guideline for SES Timeline Evacuation Model* was prepared by Molino S. et al in 2013 briefing the industry on the application of the guideline.

The timeline assessment of evacuation potential relates to the regional evacuation of floodplains through doorknocking by SES volunteers through to the evacuation of all occupants for the region.

At the centre of the timeline methodology is the following concept:

Surplus Time = Time Available – Time Required

If surplus time is positive then evacuation of all occupants is feasible, while a negative value implies evacuation of all occupants is not likely to be able to be achieved. The determination of the two times; ‘Time Available’, and ‘Time Required’ is summarised in the following sections.

7.9.2 Flood Depths & Timing

To inform this review of flood timing, water depth time series have been extracted at seven locations throughout the study area. The locations of the assessment points has been selected to provide hydrographs for locations in the upper and lower catchment, and for areas in floodway, flood storage and flood fringe areas.

The locations of the seven assessment points are shown in **Figure 7-3**. A comparison of surface and peak flood levels for the 1% AEP and PMF event for each location are summarised in **Table 7-3**. The surface levels show that there are significant changes in elevation from the upper catchment to the low lying areas of the Marrickville Valley.

The PMF flood depths can be up to 1.9m greater than in the 1% AEP. The peak depth ranges shown in **Figure 7-3** show that, whilst greater depths are generally in the lower catchment, peak PMF depths exceed 1 metre in middle and upper catchment areas too.

Table 7-3 Summary of Water Level Inspection Points

ID	Location	Surface Elevation (m AHD)	Peak 1% AEP Level (m AHD)	Peak PMF Level (m AHD)
1	Mackey Park (Carrington Road)	1.01	2.2	3.1
2	Council Depot (Unwins Bridge Road)	3.9	4.2	4.8
3	Marrickville Industrial Area (Sydenham Rd)	2.48	3.0	4.9
4	Marrickville Station (Illawarra Road)	9.47	9.8	10.4
5	Marrickville Metro (Edinburgh Road)	4.38	4.9	5.0
6	Marrickville Oval (Livingstone Road)	12.77	13.5	14.3
7	Addison Road near Park Road	23.8	23.91	24.1

The water depth time series for the seven locations has been extracted for two events; 1% AEP 2 hour and PMF 60 minute, shown in **Figure 7-4** and **Figure 7-5** respectively. These are the critical durations for these design events. Note that the 1% AEP model was simulated for a period of 6 hours, while the PMF event was simulated for a period of 3.5 hours from the onset of rainfall with both figures reflecting the total time period available for the respective storm simulations.

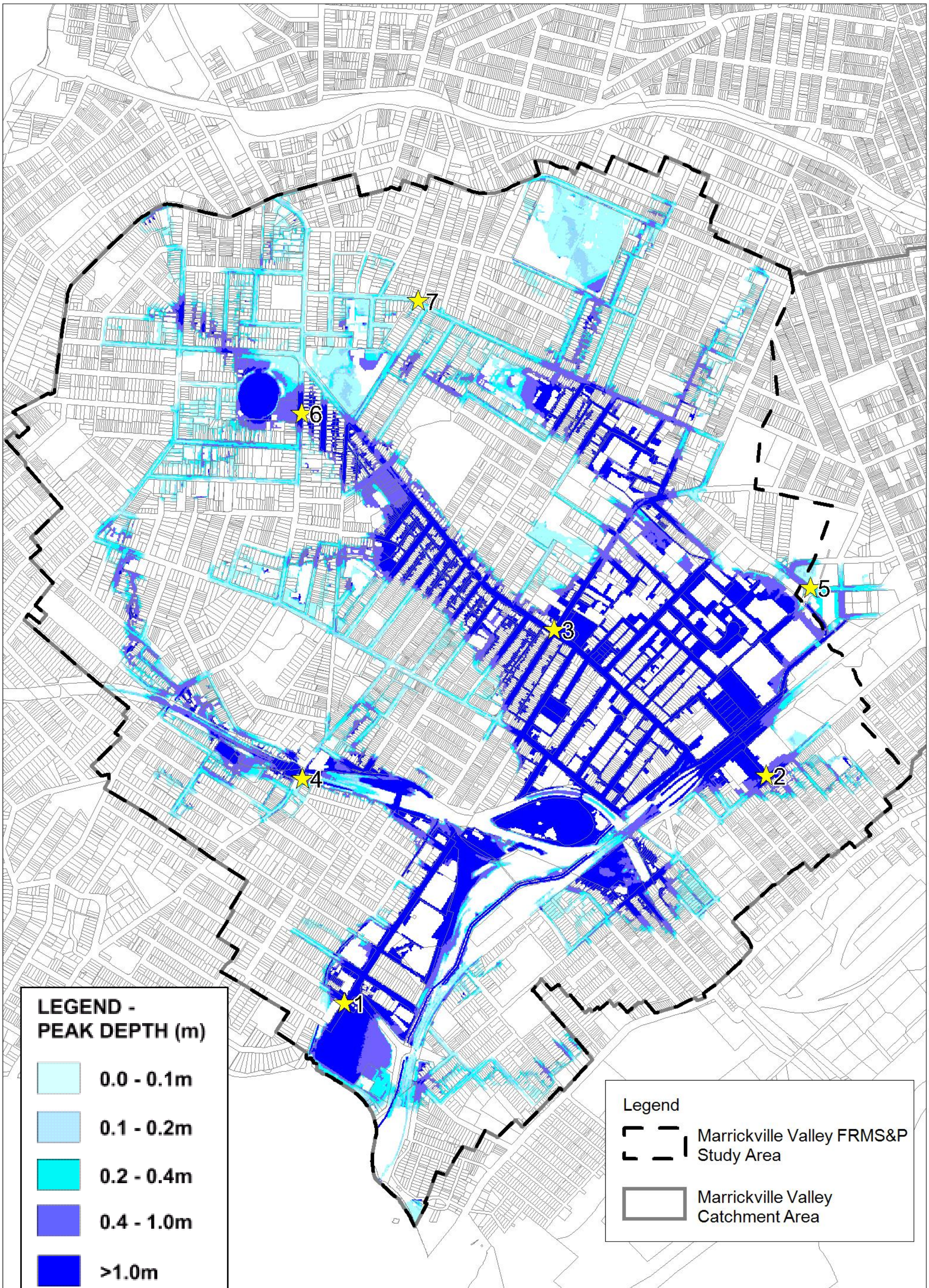


Figure 7-3 **Location of Points for Depth Time Series Assessment with PMF Peak Depth Results**

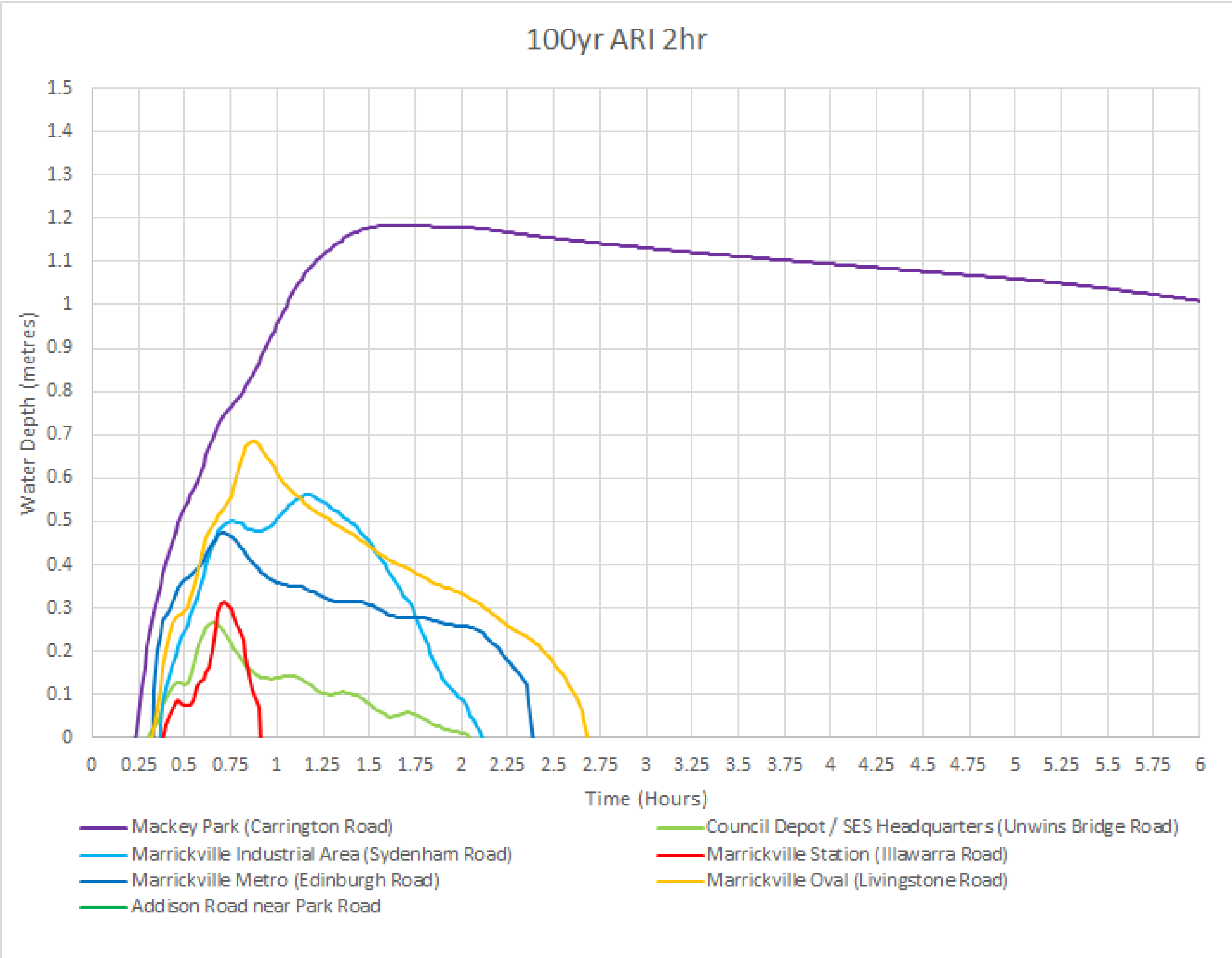


Figure 7-4 **Flood Depth Time Series for Marrickville Valley – 1% AEP 2 hour**

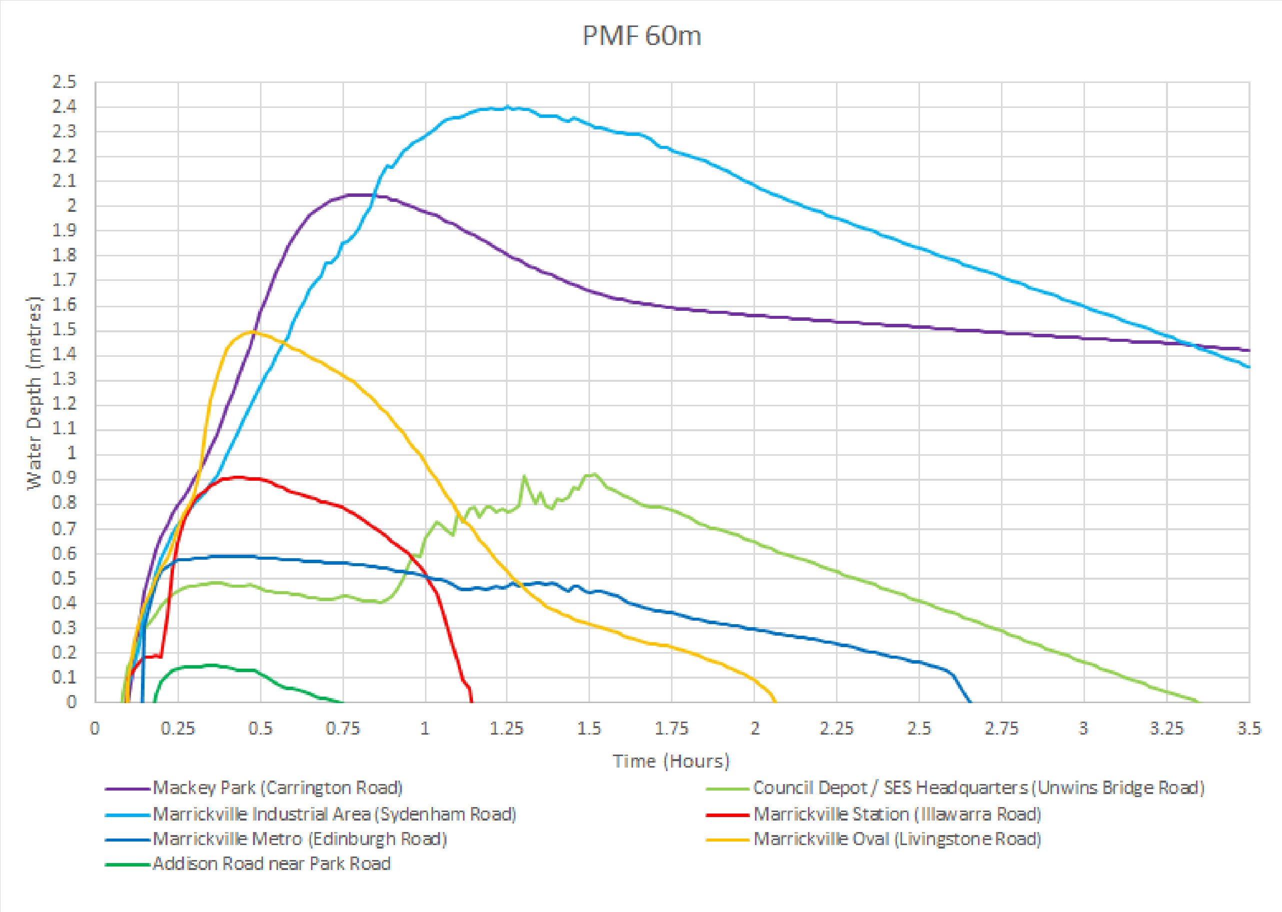


Figure 7-5 **Flood Depth Time Series for Marrickville Valley – PMF 60 minutes**

A summary of the flood timings based on these hydrographs are summarised in **Table 7-4**.

For the 1% AEP, five of the seven locations experience flood depths greater than 0.3. The time to depths reaching 0.3m is 20 minutes to 40 minutes across the affected sites. The Council Depot and Addison Road sites did not experience flooding above 0.3m. The duration of flooding above 0.3m varied widely across the sites, ranging from 0.1 hours at Marrickville Station to 5.5 hours at Mackey Park.

In the PMF, only Addison Road had flood depths below 0.3m; all other sites experienced peak flood depths above 0.3m. The time to reach 0.3m was significantly shorter in the PMF, with all affected sites having less than 15 minutes. Of these, the majority had less than 10 minutes.

The duration of flooding was also longer in the PMF. Both Mackey Park and the Marrickville Industrial Area recorded times of over 3.5 hours, which was the duration of the model run. Other sites had inundation times ranging from 0.9 hours to 2.6 hours.

Table 7-4 Summary of Flood Timings

ID	Location	Time to reach 0.3m depth (min)		Duration of >0.3m depth (hr)	
		1% AEP	PMF	1% AEP	PMF
1	Mackey Park (Carrington Road)	21	8	5.5	> 3.5
2	Council Depot (Unwins Bridge Road)	0	9	-	2.6
3	Marrickville Industrial Area (Sydenham Rd)	33	9	1.2	> 3.5
4	Marrickville Station (Illawarra Road)	42	13	0.1	0.9
5	Marrickville Metro (Edinburgh Road)	26	9	1.1	1.9
6	Marrickville Oval (Livingstone Road)	31	8	1.6	1.4

ID	Location	Time to reach 0.3m depth (min)		Duration of >0.3m depth (hr)	
		1% AEP	PMF	1% AEP	PMF
7	Addison Road near Park Road	0	0	-	-

Based on the flood depth series shown in **Figure 7-4** and **Figure 7-5**, discussion of rate of rise and duration of inundation is included in the sections below.

7.9.2.2 Rate of Rise

For both the 1% AEP and PMF critical events the rate of rise is considered extreme in the Marrickville Valley. In the 1% AEP event at all locations except for Mackey Park (Carrington Road) the peak of the flood is reached less than 1 hour after the onset of rainfall, while for the PMF event this occurs within 30 minutes of the onset of rainfall.

From the onset of rainfall for the PMF event within 15 minutes all locations have depths of flooding exceeding 0.5 metres which is considered unsafe to drive through. A recent research by *Water Research Laboratory (2016)*, has identified that small cars can become buoyant and be washed off roads in flows as shallow as 0.15 metres and large four wheel drive vehicles can be rendered unstable by flood water 0.45 metres high. Another recent study by *G.P.Smith (2015)* has identified that primary age children and the elderly can become unstable and lose their footing in flows as shallow as 0.5 metres.

The fast rate of rise aligns with the expected behaviour of a catchment such as the Marrickville Valley. As it is a relatively smaller catchment that is heavily urbanised the critical duration of flooding is relatively shorter and flash flooding is more likely as confirmed within the above analysis of model results.

7.9.2.3 Duration of Flooding

An advantage for flood emergency response within smaller catchments such as the Marrickville Valley is that the duration of flooding until floodwaters recede is typically significantly shorter than larger riverine catchments.

For both the 1% AEP and PMF events, two of the seven locations have extremely short flood durations with floodwaters receding approximately 1 hour after the onset of rainfall. This extremely short duration of inundation is due to the following at these two locations:

> Addison Road is located in the upper catchment with flooding on this portion of Addison Road being overland flow;

> Illawarra Road is mostly elevated above the adjoining major floodplain running through the railway line underneath the road, therefore the flooding of Illawarra Road is considered flood fringe.

Therefore based on this evidence overland flow and flood fringe areas across the Marrickville Valley are expected to have very short durations of flooding, even for the PMF event.

Most other locations also have relatively short duration flooding with floodwaters expected to recede less than 3.5 hours after the onset of rainfall for both the 1% AEP and PMF events. The only locations where the duration of flooding is expected to exceed 6 hours for both the 1% AEP and PMF events is Carrington Road near Mackey Park which is the downstream end of the catchment. This area is low lying with surface elevations along Carrington Road of 1.0m AHD, while also being at the downstream edge of the Marrickville Valley and subjected to tailwater flooding from the Cooks River. All of these factors result in a relatively longer duration of flooding being expected along Carrington Road downstream of the rail interchange.

For the PMF event these factors also contribute to long duration flooding upstream of the rail interchange with the low-lying Marrickville Industrial Area showing duration in excess of 6 hours for this extreme event, however, not for the 1% AEP event.

While it is difficult to confirm as the model simulation time was halted at 3.5 hours it is assumed that the duration of flooding at Carrington Road near Mackey Park has flooding duration of less than 24 hours, While the expected duration of flooding at these low-lying locations is expected to be longer than the rest of the

Marrickville Valley, sub-daily durations of isolation are relatively short when compared to large riverine catchments within NSW such as the Nepean River.

7.9.3 Time Available

The 'Time Available' is dependent on rate of rise of waters, meaning it varies for each evacuation scenario. From the flood timing assessment included above, the rate of rise is extreme for the entire Marrickville Valley with significant flooding occurring:

- In less than 15 minutes (0.25 hours) from the onset of rainfall for the PMF 60 minute event;
- In less than 30 minutes (0.5 hours) from the onset of rainfall for the 1% AEP 2 hour event.

Therefore there is very little time available from the onset of storm burst rainfall for evacuation to occur. In addition the volume of rainfall occurring is extreme in both a 1% AEP 2 hour storm (average rainfall intensity of 60 mm/hr) and PMF 60 minute storm (rainfall intensity over 300 mm/hr). Therefore it is unlikely that evacuating during the early stages of a design storm burst rainfall event will be safe as both vehicle safety and pedestrian safety is compromised under such heavy rainfall.

As a result the only form of flood evacuation trigger for Marrickville Valley that will provide sufficient available time to facilitate evacuation is flood forecasting methods as observed rainfall or flooding means that the opportunity to evacuate low-lying areas has already passed. Further discussion on available flood forecasting tools is discussed in **Section 7.8.1.1**.

7.9.4 Time Required for SES Assisted Evacuation

The SES evacuation timeline model uses the following equation to calculate 'Time Required' to evacuate residents by doorknocking by SES volunteers:

> *Time Required = Warning Acceptance Factor (WAF) + Warning Lag Time (WLT) + Travel Time (TT) + Travel Safety Factor (TSF)*

Where the following values are recommended in the guideline:

> Warning Acceptance Factor = 1 hour – accounts for the delay between occupants receiving the evacuation warning and acting upon it.
>
> Warning Lag Time = 1 hour – an allowance for the time taken by occupants to prepare for evacuation such as packing their belongings etc.
>
> Travel Time = Variable – the number of hours taken for the evacuation of all vehicles based on road capacity. NSW SES recommend a road lane capacity of 600 vehicles per hour. As there are many evacuation routes to flood free land across the Marrickville Valley floodplain travel time is assumed to be negligible (in the order of minutes, not hours)
>
> Travel Safety Factor = Variable – added to travel time to account for any delays along the evacuation route for example resulting from accidents, this value is a variable of Travel Time and also assumed to be negligible in the case of Marrickville Valley.

Note that time required is calculated from the time that SES are on site and ready to begin doorknocking. Before this time there is an additional phase of mobilisation of SES staff which is the time taken to coordinate and travel to residences to commence doorknocking. There is no data available on mobilisation time for local SES services. For the purposes of this analysis it is assumed that it will take half an hour to coordinate SES staff and mobilise them to the flood affected areas.

Based on the above contributors, the overall time required for evacuation of the Marrickville Valley floodplain is a minimum of 2.5 hours (2 hours for WAF and WLT and 0.5 hours for mobilisation). It should be noted that this is a low bound estimate, as various factors such as Travel Time, and Travel Safety Factor have been disregarded.

Therefore in relation to SES doorknocked evacuation for the Marrickville Valley floodplain, evacuation needs to be triggered at least 2.5 hours prior to a storm burst rainfall event occurring.

While the Bureau of Meteorology (BoM) provide various flood forecasting tools, it is assumed there are no forecasting tools currently available that can provide the requisite confidence to trigger an evacuation based on flood forecasting 2.5 hours in the future.

Therefore it is concluded that SES doorknocked evacuation is not a reliable emergency response in the Marrickville Valley catchment. While SES assisted evacuation may be suitable for more long duration rainfall events for the critical storm burst rainfall events which result in flash flooding this approach is not appropriate.

7.9.5 Improvements to the Evacuation Timeline

While the SES doorknocked evacuation is unlikely to be able to evacuate flood affected residents of the Marrickville Valley, a number of alternative approaches may be implemented to improve the evacuation timeline:

- Use of alternative flood warning systems: **Section 7.8** discusses alternatives to the SES doorknock approach to flood warning with radio and television warnings, PA systems, and telephone based approaches all providing potential reductions to the time required for evacuation compared to doorknocking.
- Self-managed evacuation;
- Improved flood awareness.

The second and third points listed above are discussed further in the following sections. The other alternative to improve the emergency timeline is to utilise shelter-in-place and not evacuation, with the suitability of this approach discussed further in **Section 7.10**.

7.9.5.1 Self-Managed Evacuation

Section 3.18.6 of the Local Flood Plan notes that an alternative to SES assisted evacuation is self-managed evacuation. This describes where people make their own decision to evacuate earlier and move to alternate accommodation, using their own transport.

Self-managed evacuation has a number of advantages:

- People can be evacuated far quicker than SES assisted evacuation as various factors in the evacuation timeline are reduced or removed completely such as accounting for time for SES to mobilise, and doorknocking time.
- Self-managed evacuation reduces the strain on SES resources as part of the floodplain will be evacuated without needing to be doorknocked or otherwise prompted, if residents organise their own accommodation then emergency shelters will have additional capacity. Also less coordination is required on the part of SES as the scale of the evacuation exercise is lessened by some people being self reliant.
- Traffic conditions during an evacuation procedure should be improved if some residents have evacuated themselves prior to the SES evacuation.

However, self-managed evacuation can also pose a risk if not conducted in an appropriate way. Residents could place themselves at higher risk for example if they evacuate to a location which is even more flood affected, drive through flood waters, or could increase traffic congestion if the wrong route is selected.

A way for Inner West Council to encourage and confirm the adequacy of any self-managed evacuation is through flood emergency response development controls. This could be through implementing requirements for new developments to develop flood emergency response plans particularly large scale development such as medium and high density residential.

Another alternative to improve self-managed evacuation could be through requiring site specific flood warning systems, however these systems typically rely on observed flooding which has been found to not be appropriate for Marrickville Valley. Further discussion of development controls relating to flood emergency response is included in **Section 8.6.2**.

7.9.5.2 Improved Flood Awareness

For the SES evacuation timeline model, two factors are expected to take one hour each in order for residents to evacuate; Warning Acceptance Factor and Warning Lag Time. These two factors both contribute to the poor outcome for the Marrickville Valley evacuation timeline, however both can feasibly be significantly reduced through improved flood awareness:

> Warning Acceptance Factor, accounts for the delay between occupants receiving the evacuation warning and acting upon it. If people are aware of the flood risk of the area that they live in, then it is reasonable to expect that they will acknowledge the seriousness of any flood warning, and perhaps begin evacuating immediately instead of one hour after receiving the warning.

> Warning Lag Time, an allowance for the time taken by occupants to prepare for evacuation such as packing their belongings etc. If residents are aware of the flash flooding nature of the catchment they are in, then they will know that they have very limited time to respond before flooding commences, leaving the majority of their belongings behind to ensure they evacuate as soon as possible for their own safety.

Based on the above considerations a comprehensive flood awareness program for the Marrickville Valley, educating residents of the seriousness of the flood risk and the flash flooding nature of the catchment could drastically improve the evacuation timeline. Currently the processes of residents in evacuation is expected to take on average 2 hours, however this could be reduced to as little as 15 minutes if residents are suitably aware of flood risk in the area.

7.10 Shelter-in-Place Potential

The implementation of appropriate shelter-in-place refuges to effectively reduce flood risk to life requires consideration of the following:

> Stability of shelter-in-place structure;

> The duration of flooding of the refuge area; and,

> The feasibility of flood free refuge area.

The potential for shelter-in-place to be implemented for the Marrickville Valley floodplain based on these three factors is investigated in the following sections.

The advantage of shelter-in-place is that people do not require as long to respond for this type of emergency response to be appropriate. As opposed to evacuation where people are likely to have to travel a significant distance to reach flood free land, for shelter-in-place people are likely only going to need to access a mezzanine level or first floor within the same building. Therefore the response is far more foolproof for flash flooding environments and can be suitable even at night when people are likely to be asleep and not able to respond to evacuation warnings.

7.10.1 Structural Stability

The collapse of a shelter-in-place refuge would result in almost certain loss of life and therefore is not acceptable under any flood event. To determine the likelihood of this occurring the structural stability of shelter-in-place refuges in the event of flooding needs to be assessed.

An updated set of hazard thresholds has been proposed within the *Technical Flood Risk Management Guideline: Flood Hazard* (Commonwealth Government, 2014) which focus more on the hydraulic scenarios where pedestrian, vehicle and building stability is at risk.

The technical guideline provides guidance on the implementation of the *AEM Handbook 7: Managing the floodplain: best practice in flood risk management in Australia* (2014). This is a national handbook by the National Flood Risk Advisory Group (NFRAG), working with the Australian Emergency Management (AEM) Institute to update national best practice in flood risk management.

The flood hazard curves are shown in **Figure 7-6**. The two hazard categories relevant to structural stability are H5; where structural stability can be achieved for specially engineered buildings, and H6; where no structural stability cannot be guaranteed for any buildings.

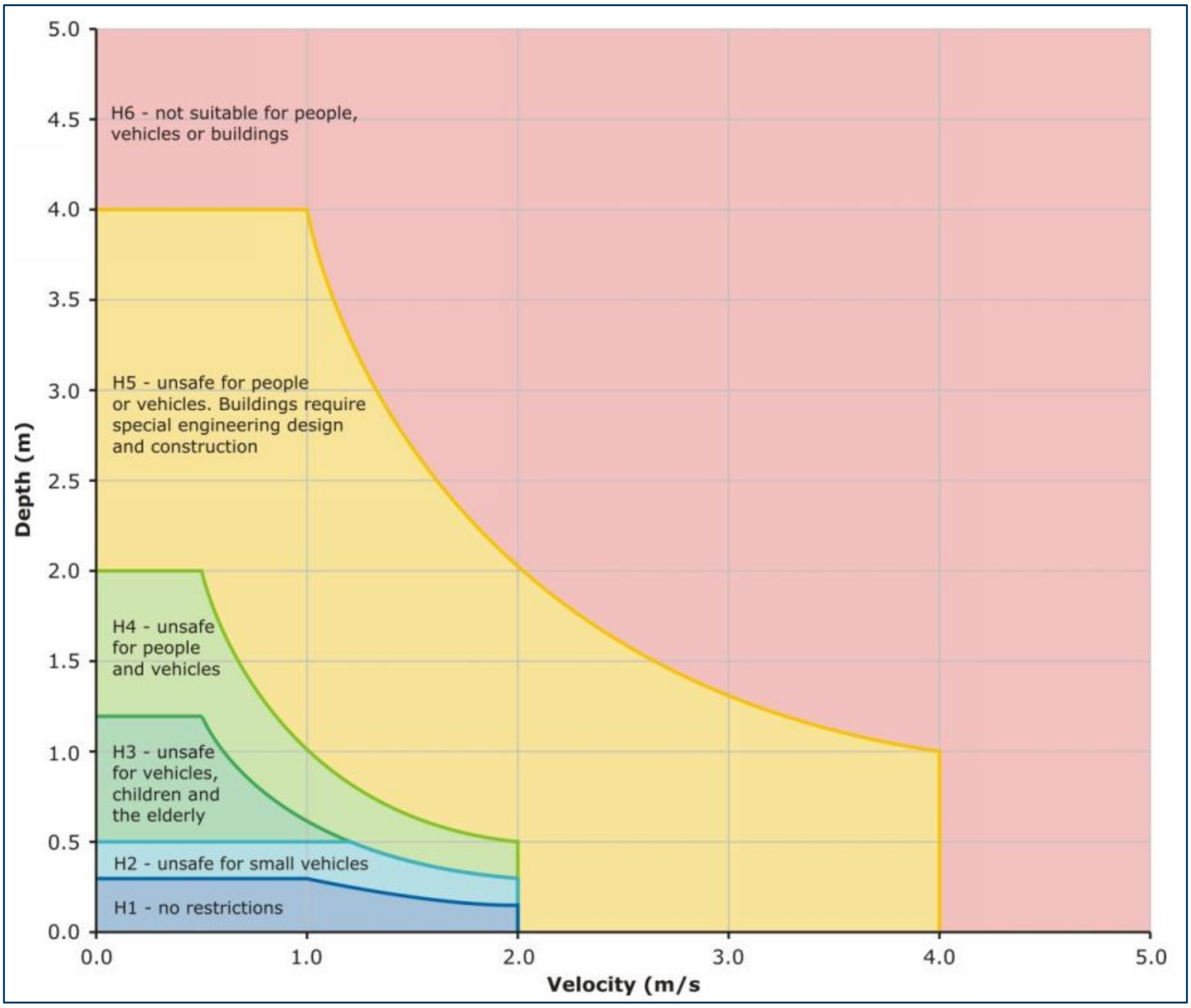


Figure 7-6 **Combined Flood Hazard Curves (Source: Commonwealth Government, 2014)**

Though PMF event is the design event for emergency response (refer to **Section 7.4**), flood hazard categories H5 and H6 have been mapped for the 1% AEP event for Marrickville Valley catchment shown in **Figure 7-7**.

The results show that H6 areas where building stability is compromised are generally confined to road reserve and dedicated waterways:

- Eastern channel is classified as H6 for the majority of its length, however this is contained within the channel extents and therefore does not pose a risk to any structures;
- Storage DPS1 within the catchment is classed as H6 due to the extreme flooding depths in the 15 AEP event in the basin;
- All other locations are very localised and not considered a significant risk.

The extent of H5 areas shown in **Figure 7-7** are where standard buildings may be unstable but buildings designed for flood affectation may be stable. The H5 extents are more widespread than H6 but are generally confined to road reserves. At these locations any prospective shelter-in-place refuges would need to be specially engineered to withstand flood forces in the 1% AEP event.

Since majority of the H5 and H6 areas are located within the road reserves, structural building controls in the DCP are not warranted. These should only be considered on a case by case basis if deemed necessary.

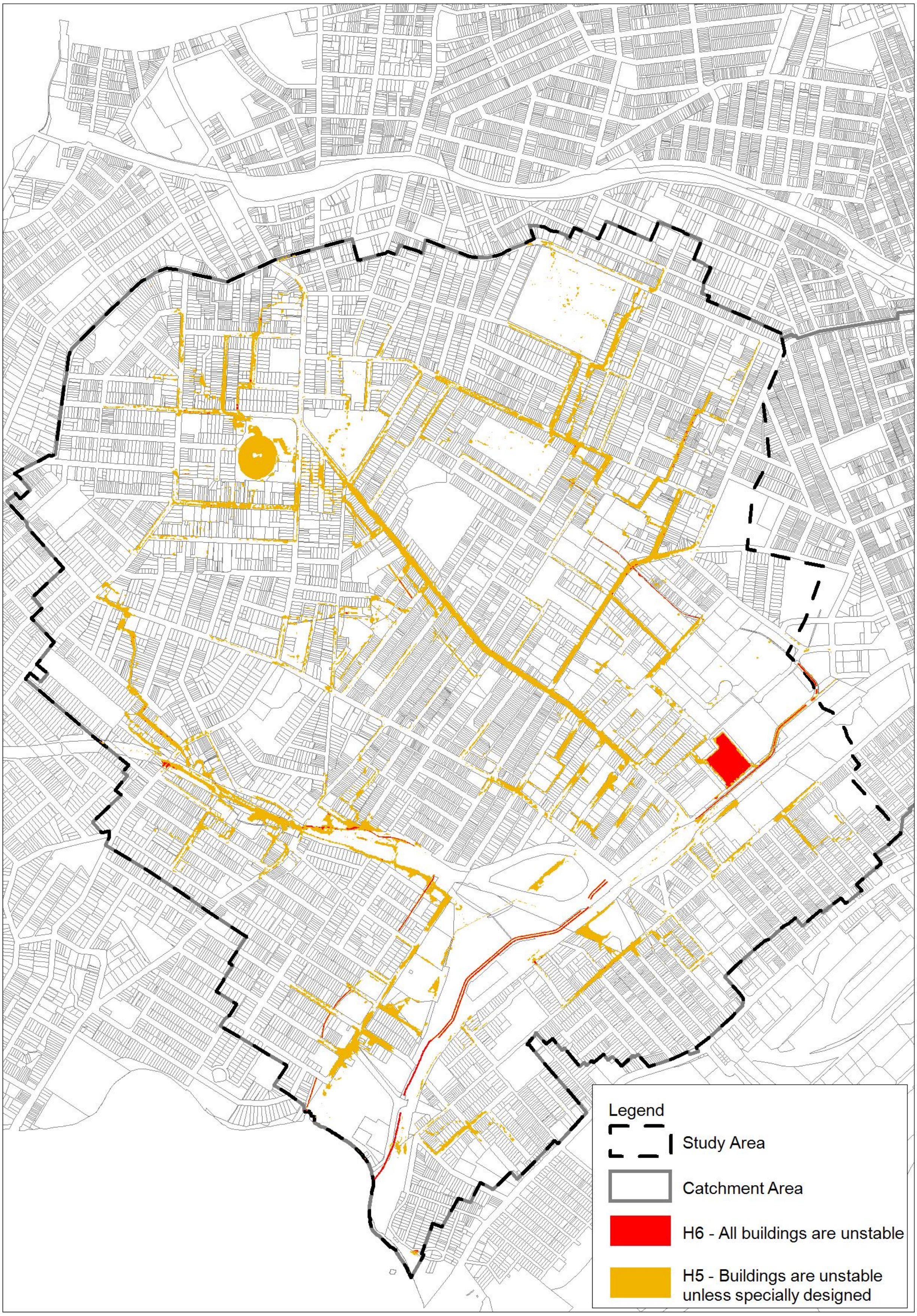


Figure 7-7 **Building Stability Hazard Categories for Marrickville Valley**

7.10.2 Duration of Flooding

The duration of inundation (the time for which the location is submerged) is guided by the water level time series for Marrickville Valley discussed in **Section 7.9.2.3**. The analysis shows that the duration of flooding for Marrickville Valley is relatively short with most locations flood free less than 3.5 hours after the onset of rainfall for the PMF event.

The only locations where the duration of flooding is expected to exceed 6 hours for the PMF event is the low lying Carrington Road near Mackey Park and parts of the Marrickville Industrial Area. It is assumed that the duration of flooding at these locations has flooding duration of less than 24 hours, while longer than the rest of the Marrickville Valley, sub-daily durations of isolation are relatively short when compared to large riverine catchments within NSW such as the Nepean River.

As the maximum duration of flooding is expected to be sub-daily for the majority of the floodplain the flood risk to life associated with any prospective shelter-in-place isolation is expected to be manageable through provision of supplies / services to the refuges.

7.10.3 Flood Free Refuge

Flood hazard exposure is the main risk to life related to flooding. Therefore if shelter-in-place is implemented where occupants will remain on site for the duration of the flooding event, it is essential that refuge not expose them to any direct flood hazard, i.e. that the refuge is flood free. As a result flood refuge should have floor levels located above the PMF water levels.

PMF peak depths vary throughout the Marrickville Valley. In the upper catchment where overland flow typically occurs and fringe areas of the floodplain PMF depths can be less than 0.5 metres, and even lower than the Flood Planning Level (1% AEP plus 500mm freeboard). In these locations it is not onerous at all to require for shelter-in-place refuge above the PMF level.

In the lower portions of the floodplain PMF peak depths become far more significant, in particular within the Marrickville Industrial Area where PMF depths are between 2-4 metres. For these locations, shelter-in-place refuges become more onerous to construct as they will likely require a mezzanine level or a first floor to be constructed. However such elevated levels are possibly advantageous to future industrial developments in the area assuming that they can be allowed for within height restrictions for the area.

7.11 Summary and Recommendations

For the Marrickville Valley there is an existing local emergency management document for flooding, the *Marrickville Flood Emergency Sub Plan* (SES, 2015). This document outlines the emergency response procedures and the responsible parties and their roles in the event of flooding. Upon review, the provisions of the Plan are mostly appropriate.

For vulnerable properties that are affected by the 1% flood event it is recommended that individual flood response plans are developed.

With respect to the evacuation timeline for the Marrickville Valley, as the catchment is affected by flash flooding there is insufficient time to evacuate residents using the SES assisted doorknock approach. A number of alternatives should be considered to improve the evacuation timeline:

- Use of alternative flood warning systems including social media and telephone based approaches all providing potential reductions to the time required for evacuation compared to doorknocking.
- Self-managed evacuation which can be implemented for all new developments through requirements within development controls relating to preparation of a flood emergency response plan and site specific flood warning systems.
- Improved flood awareness is likely to significantly reduce the time required for residents to evacuate as it improves awareness of the severity of the flood risk and the flash flooding nature of the catchment.

The other alternative to evacuation is the use of shelter-in-place provisions which can be applied to new development through development controls. This is assumed to be a suitable alternative for the majority of the Marrickville Valley and reduces the strain on SES resources and reduces the time required for response.

8 Review of Flood-Related Policies and Planning

The Marrickville Valley floodplain is located in the Marrickville area of Inner West Council LGA where development is controlled through the Marrickville Local Environment Plans (LEP), Marrickville Development Control Plan (DCP) and associated policies. Specifically, the study area falls under the *Marrickville LEP 2011* and *Marrickville DCP 2011*. The LEP is a planning instrument which designates land uses and permissible development in the LGA, whilst the DCP regulates development with specific guidelines and parameters. Management policies and plans are often used to provide additional information regarding development guidelines and parameters.

This section summarises the current flood controls covered by the LEP, DCP and relevant policies and plans in **Section 8.1**, with **Section 8.2** summarising the associated flood planning maps currently available for the area. A summary of the manuals and guidelines relevant to flood planning for Marrickville Valley is included in **Section 8.3**.

A strategic planning review included in **Section 8.4** summarises the proposed land use zoning for Marrickville Valley, with the potential implications of redevelopment and intensification of residential development also discussed. In addition the current Flood Planning Level is reviewed in **Section 8.5**.

Development controls suitable for application above the FPL up to the PMF level are discussed in **Section 8.6** with commentary on the necessity for an application for 'exceptional circumstances' in accordance with the S117 directive.

It should be noted that the recommendations provided in the following sections have been made with regards to a review of the relevant planning documentation within the context of the flooding behaviour of the Marrickville Valley floodplain and may not be appropriate for the Cooks River floodplain.

8.1 Current Flood Related Development Controls

8.1.1 Local Environment Plan - Flood Planning Clause

Section 6.3 Flood Planning of the LEP outlines controls and objectives for land below the Flood Planning Level (FPL), which is defined as the 1% AEP plus a 0.5 m freeboard. 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; and

> To avoid significant adverse impacts on flood behaviour and the environment.

The LEP states that development consent must not be granted for 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;

> Will not 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.

The wording of this section of the LEP is more or less standard across all Councils within the state of New South Wales.

8.1.2 Marrickville Development Control Plan 2011

There are two sections of the Marrickville DCP 2011 which contain development controls relevant to flood risk, both within Part 2 – Generic Provisions:

- Part 2.22 – Flood Management - This section recognises that there are some flooding risks that require development controls and guidelines in order to reduce or eliminate their impacts; and,
- Part 2.25 – Stormwater Management - This section relates to stormwater drainage for all development types. The flow of stormwater from developments needs to be managed so as to negate or reduce to an acceptable frequency the possibility of flooding buildings and/or the danger to life at any location, through the storage of stormwater where appropriate in developments and the control of major development drainage systems.

While the stormwater section of the DCP does identify some development controls that are relevant to flood management, the majority of flood related controls are identified in the flood management section.

8.1.2.1 Development Specific Controls

The flood related controls are applied to different development conditions with unique set of controls applied to the following:

- Residential development (new):
  - Minimum floor level and flood compatible materials to the relevant Flood Planning Level (FPL);
  - Flood free access must be provided where practical;
  - If additions or alterations are less than 30 m^2 then minimum floor level requirements may not be applied where practical alternatives do not exist, flood proofing to FPL still apply.
- Non-habitable areas: No floor level requirements except for “flood sensitive equipment”, flood compatible materials to the FPL are applicable.
- Non-residential development (new): Same controls as new residential development but minimum floor level requirements may not be applied if flood proofed to the equivalent FPL.
- Change of use of existing building: Change of existing use with floor levels below FPL will be considered if pollutant materials are not located below the FPL and flood risk does not increase elsewhere as a result of the change of use.
- Subdivision: Must consider that the flood risk of the subdivision site will be compatible with the proposed land use of the subdivision, must also consider the impact on flood risk on adjoining properties.
- Underground garages:
  - Basement entry levels must be located above the 1% AEP plus 500 mm;
  - Suitable pumps must be applied to basements in the floodplain;
  - Flood warning systems, signage and exits for basement areas;
  - Reliable access for pedestrians to refuge above the PMF level.

8.1.2.2 General Development Controls

In addition to the above development controls tailored to the relevant development type, there are also development controls that are applicable to almost all development:

- Filling in the floodplain: The applicant must demonstrate that the development will not increase flood hazard or risk elsewhere, based on the following:
  - Flood levels not increased by more than 100mm;
  - Downstream velocities are not increased by more than 10%;
  - Flows are not redistributed by more than 15%;
  - Potential for cumulative effects of continued development are minimal;
  - Development potential of surrounding properties not adversely affected;
  - Flood liability is not increased;
  - The development creates no local drainage flow / runoff problems.
- Flood emergency response: A site emergency response flood plan must be prepared with adequate flood warning and reliable pedestrian access to the PMF level; and

- For overland flow, which is defined as minor flows of depth less than 300mm and flow less than 2 m^3/s, a freeboard of 300mm is adopted as opposed to the standard 500mm.

It is noted that the there are no flood related provisions in the DCP for development in heritage conservation areas. Given that some of the heritage conservation areas within the Marrickville Valley are flood affected, it is recommended that Council consider provisions of flood related controls in the DCP for development in heritage conservation areas.

8.2 Current Flood Planning Maps

8.2.1 Development Control Plan - Flood Planning Area Mapping

The Marrickville DCP 2011 under Section 2.22.2 outlines the Flood Planning Area that the flooding section relates. In addition the DCP refers to a Flood Planning Area Map (dated 19/05/2015) that identifies:

- "Overland flow" affected properties which are those affected by the 1% AEP with the mapped properties for Marrickville Valley assumed to be an outcome of the *Marrickville Valley Flood Study* (WMAwater, 2013).
- Cooks River Flood Planning Area extents which identifies land under the 1% AEP with 0.4 metre sea level rise to the year 2050, level plus 500mm freeboard.

The mapping from the DCP FPA mapping for the Marrickville Valley is shown in **Figure 8-1.**

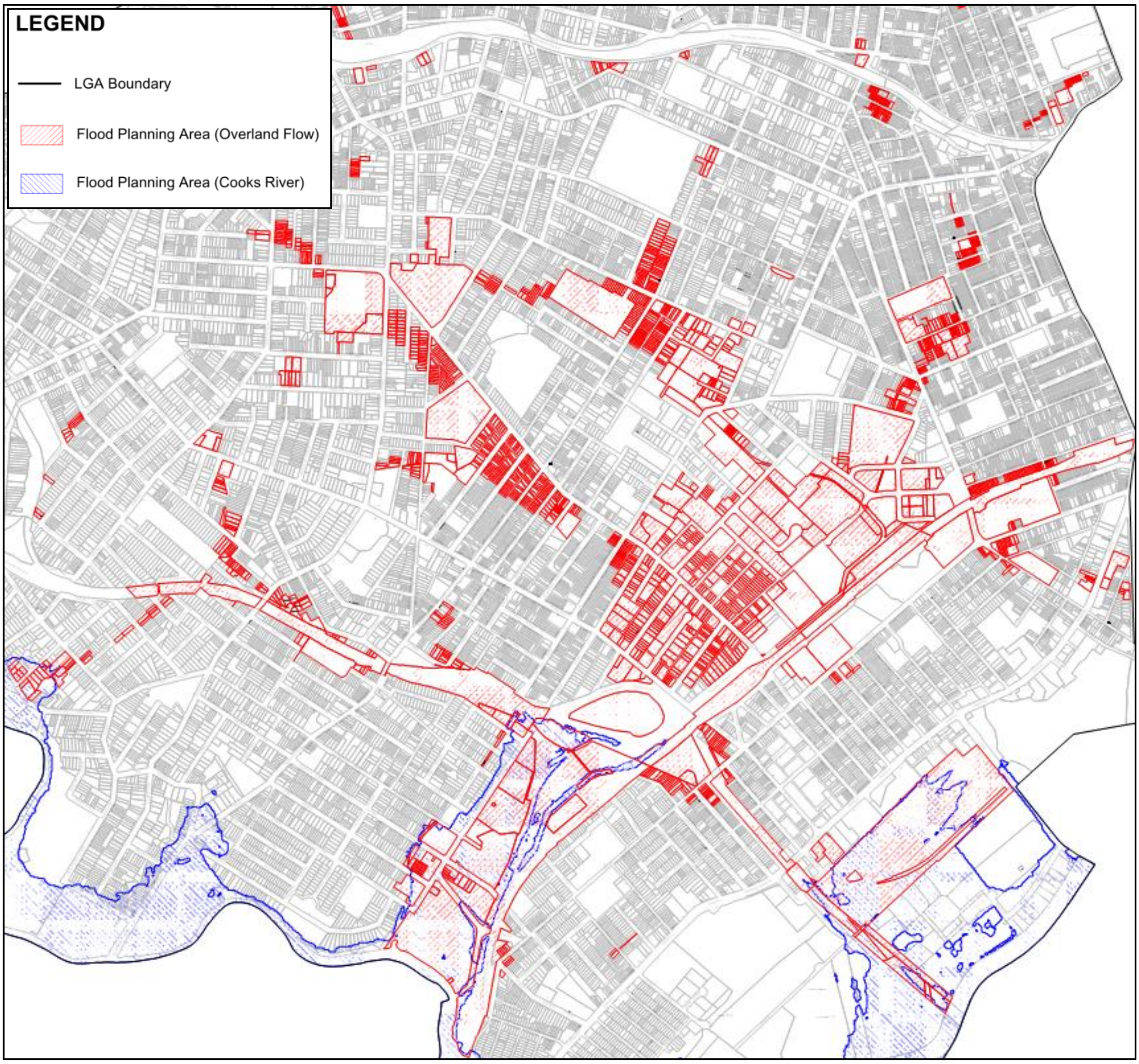


Figure 8-1 **Current Flood Planning Area Mapping for Marrickville DCP 2011 (Dated 19/5/2015)**

8.3 Relevant Policies, Guidelines and Manuals

A description of the policies, guidelines and manuals relevant to this review are summarised in **Table 8-1**. This provides background on the context of the documents and how they interact with the flood policy and planning controls of Marrickville Area of Inner West Council LGA.

In NSW, flood risk management promotes a flexible merit based approach as outlined within the first policy provision of the *Flood Prone Land Policy* (NSW Government, 2005). This approach is adopted throughout the manual, where recommendations are noted but rarely are prescriptive requirements identified. The exception would be the subsequent S117 directive where quite clear requirements are outlined.

Table 8-1 Description of Relevant Policies, Guidelines and Manuals

Document	Context
Flood Prone Land Policy (NSW Government, 2005) And *Floodplain Development Manual* (NSW Government, 2005)	The Policy was prepared in 1984 by the NSW Government with the following objective: *"To reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone land, and to reduce public and private losses resulting from floods. At the same time the policy recognises the benefits flowing from the use, occupation and development of the floodplain."* The Floodplain Development Manual (FDM) was prepared to support the NSW Government's *Flood Prone Land Policy*. The manual was prepared to provide a framework for implementing the policy. The Manual has established the flood risk management process across NSW since its release, and sets out the roles and responsibilities of Councils and other consent authorities as well as developers and residents.
S117 Directive for Development Controls on Low Flood Risk Areas (NSW Government, 2007)	In January 2007, the NSW Department of Planning and Department of Natural Resources (now Office of Environment and Heritage) jointly released a *guideline on development controls for low flood risk areas – floodplain development manual* (NSW Government, 2007). The guideline was issued to provide additional guidance to Councils on matters dealt with in the FDM (NSW Government, 2005). As the directive is framed as an addendum to the FDM, the directive contains the same legal weight as the FDM.
Managing the floodplain: a guide to best practice in flood risk management in Australia Volume 7 (AEM, 2013)	This handbook provides guidance on best practice principles to management of flood risk as presently understood in Australia, rather than describing current varied practice. Every attempt has been made to adopt a national approach to terminology, policy and guidance arrangements. The handbook has been developed by a national consultative committee representing a range of state and territory agencies involved in the delivery of support services, and is sponsored by the Commonwealth Attorney-General's Department.
Construction of Buildings in Flood Hazard Areas (ABCB, 2012)	The Australian Government and State and Territory Government Building Ministers responsible for building regulatory matters directed the ABCB to develop a standard for the design and construction of certain new buildings in flood hazard areas. The Standard aims to reduce the risk of death or injury of building occupants as a result of buildings subjected to certain flood events. This document forms part of the Building Code of Australia. The document provides recommendations regarding approach to construction within flood hazard areas but refers to flood planning being the task of the 'relevant authority'. Therefore the recommendations within the document are quite broad and allow for the relevant authority to implement its own variations to the core principles.

Document	Context
State Environmental Planning Policy (Housing for Seniors and People with a Disability) (2004)	The SEPP applies to land within New South Wales that is land zoned primarily for urban purposes or land that adjoins land zoned primarily for urban purposes, but only if development for the purpose of any of the following is permitted on the land: > dwelling-houses, > residential flat buildings, > hospitals, > development of a kind identified in respect of land zoned as special uses, including (but not limited to) churches, convents, educational establishments, schools and seminaries, or the land is being used for the purposes of an existing registered club. Schedule 1 of the SEPP indicates that it does not apply to land identified as floodway or high flooding hazard. The SEPP over-rides any provisions in the Marrickville LEP and DCP.
State Environmental Planning Policy No 32—Urban Consolidation (Redevelopment of Urban Land)	The SEPP does not apply to land that has been identified as a floodway. However, it can be applied to other urban land in certain circumstances to allow multi-unit housing. The SEPP over-rides any related provisions within the Marrickville LEP and DCP.
State Environmental Planning Policy (Exempt and Complying Development Codes) 2008	The SEPP enacts the concept of 'flood control lots' by which Council can identify those lands where complying development would trigger specific controls with respective to complying development or a need for consent from Council (which would otherwise not be required) by virtue of the land being flood-affected. Flood control lots are defined as *a lot to which flood-related development controls apply in respect of development for the purposes of industrial buildings, commercial premises, dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (other than development for the purposes of group homes or seniors housing).* Details of development standards for flood control lots can be found in Part 3, Division 2, Subdivision 9, Clause 3.36C of the SEPP. As part of this clause flood affected properties may be eligible for a Complying Development Certificate (CDC) if the development does not lie within one of the following a) Flood storage area, b) Floodway area, c) Flowpath, d) High hazard area, or e) High risk area. For developments outside of these zones specific controls that arise in the SEPP mean that development on flood control lots in an identified flood-planning area must: > have all habitable rooms no lower than the floor levels set by the council for that lot, and > have the part of the development at or below the flood planning level constructed of flood compatible material, and > be able to withstand the forces of floodwater, debris and buoyancy up to the flood planning level (or if on-site refuge is proposed, the probable maximum flood level), and > not increase flood affectation elsewhere in the floodplain, and > have reliable access for pedestrians and vehicles from the development, at a minimum level equal to the lowest habitable floor level of the development, to a safe refuge, and > have open car parking spaces or carports that are no lower than the 20-year flood level, > have driveways between car parking spaces and the connecting public roadway that will not be inundated by a depth of water greater than 0.3m during a 1:100 ARI flood event. The SEPP over-rides any related provisions within the Marrickville LEP and DCP.

Document	Context
Managing Flood Risk through Planning Opportunities – Guidance on Land Use Planning in Flood Prone Areas (HNFMSC, 2006) and *Designing Safer Subdivisions – Guidance on Subdivision Design in Flood Prone Areas* (HNFMSC, 2006)	These two guidelines were prepared by the Hawkesbury Nepean Floodplain Management Steering Committee (HNFMSC). The committee consisted of representatives from various NSW state government agencies including the now Department of Planning and Environment, State Emergency Service, Sydney Catchment Authority (now WaterNSW), the now Roads and Maritime Services and the now Office of Environment and Heritage. In addition the committee contained local councils within the Hawkesbury Nepean floodplain. The objective of the committee was to oversee the delivery of a floodplain risk management strategy for the Hawkesbury Nepean catchment in western Sydney. The documents aim to provide local councils, government agencies and professional planners with a regionally consistent approach to developing local policies, plans and development controls which address the hazards associated with the full range of flood events up to the Probable Maximum Flood (PMF). Marrickville Valley lies outside the Hawkesbury Nepean floodplain meaning that the guideline is not strictly applicable to this study. However through the contributions of the various relevant stakeholder State Government Agencies in the formulation of these two guidelines, the discussion within the two documents provides useful insight.

8.4 Strategic Planning Review

The Marrickville LEP 2011 identifies land use zones for the Marrickville Valley Study Area which note the type of land use that is permissible on the assigned land in the future. A summary of the areas of each land use within the Marrickville Valley catchment are summarised in **Table 8-2**.

Table 8-2 Marrickville Valley Land Uses – Area Breakdown

Land Type	Land Use	Land Use Summary		Land Type Summary	
		Area (ha)	% of Study Area	Area (ha)	% of Study Area
Business	B1 Neighborhood Centre	4.2	1%	29.7	4%
	B2 Local Centre	16.3	2%		
	B4 Mixed Use	1.0	0%		
	B5 Business Development	4.2	1%		
	B7 Business Park	4.0	1%		
Industrial	IN1 General Industrial	66.1	10%	90.1	14%
	IN2 Light Industrial	24.0	4%		
Residential	R1 General Residential	25.0	4%	286.9	44%
	R2 Low Density Residential	249.6	38%		
	R3 Medium Density Residential	2.4	0%		
	R5 Large Lot Residential	9.9	2%		
Recreation	RE1 Public Recreation	31.2	5%	38.4	6%
	RE2 Private Recreation	7.3	1%		
Special Purpose	SP2 Infrastructure	73.3	11%	73.3	11%
Miscellaneous	Road Reserve / Unzoned Land	135.4	21%	135.4	21%

The majority of the study area is zoned as R2 low density residential (38%), unzoned land / road reserve (21%), SP2 special purpose infrastructure (11%), and IN1 general industrial (10%). All other land uses have cumulative areas of 5% or less of the total study area.

With respect to land use types nearly half of the study area is residential (44%), with business (4%) and industrial (14%) all combining to mean that just under two thirds (62%) of the entire study area is developable land.

The layout of the land uses for the study area with the 1% AEP flood extents shown in **Figure 8-2.**

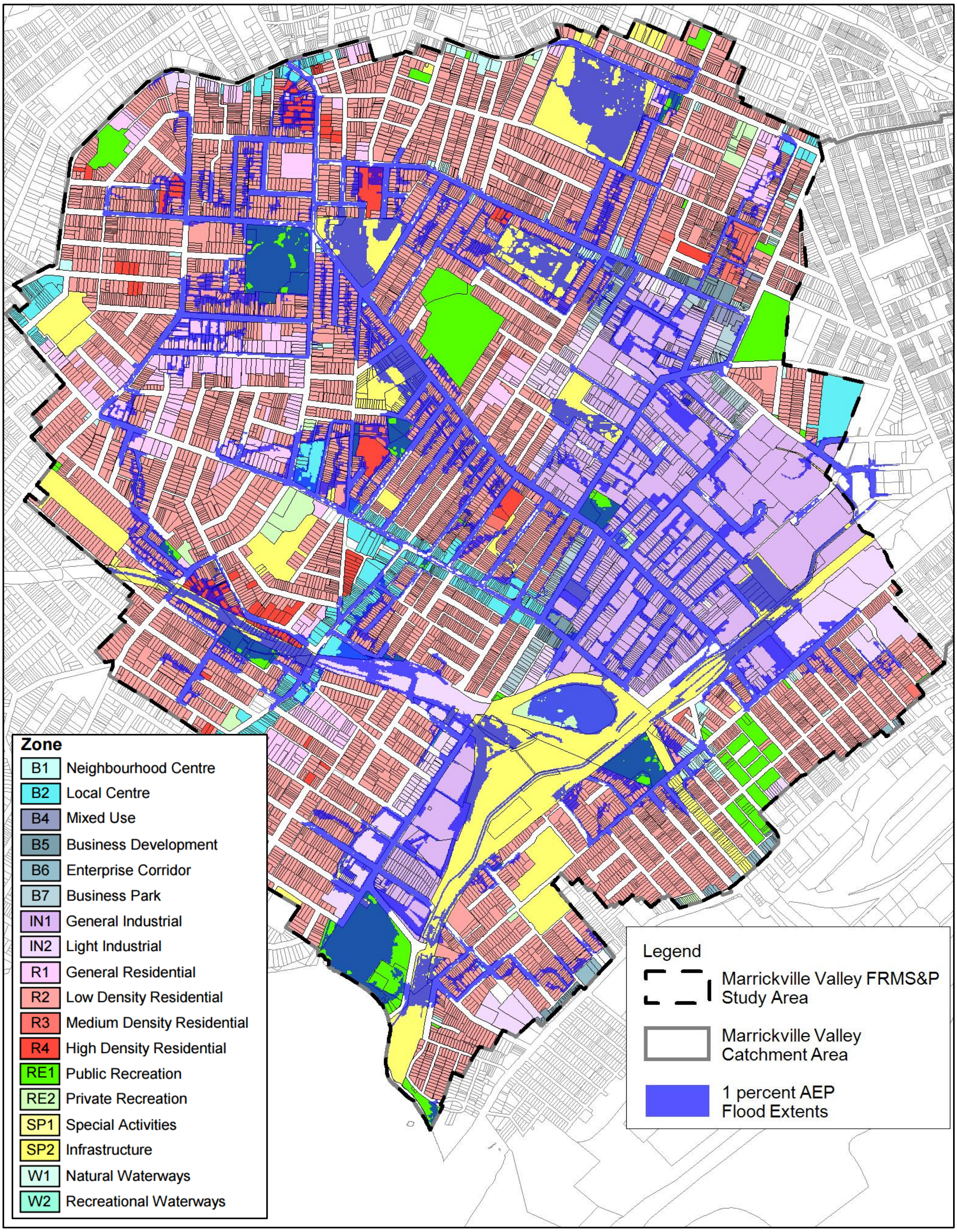


Figure 8-2 **Land Use Zones for the Marrickville Valley Floodplain**

As can be seen from **Figure 8-2** the majority of flood affected land uses are either R2 low density residential in the upper areas of the catchment, with IN1 general industrial being the primary flood affected land use in the lower portions of the floodplain. There are also numerous large SP2 special purpose infrastructure sites that are flood affected in the upper catchment which correspond to a number of primary and high schools.

The fact that low density residential and industrial land uses are the most flood affected developable land means that they are the major source of flood risk for the study area, which is a consideration in the review of flood related development controls.

8.4.1 Redevelopment of the Floodplain

It is noted that the proposed land use zonings discussed in **Section 8.4** in a lot of instances may represent the potential for an intensification of development in the future, resulting in additional occupation of the floodplain.

While any future intensification of development implies additional occupation of the floodplain, it does not inherently imply an increase in the cumulative flood risk for the floodplain due to the existing high occupation of the floodplain for Marrickville Valley. Redevelopment offers the opportunity to replace relatively high flood risk existing developments with new developments that have a low flood risk through the use of flood-related development controls.

For example in relation to risk to property, analysing the existing damage analysis outcomes summarised in **Table 6-8**, a total of 1,228 properties lie below the 1% AEP level with 675 of those being residential. If in the future these properties are replaced with properties with minimum floor levels above the residential FPL then the cumulative risk to property will be significantly reduced.

Similarly in relation to risk to life, currently the emergency response procedures for the site mean that risk is high for the area, where in the future developments can be designed with site specific flood emergency response plans or shelter-in-place refuges above the PMF level which will significantly reduce risk to life for the floodplain.

Generally the current controls are effective in ensuring future development has an acceptable / tolerable level of flood risk to both property and people, whereas the existing development of the floodplain has a higher flood risk. Therefore it is recommended that development within the floodplain that is in accordance with development controls, even if it represents intensification, be considered on its merits as it will potentially represent a reduction in flood risk.

8.4.2 Intensification of Residential Development

The majority of flood affected residential land within the Marrickville Valley is zoned as low density (R2). While this ensures that the occupation of the floodplain is unlikely to exceed current levels for residential areas, alternatively there are some potential advantages of multi-unit residential developments.

With respect to multi-unit residential buildings in the floodplain and the potential advantages and disadvantages of this type of development in relation to flood risk, the subdivision guideline for HNFMSC (2006) contains the following discussion:

> *Whilst there are substantial damage reduction benefits in multi-storey unit construction, this should not be used as justification for increasing the overall numbers of households in high hazard areas where it would otherwise not be acceptable because of evacuation difficulties. Although the units may provide an opportunity for refuge within the building in flash flood events, it is much safer if residents are evacuated particularly in locations where inundation lasts for long periods. The numbers of people housed in any new floodplain development, regardless of design or type, should be consistent with the SES evacuation plan for the area.*
>
> *However, if residential development is considered an acceptable land use in a vulnerable flood prone area, then flood damages can be reduced if high rise or multi-storey unit development is adopted rather than single or two-storey dwelling houses, villas and townhouses.*

As discussed within **Section 7**, the reliance on SES assisted evacuation is not recommended for Marrickville Valley with shelter-in-place refuge seen as more acceptable for this catchment. Therefore the above extract is generally supportive of this development type.

With respect to potential flood impacts and conveyance and multi-storey buildings on large lots, the subdivision guideline for HNFMSC (2006) contains the following discussion:

> *Additional benefits can be delivered through multistorey high-rise units. By achieving the same yield in a vertical plane rather than by increasing the overall footprint of the buildings, the potential for flow obstruction is reduced. This gives more opportunities to maintain lower velocities between the buildings on the site thereby reducing the potential for damage due to flowing water. As the forces are proportional to the square of the velocity any reduction in velocity produces significant advantages.*
>
> *There are also more opportunities for buildings to be orientated and positioned to minimise concentration of floodwaters and improve flow through the development when subdivision and building design are integrated.*

The model results for the area show that the flow obstruction resulting from existing building footprints is significant, therefore the use of larger lot developments may provide conveyance advantages across the floodplain as discussed in the above extract.

The use of multi-unit residential developments provide several advantages over the existing typical smaller lot single storey residential currently within Marrickville Valley:

- Provision of shelter-in-place refuge above the PMF level is less onerous for multi-storey developments;
- As noted in the extract above there are better opportunities to orientate building footprints to better convey floodwaters in larger lot developments; and,
- Elevation of minimum floor level requirements above the 1% AEP plus 0.5 metre (which can be up to 1.5 metres higher than street level) would be less onerous for larger residential developments.

Nevertheless the intensification of development in the floodplain does pose significant risks that would need to be addressed through suitable flood planning and accompanied by flood mitigation measures.

It should be noted that approval from the Minister of Environment will be required for planning controls that allow shelter in place refuges for levels above the flood planning levels. Alternatively, Council could request site-based flood management plans as part of the development application condition.

8.5 Flood Planning Level Review

8.5.1 Review of Residential FPL

The current residential FPL is equal to the 1% AEP level plus 0.5m freeboard. With respect to the design flood event to be adopted for the FPL the FDM (NSW Government, 2005) states the following:

> *In general, the FPL (minimum floor level) for standard residential development would be the 1% AEP flood event plus a freeboard (typically 0.5m).*

The guidance within the FDM related to the residential FPL is further reinforced within the *Guideline on development controls for low flood risk areas – floodplain development manual* (NSW Government, 2007). Within this directive it is stated that:

> *This Guideline confirms that, unless there are exceptional circumstances, councils should adopt the 100 year flood* (1% AEP) *as the FPL for residential development.*

Therefore based on the FDM (NSW Government, 2005) and the subsequent guideline released in 2007 the currently adopted FPL for residential development of the 1% AEP event plus 0.5 metre freeboard is appropriate. In addition, based on this guidance there is limited scope for revision of the residential FPL without an application for exceptional circumstances to the NSW Government, discussed further in **Section 8.6**.

The peak 1% AEP depths for the residential areas of the Marrickville Valley are typically between 0.4 – 0.6 metres, however significant portions of the floodplain in these areas have 1% AEP depths up to 1 metre. Accounting for the 0.5 metre freeboard the depth above street level to future floor levels above the residential FPL would be up to 1.5 metres. This elevation of the minimum floor level above the street level is not very feasible for the existing residential type of small lot single detached dwellings. As noted in the section above it could be more feasible for larger multi-unit residential developments.

The existing exemption of minor additions (less than 30m²) from residential FPL requirements is seen as particularly relevant for the Marrickville Valley where complete re-development is less likely to occur than renovation or extension of existing houses.

It is recommended that this exemption be maintained so that minor alteration and renovation of existing dwellings be continued without onerous controls. Such minor additions are unlikely to result in a significant increase in flood risk, meaning the exemption is suitable.

8.5.2 Review of Commercial / Industrial FPL

The current requirement for non-residential development (assumed to be referring to industrial and commercial developments) is the 1% AEP plus 0.5m freeboard, or alternatively flood levels can be below the FPL if they are flood proofed to that level.

With respect to commercial and industrial developments, the FDM allows for more variability on approach towards FPL than what is discussed for residential development:

> *The decision on appropriate FPLs for commercial and industrial developments relates more to economic benefits versus costs. Therefore there is greater potential for FPLs for these developments to be based on event more common than the 1% AEP flood. However, danger to personal safety for personnel, clients etc still requires careful consideration, particularly where more frequent events are used as the basis for FPLs*.

Therefore unlike for residential developments, the State Government allows for a lot more flexibility on acceptable FPLs for commercial and industrial. In relation to use of flood proofing in commercial developments, the FDM states:

> *In commercial buildings the adopted floor level is also affected by economics and commercial risk-taking considerations. This can result in a superficially attractive decision by a commercial enterprise on the assumption that it can build the cost of flood losses into its operating costs in exchange for the savings in capital costs associated with not having to raise floors above flood level.*
>
> *However, the expectation of losses is often forgotten with potentially disastrous consequences on the financial stability of the enterprise when damages or losses subsequently occur.*
>
> *Councils have a duty of care in approving such developments to ensure proper evaluation has been carried out and in determining appropriate development conditions. They may require the proponent to submit detailed advice of measures proposed to avoid or cater for flood losses.*
>
> *Irrespective of the proponent's desires, the overriding consideration should be that the proposed development will not adversely affect flood behaviour or increase the potential for danger to personal safety or property, whether public or private. The proper course is to determine levels of acceptable risk for specific areas from within the overall framework of the floodplain risk management plan. Decisions must not be made on an individual and ad hoc basis.*

From the above extract the FDM provides points countering the use of flood proofing to replace FPL requirements, it states that this is still a viable option if Council determines that this is an acceptable level of risk for specific areas and the decision is not of an ad hoc nature.

Therefore review of the FDM (NSW Government, 2005) shows that there is scope for Councils to implement the current approach where floor levels for these developments may be below the 1% AEP plus 0.5m. The current alternative requirement of flood proofing to the equivalent level provides the necessary protection of the structure itself however it is assumed that flood proofing will provide no protection to the contents of these properties.

It is noted that the industrial areas of the Marrickville Valley are typically the worst affected flooding areas, with depths often exceeding 1.0 metres in the 1% AEP. Accounting for freeboard the required floor levels heights for the FPL are likely to be over 1.5 metres above street level. Therefore it is noted that in Marrickville Valley most industrial developments will opt to flood proof to the FPL level as elevating floor levels to the required FPL will be seen as less feasible.

8.5.3 Consideration of Climate Change within FPL

As stated within Appendix K of the *Floodplain Development Manual* (NSW Government, 2005), the uncertain effects of climate change is normally accounted for in freeboard, typically assumed to account for roughly 0.2 m of the 0.5 m freeboard typically adopted.

However as stated in the 2010 *Flood Risk Management Guide: Incorporating sea level rise benchmarks in flood risk assessment*, the freeboard should be considered to address only some of the uncertainty associated with estimating climate change impacts as the potential impact of climate change is much larger than anticipated in 2005. As a result it may be necessary in some cases to accommodate climate change into Flood Planning Levels through other methods (such as in the baseline Design Event). An example of this is in current policy for Cooks River where the design event for FPL is the 1% AEP accounting for a 0.4m sea level rise scenario.

The summary of climate change impacts for Marrickville Valley included in **Section 5.5** concluded that sea level rise has negligible impact on 1% AEP levels for the majority of the floodplain. The impacts on flooding resulting from rainfall increase are more significant, with coincident rainfall increase and sea level rise having the greatest effect. The peak water level increase for the 30% rainfall increase scenario and 0.4m sea level rise event was 0.4 metres at two locations, with water level increases at all other locations not exceeding 0.3 metres. It should be noted that this assessment has been based on the 2013 flood study. These levels are conservative and likely to be less based on the new flood results from the model update undertaken as part of this study (**Section 5.1.3**).

The typical impact of climate change, accounting for both sea level rise and rainfall increase is not significant enough to require consideration within the design event as is the case for Cooks River where sea level rise effects are expected to be more significant.

8.6 Development Controls above the Flood Planning Level

The *Guideline on development controls for low flood risk areas – Floodplain Development Manual* refers to areas above the residential Flood Planning Level (FPL) but below the Probable Maximum Flood (PMF) and states the following:

The Guideline also notes that, unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land above the residential FPL (low flood risk areas). In proposing a case for exceptional circumstances, a Council would need to demonstrate that a different FPL was required for the management of residential development due to local flood behaviour, flood history, associated flood hazards or a particular historic flood.

The directive provides a number of exemptions, where development controls may be applied above the residential FPL without requiring an application for exceptional circumstances:

> *Low risk areas are areas where no development controls should apply for residential development but the safety of people and associated emergency response management needs to be considered and may result in:*
>
> - *Restrictions on types of development which are particularly vulnerable to emergency response, for example developments for aged care; and,*
> - *Restrictions on critical emergency response and recovery facilities and infrastructure. These aim to ensure that these facilities and the infrastructure can fulfil their emergency response and recovery functions during and after a flood event. Examples include evacuation centres and routes, hospitals and major utility facilities.*

The above exemptions apply to two types; vulnerable developments and emergency response infrastructure, which controls may be applied to above the FPL. These two categories are reviewed in further detail in the following sections.

8.6.1 Development Controls for Vulnerable Developments

As discussed within **Section 7.5** for the purposes of this FRMS&P the following development types are considered 'vulnerable' developments in relation to flood risk:

> Schools;
> Preschools;
> Childcare centres;
> Aged care facilities;
> Retirement villages;
> Medical Centres.

Under the current development controls for Marrickville these development types do not have specific development controls to address the additional flood risk. Under the current DCP these developments would be classified under 'non-residential development' and have floor level requirements to the 1% AEP plus 0.5m freeboard, or flood-proofing to the equivalent level.

It is recommended that specific development controls be developed for these high risk sites. Typically floor level requirements for these developments are set at the PMF level. While this is more onerous than the current controls, it is expected to significantly reduce the flood risk for these sites as floor levels are located above the highest expected flood level.

Development controls up to the PMF level for these development types are exempt from the requirements of the S117 directive in the first bullet point of the above extract. These controls could therefore be applied without the requirement of application for 'exceptional circumstances' to the State Government.

It is noted that Council is not the consent authority for schools and hence the recommended development controls do not apply to schools.

8.6.2 Development Controls for Emergency Response

The current DCP has the following requirements for emergency response provisions:

> A site emergency response flood plan must be prepared in case of a PMF flood;
> Adequate flood warning systems, signage and exits must be available to allow safe and orderly evacuation without increased reliance upon the SES;
> Reliable access for pedestrians or vehicles must be provided from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF.

As discussed in **Section 7** based on a review of emergency response potential for the Marrickville Valley, SES assisted evacuation is not seen as a suitable emergency response due to the flash flooding nature of the catchment. Alternatively site specific evacuation procedures or shelter-in-place refuge is seen as a more preferential emergency response.

In this way the current development controls are ideal in that they discourage reliance on the SES and encourage the development of site specific evacuation routes or refuge above the PMF level. Potential amendments could include additional requirements for shelter-in-place refuge to ensure suitable safety, including:

> Assessment of the structural stability of the refuge including consideration of flood forces up to the PMF event;
> Assessment of sufficient space to temporarily allow for the refuge of all occupants of the site;
> Inclusion of emergency provisions such as power generators or medical supplies in the event of isolation.

Though these recommended requirements would provide developers additional information in relation to suitable shelter-in-place, generally the current controls for emergency response are suitable.

These emergency response controls are applicable above the FPL up to the PMF level, however do not require an application for 'exceptional circumstances' with the State Government. The reason for this is that an exemption is made for 'critical emergency response and recovery facilities' as noted within the second bullet point of the S117 directive excerpt in **Section 8.6**.

8.6.3 Basement Entry Levels

Basement carparks have the following requirements currently for the Marrickville Area of Inner West Council LGA:

- The internal driveway must be located above the 1% AEP plus 0.5m freeboard prior to descending into the underground garage;
- Suitable pumps must be provided within the garage to allow for the drainage of stormwater should the underground garage become inundated during flooding;
- Adequate flood warning systems, signage and exits must be available to allow safe and orderly evacuation without increased reliance upon the SES;
- Reliable access for pedestrians or vehicles must be provided from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF

The FDM (NSW Government, 2005) or the associated S117 directive (NSW Government, 2007) do not have any discussion of additional flood risk posed by basements. However, the risks associated with basement carparks are discussed in the Hawkesbury Nepean guideline (HNFMSC, 2006):

> *Underground or basement car parks (i.e. below ground level) or covered bunded car park facilities are subject to inundation as flood waters rise. The collective value of parked vehicles and stored items is considerable. Basement parking should ideally be fully flood protected without the reliance on mechanical devices. To avoid early inundation, they should be designed with entry ramps, ventilation entry points and pedestrian exits positioned in such a way as to ensure that water would not enter until the last possible moment in a flood event. However, it should be recognised that such design measures to prevent early entry of water can cause problems with rapid flooding of the car park if waters continue to rise above the level of the ramp, which acts then like a breeched levee.*
>
> *Any cars remaining under water in a car park could be assumed to be written off.*

The Hawkesbury Nepean guideline goes on to discuss how the flood risks associated with basement carparks may be addressed through emergency response planning:

> *This can be very dangerous for anyone trapped in the car park and clearly marked, separate pedestrian exits are essential. Where it is possible to do so, it is preferable to have the crest level of all accesses to the basement at or above the PMF.*
>
> *Multi-storey buildings can provide occupants with high-level refuges during short duration floods. In flash floods, this may be preferable to evacuation if vehicles are parked in underground car parks. In such circumstances, an accessible refuge not only needs to be provided but clear signage to the refuge needs to be posted within the public areas of the building including the car park.*

However the issue with having a requirement for basement entry levels to be located above the PMF is that this is technically a development control that applies to a low risk area (above the residential FPL) as defined within the S117 Directive (NSW Government, 2007). Therefore an exceptional circumstance application would need to be made to the State Government to introduce PMF entry level requirements for basement carparks, which does not seem justified based upon the level of flood risk in Marrickville Valley.

The current requirements of entry levels to the FPL with pumping capacity for property protection and emergency response provisions to the PMF to address risk to life are considered an appropriate set of controls. Alternatives may be to require temporary 'pop-up' barriers to provide flood protection to the PMF level however these types of solutions are not seen as 'fail safe' as there is a chance that they will not rise and therefore not achieve their desired flood protection purpose.

8.7 Summary and Recommendations

This review of flood planning and policy considerations for the Marrickville Valley concludes that generally the current development controls for the Marrickville Valley are appropriate based upon a review of relevant manuals and guidelines.

A strategic planning review has been completed based on land use zoning mapping from the 2011 Marrickville LEP, and it showed that low density residential and industrial land uses are the most flood affected developable land means that they are the major source of flood risk for the study area.

In discussion of the potential intensification of development that may occur in the floodplain resulting from these land use zones, redevelopment offers the opportunity to replace relatively high flood risk existing developments with new developments that have a low flood risk through the use of flood mitigation measures and flood-related development controls. In relation to higher density residential development in the floodplain, multi-unit residential developments provide several advantages over the existing typical smaller lot single storey residential currently within Marrickville Valley.

A review of the current Flood Planning Level shows that the residential FPL is appropriate based on a review of the flood behaviour of the catchment and current guidance in both the Floodplain Development Manual and S117 Directive. Review of these guidelines shows that there is scope to potentially revise the current Commercial / Industrial FPL which could provide significant benefits in the Marrickville Valley considering the amount of flood affected industrial zoned land. A review of the climate change impacts in the Marrickville Valley suggests that the impacts of climate change can be suitably accounted for within the standard freeboard allowance. Therefore it is recommended that the current climate 1% AEP event be maintained as the design event for the FPL in Marrickville Valley.

Finally a review was conducted of the development controls applicable above the FPL up to the PMF level in light of the S117 Directive requirement for ‘exceptional circumstances’ applications:

- It is recommended that specific development controls be developed for high risk ‘vulnerable developments’ such as childcare centres, medical centres and aged care facilities. Typically floor level requirements for these developments are set at the PMF level. Development controls up to the PMF level for these development types are exempt from ‘exceptional circumstances’ application requirement of the S117 directive.
- Currently there are several development controls relating to emergency response which are applicable up to the PMF. However these controls do not require an application for ‘exceptional circumstances’ with the State Government, the reason for this is that an exemption is made for ‘critical emergency response and recovery facilities’. Therefore the current controls are suitable, with potential to apply additional controls relating specifically to shelter-in-place.
- The current basement carpark entry requirements are to the 1% AEP plus 0.5 metre freeboard, with requirements for pumping and emergency response for the basement are considered appropriate. Increasing entry level requirements to the PMF is not recommended as it would require an application to the State Government for ‘exceptional circumstances’ which do not seem appropriate based on flood risk in the Marrickville Valley.

9 Flood Risk Management Options

9.1 Background

9.1.1 Managing Flood Risk

Flood risk can be categorised as existing, future or residual risk.

> **Existing Flood Risk** – existing buildings and development on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding;

> **Future Flood Risk** – buildings and developments that may be built on flood prone land in the future. Such buildings and developments would be exposed to a flood risk when they are built; and

> **Residual Flood Risk** – buildings and development that would be at risk if a flood were to exceed management measures already in place. Unless a floodplain management measure is designed to withstand the PMF, it may be exceeded by a sufficiently large event at some time in the future.

The alternate approaches to managing risk are outlined in **Table 9-1**.

Table 9-1 Flood Risk Management Alternatives (SCARM, 2000)

Alternative	Examples
Preventing / Avoiding risk	Appropriate development within the flood extent, setting suitable planning levels.
Reducing likelihood of risk	Structural measures to reduce flooding risk such as drainage augmentation, levees, and detention.
Reducing consequences of risk	Development controls to ensure structures are built to withstand flooding.
Transferring risk	Via insurance – may be applicable in some areas depending on insurer.
Financing risk	Natural disaster funding.
Accepting risk	Accepting the risk of flooding as a consequence of having the structure where it is.

Measures available for the management of flood risk can be categorised according to the way in which the risk is managed. There are three broad categories:

> **Flood modification measures** – Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These options reduce the risk through modification of 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.

9.2 Flood Modification Options

9.2.1 Methodology for Identifying Options

The identification of appropriate flood risk management options for assessment within the Marrickville Valley floodplain has been achieved through the following steps:

> Assess flood behaviour throughout the catchment to determine the areas with frequent and significant flooding in larger events. These are the locations where flood risk management measures are most in need. Flood behaviour for the Marrickville Valley catchment is summarised in **Section 5.**Error! Reference source not found.

- Once the areas have been identified, it is possible to assess each location to formulate a preliminary list of feasible flood risk management options at each location. The feasibility of each preliminary option can be evaluated in relation to anticipated costs and benefits; and,
- Based on the review of preliminary options it is possible to identify a final list of options which can be assessed in further detail, through hydraulic modelling, costing, flood damages assessment, and multi-criteria assessment. This detailed assessment provides sufficient basis for their potential adoption within the Floodplain Risk Management Plan.

9.3 Flood Modification Measures

Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These measures reduce the risk through modification of the flood behaviour in the catchment.

9.3.1 Preliminary Flood Modification Options

For the Marrickville Valley study area a range of modification measures were considered including:

- Detention basins: Detain floodwaters to reduce the amount of flood affectation downstream. Suitable locations for this flood modification option are large public reserves in the catchment that can provide sufficient flood storage to significantly reduce peak discharges;
- Drainage upgrades: Aim is to improve conveyance of trunk drainage lines to reduce overland flow by upgrading of trunk drainage pipes where pipe capacity was found to be the limiting factor on drainage capacity and new drainage pipes diverting floodwaters to main channels with additional capacity; and
- Road raising: Improve flows over roadways by limiting road overtopping and diverting floodwaters into adjoining areas; and
- Creation of overland flowpaths: Divert floodwaters from adjoining properties.

In total, 69 preliminary flood modification options across 15 areas were identified for the Marrickville Valley floodplain. These options were developed to address all of the flood affected areas where practicable. The location of preliminary flood modification options and details are provided in **Appendix J**.

An initial desktop assessment was undertaken for the preliminary flood modification options based on approximate capital cost, number of flood affected properties benefitting (directly and indirectly), and likely constraints. From the list of preliminary options, a final list of measures was compiled in consultation with Council to determine which options were to be assessed through detailed hydraulic modelling. A summary of the final flood modification options selected for assessment is presented in **Table 9-2**.

Table 9-2 Final List of Floodplain Risk Management Options for Marrickville Valley Catchment

Drainage Line/Area	ID	Modification Type
Wardell Rd, Frazer Rd, Lawson Ave	FM1.1	Install new 900mm diameter pipe to re-direct flows from Morton Ave, down Frazer St to Frazer St low point adjacent to Lawson Ave. Install a new 1.8m X 1.2m box culvert from the low point along Frazer St to a new surcharge pit in Marrickville Oval. Additional sag inlet pits to increase inflows into the pipes.
	FM1.2	Divert flows from Wardell Rd via Morgan St and down Bishop St to Marrickville Oval via 600mm diameter pipes. Install a new 1.8m X 1.2m box culvert from the low point along Frazer St to a new surcharge pit in Marrickville Oval.
Pile St, Livingstone Rd and Marrickville Oval	FM2.1	Install orifice plate on Marrickville Oval basin outlet to maximise basin flood attenuation for up to the 20% AEP event
	FM2.3	Divert George Street catchment from Livingstone Road sag to Centennial St via 600mm diameter pipes
Northcote St and Sydenham Rd	FM3.1	Divert flows from Jarvie Park to Malakoff Tunnel with a new minimum 1050mm diameter pipe, upgrade drainage in Petersham Rd to 750mm diameter pipe and Northcote St to 450mm diameter pipe
	FM3.2	Install new pits and 1200mm diameter pipe along Sydenham Rd to divert flows from the intersection of Sydenham Rd and Petersham Rd to Malakoff Tunnel.
	FM3.3	New drainage in Sydenham Road and connect to Western Channel via 600mm diameter pipes
	FM3.4	Increase inlet capacity on Despointes St with 450mm diameter pipes, Silver St with 450mm diameter pipes and Sydenham Road near Garners Ave with 600mm diameter pipes
Neville St, Surrey St and Illawarra Rd	FM5.2	Demolish brick wall and structures built over drainage easement between Park and Neville Streets and upsize pipe to 450mm.
	FM5.3	Upgrade drainage in Addison Rd between Park Rd and Gordon Lane via 600mm diameter pipes
	FM5.4	New raised road thresholds at Park St, Neville St and Essex St
	FM5.6	Increase inlet capacity in Illawarra, York and Shephard Streets via 450mm diameter pipes
	FM6.1	Upgrade drainage in Newington Rd to 600mm diameter pipes

Drainage Line/Area	ID	Modification Type
Addison Rd, Newington Rd and Browns Ave	FM6.4	Install new inlet pits and 600mm diameter pipes along England Ave, Agar St and Wemyss St
Marrickville Industrial Area (MIA) - Addison Rd and Enmore Rd	FM 7.1	Upgrade drainage and additional inlet capacity near Smith St, Enmore Rd and Cook Rd. Install 600mm diameter pipes along Enmore Rd and Cook Rd, and 1800mm x 600mm box culvert along Smith St.
	FM7.5	Duplicate existing 600mm diameter pipe and new pits in Denby St and threshold on Denby St at Addison Rd
Crawford Pl, Livingstone Rd, Arthur St and Moyes St	FM8.1	New drainage in Arthur Street and connect to Malakoff tunnel via 600mm diameter pipe
	FM8.2	New drainage in Robert Street via 600mm diameter pipe
Marrickville Rd and Illawarra Rd	FM9.1	New drainage in Marrickville Road and connect to Malakoff tunnel via 600mm diameter pipes
Marrickville Industrial Area (MIA) Marrickville Rd, Meeks Rd, Myrtle St	FM10.1	Divert Marrickville Rd flows down Barclay Street to Sydenham Detention Basin via 600mm diameter pipes
	FM10.4	Divert flows from rail and Charlotte Ave into Western Channel via 900mm diameter pipe
Unwins Bridge Rd and Tillman Park	FM11.1	Construct overland flow Path from Unwins around edge of park to rail culvert
	FM11.2	Construct overland flow path from childcare centre around edge of park to rail culvert
	FM11.3	Upgrade drainage in Unwins Bridge Rd and Terry St via 600mm diameter pipes to connect to existing twin 900mm diameter pipes
	FM11.4	Upgrade drainage in Unwins Bridge Rd at Bridge Street via 450mm diameter pipe
Carrington Rd	FM12.1	Upgrade drainage in Cary St and Premier St to install new 750mm diameter pipes and inlet pits
	FM12.2	Upgrade drainage in Renwick St to install 750mm diameter pipes
	FM12.4	Remove checkboards in central channel, install GPT and backflow prevention and optimise pump station operation
	FM12.5	Raise channel wall to stop overflows in Cary street
	FM13.1	Upgrade drainage in Gannon St and Edwin St to 600mm diameter pipes

Drainage Line/Area	ID	Modification Type
Unwins Bridge Rd and Tramway Ave	FM13.2	Upgrade drainage in Griffiths St to 600mm diameter pipes
	FM13.5	Upgrade drainage in Brooklyn St and Union St to install 375mm - 450mm diameter pipes
Sutherland St and Unwins Bridge Rd	FM14.1	Upgrade the existing 675mm diameter pipe to a 1200mm diameter pipe or duplicate the pipe underneath Bolton St and railway line
Marrickville Industrial Area (MIA) - Victoria Rd and Sydenham Rd	FM15.1	Upgrade and extend drainage in Victoria Road south of Sydenham Rd and Victoria Lane to 600mm diameter pipes and Victoria Lane and Meeks Road to 600mm diameter pipes
	FM15.2	Upgrade and extend Drainage in Victoria Road north of Sydenham Rd to 600mm diameter pipes
	FM15.3	Divert Buckley St and Wilkinson Ln along Shirlow St to Sydenham pit via 1500mm diameter pipe
	FM15.5	Upgrade drainage in Faversham St to 600mm diameter pipes
	FM15.7	Upgrade drainage in Sydney Street with 600mm diameter pipe and Vincent Street with 900mm diameter pipe
	FM15.9	Drainage works along Saywell Street*. Duplicate 2.0m x 1.2m box culvert between Cadogan Lane and Sloane St and duplicate 3.0m x 1.2m box culvert between Sloane St and Sydenham pit. New junction chamber to connect existing and new culverts.
	FM15.10	Combination of FM15.3 and FM15.9*

**These options have been identified in lieu of option FM15.8 which was identified to be unfeasible during the option model set-up stage.*

To test the feasibility of each of the hydraulically assessed structural flood modification options, they were first run for the 2 year ARI and 1% AEP events to ensure they worked as expected and did not result in adverse flooding behaviour. The results of this analysis are summarised in the following sections which describe the outcome of the 2 year ARI and 1% AEP hydraulic modelling, and whether the option should be considered for further analysis. Peak flood depths and flood level difference plots for the 2 year ARI and 1% AEP have been prepared for each option, and the figures are provided in **Appendix K**.

9.3.2 FM 1.1

Description

An existing 750mm diameter pipe collects runoff from Morton Ave and traverses under properties along Wardell Rd, Jarvie Ave and Bishop St to connect to an existing 1050mm diameter pipe that runs underneath Marrickville Oval. In this option a new 900mm diameter pipe with additional inlet pits will re-direct runoff from Morton Ave to Frazer St and continue down Frazer St to connect to a new 1800mm X 1200mm box culvert from the sag along Frazer St to a new surcharge pit in Marrickville Oval. This option aims to reduce flooding for properties along Wardell Rd, Jarvie Ave, Bishop St, and Lawson Ave where up to approximately 600mm depth of flooding is observed in the 2 year ARI event.

***Modelling* Results**

The results highlight that the proposed diversion provides water level reductions of up to 30mm in the 2 year ARI event along Wardell Rd and Jarvie Ave, up to 90mm along Bishop St and up to 150mm along Frazer St and Lawson Ave. For the 1% AEP event water level reductions of up to 50mm are observed along Wardell Rd, Jarvie Ave, Bishop St, Frazer St and Lawson Ave. For the 1% AEP event this option removed over floor flooding for 4 properties.

9.3.3 FM 1.2

Description

An existing 750mm diameter pipe collects runoff from Morton Ave and traverses through properties along Wardell Rd, Jarvie Ave and Bishop St to connect to an existing 1050mm diameter pipe that runs underneath Marrickville Oval. In this option, additional inlet pits will collect runoff from Wardell Rd at the intersection of Morgan St and direct flows to the low point in Frazer St via new 600mm and 900mm diameter pipes in Morgan St and Bishop St, respectively. A new 1800mm X 1200mm box culvert will connect from the sag along Frazer St to a new surcharge pit in Marrickville Oval. This option may result in reduced flooding for properties along Wardell Rd, Jarvie Ave, Bishop St, Frazer Ave and Lawson Ave where up to approximately 600mm depth of flooding is observed in the 2 year ARI event.

***Modelling* Results**

The results highlight that the proposed diversion provides water level reductions of up to 20mm in the 2 year ARI event along Wardell Rd and Jarvie Ave, up to 60mm along Bishop St and up to 150mm along Frazer St and Lawson Ave. Increases in flood levels of up to 40mm are observed along Wardell Rd but these are confined within the road corridor and within the Marrickville Oval. For the 1% AEP event water level reductions of up to 60mm are observed along Bishop St, Frazer St and Lawson Ave. Increases in flood levels of up to 60mm are observed along Wardell Rd but these are confined within the road corridor.

The increases along Wardell Road are attributed to changes in catchment inflows, which for the option are applied to the new pit and pipe network along Morgan Street.

9.3.4 FM 2.1

Description

This option is to modify the basin outlet pit to install a 450mm outlet pit from the existing pit connected to a new pit with a high level inlet (approximately 500mm above the existing grate). In order to retain flows in a 20% AEP, the basin spillway to the north (approximately 9m wide) is raised to the existing 20% AEP flood level and modified to maintain the same spillway discharge for larger events. The objective of the proposed option is to throttle flows at the basin outlet to maximise basin flood attenuation up to the 20% AEP event. This option may result in reduced flooding for properties downstream of the basin in Livingstone Road and Petersham Road.

***Modelling* Results**

The results highlight that the proposed option increases the detention depth in Marrickville oval by up to 160mm in the 2 year ARI event and hence water level reductions of up to 80mm are observed downstream for properties along Livingstone Rd, Brereton Ave, Petersham Rd, Sydenham Rd and Boland Ave. For the 1% AEP event increases in water levels of up to 50mm are observed within the basin and properties downstream along Livingstone Rd, Brereton Ave, Petersham Rd, Sydenham Rd and Boland Ave. This is due to overtopping of the basin which is resulting in increased flooding downstream. This is due to the limitations in the model grid size to accurately fine tune the modified spillway to maintain the same flows. It is believed that refinements to the model setup would enable better results to be achieved for the 1% AEP with no increases in flood levels.

9.3.5 FM 2.3

Description

An existing 450mm diameter pipe runs along George St and connects to a 750mm diameter pipe along Livingstone Rd which then connects to a 750mm diameter pipe along Pile St. This option proposes a new 600mm diameter pipe with additional inlet pits along George St that will divert the runoff from George St and Livingstone Rd to the 1450mm X 2100mm box culvert underneath Centennial St via Hawkhurst St. This option may result in reduced flooding for properties along Livingstone Rd, Brereton Ave and Petersham Rd, which currently lie along an overland flow path from George St, Pile St and north of Marrickville Oval and experience approximately 30mm to 400mm depth of flooding in the 2 year ARI event.

***Modelling* Results**

The results highlight that the proposed diversion provides water level reductions of up to 30mm in the 2 year ARI event along Livingstone Rd, Brereton Ave, and several adjoining properties. Minor increases in flood levels of up to 40mm are observed but these are confined within the open channel between Boland Ln and Centennial St. Minimal differences are observed in 1% AEP event.

9.3.6 FM 3.1

Description

An existing 1050mm diameter pipe carries stormwater flows from Petersham Rd to the open Western Channel near Northcote St via Jarvie Park. In this option, a new 1050mm diameter pipe will divert flows from Jarvie Park to the existing box culvert underneath Malakoff Street (Malakoff Tunnel). In addition, pipes along Petersham Rd near Graham Ave and Stanley St will be upgraded to 750mm diameter and a new 450mm diameter pipe will be installed at the junction of Yabsley Ave and Northcote St. These upgrades aim to alleviate flooding in Jarvie Park and for properties along Petersham Rd, Northcote St and Carew Ln, where approximately 10mm to 300mm depth of flooding is observed in the 2 year ARI event, by diverting flows to Malakoff Tunnel from Western Channel, which the downstream section is currently running at capacity in a 2 year ARI event.

***Modelling* Results**

The results highlight that the proposed diversion and upgrades provide water level reductions of up to 100mm in the 2 year ARI event in Jarvie Park and for properties along Northcote St, Carew Ln and Malakoff St. For the 1% AEP event water level reductions of up to 30mm are observed in Jarvie Park and for properties along Carew Ln. However, localised increases in water level of up to 20mm are observed along Convent Ln and Warnam Ln. These increases are caused due to the additional flows in the Malakoff Tunnel which is at capacity in the 1% AEP event. The addition of flows results in reduced capacity of the upper Malakoff Tunnel to accept flows from the Sydenham Rd area. This results in increases in water levels in the area thereby causing increased overland flow for properties along Convent Ln and Warnam Ln.

9.3.7 FM 3.2

Description

This option involves installation of a new 1200mm diameter pipe along Sydenham Rd starting at Petersham Rd and joining the existing box culvert underneath Malakoff Street (Malakoff Tunnel). Additional pits and pipes will connect Park Rd and Neville St drainage to this new pipe. This option will collect overland flows off Sydenham Rd and divert it from the Western Channel to Malakoff Tunnel aiming to have general water level reductions along the route of the pipe and adjacent areas.

***Modelling* Results**

For the 2 year ARI event, water level reductions of up to 40mm are observed along Sydenham Rd, Northcote St, Carew Ln, Malakoff St, Warnam St, Despointes St and Peace Ln. Reductions in water levels of up to 130mm are observed in the Western Channel extending up to Garners Ln. For the 1% AEP event water level reductions of up to 40mm are observed along Sydenham Rd, Northcote St, Carew Ln and Warnam St. For the 1% AEP event this option removed over floor flooding for 2 properties.

9.3.8 FM 3.3

Description

This option includes a new 600mm diameter pipe along Sydenham Rd starting near Despointes St and connecting to the Western Channel box culvert underneath Illawarra Rd. This option will collect overland flows off Sydenham Rd and discharge to the Western Channel.

***Modelling* Results**

For the 2yr event, water level reductions of up to 20mm are observed at some locations along Sydenham Rd, Despointes St and Peace Ln. Increases of up to 40mm are observed in the Western Channel downstream of Peace Ln. For the 1% AEP event water level reductions of up to 30mm are observed along Illawarra Rd and increases of up to 50mm are observed in the Western Channel upstream and downstream of Peace Ln.

9.3.9 FM 3.4

Description

Existing 300mm diameter pipes collect street runoff from Despointes St and Silver St and discharge into the Western Channel. In this option, these pipes will be upgraded to 450mm diameter to help alleviate flooding along the streets where 200mm to 900mm depth of flooding is observed in the 2 year ARI event. In addition, a new 600mm diameter pipe along Sydenham Rd between Garners Ave and Garners Ln will collect overland flows off Sydenham Rd and discharge to the Western Channel.

***Modelling* Results**

For the 2 year ARI event, water level reductions of up to 30mm are observed on Despointes St, Sydenham Rd and Garners Ave and up to 180mm along Silver St. Increases of up to 110mm are observed in the Western Channel downstream of Peace Ln. For the 1% AEP event water level reductions of up to 60mm are observed along Sydenham Rd, Despointes St, Peace Ln, Illawarra Rd, Le Clos Ave and Silver St. Increases of up to 180mm are observed in the Western Channel between Malakoff St and Garners Ave. In addition increases of up to 420mm are observed at a few properties along Frampton Ave. This is attributed to the increases in water levels in the Western Channel preventing this area from draining to an outlet location with capacity to accept the flows.

9.3.10 FM 5.2

Description

This option involves demolition of existing brick walls and structures built over the existing drainage easement between 80-82 Neville Street and 34-36 Park Road and upgrade the existing 300mm diameter pipe along this easement to a 450mm diameter pipe. The option may result in reduced flooding along Park Rd and Neville St, however, may have small increases in flooding downstream of Neville St due to the additional flow coming through the drainage easement.

***Modelling* Results**

The results highlight that the proposed upgrades provide localised water level reductions of up to 170mm in the 2 year ARI event for a few properties along Park Rd and Neville St. However, increases in water levels of up to 50mm are observed along Surrey St, Essex St, several adjoining properties and at the Addison Road Community Centre. For the 1% AEP event water level reductions of up to 50mm are observed for a few properties along Park Rd and Neville St and increases in water levels of up to 20mm along Surrey St, Essex St and at the Addison Road Community Centre. For the 1% AEP event this option removed over floor flooding for 2 properties.

9.3.11 FM 5.3 and FM 5.4

Description

The existing 750mm diameter pipes along Addison Rd between Park Rd and East St have capacity to take more flows based on the pipe capacity assessment (**Section 5.4**). In this option, new 600mm diameter pipes with additional inlet pits between Park Rd and Gordon Ln will divert the overland flows to the existing Addison Rd 750mm pipe network with additional capacity. In addition, the road levels (thresholds) at the intersections of Park St, Neville St and Essex St with Addison Rd will be raised by 100mm to prevent overtopping of overland flows from Addison Rd.

***Modelling* Results**

The results highlight that the proposed raising of road thresholds and new pipes provide water level reductions of up to 50mm in the 2 year ARI event along Neville Ln, Surrey St, Essex St and at the Addison Road Community Centre. For the 1% AEP event water level reductions of up to 30mm are observed along Park Rd, Neville Ln, Surrey St, Essex St, Charles St and at the Addison Road Community Centre. For the 1% AEP event this option removed over floor flooding for 9 properties.

9.3.12 FM 5.6

Description

Existing 300mm to 375mm diameter pipes collect street runoff from Illawarra Rd, York St and Shepherd St and discharge into the Eastern Channel which traverse these streets. The pipes will be upgraded to 450mm diameter to help alleviate overland flooding from Addison Road.

***Modelling* Results**

For the 2 year ARI event, water level reductions of up to 400mm are observed along York St, 150mm along Illawarra Rd and Meeks Ln, and 50mm along Shepherd St, Meeks Ln and Handley St. Increases of up to 260mm are observed in the Eastern Channel downstream of Meeks Ln. These are confined within the open channel. For the 1% AEP event water level reductions of up to 120mm are observed along York St, 60mm along Illawarra Rd, Shepherd St, Meeks Ln, Handley St, Jazeb St, Denby St, Brompton St, Cook Rd and Smith St. For the 1% AEP event this option removed over floor flooding for 11 properties.

However, minor increases of up to 10mm are observed in the Eastern Channel downstream of Meeks Ln and also for properties along Fitzroy St, Lillian Fowler St, Saywell St and Sydenham pit. This is attributed to the increases in flow in the Eastern Channel causing flows to breakout of the channel along Smith St. A possible solution could be to raise the channel walls to prevent the breakout. This option can be optimised to resolve these issues during future investigation and design stages.

9.3.13 FM 6.1

Description

An existing 300mm diameter pipe on Newington Rd between Wemyss St and England Ave diverts runoff from Brown Ave and Wemyss St to a 1050mm diameter drainage pipe that runs between the rear of properties along England Ave and Agar St and connects to Addison Rd drainage. This pipe will be upgraded to a 600mm diameter pipe with additional inlet pits and a new 600mm diameter pipe along the other side of Newington Rd will collect and convey additional flows to the existing 1050mm diameter pipe. This option may help alleviate flooding for the properties along England Ave and Agar St where approximately 30mm to 230mm depth of flooding is observed in the 2 year ARI event.

***Modelling* Results**

The results demonstrate that the proposed upgrade and new pipe provides water level reductions of up to 40mm in the 2 year ARI event for properties along England Ave and Agar St. Minor increases of up to 30mm are observed on Newington Rd but these are within the road reserve. For the 1% AEP event minor water level reductions of up to 20mm are observed along few properties along England Ave and Agar St.

9.3.14 FM 6.4

Description

This option involves new 600mm diameter pipes and inlet pits along England Ave, Agar St and Wemyss St. These pipes will divert overland flows to the drainage lines along Addison Rd which have additional capacity. This option may result in water level reductions for properties north and south of Addison Rd where approximately 20mm to 650mm depth of flooding is observed in the 2 year ARI event.

***Modelling* Results**

For the 2 year ARI event, water level reductions of up to 20mm are observed along Illawarra Rd, York St, Shepherd St, and Meeks Ln. For the 1% AEP event water level reductions of up to 20mm are observed along England Ave, Addison Rd, Shepherd St, Meeks Ln, Denby St, Brompton St, Cook Rd and Smith St.

However minor increases of up to 20mm are observed in a 1% AEP event at some properties along England Ave and Agar St. Minor increases of up to 30mm are also observed in the Eastern Channel and Sydenham pit due to the increased flows upstream in the pipe network. This has attributed to the increase in flow in the Eastern Channel.

9.3.15 FM 7.1 and FM 7.5

Description

This option involves a new 600mm diameter pipe along Cook Rd and Enmore Rd to connect to a new 1800mm x 600mm box culvert along Smith St that will connect to the existing open channel (Eastern Channel) at the back of the properties along Smith St. This may help alleviate flooding along Cook Rd, Enmore Rd, Smith St and Victoria Rd where approximately 100mm to 400mm depth of flooding is observed in the 2 year ARI event.

In addition, a new 600mm diameter pipe along Denby St together with raised road threshold levels at the intersection of Denby St with Addison Rd may prevent overtopping of overland flows from Addison Rd and reduce flooding along Denby St where approximately 100mm to 800mm depth of flooding observed in the 2 year ARI event.

***Modelling* Results**

For the 2 year ARI event, water level reductions of up to 110mm on Brompton St, 50mm on Cook Rd and Enmore Rd, 100mm on Victoria and 300mm on Smith St are observed. Increases of up to 90mm are observed in the open channel. No impacts are observed near Denby St.

For the 1% AEP event water level reductions of up to 50mm are observed along Enmore Rd and Smith St, up to 40mm along Victoria Rd between Enmore Rd and Central Ln, and for properties on the eastern side of Victoria Rd. Increases of up to 30mm are observed in the open channel, properties along Fitzroy St and the Sydenham pit. Water level reductions of up to 50mm are observed along Addison Rd and Philpott St. For the 1% AEP event this option removed over floor flooding for 3 properties.

9.3.16 FM 8.1 and FM 8.2

Description

An existing 600mm diameter pipe along Arthur St connects to a 1050mm diameter pipe underneath the railway corridor which then connects into the Malakoff Tunnel underneath McNeilly Park. It is proposed that a new 900mm diameter pipe will connect the existing 600mm diameter pipe to the Malakoff Tunnel underneath Arthur St. In addition, a new 600mm diameter pipe along Robert St will connect to the existing 600mm diameter pipe along Arthur St.

This option could help alleviate flooding along Livingstone St, Arthur St, Warburton St, Jersey St, Illawarra Rd and the railway corridor where approximately up to a 1m depth of flooding is observed in the 2 year ARI event.

***Modelling* Results**

For the 2 year ARI event water level reductions of up to 50mm are observed along Livingstone St, Arthur St, Illawarra Rd, the railway corridor and Western Channel. For the 1% AEP event widespread reductions of up to 50mm are observed at McNeilly Park and along Illawarra Rd, Byrnes St, O'Hara St, Myrtle St, Carrington Rd and at Mackey Park. However, widespread increases in water levels of up to 70mm are observed along properties south of Sydenham Rd between Northcote St and Garners Ave and in the Marrickville Industrial Area (MIA) including the Sydenham Pit.

In the 1% AEP event Malakoff Tunnel is running at capacity between Malakoff St and McNeilly Park, hence the addition of flows at Arthur St results in reduced capacity of the upper Malakoff Tunnel to accept flows from the Sydenham Rd area. This results in increases in water levels in the area thereby causing increased overland flow along properties south of Sydenham Rd and diverting flows down Sydenham Rd to the MIA which increases loads on the Sydenham Rd and MIA drainage networks.

A possible solution could be to connect the new 900mm diameter pipe to Malakoff Tunnel downstream of McNeilly Park where it has capacity for PMF flows as shown in the pipe capacity assessment (**Section 5.4**). This option can be optimisated to resolve these issues during future investigation and design stages.

9.3.17 FM 9.1

Description

This option involves new a 600mm diameter pipe with inlet pits along Marrickville Rd between Livingstone Rd and Malakoff St. The new pipe will connect to the existing 2.9m X 2.9m box culvert underneath Malakoff St (Malakoff Tunnel). This option may help alleviate flooding for the properties in the Marrickville centre specifically in Illawarra Road and Central Avenue. This option may also help alleviate flooding for the properties along Lilydale St, Marrickville Rd, Petersham Rd and Malakoff St where approximately 20mm to 300mm depth of flooding is observed in the 2 year ARI event.

***Modelling* Results**

The results highlight that the proposed new pipe provides water level reductions of up to 50mm in the 2 year ARI event for properties along Cecilia St, Carew Ln and Malakoff St. For the 1% AEP event minor water level reductions of up to 20mm are observed at a few properties along Depot Ln, Malakoff St and Cecilia St.

However minor increases of up to 20mm are observed along Malakoff St, Convent Ln, Despointes St, Peace Ln and Illawarra Rd near the Western Channel in a 1% AEP event. These increases at the upstream end of Malakoff Tunnel are caused due to the additional flows in the Malakoff Tunnel which is at capacity in the 1% AEP event (as per description for FM8.1 and FM8.2).

It is recommended that this option could be optimised through alternative pit placement, pipe connections and possible throttling of flows into Malakoff Tunnel for higher events. This option may also be more effective in combination with another option which reduces flows entering Malakoff Tunnel at the upstream end near Sydenham Road.

9.3.18 FM 10.1

Description

An existing 450mm diameter pipe along Marrickville Rd connects to a 750mm diameter pipe underneath Fraser Park. A new 600mm diameter pipe with inlet pits will re-direct flows from Marrickville Rd to Sydenham Rd via Barclay St.

***Modelling* Results**

For the 2 year ARI event the proposed diversion provides water level reductions of up to 140mm along Barclay St, 60mm along Marrickville Rd and 20mm at Fraser Park. No differences are observed in the 1% AEP.

While this option does not provide any benefit in the 1% AEP event, this option combined with FM 15.3 could provide water level reductions in the area as FM 15.3 provides increased capacity in the network along Sydenham Rd, Sloane St and Saywell St.

9.3.19 FM 10.4

Description

This option involves a new 900mm diameter pipe with inlet pits along Myrtle St which will divert flows from Charlotte Ave to the Western Channel. This option may help alleviate flooding for properties along Charlotte Ave and Myrtle St where up to 700mm depth of flooding is observed in the 2 year ARI event.

***Modelling* Results**

For the 2 year ARI event the proposed new pipe provides water level reductions of up to 160mm along Victoria Rd at the rail bridge, 700mm for the property along Myrtle St and 30mm along Carrington Rd. Increases of up to 50mm are observed in the Western Channel. For the 1% AEP water level reductions of up to 50mm are observed along Victoria Rd at the rail bridge and Myrtle St.

9.3.20 FM 11.1 and FM 11.2

Description

This option involves construction of an overland flowpath along the north-eastern boundary of Tillman Park from Unwins Bridge Rd to the railway culvert and along the south-western boundary of Tillman Park from the Early Learning Centre to the railway culvert. This option may alleviate flooding along Unwins Bridge Rd where up to 900mm depth of flooding is observed in the 2 year ARI event.

***Modelling* Results**

The modelling results highlight that this option provides water level reductions of up to 150mm along Unwins Bridge Rd and up to 220mm at the Early Learning Centre for the 2 year ARI event. Increases of up to 900mm are observed downstream but these are mainly along the constructed overland flowpaths and are confined to the Park. For the 1% AEP event water level reductions of up to 230mm are observed at several locations along Unwins Bridge Rd, Terry Street, Belmore St and Railway Rd. For the 1% AEP event this option removed over floor flooding for 10 properties.

9.3.21 FM 11.3

Description

An existing 525mm diameter and 600mm diameter pipe on Unwins Bridge Rd connects to twin 900mm diameter pipes underneath Tillman Park. In this option, new 600mm diameters pipes along Unwins Bridge Rd and Terry St will connect to the existing twin pipes to divert additional overland flows. This option may result in decreases in flood levels along Unwins Bridge Rd and surrounding areas where up to 900mm depth of flooding is observed in the 2 year ARI event.

***Modelling* Results**

For the 2 year ARI event up to 80mm decreases in water levels are observed along Unwins Bridge Rd and Belmore St. Increases of up to 600mm are observed downstream but these are mainly confined to the Park. For the 1% AEP event water level reductions of up to 20mm only are observed at several locations along Unwins Bridge Rd, Terry Street, Belmore St, Railway Rd and Tillman Park. For the 1% AEP event this option removed over floor flooding for 2 properties.

9.3.22 FM 11.4

Description

An existing 675mm diameter pipe along Unwins Bridge Rd connects into a 900m diameter and 750mm diameter pipe along Bridge St. A new 450mm diameter pipe and additional inlet pits along Unwins Bridge Rd near Bridge St will divert additional runoff to the existing pipes along Bridge St. This option may result in decreases in flood levels along Unwins Bridge Rd where up to 900mm depth of flooding is observed in the 2 year ARI event.

***Modelling* Results**

For the 2 year ARI event up to 80mm decreases in water levels are observed along Unwins Bridge Rd and up to 20mm along Belmore St. For the 1% AEP event minor water level reductions of up to 50mm are observed along Unwins Bridge Rd.

9.3.23 FM 12.1 and FM 12.2

Description

Existing 450mm diameter pipes along Renwick St, Cary St and Premier St and discharge into the Western Channel. New 750mm diameter pipes and inlet pits will collect additional overland flows from these streets and discharge into the Western Channel. This option aims to reduce flooding along the streets and intercept runoff from bypassing the Western Channel and entering Central Channel along Carrington Rd thereby reducing flooding along Carrington Rd.

***Modelling* Results**

For the 2 year ARI event decreases in water levels in the order of 20mm to 60mm are observed along Renwick St and Carrington Road. Increases in flood levels are seen in the Western Channel between Renwick St and Cary St due to additional flows. For the 1% AEP event decreases in water levels up to 80mm are observed along Renwick St. Increases in flood levels are seen in the Western Channel between Renwick St and Cary St due to additional flows and also up to 40mm for some properties along Renwick St. For the 1% AEP event this option removed over floor flooding for 5 properties.

9.3.24 FM 12.4

Description

During set-up this option was optimised to include installation of a weir to 1.1m AHD in the central channel to divert the flows into the Mackey Park pump station (DPS2). The proposed option is to prevent the backflow from the Cooks River in the Central Channel entering the pump station and thereby optimising the pump station operations at Mackey Park to pump more catchment flows away from the area. The aim is to reduce flood levels on Carrington Road and surrounding industrial area.

***Modelling* Results**

The modelling results show that the reduction in flood levels in a 2 year ARI event are in the order of 20mm to 120mm in vicinity of Carrington Road, Renwick St east of Carrington Rd and along the Central Channel alignment. Maximum reductions up to 120mm are observed at a low point on Renwick Street. In a 1% AEP event the impacts are negligible due to the large volume of water stored in the area.

Further optimisation of this option could be to explore increasing the capacity of pumps to achieve further reductions in flood levels.

Remove checkboards in central channel, install GPT and backflow prevention and optimise pump station operation

9.3.25 FM 12.5

Description

The proposed option is to raise the Western Channel wall between Renwick St and Cary St to prevent overflows into adjacent properties and in Cary Street. Reduction in flood levels are expected in Cary Street and Renwick Street

***Modelling* Results**

Raising the channel wall prevents the over flow entering the properties on the eastern side of the channel between Renwick Street and Cary Street in a 2 year ARI event. In a 1% AEP event the impacts are minor. This option does not provide major benefits as expected for properties along Renwick St and Cary St near the channel due to the topography grading back towards the channel. The raised wall traps some water behind it preventing it from entering back into the channel.

9.3.26 FM 13.1, FM 13.2 and FM 13.5

Description

This option involves new 600mm diameter pipes with inlet pits along Gannon St and Griffiths St to connect to an existing 1500mm x 700mm box culvert underneath the railway corridor. This option may help alleviate flooding along these streets where up to 700mm depth of flooding is observed in the 2 year ARI event. In addition new pits and 450mm diameter pipes at the intersection of Brooklyn St and Union St will connect to an existing 1200mm X 450mm box culvert.

***Modelling* Results**

The modelling results highlight that the proposed new pits and pipes provide reductions in water levels up to 50mm along Gannon St, however increases in water levels up to 100m along Gannon St, Griffiths St and Unwins Bridge Rd in the 2 year ARI event. The increases are due to the downstream pipe at capacity for the 2 year ARI event. Negligible benefits are observed on Brooklyn St and Union St. For the 1% AEP event minor decreases in water levels of up to 20mm are observed on Brooklyn St and Gannon St but some increases in water levels of up to 20mm are observed on properties along Unwins Bridge Rd and Griffiths St.

9.3.27 FM 14.1

Description

Existing 600mm diameter pipes connect inlet pits at the intersection of Unwins Bridge Rd and Sutherland St to a 675mm diameter pipe that passes underneath the railway line and connects to the Eastern Channel. These pipes will be upgraded to 1200mm diameter pipes. This option may result in decreases in flood levels along Unwins Bridge Rd and surrounding areas by discharging additional flows into the Eastern Channel. Greater than 1m flood depth is observed in some of these areas for the 2 year ARI event.

***Modelling* Results**

The modelling results highlight that the proposed upgrades provide water level reductions of up to 150mm along the railway corridor and for a few properties along Bolton St and up to 30mm along Unwins Bridge Rd. For the 1% AEP event additional reductions of up to 80mm are observed along George St, Hogan Ave, Sutherland St and Briar Ln.

9.3.28 FM 15.1 and FM 15.2

Description

For Victoria Rd north of Sydenham Rd up to 300mm depth of flooding is observed in the 2 year ARI event. Two 450mm diameter pipes on either side of the road discharge runoff into an existing box culvert underneath the Victoria Rd and Sydenham Rd intersection which connects to the Sydenham pit. The pipe along the eastern side of the road will be extended and upgraded to a 600mm diameter pipe to help alleviate flooding in the area.

For Victoria Rd south of Sydenham Rd up to 500mm depth of flooding is observed in the 2 year ARI event. Two 375mm diameter pipes on either side of the road discharge runoff into an existing box culvert underneath the Victoria Rd and Sydenham Rd intersection which connects to the Sydenham pit. The pipe along the eastern side of the road will be extended and upgraded to 600mm diameter pipe to help alleviate flooding in the area.

In addition, new 600mm diameter pipes along Victoria Ln and Meeks Ln will collect additional flows and convey them to the Sydenham pit.

***Modelling* Results**

For the 2 year ARI event less than 20mm reductions in water levels are observed along Victoria Rd north of Sydenham Rd, no reductions along Victoria Rd south of Sydenham Rd and up to 20mm reductions along Victoria Ln, Meeks Ln and Vincent St. For the 1% AEP event no impact on flood behaviour is observed.

While this option does not provide any benefit in the 1% AEP event, this option combined with FM 15.3 could provide water level reductions in the area as FM 15.3 provides increased capacity in the network along Sydenham Rd, Sloane St and Saywell St.

9.3.29 FM 15.3

Description

This proposed option is to divert flows from Buckley St and Wilkinson Ln into Shirlow St via a new 1500mm diameter pipe to the Sydenham pit. This option may alleviate flooding in the vicinity of the proposed works.

***Modelling* Results**

The modelling results show there are negligible benefits for the 2 year ARI event but for the 1% AEP event the extent of reduction in flood levels is significant with reductions of up to 200mm observed along Shirlow St and Garden St. The reductions on Buckley St and Sydenham Rd are up to 80mm. The increases in levels in the Sydenham pit is due to the additional flows. This option provides increased capacity in the network along Sydenham Rd, Sloane St and Saywell St, which could provide opportunity for upgrades in the western industrial area catchments to improve flooding in those areas.

For the 1% AEP event this option removed over floor flooding for 14 properties.

9.3.30 FM 15.5

Description

An existing 450mm diameter pipe along Faversham St will be upgraded to a 600mm diameter pipe. This option will provide additional capacity and collect overland flows off Faversham St.

***Modelling* Results**

The modelling results highlight that this option has no impact on flood behaviour in the 2 year ARI and 1% AEP event. While this option has resulted in increased flows through the upgraded pipe, these are minor and hence do not provide any benefits to flooding.

9.3.31 FM 15.7

Description

An existing 600mm diameter pipe along Vincent St and Sydney St connects to a 1050mm diameter pipe along Sydenham Rd. A new 600mm dimeter pipe along Sydney St and 900mm diameter pipe along Vincent St will collect the overland flows and discharge downstream to the existing 1050mm diameter pipe that eventually discharges into the Sydenham Pit. This option may alleviate some of the flooding identified in the surrounding area.

***Modelling* Results**

The results highlight that while although up to 100mm reduction in water levels are observed along Sydney St, there is an increase in flood levels up to 10mm along Vincent St for the 2 year ARI event. The increases are a result of the additional flows in the downstream 1050mm diameter pipe from the new 600mm diameter pipe along Sydney St. This pipe is currently at capacity in a 2 year ARI event and the additional flows have surcharged onto Vincent St causing increased flooding. Similarly for the 1% AEP event increases in water level are observed along Sydenham Rd and Barclay St.

While this option does not provide much benefit and causes increases in flood depths along Vincent St and Barclay St, this option combined with FM 15.3 could provide water level reductions in the area as FM 15.3 provides increased capacity in the network along Sydenham Rd, Sloane St and Saywell St.

9.3.32 FM 15.9

Description

The proposed option is to duplicate the existing 2000mm x 1200mm box culvert underneath Saywell St between Cadogan Lane and Sloane St and duplicate the existing 3000mm x 1200mm box culvert underneath Saywell St between Sloane St and the Sydenham pit. A new junction chamber will be installed to connect existing and new culverts. A number of new large inlet pits are proposed to take more flows into the proposed pipe network. This option is expected to reduce flood levels in the industrial area between Saywell St and Sydenham Rd.

***Modelling* Results**

The modelling results show there are negligible benefits for the 2 year ARI event as this area only has small depths of flooding in the 2 year ARI event. For the 1% AEP event decreases in flood levels of up to 500mm are observed within the industrial area. The reduction of flood levels between Sydenham Rd and Marrickville Rd are in an order of 100mm to 150mm. Maximum reduction of flood levels are seen on Saywell St, Sydenham Rd, Shirlow St, Sloane Ln, Sloane St, Cadogan Ln and Cadogan St. The increases in water levels in the Sydenham pit are due to the additional flows. For the 1% AEP event this option removed over floor flooding for 23 properties.

It is likely that this option could be optimised for the 2 year ARI event by providing additional inlet pits in flooded areas such as between Sydenham Rd and Marrickville Rd as the underground network now has additional capacity to accept more flows from these areas.

9.3.33 FM 15.10

Description

This option is a combination of FM15.3 and FM15.9. The proposed works are to divert flows from Buckley St and Wilkinson Ln into Shirlow St via a 1500mm diameter pipe to Sydenham pit along with duplication of the existing drainage network in Saywell Street. This upgrade includes duplication of the existing 2000mm x 1200mm box culvert between Cadogan Lane and Sloane St and duplication of the existing 3000mm x 1200mm box culvert between Sloane St and Sydenham Pit.

***Modelling* Results**

The modelling results show there are negligible benefits for the 2 year ARI event as this area only has small depths of flooding in the 2 year ARI event. For the 1% AEP event decreases in flood levels of up to 600mm are observed within the industrial area. The reduction of flood levels are seen in the industrial area between Marrickville Rd and Saywell St. Maximum reduction of flood levels in the order of 200mm to 600mm are seen on Marrickville Rd, Barclay St, Buckley St, Sydenham Rd, Shirlow St, Sloane Ln, Sloane St, Cadogan Ln, Cadogan St and Saywell St. The increases in water levels in the Sydenham pit are due to the additional flows. For the 1% AEP event this option removed over floor flooding for 37 properties.

As for FM 15.9, it is likely that this option could be optimised for the 2 year ARI event by providing additional inlet pits in flooded areas such as between Sydenham Rd and Marrickville Rd as the underground network now has additional capacity to accept more flows from these areas.

9.4 Property Modification Measures

The following four property modification measures have been assessed for Marrickville Valley:

> Voluntary purchase;
> House raising;
> Land swap;
> Flood proofing;
> Increased street sweeping; and
> Stormwater pit maintenance.

9.4.1 PM 1 – Voluntary Purchase

Voluntary purchase is the optional purchase of pre-selected properties funded jointly by Council and the State Government. It would free both residents and emergency services personnel from the hazard of future floods by removing the risk, and is achieved by the purchase of properties and the removal and demolition of buildings. Properties could be purchased by Council at an equitable price and only when voluntarily offered. Such areas would then need to be re-zoned under the LEP to a flood compatible use, such as recreation or parkland, or possibly redeveloped in a manner that is consistent with the flood hazard.

This option identifies the worst affected properties on the floodplain and, through state government assistance; properties become eligible for voluntary purchase so that the flood risk for these properties can be removed. **Figure 9-1** identifies the properties that are subject to over floor flooding for the 2 year ARI event.

Voluntary House Purchase is funded by Council with assistance from the State Government. However, due to the relatively expensive nature of such a program, limited availability of Government and/or Council funding can be a major constraint to undertaking Voluntary House Purchases. Typically, only a small number of properties within a floodplain can be considered for Voluntary Purchase, however more can be assisted if funding is available.

The following criteria have been established to identify properties that may merit further investigation for voluntary purchase:

> The property is a residential property;
> Overfloor flooding occurs in a 2 year ARI event; and
> No viable flood modification options are identified within the vicinity of the property.

The following twelve (12) properties were identified as fulfilling the criteria for voluntary house purchase.

> 215 Sydenham Rd, Marrickville;
> 217 Sydenham Rd, Marrickville;
> 219 Sydenham Rd, Marrickville;
> 221 Sydenham Rd, Marrickville;
> 223 Sydenham Rd, Marrickville;
> 4 McRae St, Petersham;
> 3 Audley St, Petersham;

> 30 Morgan St, Petesham;
> 18 Fotherigham St Enmore;
> 1 Wells Ave, Tempe;
> 3 Wells Ave, Tempe; and
> 5 Wells Ave, Tempe.

Since a detailed floor level survey has not been undertaken and over floor flooding has been estimated based on a desktop assessment, the validity of this information and the suitability of the subject properties for voluntary purchase would need to be verified by Council prior to proceeding with applications for voluntary purchase of these properties.

9.4.2 PM 2 – House Raising

House raising is a measure designed to reduce the incidence of over-floor flooding of existing buildings through works funded by Council, and with assistance from the NSW Office of Environment and Heritage (OEH). The Guidelines for voluntary house raising schemes (OEH, 2013a) sets out ineligibility criteria for house raising under the Voluntary House Raising (VHR) scheme and include the following:

> Properties which are already benefiting substantially from other floodplain mitigation measures, such as houses already protected by a levee, and those that will be under future plans.

> Properties that would not achieve a positive benefit through damage reduction relative to cost (i.e. benefit-cost ratio less than 1). Consideration may be given to lower benefit-cost ratios where there are substantial social and community benefits, or where the VHR is compensatory work for the adverse impacts of other mitigation works.

The scheme should involve raising residential properties above a minimum design level, generally the council's flood planning level (FPL), and comply with the council's relevant development control requirements. This option is not applicable for properties which are "slab on ground" construction.

The following criteria have been established to identify properties that may merit further investigation for house raising:

> The property is a residential property with pier construction (i.e. not slab on ground);
> Overfloor flooding occurs in a 2 year ARI event; and
> No viable flood modification options are identified within the vicinity of the property.

Given that majority of the houses in the study area are slab on ground, no suitable properties were identified as fulfilling the criteria for house raising. However since a detailed floor level survey has not been undertaken and over floor flooding has been estimated based on a desktop assessment, the validity of this information and the suitability of the properties for house raising would need to be verified by Council.

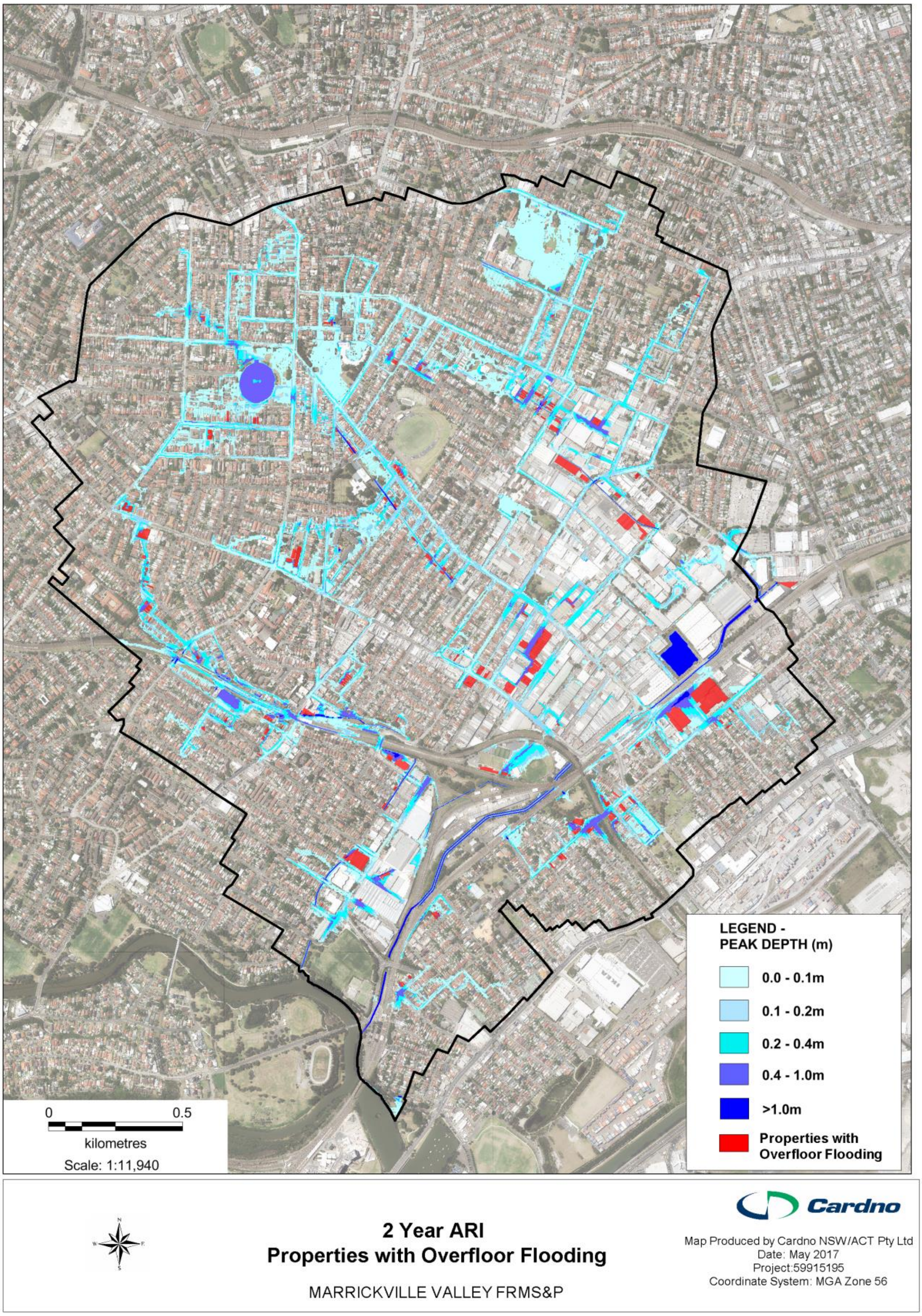


Figure 9-1 **Properties with over floor flooding in a 2 year ARI event**

9.4.3 PM 3 – Land Swap

An alternative to voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land outside of the flood prone area, such as an existing park, for a parcel of flood prone land with the appropriate transfer of any existing facilities to the acquired site. After the land swap, Council would then arrange for demolition of the building and have the land re-zoned under the LEP to open space.

Since a detailed floor level survey has not been undertaken and over floor flooding has been estimated based on a desktop assessment, it is recommended that Council undertake a detailed floor level survey to validate if properties identified for voluntary purchase are suitable for land swap.

9.4.4 PM 4 – Flood Proofing Guidelines

Flood proofing involves undertaking structural changes and other procedures in order to reduce or eliminate the risk to life and property, and thus the damage caused by flooding. Flood proofing of buildings can be undertaken through a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding. It is primarily suited to industrial or commercial properties.

The Floodplain Development Manual (NSW Government, 2005) advises that flood proofing is an additional measure to other measures. It is noted that flood proofing may minimise structural and contents damage but the occupants may still experience social and economic disruption caused by flooding.

Potential flood proofing measures include modifications or adjustments to building design, site location or placement of contents. Measures range from elevating or relocating a building and temporary flood barriers to the intentional flooding of parts of the building during a flood in order to equalise pressure on walls and prevent them from collapsing.

Option PM4 provides for the development of guidelines on flood proofing measures that may be considered for properties located within the floodplain. These guidelines could be included as an attachment to the DCP.

Examples of proofing measures include:

> All structural elements below the FPL shall be constructed from flood compatible materials;
> All structures must be designed and constructed to ensure structural integrity for immersion and impact of debris up to the 100 years ARI flood event. If the structure is to be relied upon for shelter-in-place evacuation then structural integrity must be ensured up to the level of the PMF; and
> All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the FPL.

The NSW SES Flash Flood Tool Kit (SES, 2012) provides businesses with a template to create a flood-safe plan and to be prepared to implement flood proofing measures.

In addition to flood proofing measures that are implemented to protect a building, temporary / emergency flood proofing measures may be undertaken prior to or during a flood to protect the contents of the building.

These measures are generally best applied to commercial properties.

These measures should be carried out according to a pre-arranged plan and may include:

> Raising belongings by stacking them on shelves or taking them to a second storey of the building;
> Securing objects that are likely to float and cause damage;
> Re-locating waste containers, chemicals and poisons well above floor level; and
> Installing any available flood proofing devices, such as temporary levees and emergency water sealing of openings.

Flood proofing barriers ranging from single door entries and car park entries to whole building frontages have been installed to new buildings and retrofitted to existing buildings. The systems vary in design, operation and their aesthetic impact. They include:

> Flood proof doors – being a normal use pedestrian door or bi-fold flood barriers that recess into a wall cavity (potentially for a double-door shop front);

- Flood proof roller doors – typical roller doors in appearance which seal at the frame edges to exclude water ingress;
- Manual flood barriers – generally removable panels that slot into a frame installed across the opening (a single person operation);
- Automatic flood barriers – a solid barrier that rises from a recess in the ground. The barriers can raise automatically using float switches / water level sensors and utilise battery backup / uninterruptable power supplies; and
- Temporary levees – a temporary levee wall created by planks installed within guideposts or tilt-up panels.

A significant advantage of these systems is that they can be retrofitted to existing buildings where permanent flood protection systems are not reliant on mechanical or manual input. The manual flood barrier systems rely on persons to install the components, however a flood event may occur at a time when the property is unoccupied, thereby relying on pre-emptive installation of the system prior to leaving the premises.

Automatically operated systems require regular maintenance and testing to ensure they will operate to specifications. Training on installation and operation of the devices would also be required. Some devices also preclude access as they are designed as barriers to be impermeable to flood water. Flooding in the catchment is primarily of short duration and rapid rise, meaning the flood proofing systems must be installed quickly but that they may not be required to be installed for extended periods.

Building Entries

Flood proof doors are designed as functional systems and may impact on aesthetics and accessibility. For example, some doors may be more suited as fire-exits rather than shop entries where they may be too obtrusive. Slot in barriers may be the most applicable method for flood proofing entries to commercial buildings. Care in storage of the barriers and ready access to them in case of a flood event will also be required.

Basement Car Parks

Flood proof roller doors may be suitable to replace existing roller doors to exclude flood waters from inundation of garages. Automatic flood barriers rising from the ground are potentially applicable to retrofit existing entry ramps into basement car parks to provide flood proofing to the required level.

The ability of these flood proofing measures to exclude inundation of flood water is dependent on the installation and maintenance. Systems not properly installed or maintained will compromise their effectiveness at providing barriers to flooding. A flood proofing strategy will need to be developed to assess the applicability of measures for specific locations in the catchment and acceptance / operation of the systems by users and property owners.

9.4.5 PM 5 – Increased Street Sweeping

Vegetated road sides result in significant leaf and branch drop which build up over time and often results in drainage inlet pits blocking rapidly when runoff events occur. This can lead to concentrated and uncontrolled overland flows occurring downslope of these inlets thereby increasing surface flows through streets and private properties. It is recommended that regular street sweeping is undertaken to reduce the potential for the inlets to become blocked and subsequently reduce the frequency of uncontrolled overland flows on streets and through private properties.

9.4.6 PM 6 – Stormwater Pit Maintenance

In addition to regular street sweeping which reduces the potential for inlet pits to become blocked, it is also recommended that stormwater pits in areas subject to flooding are cleaned on a more frequent basis. Suction machines can be used to remove silt and rubbish from the pits.

9.5 Emergency Response Modification Measures

The following emergency response options have been assessed for Marrickville Valley.

- Identification of evacuation centres;

- Information transfer to the NSW SES;
- Flood response for vulnerable properties;
- Local evacuation measures;
- Flood awareness and education;
- Interactive flooding mapping; and
- Education and awareness of littering.

9.5.1 EM 1 –Evacuation Centres

There are no evacuation centres identified within the Marrickville Flood Emergency Sub Plan. It is recommended that evacuation centres for flood events be reviewed and updated for the whole of the Inner West Council area and centres be rationalised for all types of emergencies.

In order to assist with this process, the following potential sites within the Marrickville Valley have been identified that may be suitable to function as evacuation centres during and following a flood event.

- Marrickville Town Hall;
- Petersham Town Hall;
- St Peters Town Hall; and
- Annette Kellerman Aquatic Centre.

Council and the SES should liaise with the managers of the venues identified to determine appropriate evacuation centres.

9.5.2 EM 2 – Information transfer to the NSW SES

The findings of this FRMS are an important source of catchment specific information for the NSW SES and Council. Details of flood risks at specific locations are important for planning of operational tasks and for the future review of the Marrickville Flood Emergency Sub-Plan.

9.5.3 EM 3 – Flood Response for Vulnerable properties

The flash flooding nature of Marrickville Valley will make it difficult for SES to coordinate the evacuation of vulnerable sites such as child care centres, schools, aged care centres, and retirement villages within the time available from the onset of rainfall.

It is therefore recommended that individual flood response plans for those vulnerable developments that are affected by the 1% flood event be a provision in the DCP. It is also recommended that Council with assistance from SES encourage the owners/tenants of current vulnerable properties to develop site based flood plans.

9.5.4 EM 4 – Local Evacuation Measures

The currently adopted flood evacuation procedures involve SES doorknocking. The review of the evacuation timeline for Marrickville Valley concluded that the catchment is affected by flash flooding and there is insufficient time to evacuate residents using the SES assisted doorknock approach. A number of alternatives is recommended to improve the evacuation timeline:

- Use of alternative flood warning systems including social media and telephone based approaches all providing potential reductions to the time required for evacuation compared to doorknocking;
- Self-managed evacuation which can be implemented for all new developments through requirements within development controls relating to preparation of a flood emergency response plan and site specific flood warning systems; and
- Improved flood awareness is likely to significantly reduce the time required for residents to evacuate as it improves awareness of the severity of the flood risk and the flash flooding nature of the catchment.

The other alternative to evacuation is the use of shelter-in-place provisions which can be applied to new development through development controls. This is assumed to be a suitable alternative for the majority of the Marrickville Valley and reduces the strain on SES resources and reduces the time required for response.

9.5.5 EM 5 – Flood Awareness and Education

Flood awareness is an essential component of flood risk management for people living in the floodplain. The affected community must be made aware of, and remain aware of, their role in the overall floodplain management strategy for their area. This includes preparations to reduce the risk of damage, the defence of their property and their evacuation (if required) during a flood event.

Flood awareness campaigns need to be an ongoing process and require the continuous effort of relevant organisations (e.g. Council and NSW SES). A major factor determining the degree of awareness within the community is the frequency of moderate to large floods in the recent history of the area. For effective flood emergency planning, it is important to maintain an adequate level of flood awareness during the extended periods when flooding does not occur. A continuous awareness program needs to be undertaken to ensure new residents are informed, awareness among long-term residents is maintained, and to allow for changing flood behaviour and new developments.

Review of the demographic characteristics of the catchment (**Section 2.6**) identified that languages other than English are the first language of a proportion of the community. Therefore, education programs and the publication of outcomes of this Study will need to consider platforms that may be effective across several different languages, particularly those prevalent in the community.

It is recommended that webpages within Council’s websites, dedicated to awareness of flooding, are developed and promoted. These webpages should link to the SES floodsafe or stormsafe website and Marrickville SES Unit website for announcements. It’s also recommended to amend Council call centre on-hold message to guide people to website to help prepare for flood events and only call SES in an emergency.

The use of local and social media and other means to reinforce flood awareness when it is most within the public consciousness, following significant flood events, may also be valuable.

9.5.6 EM 6 – Interactive Flood Mapping

As part of the Leichhardt FRMS&P, Inner West Council (previously Leichhardt Council) in collaboration with Cardno, developed an interactive web viewer to represent the final stages of this community consultation. The interactive web viewer was developed with the purpose of presenting flood results clearly and provide a new way for the community to engage with the results of the floodplain risk management process.

The web map displays results for 1% AEP and PMF events including depth, hazard and flood level from the FRMS&P. Usually these results are only available through figures in a report which, due to a large area covered by the report, may potentially be irrelevant or not useful to community members seeking flood information about their street or neighbourhood. Instead of sorting through pages of technical reports and figures, members of the community can view these results in a single website and view detailed information that is relevant to them.

The value of an interactive web map is that the community is able to see where their neighbourhood is affected, view potential egress routes in case of evacuations and understand the extent of flood risk within their community.

It is recommended that Council consider implementing a web based mapping tool for the entire Inner West Council area including the Marrickville Valley catchment.

9.5.7 EM 7 – Education and Awareness of Littering

One of the key topics discussed at the community workshops undertaken as part of this study was the issue of littering, particularly domestic and industrial rubbish, and the impact it has on flooding in the area. Litter can cause blockages in stormwater drainage pits and pipes which lead to concentrated and uncontrolled overland flows occurring downslope and thereby increasing surface flows through streets and private properties.

The definition of ‘litter’ under section 144A of the NSW Protection of the Environment Operations Act 1997 (POEO Act) is as follows:

‘Litter’ includes:

(a) 'any solid or liquid domestic or commercial refuse, debris or rubbish and, without limiting the generality of the above, includes any glass, metal, cigarette butts, paper, fabric, wood, food, abandoned vehicles, abandoned vehicle parts, construction or demolition material, garden remnants and clippings, soil, sand or rocks, and;

(b) any other material, substance or thing deposited in a place if its size, shape, nature or volume makes the place where it is deposited disorderly or detrimentally affects the proper use of that place, deposited, in or on a place, whether or not it has any value when or after being deposited in or on the place.'

Raising awareness and educating the community can influence peoples' behaviour and encourage them to dispose litter appropriately and responsibly.

Some of the education and awareness campaigns/ programs for Council to consider include:

> Drain stencilling;

> Educational campaigns for users of commercial and industrial bins;

> Signage and factsheets; and

> Put links on Council website to available resources and information such as the NSW Government's "Hey Tosser!" litter prevention campaign.

10 Economic Assessment of Options

10.1 Preliminary Costing of Options

Preliminary cost estimates have been prepared for those Flood Modification measures that allow for an economic assessment via consideration of the cost of implementation and the associated reduction in flood damages (**Table 10-1**). For other measures (Planning, Emergency Management), costs were estimated only on the basis of cost to implement, and were done for the purpose of comparison in the multi-criteria assessment detailed in **Section 11** of this report.

Prior to a measure proceeding it is recommended that, in addition to detailed analysis and design of the measure, these costs be revised to achieve a more accurate assessment for overall budget allocation. Detailed rates and quantities will also be required at the detailed design phase. A cost breakdown for each option is provided in **Appendix L**.

Table 10-1 Cost Estimates for Quantitatively Assessed Measures

Drainage Line/Area	Option ID	Capital Costs (incl. GST)	Ongoing (Annual) Costs (incl. GST)*
Wardell Rd, Frazer Rd, Lawson Ave	FM1.1	$2,328,000	$23,280
	FM1.2	$2,208,900	$22,089
Pile St, Livingstone Rd and Marrickville Oval	FM2.1	$72,000	$720
	FM2.3	$2,436,000	$24,360
Northcote St and Sydenham Rd	FM3.1	$936,100	$9,361
	FM3.2	$2,288,700	$22,887
	FM3.3	$526,300	$5,263
	FM3.4	$631,200	$6,312
Neville St, Surrey St and Illawarra Rd	FM5.2	$222,600	$2,226
	FM5.3 & FM5.4	$1,465,800	$14,658
	FM5.6	$324,600	$3,246
Addison Rd, Newington Rd and Browns Ave	FM6.1	$422,900	$4,229
	FM6.4	$580,800	$5,808
Marrickville Industrial Area (MIA) - Addison Rd and Enmore Rd	FM 7.1 & FM 7.5	$1,681,100	$16,811
Crawford Pl, Livingstone Rd, Arthur St and Moyes St	FM8.1 & FM 8.2	$343,800	$3,438

Drainage Line/Area	Option ID	Capital Costs (incl. GST)	Ongoing (Annual) Costs (incl. GST)*
Marrickville Rd and Illawarra Rd	FM9.1	$774,800	$7,748
Marrickville Industrial Area (MIA) Marrickville Rd, Meeks Rd, Myrtle St	FM10.1	$811,600	$8,116
	FM10.4	$499,300	$4,993
Unwins Bridge Rd and Tillman Park	FM11.1 & FM 11.2	$477,900	$4,779
	FM11.3	$404,300	$4,043
	FM11.4	$404,400	$4,044
Carrington Rd	FM12.1 & 12.2	$1,722,200	$17,222
	FM12.4	$95,500	$955
	FM 12.5	$347,400	$3,474
Unwins Bridge Rd and Tramway Ave	FM13.1, FM 13.2 and FM 13.5	$660,600	$6,606
Sutherland St and Unwins Bridge Rd	FM14.1	$563,300	$5,633
Marrickville Industrial Area (MIA) - Victoria Rd and Sydenham Rd	FM15.1 & FM 15.2	$946,900	$9,469
	FM15.3	$1,604,400	$16,044
	FM15.5	$153,800	$1,538
	FM15.7	$951,500	$9,515
	FM 15.9	$2,543,500	$25,435
	FM 15.10	$4,112,200	$41,122

**The ongoing costs have been based on an estimate of 1% of the capital cost.*

10.2 Annual Average Damages assessment

An assessment of AAD for the existing condition was presented in **Section 6**. As the flood modification options selected are predominantly concerned with the reduction of local flood impacts, rather than assess the catchment wide damages, the reduction in damages resulting from local decreases in flood depths and extents has been considered. The results (all incl. GST) are summarised in **Table 10-2**, noting that the AAD under existing conditions is $40,646,536 (incl. GST).

Table 10-2 Reduction in Damages Associated with Each Option

Drainage Line/Area	Option ID	Total AAD	Total Reduction in AAD
Wardell Rd, Frazer Rd, Lawson Ave	FM1.1	$20,123,867	$141,810
	FM1.2	$20,232,832	$32,845
Pile St, Livingstone Rd and Marrickville Oval	FM2.1	$20,196,420	$69,256
	FM2.3	$20,212,077	$53,599
Northcote St and Sydenham Rd	FM3.1	$20,261,253	$4,424
	FM3.2	$20,163,244	$102,433
	FM3.3	$20,202,385	$63,292
	FM3.4	$20,263,044	$2,633
Neville St, Surrey St and Illawarra Rd	FM5.2	$20,062,416	$203,261
	FM5.3 & FM5.4	$20,032,788	$232,889
	FM5.6	$19,782,033	$483,644
Addison Rd, Newington Rd and Browns Ave	FM6.1	$20,211,013	$54,664
	FM6.4	$20,176,407	$89,270
Marrickville Industrial Area (MIA) - Addison Rd and Enmore Rd	FM7.1 & FM7.5	$20,261,078	$4,599
Crawford Pl, Livingstone Rd, Arthur St and Moyes St	FM8.1 & FM8.2	$20,254,250	$11,427
Marrickville Rd and Illawarra Rd	FM9.1	$20,213,649	$52,028
	FM10.1	$20,247,717	$17,960

Drainage Line/Area	Option ID	Total AAD	Total Reduction in AAD
Marrickville Industrial Area (MIA) Marrickville Rd, Meeks Rd, Myrtle St	FM10.4	$20,261,593	$4,084
Unwins Bridge Rd and Tillman Park	FM11.1 & FM11.2	$19,963,226	$302,451
	FM11.3	$20,154,685	$110,992
	FM11.4	$20,216,994	$48,683
Carrington Rd	FM12.1 & FM12.2	$20,201,103	$64,574
	FM12.4	$20,261,471	$4,206
	FM12.5	$20,266,330	-$653
Unwins Bridge Rd and Tramway Ave	FM13.1, FM13.2 & FM13.5	$20,221,407	$44,269
Sutherland St and Unwins Bridge Rd	FM14.1	$20,210,005	$55,672
Marrickville Industrial Area (MIA) - Victoria Rd and Sydenham Rd	FM15.1 & FM15.2	$20,259,100	$6,576
	FM15.3	$20,244,210	$21,467
	FM15.5	$20,266,215	-$538
	FM15.7	$20,266,932	-$1,255
	FM15.9	$20,217,932	$47,745
	FM15.10	$20,214,809	$50,868

10.3 Benefit Cost Ratio of Options

The economic evaluation of each modelled option was performed by considering the reduction in the amount of flood damages incurred for the design events and then comparing this value with the cost of implementing the option.

The existing condition was used as the base case to compare the performance of modelled options. Inputs for the assessment include those data derived from the desktop floor level assessment along with damage curves for other similar areas. The flood extents for all the design events were considered for this evaluation. The preliminary costs of each measure were used to undertake a benefit-cost analysis on a purely economic basis.

Table 10-3 summarises the results of the economic assessment of each of the flood modification options. The indicator adopted to rank these measures on economic merit is the benefit-cost ratio (BCR), which is based on the net present worth (NPW) of the benefits (reduction in AAD) and the costs (of implementation), adopting a 7% discount rate and an implementation period of 50 years.

The benefit-cost ratio provides an insight into how the damage savings from a measure relate to its cost of construction and maintenance.

- Where the benefit-cost ratio is greater than one (BCR >1) the economic benefits are greater than the cost of implementing the measure.
- Where the benefit-cost is less than one but greater than zero (0 < BCR < 1) there is still an economic benefit from implementing the measure, but the cost of implementing the measure is greater than the economic benefit.
- Where the benefit-cost is equal to zero (BCR = 0), there is no economic benefit from implementing the measure.
- Where the benefit-cost is less than zero (BCR < 0), there is a negative economic impact of implementing the measure.

Table 10-3 Summary of Economic Assessment of Flood Modification Options

Drainage Line/Area	Option ID	NPW of Reduction in AAD	NPW of Cost of Implementation of Option	Benefit Cost Ratio	Economic Ranking
Wardell Rd, Frazer Rd, Lawson Ave	FM1.1	$2,099,000	$2,673,000	0.79	14
	FM1.2	$487,000	$2,536,000	0.19	22
Pile St, Livingstone Rd and Marrickville Oval	FM2.1	$1,026,000	$83,000	12.36	2
	FM2.3	$794,000	$2,797,000	0.28	20
Northcote St and Sydenham Rd	FM3.1	$66,000	$1,075,000	0.06	27
	FM3.2	$1,517,000	$2,628,000	0.58	15
	FM3.3	$937,000	$605,000	1.55	10
	FM3.4	$39,000	$725,000	0.05	28
Neville St, Surrey St and Illawarra Rd	FM5.2	$3,009,000	$256,000	11.75	3
	FM5.3 & FM5.4	$3,447,000	$1,683,000	2.05	6
	FM5.6	$7,159,000	$373,000	19.19	1
Addison Rd, Newington Rd and Browns Ave	FM6.1	$810,000	$486,000	1.67	8
	FM6.4	$1,322,000	$667,000	1.98	7
Marrickville Industrial Area (MIA) - Addison Rd and Enmore Rd	FM 7.1 & FM 7.5	$69,000	$1,930,000	0.04	29
Crawford Pl, Livingstone Rd,	FM 8.1 &	$170,000	$395,000	0.43	18

Drainage Line/Area	Option ID	NPW of Reduction in AAD	NPW of Cost of Implementation of Option	Benefit Cost Ratio	Economic Ranking
Arthur St and Moyes St	FM 8.2				
Marrickville Rd and Illawarra Rd	FM 9.1	$771,000	$890,000	0.87	12
Marrickville Industrial Area (MIA) Marrickville Rd, Meeks Rd, Myrtle St	FM 10.1	$266,000	$932,000	0.29	19
	FM 10.4	$61,000	$574,000	0.11	25
Unwins Bridge Rd and Tillman Park	FM 11.1 & FM 11.2	$4,477,000	$549,000	8.15	4
	FM 11.3	$1,643,000	$465,000	3.53	5
	FM 11.4	$721,000	$465,000	1.55	9
Carrington Rd	FM 12.1 & FM 12.2	$956,000	$1,978,000	0.48	17
	FM 12.4	$63,000	$110,000	0.57	16
	FM 12.5	-$10,000	$399,000	-0.03	31
Unwins Bridge Rd and Tramway Ave	FM 13.1, FM 13.2 & FM 13.5	$656,000	$759,000	0.86	13
Sutherland St and Unwins Bridge Rd	FM 14.1	$824,000	$647,000	1.27	11
Marrickville Industrial Area (MIA) - Victoria Rd and Sydenham Rd	FM 15.1 & FM 15.2	$98,000	$1,088,000	0.09	26
	FM 15.3	$318,000	$1,842,000	0.17	24
	FM 15.5	-$8,000	$177,000	-0.05	32
	FM 15.7	-$19,000	$1,093,000	-0.02	30
	FM 15.9	$707,000	$2,920,000	0.24	21
	FM 15.10	$853,000	$4,721,000	0.18	23

The top five highest ranking flood management options are FM 5.6, FM 2.1, FM 5.2, FM 11.1 & 11.2, and FM 11.3.

It is noted that the economic analysis has only incorporated changes to economic damages to properties, and does not consider social factors, risk to life and environmental factors. These types of benefits are difficult to quantify in dollar terms.

So, while an option may have a BCR less than one, it may still be a worthwhile option to implement due to other factors such as making a road flood free, which doesn't have any damages reduction associated with it.

The multi criteria analysis (**Section 11**) incorporates some of these non-quantifiable impacts into the decision making process.

Options FM 12.5, FM 15.5 and FM15.7 have a negative economic impact and have been excluded from the multi criteria analysis since there are other options in the same drainage line/area that provide higher economic benefits.

11 Multi Criteria Assessment

To assist Council in identifying the flood mitigation options that provide the most benefits for the community, all options need to be compared against each other based on factors including but not limited to the reduction in flood risk and economic flood damages.

Evaluating what constitutes an appropriate strategy for floodplain management is a significant analytical and policy challenge. Impacts associated with flooding include risk to assets and also risk to life. Urban areas impacted by flooding are valued in a number of ways by communities, organisations and individuals. Such challenges have led to the exploration of alternative policy analysis tools, one being Multi Criteria Assessments (MCA). The goal of MCA is to attempt to directly incorporate multiple values held by community and stakeholders into the analysis of management alternatives while avoiding the reduction of those values into a standard monetary unit. In doing so, one can consider different floodplain management options in the context of economic criteria as well as other criteria such as social, political or environmental aspects. Community and stakeholders can also assign explicit weights to those values to reflect their preferences and priorities. Therefore, MCA provides opportunities for the direct participation of community and stakeholders in the analysis.

A MCA approach was used 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 each option. The principal value of such a system is that it allows comparisons to be made between alternatives using a common index. In addition, the MCA 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 Council, community and 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. In order to keep the scoring system simple a framework has been developed for each criterion.

11.1 Scoring System

The scoring system subjectively ranks each option against a range of criteria given the background information on the nature of the catchment and floodplain as well as community preferences. The scoring is based on a triple bottom line approach; incorporating economic, social and environmental criteria.

Each of the criteria has been given a weighting to reflect its importance with regards to floodplain management. This weighting was developed in discussion with Council and will also be reviewed with regards to submissions received from the public during the public exhibition period.

Scoring systems were developed separately for *Flood Modification Options* and *Property Modification and Emergency Management* works. The criteria adopted, scoring system applied and the relevant weightings for both of these systems are shown in **Table 11-1** and **Table 11-2** and include:

Economic	Benefit cost ratio
	Implementation complexity
	Staging of works
Social	Reduction in risk to life
	Emergency access
	Social disruption
	Community and stakeholder support
Environmental	Heritage conservation areas and heritage items

Recreation and flora / fauna impacts including street trees

Acid sulfate soils and contaminated land

Visual impact

The assignment of each option with a score for each criteria is shown in its entirety in **Appendix M**. The score for each category (i.e. economic, environment and social) is determined by the score for each criteria, factored by a weighting as shown in **Table 11-1** and **Table 11-2**.

The overall MCA score for the option is then calculated by the weights for each of the categories as follows:

> Category Weighted Score = Category Weighting X Criteria Weighting X Criteria Score; and

> MCA Score = Category Factor X Category Weighted Score.

Table 11-1 Multi-Criteria Assessment – Scoring System for Flood Modification Measures

Category	Category Weighting	Category Factor	Factored Category Weighting	Criteria	Criteria Weighting	Metric	-4	-3	-2	-1	0	1	2	3	4
Economic	4	1.3	0.33	Benefit Cost Ratio	5	Comparison of economic benefits against the capital and operating costs.	< -2	-1 to -2	-0.5 to -1	0 to -0.5	0	0 to 0.5	0.5 to 1	1 to 2	> 2
				Implementation Complexity	3	Implementation or construction timeframe and challenges	Implementation timeframe greater than 3 years with major constraints, challenges and uncertainties which may render the option unfeasible	Implementation timeframe greater than 3 years with significant constraints, challenges and uncertainties which may increase costs or timeframes significantly	Implementation timeframe 2 to 3 years with some significant constraints and challenges which may increase costs or timeframes significantly	Implementation timeframe 2 to 3 years with some significant constraints and challenges which may increase costs or timeframes slightly	NA	Implementation timeframe less than 2 years with significant constraints, challenges and uncertainties which may increase costs or timeframes significantly	Implementation timeframe less than 2 years with constraints, challenges and uncertainties which may increase costs or timeframes slightly	Implementation timeframe less than 1 year. No constraints or challenges.	No construction requirements (e.g. planning related option)
				Staging of Works	1	Ability to stage proposed works	NA	NA	NA	NA	Works cannot be staged	Some minor components of the works may be staged	Significant components of the works can be staged	NA	NA
Social	4	1.0	0.25	Reduction in risk to life	4	Change in number of properties with over floor flooding in 1% AEP event and reduced flooding for sensitive land uses (e.g. schools, child care facilities, aged care)	Net increase in risk to life	Impacts to >20 properties but net overall reduction	Impacts to 10 to 20 properties but net overall reduction	Impacts to 1 to 10 properties but net overall reduction	No change	Reduction to 1 to 5 properties and/or a sensitive land use and net overall reduction in risk	Reduction to 5 to 10 properties and/or sensitive land use and net overall reduction in risk	Reduction to 10 to 20 properties and/or multiple sensitive land uses and net overall reduction in risk	Reduction to >20 properties and/or multiple sensitive land uses and net overall reduction in risk
				Emergency Access	3	Flood depth and duration changes for critical transport routes in 1% AEP event	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	Minor increase local or main road flooding	No Change	Minor decrease local or main road flooding	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	All roads flood free in vicinity of option
				Social Disruption	3	Flood depth and duration changes for transport routes in 2 yr ARI event	Key access roads become flooded that were previously flood free	Significant increase in main road flooding	Moderate increase in local or main road flooding	Minor increase local or main road flooding	No Change	Minor decrease local or main road flooding	Moderate decrease in local or main road flooding	Significant decrease in main road flooding	All roads flood free in vicinity of option
				Community and Stakeholder Support	4	Level of agreement from community, Council and related agencies	NA	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	No responses	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions	NA
Environmental	3	0.75	0.25	Heritage Conservation Areas and Heritage Items	2	Impacts to heritage items identified in the FRMS	Likely Impact on State, National or Aboriginal heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	Minor impact on a contributory item within a heritage conservation area	No impact	Reduces impact of flooding on heritage item or heritage conservation area	Positive contribution to heritage item or heritage conservation area	NA	NA
				Recreation and Flora / Fauna Impacts including Street Trees	4	Impacts or benefits to flora / fauna or passive/active recreational areas	NA	Likely broad-scale vegetation / habitat impacts and/or significant impact on recreation areas	Likely isolated vegetation / habitat impacts and/or impact on recreation areas	Removal of isolated trees, minor landscaping and/or minor impact on recreation areas	No impact	Planting of isolated trees or minor landscaping and/or minor improvement on recreation areas	Likely isolated vegetation / habitat benefits and/or moderate improvement on recreation areas	Likely broad-scale vegetation / habitat benefits and/or major improvement on recreation areas	NA
				Acid Sulfate Soils and Contaminated Land	1	Disruption of PASS and/or Disruption of Contaminated Land	NA	NA	Any work within Class 1 or 2 ASS area. Excavation >1m within Class 3 ASS area.	Surface works within Class 2 ASS area. Excavation <1m or surface works within Class 3 ASS area.	Works not within areas identified as PASS or contaminated land	NA	NA	NA	NA

Category	Category Weighting	Category Factor	Factored Category Weighting	Criteria	Criteria Weighting	Metric	-4	-3	-2	-1	0	1	2	3	4
									Excavation >2m within Class 4 ASS area.	Excavation <2m or surface works within Class 4 ASS area.					
									Excavation works at contaminated land site likely to be RSW	Excavation works at contaminated land site likely to be GSW					
				Visual Impact	3	Impact of completed works on visual amenity or or function of public domain	NA	Significant loss of existing visual amenity or public domain	Partial loss of existing valued visual amenity or public domain	Minor loss of existing valued visual amenity or public domain	No Change	Minor improvement to visual amenity or public domain	Moderate improvement to visual amenity or public domain	Significant improvement to visual amenity or public domain	NA

Table 11-2 Multi-Criteria Assessment – Scoring System for Property and Emergency Response Measures

Category	Category Weighting	Category Factor	Factored Category Weighting	Criteria	Criteria Weighting	Metric	-4	-3	-2	-1	0	1	2	3	4
Economic	4	1.3	0.33	Capital Cost	4	Capital Cost of Option	Greater than $1M	$500,000-$1M	$50,000-$500,000	$5,000-$50,000	Existing infrastructure or council policy continued	Less than $5,000	NA	NA	NA
				Operating and Maintenance Cost	4	Annual Operating Cost of Option	Greater than $500,000	$50,000-$500,000	$5,000-$50,000	Less than $5,000	No additional ongoing costs	NA	NA	NA	NA
				Implementation Complexity	3	Implementation timeframe and challenges	Implementation timeframe greater than 1 year with major constraints, challenges and uncertainties which may render the option unfeasible	Implementation timeframe greater than 1 year with significant constraints, challenges and uncertainties which may increase costs or timeframes significantly	Implementation timeframe 6 months to 1 year with some significant constraints and challenges which may increase costs or timeframes significantly	Implementation timeframe 6 months to 1 year with some significant constraints and challenges which may increase costs or timeframes slightly	NA	Implementation timeframe less than 6 months with significant constraints, challenges and uncertainties which may increase costs or timeframes significantly	Implementation timeframe less than 6 months with constraints, challenges and uncertainties which may increase costs or timeframes slightly	Implementation timeframe less than 6 months. No constraints or challenges.	No construction requirements (e.g. planning related option)
Social	4	1	0.20	Increased Awareness	5	Level of likely increased awareness	NA	NA	NA	NA	No increased awareness of flooding and appropriate response	NA	NA	Increased awareness likely to protect property	Increased awareness likely to protect life
				Improved Response	5	NA	NA	NA	NA	NA	No change	NA	NA	Additional flood data available to response agencies	Improved flood response arrangements
				Reduction in risk to life	5	NA	NA	NA	NA	NA	No Change	NA	NA	Likely to reduce injury.	Likely to save lives
				Compatibility of proposed works / option with Council Plans & Policies	3	Level of compatibility	Conflicts directly with objectives of several plans and policies	Some conflicts with several objectives or direct conflicts with one or few objectives	Some conflicts with one or few objectives	Minor conflicts with one or very few objectives	Not relevant to objectives	Minor support for one or very few objectives	Some support for one or few objectives	Some support for several objectives or achieving one or few objectives	Achieving objectives of several plans and policies
				Community and Stakeholder Support	3	Level of agreement	NA	Strong opposition by numerous submissions	Moderate opposition in several submissions	Individual submissions with opposition	No responses	Individual submissions with support	Moderate support in several submissions	Strong support by numerous submissions	NA
Environmental	3	0.75	0.25	Heritage Conservation Areas and Heritage Items	2	Impacts to heritage items identified in the FRMS	Likely Impact on State, National or Aboriginal heritage Item	Likely impact on local heritage item	Likely impact on contributory item within a heritage conservation area	Minor impact on a contributory item within a heritage conservation area	No impact	Reduces impact of flooding on heritage item or heritage conservation area	Positive contribution to heritage item or heritage conservation area	NA	NA

Category	Category Weighting	Category Factor	Factored Category Weighting	Criteria	Criteria Weighting	Metric	-4	-3	-2	-1	0	1	2	3	4
				Recreation and Flora / Fauna Impacts including Street Trees	4	Impacts or benefits to flora / fauna or passive/active recreational areas	NA	Likely broad-scale vegetation / habitat impacts and/or significant impact on recreation areas	Likely isolated vegetation / habitat impacts and/or impact on recreation areas	Removal of isolated trees, minor landscaping and/or minor impact on recreation areas	No impact	Planting of isolated trees or minor landscaping and/or minor improvement on recreation areas	Likely isolated vegetation / habitat benefits and/or moderate improvement on recreation areas	Likely broad-scale vegetation / habitat benefits and/or major improvement on recreation areas	NA
				Acid Sulfate Soils and Contaminated Land	1	Disruption of PASS and/or Disruption of Contaminated Land	NA	NA	Any work within Class 1 or 2 ASS area.	Surface works within Class 2 ASS area.	Works not within areas identified as PASS or contaminated land	NA	NA	NA	NA
									Excavation >1m within Class 3 ASS area.	Excavation <1m or surface works within Class 3 ASS area.					
									Excavation >2m within Class 4 ASS area.	Excavation <2m or surface works within Class 4 ASS area.					
									Excavation works at contaminated land site likely to be RSW	Excavation works at contaminated land site likely to be GSW					
				Visual Impact	3	Impact of completed works on visual amenity or function of public domain	NA	Significant loss of existing visual amenity or public domain	Partial loss of existing valued visual amenity or public domain	Minor loss of existing valued visual amenity or public domain	No Change	Minor improvement to visual amenity or public domain	Moderate improvement to visual amenity or public domain	Significant improvement to visual amenity or public domain	NA

11.2 Outcomes

The scores and rankings of each of the options is provided in **Appendix M**. The total score of each option was calculated by scoring and weighting each criteria and category as per **Table 11-1** and **Table 11-2** and then summing the total of all criteria.

Each of the options was then ranked against each other based on the total scores, allowing identification of the preferred options, namely those that provide the greatest benefit to the community. These total scores and rankings are also shown in **Appendix M**.

Table 11-3 provides a ranked list of flood modification options for consideration for inclusion in the FRMP. The options selected for inclusion should be based on both their likely benefits and the likely funding available from Council and the State Government.

Table 11-3 Summary of MCA Evaluation of Flood Modification Options

Drainage Line/Area	Option ID	BCR	MCA Score	Overall Rank
Wardell Rd, Frazer Rd, Lawson Ave	FM1.1	0.79	9.58	8
	FM1.2	0.19	2.29	28
Pile St, Livingstone Rd and Marrickville Oval	FM2.1	12.36	8.42	14
	FM2.3	0.28	7.04	21
Northcote St and Sydenham Rd	FM3.1	0.06	6.04	22
	FM3.2	0.58	8.67	11
	FM3.3	1.55	8.81	10
	FM3.4	0.05	8.50	13
Neville St, Surrey St and Illawarra Rd	FM5.2	11.75	5.79	24
	FM5.3 & FM5.4	2.05	14.63	2
	FM5.6	19.19	16.52	1
Addison Rd, Newington Rd and Browns Ave	FM6.1	1.67	9.06	9
	FM6.4	1.98	11.27	5
Marrickville Industrial Area (MIA) - Addison Rd and Enmore Rd	FM 7.1 & FM7.5	0.04	8.10	15
Crawford Pl, Livingstone Rd, Arthur St and Moyes St	FM8.1 & FM8.2	0.43	1.73	29
Marrickville Rd and Illawarra Rd	FM9.1	0.87	3.79	27
Marrickville Industrial Area (MIA) Marrickville Rd, Meeks Rd, Myrtle St	FM10.1	0.29	4.35	26
	FM10.4	0.11	5.85	23
Unwins Bridge Rd and Tillman Park	FM11.1 & FM11.2	8.15	13.67	3

Drainage Line/Area	Option ID	BCR	MCA Score	Overall Rank
	FM11.3	3.53	12.42	4
	FM11.4	1.55	8.63	12
Carrington Rd	FM12.1 & FM12.2	0.48	7.71	17
	FM12.4	0.57	10.27	6
Unwins Bridge Rd and Tramway Ave	FM13.1, FM13.2 & FM13.5	0.86	7.21	18
Sutherland St and Unwins Bridge Rd	FM14.1	1.27	9.94	7
Marrickville Industrial Area (MIA) - Victoria Rd and Sydenham Rd	FM15.1 & FM15.2	0.09	7.10	19
	FM15.3	0.17	5.31	25
	FM15.9	0.24	7.04	20
	FM15.10	0.18	7.71	16

Table 11-4 provides a ranked list of property modification and emergency response options for consideration for inclusion in the FRMP.

Table 11-4 Summary of MCA Evaluation of Property and Emergency Modification Options

Option	MCA Score	Overall Rank
PM 1 – Voluntary Purchase	-12.13	12
PM 2 – House Raising	-11.82	11
PM 3 – Land Swap	-16.41	13
PM 4 – Flood Proofing	0.68	9
PM 5 - Increased Street Sweeping	3.19	7
PM 6 - Stormwater Pit Maintenance	-0.93	10
EM 1 – Identification of Evacuation Centres	2.04	8
EM 2 – Information transfer to NSW SES	10.13	1
EM 3 – Flood Response for Vulnerable Properties	5.42	4
EM 4 – Local Evacuation Measures	3.64	6
EM 5 – Flood Awareness and Education	7.02	3
EM 6 – Interactive Flood Mapping	8.30	2
EM 7 – Education and Awareness of Littering	3.75	5

The rankings are proposed as the basis for selecting management options for inclusion in the FRMP, and for prioritising their implementation.

It is noted that both structural (flood modification) and non-structural (property modification and emergency response) options have been considered separately. It is difficult to directly compare these two types of measures. Furthermore, funding sources and implementation timeframes for the two different types of measures are typically different.

12 Conclusion

This report presents the findings of the Floodplain Risk Management Study stage of the Flood Risk Management Process for the Marrickville Valley catchment, in accordance with the Floodplain Development Manual (NSW Government, 2005). The investigations undertaken as part of this process identified a number of issues within the floodplain. Based on these issues, a series of floodplain management options were developed and recommended.

The outcomes of the multi-criteria assessment provide a sound basis upon which Council can make decisions about undertaking works, making planning decisions and developing response arrangements to reduce the impact of flooding on property and life. The implementation strategy may not necessarily approach the options from “highest ranking to lowest ranking” but will also need to incorporate various other considerations such as existing works programs, availability of funding and other opportunities to combine floodplain works with other activities.

The options identified as having significant flood reductions that also do not have adverse social or environmental impacts will be incorporated into the *Marrickville Valley Floodplain Risk Management Plan* as the proposed management actions. This document will recommend a cost-effective plan to manage flood risk and will outline the process of implementation for recommended management actions within the floodplain.

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