Floodplain Risk Management Study & Plan – Final

Coogee Bay Floodplain Risk Management Study & Plan

59914005

Prepared for
Randwick City 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 Coogee Bay Floodplain Risk Management Study and Plan is developed from the previous Flood Study, prepared by BMT WBM in 2013 for Randwick City Council.

Executive Summary

Flow Behaviour and Flood Risk

The Coogee Bay catchment is a heavily urbanised catchment with the following flow regime typical throughout the catchment:

> Along most major flowpaths, which generally represent the predevelopment creek lines, significant trunk drainage pipes have been placed underneath the local low points, often capable of conveying the relatively infrequent flood events (typically up to 20% - 5% AEP events).

> Due to the development of residential properties, and the construction of road embankments across local low points, the majority of flowpaths do not have a consistently falling grade in the direction of flow, leading to areas of significant ponding due to the obstruction of flow. The most prominent example of this is where the raising of Arden Street and Goldstein Reserve in the past has resulted in an obstruction of flow to Coogee Beach which leads to excessive ponding in the Coogee Oval depression. Similarly, throughout the upper catchment, the development of the catchment has resulted in local low points being established with limited discharge opportunities available. This leads to situations of minor ponding from small local catchments, disconnected from any major overland flowpaths.

The key locations of flooding are three major flowpaths that convey flow from the majority of the catchment crossing Carrington Road, which acts as a flow obstruction, running along Dolphin Street and the adjoining public reserve, before diverting into the Coogee Bowling Club and Coogee Tennis Club, and from here crossing Brook Street and discharging to the Coogee Oval depression. Floodwaters then discharge either through the trunk drainage line that discharges to the north of Coogee Beach, or if ponding is sufficient to overtop Arden Street and Goldstein Reserve then discharge occurs to Coogee Beach via the promenade.

The other location with significant flood risk is the depression on Rainbow Street. There is no overland discharge point from this location, resulting in flows from the surrounding catchment all converging to the one depression, which is drained by a 1.05m diameter pipe conveying flows to the north-east and discharging to the sea. For large infrequent flooding events the capacity of the pipe is exceeded and significant flooding occurs within the Rainbow Street depression, up to depths of 7 metres in the Probable Maximum Flood (PMF) event.

Impact of Flooding

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 Probable Maximum Flood being 586 properties. Economic impacts of flooding are also significant due to flooding over the floor level of both residential and commercial properties, as well as garden damage for residential properties combining to represent a significant expense in flood events ranging from the 20% AEP to the PMF event. The Annual Average Damage for the catchment is expected to be just under $2.1 million dollars with the contributions of the various design flood events summarised in the table below.

Design Event	Properties with Overfloor Flooding	Total Damage ($)	AAD ($)	Contribution to Combined AAD (%)
PMF	586	$56,336,000	$83,500	4%
0.5% AEP	269	$27,226,000	$74,600	4%
0.2% AEP	223	$22,476,000	$91,800	4%
1% AEP	154	$14,256,000	$427,300	20%
5% AEP	72	$7,109,000	$828,500	40%
20% AEP	27	$3,936,000	$590,500	28%
Combined		-	**$2,096,200**	**-**

Emergency Response Arrangements

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.

A review of the existing emergency response arrangements for the catchment conclude that due to the fast rate of rise experienced throughout the catchment where time available for evacuation is less than an hour, that co-ordinated SES assisted regional evacuation is not possible.

However, for catchments such as this, evacuation may occur at a more localised level through a different sequence of events; occupants visually see flooding in their vicinity and respond instinctively by moving to higher ground. This sequence relies less on warning systems and emergency services co-ordination and more on the common sense and preparedness of the resident to respond to observed flooding through evacuation.

A key advantage of localised evacuation for overland flow flooding type is that the flow paths are relatively confined, as proven by the fact that the maximum distance to flood free land does not exceed 50 metres for the majority of the floodplain. Alternatively, a review of shelter-in-place potential for the catchment shows that this form of emergency response could also be suitable for the area due to the relatively short duration of isolation.

The one exception is the localised depression on Rainbow Street where the depth of flooding and stability of structures cannot be guaranteed meaning shelter-in-place is not possible, and the geometry of the depression meaning localised evacuation is not as self-evident as for other parts of the catchment.

Emergency response to flooding can be enhanced through the implementation of educations programs communicating flood risk and appropriate response, flood warning systems and provision of facilities and services to assist in a flood event. Opportunities to enhance emergency response within the Coogee Bay catchment have been assessed and incorporated into flood management options.

Flood Related Planning Controls

A review of Flood Planning Levels for the catchment was conducted to assess the currently adopted levels and any potential alternative levels that could be adopted. This assessment was done through an assessment of the flood risk associated with the various alternatives including consideration of climate change, the adopted freeboard level and the Flood Planning Area that assigns planning controls on properties. The outcome of the review was that Council's currently adopted Flood Planning Level of the 1% AEP plus 0.5 metre freeboard was appropriate for the Coogee Bay catchment.

In addition, there are currently different Flood Planning Level requirements for overland flow affectation which relate floor levels to design flood depths and not levels. This is found to be an effective way to apply floor level requirements to steep sites with significant grade changes where it is not possible to represent the entire site with one Flood Planning Level. This was found to be particularly useful in limiting how onerous level requirements are for the type of flooding commonly encountered in the Coogee Bay floodplain and is recommended to be retained.

A wider review of the Council's flood related development controls was also conducted. Recommendations were made to be considered as part of future amendments to the Randwick Local Environment Plan and Randwick Development Control Plan.

Flood Risk Management Options

For the Coogee Bay catchment, a range of flood risk management options were considered to improve the flood risk including flood modification, emergency response modification, and property 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. A range of flood modifications were considered for the Coogee Bay catchment including:

> Detention basins.

> Drainage upgrades: Two types of drainage upgrade were considered:

- Addition of inlet pits where it was found that existing pit capacity was the limiting factor on capacity;
- Upgrading of trunk drainage pipes where pipe capacity was found to be the limiting factor.

> Levees.

Following a preliminary assessment of options including hydraulic modelling, the flood management options identified for detailed assessment were:

> Option FM1 – Upper Dolphin: Additional pit inlets at Clyde Street, upper Dolphin flowpath, and Courland Street (combined FM1a, FM1b and FM1c);

> Option FM6 – Abbott Street: Additional pit inlets at Abbott Street depression;

> Option FM7 – Bardon Park: Detention basin constructed in Bardon Park to ease flooding for Coogee Tennis Club, Coogee Bowling Club, and Brook Street; and,

> Option FM11 – Coogee Oval: Additional pit inlets at Coogee Oval and upgrading of three trunk drainage lines discharging from Coogee Oval.

It should be noted that potential flood modification measures were identified and evaluated for the Rainbow Street depression (such as increasing the outlet pipe size), however, based on preliminary model runs and constraints assessment none of the options identified were shown to be feasible. Due to the unique nature of flooding at this location and the need for more detailed background information (e.g. geotechnical data), further assessment of flood risk management at the Rainbow Street depression is not feasible within the scope of this FRMS&P. However, due to the high hazard and significant flood risk present at this location, it has been recommended that a detailed analysis of flood risk management be undertaken as an outcome of this FRMS&P.

One of the original options was to consider reducing the flooding on Brook Street near Smithfield Avenue. Initial investigations suggested pipe upgrades were not feasible. In response to a number of submissions from residents during the public exhibition, a detailed assessment of this option is proposed for addressing overland flooding near the intersection of Brook Street and Smithfield Avenue..

An economic analysis of the detailed flood modification options found that the proposed upper dolphin drainage upgrades was by far the best performing option from an economic perspective. This measure had a benefit cost ratio of 2.43 while the other three options have ratios of 0.11 or less. The damages summary for the upper dolphin drainage upgrade is included in the table below.

	Properties with Overfloor Flooding Removed	Properties with Overground Flooding Removed	Total Damage Reduction ($)	AAD Reduction ($)
FM1 - Upper Dolphin Drainage Upgrade				
20% AEP event	1	25	$145,511	$21,827
5% AEP event	2	9	$154,201	$22,478
1% AEP event	2	4	$178,271	$6,649
0.5% AEP event	2	2	$69,325	$619
0.2% AEP event	0	0	-$4,421	$97
Total				**$51,670**

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. A review of property modification measures including Voluntary House Raising and Voluntary Purchase found that these modification options were not feasible for the Coogee Bay catchment due to the following:

> Few properties in the catchment met the flood risk and hazard criteria for consideration under these schemes as set-out by the NSW Office of Environment and Heritage (OEH);

- The properties that were eligible from a flood risk perspective were either of commercial land use as was the case with the Coogee Tennis Club, or multi-unit residential apartments meaning house raising and voluntary purchase were not cost-effective or feasible; and,
- The high median house price for the Coogee and South Coogee suburbs mean that any voluntary purchase or land swap was unlikely to be cost effective.

While these conventional property modification measures were found to not be feasible, property modification in the form of development controls can be an effective way of reducing flood risk.

The existing planning and development controls for the catchment were reviewed within the context of the flood behaviour and risk identified in the Flood Study (BMT WBM, 2013). The majority of the recommended amendments to these controls relate to a slight re-wording and re-organising of policies and will not have a significant impact on flood risk for Coogee Bay. The one exception is if controls were revised to require flood emergency response provisions, whether they be evacuation or shelter-in-place, to be required to the PMF. This will have negligible economic impact, but the social benefits could be significant in reduced risk to life.

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:

- Public awareness and education;
- School education program;
- Flood markers and signage;
- Local flood warning systems;
- Localised evacuation procedures; and,
- Local flood response plan for the Rainbow Street depression.

Preliminary assessment of the evacuation timeline for Rainbow Street depression found that a local flood response plan is likely to be possible for the area and has been recommended for development as an outcome of this FRMS&P.

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 results of the MCA are shown in the table below. The highest ranking option is the proposed drainage upgrades along upper Dolphin Street. Although, they don't provide any reduction in the economic costs of flooding, several emergency response options and one property modification measure ranked favourably within this assessment due to the reduction in flood risk to life provided by these options. To assist Council with their implementation, each of the recommended options has been given a priority (high, medium or low) corresponding to their ranking.

Option ID	Option Description	MCA Score	Overall MCA Rank	Implementation Priority
FM1	Upper Dolphin Drainage Upgrade	6	1	High
FM10	Brook Street Detailed Investigation	6	1	High
FM16	Rainbow Street Detailed Investigation	6	1	High
PM5	Emergency Response Development Controls	6	1	High
PM6	Public Access to Flood Data	6	1	High
EM5	Localised Evacuation	6	1	High
EM6	Rainbow Street Evacuation	6	1	High
-	Post Flood Data Collection	N/A	1	High
-	Pit and Pipe Maintenance	N/A	1	High
EM1	Public Awareness and Education	5	2	Medium
EM3	Flood Signage	5	2	Medium

Option ID	Option Description	MCA Score	Overall MCA Rank	Implementation Priority
EM2	School Education Program	4	3	Low
EM4	Flood Warning System	4	3	Low
FM6	Abbott Street Drainage Upgrade	2	4	N/A
FM7	Bardon Park Basin	2	4	N/A

The outcomes of this ranking process of the options from the table above have been used to guide the implementation strategy which is the primary component of the Floodplain Risk Management Plan (FRMP).

Implementation and Funding

In order to achieve the implementation of relevant recommendations of this FRMS&P, a program of implementation has been developed. Once the public exhibition process is complete and the FRMS&P document has been finalised, the remaining steps in progressing the floodplain risk management process are:

- The Floodplain Management Committee will consider and support relevant recommendations of this Plan for adoption by Council;
- Council will adopt the final Plan and submit applications for funding assistance to relevant State and Commonwealth agencies, as appropriate;
- The flood management actions will be prioritised for funding through the Integrated Planning and Reporting Process; and
- As funds become available from OEH, the Commonwealth, other state government agencies, and/or from Council's own resources, recommended management actions will be implemented in accordance with the established priorities.

The estimated costs of implementing the Plan by Council and relevant State Agencies include approximately $583,900 in capital costs and $104,900 in annualised recurrent costs.

Outcomes and Recommendations

It is impractical to eliminate all flood risks from the Coogee Bay floodplain. Instead, the aim of the recommendations of this FRMS&P is to ensure that existing and future development is exposed to an 'acceptable' level of risk.

The key findings of this FRMS&P is that although there is a significant flood risk within the Coogee Bay floodplain, the potential for this flood behaviour to be managed through on ground works (such as drainage upgrades) is limited. This is due to the highly urbanised catchment, high density population and steep catchment (and hence fast flowing floodwaters).

However, due to the generally shallow nature of the flow and the relatively short period of flooding, flood risk can be effectively managed through the implementation of development controls, emergency response measures and minor works. The effective implementation of development controls will be of key importance in reducing the damages and risk to life associated with flooding into the future through the construction of flood compatible buildings and assets.

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Glossary and Abbreviations

Australian Height Datum (AHD)	A standard national surface level datum approximately corresponding to mean sea level.
Average Exceedance Probability (AEP)	Refers to the probability or risk of a flood of a given size occurring or being exceeded in any given year. A 90% AEP flood has a high probability of occurring or being exceeded each year; it would occur quite often and would be relatively small. A 1% AEP flood has a low probability of occurrence or being exceeded each year; it would be fairly rare but it would be relatively large. The 1% AEP event is equivalent to the 1 in 100 year Average Recurrence Interval event.
Average Recurrence Interval (ARI)	The average or expected value of the periods between exceedances of a given rainfall total accumulated over a given duration. It is implicit in this definition that periods between exceedances are generally random. That is, an event of a certain magnitude may occur several times within its estimated return period.
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 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.
NPER	National Professional Engineers Register. Maintained by Engineers Australia.
NSW	New South Wales
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 Average Recurrence Interval.

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Figures

1 Introduction

Cardno (NSW/ACT) Pty Ltd ('Cardno') was commissioned by Randwick City Council ('Council') to undertake a Floodplain Risk Management Study and Plan (FRMS&P) for the Coogee Bay catchment (**Figure 1-1**). This FRMS&P has been undertaken to define the existing flooding behaviour and associated hazards, and to investigate possible flood risk management options to reduce flood damage and risk to life. The future flood risk has also been considered through the assessment of potential impacts of changes in rainfall on flood behaviour.

The *Coogee Bay Flood Study* was prepared in 2013 by BMT WBM for Randwick City Council to define the flood behaviour in the study area, including both mainstream and overland flooding. The Flood Study (BMT WBM, 2013) has subsequently been adopted by Council. The Flood Study forms the basis of the flood data used for this FRMS.

As part of the Floodplain Risk Management Study component, a number of flood management options have been examined to manage flooding within the Coogee Bay catchment. The identification and examination of these options was done in accordance with the *NSW Floodplain Development Manual: The Management of Flood Liable Land* (NSW Government, 2005). The Floodplain Risk Management Plan component of this report details the implementation strategy for these mitigation options.

This study has been prepared with the assistance of the NSW Office of Environment and Heritage (OEH).

1.1 Study Context

In the past, flooding of the Coogee Bay catchment has caused property damage, restricted property access and has been a general inconvenience to the community. These flooding issues have prompted Randwick City Council, through an established Floodplain Management Committee to prepare a comprehensive and integrated Floodplain Risk Management Plan for the Coogee Bay floodplain.

The preparation of this FRMS&P follows on from the Coogee Bay Flood Study (WBM BMT, 2013) and forms the fourth and fifth stage of the floodplain risk management process as defined by the Floodplain Development Manual (NSW Government, 2005):

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 Objectives

1.2.1 Floodplain Risk Management Study Objectives

The aim of the Floodplain Risk Management Study as articulated in the brief prepared by Council is to:

> Review the *Coogee Bay Flood Study* (BMT WBM, 2013) and, if necessary, update the Flood Study model using the latest available data and technology, as appropriate;

> Review Council's existing environmental planning policies and instruments, including Council's long-term planning strategies for the study area;

> Identify residential flood planning levels and the flood planning area;

> Identify works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future, over the full range of potential flood events;

> Assess the effectiveness of these proposed works and measures for reducing the effects of flooding on the community and development, both existing and future;

> 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;

> Review flood information and address the issues identified for consideration in any future flood plan based on the guideline *SES Requirements from the Floodplain Risk Management Process* (NSW Government, 2007);

> Examine the present flood warning system, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's (SES's) development and disaster planning requirements; and,

> Identify modifications that are required to current policies in light of the investigations.

1.2.2 Floodplain Risk Management Plan Objectives

The objectives of the Floodplain Risk Management Plan are to:

> Provide a practical framework and implementation plan for managing flood risk within the study area;

> Formulate a cost effective plan for the study area based on the findings of the *Floodplain Risk Management Study*;

> Provide a priority program for implementation of the recommended works and measures in accordance with Appendix H of the *Floodplain Development Manual* (NSW Government, 2005);

> Provide governance and leadership direction for floodplain risk management;

> Ensure that intergenerational equity is maintained through achieving a balance between reducing flood vulnerability for the current and future generation, without overly burdening the current generation with costs and avoiding the transfer of costs or risk to future generations;

> Disseminate the outcomes of the FRMP to state agencies including those directly impacted by the decisions identified e.g. police and emergency services; and

> Provide for management of flood risk to public assets (e.g. services and utilities) and private property.

1.3 Report Structure

The structure of this report is outlined below:

> Details of the data used in the study and how it was obtained (**Section 2**);

> Description of the features of the catchment and floodplain (**Section 3**);

> An overview of the existing flood behaviour and issues (**Section 4**);

> An assessment of the existing and future economic impact of flooding (flood damages) (**Section 5**);

> A review of the existing emergency response arrangements (**Section6**)

> A review of the flood planning levels for development (**Section 7**);

> A review of the current policies and planning relevant to flooding (**Section 8**);

> An assessment of the potential options for the management of flooding identified as being suitable for various parts of the Coogee Bay floodplain (**Section 9**);

> Review of the hydraulic modelling outcomes of each of the detailed options assessed (**Section 10**);

> Economic assessment of the management options based on expected costs and benefits (**Section 11**);

> Triple bottom line assessment of management options using a Multi-Criteria Assessment (**Section 12**);

> The implementation program for the works and additional studies proposed within the Plan (**Section 13**);

> Recommendations and conclusions of the FRMS&P (**Section 14**); and

> A summary of the qualifications for the Study and Plan (**Section 15**) and a bibliography (**Section 16**).

Figure 1-1 Study Area - Coogee Bay Catchment

2 Available Data

The data used in the preparation of this as obtained from three main sources as follows:

> Review of Coogee Bay Flood Study;

> Collation and review of data inputs; and

> Stakeholder and community consultation.

2.1 Coogee Bay Flood Study

2.1.1 Flood Study Approach

The *Coogee Bay Flood Study* (BMT WBM, 2013) is the key input study to the FRMS&P. The primary objective of the Flood Study was to define flood behaviour in the study area under existing conditions for the 5%, 20%, 1%, 0.5% and 0.2% Annual Exceedance Probability (AEP) flood events and the Probable Maximum Flood (PMF).

A detailed 1D / 2D hydrological and hydraulic model was established to describe the flooding behaviour throughout the study area. The following summarises the composition of the model:

> Hydrological modelling was undertaken to define flood behaviour in the Coogee Bay catchment through the application of the Direct Rainfall methodology. Design rainfall intensities were applied using the methods to estimate IFD curves from AR&R (2001).

> An initial and continuing rainfall loss approach was applied to the hydrology. Initial losses of 50 mm and 5 mm was applied to pervious and impervious areas respectively, with continuing losses of 5 mm and 0 mm respectively.

> A 2m grid cell was applied using DEM sampling points using LiDAR at 0.5m contour intervals.

> A downstream boundary condition of standing water at 1 m AHD was applied. This represents an average spring high tide occurring in Coogee Bay.

> Stormwater pits and pipes throughout the catchment were included as 1D elements in the hydraulic model with details based on GIS data provided by Randwick Council (see **Section 2.2**). Sag pit inlet capacities were applied using the pit sizes detailed in the GIS data.

> Stormwater pipe blockage was not applied for the 1D network. Inlet rating curves were adopted for the various types of inlet pits including varying sizes of kerb inlets and square grated inlets. All inlet pits were assumed to be sag pits (where inlet capacity relates to the depth of ponding) and no blockage factor was applied to inlet rating curves.

> Roughness was applied to the topographic grid in values correlating to land use obtained from Council's GIS. A higher roughness was applied to the surfaces experiencing sheet flow where flow depth is <30mm and increases proportionally until reaching a lower limit value once flow depth exceeds 150mm.

> Raised building blocks were not included in the model, alternatively a high roughness value was applied where building polygons were delineated in Council's GIS.

The Flood Study model was calibrated and verified against three historical storms; October 1959, January 1999, and May 2009. The purpose of the calibration was to assess if the computer-based model accurately predicts the observed flooding from these historical events. In the event that the model results did not adequately replicate the observed flooding, the model would have been subject to further refinement to better describe flooding in the catchment. The results of the calibration and verification undertaken by BMT WBM (2013) showed that the model was capable of reproducing the observations from these historical events, providing confidence in the overall modelling results.

The Flood Study described the flood behaviour of flows, peak water levels, peak water depths and peak flow velocities for a range of design storm events. The provisional hazard and hydraulic categories were determined for flood affected areas in the Coogee Bay catchment. The modelling assumed that there was no blockage of hydraulic structures (i.e. the stormwater network).

The flood extents presented in the Flood Study were shown as raw model results and were not “trimmed” to remove disconnected patches of flooding and areas with minor depths.

A series of sensitivity analyses were undertaken to test the impact of the following on flood behaviour:

> 100% blockage of the stormwater network;

> Change in rates of infiltration (initial loss of 15mm was tested, 50mm was adopted in design events based on calibration results);

> A 0.9 m sea level rise; and

> Climate change (10% and 25% increases in rainfall intensities).

Outputs from the *Coogee Bay Flood Study* (BMT WBM, 2013) provided to Cardno for purposes of the FRMS&P included the Flood Study report, TUFLOW model and model results. Further information on the Flood Study outputs and methodology can be found in the Flood Study final report (BMT WBM, 2013).

It should be noted that the original modelling work undertaken for the Flood Study used Tuflow version 2010-10-AB-w32. During the latter stages of the Flood Study, BMT-WBM discovered the stability of the model was being ‘pushed to its limits’, due to the steep nature of the Coogee Bay catchment. Therefore, the original models were converted by BMT-WBM to a newer version of Tuflow (2012-05-AD-w64) to provide a more stable model to take forward into the Floodplain Risk Management process. Comparison with the original model results have shown that peak flood levels are typically within 50mm.

2.1.2 Flood Study Review

2.1.2.1 Overview

A detailed review of the Flood Study hydrological and hydraulic modelling has been conducted as part of the FRMS&P process. With regards to general approach, the flood behaviour has been estimated by the Flood Study using available data and up to date technology. The quality of the data is reported to be of good quality for the LiDAR, rainfall data and the pit and pipe network.

For the calibration events, three historical storms were investigated. The available data for these events was good for rainfall and reasonable for flood level records. Numerous flood photographs for the May 2009 event were used to estimate flood levels in various parts of the catchment that allowed for the model to be calibrated. The model could only be verified for the other two historical events using anecdotal evidence and a small amount of photographs. As such, it is concluded that the model has been calibrated using the historical flooding data available and estimates flood behaviour in Coogee with reasonable accuracy.

It was noted by a resident during the public exhibition (**Section 2.3.4**) that the flood depths within the Coogee Tennis Club basement reported in the Flood Study vary from those recorded for the May 2009 calibration event. Further investigation identified that the basement level within the flood model was incorrectly shown as being lower than the tennis courts. This explains the differences in observed flood depths inside the tennis club to that shown in the *Coogee Bay Flood Study* (BMT-WBM, 2013). It should be noted that flood depths above the floor level rather than flood levels have been incorrectly represented at this location, therefore flood levels across this area remain valid.

There are high levels of correlation between the flood model and nearby observations at the Bowling Club for the May 2009 flood model calibration event. The levels were also well represented at many other locations in the catchment where flood marks were collected (Oswald Street, Bowling greens, Coogee oval, Senior Citizens Centre). Furthermore, the model was also calibrated for the January 1999 event and validated for the October 1959 event. In both cases the model represented flow behaviour accurately. On this basis, the misrepresented depths do not highlight any concerns with the modelling of flood behaviour in the Coogee Bay catchment.

2.1.2.2 Adopted Hydraulic Modelling of Buildings

Council identified that review of the flood study hydraulic model was required at three locations, namely:

> 62 Frenchmans Road Randwick;

> Coogee Bay Road between Brook Street and Arden Street; and,

> 51 Bream Street Coogee.

At these locations flow is shown going through buildings in the flood maps. This appears to be anomalous because in reality overland flow could not penetrate these buildings. This flood behaviour is evident due to the approach of inclusion of building obstruction in the model using a high roughness value rather than a raised terrain / grid levels for the building footprint. The following summarises the roughness approach adopted in the Flood Study model:

> For flood depths up to 0.03m, a Manning's roughness value of 0.05 is applied;

> Above a depth of 0.15 m, a Manning's roughness value of 1.0; and,

> Between flood depths of 0.03 m and 0.15 m, there is a linear interpolation of the roughness values.

As a result of this approach flow is permitted to pass through a building at a depth of up to 0.15 m relatively unimpeded, above this depth it is assumed that the flows interact with suspended floors and therefore an excessive roughness is applied.

As part of the Flood Study review two sensitivity analysis runs were conducted to investigate the sensitivity to modelling the buildings in an alternative manner in order to eliminate flows through the buildings which are discussed further in the following sections.

2.1.2.3 Sensitivity Analysis – Increased Building Roughness

Sensitivity analysis for buildings was undertaken by increasing the roughness value for the building polygons to a constant 1.0 roughness across all flood depths. This resulted in a significant increase in roughness for flood depths of between 0.03 to 0.15 metres.

This sensitivity analysis was assessed across the entire Coogee Bay catchment for the 1% AEP 2 hour event, with results shown in **Figure 2-1**.

The results show minor localised areas of water level increases of between 0.1 – 0.2 metres around building polygons in the upper catchment. There are more widespread areas of water level decreases in the major flowpath areas downstream of between 0.05 – 0.2 metres. This suggests the increased roughness results in slight slowing down of the flow, and a general reduction in flood depths throughout the lower floodplain.

As the increased roughness approach will increase instances of disconnected ponding in the upper catchment and results in reduced water levels across the more significant flowpaths, the adoption of the Flood Study results is justified.

2.1.2.4 Sensitivity Analysis – Blockage of Buildings

Sensitivity analysis was undertaken that assessed the impact of raising the terrain / grid levels for building polygons, effectively making all buildings complete flow obstructions. This sensitivity analysis was carried out for a localised pilot catchment near Dolphin Street and Coogee Street to the west of Carrington Road. The assessment was conducted for the 1% AEP 2-hour event.

The preliminary results of this analysis are shown in **Figure 2-2**, with the context of the pilot catchment across the wider catchment, as well as close view of the impacts in the pilot catchment

The results show minor water level increases of between 0.1 – 0.2 metres in some residential backyards in the pilot catchment. At the boundary of the building outlines there are far higher localised impacts of over 0.5 metres but this could potentially be an erroneous interaction of the model with the vertical walls. Overall the water level impacts seem to be relatively insignificant beyond a very localised scale.

It is also important to note that the 2m grid cell size in the model would effectively cut off flow between buildings that are less than 2m apart, whereas there would in reality be flow between these buildings. This could explain some of the larger localised impacts seen in the pilot catchment.

It is concluded from these results that revision of the Flood Study model at the locations requested for consideration by Council would not add value to the outcomes of the modelling. The changes required to address the three locations listed by Council would ultimately require similar changes to the model across the entire Coogee Bay catchment. This would require an entire revision of the Flood Study maps which is not considered necessary based on sensitivity analysis results as the change in water level results have been found to be relatively minor.

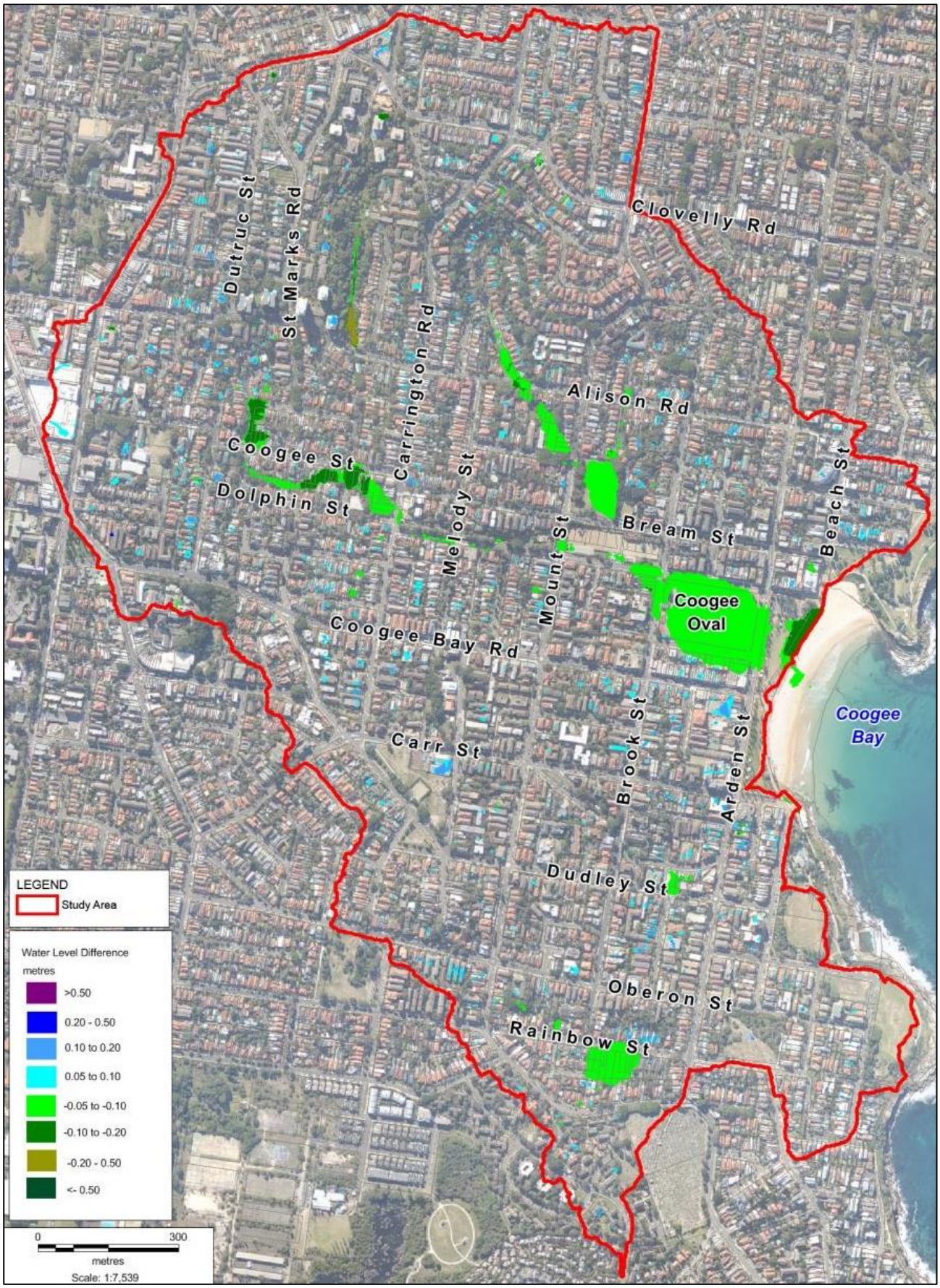

Figure 2-1 Water Level Differences – Increased Building Roughness – 1% AEP 2 hour

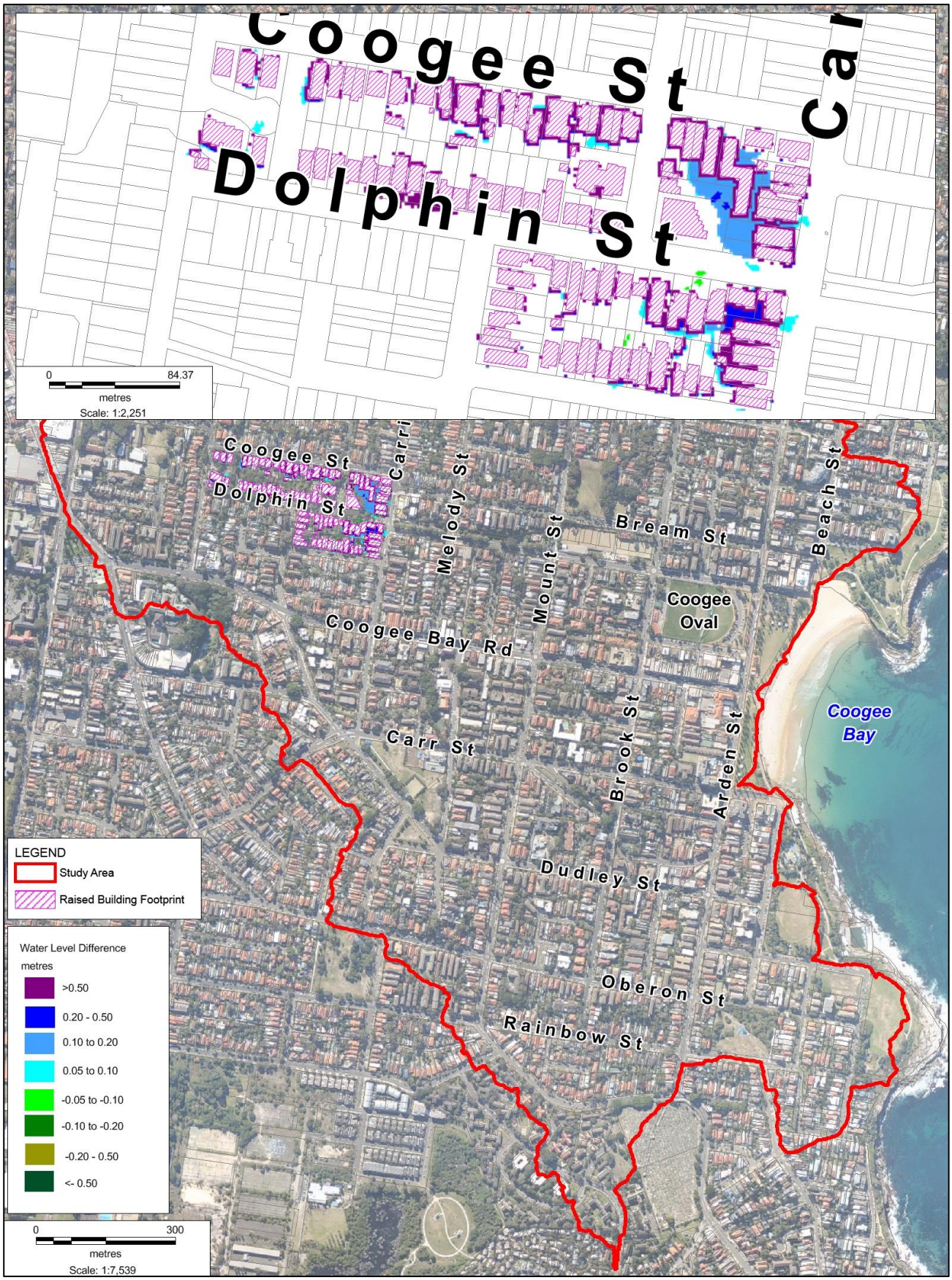

Figure 2-2 Water Level Differences – Blocked Buildings – 1% AEP 2 hour

2.2 Additional Data

2.2.1 Floor Level Survey

Registered surveyors undertook a survey of floor levels of buildings located within the 1% AEP flood event +0.5 m freeboard in April 2014. A total of 913 properties were surveyed within the Coogee Bay floodplain by Sydney Surveyors, with floor levels surveyed for 853 of those properties. The 60 properties that were surveyed but did not have a floor level recorded were those that do not have buildings present on the site such as public reserves, and vacant lots. Other data that was recorded in the survey included:

> Ground level (in m AHD);

> Number of buildings and number of storeys;

> Land use type, residential, commercial, or industrial;

> If commercial, the name and nature of business type;

> Premises size (small, medium, or large), and approximate floor area;

> If people lived in the residence;

> Information relating to flood proofing of materials; and,

> Easting and Northing (in MGA zone 56 co-ordinates).

This information is critical for identifying which properties are affected by overfloor flooding and in assessing the economic damages associated with flooding (see **Section 5**). This information has been provided separately to Council for privacy reasons and is not included in this FRMS&P report.

2.2.2 GIS Data

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

> Stormwater network, including pit and pipe data;

> Cadastre;

> Building footprints;

> Aerial photography;

> Land use zoning; and

> Roads.

In addition, Council supplied surface contours at 0.5 metre intervals based on Aerial Laser Survey (ALS) recorded in 2006. This data acted as the basis for the 2D hydraulic model terrain adopted in the *Coogee Bay Flood Study* (BMT-WBM, 2013).

2.2.3 Site Inspection

Site inspections of the study area were conducted by Cardno hydraulic engineers on two occasions: 8 April 2014 and 29 May 2014. The site visits provided the opportunity to review flood issues identified as part of the Flood Study (BMT WBM, 2013), and to identify and review the feasibility of potential flood mitigation options.

2.3 Stakeholder and Community Consultation

2.3.1 Coogee Bay Floodplain Risk Management Committee

The primary mechanism by which the study team engaged in consultation with key stakeholders and the community is via the Coogee Bay Floodplain Risk Management Committee (the 'Committee') convened by Council. The Committee includes membership by the following individuals:

> Councillor Murray Watson;

> Councillor Tony Bowen;

> Two community representatives;

> A number of staff from Council who have involvement in the study, including the:

- Manager, Technical Services,
- Manager, Development Assessment,
- Manager, Strategic Planning,
- Coordinator, Development Assessment,
- Coordinator, Engineering Services, and
- Drainage Engineer;

> The SES Local Controller;

> Floodplain Engineer from the OEH;

> Sydney Water; and,

> Bureau of Meteorology (BoM).

The Cardno study team met with the Committee on 26 November 2014 to discuss the following:

> Provide information on the floodplain management process;

> Provide an overview of the Flood Study (BMT WBM, 2013) and additional investigations undertaken by Cardno;

> Present preliminary FRMS&P findings; and

> Review the proposed flood modification options.

The primary intent of this meeting was to seek feedback from the Committee on the flood modification options, and to provide Committee members with an opportunity to ask questions about the FRMS&P. The Committee members were generally supportive of the preliminary options developed and assessed by Cardno, and did not offer any specific advice or recommendations on any changes to the options assessed or for the inclusion of additional options. The flood risk management options are discussed further in **Section 9**.

The Committee also discussed the property tagging process, whereby flood affected properties are identified under Section 149 of the *Environmental Planning and Assessment Act 1979* (EP&A Act) as being subject to a natural hazard, and potentially also subject to a relevant development control.

The Committee requested that they be provided an opportunity to review the Draft FRMS&P prior to it being placed on public exhibition. A committee meeting was held at Randwick City Council chambers on 4 April 2016 where the Draft Report (Rev C) was presented to the committee. The report has been amended slightly prior to public exhibition in response to comments from the committee (Rev D). It was agreed in the meeting that the document was suitable for public exhibition.

A Floodplain Committee meeting to discuss the outcomes of the public exhibition as well as the resulting changes to the report (Rev E) was undertaken on 15 November, 2016.

2.3.2 Agency Consultation

A number of relevant stakeholder agencies were consulted through the study to inform them on the FRMS&P objectives, its potential relevance to each agency and to request any useful information relating to the Coogee Bay catchment that the various agencies could provide.

This consultation process was conducted over the phone and via email with contacts provided by Randwick City Council. The agencies that were consulted during the study included:

> Sydney Water Corporation;

> NSW Office of Environment and Heritage (OEH);

> NSW State Transit Authority (STA);

> NSW State Emergency Service (SES);

> Council's strategic planning, and engineering services teams.

The key outcomes of the agency consultation were:

> State Emergency Service noted that there was not an existing Flood Plan for the Coogee Bay area and confirmed that a regional Emergency Management Plan (EMPLAN) was under development. The development of the EMPLAN would be informed by the flood information provided within the Flood Studies and Floodplain Risk Management Studies and Plans in preparation for the region.

> Sydney Water noted that that across their sewer network there are designed release points, including several within the Coogee Bay catchment which are relatively smaller outlets. In addition, there are uncontrolled wet weather overflows however in their experience the capacity of the Coogee Bay sewer network is relatively good, with the Coogee diversion to Malabar being of sufficient capacity.

> State Transit Authority noted that the flooding of Coogee Oval was a concern given the existing bus terminal on Arden Street opposite the oval.

> Council's planning team noted that they were in the process of reviewing the Section 149 certificates system for the LGA with the assistance of Council's floodplain officers.

2.3.3 Community Newsletter

The wider community was advised of the FRMS&P via the distribution of a newsletter on 5 August 2014 to all those properties lying within the Flood Planning Area. The purpose of the newsletter was to advise that Council was undertaking the FRMS&P and to provide information on the floodplain management process and flood risk in the study area. A copy of the newsletter is provided in **Appendix A**.

2.3.4 Public Exhibition

The community was invited to comment on the draft FMRS&P via public exhibition of the document. The report was placed on public exhibition between 8 July 2016 and 5 August 2016. The public exhibition was advertised via the following methods:

> On line via YoursayRandwick (including the draft FPRMSP, map of the flood affected properties, summary map of the mitigation options, frequently asked questions)

> An information letter including frequently asked questions was sent to all residents within the flood planning area (2,866 letters sent)

> Advertisement in the Southern Courier

> All documents were made available in the reception area of the Council Administration Centre and at Council's three libraries.

A community information session was held on Thursday 21 July, 6-8pm at the Coogee Legion Club, 200 Arden Street Coogee. The purpose of the drop-in session was to enable the public to ask questions directly of the study team including Randwick Council staff and consultant staff from Cardno.

The following summarises the key outcomes of the public exhibition period and the responses received:

> 861 persons visited the Coogee Bay FPRMS&P page on Yoursay Randwick;

> 248 persons downloaded the Draft FPRMS&P Report, 346 downloaded the flood affected area map, 183 people downloaded the flood mitigation options map, and 45 people downloaded the FAQ sheet;

> Residents from a total of 15 properties attended the drop-in session;

> A total of 10 queries were lodged on the public exhibition website, two email queries were received from residents following the drop-in session, and Council received numerous telephone enquiries from residents regarding the Study.

Following review of submissions from the public during the exhibition period, amendments have been made to this FRMS&P Report. A summary of submissions and responses to these submissions is included in **Appendix B**. The most significant change to the FRMS&P as a result of public comment was the inclusion of an additional floodplain management option for flooding near the intersection of Brook Street and Smithfield Avenue (refer to **Section 9.2** for further details).

The FRMS&P reduced the number of properties that were tagged as flood affected following the completion of the Flood Study. Analysis following the public exhibition resulted in the removal of flood tagging for a further ten properties, and the re-inclusion of seven properties to the tagging all of which were previously tagged under the Flood Study.

3 Study Area Description

3.1 Overview

The characteristics of the study area can influence the type and extent of flood mitigation measures available for implementation. Characteristics such as the extent of developed areas, topography, soil types and the presence of ecological habitats, threatened species, heritage sites may define or constrain flood mitigation measures in one way or another. In some cases, it will be via a statutory instrument that either precludes, or requires modification of, the flood mitigation measure at that location, whereas in other cases the characteristic of the subject site may require additional work to be done in order to implement the measure, such as treatment of Acid Sulfate Soils (ASS).

Social characteristics may impact the community's response to flooding and therefore affect the type of flood mitigation measures proposed. Key social characteristics include the type of development present, turnover of residents, high rates of visitation and languages spoken by residents. It is, therefore, helpful to understand those factors that will influence the type and location of flood management measures that might be suitable (see **Section 9**), and this information is also used in the options assessment process (see **Section 12**).

The following study area characteristics have been discussed in this section:

> General catchment description;

> Topography and soils;

> Land use and land tenure;

> Flora and fauna;

> Cultural heritage; and,

> Demographic profile.

3.2 Coogee Bay Catchment

The Coogee Bay catchment covers an area of 2.9 km^2 and includes the majority of the suburb of Coogee, as well as the northern part of South Coogee, and the eastern part of Randwick (**Figure 1-1**).

The drainage system that captures stormwater consists of open channels, covered channels, in-ground pipes, culverts and pits which convey runoff from the catchment to Coogee Bay via the stormwater outlet located at the northern end of Coogee Beach. There are a number of smaller stormwater outlets further south which discharge to the sea adjacent to Wolseley Road and Beach Street. The majority of the trunk drainage system is owned by the Council, with some parts of the system owned by the Sydney Water Corporation. There is also inter-allotment drainage that conveys stormwater through private properties, some of which is Council owned infrastructure, and some of which is privately owned. This can have implications for any upgrades proposed by this study.

The majority of the catchment is fully developed and consists predominantly of medium to high-density residential and commercial development with some open space areas, including Coogee Bay Oval, the foreshore reserve, Bardon Park, Baker Park, Dunningham Reserve, Goldstein Reserve, Grant Reserve, Coogee Bowling Club and Fred Hollow Reserve. The main commercial precinct within the study area is located on the lower section of Coogee Bay Road and Arden Street, including the beach promenade.

Flooding in the catchment is primarily due to overland flow resulting when the stormwater drainage system reaches capacity. Further discussion on flooding behaviour is provided in **Section 4**. The main overland flow paths are shown in **Figure 4-1**.

A key feature of the catchment is the presence of 'trapped' low points. These areas, due to topographical and stormwater capacity constraints, result in significant ponding and flooding of properties and roads. An example of a ponding area is the Rainbow Street 'sag' in South Coogee. The topography of this depression provides no overland flow outlet, and drainage from the depression is restricted to the trunk drainage discharging from the depression, otherwise sub-surface infiltration. Floodwaters also pond on Coogee Oval,

which effectively acts as a retention basin due to the comparative elevation of Arden Street to the east and capacity limitations in the stormwater outlet to Coogee Bay.

3.3 Topography & Soils

3.3.1 Topography

The topography of the study area consists of steep landform in the upper catchment which is on the western northern and southern sides of the catchment. These ridgelines of the catchment are elevated at between 60 – 85 m AHD and generally grade very steeply towards the centre of the catchment.

The lower catchment generally has more gentle slopes, with elevations between 5 – 30 m AHD in the lower catchment from Clyde Street in central Coogee to the promenade at Coogee Beach. The promenade is elevated quite high above Coogee Beach with the recreational area and surrounding commercial areas at a level of 6 – 8 m AHD and the beach between 0 – 2 m AHD.

The topography of the Coogee Bay catchment is shown in **Figure 3-1**.

3.3.2 Soil Profile

A review of the Soil Landscapes of the Sydney 1:100,000 Sheet indicates that the study area is located on several soil landscape groups, and some limitations to development may be present as a result of this. Soil landscapes underlying the area are shown in **Figure 3-2** and potential soil limitations are outlined below.

> Tuggerah – comprises deep (>200cm) podzols on dunes and podzol/humus podzol intergrades on swales. Limitations include extreme wind erosion hazard, non-cohesive, highly permeable soil, very low soil fertility, localised flooding and permanently high water tables.

> Newport – comprises shallow (<50cm), well sorted siliceous sands overlying moderately deep (<150cm) buried soils including podzolic soils with sandy topsoils on crests and gentle slopes; deep podzols on steep slopes, lower slopes and in depressions. Limitations include very high soil erosion hazard, localised steep slopes, very low soil fertility and non-cohesive topsoils.

> Hawkesbury – shallow (>50cm, discontinuous lithosols/siliceous sands associated with rock outcrop; earthy sands, yellow earths and some yellow podzolic soils on inside benches and along joints and fractures; localised yellow and red podzolic soils associated with shale lenses; siliceous sands and secondary yellow earths along drainage lines. Limitation include extreme soil erosion hazard, mass movement (rock fall) hazard, steep slopes, rock outcrop, shallow, stony, highly permeable soil, and low soil fertility.

> Lambert – shallow (<50cm) discontinuous earthy sands and yellow earths on crests and inside of benches; shallow (<20cm) siliceous sands/lithosols on leading edges; shallow to moderately deep (<150cm) leached sands, grey earths and gleyed podzolic soils in poorly drained areas; localised yellow podzolic soils associated with shale lenses. Limitations include very high soil erodibility, highly permeable soil, very low soil fertility.

> Narrabeen – deep (>200cm) calcareous sands on beaches, siliceous sands and occasional calcareous compressed sands on foredunes. Limitations include extreme wind and wave erosion hazard, non-cohesive soil, very low soil fertility and high soil permeability.

Geotechnical and soil investigations (including consideration of potential soil limitations) may be required should any larger-scale structural management options be proposed as part of the floodplain risk management process to ensure that environmental and design risks are considered and mitigated.

3.3.3 Acid Sulfate Soils

Acid sulphate Soils (ASS) are natural soils that form in seawater or brackish water environments. They are common in every estuary and estuarine floodplain in NSW. These soils contain iron sulphides that are stable when waterlogged, however, when exposed to air after drainage or excavation, the soils rapidly form sulphuric acid. This acid can leak into the surrounding area acidifying neighbouring drains, wetlands, creeks, estuaries and bays causing severe environmental damage.

A review of Council's LEP 2012 mapping Indicates that the study area comprises Class 4 and Class 5 acid sulfate soils (refer **Figure 3-2**). Council consent is required for works in these areas, as follows:

> Class 4:
  - Works beyond two metres below natural ground surface; or
  - Works by which the watertable is likely to be lowered beyond two metres below natural ground surface

> Class 5:
  - Works within 500 metres of adjacent Class 1, 2, 3, or 4 land, which are likely to lower the watertable below one metre AHD on adjacent Class 1, 2, 3 or 4 land.

3.4 Land Use and Land Tenure

3.4.1 Land Use

Land use zonings for the Coogee Bay catchment are outlined within the Randwick Local Environmental Plan (LEP) 2012, with the land use zonings from the LEP shown in **Figure 3-3**.

The majority of the study area is zoned R3 – Medium Density Residential or R2 – Low Density Residential. There is a small area of land zoned B2 – Local Centre near the beach surrounding Coogee Bay Road, with an additional small pocket on the north-east side of Coogee Oval fronting the beach.

There are also large areas zoned RE1 – Public Recreation, largely along the foreshore, with one smaller area of RE2 – Private Recreation behind Battery Street, Coogee. On the corner of Battery and Beach Streets is land zoned SP2 – Infrastructure, which appears to be associated with the University of NSW.

A percentage break-down of land zonings within the Probable Maximum Flood (PMF) extents for the Coogee Bay catchment has been included in **Table 3-1**.

Table 3-1 **Land Zoning Area Breakdown within Probable Maximum Flood Extents**

Zone	Zone Description	Area % of Probable Maximum Flood Extents
B1	Neighbourhood Centre	1.5%
B2	Local Centre	5.3%
R2	Low Density Residential	18.5%
R3	Medium Density Residential	56.9%
RE1	Public Recreation	17.0%
SP2	Infrastructure	0.9%

3.4.2 Land Tenure

Land tenure is important in terms of both flood mitigation options as landowner consent or other permits and approvals may need to be obtained prior to undertaking the work. It is assumed the vast majority of land with residential or commercial zonings is privately owned.

The notable publically owned open space areas include:

> Coogee Oval;

> Coogee Beach Promenade;

> Bardon Park (owned by Crown Lands);

> Fred Hollows Reserve;

> Trenerry Reserve;

> Clyde Street Park; and,

> Reserve running along Dolphin Street.

The locations of the above open space reserves are shown in **Figure 3-3**.

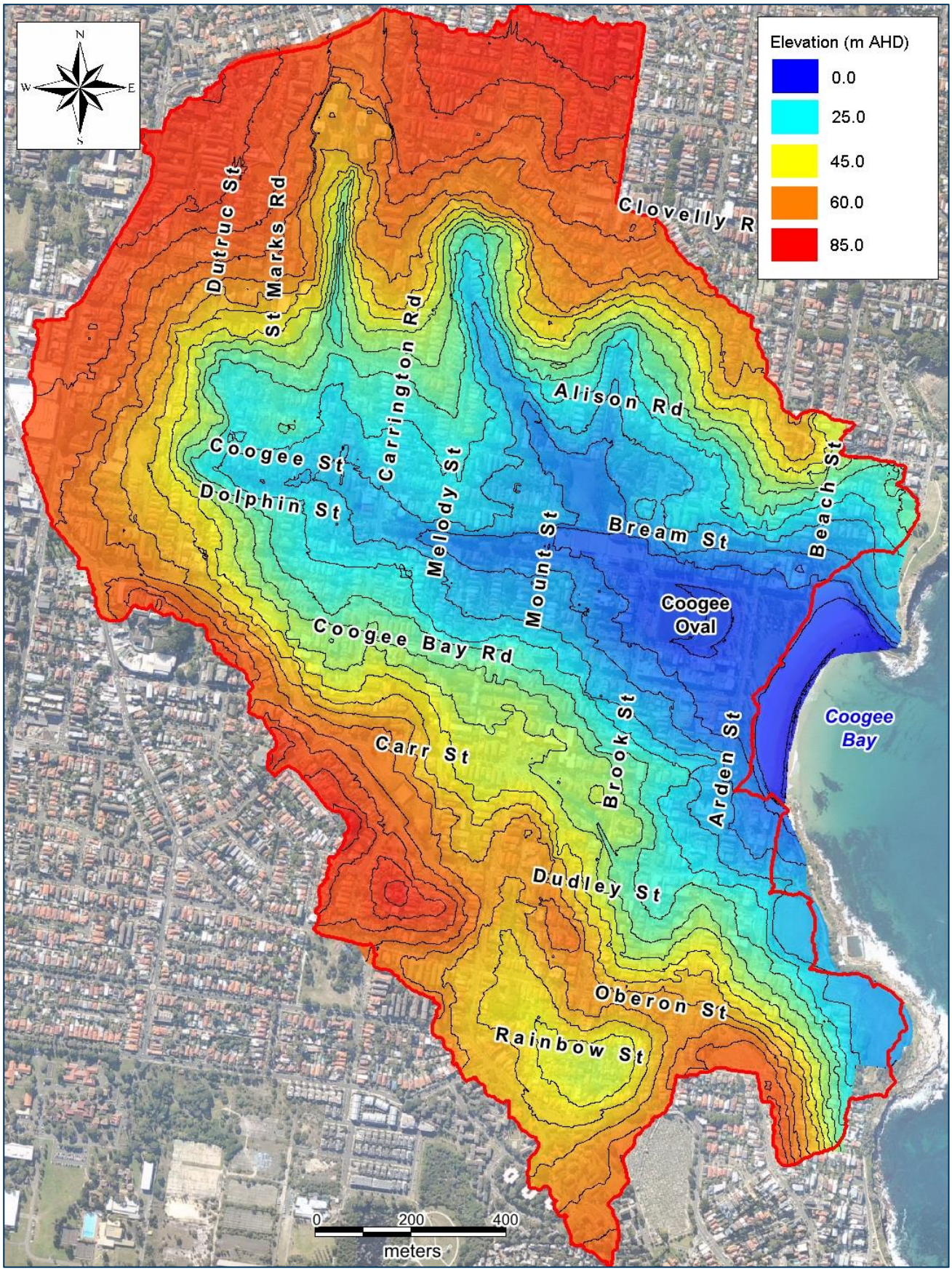

Figure 3-1 Coogee Bay Catchment Topography (Contour Interval 5 metres)

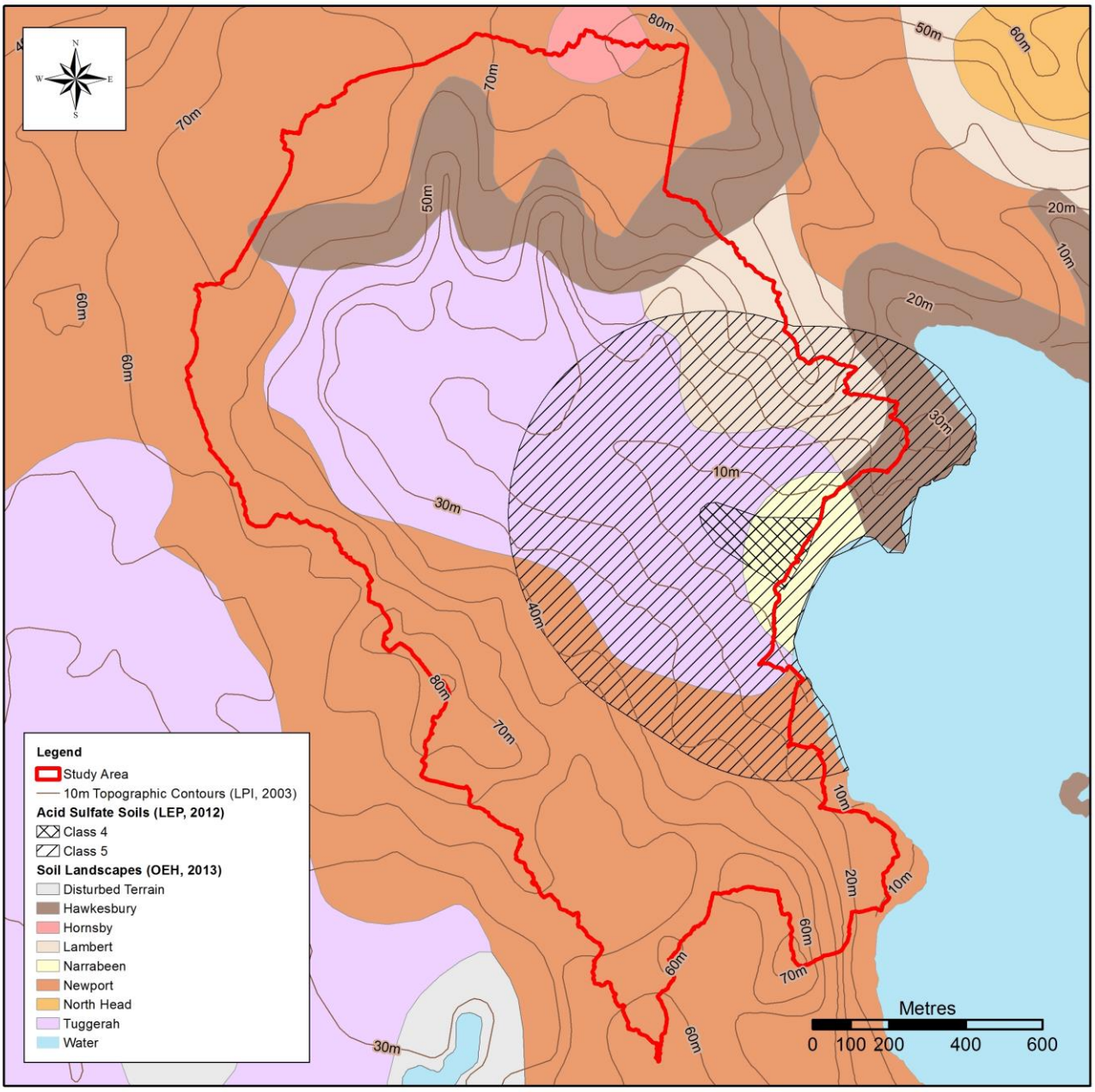

Figure 3-2 Soil Landscapes and Acid Sulfate Soil Risk

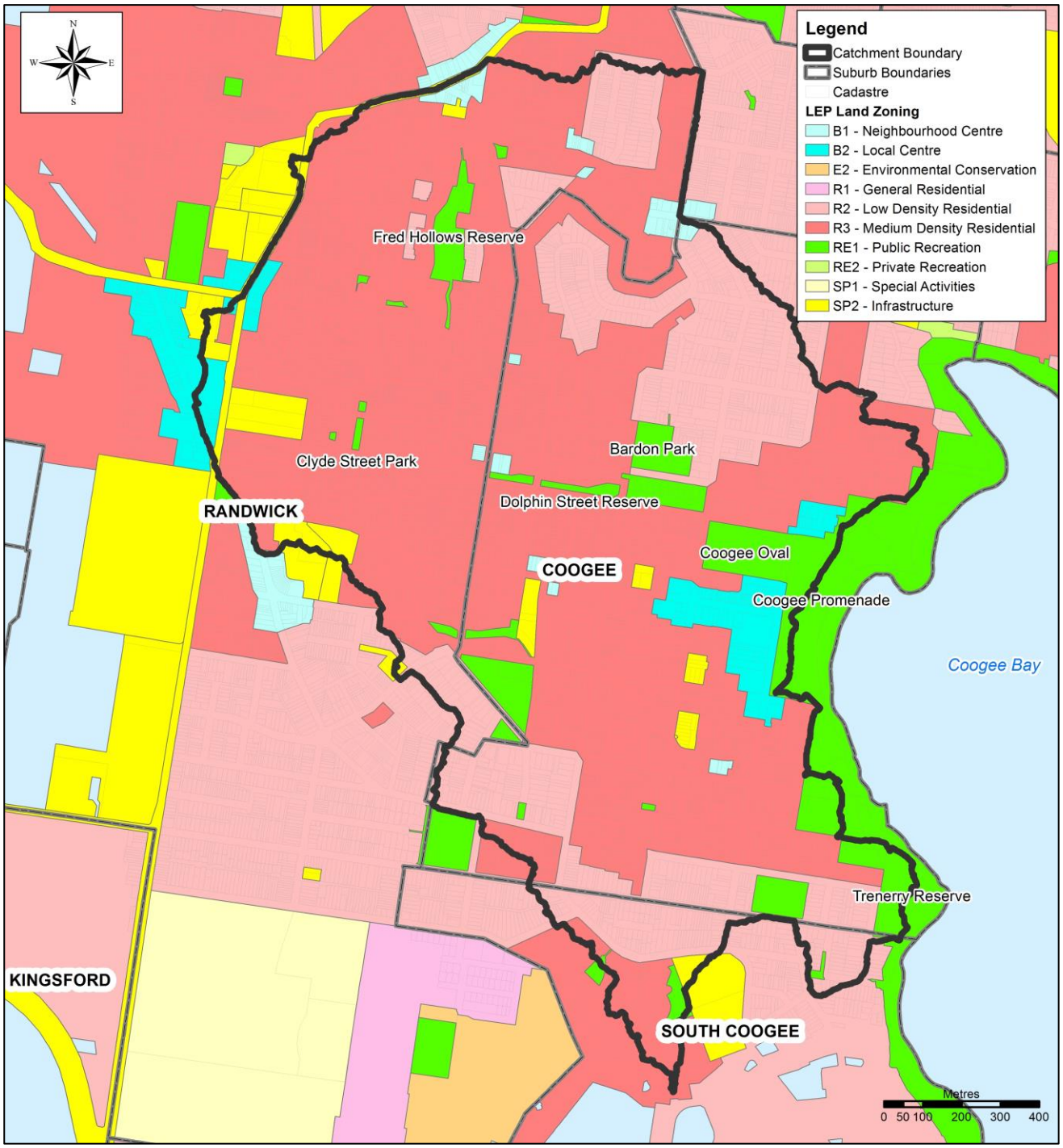

Figure 3-3 Randwick Local Environmental Plan Land Use Zoning with Location of Open Space Reserves

3.5 Flora and Fauna

There are no national parks or reserves in the study area. The nearest national parks are Sydney Harbour National Park (located approximately 6km to the north) and Botany Bay National Park (located approximately 6km to the south).

A search of the Australian Department of the Environment's Protected Matters Search Tool (DotE, 2015a) undertaken on 14 October 2015 indicated that within an area 2km around the study area, two threatened ecological communities are known or likely to occur, namely:

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

> Eastern Suburbs Banksia Scrub of the Sydney Region (Endangered)

The search also indicated that a total of 58 threatened species and 53 migratory species are known, likely or may occur in the area.

A search of the OEH (2015a) Bionet database was undertaken on 14 October 2015 to assess relevant biodiversity features within the study area, with the outcomes of this search included in **Appendix C**. A total of 67 threatened flora sightings have been recorded within a 10km area around the study area, consisting of 15 species (refer **Appendix C**). Approximately 769 threatened fauna sightings have been recorded in the study area, consisting of 44 bird species, 11 mammal species, 1 reptile species and 1 amphibian species (refer **Appendix C**).

Consideration should be given to the potential presence of endangered vegetation communities and threatened species when considering the development of flood mitigation works. Species type, abundance and distribution should be considered, and further investigation may be required if impacts are anticipated.

It is also noted that within the Coogee Bay catchment there is remnant vegetation within Fred Hollows Reserve and Trenerry Reserve (coastal reserve at the end of Rainbow and Oberon Street).

3.6 Aboriginal and Non-Aboriginal Cultural Heritage

3.6.1 Aboriginal Heritage

'Traditional Custodians' is the term to describe the original Aboriginal or Torres Strait Islander people who inhabited an area (DLG, n.d). A number of traditional Aboriginal clan groups occupied the land in the Randwick area prior to the arrival of Europeans. The culture of these peoples included diversity in language, lifestyle, ceremony, kinship and spirituality. Many ancestors of the traditional owners of the Randwick area still reside within La Perouse and surrounding suburbs (Randwick City Council, 2015). Aboriginal objects and places of heritage significance provide evidence relating to Aboriginal habitation of an area and are of special cultural significance to Aboriginal people because of their spiritual, ceremonial, historic, social or educational values.

A search of the Aboriginal Heritage Information System (OEH, 2015b) in October 2015 showed that 1 item of Aboriginal archaeological and heritage significance are known to be present in the study area. In addition, although much of the land in the study area has been disturbed, there is potential for Aboriginal objects to exist in some locations even though they have not been formally recorded.

All Aboriginal sites are protected under the *National Parks and Wildlife Act 1974* (NPW Act) and any works likely to impact on Aboriginal object or place of heritage significance are only permitted where an Aboriginal heritage impact permit has been issued by the NSW Office of Environment and Heritage. Known Aboriginal sites should be left undisturbed if possible, and under the NPW Act it is a requirement that proposed developments show "due diligence" with regard to Aboriginal heritage in the area.

3.6.2 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 study area. Searches were undertaken of the following databases:

- Australian Heritage Database which incorporates World Heritage List; National Heritage List; Commonwealth Heritage List (DotE, 2015b);
- State Heritage Register (OEH, 2015c); and
- Local Council Heritage as listed on the *Randwick Local Environmental Plan 2012* (Randwick City Council (2012a).

Within the suburbs of Coogee, Randwick and South Coogee, one Commonwealth heritage item was recorded (refer **Table 3-2**). A further 53 items were recorded but have non-statutory status under Commonwealth legislation (but are likely to be picked up in the State and Local heritage registers).

Based on a search of the State Heritage Register (OEH, 2015c) a total of 18 heritage items were identified as being listed under the NSW *Heritage Act 1977*, with an additional 19 identified as being listed by State Agencies under Section 170 of the Act (refer **Table 3-2**). The NSW Heritage Council is the consent authority for any development proposal affecting State Heritage Items, or for any site covered by an Interim Heritage Order under the *Heritage Act 1977*.

In addition to items listed under Commonwealth and State legislation, there are 470 items of local significance listed on the *Randwick Local Environmental Plan 2012* (Randwick City Council, 2012a) in addition to 20 heritage conservation areas and 19 listed archaeological sites. Where alteration of a heritage item or undertaking development in a heritage conservation area is proposed, the proponent must refer to the *Randwick Local Environmental Plan 2012* and Part B of *the Randwick Development Control Plan 2012* 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. Heritage features in the study area are shown on **Figure 3-4**.

Note that there are no state heritage items listed in **Table 3-2** that lie within the Flood Planning Area for the Coogee Bay catchment as shown in **Figure 3-4**. However as shown in **Figure 3-4** there appears to be up to 10 local heritage sites that have at least a portion of the heritage site that lies within the Flood Planning Area.

Table 3-2 **Summary of Non-Indigenous Heritage Items**

Item name	Address	Suburb	Information Source
School of Musketry and Officers Mess, Randwick Army Barracks	Bundock Street	South Coogee	Commonwealth Heritage List
Cliffbrook	45-51 Beach Street	Coogee	State Government – Heritage Act
McIver Women's Baths	Grant Reserve	Coogee	State Government – Heritage Act
Wylie's Baths	4B Neptune Street	Coogee	State Government – Heritage Act
Coogee - Randwick Outfall	Northern Headland of Coogee Beach	Coogee	State Government - Section 170
Electricity Substation No. 141	135S Brook Street	Coogee	State Government - Section 170
Electricity Substation No. 198	114A Brook Street	Coogee	State Government - Section 170
Electricity Substation No. 280	15S Higgs Street	Coogee	State Government - Section 170
Electricity Substation No. 289	1S Abbott Street	Coogee	State Government - Section 170
Avonmore Terrace	26-42 The Avenue	Randwick	State Government – Heritage Act
Big Stable Newmarket	29-39 Young Street	Randwick	State Government – Heritage Act
Corana and Hygeia	211-215 Avoca Street	Randwick	State Government – Heritage Act
Electricity Substation No. 349	2S Frances Street	Randwick	State Government – Heritage Act
Emanuel School	18-20 Stanley Street	Randwick	State Government – Heritage Act
Hooper Cottage	17 Gilderthorpe Avenue	Randwick	State Government – Heritage Act

Item name	Address	Suburb	Information Source
Nugal Hall	16-18 Milford Street	Randwick	State Government – Heritage Act
Randwick Post Office (former) and Jubilee Fountain	124 Alison Road	Randwick	State Government – Heritage Act
Randwick Presbyterian Church	162 Alison Road	Randwick	State Government – Heritage Act
Rathven	43 St Marks Road	Randwick	State Government – Heritage Act
Ritz Theatre	43 St Pauls Street	Randwick	State Government – Heritage Act
Sandgate	128 Belmore Road	Randwick	State Government – Heritage Act
St. Jude's Anglican Church, Cemetery, Rectory, Vergers Residence	102-108 Avoca Street	Randwick	State Government – Heritage Act
Substation	60 Bundock Lane	Randwick	State Government – Heritage Act
Venice	66 Frenchmans Road	Randwick	State Government – Heritage Act
Birds Gully Stormwater Channel No 10	Avoca Street	Randwick To Botany Wetlands, Daceyville	State Government - Section 170
Electricity Substation No. 281	2S Albert Street	Randwick	State Government - Section 170
Electricity Substation No. 301	1S Gordon Street	Randwick	State Government - Section 170
Electricity Substation No. 33	52 Coogee Bay Road	Randwick	State Government - Section 170
Electricity Substation No. 341	55-61 Canberra Street	Randwick	State Government - Section 170
Electricity Substation No. 349	2A Frances Street	Randwick	State Government - Section 170
Electricity Substation No. 362	245 Oberon Street	Randwick	State Government - Section 170
Gate and Fence	High Street	Randwick	State Government - Section 170
Main Block, Former	High Street	Randwick	State Government - Section 170
Outpatients Buildings, Former	High Street	Randwick	State Government - Section 170
Randwick Fire Station	4 The Avenue	Randwick	State Government - Section 170
Randwick Reservoir (WS 0101)	Howard Street	Randwick	State Government - Section 170
Statue of Captain James Cook RN	Belmore Road	Randwick	NSW Government Gazette
Super Intendant's Residence	High Street	Randwick	State Government - Section 170
The Prince of Wales Hospital	High Street	Randwick	State Government - Section 170

Figure 3-4 Heritage Items in the Study Area

3.7 Demographic Profile

A knowledge of demographic profile assists in the preparation and evaluation of flood management options which are appropriate for the local community. For example, the data is relevant in the consideration of emergency response or evacuation procedures (e.g. information may need to be presented in a range of languages and special arrangements may need to be made for less mobile members of the community).

The demographic profile of the Coogee Bay catchment presented in this report includes the suburbs of Coogee and South Coogee. Although a small part of the suburb of Randwick falls within the Coogee Bay catchment, the majority of this suburb lies outside of the catchment and was therefore not considered within the demographic analysis due to the risk of bias. Population data for was sourced primarily from the Australian Bureau of Statistics (ABS) 2011 Census and aggregated to produce an overall synopsis for general area based on the Coogee and South Coogee statistics. Data on property values were sourced from Australian Property Monitor (http://apm.com.au/).

The total population of Coogee and South Coogee as at the 2011 Census was just over 19,000, and in 2013, the population increased by 2% (id, 2015). A summary of the key population statistics is provided below:

> The largest demographic is aged 20-29 years, comprising 24% of people living in Coogee and South Coogee. In total 79% of the population are aged below 55 years, which indicates a community which is likely to be primarily able-bodied, able to evacuate effectively and/or assist with evacuation procedures. 15% of respondents are aged 14 years or younger. Younger children in particular may require assistance during a flood event;

> Of all respondents, 95% speak only English or speak English 'well or very well'. Of those who speak a language other than English at home, the main language spoken is Greek (2.6%), followed by Chinese (2.0%), French (1.7%) and German (1.2%). Of Chinese speakers, just over half speak Mandarin, and the majority of the remainder speak Cantonese. This data indicates English would be the appropriate means of communication with the community. Where materials are provided in other languages, Council should consider Greek and Chinese translations;

> 82% of respondents have an internet connection, the majority having broadband. This indicates that internet based communications may be an effective means of communication with residents;

> A total of 27.2% of residents live in a detached house, 12.9% in a semi-detached dwelling, and 59.7% in a unit;

> Regarding the residential tenure status, 45.1% are owners and 52.3% renters;

> Of all respondents to the 2011 Census, 19.2% were not resident in the area 1 year ago, and 46.0% were not resident in the area 5 years ago. These statistics highlight the relatively high turnover of residents within the study area, indicating that regular communication of flood risk, or provision of flood information to new tenants will be important; and,

> In Coogee and South Coogee respectively, the median house prices were $1,808,000 and $1,950,000, as compared to a median house sale value of $1,491,000 for the Randwick LGA. Unit prices were $795,000 and $781,000 for Coogee and South Coogee respectively, compared to the median sale value of $720,000 for the Randwick LGA. This data is based on the previous 12 months of sales data up until October 2014. In NSW, the median house price is $535,000, and unit price is $550,000 (APM, 2015), significantly lower than the median property values in the Coogee Bay catchment. This information has implications for the economic damages incurred during a flood event.

Additional information on the economic profile of the area was sourced from id (http://www.id.com.au). The highest proportion of registered businesses within the LGA includes (id, 2015):

> Professional, scientific and technical services (16.6%);

> Rental, hiring and real estate services (13.5%); and,

> Construction (13.1%).

Businesses falling under these categories would all contribute in some way to the local economy. However, one of the tourism and hospitality industry is one of the most readily visible industries within the study area that has potential to be impacted by flooding. Although representing only 4.6% of the total registered businesses in the LGA under the category of accommodation and food services (id, 2015), tourism and hospitality contributes significantly to the local economy, totalling $355 million to the economy of the City of Randwick in 2012/2013 (id, 2015), a proportion of which would be derived from businesses located within the study area.

A large number of businesses located in the lower catchment, particularly along the downstream end of Coogee Bay Road and the section of Arden Street opposite the promenade, fall under this category. In addition, tourism and hospitality businesses within the LGA provide direct employment for just under 2,000 people (id, 2015). Hence, any flood related impacts on tourism and hospitality businesses in the Coogee Bay floodplain have potential to negatively impact on the local economy.

4 Flood Behaviour

The focus of this study is on catchment flooding, that is, flooding caused by excessive rainfall on the catchment creating overland flow. The catchment is heavily urbanised with the following flow regime typical throughout the catchment:

> Along most major flowpaths, which generally represent the predevelopment creek lines, a significant trunk drainage line has been placed underneath the local low point, often capable of conveying the relatively infrequent flood events (typically up to 20% - 5% AEP events);

> Due to the development of residential properties, and the construction of road embankments across local low points, the majority of flowpaths do not have a consistently falling grade in the direction of flow, leading to areas of significant ponding due to the obstruction of flow. The most prominent example of this is where the raising of Arden Street and Goldstein Reserve in the past has resulted in an obstruction of flow to Coogee Beach which leads to excessive ponding in the Coogee Oval depression. Similarly throughout the upper catchment, the development of the catchment has resulted in local low points being established with limited discharge opportunities available. This leads to situations of minor ponding from small local catchments, disconnected from any major overland flowpaths.

4.1 Flowpaths

Flooding within the Coogee Bay catchment is primarily confined to 12 key overland flowpaths (**Figure 4-1**). Eight of these flowpaths are tributaries of the main catchment within Coogee which discharges to the Coogee Oval depression, two flow to the local low point near Rainbow Street, and two discharge to the south of Coogee Beach near Carr Street. A summary of the flood behaviour for each of the 12 flowpaths have been summarised below:

> A - Dolphin Flowpath: The major tributary of Coogee Bay includes a major trunk drainage line that runs under the low point for its entire length. From Judge Street to the west, the flowpath follows the low point along the rear of residential properties between Coogee and Dolphin Streets, with a number of significant ponding locations resulting from local flow obstructions. The flowpath crosses Carrington Road, which acts as a flow obstruction, running along Dolphin Street and the adjoining public reserve, before diverting into the Coogee Bowling Club and Coogee Tennis Club, and from here crossing Brook Street and discharging to the Coogee Oval depression. Floodwaters then discharge either through the trunk drainage line that discharges to the north of Coogee Beach, or if ponding is sufficient to overtop Arden Street and Goldstein Reserve then discharge occurs to Coogee Beach via the promenade.

> B - Courland Flowpath: One of two south orientated tributaries to the Dolphin Flowpath originates at a relatively high elevation near Bligh Place. The flowpath converges to a section of remnant natural creek channel within Fred Hollows Reserve, passing under the elevated Alison Road embankment through a large culvert. Downstream of Alison Road a large diameter pipe conveys flow below a heavily urbanised and disrupted flowpath through residential area, with an area of ponding upstream of Courland Street, with flows converging with the Dolphin Flowpath at the intersection of Courland and Coogee Street.

> C - Clyde Flowpath: Flows from the surrounding steep residential area converge at Clyde Street flowing south into the Clyde Street open space reserve and adjoining low-lying residential properties. The Coogee Street embankment to the south acts as a major flow obstruction resulting in excessive ponding upstream, with a large diameter pipe conveying flow to the upper Dolphin Flowpath. Any excess overland flow is diverted along Coogee Street before converging with the Dolphin Flowpath on Coogee Street.

> D - Queen Flowpath: Flows from the south-west of Coogee Bay converge on a heavily urbanised and disrupted low point through residential area to the west of Carrington Road. The flow here could be best described as disconnected ponding, with flow converging with the Dolphin Flowpath at the intersection of Carrington Road and Dolphin Street.

> E - Carrington Flowpath: A small catchment to the north of the Dolphin Flowpath near Carrington Road diverts flow through residential properties as disconnected ponding. Due to the size of the catchment, the flowpath only forms for large infrequent flood events greater than the 1% AEP event.

> F - Pauling Flowpath: The second major south orientated tributary to the Dolphin Flowpath originates from the elevated plateau near Clovelly Road. Flow from the steep embankments surrounding Pauling Avenue converge on the low point within the road reserve, with a large diameter pipe conveying flows beneath the road. The flowpath crosses Alison Road before entering a residential area with excessive ponding between Abbott Street and Mount Street. Overland flow converges within a natural basin at Bardon Park before overtopping Bream Street to converge with the Dolphin Flowpath at the Coogee Tennis Club.

> G - Leeton Flowpath: Flows from the surrounding catchment converge at Leeton Avenue with the south-orientated road aligning with a local low point. The flowpath enters a number of residential properties to the south of Leeton Avenue before converging with the Pauling Flowpath at Bardon Park.

> H - Smithfield Flowpath: A small catchment with relatively gentle grade has flows that converge at a local low point within residential properties to the south of Arcadia Street. There is a poorly defined low point within residential areas either side of Brook Street with flows entering Bardon Park to the west.

> I - Rainbow / Oberon Flowpath: These two flowpaths on the south of Coogee Bay divert flows in a south-west direction to a low point near Rainbow Street. There is no overland discharge point meaning flows from the surrounding catchment all converge to the one depression, which is drained by a 1.05m diameter pipe conveying flows to the north-east and discharging to the sea. For large infrequent flooding events the capacity of the pipe is exceeded and significant ponding occurs within the Rainbow Street depression, up to depths of 7 metres in the Probable Maximum Flood (PMF) event.

> J - Mount Flowpath: A small upper catchment discharges through residential properties via a heavily disturbed low point to the west of Mount Street, the flow can best be described as disconnected ponding. Excessive flow is diverted east along Carr Street as shallow sheet flow, with a portion of the flow diverting south-east down Havelock Avenue road reserve and the remainder continuing east along Carr Street.

> K - Havelock Flowpath: Flow from the steep western portion of the catchment is conveyed as sheet flow down Havelock Avenue, while the southern portion of this catchment causes ponding in the commercial properties between Dudley Street and Havelock Avenue. The two flowpaths converge and follow the low point along the road reserves of Havelock Avenue, Arden Street and Carr Street before discharging to the sea south of Coogee Beach.

4.2 Hydrology Catchments

The sub-catchments within the Coogee Bay catchment for the flowpaths described in **Section 4.1** are shown in **Figure 4-1**. A summary of sub-catchment areas is included in **Table 4-1** below.

Table 4-1 **Coogee Bay Hydrology Sub-catchment Areas**

ID	Catchment	Sub-catchment Area (ha)
A1	Dolphin Flowpath – Upper Catchment (upstream of Carrington Road)	19.5
A2	Dolphin Flowpath – Middle Catchment (Carrington Road to Coogee Oval)	23.4
A3	Dolphin Flowpath – Lower Catchment (Coogee Oval)	31.8
B1	Courland Flowpath	25.8
C1	Clyde Flowpath	20.7
D1	Queen Flowpath	17.7
E1	Carrington Flowpath	6.6
F1	Pauling Flowpath	37.7
G1	Leeton Flowpath	12.6
H1	Smithfield Flowpath	7.8
I1	Rainbow Flowpath	26.9
J1	Mount Flowpath	10.6
K1	Havelock Flowpath	19.3
L1	South-east catchment	16.0

Note that there is one additional catchment to the south-east of Coogee Bay which does not have any significant flowpath, with flow conveyed to the ocean as negligible amounts of sheet flow for the catchment.

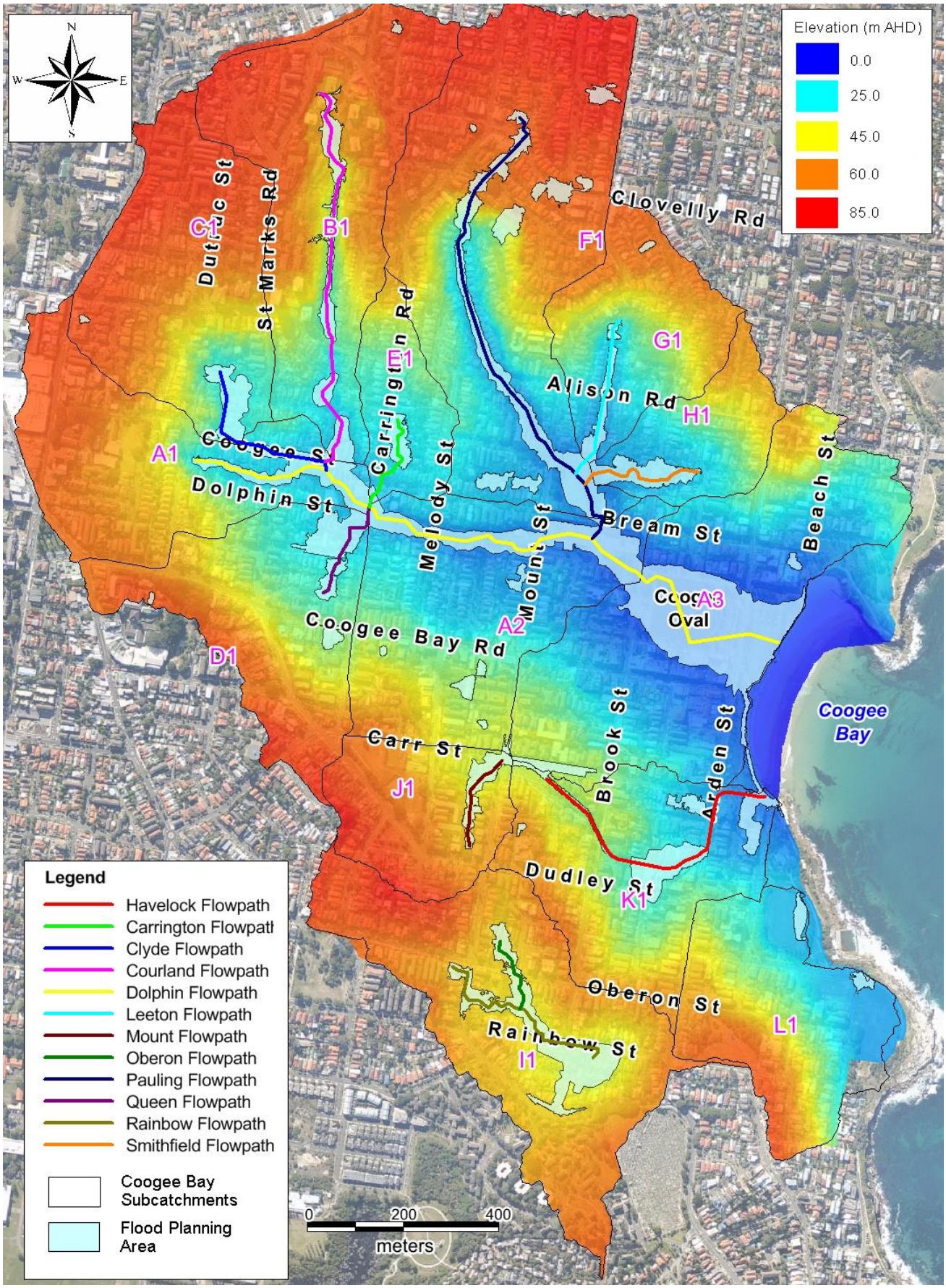

Figure 4-1 Coogee Bay Overland Flowpaths and Subcatchments

4.3 Critical Duration

As part of the *Coogee Bay Flood Study* (BMT-WBM, 2013) the full range of rainfall durations were modelled in the hydrology model in order to identify the critical storm duration for design event flooding in the catchment. Design durations considered included the 15 minute, 30 minute, 45 minute, 60 minute, 90 minute, 2 hour, 3 hour, 4.5 hour, 6 hour and 9 hour durations.

The design flood results are the maximum condition from the combined 90-minute, 2-hour and 9-hour duration events, for which the distribution at the 1%AEP event is presented in Figure 6-1 (in the Flood Study). For the 1% AEP event for the upstream portions of the catchment the shorter durations storms are critical, however generally the 2 hour duration is critical across the majority of the study area. Therefore, only the 2 hour storm has been included in the consideration of the following:

> Flood extents and flood affectation;

> Options modelling;

> Damages assessment;

> Climate change scenarios.

It is noted that the duration of rainfall relates to the entire duration of rainfall, with the high intensity storm burst of the event occurring in a far shorter period than the total duration. For example the majority of rainfall depth for the 2 hour event occurs within a half hour storm burst within the event, meaning it is considered a short duration rainfall. The PMF event was modelled for all short durations including 15 minute, 30 minute, 45 minute, and 4.5 hour durations.

As noted in **Section 2.1.1** the original Flood Study models were converted by BMT-WBM to a newer version of Tuflow (2012-05-AD-w64) to provide a more stable model to take forward into the Floodplain Risk Management process. Therefore, the above outputs from the FRMS&P are based on these newer model results. Flood Planning Levels (FPL's) and Flood Planning Area (see **Section 7**) are based on the adopted Flood Study results, being the older version results.

In accordance with AR&R (1987) all design durations for the various AEP's have been modelled with the same rainfall temporal pattern as that modelled within the 1% AEP. Therefore, the assumption of the 2 hour storm being critical throughout the Coogee Bay catchment has been extended to apply to the 20%, 5%, 0.5% and 0.2% AEP design events as well. For the PMF event it was found that all four rainfall event durations were critical throughout the catchment, therefore all have been considered within this FRMS&P.

4.4 Flood Extents

In the *Coogee Bay Flood Study* (BMT-WBM, 2013) the full extent of flooding was reported with no filtering of results to exclude minor flooding. This approach has been revised as part of this FRMS&P to remove areas of negligible flood affectation from flood extents. The following approach was adopted:

> <u>Areas where the depth does not exceed 0.15m.</u> It has been concluded that depths less than 0.15 metres do not represent significant risk to life or property and flooding is considered negligible at these depths;

> <u>Areas of flooding with a continuous area of affectation less than 100m^2</u>. Areas of flooding less than 100m^2 are considered isolated areas of ponding that represent areas of negligible flood affectation; and,

> <u>Site inspection observations.</u> A ground truthing process was conducted by Cardno staff on 29 May 2014 to confirm the hydraulic model results from the Coogee Bay Flood Study (BMT-WBM, 2013). The outcome of this ground truthing process was the removal of areas of flood affectation that were determined to be insignificant or unrealistic based on observed site conditions

Figure 4-2 shows the flood extents for all modelled design flood events; 20%, 5%, 1%, 0.5%, and 0.2% AEP events and the PMF event. The number of flood affected properties for these events in included in **Table 4-2**. In this instance flood affected properties are defined as any properties that have any portion of the cadastral lot affected by the relevant flood extent.

Figure 4-2 Coogee Bay Flood Extents

Table 4-2 **Number of Flood Affected Properties in Coogee Bay Catchment**

Design Event	Number of Flood Affected Properties[1]	Percentage of Total Properties in the Catchment
20% AEP	165	5.4%
5% AEP	332	10.9%
1% AEP	531	17.5%
0.5% AEP	717	23.6%
0.2% AEP	836	27.6%
PMF	1,628	53.7%

[1] In this instance flood affected properties are defined as any properties that have any portion of the cadastral lot affected by the relevant flood extent. The building within the property may not necessarily be affected.

It can be seen that the flood extents for the 20%, 5% and 1% AEP flood events are typically confined to the major overland flowpaths described in **Section 4.1**, with only a few instances of disconnected ponding occurring in the upper catchment for these events. While for the less frequent events, particularly the PMF event the extent of flooding greatly exceeds these major flowpaths with significant flooding throughout the catchment, although this comprises of mostly disconnected ponding in the upper catchment.

This filtering approach to mapping flood extents is seen as a more focused assessment of flood affectation for properties within the Coogee Bay catchment. This process has also been adopted in the determination of the Flood Planning Area for Coogee Bay catchment with further details provided in **Section 7.6**.

4.5 Ponding

As outlined in **Section 4.1**, there are various locations throughout the catchment where significant ponding of flood waters occurs in all flood events. The locations of significant ponding for Coogee Bay catchment are shown in **Figure 4-3**, with the peak depth results for the 1% AEP event shown.

The occurrence of significant ponding in frequent flood events may be caused by one or a combination of the following issues:

> Overland flow obstruction: This can be caused by any number of things, a low point being cut into the flowpath, a raised embankment being constructed across the flowpath, a constriction of flowpath width, or a structure that blocks flow such as a concrete wall or building. The majority of these flow obstructions will occur in residential development areas as opposed to public reserve or road reserve where natural topography is likely to less altered;

> Trunk drainage capacity: Where the trunk drainage under the flowpath has insufficient capacity to convey frequent flood events. This issue is discussed further in **Section 4.6**.

The peak depths at selected ponding locations for the 20%, 5%, 1% AEP and the PMF flood event, and an indication if the ponding is caused by trunk drainage capacity, or overland flow constriction have been summarised in **Table 4-3**.

4.6 Trunk Drainage Capacity

As mentioned within the flowpath descriptions included in **Section 4.1**, most major tributaries within the Coogee Bay catchment have trunk drainage lines, or large capacity stormwater pipes to convey the more frequent flood events with only minimal overland flow. However as shown in **Section 4.3**, there are locations where it is considered that significant ponding is occurring as a result of trunk drainage capacity issues.

There are two elements of a trunk drainage capacity assessment such as this to consider:

> Inlet pit capacity: It is possible that while the underlying stormwater pipe may have available capacity to convey additional flow during a flood event, if there is insufficient pit inlet capacity, or in some cases that no pit inlets exist at low points, then overland flow cannot enter or is restricted to the drainage network;

> Pipe / culvert capacity: The hydraulic capacity of the concrete pipe / culvert network is affected by the size of the pipe / culvert, the gradient of the structure, and potentially tailwater effects. If the pipe / culvert capacity is surpassed then excess flows will be surcharged from the drainage network resulting in overland flow.

Based on a review of the hydraulic model results for the selected design events; 20%, 5%, 1% AEP and Probable Maximum Flood, it is possible to calculate the approximate Annual Exceedance Probability capacity of the trunk drainage network at various locations within the catchment. For the purposes of this assessment, capacity has been defined to be exceeded when:

> Peak pipe flow for the less frequent AEP is approximately equal to the design event in question, this indicates pipe / culvert capacity has been reached; or,

> Significant overland flow occurs at the low point above the trunk drainage line. If this occurs without the above then it is assumed it is an inlet pit capacity issue.

The outcome of the trunk drainage capacity assessment for the various ponding locations (identified in **Section 4.3**) is included in **Table 4-3**.

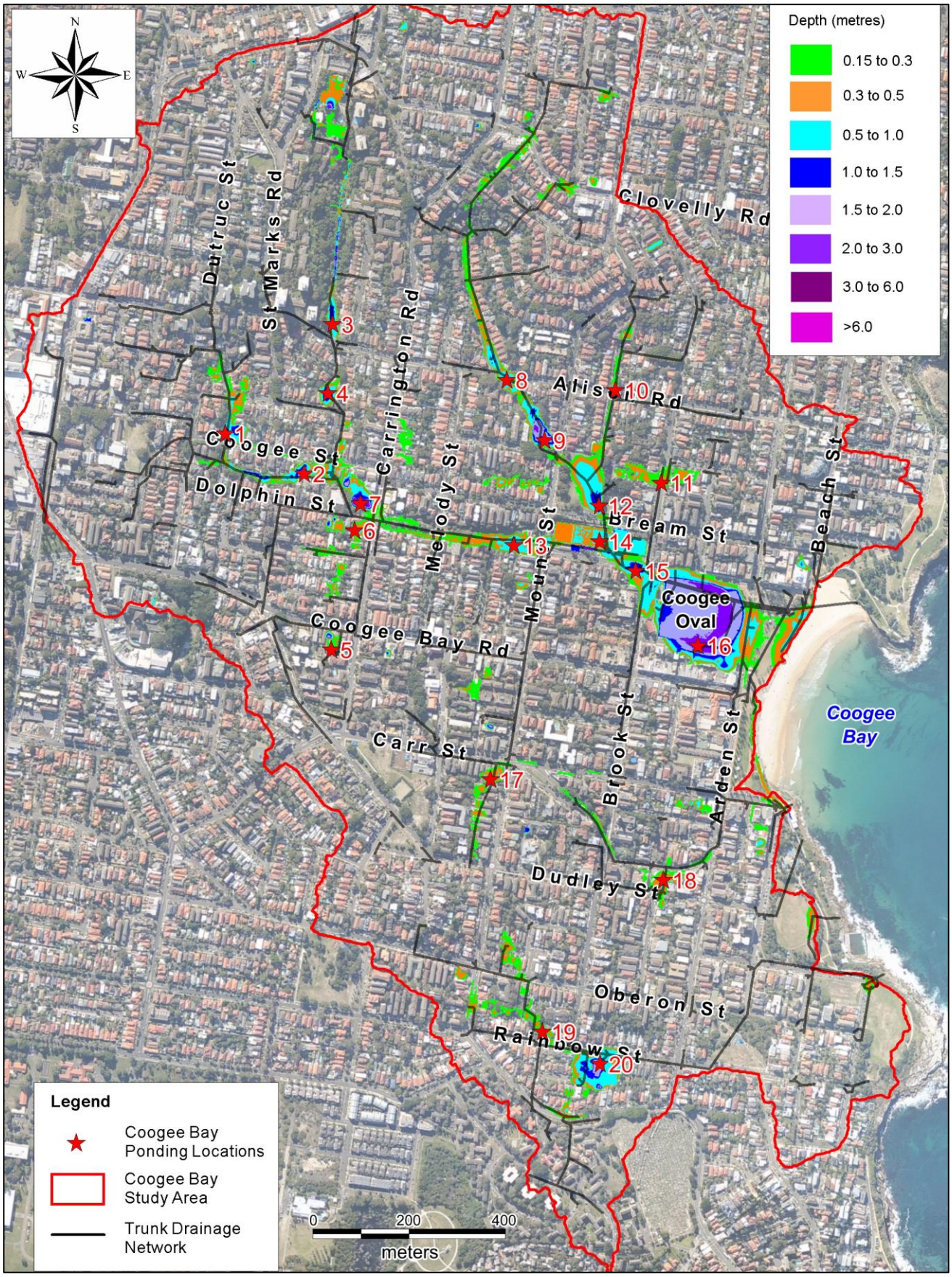

Figure 4-3 Coogee Bay - Ponding Locations showing 1% AEP Peak Depths

Table 4-3 **Coogee Bay Ponding Behaviour Summary**

ID	Location	Peak Ponding Depth (metres)				Pipe Diameter / Culvert Dimensions (metres)	Approx. Pipe / Culvert Capacity (AEP)	Inlet Pit at Ponding Location	Likely Cause of Ponding
		20% AEP	5% AEP	1% AEP	PMF				
1	Clyde Street	0.7	1.1	1.4	2.2	1.2	5%	Yes	Flow obstruction - Coogee Road embankment. Insufficient pit inlets.
2	Upper Dolphin Flowpath	1.3	1.4	1.9	2.8	1.8	5%	No	Flow obstruction - local depressions. No pit inlets available.
3	Fred Hollows Reserve	0.0	0.9	2.1	4.3	1.2	5%	Yes	Flow obstruction - Alison Road embankment.
4	Courland Street	1.8	1.9	2.1	3.1	1.35	5%	No	Flow obstruction - local depression. No pit inlets available.
5	McAnally Lane	0.4	0.5	0.6	1.0	0.3	20%	No	Flow obstruction - local depression. No pit inlets available.
6	Lower Queen Flowpath	0.5	0.6	0.8	1.6	0.9	5%	No	Flow obstruction - local depression. No pit inlets available.
7	Carrington Road	2.0	3.2	3.9	5.1	1.88W x 1.82H	5%	No	Flow obstruction - local depression. No pit inlets available.
8	Pauling Avenue	0.0	0.9	1.2	2.0	1.2m	5%	Yes	Insufficient pit / pipe capacity.
9	Abbott Street	0.9	1.6	2.2	3.2	1.2m	5%	No	Flow obstruction - local depression / concrete wall. No pit inlets available and insufficient pipe capacity.
10	Leeton Avenue	0.3	0.4	0.5	0.9	0.6W x 0.9H	20%	Yes	Flow obstruction - local depression. Insufficient pipe capacity.
11	Smithfield Avenue	0.0	0.5	0.8	1.2	0.45m	5%	Yes	Insufficient pit / pipe capacity.
12	Bardon Park	0.8	1.0	1.3	2.2	1.22W x 1.21H	5%	No	Flow obstruction - Natural detention basin. No pit inlets available, insufficient pipe capacity.
13	Dolphin Street	0.8	0.9	1.1	2.4	1.83W x 1.92H	5%	Yes	Insufficient pit / pipe capacity.
14	Coogee Tennis Club	0.4	0.4	0.5	1.3	2.88W x 1.38H	20%	No	Flow obstruction - Concrete walls. No pit inlets available, insufficient pipe capacity.
15	Brook Street	0.8	1.1	1.4	2.9	2.88W x 1.38H	5%	Yes	Flow obstruction - Natural detention basin. Insufficient pit / pipe capacity.
16	Coogee Oval	1.0	1.7	2.5	3.3	1.5 1.5 1.05	5%	Yes	Flow obstruction - natural regional depression. Insufficient pit / pipe capacity.
17	Mount Street	0.6	0.7	0.8	1.3	0.75	5%	Yes	Flow obstruction - local depression. No pit inlets available.
18	Dudley Street	0.4	0.6	0.7	1.2	0.6	20%	Yes	Flow obstruction - commercial buildings. Insufficient pit / pipe capacity.
19	Upper Rainbow Street	0.4	0.6	0.8	3.3	-	-	No	Flow obstruction - local depression. No pit inlets available.
20	Rainbow Depression	0.4	1.5	2.1	7.1	1.05	5%	Yes	Flow obstruction - natural regional depression. Insufficient pit / pipe capacity.

4.7 Climate Change

The effects of climate change on flooding are typically incorporated 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.

As part of the *Coogee Bay Flood Study* (BMT-WBM, 2013) sensitivity testing of the hydraulic model was conducted for the impact of climate change related sea level rise. A sea level rise value of 0.9 metres was adopted, corresponding to the predicted sea level for the year 2100 from the *Practical Consideration of Climate Change Guideline for Floodplain Risk Management* (NSW Government, 2007).

The outcome of the sensitivity testing found that water level impacts were less than 0.1 metres for the entire Coogee Bay catchment. The lack of sensitivity to sea level rise is a result of the relative elevation of the floodplain compared to sea levels, with the lowest flooding location, the Coogee Bay depression having a minimum level of 4.5 metres AHD.

Therefore the impact of sea level rise have not been investigated further as part of this study.

As requested by Council, climate change related rainfall increase has been modelled for the three scenarios identified in the *Practical Consideration of Climate Change Guideline for Floodplain Risk Management* (NSW Government, 2007); 10% rainfall increase, 20% rainfall increase, and 30% rainfall increase.

These three rainfall increase scenarios have been modelled for the 2 hour duration event for the 20%, 5%, 1%, 0.5%, and 0.2% AEP events. The PMF event has not been modelled for any of these rainfall increase scenarios. The water level increases for the 1% AEP event for the various climate change scenarios are summarised in **Table 4-4**.

Table 4-4 **Climate Change Impacts for the 1% AEP 2 hour event**

ID	Location	Water Level Increases above Existing Scenario – 1% AEP 2 hour		
		10% Rainfall Increase	20% Rainfall Increase	30% Rainfall Increase
1	Clyde Street	0.1	0.2	0.3
2	Upper Dolphin Flowpath	0.1	0.2	0.3
3	Fred Hollows Reserve	0.4	0.8	1.3
4	Courland Street	0.0	0.1	0.1
5	McAnally Lane	0.0	0.1	0.1
6	Lower Queen Flowpath	0.1	0.1	0.2
7	Carrington Road	0.1	0.2	0.3
8	Pauling Avenue	0.1	0.2	0.3
9	Abbott Street	0.1	0.2	0.3
10	Leeton Avenue	0.0	0.1	0.1
11	Smithfield Avenue	0.0	0.1	0.1
12	Bardon Park	0.2	0.3	0.4
13	Dolphin Street	0.1	0.2	0.2
14	Coogee Tennis Club	0.1	0.1	0.2
15	Brook Street	0.2	0.3	0.4
16	Coogee Oval	0.1	0.1	0.2
17	Mount Street	0.1	0.1	0.1
18	Dudley Street	0.1	0.1	0.1
19	Upper Rainbow Street	0.1	0.1	0.2
20	Rainbow Depression	0.2	0.4	0.6
Average Depth across all Locations (m)		**0.1**	**0.2**	**0.3**

The outcome of this climate change assessment shows that the severity of flooding is expected to increase significantly if rainfall increases occur in the future due to climate change. Another way of considering this is that rainfall increases are expected to significantly increase the frequency of major flooding. In order to place the scale of this impact, based on average depths for all 20 locations within the catchment:

- The depths of flooding for the future 1% AEP resulting from a 10% rainfall increase is approximately equivalent to the current climate 0.5% AEP; and,
- The depths of flooding for the future 1% AEP resulting from a 30% rainfall increase is approximately equivalent to the current climate 0.2% AEP.

5 Economic Impact of Flooding

5.1 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 5-1**.

Table 5-1 **Types of Flood Damages**

Type	Description
Direct	Building contents (internal) Structural damage (building repair) 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 service)
Intangible	Social (increased levels of insecurity, depression, stress) Inconvenience (general difficulties in post-flood stage)

The direct damage costs, as indicated in **Table 5-1**, 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.

5.2 Input Data

5.2.1 Floor Level and Property Survey

There are 545 properties potentially impacted by flooding in the 1% AEP, and a total of 1,504 properties potentially impacted by flooding in the PMF. Of these, 805 had surveyed floor levels. For all surveyed properties a range of other details were recorded to inform the damages analysis relating to land-use, building size, occupation, and flood proofing. A further 61 properties were included in the survey but were identified as being vacant. For further details of floor level survey refer to **Section 2.2.1**.

The majority of properties with no survey data available were properties above the Flood Planning Level (1% AEP plus 0.5 metre freeboard). These properties represent those that will only be impacted by less frequent flood events. Floor levels were estimated for these properties. The floor level was assumed to be equal to the highest topographical level on the property. The properties were all assumed to have low set buildings on residential properties with an area of 200m^2 (based on a catchment average of 219m^2). 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.

5.2.2 Hydraulic Model Result Inputs

To inform the damages analysis summarised in **Section 5.3**, peak water level results are required to determine the depth of over-floor flooding and over-ground flooding for each site. To inform this assessment, the peak water level within each land parcel was extracted. This allows all properties with flooding to be included in the assessment, not only the properties with flooding at the location of the existing building (i.e. damages can occur to fences, gardens and other exterior property features even when the

primary building is not impacted). This can be considered a conservative approach as the peak water level may be higher than the water level at the existing building location. However, as the average lot sizes in the catchment are quite small comparative to the average building sizes provided in GIS supplied by Council, this is unlikely to significantly impact the damages outcome.

5.3 Damage Analysis Methodology

A flood damages assessment was undertaken based on damage curves that relate the depth of inundation by floodwaters and potential damages to flood affected properties. Ideally, the damage curves adopted for the analysis should be tailored for the specific catchment for which the study is being carried out. However, damages data is not available for most catchments (including Coogee Bay catchment) and recourse is generally made to damage curves developed for other catchments.

The NSW Office of Environment and Heritage (OEH) has carried out research on flood damages and prepared a (draft) methodology for the development damage curves based on state-wide historical data. It is noted that this methodology relates only to residential properties and does not cover industrial or commercial properties.

Although the OEH methodology comprises the standard recommendation for these studies, and there are currently no prescribed guidelines regarding the use of damage curves in NSW. However, based on Cardno's experience on numerous projects, and in consultation with the OEH, the OEH damages curves were adopted for this FRMS&P.

The following sections set out the methodology for the determination of economic damages from flooding within the within Coogee Bay floodplain. It should be noted that at the time of writing of the report, the most up to date Average Weekly Earnings (AWE) used for the calculation within residential damage curves was March 2015. The most up to date Consumer Price Index (CPI) used within commercial and industrial damager curves was September 2015.

5.3.1 Residential Damage Curves

The DECC (now OEH) *Floodplain Management Guideline: Residential Flood Damage Calculation* (NSW Government, 2007) was used in the creation of the residential damage curves. These guidelines include a template spreadsheet program that determines damage curves for three types of residential buildings, namely:

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

A nominal $3,000 of garden damage was assumed once overground flooding was present in all cases.

Damages are generally incurred on a property prior to any over floor flooding. The OEH curves allow for damages to be incurred when the water level reaches the base of the house, assumed to be 0.1 m, and 1.5 m below the floor level for slab on ground, and high set slab respectively). Damages of this type are generally direct external damages (sheds, gardens), direct structural damages (foundational damage) or indirect damages (garden amenity and debris clean-up).

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

- A value of 200m^2 was adopted as a conservative estimate of the floor area for residential dwellings in the floodplain when areas had not been surveyed.
- The effective warning time has been assumed to be zero due to steep escarpment and flashy nature of flooding and also the absence of any flood warning systems in the catchment. A long effective warning time allows residents to prepare for flooding by moving valuable household contents (e.g. the placement of valuables on top of tables and benches).
- The Coogee Bay catchment is within a large metropolitan area, and as such is not likely to cause any post-flood inflation. These inflation costs are generally experienced in remote areas, where re-construction resources are limited and large floods can cause a strain on these resources.

5.3.2 Average Weekly Earnings

The OEH curves are derived for late 2001, and as part of this Study were updated to represent 2015 dollars. General recommendations by OEH are to adjust values in residential damage curves by Average Weekly Earnings (AWE), rather than by the inflation rate as measured by the Consumer Price Index (CPI). OEH proposes that AWE is a better representation of societal wealth, and hence an indirect measure of the building and contents value of a home. The most recent data for AWE from the Australian Bureau of Statistics at the time of the assessment was for March 2015. Therefore all ordinates in the residential flood damage curves were updated to March 2015 dollars.

While not specified, it has been assumed that the curves provided by OEH were derived in November 2001, which allows the use of November 2001 AWE statistics (issued quarterly) for comparison purposes. November 2001 AWE is shown in Table D1 of the OEH guidelines, and March 2015 AWE were taken from the Australian Bureau of Statistics website (www.abs.gov.au), as shown in **Table 5-2**.

Table 5-2 **AWE Statistics for Residential Damage Curve**

Month	Year	AWE
November	2001	$676.40
March	2015	$1,136.90
Change		68%

Consequently, all ordinates on the damage curves were increased by 68% compared to the curves presented in the OEH Guidelines. It should be noted that GST is not included in these values.

5.3.3 Commercial Damage Curves

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

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

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

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

The Consumer Price Index (CPI) was used to bring the 1990 data to September 2015 dollars (this data was obtained from the Australian Bureau of Statistics website (www.abs.gov.au). The CPI data is shown in **Table 5-3**.

The commercial properties were not classified into different value categories (low, medium, or high) in the survey data. Given the consumer based nature of the majority of commercial property (restaurants, domestic goods etc.) low value was assumed for all commercial properties. Consequently, damages have been increased by 89%. GST is not included in these values.

Table 5-3 **CPI Statistics for Commercial Property Damage Estimation**

Month	Year	CPI
June	1990	102.50
September	2015	193.87
Change		89%

5.3.4 Industrial Damage Curves

There were no industrial properties within the study area, and consequently these curves were not required.

5.3.5 Adopted Damage Curves

An example of the adopted damage curves are shown in **Figure 5-1**. For purposes of illustration, the commercial damage curves are shown for a property with a floor area of 100m^2, although the size will be individually determined for each commercial property when calculating catchment damages.

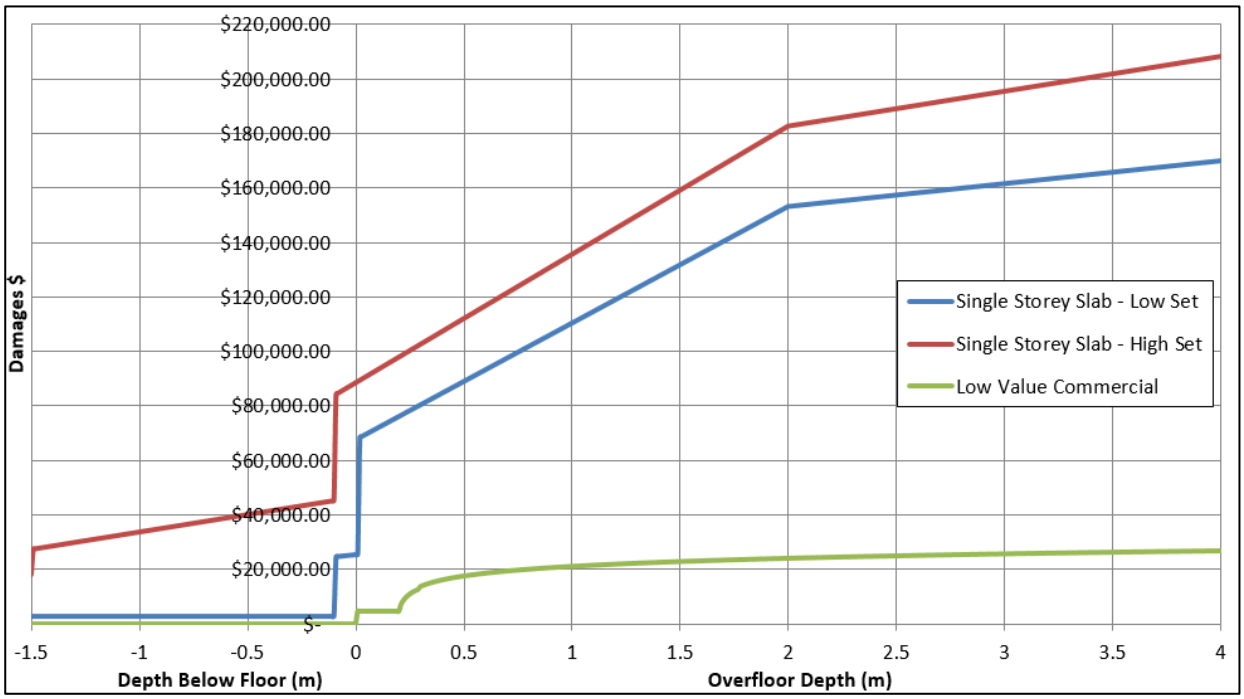

Figure 5-1 Indicative Damage Curves Adopted for Coogee Bay Catchment

5.3.6 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 (or 100 year ARI) design event has a probability of occurring of 1% in any given year, and as such the 1% AEP flood damage is plotted at this point on the AAD curve. AAD is then calculated by determining the area under this curve. The AAD curve for Coogee Bay is shown in **Figure 5-2**.

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).

5.4 Damages Results

5.4.1 Total Damages

A summary of the total damage results for Coogee Bay catchment is shown in **Table 5-4**, including:

- The number of properties, both residential and commercial with overfloor flooding;
- The average depth of overfloor flooding for both residential and commercial properties;
- The number of properties, both residential and commercial with overground flooding (garden damage); and
- Total damage value for the catchment.

The above results are listed for all design events; 20%, 5%, 1%, 0.5%, and 0.2% AEP and the PMF event.

The results in **Table 5-4** show that the number of residential properties with both overfloor and overground damages significantly exceeds the number of commercial properties across all design events. This result aligns with the summary of land uses for the catchment (**Section 3.4**) which shows the majority of the catchment area is residential land use with relatively localised areas of commercial.

Table 5-4 **Existing Damage Analysis Results**

	Properties with overfloor flooding	Average overfloor flooding depth (m)	Properties with overground flooding	Total Damage ($)
PMF				
Residential	522	1.21	1431	$52,727,000
Commercial	64	1.52	73	$3,609,000
Total	586		1504	**$56,336,000**
0.2% AEP				
Residential	226	0.76	805	$23,291,000
Commercial	43	1.26	63	$3,935,000
Total	269		868	**$27,226,000**
0.5% AEP				
Residential	184	0.63	674	$18,713,000
Commercial	39	1.26	62	$3,763,000
Total	223		736	**$22,476,000**
1% AEP				
Residential	129	0.58	503	$12,493,000
Commercial	25	0.79	42	$1,763,000
Total	154		545	**$14,256,000**
5% AEP				
Residential	55	0.57	329	$5,965,000
Commercial	17	0.62	27	$1,144,000
Total	72		356	**$7,109,000**
20% AEP				
Residential	20	0.78	173	$3,345,000
Commercial	7	0.68	12	$591,000
Total	27		185	**$3,936,000**

5.4.2 Annual Average Damages

The existing scenario annual average damage curve for the Coogee Bay catchment is shown in **Figure 5-2**. A summary of the AAD for each design event is included in **Table 5-5**.

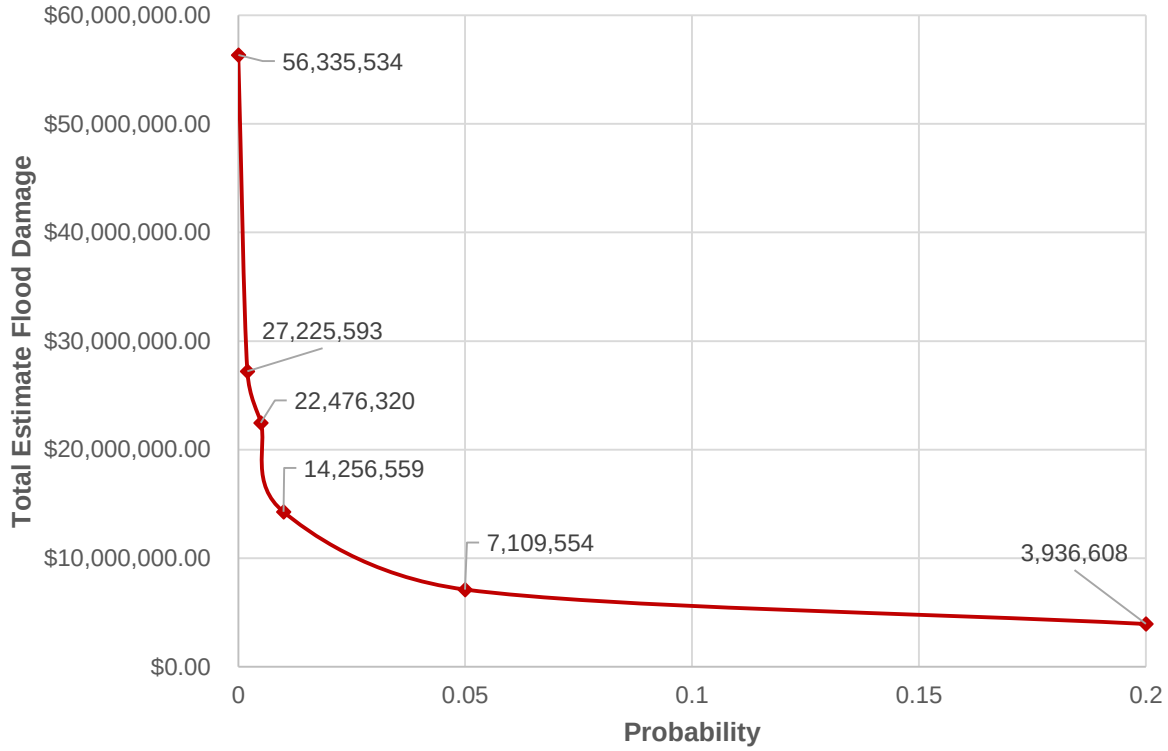

Figure 5-2 Average Annual Damage Curve (Existing Condition) for the Coogee Bay Catchment

Table 5-5 **Annual Average Damage – Design Event Summary**

Design Event	Total Damage ($)	AAD ($)	Contribution to Combined AAD (%)
PMF	$56,336,000	$83,500	4%
0.5% AEP	$27,226,000	$74,600	4%
0.2% AEP	$22,476,000	$91,800	4%
1% AEP	$14,256,000	$427,300	20%
5% AEP	$7,109,000	$828,500	40%
20% AEP	$3,936,000	$590,500	28%
Combined	-	**$2,096,200**	**-**

The combined annual average damage for the Coogee Bay catchment considering all design events is **$2,096,200** (excluding GST). Of this combined AAD, the 5% AEP design event contributes the greatest, with 40% of the total AAD being a result of the 5% AEP event.

5.5 Climate Change Impacts on Damages

An assessment of the possible impacts of climate change on the flood damages in the Coogee Bay floodplain has been undertaken. Flood damages were calculated for an increase in rainfall intensity of 10%, 20% and 30%. It should be noted that these damages assume all of the buildings in the floodplain to be in the current state.

The flood models were rerun for all the design storm events for these three climate change scenarios prior to recalculating the damages. The results are influenced by the impact of rainfall intensity on the more frequent events having a much higher amount of damages than in existing conditions.

The outcome of the climate change damage analysis are shown in **Table 5-6**.

Table 5-6 **Economic Assessment of Climate Change Impacts**

	Additional properties with overfloor flooding	Additional properties with overground flooding	Total Damage Increase ($)	AAD Increase ($)	% Increase in AAD
10% Rainfall Increase					
20% AEP event	4	49	$537,000	$80,000	14%
5% AEP event	89	314	$4,526,000	$380,000	46%
1% AEP event	197	559	$8,041,000	$251,000	59%
0.5% AEP event	235	648	$3,781,000	$30,000	32%
0.2% AEP event	269	780	$2,570,000	$10,000	13%
Total				**$751,000**	**37%**
20% Rainfall Increase					
20% AEP event	20	104	$1,569,000	$235,000	40%
5% AEP event	133	429	$9,476,000	$828,000	100%
1% AEP event	233	640	$11,850,000	$427,000	100%
0.5% AEP event	262	734	$6,286,000	$45,000	49%
0.2% AEP event	317	868	$6,016,000	$18,000	25%
Total				**$1,553,000**	**77%**
30% Rainfall Increase					
20% AEP event	42	182	$3,148,000	$472,000	80%
5% AEP event	168	502	$12,349,000	$1,162,000	140%
1% AEP event	256	724	$13,931,000	$526,000	123%
0.5% AEP event	289	807	$8,775,000	$57,000	62%
0.2% AEP event	337	923	$8,852,000	$26,000	35%
Total				**$2,243,000**	**111%**

The results shown in Table 5-6 above show that the total AAD increases 37%, 77%, and 111% above current AAD for the catchment for the 10%, 20, and 30% rainfall increase scenarios respectively. This implies that the AAD resulting from a 30% rainfall increase is over double the AAD for current climate conditions. Based on these figures it is clear that the potential impacts of climate change could have a significant impact on the cost of flooding for the Coogee Bay catchment.

6 Emergency Response Arrangements

6.1 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, 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 regional documents relevant to flood emergency response; a Regional Emergency Management Plan (EMPLAN) (previously referred to as DISPLAN), and a Local Flood Plan. These documents are intended to provide information to residents and other authorities relating to identified evacuation centres, evacuation procedures and actions in the event of flooding.

In lieu of these two regional documents a review of the state wide equivalent documents has been conducted in **Section 6.2**, as well as a review of national guidelines on flash flood emergency response in **Section 6.3**.

It is understood that SES is currently preparing a regional EMPLAN and Local Flood Plan. To inform the formulation of this document, a review of the flood emergency response potential for the Coogee Bay catchment is summarised below including critical and vulnerable developments (**Section 6.5**), potential evacuation centres (**Section 6.6**), suitable evacuation routes (**Section 6.7**), and flood warning systems (**Section 6.8**). In addition there is an assessment of the evacuation timeline for the catchment (**Section 6.9**), and a review of the potential for shelter-in-place refuge (**Section 6.10**).

6.2 Flood Emergency Response Documentation

6.2.1 EMPLAN

The Coogee Bay floodplain is located within the Sydney Metropolitan Emergency Management Region. Flood emergency management for the Coogee Bay floodplain is organised under the *New South Wales State Emergency Management Plan* (EMPLAN) (2012). No regional EMPLAN has been prepared for this district.

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 EMPLAN was developed with a comprehensive approach to emergency management. The Plan 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 sub plans 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.

6.2.2 State Flood Plan

A local flood plan has not been prepared for the local area containing the Coogee Bay floodplain. As such, the *New South Wales State Flood Sub-plan* (SES, 2015) is used to set out the arrangements for the emergency management of flooding.

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

It is identified in the Flood Sub-Plan that Local Government plays an important role at the local level in all phases of emergency management that may vary from area to area. The agreed responsibilities of Local Governments are to be listed in Local Flood Sub-Plans.

The State Flood Plan sets out the planning framework for the development and maintenance of a Flood Sub Plan at the following levels:

> The State of New South Wales;

> Each SES Region; and

> Each council area with a significant flood problem. In some cases the flood problems of more than one council area may be addressed in a single plan or the problems of a single council area may be addressed in more than one.

6.3 Emergency Response Guideline for Flash Flooding

In 2013, the Australian Fire and Emergency Service Authorities Council (AFAC) released a guideline on emergency planning for flash flood events providing a useful insight into the position of the 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 Coogee Bay floodplain can be described as flash flooding based on the above definition as there is a rapid rate of rise and most roads throughout the floodplain are flooded in under 6 hours.

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,

> 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); and,
  - Their health while isolated (pre-existing condition or sudden onset).

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.

6.4 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.

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".*

Based on these comments, the PMF should be adopted as the design flood event when considering emergency response. This is an envelope approach as the risk associated with all flood events is encompassed within the consideration of the Probable Maximum Flood. As noted above the Flood Planning Level is based on the 1% AEP event so the most significant risk to life and property occurs in events greater than this**.**

6.5 Critical Infrastructure and Vulnerable Developments

In the event of flooding, certain public infrastructure becomes 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;
  - Childcare centres;

- Aged care facilities;
- Retirement villages;
- Caravan Parks

> **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;
- Sewerage facilities;
- Electricity substations;
- Emergency services such as ambulance stations, fire stations, and police stations;
- NSW SES facilities.

The vulnerable developments and critical infrastructure within the Coogee Bay study area have been mapped in **Figure 6-1**. There are no vulnerable developments or critical infrastructure that are identified as flood affected within any of the major flowpaths of the study area. However, access to these locations may be impacted during a flood event.

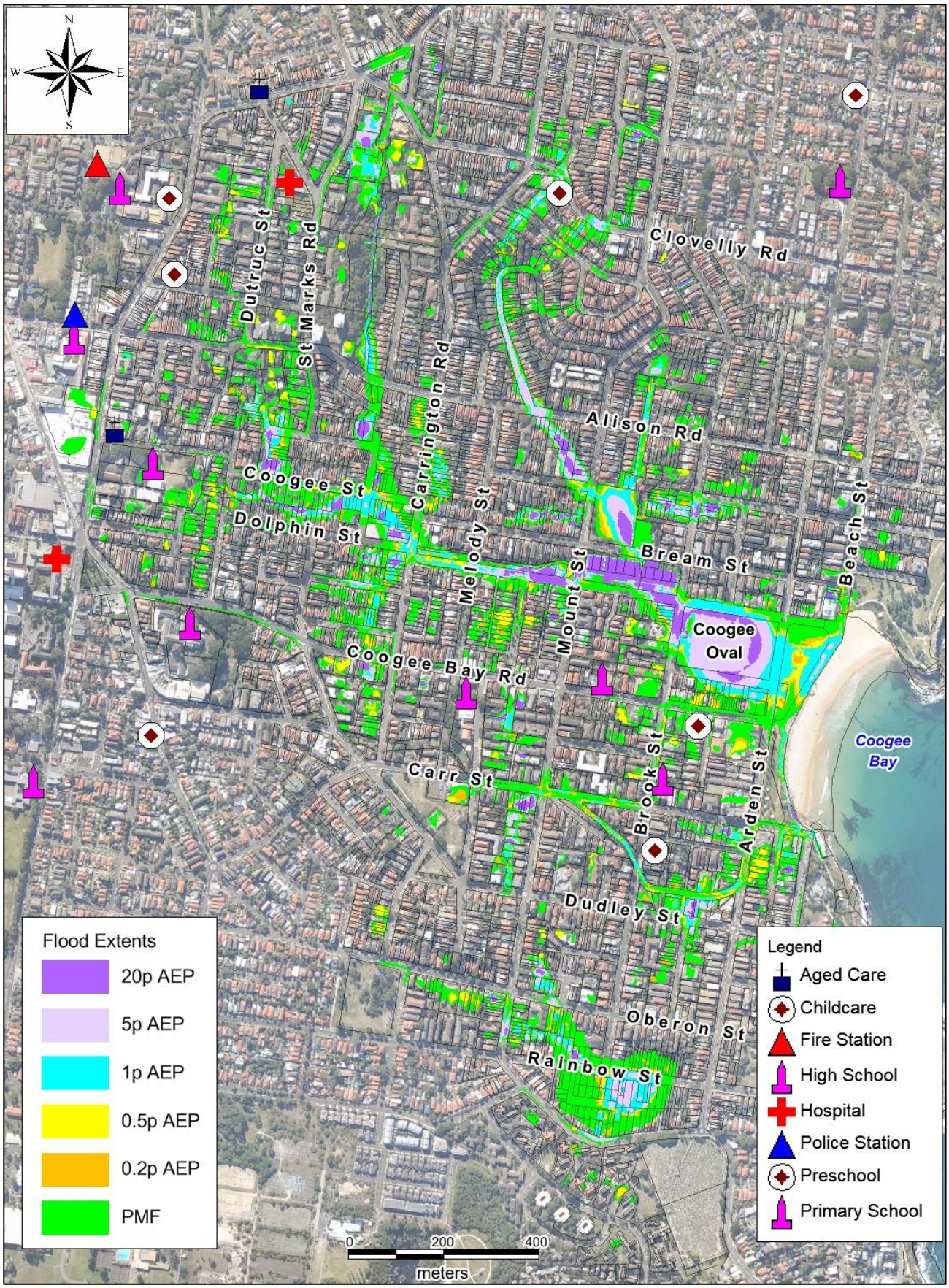

Figure 6-1 Critical Infrastructure and Vulnerable Land Uses

6.6 Evacuation Centres

As mentioned in **Section 6.4**, there are no SES evacuation centres identified within the Coogee Bay catchment and surrounds. A number of sites have been identified in **Table 6-1** that may be suitable to function as evacuation centres during and following a flood event. The six locations are also shown in **Figure 6-2**.

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;
- Either publically owned space or a community space such as schools, concert halls, town halls etc.; and,
- Site with sufficient covered space to accommodate a large number of evacuees.

Council and the SES should liaise with the owners and / or managers of the venues identified to determine appropriate evacuation centres. The selected locations should be identified in a local flood plan or EMPLAN when it is prepared.

Table 6-1 **Potential Evacuation Centres**

ID*	Name of Venue	Address
1	Randwick Girls High School	Barker Street, Randwick
2	Randwick Town Hall	Francis Street (near Avoca Street), Randwick
3	Rainbow Street Public School	90 Rainbow Street, Randwick
4	Coogee Public School	Byron Street (near Carr Street), Coogee
5	St Anthony's School	58 Arden Street, Clovelly
6	Our Lady of the Sacred Heart School	193 Avoca Street, Randwick

6.7 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 be accessed;
- Isolation from supplies: Isolation from drinking water, food, amenities, and communication lines.

It is assumed that isolation from medical services rather than isolation from supplies, poses a greater risk to life for the short durations of isolation likely to be experienced in the Coogee Bay catchment. 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 Coogee Bay 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 Prince of Wales Hospital in Randwick.

The evacuation route assessment has found that all areas of the Coogee Bay catchment have access to Prince of Wales Hospital via flood free roads, with the key regional evacuation routes shown in **Figure 6-2**. This means that there is negligible risk of isolation for the Coogee Bay catchment, a risk that is even lower when taking into account the comparative short durations of flooding associated with overland flow.

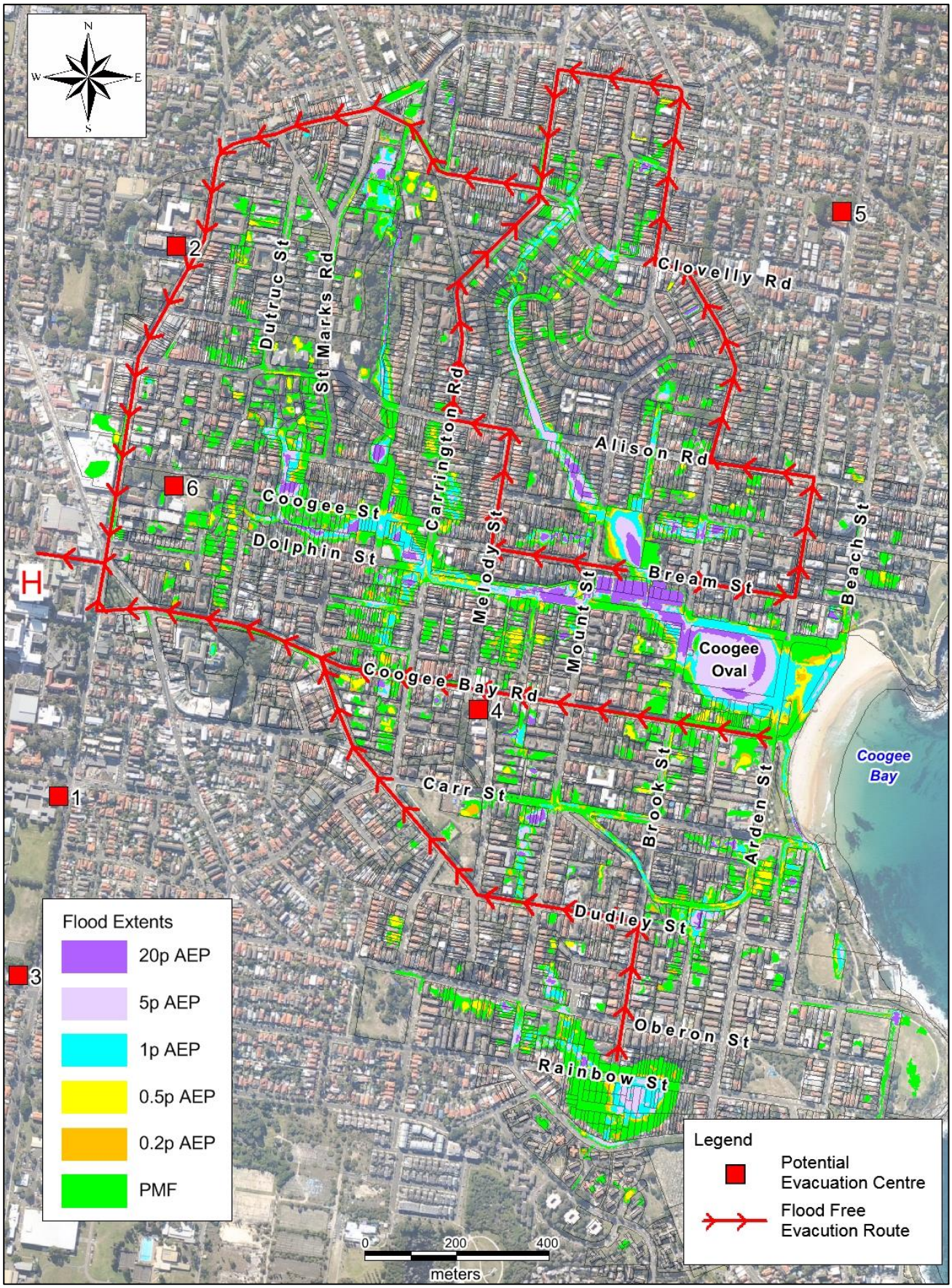

Figure 6-2 Evacuation Routes to Prince of Wales Hospital and Potential Evacuation Centres

6.8 Flood Warning Systems

The critical duration of flood events and response times available for the Coogee Bay Catchment floodplain limit the feasible implementation of a flood warning system. The short duration flooding experienced in local systems is not well suited to flood warning systems. However, for flash flood catchments (such as Coogee Bay Catchment), 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.

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

Flood Warnings Issued by BoM

Coogee Bay floodplain is affected by flash flooding, and as such it is difficult to provide any flood warning in advance of floods. Where possible, the BoM will issue a severe weather / flood warning to the Regional SES headquarters. Where that alert is relevant to the Coogee Bay 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.

Activation of Local SES Command

SES staff are advised and placed on alert when the SES Local Command has been issued with a flood warning by the BoM. The BoM's flood warning is also forwarded by SMS to the relevant individuals and organisations.

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

Local Flood Warning System

There may be opportunity to provide improved flood warning for residents within the floodplain, such as via SMS alerts of pending storm events.

Alternatively, the Australian Emergency Alert System could be used by the SES to disseminate SMS flood warnings. This may be the most suitable mechanism to provide flood warnings in the Coogee Bay 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.

Management of the Public Domain

Some locations in the Coogee Bay Catchment (such as the esplanade) are high usage public spaces. The provision of temporary refuges which can be accessed in a few minutes, even a small warning time may provide the public with sufficient time to seek refuge. The provision of rapid flood warnings within the Coogee Bay Catchment may be delivered through an automated process that triggers a warning (e.g. with the installation of water level sensors placed in trapped depression areas). The warning itself could be delivered through the use of suitably located electronic information boards at key locations. Another option is to have a public address system, which can relay a recorded message.

6.9 Evacuation Timeline

6.9.1 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.

6.9.2 Time Available

The 'Time Available' is dependent on rate of rise of waters, meaning it varies for each evacuation scenario. While the rate of rise varies across the entire catchment, the slowest rate of rise has been assessed which is assumed to occur at Coogee Bay Oval as it is a relatively large storage area at the downstream end of the catchment. The water level time series for three flood events have been presented in **Figure 6-3**; the 20% AEP (2h), 1% AEP (2h), and Probable Maximum Flood (four rainfall durations the 15 minute, 30 minute, 45 minute, and 4.5 hour).

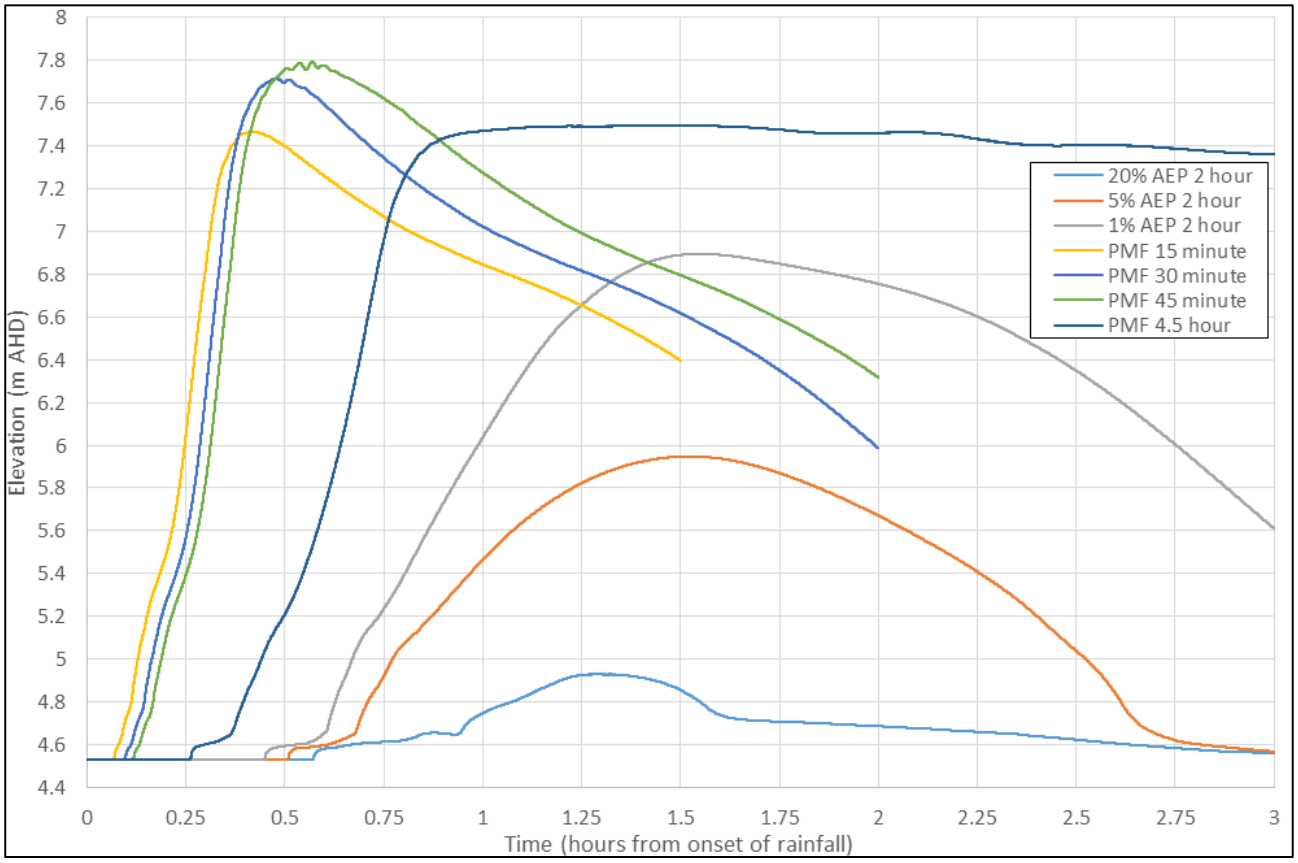

Figure 6-3 Water Level Time Series for Coogee Oval

From the water level time series shown in **Figure 6-3**, the rate of rise is significant even for the Coogee Bay Oval with significant flooding occurring:

- In less than 15 minutes (0.25 hours) from the onset of rainfall for the PMF 15 minute, 30 minute, and 45 minute events;
- In less than 30 minutes (0.5 hours) from the onset of rainfall for the PMF 4.5 hour event;
- In less than 45 minutes (0.75 hours) from the onset of rainfall for the 1% AEP 2 hour and 5%AEP 2 hour events, and;
- The peak flooding depth is reached within 75 minutes (1.25 hours) for the 20% AEP 2 hour event.

6.9.3 Time Required for SES Assisted Evacuation

The SES evacuation timeline model uses the following equation to calculate 'Time Required':

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:

WAF = 1 hour – accounts for the delay between occupants receiving the evacuation warning and acting upon it.

WLT = 1 hour – an allowance for the time taken by occupants to prepare for evacuation.

TT = 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 Coogee Bay floodplain travel time is assumed to be negligible (in the order of minutes, not hours)

TSF = 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 TT between 1 hour and 3.5 hours.

Note that time required is calculated from the time that SES have mobilised and are ready to begin doorknocking. Before this time there are also two additional phases:

- Forecast and actual rainfall monitoring: For Coogee Bay there are inadequate flood forecasting tools in place for forecasting to be used to inform flood evacuation. Instead actual rainfall monitoring is the only feasible warning system; and
- Mobilisation: The time taken for SES to mobilise and travel to residence to commence doorknocking. There is no data available on mobilisation time for local SES services so this has not been included in the evacuation timeline for Coogee Bay.

Based on the above contributors, the overall time required for evacuation of the Coogee Bay floodplain is a minimum of 5 hours (2 hours for WAF and WLT, 3 hours for actual rainfall monitoring). It should be noted that this is a low bound estimate, as various factors such as Travel Time, Travel Safety Factor and SES mobilisation have been disregarded.

Therefore in relation to SES assisted evacuation for the Coogee Bay floodplain, the surplus time is negative as the time available (less than 15 minutes for the PMF 15 minute storm) is less than the time required (minimum of 5 hours). This means that SES assisted evacuation is not possible for the Coogee Bay catchment due to the flash flooding nature of the floodplain.

6.9.4 Localised Evacuation

The SES timeline approach to assess time required to evacuate is based on a specific sequence of events; SES monitor, and notify occupants of a region to evacuate following initial reluctance. However evacuation may occur at a more localised level through a different sequence of events; occupants visually see flooding in their vicinity and respond instinctively by moving to higher ground.

This sequence relies less on emergency services co-ordination and more on the common sense of the resident to respond to observed flooding through evacuation.

A key advantage of localised evacuation for overland flow flooding type is that the flow paths are relatively confined, as proven by the fact that the maximum distance to flood free land does not exceed 50 metres for the majority of the floodplain.

The average travel speed for an unassisted ambulant, the slowest type of pedestrian, is approximately 0.57 m/s (Proulx, G., 2002). Applying this travel speed across a 50 metre distance, the maximum time taken for pedestrians in the majority of the floodplain to access flood free land is less than 90 seconds (1.5 minutes). Comparatively, with an average walking speed of 1.27 m/s, an able-bodied adult can walk 50 metres in less than 40 seconds.

The peak rate of rise of floodwaters for Coogee Oval in the PMF 15 minute event is 0.15 metres / minute, meaning that under the worst case scenario floodwaters could rise 0.23 metres in the 1.5 minutes taken for unassisted ambulants to evacuate the floodplain. While this rate of rise is significant it is still safe to assume that the vast majority of pedestrians will be able to evacuate the floodplain due to the narrow nature of the floodplain.

The assumption that localised evacuation may be possible for the majority of the floodplain is made on the assumption that residential properties in the floodplain will have suitable flood awareness and will be ready to observe flooding and react instinctively to move to high ground. This also assumes that flooding will occur during waking hours and it is observations of flooding will be reduced at night time. Further discussion of options to improve flood awareness within the catchment is discussed in **Section 9.4**.

There are two locations where the width of the floodplain exceeds 50 metres and therefore it can be assumed that evacuation will be more difficult:

- Coogee Bay Oval: The minimum distance to flood free land from the centre of Coogee Bay Oval is approximately 100 metres, meaning the time taken for unassisted ambulants to access flood free land would be 3 minutes, during which time flood levels could rise nearly 0.5 metres. However the emergency response risks for the site are quite low as evacuation is available on all sides and it can be assumed that the playing field will be unoccupied in the event of severe rainfall events.
- Rainbow Street Depression: There are a number of severe emergency response issues for the PMF event including the large number of residential properties that lie within the floodplain, an overland flowpath that restricts exit from residential properties on Rainbow Street, and the distance to flood free land from the end of the cul-de-sac on Marian Street is over 120 metres.

Due to the exceptional risk associated with evacuation constraints for the Rainbow Street depression, a localised assessment of potential flood emergency response provisions for the area has been included in **Section 9.4.6**.

6.10 Shelter-in-Place Potential

The implementation of appropriate shelter-in-place 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 Coogee Bay floodplain based on these three factors is investigated in the following sections.

6.10.1 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 6-4**. 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.

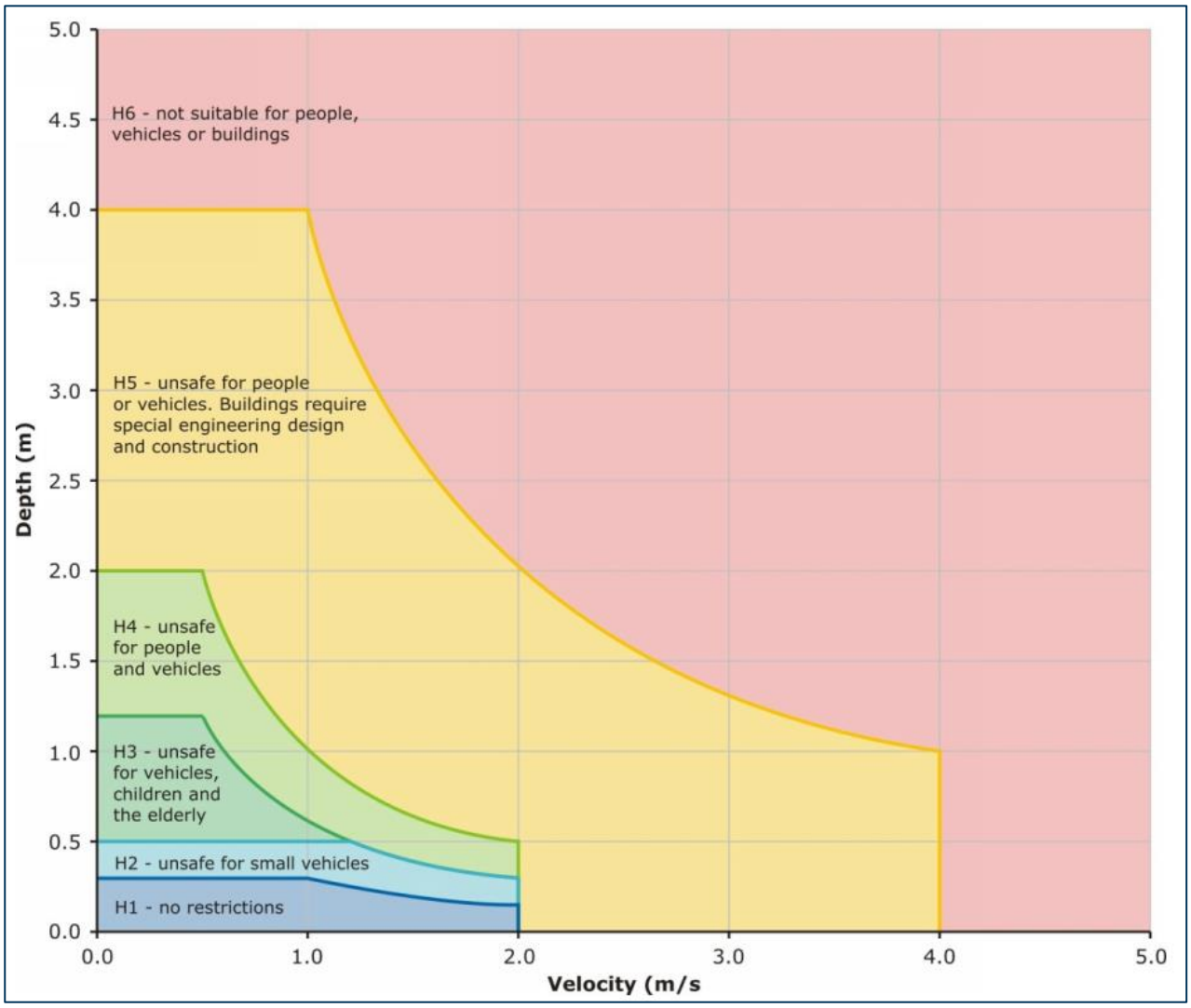

Figure 6-4 Combined Flood Hazard Curves (Source: Commonwealth Government, 2014)

Flood hazard categories H5 and H6 have been mapped for the PMF event for Coogee Bay catchment shown in **Figure 6-5**.

The results show that H6 areas where building stability is compromised are generally confined to road reserve and public reserve spaces such as Coogee Oval, but a number of residential areas are classed as H6:

- Rainbow Street depression, where a significant number of residential properties will have unstable buildings due to the excessive depth of flooding for the PMF event (up to 7 metres);
- For a small group of steep residential properties on the northern side of Pauling Avenue where the excessive velocity of flows in the PMF event lead to potential building instability;
- For significant portions of the Coogee Tennis Club and Coogee Bowling Club

For these locations shelter-in-place is not recommended as structural stability cannot be guaranteed in the PMF event.

The extent of H5 areas shown in **Figure 6-5** are where standard buildings may be unstable but buildings designed for flood affectation may be stable. The H5 extents are more widespread than H5 with a significant portion of the floodplain falling within this category. At these locations any prospective shelter-in-place refuges would need to be specially engineered to withstand flood forces in the PMF event.

Figure 6-5 Building Stability Hazard Categories for Coogee Bay

6.10.2 Duration of Flooding

This duration of flooding relates to the length of isolation of any shelter-in-place refuges within the floodplain. The duration of inundation (the time for which the location is submerged) is guided by the water level time series for Coogee Oval presented in **Figure 6-3**, which due to its location on the downstream end of the floodplain is the location expected to have the longest duration of flooding.

The results show that for frequent flood events, the 20% AEP, 5% AEP, and 1% AEP events the duration of flooding is under 3 hours in all instances. This short duration of flooding is a result of the overland flow flooding nature of the catchment.

For the PMF event the length of recorded water levels means it is difficult to determine the duration of flooding but the three short duration storms; 15 minute, 30 minute and 45 minute, all seem to be flooded in the order of 3 hours. The 4.5 hour duration storm has a much longer duration of flooding but it is not expected to exceed 24 hours.

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.

6.10.3 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.

While this is assumed to be feasible for the majority of the floodplain as PMF flood depths are typically less than 2 metres above existing ground levels, the depth of flooding at Rainbow Street depression exceeds 7 metres in some locations.

Therefore the implementation of shelter-in-place for the Rainbow Street depression is assumed to not be feasible as it would require refuge floor levels to be elevated up to 7 metres above existing ground levels. In addition to consideration of structural stability, shelter-in-place is not possible for the Rainbow Street depression which supports the need for a localised flood emergency response plan as discussed in **Section 9.4.6**.

7 Flood Planning Level Review

7.1 Overview

As stated within Appendix K of the *Floodplain Development Manual* (NSW Government, 2005):

> *Flood Planning Levels (FPL's) are an important tool in the management of flood risk. They are derived from a combination of a flood event, and a freeboard.*

The Flood Planning Level (FPL) for the majority of flood prone areas across New South Wales has been traditionally based on the 1% AEP flood level plus a freeboard which is generally set at 0.5 m for habitable floor levels. For Coogee Bay, the Flood Planning Level has historically been the 1% AEP flood level plus a varying freeboard. Further details of the current FPLs can be found in **Section 7.2**.

With the completion of the *Coogee Bay Flood Study* (BMT WBM, 2013) and new data available on flood behaviour, a review of these historical Flood Planning Levels is appropriate to ensure new development is consistent with the known flood behaviour.

Various factors for consideration in determining an appropriate FPL for a particular floodplain include:

- The Flood Planning Levels and minimum floor level requirements currently adopted by Randwick City Council, and how this approach compares to other Councils in NSW. This is discussed in **Section 7.2**;
- Current guidance on the application of flood related controls provided by the NSW State Government within planning directives and related documents, including the Guideline on development controls for low flood risk areas – floodplain development manual (NSW Government, 2007). This is discussed in **Section 7.3**;
- The design event adopted within the Flood Planning Level, including consideration of the possibility of coincident ocean surge at the time of flooding, the duration of inundation and the impacts this has on flood risk. This is discussed in **Section 7.4**;
- The freeboard adopted within the Flood Planning Level which accounts for modelling uncertainties, local flooding effects and potentially climate change. This is discussed in **Section 7.5**;
- The determination of the Flood Planning Area and the number of flood affected properties is discussed in **Sections 7.6**;

7.2 Current Flood Planning Level

7.2.1 Local Environment Plan

The Randwick Local Environment Plan (LEP) 2012 defines the Flood Planning Level in Section 6.3 Flood Planning, under Item (5):

> *Flood planning level means the level of a 1:100 ARI (Average Recurrence Interval) flood event plus 0.5 m freeboard.*

Where the 1:100 Average Recurrence Interval is equivalent to a 1% Annual Exceedance Probability (AEP).

7.2.2 Development Control Plan

The Randwick City Council Development Control Plan (DCP) 2013 under Part B8 Water Management under Sub-section 5.3, identifies minimum floor levels for different types of development. The intent of the clause is to '*ensure that floor levels are set at an appropriate height to reduce the frequency of inundation of structures and floors to an acceptable probability*.'

The minimum floor level requirements are provided in **Table 7-1**.

Table 7-1 **Floor Levels for Buildings (Source: Randwick DCP 2013)**

Scenario	Floor Level
Habitable floors – all development (excl. critical facilities)	
Inundated by flooding	1% AEP + 0.5 m freeboard
Inundated by overland flow path	Two times the depth of flow in 1% AEP flood with a minimum of 0.3 m above the surrounding surface
Habitable floors – critical facilities – including hospitals, police, fire, ambulance, SES stations, major transport facilities, major sewage or water supply or electricity or telecommunication plants, schools, nursing homes and retirement villages	
Inundated by flooding	PMF + 0.5 m freeboard
Inundated by overland flow path	Two times the depth of flow in PMF with a minimum of 0.3 m above the surrounding surface
Non-habitable floors – residential outbuildings including laundries and sheds (excludes garages which are considered habitable)	
Gross floor area less than or equal to 10 m^2	1% AEP but not less than 0.15m above surrounding ground level
Gross floor area greater than 10 m^2	Two times the depth of flow in PMF with a minimum of 0.3 m above the surrounding surface
Non-habitable floors – industrial and commercial – including areas such as office space, show rooms, child care facilities, residential floor levels for hotels and tourist establishments	
Located on flooding or overland flow path	1% AEP but not less than 0.15 m above surrounding ground level.
Materials storage locations	
Materials sensitive to flood damage, or which may cause pollution or to be potentially hazardous during flooding	1% AEP + 0.5 m freeboard
Minor Additions - A maximum 10 square metres for existing single and dual occupancy dwellings or up to 10 percent of the existing gross floor area for all other development	
All types of flooding	Existing lowest habitable floor level

Where overland flow is defined as:

- The maximum cross sectional depth flowing through and upstream of the site is less than 0.25m for the 1% AEP flood for other than critical facilities, or 0.25m for the PMF for critical facilities; and
- Existing surface levels within the site are above the floor level requirements, at the nearest downstream trapped low points; and,
- The flood study demonstrates that blockage to any upstream trapped low point does not increase the depth of flow to greater 0.25m.

Within the DCP a number of additional requirements are applied relevant to minimum floor levels:

- A certificate by a registered surveyor shall certify that the floor levels are not less than the required level.
- Where the lowest habitable floor area is elevated more than 1.5 m above ground level, a restriction is to be placed on the title of the land confirming that the sub-floor area is not to be enclosed.

7.3 Section 117 Directive - Development Controls on Low Flood Risk Areas

In January 2007, the then NSW Department of Planning and the Department of Natural Resources 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).

The guideline refers to areas above the residential FPL (typically 1% AEP plus 0.5m freeboard) but below the PMF and states the following:

These are areas where no development controls should apply for residential developments 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.*

This Guideline confirms that, unless there are exceptional circumstances, councils should adopt the 1% AEP flood as the basis of the FPL for residential development. 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.

Reviewing the current Flood Planning Level and minimum floor level approaches for Randwick City Council against the 2007 s117 directive:

- The current Flood Planning Level of the 1% AEP plus 0.5m freeboard adopted for flooding is in accordance with the provisions set out in the s117 Directive;
- The application of a minimum floor level requirement to the PMF level plus freeboard for critical infrastructure is in accordance with the provisions set out in the s117 directive.

The Guideline on Development Controls on Low Risk Areas confirms that, unless there are exceptional circumstances, councils should adopt the 1% AEP flood as the basis FPL for residential development. 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.

Appendix K of the *Floodplain Development Manual* (NSW Government, 2005) outlines a range of issues relating to risk which may be considered, including social factors, economic factors, environmental factors (including sea level rise), cultural factors and planning and governance. Review of these factors in earlier sections of this report suggest that there are no significant exceptional circumstances that would justify adoption of a Flood Planning Level higher than the current 1% AEP plus 0.5 metre freeboard.

7.4 Consideration of Flood Risk

7.4.1 Likelihood of Flooding

Table 7-2 has been reproduced from the NSW Floodplain Development Manual (NSW Government, 2005) to indicate the likelihood of occurrence of an event in an average lifetime of 70 years to show the potential risk to life. It should be noted that life expectancy in Australia is actually now approximately 82 years (Google Public Data, from World Bank sources, accessed 9 April 2015) and therefore the data in this table represents a non-conservative assessment of the likelihood of experiencing a flood event in an average lifetime.

Analysis of the data presented in **Table 7-2** gives a perspective on the flood risk over an average lifetime. The data indicates that there is a 50% chance of a 1% AEP event occurring at least once in a 70 year period. Given this potential, it is reasonable from a risk management perspective to give further consideration to the adoption of the 1% AEP flood event as the basis for the Flood Planning Level. Given not only the cost of damages but also the social issues and the non-tangible effects (such as stress and trauma), it is appropriate to limit the exposure of people to floods.

Note that there still remains a 30% chance of exposure to one 0.5% AEP year magnitude flood over a 70 year period. This gives rise to the consideration of the adoption of a rarer flood event (such as the 0.5% AEP or up to the PMF) as the Flood Planning Level for some types of development.

Table 7-2 **Probability of Experiencing a Given Design Flood (or Higher) in a 70 Year Period**

Likelihood of Occurrence in Any Year (AEP)	Probably of Experiencing At Least One Event in 70 Years (%)	Probability of Experiencing At Least Two Events in 70 Years (%)
10% AEP	99.9	99.3
5% AEP	97	86
2% AEP	75	41
1% AEP	50	16
0.5% AEP	30	5

7.4.2 Flood Range for Various AEP's

A flood range is the difference in flood depths for the different Annual Exceedance Probabilities (AEP's). The flood range for a location is proportional to the size of the catchment upstream (as this translates to larger differences in peak flows), and the smaller the floodplain width (as less floodplain storage is available water levels increase faster).

A summary of the peak flooding depths for modelled flood events; 20% AEP, 5% AEP, 1% AEP, 0.5%AEP, 0.2% AEP, and the PMF event is included in **Table 7-3** with the 20 locations previously identified in **Figure 4-3** (note that some of these flooding depths have also been reported in **Table 4-3**).

Table 7-3 **Peak Flood Depths for Locations Throughout Coogee Bay for Infrequent Flood Events**

ID	Location	Peak Flooding Depth (metres)					
		20% AEP	5% AEP	1% AEP	0.5% AEP	0.2% AEP	PMF
1	Clyde Street	0.7	1.1	1.4	1.5	1.6	2.2
2	Upper Dolphin Flowpath	1.3	1.4	1.9	2.0	2.1	2.8
3	Fred Hollows Reserve	0.0	0.9	2.1	2.6	3.3	4.3
4	Courland Street	1.8	1.9	2.1	2.1	2.1	3.1
5	McAnally Lane	0.4	0.5	0.6	0.7	0.7	1.0
6	Lower Queen Flowpath	0.5	0.6	0.8	0.9	1.0	1.6
7	Carrington Road	2.0	3.2	3.9	4.0	4.1	5.1
8	Pauling Avenue	0.0	0.9	1.2	1.3	1.4	2.0
9	Abbott Street	0.9	1.6	2.2	2.3	2.4	3.2
10	Leeton Avenue	0.3	0.4	0.5	0.6	0.6	0.9
11	Smithfield Avenue	0.0	0.5	0.8	0.8	0.9	1.2
12	Bardon Park	0.8	1.0	1.3	1.4	1.6	2.2
13	Dolphin Street	0.8	0.9	1.1	1.1	1.3	2.4
14	Coogee Tennis Club	0.4	0.4	0.5	0.6	0.7	1.3
15	Brook Street	0.8	1.1	1.4	1.5	1.7	2.9
16	Coogee Oval	1.0	1.7	2.5	2.6	2.6	3.3
17	Mount Street	0.6	0.7	0.8	0.8	0.9	1.3
18	Dudley Street	0.4	0.6	0.7	0.8	0.8	1.2
19	Upper Rainbow Street	0.4	0.6	0.8	0.9	1.0	3.3
20	Rainbow Depression	0.4	1.5	2.1	2.4	2.7	7.1
Average Depth across all Locations (m)		**0.7**	**1.1**	**1.4**	**1.5**	**1.7**	**2.6**

The water level results in **Table 7-3** show that the adoption of the 1% AEP level as the basis of determining the FPL is not significantly different from that of the 5% AEP (on average 0.3m lower than the 1% AEP), 0.5% AEP (on average 0.1m higher than the 1% AEP) or the 0.2% AEP (on average 0.3m higher than the 1% AEP).

The relatively minor flood range across the catchment supports the adoption of the 1% AEP as it provides an increased level of risk reduction over the 5% AEP without a significant increase in FPL. In comparison to the adoption of less frequent flood events the risk associated with these events is considered relatively minor as the average flood range from the 1% AEP to both the 0.5% AEP and 0.2% AEP is less than 0.3 metres, which is likely to be within the limits of the freeboard.

7.5 Freeboard

7.5.1 Factors Accounted for in Freeboard

The concept of a freeboard is to account for uncertainties in deriving design flood levels or local effects beyond the scope of the method of estimation and as such is generally used as a 'safety factor' to ensure that the design flood event that is planned for is not exacerbated due to uncertainties or local effects. This consideration may result in the adoption of an FPL higher than the design PMF level in certain cases.

When deriving an appropriate freeboard for the Coogee Bay floodplain, the following factors have been considered:

- Accuracy of model input data (e.g. ground survey): The model comprised of raw LiDAR data recorded in 2005 which according to the *Coogee Bay Flood Study* (BMT-WBM, 2013) has an accuracy of generally + / - 0.1 m. This is seen as the most accurate form of survey information for such a large catchment area. With the standard deviations stated above it is not anticipated there are many locations within the catchment with surveyed level inaccuracies exceeding 0.5 m.
- Model sensitivity: Sensitivity analysis of the hydraulic model conducted in the Coogee Bay Flood Study (BMT WBM, 2013) involved assessment of a number of parameters including:
  - Stormwater drainage blockage: A 100% blockage scenario for the entire stormwater network was assessed. The results found that generally the catchment was not sensitive to stormwater blockage with peak water level increases of 0.1 – 0.4 metres. Two locations showed excessive sensitivity; Fred Hollows Reserve, and the Rainbow Street depression, in both instances culverts are the only form of discharge in the 1% AEP which explains their sensitivity. It is noted that 100% blockage is an extreme test case and would represent the worst case scenario for blockage, and it is assumed that the catchment would be less sensitive to more moderate scenarios, for example 50% blockage.
  - Sea level: A sensitivity analysis of increased tailwater conditions assumed a level of 3.5m AHD which corresponds to a 0.5% storm surge event combined with 0.9m sea level rise scenario. The results showed no impact for every location but one, with 0.1 metre water level increases at Coogee Oval.
  - Rainfall losses: A sensitivity analysis was conducted for a reduced initial loss from the adopted 50mm to a value of 15mm. The results found that generally the catchment was not sensitive to rainfall losses with peak water level increases of 0.1 – 0.4 metres. One location showed excessive sensitivity, with water level increases of 0.9 metres at Fred Hollows Reserve.
  - Additional sensitivity analysis of the Flood Study model was conducted as part of this Floodplain Risk Management Study to assess the impacts of building blockage in the floodplain (see **Section 2.1.2.4** for further details). The results of this assessment found that the model was not very sensitive to either increased roughness in building extents or the complete blockage of buildings in the hydraulic model.
- Local factors that can result in differences in water levels across the floodplain. These factors can often not be determined in flood modelling, because they are too difficult, complex or expensive to incorporate: The Coogee Bay flood model covers a relatively small area and as such, is was able to account for most local factors such as retaining walls and other structures. The model comprised of a 2 x 2m grid and included local stormwater drainage systems meaning localised flood issues should have been accounted for in modelling.
- The cumulative effect of subsequent infill development of existing zoned land: This is not expected to be a significant factor as the floodplain is already significantly developed and the potential loss of flood

storage and additional blockage of flowpaths is expected to be negligible compared to the existing scenario which is significantly obstructed.

Therefore for the majority of the catchment the flood model is not particularly sensitive to the underlying assumptions in the model (water level increases at most locations are less than 0.4 metres).

7.5.2 Climate Change in Freeboard

As stated within Appendix K of the Floodplain Development Manual (NSW Government, 2005), climate change is normally accounted for in freeboard as well, 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).*

The impacts of a 0.9 metre sea level rise relating to climate change were assessed as part of a sensitivity analysis of sea levels conducted in the *Coogee Bay Flood Study* (BMT-WBM, 2013). The outcome of the sensitivity testing found that water level impacts were less than 0.1 metres for the entire Coogee Bay catchment. The lack of sensitivity to sea level rise is a result of the relative elevation of the floodplain compared to sea levels.

As part of this Floodplain Risk Management Study additional modelling was conducted for climate change impacts on rainfall increase with 10%, 20%, and 30% rainfall increase assessed. Further details of this assessment are included in **Section 4.7**. The results of this sensitivity testing included in **Table 4-4** show that the water level impacts of the rainfall increase are on average 0.1 metres, 0.2 metres, and 0.3 metres across the Coogee Bay catchment for the 10%, 20%, and 30% rainfall increase scenarios respectively.

Therefore on average across the Coogee Bay floodplain the water level increases resulting from potential rainfall increase associated with climate change are within acceptable limits of the 0.2 metre allowance within standard freeboard. It is concluded that as the impacts of climate change can be accounted for within freeboard that climate change runs do not need to be adopted as the design event and that the existing scenario 1% AEP event is appropriate.

7.5.3 Comparison of 0.3 and 0.5 Metre Freeboard

As part of this Floodplain Risk Management Study, two freeboards were assessed in detail:

- 0.5 metre freeboard which is standard for NSW, and recommended within the s117 directive for the state (see **Section 7.3**);
- 0.3 metre freeboard which was assessed due to the overland flow nature of flooding (i.e. lower depth of flooding and hence lower risk of uncertainty in the flood levels) and as an outcome of the floodplain risk management committee meeting during the project where the impacts of adopted a lesser freeboard were queried.

The testing found that the impacts of adopting a lower freeboard were negligible with only a small number of properties removed from the Flood Planning Area compared to the 0.5 metre freeboard.

The negligible impacts of the reduced freeboard from a 0.5m freeboard to a 0.3m freeboard is likely a result of the vertical difference between the two being only 0.2 metres. For example even if a channel has a relatively flat side slope of 1 Vertical : 10 Horizontal then the 0.2m additional freeboard only extends the Flood Planning Area (FPA) a horizontal distance of 2 metres.

Given the relatively minor reductions in flood affected properties, the adoption of a 0.3 metre freeboard is not recommended particularly in light of **Section 7.5.1** and **Section 7.5.2** above which seem to support the adoption of a 0.5 metre freeboard.

7.5.4 Freeboard Recommendations

A freeboard of 0.5m is recommended for the Coogee Bay Floodplain based on the following:

- Model sensitivities are generally in the order of 0.1 to 0.4m;

- Flood level impacts of as a result of increased rainfall due to climate change are not likely to exceed 0.3m.
- The impact of selecting a freeboard of 0.5m over a freeboard of 0.3m does not result in a significant increase in the number of properties impacted by flood related controls.

7.6 Consideration of Overland Flow

7.6.1 Current Approach

Under the current Randwick DCP 2013 the recommended Flood Planning Level for overland flow areas is variable based on the depth of flow at the location under the following relationship:

Two times the depth of flow in 1% AEP flood with a minimum of 0.3 m above the surrounding surface

Where overland flow is defined as:

- The maximum cross sectional depth flowing through and upstream of the site is less than 0.25m for the 1% AEP flood for other than critical facilities, or 0.25m for the PMF for critical facilities; and
- Existing surface levels within the site are above the floor level requirements, at the nearest downstream trapped low points; and,
- The flood study demonstrates that blockage to any upstream trapped low point does not increase the depth of flow to greater 0.25m.

7.6.2 Review of Approach

The adopted FPL approach for overland flow affected properties attempts to solve issues relating to varying design flood levels across a site. This is particularly relevant for flowpaths with steep grades, which is common within the Coogee Bay floodplain. In these instances the design flood levels for two boundaries of a site may vary in the order of a couple of metres, meaning it is not appropriate to adopt the maximum water level and apply it to the entire site at all locations. This is contrary to more mainstream or riverine flooding where design flood levels are comparatively flat grade across the length of a property and it is far more feasible to adopt one single design flood level for an entire property.

To reconcile these issues with overland flow affectation and FPL, Council's current approach allows for a design depth to be applied to flood planning levels such that the Flood Planning Level is double the maximum design flood depth above existing ground levels across the entire site to a minimum of 0.3 metres.

To better illustrate the potential impacts of the two FPL approaches, a theoretical long section has been taken along a 10 metre stretch of steep land as shown in **Figure 7-1**. The outcome in this example is that on the downstream side of the site, the overland flow FPL is 0.7 metres lower than the mainstream FPL, which is 1.2 metres above the 1% AEP flood levels at this location.

This approach has been useful in limiting how onerous FPL requirements are on overland flow affected lots, which is particularly useful for the Coogee Bay catchment where surface grades can be quite steep. Therefore it is proposed that the current approach to overland flow Flood Planning Levels be maintained.

As the overland flow FPL's provide beneficial outcomes for residents it is unlikely that they will be subject to legal challenge in the future therefore may be retained within the DCP and do not need to be moved to be included in provisions for a future LEP.

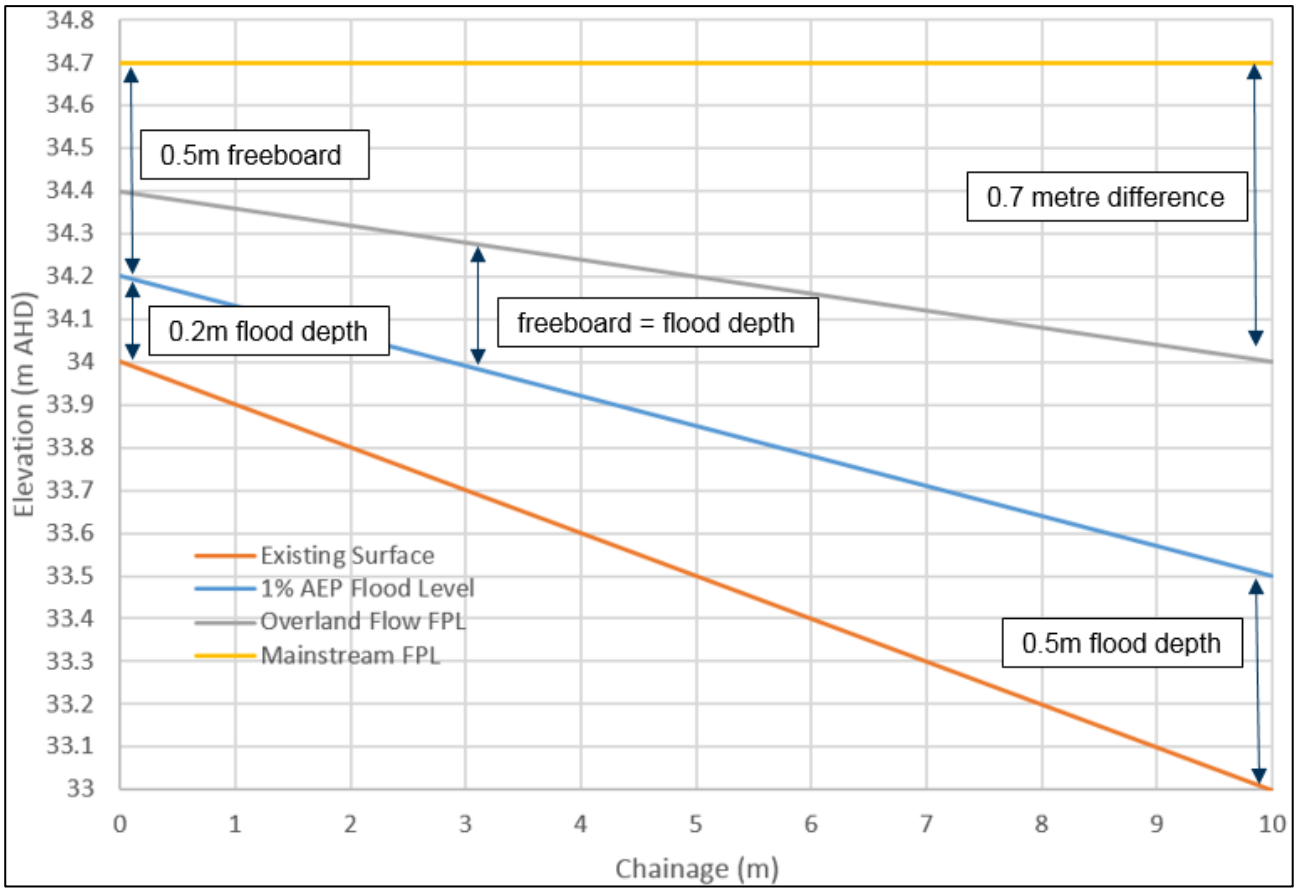

Figure 7-1 Illustration of Overland Flow FPL Outcomes for 10 Metre Section of Steep Site

7.7 Flood Planning Level Recommendations

Based on the analysis of flood risk and freeboard in the previous sections, the continued use of the FPLs outlined in Council's DCP is recommended. This is summarised in **Table 7-4**.

Table 7-4 **Recommended Flood Planning Levels**

Scenario	Floor Level	Recommendation
Habitable floors – all development (excl. critical facilities)		
Inundated by flooding	1% AEP + 0.5 m freeboard	Retain.
Inundated by overland flow path	Two times the depth of flow in 1% AEP flood with a minimum of 0.3 m above the surrounding surface	Retain.
Habitable floors – critical facilities – including hospitals, police, fire, ambulance, SES stations, major transport facilities, major sewage or water supply or electricity or telecommunication plants, schools, nursing homes and retirement villages		
Inundated by flooding	PMF + 0.5 m freeboard	Retain.
Inundated by overland flow path	Two times the depth of flow in PMF with a minimum of 0.3 m above the surrounding surface	Retain.
Non-habitable floors – residential outbuildings including laundries and sheds (excludes garages which are considered habitable)		
Gross floor area less than or equal to 10 m^2	1% AEP but not less than 0.15m above surrounding ground level	Retain.

Scenario	Floor Level	Recommendation
Gross floor area greater than 10 m^2	Two times the depth of flow in PMF with a minimum of 0.3 m above the surrounding surface	Retain.
Non-habitable floors – industrial and commercial – including areas such as office space, show rooms, child care facilities, residential floor levels for hotels and tourist establishments		
Located on flooding or overland flow path	1% AEP but not less than 0.15 m above surrounding ground level.	Retain.
Materials storage locations		
Materials sensitive to flood damage, or which may cause pollution or to be potentially hazardous during flooding	1% AEP + 0.5 m freeboard	PMF or 1% AEP + 0.5m freeboard (whichever is greater)
Minor Additions - A maximum 10 square metres for existing single and dual occupancy dwellings or up to 10 percent of the existing gross floor area for all other development		
All types of flooding	Existing lowest habitable floor level	Retain.

7.8 Flood Planning Area and Flood Affected Properties

The primary mechanism by which Council's notify landowners that their property is affected by flood risk is via a planning certificate issued under Section 149 of the *Environmental Planning and Assessment Act 1979* (commonly referred to as a Section 149 certificate).

A planning certificate under Section 149(2) discloses whether or not the land is subject to a policy that restricts the use of the land, and is a mandatory part of the conveyancing process. Section 6.3 of the Randwick LEP identifies the land to which the policy applies as:

- Land identified as "Flood Planning Area" on the Flood Planning Map, and,
- Other land at or below the Flood Planning Level.

Therefore a review has been conducted of the Flood Planning Area and the processes by which Council tags properties within its Section 149 certificate database for Coogee Bay catchment. Note that the same process has been repeated for flood extents of all design events in this study as outlined in **Section 4.4**.

7.8.1 Flood Planning Area

Minimum Depth Filter

The first factor to determining the FPA extents is the definition of significant flooding in the 1% AEP event. In this instance a 0.15 metre depth filter has been adopted for Coogee Bay. That is to say that all depths of flooding less than 0.15 metres have been excluded for the following reasons:

- A direct rainfall approach has been applied in the modelling methodology so in the model results every cell should have some form of depth value as rainfall is distributed to each cell before it is routed through the hydraulic model. Therefore a depth filter is required to remove modelling of insignificant rainfall distribution in the model cells;
- A depth of 0.15 metres corresponds to the average height of average road kerb heights, and is therefore the depth at which standard road drainage will be exceeded;
- For high velocity scenarios (up to 2 m/s) the minimum depth is 0.15 metres to the H2 hazard curve presented in the *AEM Handbook 7: Managing the floodplain: best practice in flood risk management in Australia* (Commonwealth Government, 2014) (refer to **Figure 6-4**).

Minimum Continuous Extent Area

All continuous flood affected areas less than 100 m^2 in area have been removed from the FPA as they are assumed to be isolated areas of ponding that represent areas of negligible flood affectation.

Ground Truthing Process

A ground truthing process was conducted by Cardno staff on 29 May 2014 to confirm the hydraulic model results from the Coogee Bay Flood Study (BMT-WBM, 2013) and the removal of 'ponding areas' (discussed above) were appropriate based on observed conditions throughout the catchment. The outcome of this ground truthing process was the removal of areas of flood affectation that were determined to be insignificant or unrealistic based on observed site conditions.

Consideration of Freeboard in Flood Planning Area

Finally, the 0.5 metre freeboard was added to the peak water levels of the 1% AEP event and mapped for the Coogee Bay catchment. This process was conducted manually with the impact of the 0.5 metre freeboard applied to the Flood Planning Area based on the flood behaviour expected based on hydraulic model results and outcomes of the ground truthing process.

A potential outcome of applying a Flood Planning Area based on the 1% AEP with 0.5m freeboard to the floodplain in some cases would be the application of flood related development controls on properties that are significantly removed from the flow paths, however upon review this was not a concern for the of the Coogee Bay floodplain where the extent of the 0.5 metre freeboard did not exceed the 1% AEP significantly.

The Flood Planning Area for the Coogee Bay catchment is shown in **Figure 7-2**.

7.8.2 Flood Affected Properties

The interaction of the cadastral lots with the Flood Planning Area meant that some properties that were marginally affected. The result of this is that properties would have a Section 149 (2) certificate notification applied when the associated flood risk for the property is negligible as only a small part of the site is flood affected.

In order to assess these situations and identify where these properties could be removed, a number of marginal affectation rules were applied to assess the suitable exclusion of marginal affected properties from notifications:

- Area of FPA affectation is less than 10% of the total property area;
- Area of FPA affectation is less than 10%, and no part of the property is affected by floodway;
- Area of FPA affectation is less than 10 m^2 in total for the property; and,
- Area of FPA affectation is less than 50 m^2 in total for the property.

The outcomes of this assessment was to not apply any of these principles and have all marginally affected properties notified in the Section 149 (2) certificate. The justification of this approach is that the majority of flood-related development controls (which are discussed further in **Section 8**) are relevant only to flood affected portions of land and not the entire property. Therefore the application of flood policy to marginally affected properties will not be onerous on any potential development in any way unless justified by the associated flood risk.

Therefore the total number of properties that are flood affected and will have associated notifications on Section 149 (2) certificates is 721 properties, as shown in **Figure 7-2**.

7.8.3 Impacts of Floodplain Management Options on FPL and Property Tagging

The intention is for the Flood Study to be revised within a 5 to 10 year period. The purpose of the review is to revise flood modelling based any changes in the catchment and incorporate the records of any significant flood events since the last version of the Flood Study was undertaken. When this revision is undertaken all updated drainage details, including works resulting from this Floodplain Risk Management Study would be incorporated into the revised model to assess the changes to flood depths, velocities and extents as a result of works completed. If a property is no longer within the Flood Planning Area, it would no longer be tagged as flood affected.

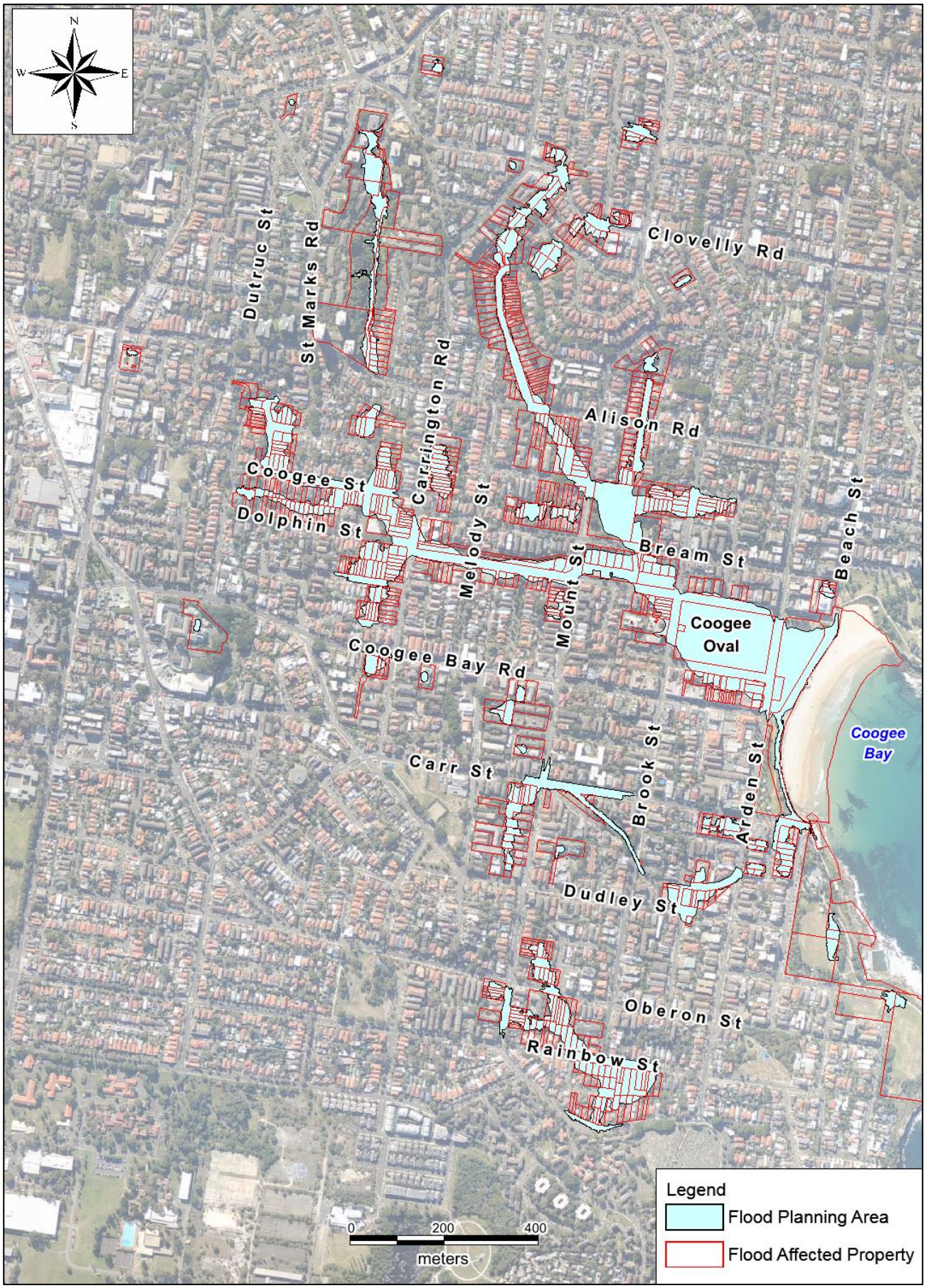

Figure 7-2 Flood Planning Area and Flood Affected Properties for Coogee Bay Catchment

8 Flood-related Planning Controls and Policies

8.1 Planning Instruments & Policies

The Coogee Bay floodplain is located in the Randwick LGA where development is controlled through the Randwick Local Environment Plans (LEP), Randwick Development Control Plan (DCP) and associated policies. Specifically, the study area falls under the *Randwick LEP 2012* and *Randwick DCP 2013*. 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 reviews flood controls covered by the LEP, DCP and relevant policies and plans. 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 Coogee Bay floodplain and may not be appropriate for all floodplains across the Randwick LGA.

8.2 Randwick Local Environmental Plan 2012

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.

Section 6.3 relates to all land within the mapped flood planning area, and to land at or below the FPL. The flood planning area map comprises a single figure that shows a small number of flood affected cadastral lots in Maroubra. It is recommended that the flood planning area mapping in the LEP be updated to be consistent with the outcomes of this Flood Risk Management Study for FPA for Coogee as summarised in **Section 7.6**.

Further, it is recommended that the LEP is updated to show applicability to all land below the PMF and the FPL dependant on the type of development.

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.

As discussed in **Section 3.4**, the review of land use zoning under the LEP highlighted that the main land uses within the floodplain comprise low and medium density residential development and public recreation areas such as parks and sports fields (**Table 8-1**). There is a significant increase in the area of residential and commercial land uses subject to flooding in the PMF event.

Table 8-1 **Land Uses within the Floodplain**

Land Use Zone	Area (ha)	
	1% AEP	PMF
B1 - Neighbourhood Centre	0.24	0.85
B2 - Local Centre	0.61	3.02
R2 - Low Density Residential	2.56	10.47
R3 - Medium Density Residential	7.00	32.24
RE1 - Public Recreation	5.87	9.63
SP2 - Infrastructure	0.02	0.51

8.3 Randwick Development Control Plan 2013

The *Randwick DCP 2013* contains a range of general and area-specific controls for designing / planning for, and managing flood risk.

The key relevant section is *B8 – Water Management*, which contains objectives and controls for development in relation to water conservation, stormwater management, groundwater and flooding, with an overall focus on Water Sensitive Urban Design (WSUD).

8.3.1 Flooding

Sub-section 5 of Section B8 addresses flooding. Reference is made to the flooding provisions in the LEP and forthcoming flood studies under preparation by Council. The sub-section applies to:

- Residential development on land below the 1% AEP (or 100 year ARI) flood plus the required freeboard; and,
- All other development on land below the PMF plus the required freeboard.

The amount of "required freeboard" is not specified. It is recommended that the first bullet point be replaced with a reference to the Flood Planning Area, as identified in the relevant adopted FRMP.

The objectives relevant to flooding articulated in the DCP are as follows:

- To control development at risk of flooding in accordance with the NSW Government's *Floodplain Development Manual*;
- To ensure that the economic and social costs which may arise from damage to property due to flooding is minimised and can be reasonably managed by the property owner and general community;
- To reduce the risk to human life and damage to property caused by flooding by controlling development on land impacted by potential floods; and
- To ensure that development is appropriately sited and designed according to the site's sensitivity to flood risk.

Sub-section 5.1 provides a link back to the floodplain management process, with an objective 'to ensure that development addresses any relevant flood studies, and is consistent with the requirements of any floodplain risk management studies or plans.'

The relevant controls require that:

- Development Applications (DAs) are to identify any flood related information including flood levels, locations of floodways or overland flow paths impacting the site;
- If required by Council, a site specific flood study or other calculations must be submitted with a DA to demonstrate there is no adverse impact on flooding by the proposed development if a flood study for the catchment has not been prepared; and
- A proposed development must comply with any catchment-specific controls in an adopted FRMP in addition to the controls in this section of the DCP.

The specific requirements for assessing flood effects for a DA are detailed in Sub-section 5.2. The objectives are:

> To ensure that development, either individually or cumulatively, minimises adverse impacts on flooding, conveyance of floodwaters and floodplain storage volume; and

> To ensure that floodways and overland flow paths are not obstructed by development.

The specific requirements are that:

> The development shall not increase flood effects elsewhere, having regard to loss of flood storage, changes in flood levels and velocities and the cumulative impact of multiple potential developments, for floods up to and including the 1% AEP flood;

> Floodways and overland flow paths must not be obstructed or diverted onto adjoining properties; and

> Areas identified as flood storage areas must not be filled unless compensatory excavation is provided to ensure that there will be no net loss of floodplain storage volume below the 1% AEP flood.

These hydraulic categories; floodway and flood storage, have been defined for the Coogee Bay catchment within the *Coogee Bay Flood Study* (BMT-WBM, 2013). It is noted that with regards to the final point relating to balancing net flood storage that this is not particularly relevant for Coogee Bay. As the flood behaviour of the site can generally be described as overland flow when compared to larger riverine catchments, the importance of flood storage is less than the requirement for floodways to not be obstructed.

It is suggested that if detailed hydraulic modelling for a site shows that a net loss of flood storage for a development results in negligible flood impacts then the objectives are met and the requirements to balance flood storage for a site are unjustified and onerous. Therefore it is recommended that the third control above be considered for removal with regards to locations affected by overland flow.

8.3.2 Floor Levels

Sub-section 5.3 relates to the minimum floor level requirements of new development within the floodplain. A detailed assessment of current floor level requirements has been assessed in the Flood Planning Level review section (refer to **Section 7**).

8.3.3 Building Components

Sub-section 5.4 Building Components requires that:

> All development is to have flood compatible building components below the minimum floor levels; and,

> All structures shall be constructed to withstand the forces of floodwater, debris and buoyancy up to and including the minimum floor level.

In relation to the first control above, it may also be prudent to consider any requirement for placing electrical services (e.g. power points and fuse boxes) above the FPL for flood affected properties. This requirement not only addresses the risk to property of flood affectation of these electrical items but more importantly the risk to life associated with electrocution for residents in the event of flooding.

In relation to the second point it is unclear the processes Council requires of developers to achieve this requirement, therefore it is recommended the control be revised to include reference to ‘certification by a suitably qualified structural engineer’ or similar.

8.3.4 Driveway Access and Car Parking

Sub-section 5.5 - driveway access and car parking requires that:

> Car parking floor levels comply with Table B – Floor Levels for Car Parking (see **Table 8-2**);

> Vehicular accesses be located either at a level where the road level is greater than or equal to the required floor level for the car park or at the highest feasible location;

> The level of any driveway between the road and car park is to be no lower than 0.3 m below the 1% AEP flood or such that the depth of inundation during the 1% AEP flood is not greater than the depth of flooding at either the car park or the road where the site is accessed;

> Underground car parking accommodating more than three vehicles shall have warning systems signage and exits to ensure adequate warning and safe evacuation;

> Barriers shall be provided to prevent floating vehicles leaving the site during the 1% AEP flood if the depth of flooding at the car space exceeds 0.3 m; and

> Vehicle access to critical facilities that have an emergency function must be achieved for floods up to the PMF.

Table 8-2 **Floor Levels for Car Parking (Source: Randwick DCP 2013)**

Scenario	Floor Level
Above ground level open car parking, car ports and garages	
Open car parking spaces and car ports	5% AEP flood
Residential garages with up to two spaces	1% AEP but not less than 0.15 m above surrounding ground level
Residential garages with more than two spaces	Applicable residential habitable floor level requirements (**Table 7-1** above)
Enclosed industrial/Commercial parking spaces	Applicable industrial/commercial floor level requirement (**Table 7-1** above)
Underground car park (where floor level is more than 0.8 m below surrounding ground level)	
All driveways	1% AEP + 0.3 m freeboard at its highest point
All emergency exits	All underground garages and car parks have emergency exits protected from inundation up to 1% AEP flood + 0.5 m freeboard with a minimum of 0.2 m freeboard from vehicle entry point
All other openings inundated by flooding or local overland flow path	All openings to be sealed up to 1% AEP + 0.5 m freeboard with a minimum of 0.3 m above surrounding ground level.

Generally the minimum garage level requirements proposed seem appropriate for the floodplain behaviour of the Coogee Bay floodplain. Due to the relatively small flood range for the catchment from the 1% AEP to the PMF event often it may not be onerous for developers to achieve driveway access to basement carparking to the PMF level (current requirement in 1% AEP plus 0.3 metre freeboard).

If the basement entrances can be shown to be flood free up to the PMF event than the risk of flooding is negligible therefore emergency exit requirements and warning system requirement are not necessary. Therefore it is recommended that it be optional for developers to choose to set entry levels to the PMF or 1% AEP plus 0.3 metre freeboard whichever is higher, or alternatively the current arrangement of the 1% AEP plus 0.3 metre freeboard with warning systems and evacuation route requirements.

8.3.5 Safety and Evacuation

Sub-section 5.6 requires that:

> All DAs include a description of the safety and evacuation methodology with all DAs, including:

- The provision of reliable and safe egress for inhabitants from the lowest habitable floor level to a publicly accessible location above the PMF level, and
- The method of access for emergency personnel.

It is recommended that this requirement be modified to state that it only applies to properties falling within the PMF extent, and that the first bullet point be simplified to required that DAs for flood affected properties provide a flood emergency response plan prepared in accordance with the requirements of the NSW Government (2005) *Floodplain Development Manual* and in accordance with the flood risk and proposed land use of the subject site. In this way, the requirement is more flexible and takes into account different types of development and flooding behaviour. Also the removal of the requirement for access to publically accessible locations allows for the potential implementation of shelter-in-place strategies which were found to be potentially feasible in many locations based on floodplain behaviour (see **Section 6.10**).

If shelter-in-place were deemed to be acceptable then development controls would need to be added considering the following provisions:

> Appropriate shelter-in-place should be set at the PMF level;

> Floor space ratio requirements should be implemented to ensure sufficient space to accommodate all residents;

> Building stability should be certified for shelter-in-place refuge up to the PMF event; and

> For refuges expected to be isolated for extended periods (which is not applicable for the majority of the Coogee Bay catchment) serviceability requirements relating to emergency access, water supply, and electricity supply should be considered.

As noted in **Section 6.4**, the design event for emergency response should be the PMF event meaning all future developments should be able to demonstrate the safety of residents up to the PMF event. However this would mean that flood controls for this section need to be applied to all properties up to the PMF event where in the current controls this is only applied to properties below the Flood Planning Level.

8.3.6 Management and Design

Sub-section 5.7 requires that land shall not be subdivided unless it is demonstrated that:

> The newly created parcels of land can be developed in accordance with the flooding requirements of the DCP. Land parcels created for the specific purpose of being transferred to Council ownership are exempt from this requirement;

> Development shall not cause or increase erosion, siltation or destruction of natural or modified watercourses, wetlands or coastal areas;

> Fencing within a floodway or overland flow path shall be of permeable open type design, and be constructed to withstand the forces of floodwaters or to collapse in a controlled manner; and

> Any proposed storage area shall be constructed and located to prevent stored materials or goods becoming hazardous during a flood.

Note: Permeable open type fences are fences with sufficient openings to allow the unobstructed flow of water.

The following recommendations are made for this clause:

> The first point be updated to include also reference to the *Floodplain Development Manual* (NSW Government, 2005);

> The fourth point in relation to materials storage is suitably addressed by minimum level requirements set-out in Sub section 5.3, therefore this control can be considered for removal.

> Any application for subdivision within the Flood Planning Area should provide building platforms at or above the Flood Planning Level and that do not exacerbate flood levels, velocities or flow distributions at any other location, including cumulative impacts of incremental development should all the proposed lots become fully developed.

> Consideration should also be given to emergency access and evacuation.

8.4 Critical Infrastructure

In accordance with the current Randwick DCP 2013 critical infrastructure with regards to flooding is defined as hospitals, police stations, fire stations, ambulance stations, SES stations, major transport facilities, major sewage or water supply or electricity or telecommunication plants, schools, nursing homes and retirement villages.

This definition of critical facilities aligns with the general definition of critical and vulnerable development commonly adopted with regards to flooding as all would be essential infrastructure in the event of flooding or represent a significant risk due to vulnerable demographics. The one additional development type which should be considered for addition to this definition is child care facilities as they also represent a high risk development type in the event of flooding.

The current minimum floor level requirements for critical infrastructure is the Probable Maximum Flood Level (PMF) plus 0.5 metre freeboard. Due to the exceptionally low probability of occurrence of a PMF event, the adoption of the PMF level is considered sufficient to ensure a suitable level of flood risk for critical developments. Therefore the adoption of a 0.5 metre freeboard in addition is considered unnecessary. This is reflected across the state with the majority of Council's not applying freeboard to PMF level for critical and vulnerable developments. However, it is recommended that where the 1% AEP plus 0.5m freeboard is higher than the PMF level, then the high level should be applied as the FPL.

The application of the PMF as the FPL for these development types is in keeping with guidance provided within the s117 directive from the NSW State Government discussed in **Section 7.3**.

Finally it is noted that a number of Council's in the state are now adopting an additional flood related clause within their LEP's to address critical infrastructure under the PMF level. While the controls are addressed in the current Randwick DCP, however under the current LEP no developments whether they be critical or otherwise need to consider flood controls if they lie above the Flood Planning Level (1% AEP plus 0.5m freeboard). Given the additional legislative power of the LEP document compared to the DCP under planning law then the inclusion of flood controls up to the PMF event for critical development should be considered added to any future LEP amendments.

8.5 Flooding Advice and Flood Related Development Controls Policy

The stated objectives of this policy are to provide guidance on flood related matters for those catchments for which FRMS&Ps have not yet been prepared, and specifically to:

> Meet Council's obligations to disclose flooding related information; and

> Establish interim flooding related controls in situations where a Council commissioned Flood Study exists but no FRMS&P has been adopted by Council.

The DCP provides all the relevant development controls and covers those matters addressed in Section 3, and it is therefore recommended that this policy re-direct to these controls if a site is to be flood affected. Once Flood Study and Floodplain Risk Management Study outcomes are adopted by Council for Coogee Bay this control will no longer be relevant for the area.

8.6 Other Relevant Policies and Plans

There are a number of other relevant policies and plans that have also been reviewed as part of this study. These are discussed in **Table 8-3**.

Table 8-3 **Other Relevant Policies and Plans**

Instrument	Discussion
A Plan for Growing Sydney **(NSW Government, 2014)**	Flood risk is explicitly addressed in the Plan in '*Goal 4: A sustainable and resilient city that protects the natural environment and has a balanced approach to the use of land and resources*.' Relevant directions and actions under this goal include: *'Build Sydney's Resilience to Natural Hazards* ▪ *Provide local Councils and communities with tools and information to shape local responses to natural hazards;* ▪ *Complete and implement the Hawkesbury-Nepean Valley Floodplain Management Review; and* ▪ *Map natural hazard risks to inform land use planning decisions.'* This is consistent with the NSW Floodplain Management Process and with the objectives of this study. Randwick LGA forms part of the Central Subregion, and contains the Randwick Health and Education Strategic Centre. The Plan states that the State Government will work with Randwick Council to identify potential lands for urban renewal and intensification around this Strategic Centre. Although the hospital and university are located outside of the Coogee Bay floodplain, there may be potential for some of this development to be identified within the study area.

Instrument	Discussion
Section 117 Directions	Under Section 117 of the EP&A Act the Minister for Planning issues Directions to planning authorities that they are required to adopt when preparing new LEPs. Relevant Directions are discussed below. *Direction 4.3 - Flood Prone Land* The objectives of this direction are: ▪ To ensure that development of flood prone land is consistent with the NSW Government's *Flood Prone Land Policy* and the principles of the *Floodplain Development Manual* 2005, and ▪ To ensure that the provisions of an LEP on flood prone land is commensurate with flood hazard and includes consideration of the potential flood impacts both on and off the subject land. The Direction applies to all flood prone land within an LGA, and contains the following provisions: ▪ A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy and the principles of the *Floodplain Development Manual 2005* (including the *Guideline on Development Controls on Low Flood Risk Areas*). ▪ A planning proposal must not rezone land within the flood planning areas from Special Use, Special Purpose, Recreation, Rural or Environmental Protection Zones to a Residential, Business, Industrial, Special Use or Special Purpose Zone. ▪ A planning proposal must not contain provisions that apply to the flood planning areas which: (a) permit development in floodway areas, (b) permit development that will result in significant flood impacts to other properties, (c) permit a significant increase in the development of that land, (d) are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services, or (e) permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, buildings or structures in floodways or high hazard areas), roads or exempt development. ▪ A planning proposal must not impose flood related development controls above the residential flood planning level for residential development on land, unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General. ▪ For the purposes of a planning proposal, a relevant planning authority must not determine a flood planning level that is inconsistent with the Floodplain Development Manual 2005 (including the *Guideline on Development Controls on Low Flood Risk Areas*) unless a relevant planning authority provides adequate justification for the proposed departure from that Manual to the satisfaction of the Director-General. It requires with respect to all re-zoning planning proposals that the consent authority satisfy the Director-General that: *'the planning proposal is in accordance with a FRMP prepared in accordance with the principles and guidelines of the Floodplain Development Manual 2005, or the provisions of the planning proposal that are inconsistent are of minor significance.'* *Direction 7.1 Implementation of the Metropolitan Plan for Sydney 2036* This direction is to give legal effect to the vision, land use strategy, policies, outcomes and actions contained in the Metropolitan Strategy (i.e. A Plan for Growing Sydney). In support of Direction 4.3, the State Government released Planning Circular PS07-003 on development controls for low flood risk areas, and in particular the release of a new guideline on that matter. It specifies that, unless there are exceptional circumstances, a Council is required to adopt a FPL corresponding to the 1% AEP flood event (+ 0.5 m freeboard). Should Council wish to adopt a different FPL, this would need to be approved via an application to Planning and Environment (P&E).

Instrument	Discussion
	The Circular does note, however, that the Guideline acknowledges that controls may need to apply to critical infrastructure (such as hospitals), evacuation routes and vulnerable developments (like nursing homes) in areas above the 1% AEP flood. This is because these types of developments and critical infrastructure are required to operate in the event of a flood greater than the 1% AEP. The circular also provides guidance on Section 149 notifications. The recommendations provided in the FRMS&P are consistent with these S117 Directions.
Metropolitan Plan for Sydney 2036 **(NSW Government, 2010)**	The Plan recognises flooding and climate change as constraints on infill and greenfield development within Sydney. It also encourages ecologically sustainable growth while reducing the risk to life and property from flooding and sea level rise.
East Subregion Draft Subregional Strategy **(NSW Government, 2007)**	This Subregional Strategy applies to Randwick LGA and requires that Council consider the most recent available information of natural hazards in their strategic and statutory planning. The Plan requires Councils to plan for land affected by flooding in accordance with the Government's *Flood Prone Land Policy* and *Floodplain Development Manual.* This FRMS&P is consistent with this requirement of the Subregional Plan. Randwick LGA is required by the state government to accommodate an additional 8,400 dwellings by 2031 as detailed in the Strategy, the majority of which will be through increased development densities. Therefore, it is important that flood risk management measures are included in Council's planning instrument and DCP to manage any impacts on or by this potential future development.
State Environmental Planning Policy (Infrastructure) 2007	Clause 15 *Consultation with councils—development with impacts on flood liable land* requires a public authority or a person acting on behalf of a public authority to consult with and take into consideration Council responses to any planned development on flood prone land. Clause 50 *Development permitted without consent* enables flood mitigation works to be carried out by or on behalf of a public authority 'without consent', i.e. subject to an internal assessment of potential environmental impacts under Part 5 of the EP&A Act.
State Environmental Planning Policy (Urban Renewal) 2010	This SEPP relates to the identification of Urban Renewal Precincts and requires that consideration be given to 'environmental factors' in the study that precedes any recommendations for rezoning of an area. This would include flooding.
State Environmental Planning Policy (Exempt & Complying Development Codes) 2008	In accordance with Clause 3.36C of the Exempt and Complying Development Codes SEPP, flood affected properties may be eligible for a complying development certificate if the development does not lie within one of the following: ▪ Flood storage area, ▪ Floodway area, ▪ Flowpath, ▪ High hazard area, or ▪ High risk area.
The Randwick City Plan **(Randwick City Council, 2013)**	The Plan was prepared under the Integrated Planning and Reporting Framework as the overarching document under which the more detailed short, medium and long term plans sit. The Plan is a strategic planning document that enforces flood planning in accordance with the precautionary approach, and identifies the preparation of FRMS&Ps for a number of catchments. This document will require updating upon adoption of the Coogee Bay FRMS&P by Council. The Budget 2014-2015 which sits under the Plan identifies an allocation of $1.2 million for drainage works, including the completion of Flood Studies and FRMS&Ps).

Instrument	Discussion
Private Stormwater Code **(Randwick City Council, 2013)**	The objectives of the Code are: ▪ To provide designers, developers, builders and the general public with a guide to Council's requirements for the disposal of private stormwater; ▪ To prevent damage to both Council and private property and to prevent nuisance and risk to the public, by controlling the disposal of stormwater from private properties; ▪ To reduce the impact of new development on Council's stormwater system and prevent flooding; and ▪ To direct stormwater back into the ground through infiltration where possible. The code outlines minimum design guidelines for stormwater design of new developments that attempt to achieve these above objectives.

8.7 Review of Planning Certificates

As discussed in **Section 7.6** the primary mechanism by which Council's notify landowners that their property is affected by flood risk is via a planning certificate issued under Section 149 of the *Environmental Planning and Assessment Act 1979* (commonly referred to as a Section 149 certificate). A planning certificate under Section 149(2) discloses whether or not the land is subject to a policy that restricts the use of the land, and is a mandatory part of the conveyancing process. For Randwick the LEP identifies flood prone land and the DCP details the relevant flood related development controls.

In addition, the planning certificate may also include additional information under Section 149(5), although this does not necessarily mean that the land is subject to any specific policy or development control at the present time. Although not obligated to provide the information, a notification made under Section 149(5) may be used by local Councils to exercise their duty of care to ensure the landowner is aware that their land is subject to hazards in the present day or in the future. This may, for example, include advice that their land is subject to future flood risk (e.g. for locations where climate change increases flood affectation).

It is understood that Council has sought external legal advice regarding the disclosure of flood related information to their community, and specifically in relation to planning certificates, and so no further advice has been provided in this FRMS&P.

The other type of information that property owners may require in order to prepare a DA is a property-specific flood report, and this may be provided either by the local Council, or by a nominated third party (always a suitably qualified engineer). The flood report provides information on the site specific flood risk to enable proponents to comply with the relevant development controls (e.g. minimum floor levels for habitable areas). It is recommended that the flood report contain the following details:

> Figure(s) showing the flood extent;

> A brief description of flood behaviour for the site (e.g. location of flow paths);

> The 1% AEP and PMF peak flood levels (m AHD) for at least one point on the site, with additional points provided depending on the size of the allotment;

> Reference to the relevant flood-related planning controls, and ideally an excerpt of the key development controls from the DCP; and

> Appropriate qualifications and/or limitations on the information provided in the report.

8.8 Summary of Recommendations for the Coogee Bay Floodplain

Based on a review of the relevant flood-related planning controls a number of recommendations were made, summarised below:

> It is recommended that all documentation adopt consistent terminology, primarily with respect to naming conventions for design flood events. It is understood that OEH is now using AEP rather than ARI, and it may be prudent to adopt a consistent approach;

> The adopted FPL in all plans and policies should be consistent with the advice provided in **Section 7** of this FRMS&P. To allow for variations between floodplains in the definition of the FPL (and associated freeboard), the following definition (or similar) could be included in the LEP and DCP:

- *Flood planning level* means the level of a 1% AEP flood event plus 0.5 metres freeboard, or other flood event and freeboard determined by an adopted floodplain risk management plan.

> The LEP should allow for development controls up to the PMF in order to:

- to enable evacuation of development with particular evacuation or emergency response issues on land subject to flooding in events exceeding the flood planning level; and
- to protect the operational capacity of emergency response facilities and critical infrastructure during extreme flood events.

> The flood planning area map in the LEP should be updated based on the outcomes of this study as per guidance provided in **Section 7.8.1**;

> A number of recommendations are made in relation to Section B8 – Water Management of the DCP:

- Under Sub-section 5 – Flooding, the text that describes the land to which the requirements apply is revised to read '*the Flood Planning Area identified in the relevant FRMS&P'*,
- Sub-section 5.2 should be revised to remove the requirement for balancing of net floodplain storage if detailed hydraulic modelling shows negligible flood impacts;
- Updating of Sub-section 5.4 on building components should be revised to include requirements for electrical components to be raised above the Flood Planning Level,
- Re-drafting of Sub-section 5.5 on driveway access and car parking as discussed in **Section 8.3.4**,
- Modification of Sub-section 5.6 on safety and evacuation to provide greater flexibility for proponents in determining the appropriate flood emergency response for the subject site, including the potential addition of requirements for shelter-in-place as detailed in **Section 8.3.5**. Council should consider the adoption of a PMF design event for safety and evacuation requirements.

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.

9.1.2 Methodology for Identifying Options

The identification of appropriate flood risk management options for assessment within the Coogee Bay catchment has been achieved through the following steps:

> Assess flood behaviour throughout the catchment to determine the locations with the greatest flood risk; both risk to life and risk to property, these are the locations where flood risk management measures are most in need. Flood behaviour for the Coogee Bay catchment is summarised in **Section 4**;

> Once the areas of greatest flood risk 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 justification for their potential adoption within the Floodplain Risk Management Plan.

Details of the option identification process for flood modification measures, property modification measures, and emergency response modification measures are included in **Section 9.2**, **Section 9.3**, and **Section 9.4** respectively.

9.2 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.

The majority of problem flooding areas in Coogee Bay are in some way caused by flow obstructions such as; a low point being cut into the flowpath, a raised embankment across the flowpath, a constriction of flowpath width, or a structure that blocks flow such as a concrete wall or building. Nevertheless, it is not often possible to remove these flow obstructions due to the following reasons:

> The increased conveyance resulting from the removal of these obstructions will effectively reduce flood risk for the existing problem area however it may increase the flooding problem for areas downstream;

> The majority of flow obstructions lie within private property or are private assets and works within this private land or removal of private assets is generally not feasible.

9.2.1 Modifications on Private Land

In discussion with Randwick City Council it was concluded that based on the demographic of the Coogee Bay catchment, residents will not find any acquisition or works to be conducted on private land to be seen as preferable. This is due to the high market value of land within this catchment (based on Bureau of Statistics figures from **Section 3.7** median house prices for Coogee and South Coogee were $1,808,000 and $1,950,000 respectively) and relatively small lot sizes placing greater significance on the retention of private land.

Therefore, flood modification options on private land have not been assessed as part of this FRMS&P, which includes inter-allotment drainage. Flood modification measures have been assessed only where they can be located within public reserve, or within easements associated with existing trunk drainage network.

9.2.2 Preliminary Flood Modification Options

For the Coogee Bay 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 upper 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. Two types of drainage upgrade were considered:

- Addition of inlet pits where it was found that existing pit capacity was the limiting factor on capacity;
- Upgrading of trunk drainage pipes where pipe capacity was found to be the limiting factor on drainage capacity.

> Levees: These are focused on the construction of levee banks to create barriers to flood waters. The construction of these levees requires sufficient space available which is a key constraint for this catchment where average lot sizes are small, and road verges widths are minimal, therefore the only option for levees was public reserves;

The identification of potential flood modification options, the feasibility of these options, and the selection of final flood modification options for detailed assessment is summarised in **Table 9-2**. The location of preliminary flood modification options shown in **Figure 9-1**.

In total, 17 preliminary flood modification options were identified for the Coogee Bay floodplain, covering 14 of the 20 locations of problem flooding in the Coogee Bay area (refer to **Section 4** for summaries of these locations), with the majority of these options assessed using hydraulic modelling.

Table 9-2 **Review of Preliminary Flood Risk Management Options for Coogee Bay Catchment**

Location ID	Location	Cause of Flooding	Option ID	Modification Type	Option Objective	Constraints	Option Modelled	Preliminary Model Results	Detailed Assessment
1	Clyde Street	Flow obstruction - Coogee Road embankment, Insufficient pit inlets	FM1a	Additional pit inlets	Remove frequent flooding by increasing inlet capacity to existing trunk drainage at three low points; one within Clyde Street public reserve and two within adjacent residential properties which do not have existing inlet pits.	The construction of inlet pits at the two low points within residential properties is not considered feasible as works would be on private land. No significant constraints for inlet pits on Clyde Street reserve as it is public open space.	Yes	The inlet pit in Clyde Street reserve significantly reduces water levels in the 20% AEP (up to 0.35 metres), and 5% AEP (0.1 metres). Impacts in less frequent events is negligible. There are no reductions in flood affected properties for any AEP.	Yes
2	Upper Dolphin Flowpath	Flow obstruction - local depressions, No pit inlets available	FM1b	Additional pit inlets	Remove frequent flooding by increasing inlet capacity to existing trunk drainage at numerous low points along this section of flowpath through the rear of residential properties which have no inlet pits.	Technically feasible subject to resolution of private property issues.	Yes	The inlet pits along the flowpath significantly reduces water levels in the 20% AEP (up to 0.8 metres), and 5% AEP (0.5 metres), with less frequent events showing minor improvements as well (up to 0.15 metres in the 1% AEP). There are minor water level increases downstream in the 1% AEP event (up to 0.02 metres) however this is the cumulative effects of FM1a, FM1c as well.	Yes
			FM2	Detention Basin at Albi Place Reserve	Alleviate flooding of these residential properties through the construction of a detention basin in the public reserve immediately upstream.	Due to the low-lying nature of the reserve and the fact that ponding is sourced from the local catchment making diversion to the detention basin difficult, the detention basin option was unlikely to be effective. Social and environmental concerns are raised with works in this reserve due to its community function and existing level of vegetation.	Yes	Preliminary modelling of the 1% AEP showed no reduction in water levels (<0.01 metres) downstream of the Albi Place Reserve resulting from the basin construction.	No
3	Fred Hollows Reserve	Flow obstruction - Alison Road embankment	FM3	Upgrade trunk drainage line	Reduce flooding of Fred Hollows Reserve upstream of Alison Road crossing through the upgrading of the drainage line that runs under Alison Road	As this is in the upper catchment the trunk drainage network cannot be effectively upgraded without this being extended for the entire length of the drainage line which is not feasible. Also the flood risk for the reserve is less than for the residential properties downstream making it an effective natural detention basin at present. Social and environmental concerns are raised with works in this reserve due to its community function and existing level of vegetation.	No	N / A	No
4	Courland Street	Flow obstruction - local depression, No pit inlets available	FM1c	Additional pit inlets	Remove frequent flooding by increasing inlet capacity to existing trunk drainage at low-point in private residential addresses	Though the drainage line runs through private residential properties, the construction of inlet pits is assumed feasible if within the existing Council owned easement for the drainage line.	Yes	The inlet pit significantly reduces water levels in the low point for all events (between 1.5 – 1.7 metre reductions for the 20%, 5%, 1%, 0.5%, and 0.2% AEP events). Impacts in PMF event are negligible. There are minor water level increases downstream in the 1% AEP event (up to 0.02 metres) however this is the cumulative effects of FM1a, FM1b as well.	Yes
6	Lower Queen Flowpath	Flow obstruction - local depression, No pit inlets available	FM4	Additional pit inlets	Remove frequent flooding by increasing inlet capacity to existing trunk drainage at low-point in private residential addresses.	There is no trunk drainage located near this low point within residential properties meaning there is no opportunity to utilise existing easement land and this option is not feasible.	No	N / A	No
7	Carrington Road	Flow obstruction - local depression, No pit inlets available	FM5	Additional pit inlets	Remove frequent flooding by increasing inlet capacity to existing trunk drainage at low-point in private residential addresses.	There is no trunk drainage located near this low point within residential properties meaning there is no opportunity to utilise existing easement land and this option is not feasible.	No	N / A	No
9	Abbott Street	Flow obstruction - local depression / concrete wall, No pit inlets available	FM6	Additional pit inlets	Remove frequent flooding by increasing inlet capacity to existing trunk drainage at low-point in private residential addresses.	No significant constraints as the construction of inlet pits is assumed feasible within the existing Council owned easement for the drainage line.	Yes	The inlet pit significantly reduces water levels in the 20% AEP (up to 0.5 metres) and makes the area flood free in this event, and the 5% AEP (0.08 metres) however impacts in all other events are negligible. There are minor water level increases downstream in the 1%, 0.5% and 0.2% AEP events (up to 0.02 metres).	Yes
12	Bardon Park	Flow obstruction - Natural detention basin, No pit inlets available, insufficient pipe capacity	FM7	Detention basin	Alleviate flooding of Coogee Bowling and Tennis Clubs downstream through the construction of a detention basin in the public reserve at Bardon Park.	Bardon Park lies in area defined as ASS Class 4, and the required scale of excavation would be significant. Social and environmental concerns are raised with works in this reserve due to its community function and existing level of vegetation. Bardon Park is owned by Crown Lands and not Council, therefore any works would require the consent of Crown Lands.	Yes	There are minor water level reductions across a wide area downstream including Coogee Bowling and Tennis Clubs, Brook Street, and Coogee Oval and surrounds (0.07 metres in the 1% AEP, with less than 0.05 metre reductions in all other events). The final design involved a significant volume of fill as well as a small levee upstream of Bream Street.	Yes
			FM8	Additional pit inlets	Reduce severe flooding of Bardon Park and overtopping of Bream Street downstream by increasing inlet capacity to existing trunk drainage.	No significant constraints	Yes	Preliminary modelling of the 1% AEP showed negligible impacts as the drainage line is likely flowing at capacity in this event.	No

Location ID	Location	Cause of Flooding	Option ID	Modification Type	Option Objective	Constraints	Option Modelled	Preliminary Model Results	Detailed Assessment
14	Coogee Tennis Club	Flow obstruction - Concrete walls, No pit inlets available, Insufficient pipe capacity	FM9	Upgrade trunk drainage line	Reduce severe flooding of Coogee Bowling and Tennis Clubs through the upgrading of the drainage line that runs through the site.	As the capacity of the drainage line is at its limit at all locations downstream across Brook Street, Coogee Oval, Arden Street, and to the discharge location at Coogee Beach, the scale of works involved would be excessive. In the context of the relatively minor reduction in flood risk for the two sites the option is not considered feasible.	No	N / A	No
15	Brook Street	Flow obstruction - Natural detention basin, Insufficient pit / pipe capacity	FM10	Detailed Investigation	Further investigate range of options to improve flooding at Brooks Street and surrounds.	N / A	No	N / A	Yes
16	Coogee Oval	Flow obstruction - natural regional depression, Insufficient pit / pipe capacity	FM11	Upgrade trunk drainage line	Reduce severe flooding of Coogee Oval through the upgrading of the drainage line that runs from the Oval to the discharge point at Coogee Beach.	Though the scale of works is significant, the potential reduction in flood risk for the severely flooded Coogee Oval and surrounds makes this option more feasible. Requires closure of Arden Street, Coogee Oval, and part of the promenade during construction causing significant social disruption. Located in ASS Class 5 area with extensive scale of excavation works required.	Yes	The duplication of all large size culverts downstream of Coogee Oval resulted in significant water level reductions in the oval and surrounds (0.7 metres in the 1% AEP, 0.4 metres in the 5% AEP, and 0.4 metres in the 0.5% AEP). Reductions in the 20% AEP and PMF events were relatively minor (less than 0.05 metres). Improvements did not extend further upstream than Brook Street.	Yes
			FM11a	Upgrade Alfreda Street drainage line	Reduce frequent flooding of the minor drainage network that drains overland flows from the overland flow on Alfreda Street directly south of Coogee Oval	Upgrading this side drainage line is unlikely to have significant impacts if the trunk drainage line downstream is at capacity. While the capacity of this network can remove local flooding from Alfreda Street in larger events Alfreda Street becomes a part of the Coogee Oval floodplain which is more regional scale flooding which cannot be solved by minor drainage network upgrades such as this.	Yes	This option has been considered within Option FM11 modelling where the drainage line through the area was duplicated and additional inlet pits were located on the southern side of Coogee Oval and at Alfreda Street. See above preliminary results summary.	No*
			FM12	Levee around oval to contain flooding to public reserve	This will remove flooding of surrounding residential and commercial properties for all events up to the design event by restricting flooding to Coogee Oval	This construction of a levee around Coogee Oval will need to be on the verge of the oval with limited space available. The levee heights required would represent a significant scope of works and could severely affect the visual amenity of the area. Located in ASS Class 5 area with disruption of soils likely.	Yes	Preliminary modelling of the 1% AEP showed that a levee height of over 2 metres was not sufficiently high to contain the 1% AEP event with any levee heights greater than this assumed to not be feasible.	No
17	Mount Street	Flow obstruction - local depression, No pit inlets available	FM13	Additional pit inlets	Remove frequent flooding by increasing inlet capacity to existing trunk drainage at low-point in private residential addresses	The construction of inlet pits at the low point within residential properties is not considered feasible as works would be on private land.	Yes	Preliminary modelling of the 20% AEP event showed almost complete removal of flood affectation. However as the inlet pit had to be located at the low point on private land the option is not feasible.	No
18	Dudley Street	Flow obstruction - commercial buildings, Insufficient pit / pipe capacity	FM14	Upgrade pipe and additional pit inlets	Reduce flooding of commercial properties through the upgrading of the drainage line that runs under Havelock Avenue and Arden Street.	As this is in the upper catchment the trunk drainage network cannot be effectively upgraded without this being extended for the entire length of the drainage line to the discharge point to the sea.	Yes	Modelling of the 1% AEP showed negligible benefits (water level decreases of approximately 0.03 metres) for an increased pipe size from 0.6m diameter to 0.9m diameter.	No
20	Rainbow Street Depressi on	Flow obstruction - natural regional depression, Insufficient pit / pipe capacity	FM15	Upgrade trunk drainage line	Reduce flood risk of residential properties through the upgrading of the drainage line that discharges to the sea.	The scope of works is significant with the depth of the existing drainage line excessive and it is assumed that it interacts with bedrock meaning excavation will be very difficult. The main source of flood risk, the PMF event, is unlikely to be addressed by any feasible scale of pipe upgrade as it would require upgrade to a PMF capacity.	Yes	A duplication of the existing 1.05m diameter pipe resulted in significant water level reductions (0.35 metres in the 1% AEP and 1.1 metres in the PMF event). However the peak depth in the PMF event was still greater than 5 metres meaning a far greater drainage capacity would be required to reduce flood risk in the PMF event which was not considered feasible. A detailed investigation for this location has been included as a separate option (FM16).	No
			FM16	Further Investigations into flood risk management works	Due to the unique nature of flooding at this location and the need for more detailed background information (e.g. geotechnical data), further assessment of flood risk management at the Rainbow Street depression is not feasible within the scope of this FRMS&P. However, due to the high hazard and significant flood risk present at this location, this option proposes that a detailed analysis of flood risk management be undertaken as an outcome of this FRMS&P.	N / A	No	N / A	No

*While Option FM11a has been modelled within the wider FM11 – Coogee Bay Oval trunk drainage upgrades option, it has not been modelled as a stand-alone option. This option may have localised benefits, particularly in frequent flood events for Alfreda Street and surrounds which should be considered for detailed assessment without the associated trunk drainage upgrades downstream.

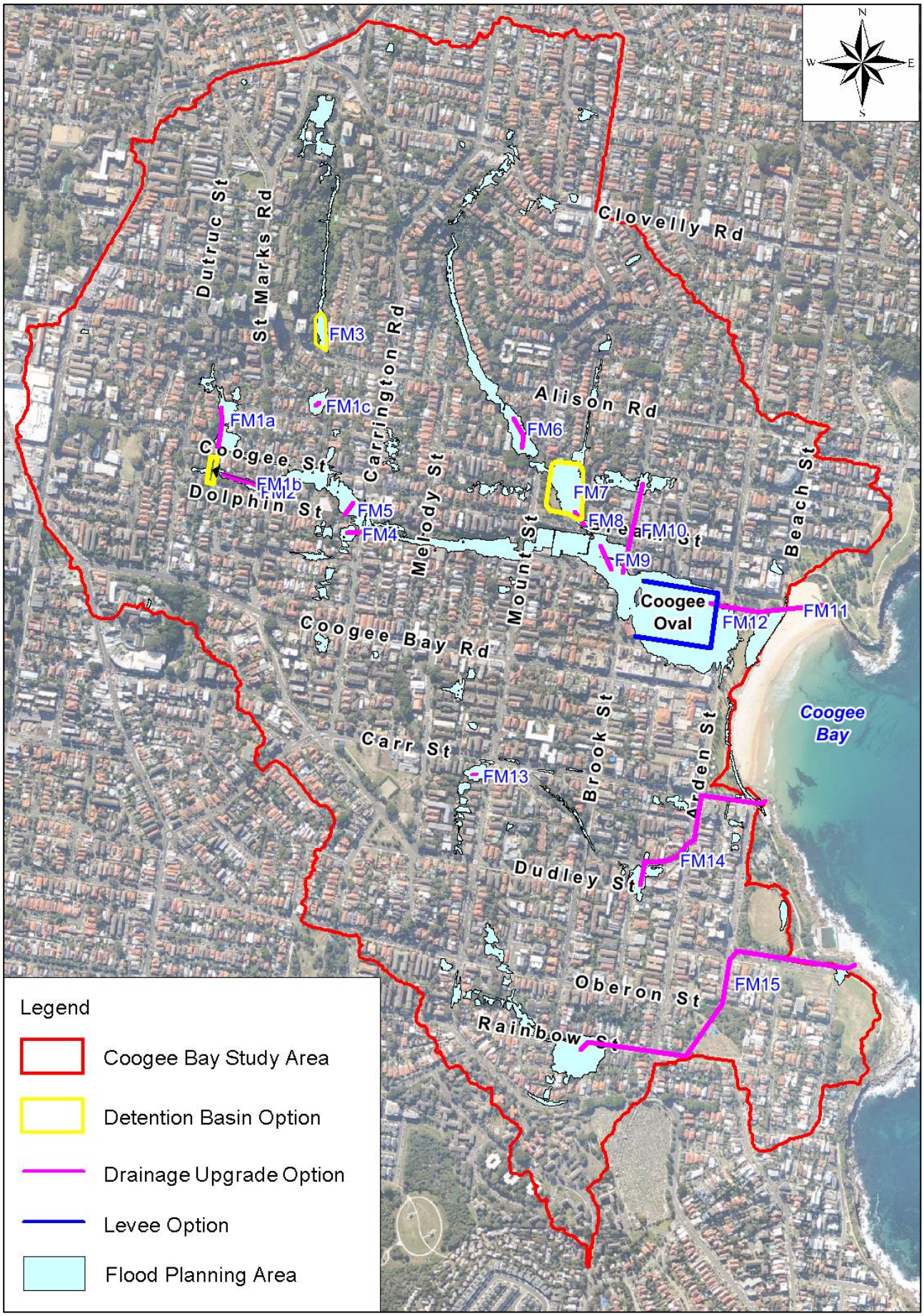

Figure 9-1 Location of Preliminary Flood Modification Options

9.2.3 Flood Modification Options Identified for Detailed Assessment

Several options have been selected for detailed assessment. This detailed assessment involves:

> A summary of the hydraulic modelling (**Section 10**);

> Detailed assessment of quantities and preliminary costing, included in **Section 11.1**;

> Damages analysis including the number of properties with reduced flooding, and the economic benefits in damage reduction included in **Section 11.2**;

> Economic benefit cost analysis included in **Section 11.3**;

> Multi-criteria scoring of each option based on a range of social, environmental and economic factors included in **Section 12**.

As noted in **Table 9-2**, there are a total of 7 flood risk management options identified for detailed hydraulic modelling. However three options are proposed in the vicinity of the upper Dolphin trunk drainage line; Clyde Street (FM1a), Dolphin Street (FM1b), and Courland Street (FM1c). These options will have impacts on each other and, therefore, have been combined into one option, referred to as Upper Dolphin – Option FM1.

The flood management options identified for detailed assessment (hydraulic modelling and economic analysis) are:

> Option FM1 – Upper Dolphin: Additional pit inlets at Clyde Street, upper Dolphin flowpath, and Courland Street (combined FM1a, FM1b and FM1c) ;

> Option FM6 – Abbott Street: Additional pit inlets at Abbott Street depression;

> Option FM7 – Bardon Park: Detention basin constructed in Bardon Park to ease flooding for Coogee Tennis Club, Coogee Bowling Club, and Brook Street; and,

> Option FM11 – Coogee Oval: Additional pit inlets at Coogee Oval and upgrading of three trunk drainage lines discharging from Coogee Oval.

In addition, although Option FM10 and Option FM16 are not proposed for hydraulic modelling as part of the FRMS&P, these option have been included in the multi-criteria assessment (**Section 12**).

9.3 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 measures aim to modify properties so that there is a reduction in flood risk.

The following four property modification measures have been assessed for Coogee Bay catchment:

> House raising;

> Voluntary purchase;

> Land swap;

> Council Redevelopment; and,

> Review of building and development controls.

9.3.1 PM1 – House Raising

House raising is a measure to reduce the incidence of over-floor flooding of existing buildings by raising them, with the works funded by Council, 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 which includes:

> Properties which are benefiting substantially from other floodplain mitigation measures, such as houses already protected by a levee or those that will be – will not be funded for VHR.

> VHR should generally return a positive new benefit in damage reduction relative to its cost (benefit–cost ratio greater than 1). Consideration may be given to lower benefit–cost ratios where there are substantial

social and community benefits or 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.
- VHR is not considered suitable in floodways and areas of high hydraulic hazard.

Based on the costs involved, estimated to be in the range of $40,000 for a standard residential house the key constraint for whether house raising would be viable is for a positive cost benefit analysis from house raising. There are a number of additional obstacles to be considered for making house raising viable, some of the issues related to this approach include:

- Difficulties in raising some houses, such as slab on ground buildings. For some slab on ground houses it may be possible to install a false floor, although this is limited by the ceiling heights, but it is assumed slab on ground properties are generally not viable;
- The potential for damage to items on a property other than the raised dwelling (such as gardens, sheds, garages, etc.) are not reduced;
- Unless a dwelling is raised above the level of the PMF, the potential for over-floor flooding still exists (i.e. there will still be a residual risk);
- The need to ensure the new footings or piers can withstand flood-related forces;
- There is potential for conflict with height restrictions imposed for a specific zone or locality within the LGA; or,
- Potential heritage constraints.

Of the properties with overfloor flooding in the 20% AEP event in the Coogee Bay catchment, a significant portion lie within floodway areas meaning they are not viable for VHR. Of the remaining properties, the majority of these are residential units which cannot feasibly be raised, meaning there are no houses within the floodplain that are appropriate for voluntary house raising.

Therefore the option has been assessed only at a preliminary level and has only been considered for purposes of providing a comprehensive options assessment.

9.3.2 PM2 – Voluntary Purchase

The voluntary purchase of existing flood affected properties is an alternative to the construction of flood modification measures for properties where house raising is not possible. Option PM2 would free both residents and emergency services personnel from the hazard of future floods by removing the risk. This can be 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.

However, due to the significant expense associated with purchase of properties in the study area (based on Bureau of Statistics figures from **Section 3.7** median house prices for Coogee and South Coogee were $1,808,000 and $1,950,000 respectively) this measure should be considered only after other, more practical measures have been investigated and exhausted.

The OEH has prepared the *Guidelines for voluntary purchase schemes* (OEH, 2013b) for voluntary purchase schemes that detail the objectives, eligibility criteria, funding and implementation procedure. Based on these guidelines a potential criteria to determine properties that are eligible for voluntary purchase are:

- Located in the high hazard zone for the 1% AEP flood event; and
- Occurrence of over-floor flooding in the 20% AEP flood event; and
- Economic value of damages for a particular property is comparable to the property market value.

Of the properties with over-floor flooding in the 20% AEP event, two buildings lie within the 1% AEP high hazard areas and meet all criteria; Coogee Tennis Club and a residential property near the Courland Street depression. The voluntary purchase of these two properties is not considered feasible due to the following:

- The provision of voluntary purchase is for residential properties only so the purchase of a non-residential property such as the Coogee Tennis Club is not feasible under the VP scheme;
- The other property is a two storey residential unit building. It is assumed to not be possible for voluntary purchase of the ground floor units which have overfloor flooding, and the voluntary purchase of all units on the lot is assumed to be too costly to be justified, especially considering the second floor units are flood-free.

Therefore, the option has been assessed only at a preliminary level and has only been considered for purposes of providing a comprehensive options assessment.

9.3.3 PM3 – 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.

Note that land swap could also raise several issues relating to moving of existing public open space which could be a potentially contentious issue for the community and therefore is not advised.

There are no existing open space lots identified within the Coogee Bay catchment that are flood free and considered suitable for a land swap. Therefore the option has been assessed only at a preliminary level and has only been considered for purposes of providing a comprehensive options assessment.

9.3.4 PM4 – Council Redevelopment

This option also provides an alternative to the Voluntary Purchase scheme. While Council would still purchase the worst affected properties, it would redevelop these properties in a flood compatible manner and re-sell them with a break even objective. For the two properties identified as suitable for voluntary purchase, this option is not considered viable as any potential re-development would result in an intensification of development in a high hazard and floodway area which is not considered acceptable.

Therefore the option has been assessed only at a preliminary level and has only been considered for purposes of providing a comprehensive options assessment.

9.3.5 PM5 – Building and Development Controls

As summarised in **Section 8.8**, a number of revisions are recommended following a review of Council's flood related development controls. The majority of these changes relate to a slight re-wording and re-organising of policies and will not have a significant impact on flood risk for Coogee Bay.

The one exception is if controls were revised to require flood emergency response provisions, whether they be evacuation or shelter-in-place, to be required to the PMF level. While this will have a negligible economic impact, the potential social benefits could be significant in reduced risk to life.

While it is difficult to determine tangible costs and benefits of this change in development control, the option has been scored within the Multi-Criteria Assessment included in **Section 12**.

9.3.6 PM6 – Public Access to Flood Data

To assist property owners in understanding their flood risk and complying with any flood related development controls, Council will need to update the S149 certificates with the relevant flood impact information. In addition, Council can make available the flood data from this study for each flood affected property, upon request by the property owner.

The objective of this option is to improve flood awareness within the development application process to ensure Council's flood-related development controls such as minimum floor levels requirements are adhered to.

Further detail regarding the recommended information may present within S149 certificates or property flood reports is provided in **Section 8.7**.

9.4 Emergency Response Modification Measures

Emergency response modification measures aim to reduce the consequences of flood risks, by modifying the behaviour of people during a flood event. Further background on the two types of emergency response; evacuation and shelter-in-place is presented in **Section 6**. Emergency response modification measures generally relate to improving evacuation as shelter-in-place is considered a property modification measure.

A review of emergency management options that look to improve flood awareness are summarised in **Sections 9.4.1** to **Sections 9.4.6**.

There is one location in the catchment, the Rainbow Street depression, where due to the distance to flood free land, the relatively fast rate of rise of floodwaters and the scale of flooding involved that local evacuation could not be assumed and that assessment of a detailed localised evacuation strategy was warranted. Therefore the preparation of a localised evacuation strategy for the Rainbow Street depression has been assessed as a stand-alone emergency response modification option as summarised in **Section 9.4.5**.

It is difficult to quantify the impact that flood educations and public awareness campaigns may have on flood risk to life across the Coogee Bay catchment. However to provide an indication of the benefits, for the purposes of this FRMS&P, a review of flood fatalities in Australia has found that the vast majority (75.7%) of fatalities occurred outside when people have entered flood waters in a vehicle or on foot (Haynes et al, 2009). All of these options attempt to limit the number of times people willingly enter floodwaters meaning the risk of loss of life could be severely reduced.

9.4.1 EM1 – Public Awareness and Education

Flood awareness is an essential component of flood risk management for people residing in the floodplain, it is important to maintain an adequate level of flood awareness during the extended periods when flooding does not occur. A continuous awareness program is required to ensure new residents are informed, the level of awareness of long-term residents is maintained, and to cater for changing circumstances of flood behaviour and new developments.

This option would focus on education of the entire LGA with the objective to educate residents that may be in the floodplain at the time of flooding, or may attempt to enter floodwaters. There are a broad range of approaches that can be adopted, which all should be done in close consultation with NSW SES:

- Develop FloodSafe Brochure and FloodSafe Toolkit;
- Develop a post-flood data collection strategy;
- Hold a FloodSafe launch event;
- Develop a flood information package for new residents.

A key concept outlined in the above brochures should be the risks associated with entering floodwaters and that for the Coogee Bay floodplain it is important to remain alert to rising floodwaters and that local evacuation to high ground may be required at any moment.

9.4.2 EM2 – School Education Program

As outlined in **Section 6.5**, there are no schools within the Coogee Bay area located in the floodplain. Nevertheless all schools in the LGA should provide education to children about flood risk. A key focus should not only be education of children attending these schools, but also education of parents / carers not to attempt to assist their children, as this is seen as a key motivation for people to enter floodwaters.

The SES has developed a tailored program for school children in primary schools. The program, includes teacher's resources, newsletters, activities and games, is designed to deliver knowledge and awareness of floods to young children. SES personnel are also available to visit schools to talk about flooding and flood response. Further details of these programs are available on the SES StormSafe website.

Education of parents / carers relating to the flood affectation of the school and the emergency response procedures in place to ensure the safety of their children could be provided directly or through children in the form of brochures etc. Particularly for the Coogee Bay floodplain it should be reinforced to parents that as all schools are flood free they should never enter floodwaters in an attempt to reach their children at school.

9.4.3 EM3 – Flood Markers and Signage

While most major regional roads and key local roads through the Coogee Bay catchment are flood free there are a number of local roads with low points that are expected to experience significant flooding.

While the above public programs can be effective in improving the long term awareness of flood risk, in the event of flooding these education programs can easily be forgotten. Therefore flood warning signage can be an effective tool to remind or inform residents of the risks associated with entering floodwaters, and to also provide practical information in the event of flooding such as recommended evacuation routes.

Appropriate flood warning signs should be posted at all locations of significant flooding. These signs may contain information on flooding issues, or be depth gauges to inform residents of the flooding depth over roads and paths. Also evacuation route mapping could be provided on these signs to assist residents.

A total of 9 flood affected road crossing locations have been identified within the Coogee Bay catchment as shown in **Figure 9-2**.

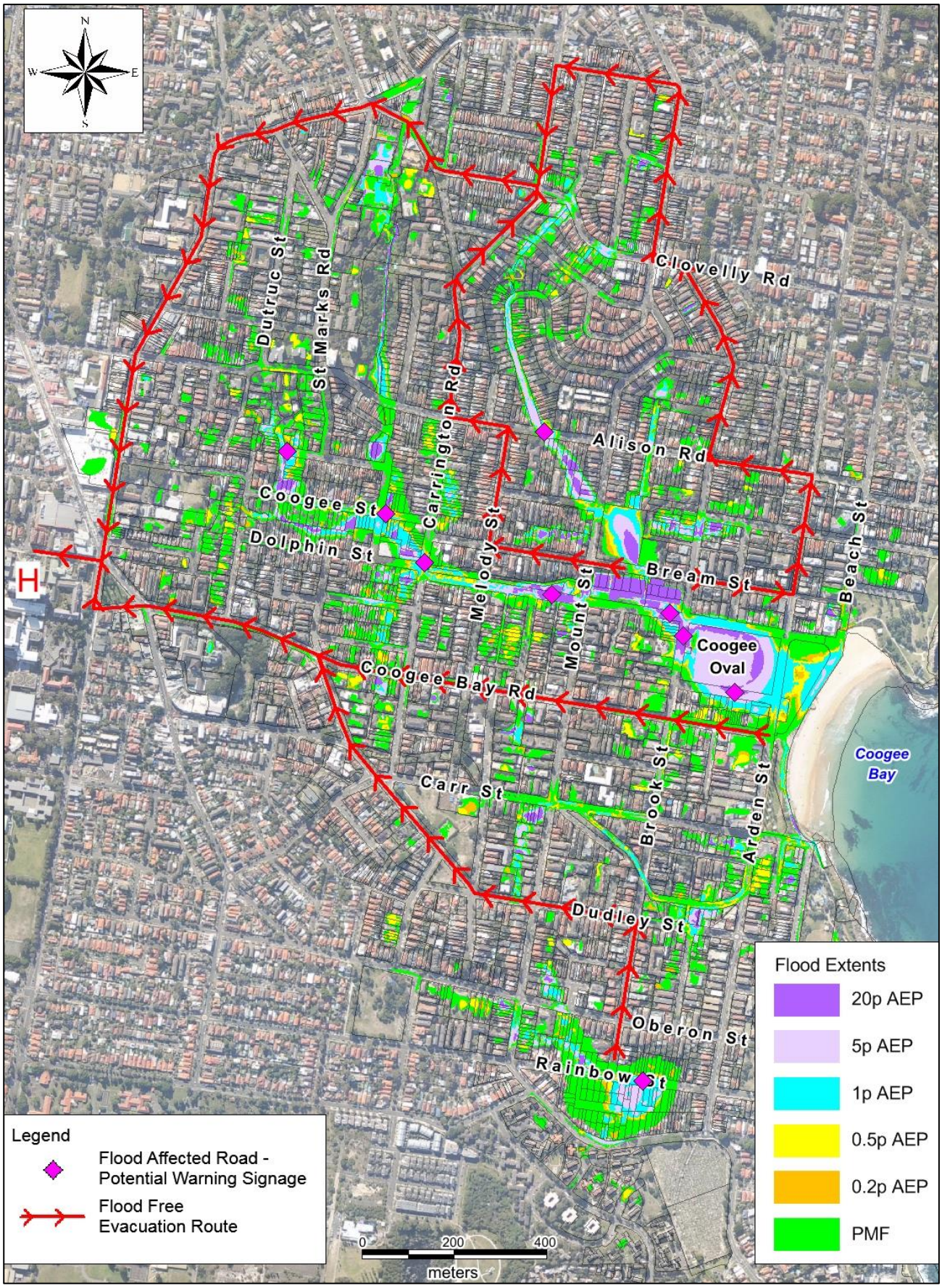

Figure 9-2 Potential Road Locations for Flood Markers and Signage

9.4.4 EM4 – Local Flood Warning System

As discussed in **Section 6.8**, there may be opportunity to provide improved flood warning for residents within the floodplain, such as via SMS alerts of pending storm events. Council currently runs an SMS alert system for community notifications, and this could potentially be adapted to provide flood warnings as well.

Alternatively, the Australian Emergency Alert System could be used by the SES to disseminate SMS flood warnings. This may be the most suitable mechanism to provide flood warnings in the Coogee Bay 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.

In addition as part of this strategy Severe Weather Warnings and Thunderstorm Warnings should be provided on Council's website and in local media.

9.4.5 EM5 – Localised Evacuation Procedures

The currently adopted flood evacuation procedures involve SES doorknocking and assisted evacuation of residents. The conclusion of the review of the evacuation timeline for Coogee Bay catchment as discussed in **Section 6** was that there is insufficient time to evacuate using regional SES assisted evacuation processes.

Nevertheless as discussed in **Section 6** it was found that due to the typically narrow floodplain (the majority of the floodplain is less than 50 metres from flood free land) that localised evacuation could be assumed based on a presumed level of flood awareness.

This option proposes the development of localised evacuation procedures. This would involve:

> Identifying suitable localise routes and destinations for all flood affected properties in the floodplain;

> Disseminating this information regularly to the community in a manner that is readily understood by residents and to ensure a high level of flood awareness is gained across the floodplain.

It is important that residents understand the risks associated with sheltering within their homes compared to finding local refuge from flooding. In addition, the importance of acting promptly when flood risk is identified must be a key component of information provided to residents.

9.4.6 EM6 – Local Flood Response Plan: Rainbow Street Locality

The following section summarises the assessment of the evacuation timeline for the Rainbow Street depression to determine whether or not a localised evacuation strategy can feasibly be developed to improve flood risk for the area.

There are a number of important levels of inundation to consider for the Rainbow Street depression which have been presented in **Figure 9-3**:

> The low point is at 40.4m AHD, however this is a localised low point at the front of one of the properties;

> A significant number of properties become inundated at a level of 41.5m AHD. The extent of surface below 41.5m AHD is shown in dark blue in **Figure 9-3**;

> At 42.0m AHD (shown in purple extents) the end of Marian Street becomes inundated, and Rainbow Street is significantly flooded. If residents at the end of Marian Street do not commence evacuation at this point they will become isolated

> At 44.0m AHD (shown in light blue extents) the intersection of Rainbow Street and Marian Street becomes inundated, at this point Marian Street becomes a Low Flood Island.

The majority of Rainbow Street has rising road access, the low lying portion will have difficulty evacuating due to flow coming across Rainbow Street.

For the range of PMF events (15 minute to 4.5 hour) the minimum approximate time to inundation for the above levels is 10 minutes to level 42.0m AHD (depth at which both Marian Street and Rainbow Street are flooded), and 25 minutes to 44.0m AHD (at which point Marian Street becomes a low flood island).

Marian Street is 180 metres long, therefore unassisted ambulants will require approximately 5 minutes to reach the Rainbow Street intersection. Therefore the only feasible way to minimise flood risk is for a localised evacuation strategy be implemented involving accurate flood warning systems, likely linked to a water level gauge installed for the area, and an extensive flood awareness strategy. This would need to have a targeted flood awareness program for the lowest lying residences to be prepared to evacuate within a matter of minutes of alarm being raised and increased vigilance during all large rainfall events.

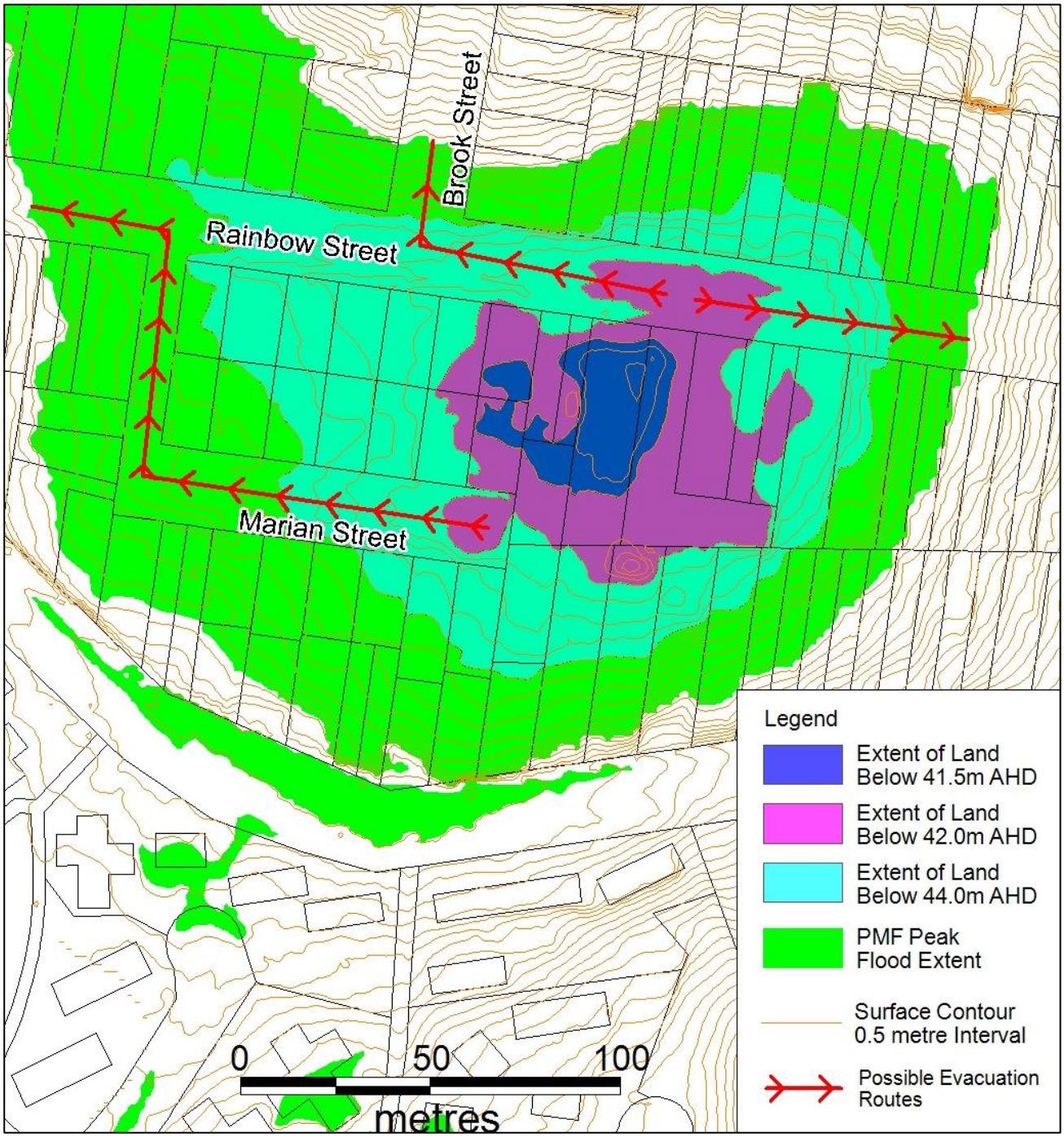

Figure 9-3 Summary of Evacuation Information for Rainbow Street Depression

9.1 Data Collection Strategies

9.1.1 Flood Data Collection

Though it does not fall within any of the three modification categories that are explored as options above, the collection of post-flood data is recommended as part of this FRMS&P. In addition to this, it is recommended that the data collected be expanded to create information that will help the community to better understand the flood event and general catchment flood behaviour. This may include the collection / determination of data such as:

- The approximate recurrence internal of the rainfall intensity and peak river / creek flows;
- The approximate recurrence interval of any major over ground flooding;
- A comparison of the storm event with previous historical events and design events. Comparison could be made against rainfall, flows or depths;
- Timings of peak flows or levels; and,
- The timing and duration of road overtopping / closures.

Following the development of the post-flood collection strategy, a post-flood information mail-out should be developed to pass this information on to the community. The purpose of presenting this data to the community is to allow them to relate their recent flood experience to other historical events and to design events.

Being able to compare their recent flood experience with predicted flows and levels from a 1% AEP or PMF event, would give them a greater understanding of what such an event would look like, and what would be required for them to be safe in such an event. Any improvement in data collection in the future will better inform Stage 2 of the Floodplain Risk Management Process which relates to review of available data.

It is particularly difficult to assign tangible economic, social and environmental benefits as the benefits are in the form of various flow on effects. Therefore data collection has not been assessed as part of the Multi-Criteria-Assessment.

9.1.2 Inlet Pit and Pipe Blockage Assessment

Randwick City Council has an existing maintenance protocol for its stormwater drainage network which includes annual cleaning of inlet pits to remove blockage materials. Inlet pits that are assessed to be more critical based on historical knowledge and sag point locations are cleaned more frequently than annually to provide a better likelihood of reduced blockage in the event of flooding.

Randwick City Council also has a CCTV assessment program for its existing stormwater pipes which assesses the condition, and confirms pipe location and class (size). The CCTV program is carried out each year and is in response to two main concerns:

- In response to residents' requests which come through day to day relating to specific locations; and,
- Gaining knowledge of critical sections such as lines located under building with no easement, and lines in poor condition.

While it is assumed that the current system of pit and pipe monitoring and cleaning is generally appropriate it is recommended that the following review be conducted:

- Review and identification of policies for general maintenance of pipes, drains and channels and determination of protocols for ownership maintenance and development / upgrade of infrastructure.
- Review the database of all drainage infrastructure and its owner and authority responsible for its maintenance.

It is recommended that following flooding at specific locations in excess of the expected affectation based on Flood Study model results for the equivalent rainfall, that consideration be given to inspection of inlet pit blockage to determine if that was a cause of the flooding and to remove blockage where appropriate.

Similar to above these options have not been costed but are recommended for consideration as an outcome of this FRMS&P.

10 Hydraulic Modelling of Options

Hydraulic modelling was undertaken to assess the likely benefits or impacts of those options selected for detailed assessment in **Section 9.2.3**. Modelling was undertaken by modifying the hydraulic model established as part of the Flood Study (WBM BMT, 2013). This allowed for the comparison of the existing case flood behaviour against the likely flood behaviour as a result of implementing various options. Details of the hydraulic model are discussed further in **Section 2.1**.

Note that the following figures have been included in **Appendix** for each of the four flood modification options modelled (preliminary discussion in **Section 9.2.3**):

- Model set-up: The alterations that were made to the hydraulic model set-up as part of the flood modification option including additional inlet pits, additional stormwater pipes, and volumes of cut and fill where implemented for the various options.
- Water level differences: The water level impacts compared to the existing scenario presented for the 20%, 5%, 1%, 0.5%, and 0.2% AEP events for each modelled option.
- Flood extent comparison: In some locations there are reductions in flood extents for frequent events (20%, and 5% AEP) for options FM1 Upper Dolphin and FM6 Abbott Street. Additional figures have been included showing these reductions in extent. For all other options and design rainfall events differences in flood extent are minor or negligible and therefore no mapping has been provided comparing extents.

Details of the hydraulic model results for each of the four flood modification options is discussed further in the following sections.

10.1 Option FM1 – Upper Dolphin

Option FM1 proposes additional inlet pits at Clyde Street, along the upper Dolphin flowpath, and Courland Street, which are flooding locations 1, 2, and 4 respectively as outlined in **Section 4.5**. This option combines Options FM1a, FM1b and FM1c, outlined in **Section 9.2.2**.

A total of 6 additional inlet locations are proposed as part of this option, with a total of 10 additional pits (two locations have double pits and one location has three pits). The intent of this option is to reduce frequent flooding at a number of locations which do not have an existing inlet pit to drain overland flow.

The reason that this option is expected to work better in frequent events is that as the existing trunk drainage line underneath is not expected to be at capacity during these events (see **Table 4-3** for estimate of drainage capacity at locations 1, 2 and 4) and therefore can take the additional flow sourced from the new inlet pits.

The key hydraulic model results for FM1 – Upper Dolphin option are:

- As shown in **Figure C7** and **Figure C8** the option provides some reduction in the flood extents in the 20% AEP at several locations, with significant extent reductions in the 5% AEP as well. The most significant benefits are experienced at Courland Street (Location 4) where in both the 20% and 5% AEP events flooding is completely removed.
- At Clyde Street (Location 1) there are water level reductions in every flood event, with a peak reduction of 0.3 metres in the 20% AEP, however all other events have more modest reductions less than 0.1 metres;
- At Dolphin Street (Location 2) the 20% and 5% AEP events have water level reductions of up to 0.6 and 0.5 metres respectively. For the 1%, 0.5% and 0.2% AEP events there are areas of more modest water level reduction of up to 0.15 metres, with areas of minor increases of up to 0.05 metres.
- Courland Street (Location 4) has significant water level reductions in every flood event with peak water level reductions of 1.6 metres in the 20% and 5% AEP event with still significant reductions of between 1.2 and 1.4 metres for the 1%, 0.5% and 0.2% AEP events.
- For the downstream areas of the Dolphin Street flowpath (flowpath A), all the way to Coogee Oval, there are minor water level increases of up to 0.02 metres for all events. These minor areas of increase are assumed to be caused by the additional flow entering the trunk drainage line at the additional inlet pits

meaning less flow is able to enter the drainage further downstream. Nevertheless the water level increases of up to 0.02 metres are considered relatively negligible.

10.2 Option FM6 – Abbott Street

Option FM6 proposes additional inlet pits at Abbott Street depression, identified as flooding location 9 as outlined in **Section 4.5**. Similar to FM1 the intent is to provide two additional inlet pits to reduce frequent flooding at this location which does not have an existing inlet pit to drain overland flow.

The capacity of the underlying trunk drainage is estimated to be equivalent to a 5% AEP event therefore it was anticipated that this option would provide good benefits for the 20% AEP with more limited benefits for other events.

The key hydraulic model results for FM6 – Abbott Street option are:

- As expected the reductions in flood extents for the 20% AEP shown in **Figure C15** are significant for the residential properties within the depression, however reductions in 5% AEP flood extent are negligible.
- This outcome is reflected in water level reductions, with up to 0.5 metres reductions experienced for the 20% AEP event, with comparatively minor reductions less than 0.1 metres experienced in the 5% AEP event.
- For the less frequent events; 1%, 0.5%, and 0.2% AEP, there are minor water level increases of up to 0.05 metres caused at Abbott Street depression. This is likely due to the fact that for these events the upstream drainage is already at capacity meaning that the inlet pits as an additional surcharge location, leading to minor water level increases.
- For the area downstream of Abbott Street, particularly Bardon Park and Coogee Oval there are minor water level increases of up to 0.02 metres (peaks of 0.03 metres for Bardon Park in the 5% AEP). These minor areas of increase are assumed to be caused by the additional flow entering the trunk drainage line at the additional inlet pits meaning less flow is able to enter the drainage further downstream. Nevertheless the water level increases of up to 0.02 metres are considered relatively negligible and are mostly restricted to public open space so are not seen as a particular concern.
- For the 5% AEP event there is a small area of water level increases of less than 0.02 metres in the upper dolphin flowpath. It is possible these impacts are caused by increased flows in the trunk drainage line downstream leading to minor reductions in flow through the Dolphin Street trunk drainage line. Nevertheless the water level impacts are considered negligible.

10.3 Option FM7 – Bardon Park

Option FM7 proposes earthworks be conducted within Bardon Park, flooding location 12 as outlined in **Section 4.5**, to increase the flood storage within the park in turn reducing flows in commercial and residential areas downstream. The earthworks include excavation of a volume of cut of approximately 5,200 m^3 and construction of an overflow bund to elevate the level that floodwaters discharge from the site.

There are no inlet pits within Bardon Park meaning that the overland flow cannot enter the trunk drainage network. However preliminary modelling found that as the trunk drainage line has a capacity equivalent to the 5% AEP event then there is negligible advantages to adding inlet pits at Bardon Park.

Under existing conditions there is negligible overtopping of Bream Street downstream for the 20% AEP event, due to the capacity of the trunk drainage line the volume of overland flow in Bardon Park is not significant. Therefore the objective is to reduce flows across Bream Street downstream for the less frequent flood events, the 5%, 1%, 0.5% and 0.2% AEP events.

The key hydraulic model results for FM7 – Bardon Park option are:

- As there is no overtopping of Bream Street in the 20% AEP there are no impacts off-site, there is a small area of water level increases in the upper dolphin flowpath but these are considered unrealistic minor model instabilities.
- There are significant areas of water level reduction downstream of Bardon Park for all other events including Coogee Tennis Club and Coogee Bowling Club, Brook Street, Coogee Oval and surrounds and the Coogee Promenade. Water level reductions vary from 0.1 metres in the 1% AEP to 0.02 metres in the 5% and 0.2% AEP events.

- There are minor water level increases of less than 0.02 metres upstream at the Abbott Street depression for the 5% AEP event. The cause of these increases is not clear and it is possibly model instability nevertheless the water level impacts are considered negligible.

10.4 Option FM11 – Coogee Oval

Option FM11 proposes increasing the trunk drainage capacity at the Coogee Oval (flooding location 16 in **Section 4.5**) on the downstream end of the Coogee Bay catchment. The intent is to provide additional discharge capacity in the hope this will alleviate flooding for a significant portion of the floodplain upstream.

There are three trunk drainage lines that discharge to one large culvert conveying flow under Coogee promenade and beach to discharge to the sea. This network was calculated to have a capacity equivalent to a 5% AEP event. In order to assess the impacts of a significantly increased capacity all of these stormwater drainage lines were duplicated with 5 additional inlet pits for the Coogee Oval.

The key hydraulic model results for FM11 – Coogee Oval option are:

- There are relatively negligible impacts for the 20% AEP event as the existing trunk drainage line had sufficient capacity for this event and the existing extent of flooding for this event was only minor. Water level increases in Coogee Tennis Club are assumed to be as a result from minor model instability and are not considered realistic.
- The modelling showed significant water level reductions for Coogee Oval for all other events; 0.45 metres in the 5% AEP, 0.7 metres in the 1% AEP, 0.4 metres in the 0.5% AEP, and 0.15 metres for the 0.2% AEP. The extent of water level reductions includes commercial properties to the south as well as the perimeter roads around the oval; Dolphin Street, Brook Street, Alfreda Street, and Arden Street.
- Water level impacts do not extend further upstream than Brook Street with any impacts shown further upstream assumed to be associated with model instability. This lack of impact upstream shows that though the capacity of trunk drainage downstream may be improved it does not influence the capacity issues further upstream. This confirms that the entire trunk drainage system is at capacity and suggests that major drainage upgrades would be required along the entire length to provide flood improvements across the entire floodplain.

11 Economic Assessment of Options

11.1 Preliminary Costing of Options

11.1.1 Flood Modification Options

Preliminary cost estimates have been prepared for the flood modification measures (**Table 11-1**), being those options that allow for an economic assessment via consideration of the cost of implementation and the associated reduction in flood damages. For other measures, approximate cost estimates were made for the purpose of comparison in the multi-criteria assessments detailed in **Section 12**.

Table 11-1 **Cost Estimates for Flood Modification Measures**

Option No.	Description	Capital Cost (excl. GST)	Ongoing (Annual) Costs (excl. GST)
FM1	Upper Dolphin Drainage Upgrades	$266,900	$2,000
FM6	Abbott Street Drainage Upgrades	$60,700	$400
FM7	Bardon Park Basin	$813,300	$2,000
FM10	Brook Street Detailed Assessment	$40,000	$0
FM11	Coogee Oval Drainage Upgrade	$3,638,300	$4,450
FM16	Rainbow Street Detailed Assessment	$40,000	$0

Prior to a measure proceeding, it is recommended that in addition to detailed analysis and design of the measure, that these costs be revised prior to budget allocation to allow for a more accurate assessment of the overall cost. Detailed rates and quantities would also be required at the detailed design phase. A capital cost breakdown of the flood modification measures is provided in **Appendix E**.

For calculation of construction costs for flood modification options a conservatively a contingency of 50% was adopted. However it should be noted that assumptions relating to unforeseen additional construction costs were not accounted for in cost estimates. An example of this is for the excavation works proposed for the Bardon Park basin, it was assumed that excavated soils from the site would have no contamination issues requiring treatment before disposal. Similarly it is assumed that no Acid Sulfate Soils (ASS) would be encountered in excavation works. Construction risks such as the two examples provided could significantly alter the capital costs associated with any of the above options. For ongoing annual costs the following assumptions were made:

- A maintenance cost of $200 / year has been assumed for each stormwater inlet pit;
- A maintenance cost of $10 / linear metre / year has been assumed for drainage pipes and culverts;
- As the Bardon Park basin does not involve any changes to drainage there is assumed to be no stormwater maintenance costs related to this option similarly as the land is currently owned by Council there are not anticipated to be any significant additional costs associated maintenance of the park. A nominal $2,000 / year has been assumed.

11.1.2 Property Modification Options

The tangible capital and ongoing costs of updating the current Council policies and plans to incorporate emergency response development controls (PM5) is difficult to determine. Similarly it is difficult to know the tangible capital and ongoing costs of updating S149 certificates and flood reports for developers (PM6). For the purposes of this assessment costs have been assumed to be negligible in comparison to other options.

11.1.3 Emergency Response Modification Options

The costs associated with the establishment of all six emergency response modification measures have been based on the following assumptions:

- For community programs such as those proposed in EM1, EM2 and EM5 a cost of $30,000 has been assumed. With the number of properties in the study area at just over 3,000, this equates to a cost of $100 / property for awareness programs. On-going costs of these programs has been assumed to be a quarter of this initial capital cost, $7,500 annually.
- For signage in EM3 a unit cost of $1,500 per sign has been assumed, with two signs at each location (for each direction of traffic) and 9 locations in total. On-going maintenance has been assumed to be $300 per sign annually.
- The establishment of dedicated flood warning systems and evacuation procedures for EM4 and EM6 has been assumed to be $60,000, with an on-going cost of $10,000 per annum.

A summary of capital and on-going costs for each of the emergency management modifications has been included in **Table 11-2**.

Table 11-2 **Cost Estimates for Emergency Response Modifications Measures**

Option No.	Description	Capital Cost (excl. GST)	Ongoing (Annual) Costs (excl. GST)
EM1	Public Awareness and Education	$30,000	$7,500
EM2	School Education Program	$30,000	$7,500
EM3	Flood Markers and Signage	$27,000	$5,400
EM4	Local Flood Warning System	$60,000	$10,000
EM5	Localised Evacuation Procedures	$30,000	$7,500
EM6	Local Flood Response Plan: Rainbow Street Locality	$60,000	$10,000

11.2 Damages Assessment

An assessment of damages for the existing condition was presented in **Section 5**. 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 reductions in properties affected by overground and overfloor flooding, total damages and AAD are presented in **Table 11-3**. Negative values in **Table 11-3** represent increases from the existing scenario.

It is assumed that emergency management modifications will not provide a reduction in flood damages.

Table 11-3 **Reduction in Damages Associated with Each Option**

	Properties with Overfloor Flooding Removed	Properties with Overground Flooding Removed	Total Damage Reduction ($)	AAD Reduction ($)
FM1 - Upper Dolphin Drainage Upgrade				
20% AEP event	1	25	$145,511	$21,827
5% AEP event	2	9	$154,201	$22,478
1% AEP event	2	4	$178,271	$6,649
0.5% AEP event	2	2	$69,325	$619
0.2% AEP event	0	0	-$4,421	$97
Total				**$51,670**
FM6 - Abbott Street Drainage Upgrade				
20% AEP event	0	8	$17,077	$2,562
5% AEP event	0	1	-$35,025	-$1,346
1% AEP event	0	0	-$18,569	-$1,072
0.5% AEP event	0	-1	-$22,255	-$102

	Properties with Overfloor Flooding Removed	Properties with Overground Flooding Removed	Total Damage Reduction ($)	AAD Reduction ($)
0.2% AEP event	0	0	-$12,243	-$52
Total				**-$10**
FM7 - Bardon Park Detention Basin				
20% AEP event	0	2	-$1,265	-$190
5% AEP event	1	1	$37,424	$2,712
1% AEP event	0	0	$128,659	$3,322
0.5% AEP event	3	-1	$133,962	$657
0.2% AEP event	0	-1	$5,844	$210
Total				**$6,711**
FM11 - Coogee Oval Drainage Upgrade				
20% AEP event	0	1	$2,484	$373
5% AEP event	2	4	$98,578	$7,580
1% AEP event	1	6	$127,275	$4,517
0.5% AEP event	3	3	$171,035	$746
0.2% AEP event	1	3	$80,090	$377
Total				**$13,593**

FM1 - Upper Dolphin Drainage Upgrade

For the Upper Dolphin option the reductions in damages are spread relatively evenly between garden damage (for example in the 20% AEP there are 25 properties with garden damage removed) and structural damage (mostly minor overfloor flooding reductions, with the exception of Courland Street depression where a property has reduced overfloor flooding of 0.3 – 0.7 metres).

The reduced benefits of the option for the less frequent events such as the 0.5% and 0.2% AEP is reflected in the damage outcomes where total damage reductions are less for these events. This is a result of the fact that the pipe only convey a smaller portion of the flood flows in the larger flood event.

FM6 - Abbott Street Drainage Upgrade

The Abbott Street drainage upgrade option provides modest reductions in damages for the 20% AEP through garden damage being removed for 8 properties. However for all other events, garden damage improvements are negligible (maximum of 1 property with garden damage removed for the 5% AEP).

For the 5%, 1%, 0.5%, and 0.2% AEP flood events the minor water level increases discussed in **Section 10.2** result in minor increases in structural damage across a large number of properties through very minor increases in overfloor flooding (an average increase of less than 0.01 metres). These increases in structural damage counteract the garden damager improvements for the 20% AEP resulting in a $10 increase in AAD for this option.

FM7 - Bardon Park Detention Basin

The Bardon Park basin option has negligible impact on flood damages for the 20% AEP event as discussed in **Section 10.3** it does not improve flood behaviour for any private properties. There are relatively negligible improvements in garden damage for any events for this option as it does not significantly impact flood extents. However there are minor reductions in structural damage for all events greater than the 5% AEP event across a large number of properties through very minor increases in overfloor flooding (an average increase of less than 0.01 metres).

FM11 - Coogee Oval Drainage Upgrade

Reflecting the flood behaviour discussed in **Section 10.4** Coogee Oval upgrades have negligible impacts on damages for the 20% AEP event. For all other flood events the upgrades provide minor reductions in garden damage (with a maximum of 6 properties with garden damage removed in the 1% AEP event). It is the reduction in structural damage that provides the greatest benefit in these events with overfloor flooding reduced for a number of commercial properties in the vicinity of the oval.

11.3 Benefit to Cost Ratio of Options

The economic evaluation of each modelled measure was assessed by considering the reduction in the amount of flood damages incurred for the design events and by then comparing this value with the cost of implementing the measure.

Table 11-4 summarises the results of the economic assessment of each of the flood management options. The indicator adopted to rank these measures on economic merit is the benefit-cost ratio (B/C), which is based on the net present worth (NPW) of the benefits (reduction in AAD summarised in **Section 11.2**) and the costs (capital and ongoing summarised in **Section 11.1**), 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 is greater than 1 the economic benefits are greater than the cost of implementing the measure;

> Where the benefit-cost is less than 1 but greater than 0, 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, there is no economic benefit from implementing the measure;

> Where the benefit-cost is less than zero, there is a negative economic impact of implementing the measure.

Table 11-4 **Summary of Economic Assessment of Flood Management Options**

Option ID	Option Description	NPW of Reduction in AAD	NPW of Cost of Implementation	B/C Ratio	Economic Ranking
FM1	Upper Dolphin	$714,327	$294,501	2.43	1
FM6	Abbott Street	-$138	$66,220	0.00	4
FM7	Bardon Park Basin	$92,617	$840,901	0.11	2
FM11	Coogee Oval	$187,594	$3,699,713	0.05	3

The outcome of the economic assessment of the flood modification measures is that:

> Option FM1 has the highest NPW reduction in AAD and the second lowest cost of implementation giving it the best BCR at 2.43;

> Option FM2 has a negligible economic benefit cost ratio due to the negligible impact on AAD, and consequently falls last in the rankings;

> Option FM3 has a moderate NPW with respect to reduction in AAD with the cost of implementation significantly greater giving it a BCR of 0.11 and ranked second of the four options economically;

> Option FM4 has significant NPW reduction in AAD but excessive capital costs of construction give it an economic ranking of third with a BCR of 0.05.

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. The multi criteria analysis (**Section 12**) incorporates some of these non-quantifiable impacts into the decision making process.

As all the emergency response modifications have no tangible benefits (damages reductions) associated they all have a Benefit Cost Ratio of 0.00.

12 Multi-Criteria Assessment

A multi-criteria matrix assessment approach was adopted for the comparative assessment of all options identified using a similar approach to that recommended in the *Floodplain Development Manual* (NSW Government, 2005). This approach to assessing the merits of various options uses a subjective scoring system. The principle merits of such a system are that it allows comparisons to be made between alternatives using a common index. In addition, it makes the assessment of alternatives "transparent" (i.e. all important factors are included in the analysis).

However, this approach does not provide an absolute "right" answer as to what should be included in the Plan and what should be omitted. Rather, it provides a method by which stakeholders can re-examine options and, if necessary, debate the relative scoring assigned.

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring simple a system was developed for each criterion as shown in.

12.1 Scoring System

A scoring system was devised to subjectively rank each option against a range of criteria given the background information on the nature of the catchment and floodplain. The scoring is based on a triple bottom line approach, incorporating economic, social and environmental criterion. The criterion and scoring system adopted includes:

Economic	Benefit cost ratio
	Capital and operating costs
	Reduction in risk to property
	Feasibility
Social	Reduction in risk to life in PMF
	Reduction in risk to life in 1% AEP
	Reduction in Frequency in Flooding
	Compatible with policies and plans
Environmental	Impact on cultural heritage sites
	Fauna / Flora impacts
	Acid sulfate soils

The scoring system summary is provided in **Table 12-1**.

12.2 Options Assessment Outcomes

The assignment of a score for each criterion for all flood modification, property modification, and emergency response modification options is shown in its entirety in the matrices presented in **Table 12-2** and **Table 12-3** respectively. The total score of each option was calculated by equally weighting each criteria and summing the total.

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 rankings have been separated for each of the three modifications types.

The rankings are proposed as the basis for selecting management options for inclusion in the Plan, and for prioritising their implementation as summarised in **Section 12.3**. For flood modification options the top ranked option is the upper dolphin drainage upgrades. Bardon Park basin is the second ranked option followed by Abbott Street drainage upgrades in third and Coogee Oval drainage upgrades the fourth ranked option.

Table 12-1 **Multi-Criteria Assessment – Scoring System**

Category	Criterion	Description of Criterion Assessment	Score				
			-2	-1	0	1	2
Economic	Benefit Cost Ratio	The cost effectiveness of the scheme, i.e. the tangible return on investment	0 to 0.1	0.1 to 1	1	1 to 1.5	>1.5
	Capital Costs	Consideration of the initial capital costs to Council	Extreme	High	Medium	Low	Very Low
			>$2 million	$500,000 - $2 million	$200,000 - $500,000	$100,000 - $200,000	$10,000 - $200,000
	Reduction in Risk to Property	Based on reduction in AAD, it establishes the tangible benefit of an option	Major increase in AAD (>$10,000)	Slight increase in AAD (<$10,000)	No Improvement	Slight decrease in AAD (<$10,000)	Major decrease in AAD ($>10,000)
	Feasibility	Establishes the feasibility of options based on constructability, and bureaucratic difficulties such as land acquisition and agreements with external agencies	There are a number of factors that pose a significant impact on the feasibility of the project	There is a factor that poses a potential impact on the feasibility of the project	May or may not be feasible	Likely to be feasible	Very likely to be feasible
Social	Reduction in Risk to Life in PMF	The impact on risk to life for the most extreme flood event, which is the design event for emergency response	Widespread or significant localised increase in risk to life	Localised or slight localised increase in risk to life	No change in risk to life	Localised or slight reduction of risk to life	Widespread or significant localised reduction of risk to life
	Reduction in Risk to Life in 1% AEP Event	The impact on risk to life for the flood planning event, which is commonly the design event for structural options	Widespread or significant localised increase in risk to life	Localised or slight increase in risk to life	No change in risk to life	Localised or slight reduction of risk to life	Widespread or significant localised reduction of risk to life
	Reduction in Frequency of Flooding	The impact of the risk management option on the frequency of flooding for public spaces but also private residences	Increases the frequency of flooding for a significant area	Increases the frequency of flooding for a minor area	No change to frequency of flooding	Reduces the frequency of flooding for a minor area	Reduces the frequency of flooding for a significant area
	Compatibility with Policies and Plans	The compatibility with Randwick City Council's policies and plans	Amendment required to either Council's current policies or plans	Slightly incompatible with Council's current policies or plans	Slightly incompatible with Council's current policies or plans, but could be grounds for reviewing policies or plans	Compatible with both Council's policies and plans	In line with and supported by Council's current policies or plans
Environment	Impact on Cultural Heritage sites	Likely impacts on any cultural heritage sites within the study area as identified in **Section 3.6**	High negative impact	Slight negative impact	No impact	N/A	N/A
	Impact on Fauna/Flora	Likely impacts on Threatened Ecological Communities and Threatened Species based on recorded locations identified in **Section 3.5**	High negative impact	Slight negative impact	No impact	Some benefit	Considerable benefit
	Disturbance of Acid Sulfate Soils	Likely disturbance of the range of classes of Acid Sulfate Soils, with emphasis on earthworks, particularly excavation.	Any work within Class 1 ASS area. Any excavation work within Class 2. Excavation >1m within Class 3. Excavation >2m within Class 4.	Surface works within Class 2 ASS. Excavation <1m or surface works within Class 3. Excavation <2m or surface works within Class 4.	Works not within areas identified as PASS	N/A	N/A

Table 12-2 **Multi Criteria Assessment Outcomes – Flood Modification Options and Property Modification Measures**

Category	Criterion	Description of Criterion Assessment	Flood Modification Options						Property Modification Options	
			FM1 - Upper Dolphin	FM6 - Abbott Street	FM7 - Bardon Park Basin	FM10 – Brook Street Detailed Assessment	FM11 - Coogee Oval	FM16 - Rainbow Street Detailed Assessment	PM5 – Emergency Response Development Controls	PM6 – Public Access to Flood Data
Economic	Benefit Cost Ratio	The cost effectiveness of the scheme, i.e. the tangible return on investment	2 (BCR = 2.43)	-2 (BCR = 0.00)	-1 (BCR = 0.11)	0 (Assumed for the study only, not for the works)	-2 (BCR = 0.05)	0 (Assumed for the study only, not for the works)	0 (Assumed that economic costs and benefits will be negligible, BCR = 1)	0 (Assumed that economic costs and benefits will be negligible, BCR = 1)
	Capital Costs	Consideration of the initial capital costs to Council	0 ($266,900)	2 ($60,700)	-1 ($813,300)	2 (Capital costs of assumed to be negligible)	-2 ($3,683,300)	2 (Capital costs of assumed to be negligible)	2 (Capital costs of assumed to be negligible)	2 (Capital costs of assumed to be negligible)
	Reduction in Risk to Property	Based on reduction in AAD, it establishes the tangible benefit of an option	2 ($51,670)	0 (-$10)	1 ($6,711)	0 (unknown outcome of study)	2 ($13,593)	0 (unknown outcome of study)	0 (No improvement to property risk)	0 (No improvement to property risk)
	Feasibility	Establishes the feasibility of options based on constructability, and bureaucratic difficulties such as land acquisition and agreements with external agencies	-1 (Majority of locations are in private backyards with limited access opportunities)	-1 (Locations are in private backyards with limited access opportunities)	1 (Reserve owned by Crown Lands, consent needed but no acquisition costs, impacts on existing use of reserve may be an issue)	2 (Feasibility of undertaking the study not the works recommended by the study)	-2 (Significant traffic issues assumed for Arden Street works, major social disruption for oval and beach promenade)	2 (Feasibility of undertaking the study not the works recommended by the study)	2 (Implementation of controls within DCP or other policy should be very feasible)	2 (Updating S149 certificates and flood reports should be very feasible)
Social	Reduction in Risk to Life in PMF	The impact on risk to life for the most extreme flood event, which is the design event for emergency response	0 (No major reductions in water level for PMF event)	0 (No major reductions in water level for PMF event)	0 (No major reductions in water level for PMF event)	0 (unknown outcome of study)	1 (Significant water level reductions for PMF event at Coogee Oval)	0 (unknown outcome of study)	2 (Could ensure safe evacuation of majority of residents)	1 (Expected reduction in risk to life through better development consideration of flooding)
	Reduction in Risk to Life in 1% AEP Event	The impact on risk to life for the flood planning event, which is commonly the design event for structural options	0 (Localised water level reductions for rear of properties)	0 (No major reductions in water level for PMF event)	1 (widespread minor water level reductions for area downstream)	0 (unknown outcome of study)	2 (Significant water level reductions for 1% event at Coogee Oval)	0 (unknown outcome of study)	1 (Expected reduction in risk to life through better responses of majority of residents)	1 (Expected reduction in risk to life through better development consideration of flooding)
	Reduction in Frequency of Flooding	The impact of the risk management option on the frequency of flooding for public spaces but also private residences	2 (Frequency is reduced at a number of locations from 20% AEP to between 1 – 5% AEP)	2 (Frequency is reduced from 20% AEP to between 1 – 5% AEP)	0 (No reduction in flood frequency at any locations)	0 (unknown outcome of study)	1 (20% AEP affectation on Coogee Oval reduced)	0 (unknown outcome of study)	0 (No impact)	0 (No impact)
	Compatibility with Policies and Plans	The compatibility with Randwick City Council's policies and plans	2 (In line and supported by Councils policies and plans)	2 (In line and supported by Councils policies and plans)	2 (In line and supported by Councils policies and plans)	2 (In line and supported by Councils policies and plans)	2 (In line and supported by Councils policies and plans)	2 (In line and supported by Councils policies and plans)	-1 (Would require revision of Council current policies)	0 (Very minor amendments to current approach required)
Environment	Impact on Cultural Heritage sites	Likely impacts on any cultural heritage sites within the study area as identified in **Section 3.6**	0 (No cultural heritage sites in vicinity)	0 (No cultural heritage sites in vicinity)	0 (No cultural heritage sites in vicinity)	0 (Undertaking the study will not impact on heritage sites)	0 (No cultural heritage sites in vicinity)	0 (Undertaking the study will not impact on heritage sites)	0 (No impact)	0 (No impact)
	Impact on Fauna/Flora	Likely impacts on Threatened Ecological Communities and Threatened Species based on recorded locations identified in **Section 3.5**	-1 (Some backyards are heavily vegetated with trees that may require removal)	0 (No flora or fauna constraints)	0 (Chance for rehabilitation and replanting of existing public park with water quality treatment potential, however loss of existing vegetation may be an issue)	0 (Undertaking the study will not impact on flora or fauna)	0 (No flora or fauna constraints)	0 (Undertaking the study will not impact on flora or fauna)	0 (No impact)	0 (No impact)
	Disturbance of Acid Sulfate Soils	Likely disturbance of the range of classes of Acid Sulfate Soils, with emphasis on earthworks, particularly excavation.	0 (Works not within areas identified as PASS)	0 (Works not within areas identified as PASS)	-1 (ASS Class 4 area)	0 (Undertaking the study will not impact on ASS)	-2 (Coastal and beach excavation of significant depth)	0 (Undertaking the study will not impact on ASS)	0 (No impact)	0 (No impact)
		Total Score	**6**	**2**	**2**	**6**	**0**	**6**	**6**	**6**
		Flood Modification Option Rank	**1**	**2**	**2**	**1**	**3**	**1**	**1**	**1**

Table 12-3 **Multi Criteria Assessment Outcomes – Emergency Response Modification Options**

Category	Criterion	Description of Criterion Assessment	Emergency Response Modification Options					
			EM1 - Public Awareness	EM2 - School Education	EM3 - Flood Signage	EM4 - Flood Warning Systems	EM5 - Localised Evacuation	EM6 - Rainbow Street Evacuation
Economic	Benefit Cost Ratio	The cost effectiveness of the scheme, i.e. the tangible return on investment	-2 (BCR = 0)	-2 (BCR = 0)	-2 (BCR = 0)	-2 (BCR = 0)	-2 (BCR = 0)	-2 (BCR = 0)
	Capital Costs	Consideration of the initial capital costs to Council	2 ($30,000)	2 ($30,000)	2 ($27,000)	2 ($60,000)	2 ($30,000)	2 ($60,000)
	Reduction in Risk to Property	Based on reduction in AAD, it establishes the tangible benefit of an option	0 (No improvement)	0 (No improvement)	0 (No improvement)	0 (No improvement)	0 (No improvement)	0 (No improvement)
	Feasibility	Establishes the feasibility of options based on constructability, and bureaucratic difficulties such as land acquisition and agreements with external agencies	1 (Likely to be feasible and relatively easy to implement)	0 (The feasibility of this scheme is unknown)	1 (Likely to be feasible and relatively easy to implement)	-1 (Implementation and broadcasting of warnings on this scale required is unknown)	1 (As majority of floodplain is 50 metres wide, seen as feasible)	1 (Timeline assessment from **Section 9.4.6** shows may be possible)
Social	Reduction in Risk to Life in PMF	The impact on risk to life for the most extreme flood event, which is the design event for emergency response	1 (Expected reduction in risk to life through better responses of majority of residents)	1 (Expected reduction in risk to life through better responses of majority of residents)	1 (Expected reduction in risk to life through better responses of majority of residents)	2 (Effective warning system could ensure safe evacuation of majority of residents)	2 (Could ensure safe evacuation of majority of residents)	2 (Could ensure safe evacuation of majority of residents)
	Reduction in Risk to Life in 1% AEP Event	The impact on risk to life for the flood planning event, which is commonly the design event for structural options	1 (Expected reduction in risk to life through better responses of majority of residents)	1 (Expected reduction in risk to life through better responses of majority of residents)	1 (Expected reduction in risk to life through better responses of majority of residents)	1 (Rate of rise is less significant in 1% AEP meaning warning less crucial)	1 (Rate of rise is less significant in 1% AEP meaning evacuation simpler in existing scenario)	1 (Extent of flooding in depression for 1% AEP not as significant so risk reduction less)
	Reduction in Frequency of Flooding	The impact of the risk management option on the frequency of flooding for public spaces but also private residences	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)
	Compatibility with Policies and Plans	The compatibility with Randwick City Council's policies and plans	2 (In line and supported by Councils policies and plans)	2 (In line and supported by Councils policies and plans)	2 (In line and supported by Councils policies and plans)	2 (In line and supported by Councils policies and plans)	2 (In line and supported by Councils policies and plans)	2 (In line and supported by Councils policies and plans)
Environment	Impact on Cultural Heritage sites	Likely impacts on any cultural heritage sites within the study area as identified in **Section 3.6**	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)
	Impact on Fauna/Flora	Likely impacts on Threatened Ecological Communities and Threatened Species based on recorded locations identified in **Section 3.5**	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)
	Disturbance of Acid Sulfate Soils	Likely disturbance of the range of classes of Acid Sulfate Soils, with emphasis on earthworks, particularly excavation.	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)	0 (No impact)
		Total Score	**5**	**4**	**5**	**4**	**6**	**6**
		Emergency Response Option Rank	**2**	**3**	**2**	**3**	**1**	**1**

12.3 Option Prioritisation and Ranking

Based on review of the analysis results, multi-criteria assessment and review of the feasibility of the options, the options have been ranked in order of preference. The MCA scores of the emergency management and flood modification options have been combined to produce an options implementation preferences list as shown in **Table 12-4**.

In addition, a priority has been assigned to each of the options to inform the implementation strategy (refer to **Section 13**). The following provides further detail on the priority categories:

- High – A total score in the multi-criteria matrix assessment of 6;
- Medium – A total score in the multi-criteria matrix assessment of 5; and
- Low – A total score in the multi-criteria matrix assessment of 4.
- Multi-criteria assessment scores lower than 4 are not strongly recommended for adoption and therefore have not been assigned an implementation priority.

The prioritisation of the various options is included in **Table 12-4**. Note that as discussed in **Section 9.1**, while not falling within the three modification categories, improved data collection is given a ranking of 1, and an implementation priority of high.

Table 12-4 **Summary of MCA Ranking and Options Implementation Preferences**

Option ID	Option Description	MCA Score	Overall MCA Rank	Implementation Priority
FM1	Upper Dolphin Drainage Upgrade	6	1	High
FM10	Brook Street Detailed Investigation	6	1	High
FM16	Rainbow Street Detailed Investigation	6	1	High
PM5	Emergency Response Development Controls	6	1	High
PM6	Public Access to Flood Data	6	1	High
EM5	Localised Evacuation	6	1	High
EM6	Rainbow Street Evacuation	6	1	High
-	Post Flood Data Collection	N/A	1	High
-	Pit and Pipe Maintenance	N/A	1	High
EM1	Public Awareness and Education	5	2	Medium
EM3	Flood Signage	5	2	Medium
EM2	School Education Program	4	3	Low
EM4	Flood Warning System	4	3	Low
FM6	Abbott Street Drainage Upgrade	2	4	N/A
FM7	Bardon Park Basin	2	4	N/A

13 Implementation Program

13.1 Overview

The floodplain management options outlined in **Section 12.3** that have a priority of high, medium or low are recommended for implementation as an outcome of the Floodplain Risk Management process. In order to achieve the implementation of relevant management actions, a program of implementation has been developed. This section attempts to achieve the objectives of the Floodplain Risk Management Plan component as outlined in **Section 1.2.2**.

The steps in progressing the floodplain risk management process from this point onwards are:

- Council will adopt the final Study and Plan and submit applications for funding assistance to relevant State and Commonwealth agencies, as appropriate;
- As funds become available from OEH, the Commonwealth, other state government agencies and/or from Council's own resources, recommended management actions will be implemented in accordance with the established priorities.
- Implementation will require in some cases more detailed cost benefit analysis, assessment and mitigation of environmental impacts and / or detailed design.

13.2 Implementation Planning Horizons

Table 13-1 provides the following information relevant to the implementation of the management actions:

- An estimate of capital and recurrent costs for each action (this may, in some cases, include existing staff and funding);
- The agency or organisation likely to be responsible for the action;
- The priority for implementation (high, medium or low) as an outcome of the FRMS (refer to **Section 12.3** for further details); and
- Performance measures to allow for the evaluation of the implementation of the FRMS&P.

13.3 NSW Floodplain Management Authority Project Assessment and Priority Ranking

This FRMS&P adopted a multi criteria assessment approach to better understand the reduction in flood risk and other benefits and impacts of various options. The recommendations of the FRMS&P were based on the outcomes of this assessment. Funding and implementation of these recommendations will not necessarily be undertaken in accordance with the ranking of the options.

The NSW Government's floodplain management grants support local government to manage flood risk. The funding for these grants comes from two programs, the NSW Floodplain Management Program and the Floodplain Risk Management Grants Scheme (jointly funded by the NSW Office of Emergency Management and the Commonwealth Government).

Applications for funding can be made by Council for the implementation of actions identified in a floodplain risk management plan. The information provided in the applications for each management action is used to rank the priority for funding of all actions across NSW.

The information presented in this FRMS&P can be used to complete the relevant applications for funding.

Table 13-1 **Implementation Program**

Option ID	Action	Indicative Costs		Potential Funding Sources / Responsibility	Priority	Performance Measure
		Capital	Recurrent			
FM1	Upper Dolphin Drainage Upgrade	$266,900	$2,000	Council / OEH	High	Drainage works are complete
EM5	Localised Evacuation	$30,000	$7,500	Council / SES	High	A localised evacuation strategy is prepared and implemented for Coogee Bay.
EM6	Rainbow Street Evacuation	$60,000	$10,000	Council / SES	High	A detailed local emergency response plan is in place for Rainbow Street.
PM5	Emergency Response Development Controls	-	-	Council / SES	High	Development controls for emergency response and critical infrastructure are adopted.
PM6	Public Access to Flood Data	-	-	Council / SES	High	S149 certificates and flood reports to developers are updated.
FM10	Brook Street Detailed Investigation	$40,000	-	Council	High	A more detailed analysis of flood modification options for Brook Street has been conducted.
FM16	Rainbow Street Detailed Investigation	$40,000	-	Council / SES	High	A more detailed analysis of flood modification options for Rainbow Street has been conducted.
EM1	Public Awareness and Education	$30,000	$7,500	Council / SES	Medium	Education program is undertaken and documented.
EM3	Flood Signage	$27,000	$5,400	Council / OEH	Medium	Signs are installed and maintained.
EM2	School Education Program	$30,000	$7,500	Council / SES	Low	Education program is undertaken and documented.
EM4	Flood Warning System	$60,000	$10,000	Council / OEH / SES	Low	Flood warning system if developed and implemented.
-	Post Flood Data Collection	-	$5,000	Council	Ongoing	Flood data (e.g. flood marks, damage and photos) collected during and following a flood event.
-	Pit and Pipe Maintenance	-	$50,000	Council	Ongoing	Review of current pit maintenance program and CCTV monitoring program
TOTAL		**$583,900**	**$104,900**			

14 Recommendations and Conclusions

This FRMS&P for the Coogee Bay catchment follows on from the Flood Study prepared in 2013. Further assessment of the existing flood behaviour has provided including a review of the capacity of the existing trunk drainage line and the key areas of flooding (**Section 4**). In addition, flood damages have been estimated to be in the order of $2.1 million in AAD for the properties examined (**Section 5**).

This knowledge of the flood hazard and flood behaviour, along with the information on the catchment characteristics (**Section 3**), existing emergency management arrangements (**Section 6**), current Flood Planning Levels (**Section 7**) and development controls relevant to flooding (**Section 8**) was used by the project team to develop a range of flood mitigation options for further assessment based on their relative costs and benefits (see **Sections 9 to 12**).

Finally, this report outlines an implementation program for the recommended flood risk management options as summarised in **Section 13**. This implementation plan summarises the associated costs, relative priorities and the responsible stakeholders involved in the future implementation of the options.

The review and analysis undertaken as part of this FRMS&P has identified that although there is a significant flood risk within the Coogee Bay floodplain, the potential for this flood behaviour to be managed through on ground works (such as drainage upgrades) is limited. This is due to the highly urbanised catchment, high density population and steep catchment (and hence fast flowing floodwaters).

However, due to the generally shallow nature of the flow and the relatively short period of flooding, flood risk can be effectively managed through the implementation of development controls, emergency response measures and minor works. The effective implementation of development controls will be of key importance in reducing the damages and risk to life associated with flooding into the future through the construction of flood compatible buildings and assets.

15 Qualifications

This report has been prepared by Cardno for Randwick City Council and as such should not be used by a third party without proper reference.

The investigation and modelling procedures adopted for this study follow industry standards and considerable care has been applied to the preparation of the results. However, model set-up and calibration depends on the quality of data available. The flow regime and the flow control structures are complicated and can only be represented by schematised model layouts.

Hence there will be a level of uncertainty in the results and this should be borne in mind in their application.

The report relies on the accuracy of the survey data and pit and pipe date provided.

Study results should not be used for purposes other than those for which they were prepared.

16 References

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