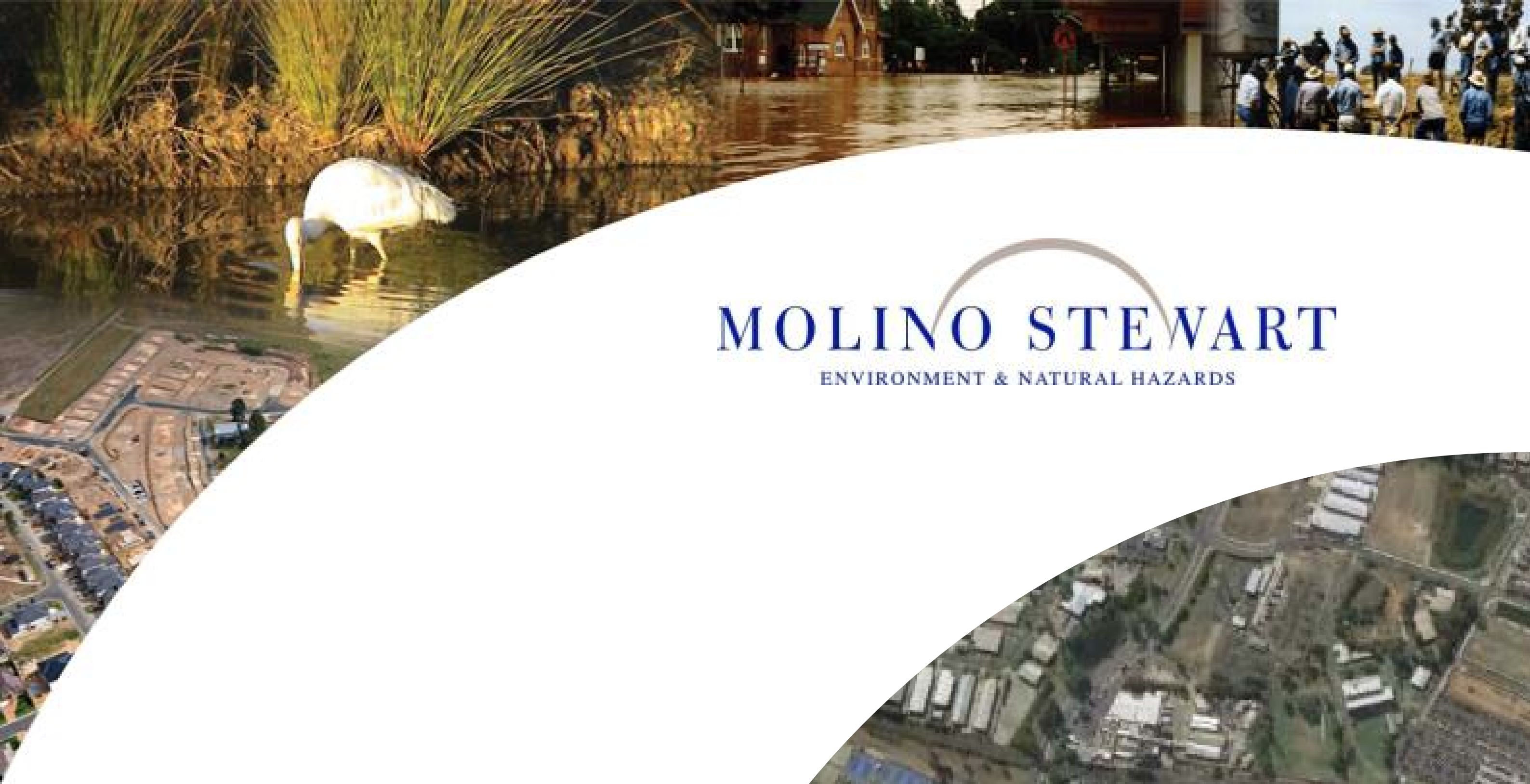

MOLINO STEWART

ENVIRONMENT & NATURAL HAZARDS

PENRITH

PENRITH CITY COUNCIL

Penrith CBD Floodplain Risk Management Study and Plan

Final Report

Penrith CBD Floodplain Risk Management Study and Plan

FINAL REPORT

for

Penrith City Council

by

Molino Stewart Pty Ltd

ACN 067 774 332

MARCH 2020

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MOLINO STEWART
ENVIRONMENT & NATURAL HAZARDS

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EXECUTIVE SUMMARY

Scope

This Floodplain Risk Management Study and Plan (FRMS&P) has been prepared by Molino Stewart for Penrith City Council with technical and financial assistance from the NSW Government's Floodplain Management Program. It has been prepared in accordance with the NSW Floodplain Development Manual.

The overall purpose of this FRMS&P is to find practical, affordable and acceptable means to manage the impacts of flooding on people, property and the environment. The FRMS&P has the following major objectives:

- To summarise flood behaviour in the catchment;
- To identify problem areas and to assess potential flood damages;
- To identify and evaluate potential risk mitigation interventions, or options;
- To develop a strategic plan for the implementation of the risk reduction measures identified.

This FRMS&P deals with local catchment flooding only, although it acknowledges the implications of mainstream flooding from the Hawkesbury-Nepean River, particularly in terms of emergency management.

Study Activities

The activities undertaken in this FRMS&P included:

- Provide a description of the catchment topography, environmental features, urban development, heritage values and social profile (Section 2)
- A review of the current urban planning instruments relating to flooding (Section 3);
- A review of the existing emergency management context (Section 4)
- A community and stakeholder consultation program to inform and obtain feedback on the study (Section 5);
- A review of the Penrith CBD Flood Study (Cardno, 2015), implementing a more accurate topographic survey (LiDAR survey undertaken in 2011), and updated stormwater system drawings (Section 6);
- A description of flood behaviour within the catchment in different design events up to the Probable Maximum Flood (PMF) (Section 7);
- As assessment of flood risks to property and people (Section 8);
- The identification and assessment of a portfolio of suitable flood risk reduction options, including measures of flood modification (i.e. to change flood behaviour), property modification (i.e. to reduce risk through changes to existing and future buildings), and response modification (i.e. to reduce risk through encouraging people to act more appropriately during floods) (Section 9);
- The Plan to guide the implementation, resourcing and maintenance of the flood risk reduction options identified in Section 9 (Section 10).

Flood Behaviour

The study area is affected by local flooding from within the catchment and by mainstream flooding from the Nepean River (Map 7, Vol. 2). Because the scope of this FRMS&P does not include mainstream flooding, flood behaviour was described in detail only for local catchment flooding.

The design flood events numerically modelled include the 20% Annual Exceedance Probability (AEP) event, the 5% AEP event, the 10% AEP event, the 2% AEP event, the 1% AEP event, the 0.5% AEP event and the Probable Maximum Flood (PMF). Each event other than the PMF was simulated with a 2 hour and a 9 hour rainfall duration. The PMF was simulated with rainfall durations of 15 minutes and 30 minutes because longer durations would not be able to generate sufficient discharge to exceed flooding caused by other events.

The flood model results show that in all design events, flood behaviour in the upper part of the catchment (i.e. upstream of Woodriff Street) is dominated by the steeper topography, which results in floodwaters concentrating in a relatively small number of overland flow paths. These run west, south west or north-west, and eventually merge to generate a larger flow path between Evan Street and Woodriff Street. Flood affectation in this upper sector of the catchment is generally limited to the properties locate along or adjacent to these flow paths. However, while flood extents are limited, flow velocities are higher than in the lower catchment.

Downstream of Woodriff Street the topographic gradient decreases significantly and floodwaters spread to affect larger areas, but with lower velocities and longer duration. A detailed description of local catchment food behaviour in the 20% AEP event, 1% AEP event and PMF is provided in Section 7.

In addition to flood extents, depth and velocity, which are provided in Maps 8 to 20 (Vol.2), flood behaviour was further described based on the hydraulic hazard (Maps 21 to 23, Vol. 2), hydraulic categories (Map 24, Vol. 2) and using the NSW State Emergency Service's Flood Emergency Response Planning Classification of Communities (DECC, 2007b) (Map 25, Vol. 2).

Flood Risks

Flood risks under current conditions were assessed for property and people. Risk to residential buildings was obtained through a damages assessment exercise undertaken according to the guidance provided by the Department of Planning, Infrastructure and Environment (DECC, 2007a). Risk to commercial buildings used state of the art stage-damage models published by the Flood Hazard Research Centre (FHRC, 2013) at Middlesex University in the UK. These stage-damage curves are based on field observations made in the UK between 2003 and 2005. As such, they provide a contemporary evaluation of the damage to buildings and building contents.

The assessment made assumptions supported by the best available literature to allow for indirect damages, damages to infrastructure, as well as social/intangible damages.

An economic analysis was then undertaken to discount to present day all the damages that would occur at different times in the future, using the NSW Treasury recommended rate of 7%. This exercise was undertaken to be able to compare flood damages with the cost of implementing and maintaining flood risk reduction works.

Risk to Buildings

The estimated building flood damages are summarised in Table 4 (residential properties) and

Table 5 (non-residential properties), and their spatial distribution is shown in Map 26 (Vol. 2) and Map 27 (Vol. 2). Distinctive features include:

- The Annual Average Damages (AAD) are about $3 million for residential properties and over $12 million for non-residential properties. AAD is a measure of the cost of flood damage that could be expected each year, on average, by the community. This excludes intangible damages such as risk to people or socio-cultural values;
- Total damages for non-residential properties are higher than residential properties, with the gap increasing in larger flood events. This is due to two main reasons: (a) the relatively high commercial and industrial floor surface area in the core of the CBD, particularly north west and south east of the intersection of High Street and Woodriff Street, where flood depth and velocity are the highest; and (b) the fact the commercial and industrial properties have generally floor levels closer to ground level than residential properties do, and as such get inundated more often.

In terms of building inundation, results show that 52 dwellings may experience above floor flooding in the 20% AEP event, with the number increasing to 164 in the 1% AEP event and 785 in the PMF. For non-residential buildings, only 17 are affected by above floor flooding in the 20% AEP event, 65 in the 1% AEP event and 199 in the PMF. It should be emphasized however that these figures are conservative as they do not account for the contribution of private stormwater systems to reduce the depth of stormwater runoff ponding next to buildings.

Risk to Infrastructure

Map 28 (Vol. 2) shows the location of critical infrastructure and vulnerable buildings across the CBD. These are distributed in the north-western part of the study area and in most instances are not affected in the 1% AEP event. The following critical buildings and infrastructure were identified:

- Penrith’s transmission electricity substation, in Museum Drive;
- Three Sydney Water wastewater pumping stations;
- Telstra’s telephone exchange, located at 90 Henry Street;
- The Nepean Hospital, in Derby Street east of Parker Street;
- The NSW Ambulance station at 668 High Street;
- The NSW Police Station located at 317 High Street;
- The NSW Fire Brigades station at 294 High Street;
- A total of 12 child care centres, five schools, one nursing home and seven disability services providers.

The extent to which each of the above buildings is flood affected is described in detail in Section 8.3.

Risk to Roads and Traffic

The frequency of road closures due to local flooding within the study areas was mapped by identifying locations where floodwaters are likely to become sufficiently deep or fast to block traffic, in each flood design event. Map 29 (Volume 2) shows the frequency with which the main roads within the study area are cut by local flooding. The associated table (Table 1, Vol. 2) shows that most are untrafficable for less than two hours with a few exceptions.

The frequency of road closure due to local flooding was further evaluated in the context of a regional evacuation from a flood caused by the Hawkesbury Nepean River. The following regional evacuation routes through the study area may be temporarily cut by local flooding:

- Mulgoa Road, south of the intersection with High Street would be cut by local flooding only in events greater than the 0.5% AEP for up to 1.5 hours;
- Jamison Road, west of Mulgoa Road may be cut in the 20% AEP event for up to 0.5 hours, in the 1% AEP for over 3 hours, and in the PMF for over 2 hours;
- The Northern Road (Parker Street) may have its south bound lanes flooded at three locations in relatively frequent events, however at least one of the three lanes remains open to traffic in events greater than the 0.5% AEP flood;
- Evan Street, from the Railway to High Street, may be cut at the intersection with Henry Street in the 5% AEP event for a duration of 0.5 hours, and in greater events for a duration of 1 hour;
- High Street, between Evan Street and Parker Street generally open to traffic in the 0.5% AEP event.

Risk to People

The analysis showed that the areas with the highest risk to people within the CBD are:

- broad areas in the lower part of the catchment which have their evacuation routes cut early and then can go underwater; and
- A few buildings affected by high velocity floodwaters in the upper catchment.

Flood Risk Reduction Measures

Flood Modification

Across the CBD 15 flood-prone areas were identified where clusters of assets are impacted by flooding. These locations were named “Hot Spots” and flood modification options were investigated for these. The following options were found to be worthwhile investigating in more detail:**Hot Spot 1 -** A series of culverts under Mulgoa Road would better manage flooding across its intersection with Jamison Road which is part of the regional flood evacuation route.

Hot Spot #2 - Installing more pipe capacity between Union Road and High Steet was found to offer significant economic advantages, having a benefit to cost ratio of 4.59.

Hot Spot #3: The model suggests increasing pipe capacity between Rodley Avenue and the Showground Stormwater Channel would reduce the frequency in which the lowest end of the residential part of the catchment is isolated by flooding. While the costs of this option would exceed its benefits in terms of damage to property, the reductions in risk to people and frequency of road inundation were deemed sufficient to recommend the option for more detailed analysis.

Hot Spot #5: The addition of a 600mm pipe from the low spot in the Belmore Street car would reduce the frequency with which the car park floods. While the option may be uneconomical in terms of damage to parked vehicles alone, its intangible benefits (e.g. reduced risk to people attempting to drive their cars away from the flooded areas) were deemed sufficient to recommend the option for further analysis.

Hot Spot #6: Modifying drainage upgrades proposed as part of two development proposals on the corner of Henry Street and Evan Street would reduce the frequency that this part of a regional flood evacuation route is cut.

Hot Spots #7 and #14: Nepean Square, K-Mart area and residential properties between Woodriff Street and Castlereagh Street were found to be problematic in terms of risk to people because several low rise houses are within high-risk low flood islands. As such, it was recommended that Councils considers upgrading the stormwater system between Castlereagh Street to Woodriff Street, and from Woodriff Street to Station Street as part of Council's long term planning strategy for future development.

Hot Spot #8: Flood modification options would not significantly change the frequency with which Parker Street could be cut. Should the southbound lanes become cut by local flooding during a regional evacuation, the NSW SES would need to temporarily provide contraflow traffic in one or two of the northbound lanes to keep traffic moving.

Hot Spot #9: The construction of a 6,200 m^3 detention basin within the park located at lot 135 Derby Street, north of Spence Park on the corner of Doonmore Street and Derby Street was found to significantly reduce downstream flooding and would have a benefit to cost ratio of 5.96. Implementation of this option may be constrained by the trees which are in the park.

Hot Spot #10: Some minor changes to drainage infrastructure near Penrith RSL to make better use of underutilised stormwater infrastructure were estimated to have a benefit to cost ratio of 22.68. .

Hot Spot #11: A pipe capacity upgrade from Rosedale Avenue to Stafford Street via Colless Street was found to have a benefit to cost ratio of 2.2.

Hot Spot #12: This risk of Council's main office basement carpark in Jane Street flooding could be reduced by replacing the existing manual flood gate to the car park entrance with an automated one, triggered by a water level detector.

Hot Spot #13: A preliminary analysis shows that above floor flooding of houses in John Tipping Grove may be reduced by increasing the capacity of the local pipe and the relevant culvert from John Tipping Grove under Mulgoa Road.

Hot Spot #15: The addition of more pipes along Jipp Street and Hand Avenue was estimated to have a benefit to cost ratio is 2.79, making the option economically worthwhile.

Property Modification

Existing Buildings

House raising or voluntary purchase were deemed unsuitable across the CBD due to the nature of the development and flood behaviour. As such property modification measures for existing buildings were assessed only when these could reduce risk to people.

Where hazardous flooding could enter a building, and evacuation to flood free ground cannot be achieved safely, the provision of a refuge above the reach of floodwaters in a structurally stable building may be a viable means of keeping people beyond the reach of floodwaters. Such provisions however cannot be mandated by Council and any decision to provide such a building modification measure to reduce flood risks would be entirely up to the property owner.

Future Buildings

Flood risks to future development can be managed through appropriate provisions in Council's planning instruments. This FRMS&P has undertaken a review of Penrith LEP 2010 and Penrith DCP 2014 and recommends changes to the use of flood planning maps, and the use of variable Flood Planning Levels to better target the risks and changes to development controls.

Response Modification

Penrith CBD may face flood emergencies arising by two types of flooding:

- Local overland flooding, which is addressed by this FRMS&P, and
- Mainstream flooding from the Nepean River, which in a PMF would affect the part of the CBD west of Castlereagh Street and Lawson Street (Map 7, Vol.2).

While mainstream flooding is not included in the scope of this FRMS&P, its implications in terms of emergency management and response modification are such that it needs to be considered in conjunction with local flooding. In this context, the following flood response modification options were assessed:

- A flood warning system for the CBD catchment;
- Appropriate response planning; and
- Raising the community awareness of flood risks.

A flood warning system for the CBD was deemed unsuitable due to the short time between the commencement of rainfall and the commencement of flooding.

In terms of response planning, the NSW SES 2012 Penrith City Local Flood Plan, which at the time this FRMS&P was undertaken was current, focuses only on mainstream flooding from the Nepean River and does not address local catchment flooding. The NSW SES has advised that the next edition of Penrith Local Flood Plan will address only local flooding including overland flooding. It is recommended that the outcomes of this study are incorporated into the new Local Flood Plan.

Using the guidance from the NSW SES, businesses and households can also develop their own flood emergency response plans which are specific to their own circumstances to reduce the direct and indirect impacts of flooding on them.

With regard to raising community awareness of flood risks, it is recommended that the following items are discussed with the NSW SES:

- Amendments to the format and wording of Section 10.7 Flood Planning Certificates, to ensure that flood risks are adequately communicated to property owners and purchasers;
- Encourage the development of household and business flood emergency response plans;
- Building leadership and community networks to enable flood preparedness;
- Provide flood related information in multiple languages.

Floodplain Risk Management Plan

The Floodplain Risk Management Plan provides guidance to Council for prioritising, implementing, resourcing and maintaining the recommended flood risk reduction options. The Plan is presented in Section 10 and summarised in Table 20.

The total capital cost of implementing the Plan is about $6.4M, including flood modification options having a benefit to cost ratio less than 1.0. These were included, despite the low benefit to cost ratio, because of their high social benefits. Overall, if all of the flood modification options are implemented, the Plan would yield damage savings of at least $22M, resulting in an overall benefit-cost ratio of about 3.4.

The Plan resourcing may entail contributions from Penrith City Council, NSW State Government (through DPIE grants), Commonwealth Government, private developers (i.e. Development Contribution Plans), property owners and occupiers of flood affected premises. It is envisaged that the Plan will be implemented progressively over a 5 to 10 year timeframe. The timing of the proposed works and measures will depend on the overall budgetary commitments of Council and the availability of funds from other sources.

PART A: CONTEXT

1 INTRODUCTION

1.1 FLOODPLAIN RISK MANAGEMENT PROCESS

The NSW Government's Flood Prone Land Policy and *Floodplain Development Manual* (NSW DPINR, 2005) are aimed at providing solutions to existing flood problems in developed areas and ensuring that new development is compatible with the flood hazard, not creating additional flooding problems in other areas and is undertaken using ecologically, economically and socially sustainable methods. Under the Policy, the management of flood prone land is the responsibility of Local Government. The NSW Government's Floodplain Management Program is administered by the Department of Planning, Industry and Environment (DPIE) and provides councils with technical and financial assistance to undertake flood and floodplain risk management studies, and for the implementation of works identified in those studies.

The primary objective of the NSW Government's Flood Prone Land Policy is to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods.

The implementation of the Flood Prone Land Policy generally culminates in the preparation and implementation of a Floodplain Risk Management Plan (FRMP) by Council, which is the ultimate objective of the current study. Community engagement is an important part of the process and this has been undertaken via Council's Floodplain Management Committee and public displays and questionnaires with the local community.

The steps in the floodplain management process are summarised in Figure 1. This report presents the Floodplain Risk Management Study and Plan (FRMS&P) for Penrith CBD.

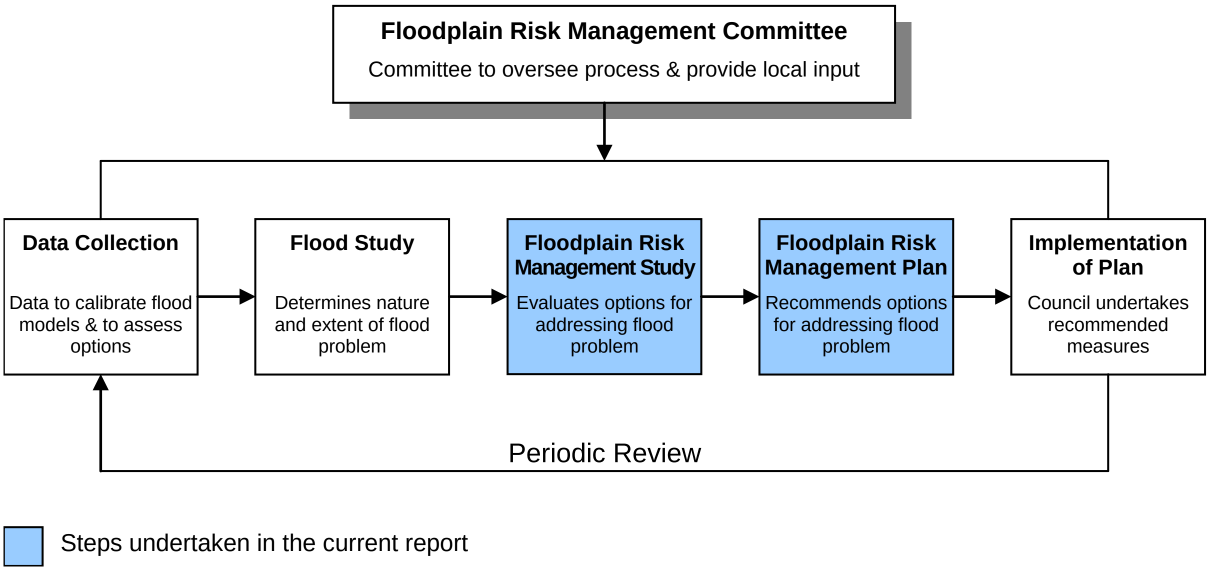

Figure 1. Floodplain risk management process in NSW (NSW DPINR, 2005)

1.2 SCOPE

Penrith City Council is responsible for local planning and land management in the Penrith CBD catchment, including the management of the flood prone land.

The overall purpose of this study is to find practical, affordable and acceptable means to manage the impacts of flooding on people, property and the environment.

The Penrith CBD FRMS&P has the following major objectives:

- To summarise flood behaviour in the catchment, drawing upon the most up to date flood studies;
- To identify problem areas and to assess potential flood damages in the study area;
- To identify and evaluate potential works, measures and restrictions aimed at reducing the social, environmental and economic impacts of flooding, addressing existing, future and continuing flood risk, over the full range of potential flood events and taking into account the potential impacts of climate change;
- To develop a strategic plan to manage existing, future and continuing flood risk, ensuring that the draft FRMP is fully integrated with Council's existing corporate, business and strategic plans, existing and proposed planning proposals, meets Council's obligations under the Local Government Act, 1993, and has the support of the local community;

1.3 OUTLINE OF THIS REPORT

This report is in two volumes.

Volume 1 includes 10 sections within four main parts:

- Part A: Context, including sections 1 to 5;
- Part B: Flood Behaviour and Impacts, including sections 6 to 8;
- Part C: Flood Risk Management Measures, including section 9;
- Part D: Floodplain Risk Management Plan (section 10).
- The overall content of each section is summarised below:
- Section 1 (this section) sets the background and the project scope;
- Section 2 provides a description of the geographic, socio-economic and environmental features of the catchment;
- Section 3 provides an overview of the existing planning and regulatory system related to flood risk management;
- Section 4 sets the emergency management context;
- Section 5 outlines the work that was done as part of this FRMS to engage with key stakeholders and the broader community;
- Section 6 summarises previous and existing flood studies and numerical models;
- Section 7 provides a summary of the flood behaviour within the study area, as described by the most recent flood studies;
- Section 8 includes an assessment of flood risks to property and people. This an assessment of flood damages to residential and non-residential buildings;
- Section 9 presents the proposed flood risk reduction measures. This includes measures of flood modification property modification and response modification;
- Section 10 provides a plan for the implementation of the preferred options.

Volume 2 of the report contains A3 maps at a suitable scale to be read in conjunction with Volume 1.

1.4 FLOOD PROBABILITY TERMINOLOGY

Appendix A provides a comprehensive glossary of technical terms and abbreviations used in this document. However, throughout the document reference is made to the magnitude of floods by reference to their probability of occurrence. This can be expressed in several different ways.

A common way of describing flood probability is in terms of its annual exceedance probability (AEP). This is the chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m3/s has an AEP of 5%, it means that there is a 5% chance of a 500 m^3/s or larger events occurring in any one year. The 1% AEP flood has a 1 in 100 chance of occurring in any year..

Throughout this document flood probability will be referred to in terms of AEP..

1.5 STUDY AREA

The Penrith Central Business District (CBD) overland flow catchment lies in an area generally bounded to the north by the Main Western Rail Line, to the east by Parker St/ The Northern Road, to the south by Jamison Road and to the west by Mulgoa Road (Map 1, Vol. 2).

2 CATCHMENT CHARACTERISTICS

2.1 CATCHMENT DESCRIPTION

The CBD catchment contains the study area entirely (Map 2, Vol.2). It mostly drains from east to west towards Peach Tree Creek which itself is a minor tributary of the nearby Nepean River. With the exception of the area west of Mulgoa Road, which is not within the study area, the catchment is highly urbanised with an extensive, though undersized, pit and pipe system and some small open channels.

The eastern end of the catchment tends to be dominated by low density residential development. The northern part of the catchment is mostly commercial development which forms the Penrith CBD. The western end of the catchment, east of Mulgoa Road, incudes predominantly medium density residential development. This area also features Nepean Square and large recreational facilities including the Penrith Showground and Penrith Park with the associated Centrebet Stadium and Howell Oval. The western parts of the catchment are also part of the Nepean River floodplain.

2.2 TOPOGRAPHY

The topography of the study area is generally mild, with an overall consistent gradient dropping from south-east (highest point is about 63m AHD) to north west (lowest point is about 24m AHD) (Map 3, Vol.2).

2.3 ENVIRONMENT

It is important to understand the environmental assets within a catchment because these may:

- be adversely impacted by flooding;
- affect flood behaviour by impeding flood flows;
- be a constraint to implementing some flood mitigation options;
- be enhanced when implementing some flood mitigation options.

Comprehensive clearing of the catchment for residential, commercial and industrial development has resulted in a dramatic reduction in natural areas. Map 4 (Vol.2) shows the areas of remnant vegetation within the catchment.

The remnant vegetation which does occur within the catchment is:

- Forest Red Gum- Rough-barked Apple grassy woodland on alluvial flats of the Cumberland Plain, Sydney Bioregion (Plant Community Type (PCT) 835);
- Grey Box - Forest Red Gum grassy woodland on flats of the Cumberland Plain, Sydney Basin Bioregion (PCT 849).

The first of these vegetation communities forms part of the River-Flat Eucalypt Forest Endangered Ecological Community (EEC) listed under the *NSW Biodiversity Conservation (BC) Act, 2016*. The second forms part of the Cumberland Plain Woodland which is listed as Critically Endangered under the NSW BC Act. .

The Cumberland Plain Woodland areas may also satisfy the Commonwealth Cumberland Plain Shale Woodlands and Shale-Gravel Transition Forest Critically Endangered Ecological Community (CEEC), depending on the condition of the vegetation. If so, it is protected under the Commonwealth *Environment Protection Biodiversity Conservation Act, 1999*.

Cumberland Plain Woodland and Riverflat Forest provide habitat for a variety of flora and fauna such as honeyeaters, cockatoos, owls and bats. Threatened fauna species which have been reported within the catchment are the Eastern Bentwing-bat (*Miniopterus schreibersii oceanensis*) and the Swift Parrot (*Lathamus discolour)* (Map 5, Vol.2). The

Eastern Bent-wing bat is listed as vulnerable in NSW and the Swift Parrot is listed as an endangered species in NSW and is listed as critically endangered under the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (the EPBC Act). No threatened flora species occur within the catchment (Map 5, Vol.2)

Threats to their continued survival include loss, fragmentation and degradation of habitat due to clearing for urban development and infrastructure, stormwater pollution and urban runoff, weed invasion by exotic species, altered fire regimes, as well as the impacts of cats, dogs and cars.

Opportunities to enhance the environment include consolidating habitat links, managing vegetation in areas of high conservation significance, revegetation and regeneration, and naturalising channels. These positive environmental outcomes, however, are not in and of themselves eligible for funding under the NSW Floodplain Management Program, unless a benefit in terms of flood risk management can be demonstrated.

2.4 URBAN DEVELOPMENT

Like many parts of Sydney, Penrith is undergoing urban renewal and consolidation. Sydney's Metropolitan Plan has identified Penrith as a Regional City which is targeted to have a population exceeding 250,000 by 2031.

In response to this, Penrith City Council in, collaboration with the Penrith Business Alliance, established Penrith Progression as an initiative to transform the Penrith CBD.

A detailed action plan has been developed in consultation with the community and other stakeholders. This plan has the potential to bring 10,000 more jobs and 5,000 dwellings into the city centre.

This is discussed in more detail in Section 3.5.

2.5 HERITAGE VALUES

A number of items of heritage significance are located in the catchment. Opportunities to protect these items from the adverse effects of flooding are considered in this FRMS&P. Any proposed floodplain risk management measures need to be sympathetic to the heritage values.

Clause 5.10 of Penrith LEP 2010 stipulates that development consent is required for a range of proposed activities including demolishing, moving or altering the exterior of a heritage item, Aboriginal object or item within a heritage conservation area. The consent authority must, before granting consent under this clause in respect of a heritage item or heritage conservation area, consider the effect of the proposed development on the heritage significance of the item or area concerned.

Regarding aboriginal heritage sites, an AHIMS search was undertaken through the NSW Office of Environment and Heritage website. The search indicated that there were no sites of aboriginal significance within the Penrith CBD.

2.6 SOCIAL PROFILE

According to the 2016 census (http://www.censusdata.abs.gov.au), the population of the Australia Bureau of Statistics (ABS)'s statistical unit corresponding to Penrith CBD is 5,586, with a density of 19.7 persons per hectare.

2.6.1 Age

Penrith Local Government Area (LGA) has a population of age similar to the NSW average, with 18.2% aged between 0 and 18, and 16.6% aged 65 years and over, compared to 18.5% and 16.3% respectively for NSW.

2.6.2 Education

Education level is significantly below the NSW average, with 15.1% of the population who have completed university, and 42.5% who have not progressed beyond year 11. These figures for NSW are respectively 23.4% and 23.2%.

2.6.3 Culturally and Linguistically Diverse Communities (CALD)

In terms of language, 19.3% of the residents do not speak English at home, while in NSW this figure is significantly higher at 26.5%.

In addition to this, 73% of the Penrith CBD population were born in Australia, compared to 65.5% for NSW.

These figures indicate that the cultural, ethnic and linguistic diversity in Penrith LGA is below the NSW average. Nevertheless, its diversity needs to be taken into consideration when communicating about flood risks and mitigation options.

2.6.4 Employment

The unemployment rate in Penrith CBD is at 9% for the whole population, and 18.6% for people aged 15 to 24. In NSW, the overall unemployment rate is lower at 6.3%. In addition to this, 31.5% of the Penrith CBD population has a part time job, compared to 29.7% in NSW. These statistics suggest that residents in the study area may have less capacity to recover from the financial impacts of flooding.

2.6.5 Dwellings

Almost all dwellings in Penrith CBD are occupied (91% vs 90.1% in NSW), and detached houses make up 31.4% of the total number of dwellings (vs 66.4% in NSW).

The most common house design features three bedrooms (49.5% vs 37.3% in NSW), followed by a dwelling with up to two bedrooms (43.5%).

In terms of tenure, figures are quite different from the NSW average, with 29% owners (64.5% in NSW) and 45.6% renters (31.8% in NSW). The low home ownership rate means that residents will have less autonomy to modify their properties to reduce risks to themselves and their assets. It also makes it more difficult for Council to communicate in writing directly with residents about flood issues.

In addition to this, 66.7% of dwellings have access to the internet, whereas in NSW this figure is higher at over 80%. This will be an important consideration in communication in relation to both community education and flood warning.

Table 1. Non-indigenous heritage items within the 100 year floodplain (Penrith LEP 2010 Schedule 5)

Item no.	Item Name	Address
I692	Penrith School of Arts (former)	7 Castlereagh Street Lots 9–11, Section 1, DP 1582
I853	Penrith Cottage	169 Cox Avenue Lot A, DP 984462
I697	Penrith Presbyterian manse (former)	154 Derby Street Lot 4, DP 25106
I698	Penrith Victorian cottage	163 Derby Street Lot Y, DP 389668
I699	Penrith Victorian cottage	194 Derby Street Lot 1, DP 2363
I177	Penrith Infants Department (1884 building)	57 Henry Street Lot 1, DP 724160
I179	Penrith Methodist Church (former)	74 Henry Street Lot 22, DP 586469
I698	Penrith TAFE Building	115–119 Henry Street Lot 111, DP 1028320
I189	Penrith Penrith Council Chambers (former)	129–133 Henry Street Lot 1123, DP 1106979
I854	Penrith “Kelvin Brae”, Federation house	142 High Street Lot 1, DP 1127355
I210	Penrith Public School and palm trees	194 High Street Lot 2, DP 502608; Lots 2–4, Section 19, DP 2296
I212	Penrith Victorian terrace and Interwar shop	219–221 High Street Lot 2, DP 224062
I209	St Aubyn’s Terrace	255–265 High Street Lot 3, DP 955837; Lot 4, DP 972
I206	St Stephen’s Anglican Church, Hall and Cemetery	258–280 High Street Lots 101 and 102, DP 597910
I723	Penrith Cottage	Cottage 288 High Street Lot 1, Section 3, DP 1582
I711	Brick villa	318–320 High Street, Lot 4, Section 2, DP 1582
I688	Memorials and lamp stand, St Nicholas of Myra Catholic Church	332–338 High Street, Lot 1, DP 782278
I201	“Cram Place”, coach house, well, pump and cast iron fence	338–340 High Street, Lot 11, DP 1013730
I713	Bank of NSW (former)	354–360 High Street, Lot 10, SP 51611
I196	Australian Arms Hotel	359 High Street, Lot 2, DP 513015
I714	High Street shops	361–365 High Street, Lots 2 and 4, SP 1380
I715	High Street shop	371–375 High Street, Lot 13, DP 616937
I716	High Street shop	377–381 High Street, Lot 12, DP 616937
I717	High Street shop	383 High Street, Lot 11, DP 616937
I718	High Street shop	387–389 High Street, Lot 1, DP 774671
I719	High Street shop	391–393 High Street, Lots 23 and 24, DP 236390
I200	Memory Park	400 High Street, Lot 1, DP 198339
I197	Fulton’s Store (former)	413–423 High Street, Lot B, DP 322318
I720	High Street shop	425–427 High Street, Lot A, DP 322318
I855	High Street shop	437 High Street, Lot 2, DP 82325
I721	High Street shop	449–451 High Street, Lot 12, DP 599349
I198	High Street shop	538–540 High Street, Lot 1, DP 779550
I722	High Street shop	542 High Street, Lot 2, DP 154388
I199	High Street shop	550–556 High Street, Lot B, DP 152524

Item no.	Item Name	Address
I690	Red Cow Hotel	569–595 High Street, Lot 1, DP 1137699
I256	Penrith Ambulance Station	668–672 High Street, Lot 12, DP 37829
s187	Station Master's House(former)	Jane Street, Lot 31, DP 1086586
I214	Victorian villa	150 Lethbridge Street, Lot 81, DP 526298
I815	"The Willows", house	65 Mulgoa Road, Lot 1021, DP 812335
I259	Penrith Power Station (former)	1 Museum Drive, Lot 1, DP 1010950
I180	Cottage	10–12 North Street, Lot 1, DP 794510; Lot B, DP 160112
I175	Weatherboard cottage	71 Parker Street, Lot 1, DP 996540
I253	Victorian house	6 Rawson Avenue, Lot 2, DP 206095
I701	Prospect Electricity building (former)	59 Station StreetLot 10, DP 1025026
I215	"Broadville", Victorian house	98 Station StreetLot 910, DP 717451
I216	"Kentucky", villa	146 Station Street, Lot 11, DP 715161

3 URBAN PLANNING CONTEXT

Appropriate land use planning is one of the most effective measures available to floodplain managers, both to reduce existing flood risks as redevelopment occurs, and to control future risk. The management and development of flood prone land must be undertaken within the current NSW legislative, policy and planning framework. This chapter summarises relevant legislation and policy as well as recent reforms by the NSW Government relating to flood development controls.

3.1 NSW FLOOD RELATED POLICIES & PLANNING CONTROLS

3.1.1 Floodplain Development Manual, 2005

The *Floodplain Development Manual* 2005 (the Manual) was gazetted on 6 May 2005 and relates to the development of flood liable land. It incorporates the NSW Flood Prone Land Policy, which aims to reduce the impacts of flooding and flood liability on individual owners and occupiers of flood prone property and to reduce private and public losses resulting from floods. To implement this policy and achieve these objectives, the Manual develops a merit based framework to assist with floodplain risk management. The Manual indicates that responsibility for management of flood risk remains with local government. It assists councils in their management of the use and development of flood prone land by providing guidance in the development and implementation of local floodplain risk management plans.

3.1.2 Guidelines on Development Controls in Low Flood Risk Areas, 2007

The Guidelines on Development Controls on Low Flood Risk Areas – Floodplain Development Manual (the Flood Planning Guidelines) were issued on 31 January 2007 as part of Planning Circular PS 07-003 at the same time as the S9.1 (previously S117) Directive described in Section 3.2.2. The Guidelines are intended to be read as part of the *Floodplain Development Manual*. They have been created to supply additional guidance on matters within the Manual, including determining the appropriate residential flood planning level (FPL) for councils and the appropriateness of applying flood related development controls on residential development in low flood risk areas. Strategic consideration of a number of key issues which must be addressed include safety to existing and future occupants of flood prone land, management of the potential damage to property and infrastructure and the cumulative impacts of development.

The Guidelines do not strictly conform with the Manual's merit based approach for the selection of appropriate flood planning levels (FPLs) because they state:

- unless there are exceptional circumstances, councils should adopt the 100-year flood as the FPL for residential development; and
- unless there are exceptional circumstances, councils should not impose flood related development controls on residential development on land above the residential FPL (low flood risk areas).

The Guidelines do not apply to all land uses (only standard residential) and recognise the need to consider the full range of flood sizes, up to and including the probable maximum flood (PMF) and the corresponding risks associated with each flood. Where there is a reason ('exceptional circumstances') a different FPL not based on the 100 year flood for standard residential development can be applied with government approval. Note by definition the FPL includes freeboard (typically 0.5m) on top of the adopted flood standard.

3.2 NSW ENVIRONMENTAL PLANNING AND ASSESSMENT ACT 1979

3.2.1 Background

The *Environmental Planning and Assessment Act 1979* (EP&A Act) creates the legislative framework for the making of plans, development assessment and approval, and protection of the environment from adverse impacts arising from development. The EP&A Act and Regulations outline the level of assessment required under State and local planning instruments and establishes the responsible consent or approval authorities.

Prior to development taking place in New South Wales a formal assessment and determination must be made of the proposed activity to ensure it satisfactorily complies with relevant planning controls and, according to its nature and scale, conforms with the principles of environmentally sustainable development.

3.2.2 Section 9.1 Directions of the Environmental Planning and Assessment Act 1979 – Direction No. 4.3 (Flood Prone Land)

Pursuant to the EP&A Act, Section 9.1 Direction No 4.3 (Flood Prone Land) was reissued on the 19 July 2007 by the Minister for Planning replacing all existing directions previously in operation. This applies to councils that have flood prone land within their Local Government Area (LGA) and any draft Local Environmental Plan (LEP) that creates, removes or alters a zone or provision that affects flood prone land.

Key objectives of Direction 4.3 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 (including the Guidelines or Development Controls on Low Flood Risk Areas); and
- To ensure that the provisions of an LEP on flood prone land are consistent with flood hazards and include consideration of the potential flood impacts both on and off the subject land.

Under Direction 4.3, when preparing draft LEPs, Councils must not include provisions that apply to flood planning areas which:

- permit development in floodway areas;
- permit development that will result in significant flood impacts to other properties;
- permit a significant increase in the development of that land;
- are likely to result in a substantially increased requirement for government spending on flood mitigation measures, infrastructure or services; or
- permit development to be carried out without development consent except for the purposes of agriculture (not including dams, drainage canals, levees, building or structures in flood ways or high hazard areas), roads or exempt development.

The Direction also requires that Councils must not impose flood related development controls above the FPL for residential development (as specified by the Guidelines in Planning Circular PS 07-003) unless a relevant planning authority provides adequate justification for those controls to the satisfaction of the Director-General.

3.2.3 Environmental Planning and Assessment Amendment (Flood Related Development Controls Information) Regulation 2007

Schedule 4, clause 7A of the Environmental Planning and Assessment Regulation 2000 (the Regulations) specifies information that can be included on Planning Certificates. Schedule 4 was amended in 2007 to include references to flood related development.

This amendment requires councils to distinguish where flood related development controls apply to nominated types of residential development and all other development. Nominated residential development includes dwelling houses, dual occupancies, multi dwelling housing and residential flat buildings, but does not include group homes or seniors living.

The effect of this is to differentiate nominated residential development on S10.7 (previously S149) planning certificates as required by Planning Circular PS 07-003.

3.3 STATE ENVIRONMENTAL PLANNING POLICIES (SEPP)

3.3.1 SEPP (Exempt and Complying Development Codes) 2008

State Environmental Planning Policies (SEPPs) are the highest level of planning instrument and prevail over LEPs to the extent of any inconsistency. *State Environmental Planning Policy (Exempt and Complying Development Codes) 2008* (Codes SEPP) defines development which is exempt from obtaining development consent and other development which can be certified with a complying development certificate (CDC) by Council or a private certifier, if it complies with prescribed criteria.

The Codes SEPP defines 'Flood Control Lots' as property where 'flood-related development controls apply'. Flood control lots are required to be noted as such on a S10.7 Certificate. These development controls may apply through an LEP or Development Control Plan (DCP). Some exempt development is not permitted on a Flood Control Lot (e.g. earthworks, retaining walls and structural support is not exempt development on a flood control lot per clause 2.29 of the SEPP).

Most complying development is permitted on Flood Control Lots where a Council or professional engineer can certify that the part of the lot proposed for development is not a:

- flood storage area;
- floodway area;
- flow path;
- high hazard area; or
- high risk area (see Clause 3.36C).

The Codes SEPP specifies various controls in relation to floor levels, flood compatible materials, structural stability, flood affectation, safe evacuation, car parking and driveways (see Clause 3.36C).

The important outcomes for this FRMP, in regard to establishing rules for housing, commercial and industrial development that could be approved as complying development is the defining of high risk areas (where complying development is excluded) and setting of minimum floor levels. The objective should be to ensure that such future development does not lead to increased flood risk to property and persons as a consequence of the application of the CDC process in comparison to outcomes otherwise likely to be achieved through the full development application (DA) process.

Flood control lots have not been specifically identified as part of this FRMS&P. However, there is sufficient information to determine whether land is a flood control lot or subject to one of the five hazard categories.

3.3.2 SEPP (Infrastructure) 2007

State Environmental Planning Policy (Infrastructure) 2007 aims to facilitate the effective delivery of infrastructure across the State by identifying development permissible without consent.

Clause 15 governs public authorities' consultation with councils for development with impacts on flood liable land (as defined by the PMF).

Part 3 Division 7 specifies that development for the purpose of flood mitigation work may be carried out by a public authority without consent.

Part 3 Division 20 specifies that development for the purpose of stormwater management systems may be carried out by a public authority without consent.

3.3.3 SEPP (Housing for Seniors or People with a Disability) 2004

SEPP (Housing for Seniors or People with a Disability) 2004 (Seniors Living SEPP) applies to urban land or (subject to a site compatability certificate) on land adjoining urban land where dwellings, hospitals and similar uses are permissible. The Seniors Living SEPP would apply to parts of the study area, and would effectively override Council's planning controls to permit residential development for older persons, and persons with a disability, to a scale permitted by the SEPP. Notwithstanding, Clause 4(6)(a) and Schedule 1 of the SEPP restricts its application if the land is identified as "floodways" or "high flooding hazard" in Council's LEP.

The Penrith LEP does not identify floodways or areas of high flooding hazard. Further, the standard instrument model LEP FRM clause and typically accepted LEP maps are not structured to accommodate the inclusion of these specific flood hazard types. Accordingly, there are no straightforward opportunities to introduce local planning controls to work in conjunction with the Seniors Living SEPP.

3.3.4 Sydney Regional Environmental Plan No 20—Hawkesbury–Nepean River (No. 2—1997)

As of 1 July 2009, Regional Environmental Plans (REPs) are no longer part of the hierarchy of environmental planning instruments in NSW. Accordingly, all existing REPs are now deemed to be State Environmental Planning Policies (SEPPs).

Sydney Regional Environmental Plan No 20—Hawkesbury–Nepean River (REP 20) integrates planning with catchment management to protect the river system. The impact of future land use is to be considered in a regional context. The plan covers primarily water quality and indirectly water quantity, environmentally sensitive areas, riverine scenic quality, agriculture, and urban and rural residential development. It controls development that has the potential to impact on the river environment. The plan applies to all parts of the catchment in the Sydney Region (15 local government areas), except for land covered by Sydney REP No. 11 - Penrith Lakes Scheme.

REP 20 has limited relevance in the context of this study.

3.4 LOCAL PLANNING INSTRUMENTS

3.4.1 Penrith LEP 2010

Penrith Local Environmental Plan 2010 LEP (PLEP) applies to the whole of the study area.

PLEP is based on the *Standard Instrument (Local Environmental Plans) Order 2006* which provides a template of mandatory and optional clauses. The standard instrument contains no compulsory clauses or map requirements specifically relevant to addressing flood hazards. However, the Department of Planning, Industry and Environment (DPIE) has adopted a model local clause in regard to flooding. A model local clause is one which has been settled by Parliamentary Counsel as acceptable and the DPIE encourages that it is used as is. However, such a clause may be varied with justification to suit local circumstances.

Clause 1.2 of PLEP specifies aims, including:

(g) to minimise the risk to the community in areas subject to environmental hazards, particularly flooding and bushfire, by managing development in sensitive areas,

(h) to ensure that development incorporates the principles of sustainable development through the delivery of balanced social, economic and environmental outcomes, and that development is designed in a way that assists in reducing and adapting to the likely impacts of climate change.

The purpose of Clause 1.2 of PLEP is descriptive and not facultative. That is it describes what the balance of the provisions in the LEP seek to achieve as opposed to setting criteria to be directly satisfied by development.

Clause 6.3 of PLEP requires the preparation of a DCP for new urban release areas as a prerequisite to development. Clause 6.3(3)(f) requires that such a DCP provides for the amelioration of natural and environmental hazards including flooding.

The principal flood related considerations of PLEP are contained in Clause 7.2. This clause is substantially the same as the model flood clause published by the DPIE. The clause applies to the following areas:

- “land identified as “flood planning land” on the Clause Application Map”, which does not apply to the study area [or]
- land below the flood planning level (FPL) defined as “100 ARI (average recurrence interval) flood event plus 0.5 metres freeboard”.

Areas that can be deduced from existing or future data as captured by the second criterion would be subject to the clause. A substantial part of the study area would therefore be subject to clause 7.2 of PLEP, because of both overland flow flooding which is the subject of this study and riverine flooding from the Hawkesbury Nepean River.

PLEP also provides a set of “Flood planning land” maps which identify ‘Flood Planning Area[s]”. These maps only delineate the industrial zoned land in the northwest corner of the study area. But as noted above, Clause 7.2 also applies all to land below the FPL.

The issues with Clause 7.2 to be addressed by the recommendations of this plan include the need to produce updated LEP maps to more clearly and comprehensively identify land subject to flood risk management considerations and to review the definition of the flood planning area. The latter consideration relates to whether the LEP should trigger consideration of flood risks (in particular evacuation) beyond the currently adopted FPL.

An overlay of the extent of 100 year overland flow flooding and the existing zonings was analysed. This did not reveal any obvious issues that would warrant a zoning correction. A review of zoning based on riverine flooding was not undertaken.

3.4.2 Proposed Amendments to PLEP

There are several Planning Proposals currently being considered by Council and the NSW Department of Planning and Environment to rezone land within the study area. The relevant Planning Proposals are:

- **Australian Arms Hotel: 351 & 359 High Street:** This is a proposal to increase the potential scale of development by increasing the permitted floorspace and height. The current 3B commercial core zoning would remain the same. The assessment of this application commenced in December 2018. This site is not directly affected by overland or riverine flooding.

- **39 and 47-49 Henry Street:** The Planning proposal is to increase the permitted floorspace to provide an incentive for the development of the site with a new mixed-use development including apartments, a hotel, and ground floor commercial and retail premises. Gateway approval to conditionally proceed with the proposal was issued on 27 September 2018. The site is affected by overland flow flooding.
- **57 Henry Street**: This Planning Proposal seeks to increase the permitted floorspace to facilitate the development for 454 dwellings and 64 jobs. Gateway approval to conditionally proceed with the proposal was issued on 26 October 2018. The site is affected by overland flow flooding.
- **Incentive clause for key sites in Penrith City Centre**: The planning proposal applies to various sites most of which are within the study area. The planning proposal is to insert an incentive clause into Part 8 of PLEP applying to identified key sites, providing a bonus floor space ratio in return for a public benefit. This planning proposal has the potential for 4,000 dwellings. Parts of the various sites within this planning proposal are affected by riverine and/or overland flow flooding. Gateway approval to conditionally proceed with the proposal was issued on 28 September 2016.

The last planning proposal is the most significant in regard to flood risk management due to the potential for substantial additional dwellings and population. While the sites are above the 100 year flood level, they in part are within the PMF riverine floodplain. Consequently, the flood evacuation strategy, being reviewed by Infrastructure NSW in conjunction with the SES, for the Hawkesbury Nepean floodplain needs to be able to manage the additional occupants. This issue stalled the progression of some of the planning proposals but the DPIE recently issued "Development Assessment Guideline: An Adaptive Response to Flood Risk Management for Residential Development in the Penrith City Centre". The Framework establishes three stages (including 4,050 dwellings in stage 1) with caps and preconditions on new development to provide guidance to Council as it proceeds with planning for growth in the City Centre.

The overland flow flood risk management issues relevant to study are not as significant as those relating to riverine flooding. Generally, the planning proposal sites affected by overland flooding have included flood impact assessments providing measures to address the overland flow flooding risks. However, the potential for overland flooding to compromise evacuation routes needed for the timely evacuation of these developments ahead of riverine floods arriving, is a matter which needs to be considered in the CBD FRMS&P.

3.4.3 Penrith DCP 2014

Penrith Development Control Plan 2014 (the DCP) applies to most of the LGA, including the study area, and provides detailed controls for development. Part C3 of the DCP deals with water management and includes controls addressing both riverine and overland flow flooding.

Clause C3.5 outlines information requirements and a range of flood risk management controls. The controls provide for minimum floor levels, flood safe access, flood proofing and filling. The 100 year flood plus 0.5m freeboard is the minimum required floor level for residential, commercial and industrial development. Of specific relevance to this study, Control 13 provides the following under the heading of Overland Flow Flooding:

a) Council has undertaken a Penrith Overland Flow Flood 'Overview' Study.

Consideration must be given to the impact on any overland flow path. Generally, Council will not support development obstructing overland flow paths. Development is required to demonstrate that any overland flow is maintained for the 1% AEP (100 year ARI) overland flow. A merit based approach will be taken when assessing development applications that affect the overland flow.

3.5 STRATEGIC PLANNING

3.5.1 Plan for Growing Sydney

A Plan for Growing Sydney (NSW Department of Planning & Environment, December 2014) details the NSW Government's plan for the future of the Sydney Metropolitan Area over the next 20 years. S9.1 Direction 7.1 presently requires this Plan to be considered when rezoning land. The Plan (pg. 8) provides key directions and actions including "Direction 4.2: Build Sydney's resilience to natural hazards."

Action 4.2.2 recognises the unique high risks associated with riverine flooding from the Hawkesbury Nepean River and requires the implementation of the Hawkesbury Nepean Floodplain Management Review being undertaken by Infrastructure NSW (now complete). No recommendations apply specifically to overland flow flooding. While 'A Plan for Growing Sydney' is currently referred to by S9.1 Direction 7.1, the Greater Sydney Commission has more recently prepared a metropolitan plan for the Sydney region.

3.5.2 Towards Our Greater Sydney 2056

In March 2018, the Greater Sydney Commission (GSC) released the final Greater Sydney Region Plan. This higher order draft Plan introduces the concept of forming 3 "city" focuses for Sydney to grow towards. The Penrith CBD is identified as a 'Metropolitan Cluster' incorporating a 'Health and Education Precinct'.

The Plan was prepared in accordance with S3.3 of the EP&A Act. The Plan notes (pg.26) that in line with legislative requirements the plan reviews the current regional plan for Greater Sydney, A Plan for Growing Sydney (2014) to inform a new Greater Sydney Region Plan.

This Plan recognises the particular flood risks associated with the floodplain of the Hawkesbury Nepean Valley, and provides Strategy 37.2:

Respond to the direction for managing flood risk in the Hawkesbury-Nepean Valley as set out in Resilient Valley, Resilient Communities – Hawkesbury-Nepean Valley Flood Risk Management Strategy.

No strategies apply specifically to overland flow flooding.

3.5.3 District Plan

Also, in March 2018 the GSC released the Western City District Plan.

This District Plan provides a 20-year vision, priorities and actions for the Western City District. The Plan recognises that the Penrith CBD is a significant commercial centre and serves a substantial catchment which extends to the west into the Blue Mountains.

The Western District is expected to grow by an additional 184,500 dwellings (accommodating a population growth of 464,450 persons) in the next 20 years. While only a minor proportion of this growth is expected to occur within the Penrith LGA, reasonably substantial dwelling and population growth is projected for the LGA. The Plan sets a 5 year target of 6,600 additional dwellings for the LGA in the period 2016-2021. The Plan does not specify growth targets for the Penrith CBD but does identify the 'Greater Penrith to Eastern Creek' growth area as a focus for land release development and urban renewal in association with investment in transport infrastructure connecting the Western

Economic Corridor around the Western Sydney Airport.

The Plan includes the Penrith CBD, the health and education precinct and the tourism precinct from Penrith Lakes along the current length of the Great River Walk to the M4 Motorway, within the Collaboration Area for Greater Penrith. It has the potential to grow up to 45,000 jobs (a 35% increase) over the next 20 years.

The Plan (pg.83) states that the Collaboration Area aims to:

- revitalise and grow the Penrith CBD;
- develop a major tourist, cultural, recreational and entertainment hub;
- protect and expand the health and education precinct;
- address flooding issues;
- implement Greater Sydney Green Grid projects and promote ecologically sustainable development;
- improve housing diversity and provide affordable housing;
- diversify the night-time economy;
- implement healthy city initiatives and improve social infrastructure.

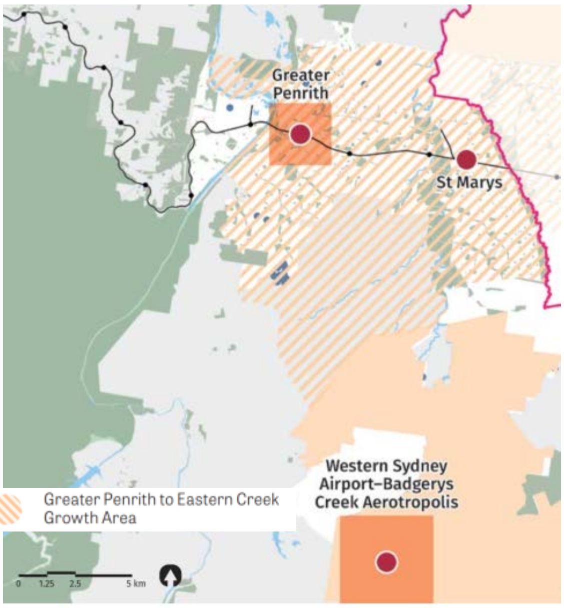

Figure 2. Greater Penrith to Eastern Creek Growth Area (GSC, 2018, pg.130 - Extract)

Together with expectations for growth, the Plan adopts 'Planning Priority W20 – Adapting to the impacts of urban and natural hazards and climate change'. The specific considerations discussed under this Planning Priority focus on the extreme flood risks associated with the Hawkesbury Nepean floodplain and not overland flow flooding.

While more specifically related to riverine flooding, the District Plan (pg.137) notes that the DPIE is leading work to develop a planning framework to address flood risks associated with the Hawkesbury Nepean floodplain up to and including a PMF. In the interim the plan recommends certain planning principles that primarily relate to riverine flooding. These include avoiding new or intensified urban development below the 100 year flood level, applying flood related controls and more flood compatible building techniques, avoiding areas of high flood risk, and avoiding works that create local and cumulative changes to flood behaviour that impact others in the floodplain.

Of relevance to the study area, the Plan also states;

Flooding constraints also affect other areas across the District, many of which are undergoing significant growth and redevelopment. This includes the Penrith City Centre, where drainage works are underway to manage flooding. Strategic planning for growth in floodprone areas must consider flood resilience to ensure buildings and communities can withstand flood events and quickly recover.

Division 3.1 of the EP&A Act includes provisions for the making and consideration of District Plans. Section 3.8 of this Act requires the implementation of the District Plan. A critical criterion for progressing a Planning Proposal is meeting the strategic planning merit test by showing that a change in zoning is required to implement the recommendations of a local, district or regional strategic plan.

3.5.4 Development Contributions Plans

A development contributions plan (CP) could provide a potential funding mechanism to contribute towards the costs associated with mitigating flood risks where required to facilitate new development.

The following CPs apply to the study area:

- Penrith City Council Section 94 Plan Library Facilities (Amendment No.1);
- Cultural Facilities Section 94 Development Contribution Plan (August 2003);
- Penrith City Local Open Space Development Contributions Plan 2007 (excluding the industrial area);
- Civic Improvement Plan for the Penrith City Centre(December 2008);
- Penrith City District Open Space Development Contributions Plan 2007 (excluding the industrial area).

The Local Open Space CP includes embellishment works within drainage reserves but none of these are located within the study area. This CP includes embellishment works to two parks (Brown Street Reserve and Judges Park) within the study area.

The District Open Space CP includes works relating to the Ripples Leisure Centre and Pool and potentially a proposed multi-purpose sports facility (site to be advised – either on public land adjacent to the City Centre or the Penrith Lakes). The approximate value of these works (2007 $s) were $2 million and $12 million respectively.

The Civic Improvements CP provides a total contribution of $57.5 million (2008 $s) towards city centre projects (excluding multi-storey car parks) of which $2 million relates to stormwater projects. The description of the drainage works in the CP (pg.34) is as follows:

Increased development in the Penrith City Centre will result in increased hard stand areas and additional run-off. Existing stormwater pipes will need to be augmented to accommodate the anticipated increase in stormwater flows. Council is undertaking a study in this regard and details of augmentation the existing piped stormwater system will be available in the near future. This schedule of works will be amended once more detailed data is available.

There would be scope to allocate the $2 million of potential Civic Improvements CP stormwater funding towards works identified by the FRMP. There could also be scope for dual use of city centre parks/public domain areas for drainage purposes, subject to satisfying relevant safety and engineering design considerations.

3.5.5 Section 10.7 Planning Certificates

A Section 10.7 (formerly S149) Planning Certificate is basically a zoning certificate issued under the provisions of the EP&A Act that is generally available to any person on request and must be attached to a contract prepared for the sale of property. The matters to be contained within the Section 149(2) Certificate are prescribed within Schedule 4 of the EP&A Regulation, 2000 and generally relate to whether planning controls [and not necessarily flood related risks] apply to a property.

A Section 10.7(5) Certificate, being a more complete but more expensive certificate, requires councils to advise of *"other relevant matters affecting the land of which it may be aware"*. These more complete certificates are not mandatory for inclusion with property sale contracts – a Section 10.7(2) Certificate being the minimum required. Where a Section 10.7(5) Certificate is obtained, this could require a council to notify of all flood risks of which it is aware.

It is recognised that S10.7 certificates should not be solely relied upon as community education tools as they have only limited circulation. The majority of flood-affected properties would not be reached in a given year. However, information on a S10.7 Certificate can reflect information that may be provided to people making general enquiries, and together are important sources of information for the community that influence what is the understood (or perceived) flood risk of property that a person owns and/or occupies or operates a business from. With the existing system of notifications on S10.7(2) certificates, if no notification appears, then it is often misunderstood to mean that property is “flood free” rather than there are no flood related development controls. For flood risk management purposes, S10.7 certificates should not confuse or mislead those people, with regard to understanding whether there are any risks of floods affecting a particular property.

Schedule 4 of the EP&A Regulation specifies flood related information that can be shown on Section 10.7 Certificates. The provisions require the following:

7A Flood related development controls information

(1) Whether or not development on that land or part of the land for the purposes of dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) is subject to flood related development controls.

(2) Whether or not development on that land or part of the land for any other purpose is subject to flood related development controls

(3) Words and expressions in this clause have the same meanings as in the Standard Instrument.

As stated in the 2007 Guidelines, the Clause 7(A)(1) of Schedule 4 of the Regulation means that Council should not include a notation for residential development on Section 149(2) Certificates in “low risk areas” if no flood related development controls apply to the land. Under Clause 7(A)(2) Council can include a notation for critical infrastructure or more flood sensitive development on Section 10.7(2) Certificates in low flood risk areas if flood related development controls apply. “Low flood risk” areas are undefined, but in the context of the 2007 Flood Planning Guidelines, it is assumed to be a reference to that part of the floodplain between the 100 year flood (plus freeboard) and the PMF.

These provisions require council to distinguish between the situation where there are flood related development controls on nominated types of “residential development” and all other development. More sensitive land uses such as group homes or seniors living is excluded from the limitation of notations for residential development. Importantly, a S10.7(2) Certificate must identify where any flood related development controls apply to any form of development, including residential development on land between the 100 year FPL and PMF if existing prior to the 2007 Guideline or if exceptional circumstances dispensation has been granted.

The FDM defines flood liable land as all land potentially affected by inundation during a flood, up to the PMF. This includes both riverine flooding and flooding from major overland flow paths. Flood mapping will identify the areas subject to overland flow flooding in the study area. However, this detail level of flood mapping is unlikely to be available across the entire LGA.

It is likely that Council will never be able to unequivocally confirm that it has mapped all areas subject to potential flooding (mainly due to the unreasonable resources that would be required to accurately map all overland flow paths), although Council may be able to say that it confidently believes it has identified the majority of properties affected by significant flooding.

Council has provided example Section 10.7(2) Certificates. The Clause 7A response for a property located above the 100 year flood (plus freeboard) within the study area is:

(1) This land has not been identified as being below the adopted flood planning level (i.e. the 1% Annual Exceedance Probability flood level plus 0.5 metre) and as such flood related development controls generally do not apply for dwelling houses, dual occupancies, multi dwelling housing or residential flat buildings (not including development for the purposes of group homes or seniors housing) if such uses are permissible on the land. Council reserves the right, however, to apply flood related development controls depending on the merits of any particular application. Should future studies change this situation this position may be reviewed.

(2) This land has not been identified as being below the adopted flood planning level (i.e. the 1% Annual Exceedance Probability flood level plus 0.5 metre) and as such flood related development controls generally do not apply for any other purpose not referred to in (1) above. Council reserves the right, however, to apply flood related development controls depending on the merits of any particular application. Should future studies change this situation this position may be reviewed.

When a site is located below the 100 year flood (plus freeboard), the notification reads the opposite to the above and omits the qualification that Council reserves the right to apply flood related development controls and so on. The following additional S10.7(5) information in regard to flood risk is identified on the example certificate for sites below the 100 year flood level (plus freeboard):

Flooding within certain urban areas

- Council has in the past conducted studies of possible overland water flows within the City of Penrith. Those studies have been carried out in good faith, but Council cannot verify their accuracy. In particular, Council believes there are limitations on the accuracy of the past studies in urban areas where the effect of flash flooding, and underground drainage and stormwater disposal systems is largely unknown.
- This property is shown on Council's flood mapping as potentially so affected.
- Council imposes flood related development controls where, in its opinion, such controls are justified. Such controls may or may not be imposed with respect to this property in the event of an application for development consent.
- If a development proposal is submitted with respect to this property, Council will consider the possibility of flood or overland flow in the context of the application. Council may impose a requirement that the applicant for development consent carry out a detailed assessment of the possible overland water flows affecting the property (a flood study) and/or may impose other controls on any development designed to ameliorate flood risk.

The above additional S10.7(5) notification is omitted for sites above the 100 year flood level (plus freeboard).

The additional flood study information derived from this FRMS should be able to provide more definitive information regarding overland flow flooding within the study area. This should lead to being able to dispense with the supplementary S10.7(5) notation.

Ideally the S10.7 certificate notations should be standardised for sites across the LGA. These should be undertaken in conjunction with the recommendations for upgrading the DCP controls and the preparation of flood maps for planning purposes.

The information regarding flood risk provided with a Section 10.7 Certificate, would not in itself lead to any alteration to the permissibility of development but is more directed towards providing factual information (important due to liability issues) to increase awareness of the potential flood risks known to Council and to provide full and consistent messaging about flood risks.

4 EMERGENCY MANAGEMENT CONTEXT

Emergency management represents one the three pillars of floodplain risk management. It is generally not affordable to treat all flood risk up to and including the PMF through flood modification and property modification measures, especially where there is a large legacy of existing risk but also future risk. Emergency management measures such as flood warning systems, evacuation planning and community flood education are aimed at increasing resilience to reduce risk to life and property, both for frequent flood events and for very rare but extreme flood events.

This chapter sets out some context for the detailed evaluation of flood response measures discussed in Section 9.

4.1 NSW STATE EMERGENCY SERVICE ROLE

As stipulated in the *State Emergency Service Act 1989*, the NSW State Emergency Service (SES) acts as the combat agency for dealing with floods (including the establishment of flood warning systems) and to co-ordinate the evacuation and welfare of affected communities. The NSW SES is tasked to protect persons from dangers to their safety and health, and to protect property from destruction or damage, arising from floods.

Details of the roles and responsibilities of the NSW SES (and other emergency services and affected parties) can be found in the *State Flood Sub Plan*, a Sub Plan of the New South Wales Disaster Plan (NSW SES, 2008). This role covers:

- **Prevention:** includes providing emergency management advice to councils;
- **Preparedness:** includes preparing and maintaining Flood Sub Plans and developing and maintaining flood intelligence systems. It also involves community education and preparing communication messages and systems for the delivery of flood information during flooding.
- **Response:** includes controlling and coordinating flood operations, communicating flood advice to at-risk communities and coordinating evacuation and rescue operations;
- **Recovery:** includes debriefs following flood operations.

4.2 FLOOD PLANS

4.2.1 Hawkesbury Nepean Flood Plan

The September 2015 edition of the Hawkesbury Nepean Flood Plan (HNFESP) (NSW SES, 2015) was the current version of the plan at the time the present report was prepared. The HNFESP is a Sub Plan of the NSW State Flood Plan which outlines the general arrangements for managing floods in NSW.

The HNFESP sets out response and recovery arrangements for flooding in the Hawkesbury Nepean Valley from Wallacia to Brooklyn. It includes an evacuation plan for the Hawkesbury Nepean Valley in the event that it is impacted by significant flooding. This applies to the lower parts of the Penrith CBD study area which are at risk from Nepean River flooding. It is generally the area west of Castlereagh Street and Lawson Street.

Local flood plans within the Hawkesbury Nepean floodplain, such as the Penrith Local Flood Plan, are subordinate to the HNFESP. Previous versions of the HNFESP used flood level thresholds at different locations to determine the scale of the corresponding flood emergency arrangements: while smaller flood events had to be managed according to the relevant local flood plan, larger events were coordinated at the state level as per the guidance provided in the HNFESP.

The September 2015 edition of the HNFESP modifies this approach, and requires that the response to and recovery from any mainstream flood event in the Hawkesbury-Nepean floodplain is managed at the state level. Local flood plans, including the Penrith Local Flood Plan, will need to be amended accordingly, and their scope will be limited to local overland flooding.

4.2.2 Penrith Local Flood Plan (2012)

The 2012 Penrith City Local Flood Plan covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding from the Hawkesbury Nepean River within the whole Penrith City LGA.

From September 2015, with the release of the new Hawkesbury Nepean Flood Plan (HNFESP), all types of mainstream flood events in the Hawkesbury Nepean floodplain are to be managed at the state level, while the scope of local flood plans is limited to overland flooding. However, the 2012 Penrith City Local Flood Plan does not address local overland flooding.

The NSW SES has advised that the next edition of Penrith Local Flood Plan will address only overland flooding. As such, the current edition of the plan has no scope in the context of this study and will not be discussed further.

4.3 FLOOD RESPONSE

A major point of contention in contemporary emergency management policy and practice relates to the advantages and disadvantages of evacuation compared to sheltering-in-place, particularly for flash flood catchments such as Penrith CBD. The NSW SES has prepared or contributed to a number of publications on this topic, which are summarised below:

4.3.1 NSW SES Position

a) Opper and Toniato (2008)

NSW SES holds the position that if development is to occur on floodplains, it must be possible to evacuate people out of the floodplain in advance of floods.

NSW SES has recognised that in an existing flash flood context, and only in that context, causing residents to attempt to evacuate at the time of flash flooding is occurring, could be a serious risk to life. Only in areas where urban redevelopment cannot be prevented under existing planning policy, it has therefore been proposed that the DCP for any new or redeveloped dwelling will require an internal refuge area above the level of the PMF. This concession has been seized upon to wrongly apply it to all flood contexts and to justify any new development.

In response, NSW SES may have no choice but to adopt a harder line and to not support any redevelopment or development in flash flood areas.

Two elements of flood isolation risk are particularly significant: structural fire and medical emergency.

An example of the problems that can arise due to isolation and the vagaries of human behaviour occurred during flooding in June 2007, when a nursing home at Wyong needed to be urgently evacuated due to its rapid isolation by floodwater and the threat of further inundation. This required six ambulance crews and other emergency services to deal with just this one facility. The management and residents had ignored early advice to evacuate before they were isolated and then had a change of mind once they were surrounded by floodwater.

b) Opper et al. (2011); AFAC (2013)

The safest place to be in a flash flood is well away from the affected area. Evacuation is the most effective strategy, provided that evacuation can be safely implemented. Properly planned and executed evacuation is demonstrably the most effective strategy in terms of a reliable public safety outcome.

Late evacuation may be worse than not evacuating at all because of the dangers inherent in moving through floodwaters, particularly fast-moving flash flood waters. If evacuation has not occurred prior to the arrival of floodwater, taking refuge inside a building may generally be safer than trying to escape by entering the floodwater.

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. It is not equivalent to evacuation. The risks of 'shelter-in-place' include:

- Floodwater reaching the place of shelter (unless the shelter is above the PMF level);
- Structural collapse of the building that is providing the place of shelter (unless the building is designed to withstand the forces of floodwater, buoyancy and debris in a PMF);
- Isolation, with no known basis for determining a tolerable duration of isolation;
- People's behaviour (drowning if they change their mind and attempt to leave after entrapment);
- People's mobility (not being able to reach the highest part of the building);
- People's personal safety (fire and accident); and
- People's health (pre-existing condition or sudden onset e.g. heart attack).

For evacuation to be a defensible strategy, the risk associated with the evacuation must be lower than the risk people may be exposed to if they were left to take refuge within a building which could either be directly exposed to or isolated by floodwater.

Pre-incident planning needs to include a realistic assessment of the time required to evacuate a given location via safe evacuation routes. This requires consideration of barriers to evacuation posed by available warning time, availability of safe routes and resources available.

Successful evacuation strategies require a warning system that delivers enough lead time to accommodate the operational decisions, the mobilisation of the necessary resources, the warning and the movement of people at risk.

Effective evacuation typically requires lead times of longer than just a couple of hours and this creates a dilemma for flash flood emergency managers. 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 (often as short as 30 minutes) and as a result provide limited prospects for using such systems to trigger planned and effective evacuation.

Initiating evacuation of large numbers of people from areas prone to flash flooding based only on forecasts may be theoretically defensible in a purely risk-avoidance context but it is likely to be viewed as socially and economically unsustainable. Frequent evacuations in which no flooding occurs, which statistically will be the outcome of forecast-based warning and evacuation, could also lead to a situation where warnings are eventually ignored by the community.

c) NSW SES (2014)

In the context of future development, self-evacuation of the community should be achievable in a manner which is consistent with the NSW SES's principles for evacuation, namely:

- Development must not conflict with the NSW SES's flood response and evacuation strategy for the existing community;
- Evacuation must not require people to drive or walk through floodwaters;
- Development strategies relying on deliberate isolation or sheltering in buildings surrounded by flood water

are not equivalent, in risk management terms, to evacuation;

- Development strategies relying on an assumption that mass rescue may be possible where evacuation either fails or is not implemented are not acceptable to the NSW SES;
- The NSW SES is opposed to the imposition of development consent conditions requiring private flood evacuation plans rather than the application of sound land use planning and flood risk management.

d) Summary

The NSW SES holds that evacuation is the preferred emergency response for floodplain communities, where this can safely be achieved. Late evacuation, through floodwater, may be a recipe for disaster and in that situation it might be safer to remain inside the building, though sheltering-in-place has a number of direct and indirect risks associated with it. Evacuating prior to flooding is therefore much preferred. Where current hydro-meteorological monitoring systems, communications systems, road infrastructure and expected community behaviours do not allow this, the SES advocates improvements to these so that evacuation can proceed safely. However, the AFAC (2013) guide makes clear that even with improvements in monitoring, insufficient time may be available to inform evacuation decisions with any confidence. If evacuations are ordered based only on predicted rainfall, the community may eventually come to ignore warnings.

5 COMMUNITY AND STAKEHOLDER ENGAGEMENT

5.1 GENERAL

The success of any floodplain management plan hinges on its acceptance by the local community and other stakeholders. This can only be achieved by engaging the community at all stages of the decision-making process. It includes collecting the community members' knowledge about flood behaviour in the study area, consulting about management options, and discussing the issues and outcomes of the study with them.

Community engagement has been an essential component of the Penrith CBD FRMS&P. This has aimed to inform the community about the development of the floodplain management study and its likely outcomes. It has also aided learning about community flood awareness and preparedness. The engagement process has also provided an opportunity for the community to participate in the study by submitting ideas about potential floodplain management measures.

5.2 PRELIMINARY CONSULTATION PROGRAM

As part of its proposal, Molino Stewart provided Council with a Preliminary Community and Stakeholder Consultation Program as an initial plan for community consultation.

The Program included details about:

- The community in the study area;
- Consultation objectives;
- Target audiences;
- Possible consultation risks;
- Consultation techniques.

The Program adopted a community and stakeholder consultation process based on two phases:

- **Phase I**, to inform the community and stakeholders on the outcomes of the Flood Studies, advise that the Floodplain Risk Management Study was being undertaken, and obtain feedback on flood affectation and possible risks;
- **Phase II**, to obtain feedback from the Community about the final draft of Floodplain Risk Management Study and Plan. This phase focused on the public exhibition of the FRMS&P.

5.3 PHASE 1: INFORMING THE COMMUNITY

5.3.1 Community Consultation

Phase 1 of the community consultation aimed to increase awareness of the property owners in the study area about the FRMS&P, identify their flood experiences and concerns, and obtain their views on possible flood risk management options.

Based on a communications plan prepared by Council and Molino Stewart, the following community consultation methods were used in Phase 1:

- Media release;
- Letters to residents and businesses;
- Survey (accompanying the letter);
- Information sheet (accompanying the letter);
- Information on Council's Have Your Say page (including an online version of the survey);
- Drop-in session (held on 17 May 2018 at Penrith City Library);
- Business breakfast chat function (organised with the Penrith CBD Corporation);
- Poster display (used in the drop-in session and business breakfast chat).

The consultation period was from mid-April 2018 to the end of May 2018.

The survey was distributed to approximately 3,500 properties across the study area. It should be noted that a large proportion of these properties did not have a flood risk and included multi-story dwellings. There were also a few responses from people living outside the study area.

There were 153 responses to the survey with 85% being from residential property owners, 12% business owners and only 3% identifying as renters. As shown in Figure 3, three-quarters of respondents had lived at the same address for more than five years.

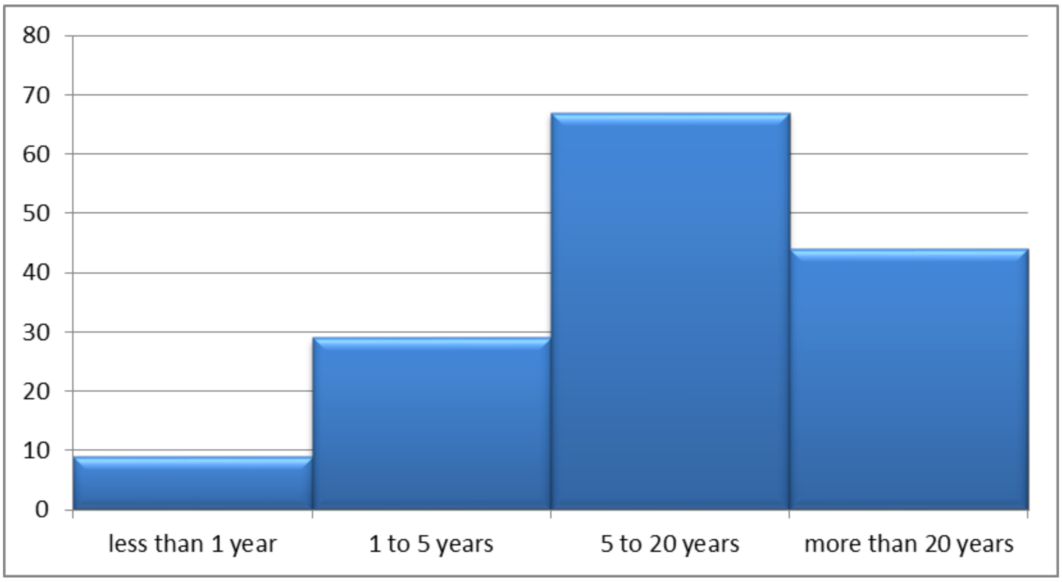

Figure 3. Number of years that respondents had lived at the same address

Approximately half (47%) of survey respondents lived in houses (bungalows). However, the diversity of land uses in the study area was demonstrated through the identification of several other types of properties owned by respondents including villas, apartments, shops, offices and industrial units.

Although the majority of respondents had lived or worked at their current address for more than five years, only 12% had experienced flooding at that address. Those respondents that identified flooding in their property were from:

- Union Street (2 responses);
- Station Street (2 responses);
- Stafford Street;
- Woodriff Street;
- Castlereagh Street;
- Brown Street;
- Taloma Street.

For some respondents flooding in their property had occurred several times during the last 20 years with the most recent flood event being in 2016.

Approximately 20% of respondents had concerns about flooding in the study area and these concerns included:

- Pooling of water in low lying areas;
- Stock could be damaged (businesses);
- Near stormwater drains;
- Uncertainty about climate change impacts
- Overdevelopment of the floodplain.

As shown in Table 1, respondents overwhelmingly supported the improvement of the stormwater drainage system in a list of possible flood risk management options. Response modification options such as the provision of flood risk information, community flood education and improving flood warning and evacuation procedures also were strongly supported. The least supported were the property modification options such as voluntary house purchase and flood proofing houses.

Table 2. Responses to possible flood risk management options

Flood Risk Management Option	Yes	No	Don't know
Improve stormwater drainage system	95%	2%	3%
Ensure all information about the potential risks of flooding is available to all residents and business owners	94%	2%	2%
Improve flood warning and evacuation procedures both before and during a flood	87%	4%	9%
Ensure all residents and business owners have Flood Action Plans	86%	5%	9%
Specify controls on future development in flood-liable areas	86%	2%	12%
Management of vegetation along creek corridors for flood mitigation	85%	5%	10%
Community education, participation and flood awareness programs	84%	5%	11%
Provide a Planning Certificate to purchasers in flood prone areas	76%	12%	12%
Removal of floodplain obstructions	69%	7%	24%
Widening and/or concrete lining of watercourses	67%	12%	21%
Construct detention basins	56%	14%	30%
Provide funding or subsidies to raise houses above major flood level	37%	34%	29%
Voluntary purchase of the most severely affected flood-liable properties	34%	22%	44%
Flood proofing of individual properties by waterproofing walls, putting shutters across doors etc	25%	42%	33%

Respondents were invited to provide other possible flood risk management options and the following options were suggested:

- Clean out culvert drains before they get blocked;
- More channels should be built;
- Prevent more residential and commercial properties in the floodplain.

Respondents were asked how they would like to learn more and be involved in the FRMS&P. As shown in Figure 4, newspapers, Council's website and public meetings were the most popular ways for respondents to be informed and consulted.

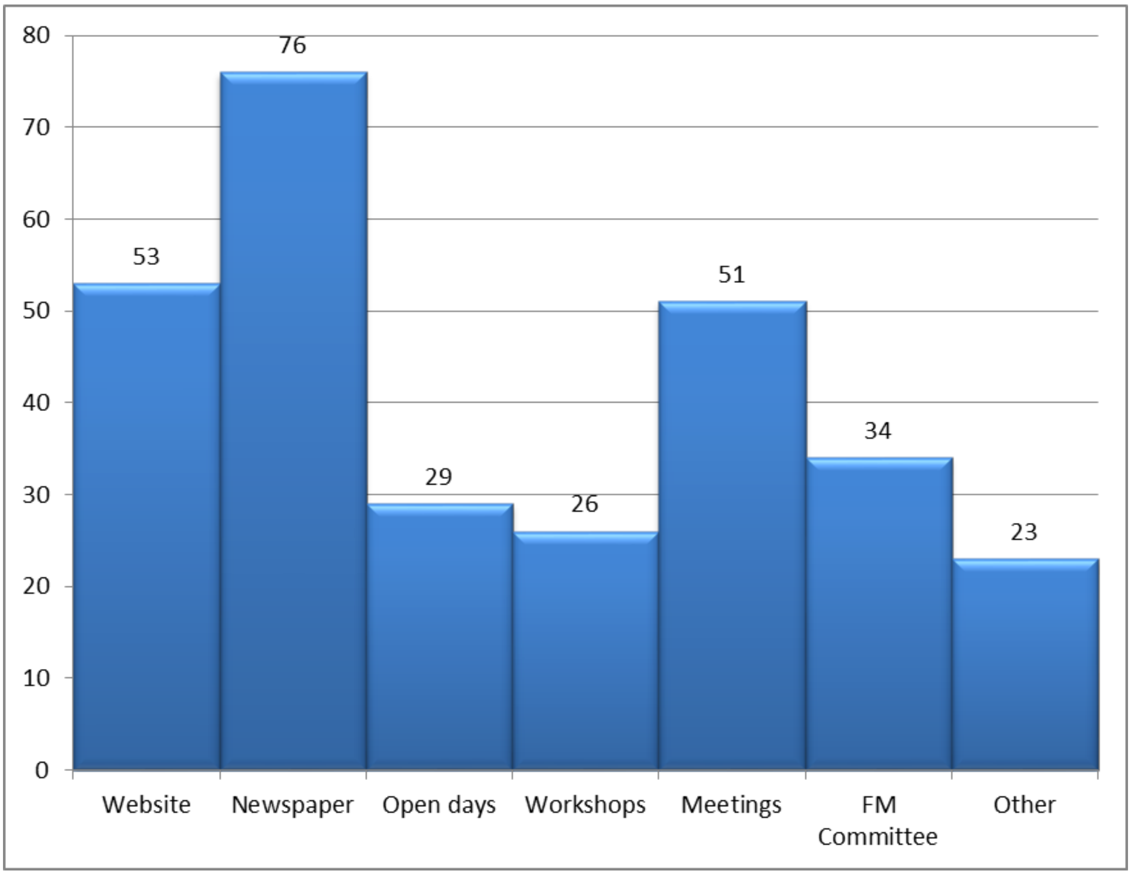

Figure 4. Ways in which respondents want to be informed and consulted about the FRMS&P

Other ways respondents wanted to be consulted included by letter, social media and by email. One respondent said, “I am 95 years old & blind - none of the above are any good to me.”

The drop-in session at Penrith City Library attracted six participants (one of which lived outside the study area). Molino Stewart staff provided a briefing on the preparation of the FRMS&P and details of flood risk modelling for the study area. Council and Molino Stewart staff discussed flood concerns and possible flood risk management options individually with participants. All participants provided their feedback through the survey.

Over 60 participants attended the business breakfast chat function which is a monthly event run by the Penrith CBD Corporation. Molino Stewart provided a brief explanation of the FRMS&P project and the flood risk to Penrith CBD businesses. Participants were encouraged to complete the survey and copies were left at the Corporation’s office along with the poster about the FRMS&P. Several businesses owners discussed flood risk and their concerns with Molino Stewart after the function, with one of the most significant businesses being the Penrith Paceway.

5.3.2 Consultation with Other Stakeholders

A range of organisations were contacted by letter to ascertain whether they have any general or specific requirements that should be addressed in the preparation of the FRMS&P. The organisations consulted were those with an interest in the management of the floodplain, an interest in the infrastructure that crosses the floodplain and in the environment of the floodplain. A letter was sent to:

- NSW State Emergency Service;
- Office of Environment and Heritage;
- Greater Sydney Local Land Services;
- Department of Planning and Environment;
- Roads and Maritime Services;
- Department of Primary Industries – Water;
- Bureau of Meteorology;
- Sydney Water;
- Penrith CBD Corporation;
- Penrith Valley Chamber of Commerce;
- Infrastructure NSW - Hawkesbury-Nepean Flood Risk Management Strategy;
- Endeavour Energy;
- Deerubbin Local Aboriginal Land Council;
- Sydney Trains.

Sydney Water was the only organisation among those listed above to respond to the initial letter and provide information on the infrastructure in the area which may be affected by flooding. Specifically, Sydney Water noted that there are several critical assets in the area, with three wastewater pumping stations within the study area and more just outside the boundary (including the Penrith wastewater treatment plant). Sydney Water provided the location, level and replacement cost of the above mentioned assets.

5.3.3 Liaison with the FM Committee

The first meeting with the Floodplain Management Committee was held on the 4 June 2018 at Penrith Council's offices. During the meeting, the project scope, progress, methodology and timeline were presented and discussed. The Committee asked clarifications about some specific aspects of the methodology, including the damages assessment methodology and the cost/benefit analysis that will be undertaken to assess the economical profitability of the recommended flood risk reduction measures. Overall, no criticisms were made and the project received full support.

5.4 PHASE 2: PUBLIC EXHIBITION

A Draft of the Penrith CBD Floodplain Risk Management Study and Plan Volume 1 (i.e. this report) and Volume 2 (i.e. mapping) were made available to the community during the Public Exhibition phase, from 14 November 2019 to 12 December 2019.

The Public Exhibition also included a community drop-in session, which was held at the Penrith Library on Wednesday 27 November. During the session, the FRMSP key outcomes were presented through a keynote presentation, which was followed by several questions. The meeting was attended by four members of the community.

During the exhibition time, five submissions were received by Council. Four of these were advanced by private citizens or businesses, while one was from Endeavour Energy. All submissions were considered and responded to. No amendments to the draft FRMSP were required.

PART B: FLOOD BEHAVIOUR AND IMPACTS

6 FLOOD STUDIES

An essential foundation for the Penrith CBD Floodplain Risk Management Study and Plan (FRMS&P) is a Flood Study that describes flood behaviour for a range of events up to and including the probable maximum flood (PMF). Flood modelling for the Penrith CBD floodplain was completed by Cardno in 2015. Results are presented in the report titled “Penrith CBD Detailed Overland Flow Flood Study-Final Report”. The modelling used for that Flood Study was reviewed to assess its suitability for the requirements of this FRMS&P. The following sections provide a summary of the flood study, its review and updates.

6.1 PENRITH CBD DETAILED OVERLAND FLOW FLOOD STUDY (CARDNO, 2015)

Penrith CBD Detailed Overland Flow Flood Study (Cardno, 2015) was commissioned to increase the accuracy of overland flood modelling in the CBD area. Compared with the previous “Overview Study”, the key features associated with Penrith CBD Detailed Overland Flow Flood Study were:

- A fine 1m grid was applied within the study area in order to identify the overland flow paths in detail; and
- Detailed one dimensional (1D) components were incorporated within the two dimensional (2D) grids, including pits, pipes, channels, and other hydraulic control structures.

The primary objective of the study was to define the flood behaviour, the flood hazard, and to quantify flood damages under existing conditions that represent the features of overland flow paths and the drainage system. The study provided information on flood extents, flood levels, flows, depths, and flood velocities for a full range of design storm events, including the 20% AEP, 10% AEP, 5% AEP, 2% AEP, 1% AEP, 0.5% AEP events together with the Probable Maximum Flood (PMF) event. This study also defined provisional hazards, hydraulic categories and quantified the flood damages for the study area.

The study developed a hydrological model to obtain upstream input hydrographs into the 1D/2D hydraulic model for the study area and established a 1D/2D hydraulic model to investigate the flood behaviour for the full range of design storm events (Cardno, 2015).

6.1.1 Hydrological Modelling

Hydrological modelling was undertaken using the following two methods:

a) Traditional hydrological modelling using XP-RAFTS

The hydrological modelling was undertaken to develop catchment runoff hydrographs through the entire catchment, including upstream areas of the 2D model domain. These hydrographs generated from the upstream area of the 2D model domain were used as inflow boundaries for the 1D/2D hydraulic modelling.

The catchment was divided into 36 sub-catchments based on the topographic features (using the 0.5-metre contour data supplied by Council), the likely flow paths and the input requirements of the hydraulic model.

The following impervious fractions were used for different types of land use: Urbanised residential = 60%, Industrial/commercial = 90%, Open space = 5%.

The model included nine detention basins which were identified in the study area based on topographic information (Cardno, 2015).

b) Direct Rainfall Method

The Direct Rainfall Method was applied directly within the 2D domain in this study. In the application of the Direct Rainfall Method, the hydrology and the hydraulics were undertaken in the same modelling package: TUFLOW.

The model was validated by comparing the XP-Rafts results with the Rational Method, and the Direct Rainfall methods from alternative modelling software SOBEK (Cardno, 2015).

6.1.2 Hydraulic Modelling

A fully dynamic one and two dimensional (1D/2D) hydraulic model was developed for the study area using the TUFLOW modelling system (version 2010-10-AD).

Channels were modelled as one-dimensional (1D) elements, where the cross-sections were surveyed to define the channel geometry. Once the channel capacity is exceeded, flow is able to spill into the two-dimensional (2D) grid and simulated as overland flow.

Stormwater drainage pits and pipes were also incorporated into the model as 1D elements. Once the pipe capacity is exceeded, excess flow spills into the 2D domain via the pits. Similarly, overland flow is able to enter the pipe network through the relevant pit when the drainage system at that location is not at capacity.

In terms of blockages to pits and pipes, this study adopted 50% blockage to all inlet pits and no blockage in pipes for design events in accordance with Council's blockage policies.

A fine grid size (1m x 1m) was used to simulate the overland flow behaviour in the study area in detail. Buildings within the floodplain in the study area were conservatively assumed to completely block overland flow, and were modelled as raised blocks in the topographic grids (Cardno, 2015).

6.2 REVIEW OF THE FLOOD STUDY

The model set up by Cardno (2015) was reviewed as part of the scope of the Floodplain Risk Management Study.

Once the reviewed model achieved sufficient stability and a practical run time, parts of the input data were modified to incorporate any information which became available after the original 2015 model by Cardno was released. These included:

- A more recent and more accurate terrain model (i.e. a LiDAR survey acquired in 2011);
- A new pipe which had been installed to increase drainage capacity in High Street, between Woodriff Street and Triangle Park;
- A new 1700x1300mm culvert which had been installed from the intersection of Lethbridge Street and Castlereagh Street to the Showground channel.

6.2.1 Blockage

Consistently with the original model developed in the Flood Study (Cardno, 2015), the revised model used a blockage factor of 50% on all pit inlet curves. A 50% factor is generally consistent with Penrith City Council mapping guidelines. This blockage approach (i.e. magnitude blockage factor, applied on all inlet pits) can be seen as a blanket/overall conservative approach, particularly for the minor flood events.

6.2.2 Climate Change

Climate change modelling for the 1% AEP design storm event has not been undertaken as part of the revised model, however it is expected that rainfall intensities will see an increase due to climate change in the future. Expected rainfall increases depend on the specific climate chance scenario and forecast period, with an increase in rainfall intensity expected to be in the order of 10-20% within the modelled area (based on Australian Climate Futures web tool developed by the CSIRO). Two-hundred year ARI rainfall intensities for this area represent a rainfall increase of approximately 12% (ARR 1987 IFD), with a preliminary 200 year ARI modelling scenario done within the TUFLOW model.

The increases in flood depth from 100 year to 200 year results were of the order of 40 cm. Whilst this increase was not specifically addressing a climate change scenario, it does indicate that should climate change modelling be undertaken, the expected flood depths increases would be expected to be relatively small.

6.3 NEPEAN RIVER FLOOD MODELLING

The most recent version of the RMA-2 model used to support the Nepean River Flood Study was adopted by Penrith City Council in November 2018 (Advisian, 2018). This shows that the western parts of the CBD study area can be affected by more extreme floods in the Nepean River (Map 7, Volume 2).

In 2014, Water NSW and Infrastructure NSW commissioned an update to the RUBICON 1D model as part of investigations into flood mitigation options for the Hawkesbury Nepean River. Further modelling has been undertaken as part of the Hawkesbury-Nepean Valley Flood Risk Management Strategy but the results of this modelling was not publicly available at the time of writing.

A Nepean River Floodplain Risk Management Study and Plan is in preparation by Penrith City Council and the Penrith CBD Floodplain Risk Management Study and Plan does not address the impacts of flooding from the Nepean River. However, it does consider the impacts of overland flows on key evacuation routes for Nepean River flooding and discusses the implications of Nepean River flooding on the appropriateness of particular planning controls to respond to overland flooding in the CBD.

7 SUMMARY OF FLOOD BEHAVIOUR

7.1 EXISTING FLOOD BEHAVIOUR

The study area is affected by local flooding from within the catchment and by mainstream flooding from the Nepean River (Map 7, Volume 2). This section provides a detailed description of the behaviour of local overland flooding (i.e. the subject of this FRMSP) and a summary of the Nepean River flood behaviour.

7.1.1 Local Overland Flooding

The flood design events numerically modelled as part of this FRMSP include the 20% AEP event, the 5% AEP event, the 10% AEP event, the 2% AEP event, the 1% AEP event, the 0.5% AEP event and the PMF. Each event but the PMF was simulated with a 2 hour and a 9 hour rainfall duration. The PMF was simulated with rainfall durations of 15 minutes and 30 minutes because longer durations would not be able to generate a sufficient discharge to exceed flooding caused by other events.

The model outcomes were filtered by eliminating the following areas from the flood extent:

- areas affected by flooding less than 150mm deep. These were eliminated because the modelling was done using the “rainfall on grid” method which means that all parts of the catchment will have some depth of water, even if only 1mm. A threshold of 150mm is often chosen to distinguish water depths that can be considered flooding as this is the minimum height residential floor levels must be above ground level to comply with the Building Code of Australia requirements;
- puddles smaller than 100 m^2;
- all areas within 2m from the footprint of each building. These were eliminated because the flood model had generated unrealistic results at these locations due to computational instabilities cause by rainwater running off the roof of each building.

For each AEP event, the filtered model results for the 2 hour and 9 hour duration runs were then merged to obtain an artefactual “envelope” event representing the worst case scenario at each location within the study area.

High resolution maps of peak flood depth and velocity are provided in Volume 2 (Map 8 to Map 20).

The model shows that in all design events, flood behaviour in the upper part of the catchment (i.e. upstream of Woodriff Street) is dominated by the steeper topography, which results in floodwaters concentrating in a relatively small number of overland flow paths. These run west, south west or north-west, and eventually merge to generate a larger flow path between Evan Street and Woodriff Street. Flood affectation in this sector of the catchment is generally limited to the properties locate along or adjacent to these flow paths. However, while flood extents are limited, flow velocities are higher than in the lower catchment.

Downstream of Woodriff Street the topographic gradient decreases significantly and floodwaters spread to affect larger areas, but with lower velocities and longer duration.

The following subsections describe flood behaviour and property affectation in detail for the 20% AEP event, 1% AEP event and PMF.

a) 20% AEP Event

Two overland flow paths originate downstream of Parker Street, at the north-eastern and south-western corners of the study area. These run south-west and north-west respectively across several residential properties until they join to form a single flow path north-east of the intersection of Doonmore Street and Derby Street. Both flow paths run along an existing series of pipes, however these are nearly at full capacity in this event.

The northern flow path starts at the corner between Parker Street and Barber Avenue, where it affects two of the three south bound lanes of Parker Street, although mostly with depths below 0.2m and modest velocities.

Between Barber Avenue and Hope Street the flow path maintains peak depths generally below 0.3m. While running through the backyard of multiple residential properties, the model shows that only seven of these have above floor flooding, with six being part of the same residential development at the eastern end of Barber Avenue.

Downstream of Colless Street the flow path runs along Hope Street, although its depth does not exceed 0.15m and as such it is not visible in the relevant flood maps contained in Volume 2. At the downstream end of Hope Street the flow path reaches the park north-east of the intersection of Doonmore and Derby Street. Only one property, adjoining the above mentioned park, is affected above floor level downstream of the intersection of Hope Street and Colless Street.

The southern flow path originates in Parker Street, between Jamison Road and Stafford Street. It then runs north-west to reach Rosedale Avenue. From here it continues to cross Stafford Road and Colless Street.

It then cuts across several residential properties between Colless Street and Doonmore Street and runs through Spence Park and Derby Street until it joins the northern flow path in the park north east of the intersection of Derby Street and Doonmore Street.

Between Parker Street and Colless Street the model results suggest that five dwellings may experience above floor flooding, whereas downstream of Colless Street there are 13 properties with above floor flooding in this event.

Downstream of Doonmore Street floodwaters continue west within an open canal which runs between several residential properties, most of which are two or three storey apartment blocks. Before reaching Evan Street, the canal is enclosed in a culvert which resurfaces about 20m past the road. The canal has spare capacity in this event, however floodwaters build up at the entrance of the culvert causing above floor flooding in two residential properties and generating an overland flow path which runs west parallel to the culvert.

Downstream of Evan Street the culvert discharges into another section of open canal, which gathers the overland flow path mentioned above. However the canal enters a second culvert upstream of the intersection of Lethbridge Street and Castlereagh Street. The capacity of the culvert is exceeded again, and a new overland flow path originates which continues flowing west. This is then joined by a second overland flow path, which originates in Jipp Street and runs north-west through Evan Street and Hand Avenue, where it causes above floor flooding in six houses.

The resulting overland flow path affects a large number of residential properties, and it causes above floor flooding in five dwellings upstream of Castlereagh Street.

The culvert is then connected to a system of two pipes running from the intersection of Castlereagh Street and Lethbridge Street to the Showground Channel. However the overland flow path veers before reaching the pipes and continues north in Castlereagh Street and west in Tindale Street. It then reaches Woodriff Street, where flow velocity and depth decrease due to the flatter topography. Here floodwaters start spreading north and south in Woodriff Street and continue west to reach Station Street through The Broadway.

From Station Street, part of the floodwaters are gathered in the Showground Channel, while a significant proportion continues north to affect Union Lane Car Park and High Street.

While some overland flooding can be seen affecting the car park, floodwaters in High Street are well managed by the existing stormwater system and drain towards Triangle Park. From this point the stormwater system runs north-west underneath Westfield and continues west along Jane Street. Downstream of Triangle Park the stormwater system has considerable spare capacity in the 20% AEP event and no significant overland flooding can be seen.

In addition to the flow path described above, which is arguably the most significant of the catchment, there is additional overland flooding developing at the boundaries of the study area, namely:

Along Henry Street and Belmore Street. Here floodwaters affect the east bound lanes of Henry Street at the intersection with Evan Street with depth peaking at 0.4m and moderate velocities (below 0.3m/s). It is expected that one of the two lanes would be trafficable in this event. Further downstream, in Belmore Street, floodwaters affect the Belmore Street car park with depths up to 0.35m and velocities up to 0.35m/s at the car park entrance.

In the industrial area north of the railway, in the north-west corner of the study area. This area includes an electricity substation which shows significant local flooding caused by ponding water with depths exceeding 0.5m. The model also shows two industrial buildings with above floor flooding, in addition to a large volume of water ponding in the underpass of Mulgoa Road under the railway;

In Nepean Square and the adjacent residential area, between Castlereagh Street and Woodriff Street. Here there is water ponding at several locations along Woodriff Street and south of Stafford Street, resulting in one house with above floor flooding. North of Stafford Street the model shows an overland flow path running from Castlereagh Street to Woodriff Street, through a low point in Brown Street. This runs parallel to an existing pipe which is flowing at full capacity. Brown Street, in particular, experiences significant street flooding, with depths up to 0.4m and velocities peaking at 0.4m/s. Several houses at this location have their access cut from the 20% AEP event and are affected by above floor flooding in greater events, in addition to being within the reach of the Nepean River mainstream flooding;

At the intersection of Jamison Road and Mulgoa Road, as a result of floodwater overtopping the Bazooka Channel before this enters a culvert under Mulgoa Road. Here Jamison Road is cut west bound by floodwaters with depth up to 0.4m. The east bound lanes also flood, but only one of the two has depths exceeding 0.25m.

b) 1% AEP event

In the 1% AEP event flood behaviour is similar to more frequent events, however flood extents, depth and hazard increase significantly. At some locations in the lower part of the catchment, new and/or more defined flow paths can be observed (e.g. the residential area east of Nepean Square).

In terms of flood affectation, the model shows that the northern overland flow path running south-west from the intersection of Parker Street and Barber Avenue in the 1% AEP causes above floor flooding in 12 properties, five more than the 20% AEP event. Flood depths remain generally below 0.5m upstream of Hope Street. Velocity peaks in Hope Street where it exceeds 2m/s, however here depths are of the order of 0.2-0.3m.

The southern flow path, which originates in Parker Street, east of Rosedale Avenue, causes above floor flooding in 39 dwellings. Flood `depths exceed 1m in the backyard of a house in Colless Street and immediately upstream of Spence Park, and velocities show isolated peaks of 0.9m/s.

The open canal downstream of Doonmore Street is at full capacity from the 5% AEP event, and in the 1% AEP it causes above floor flooding in 23 dwellings upstream of Evan Street and 31 dwellings downstream of it. Peak depths of around 1m are observed adjacent to the canal, with velocities peaking at 1m/s where the canal enters the first culvert, and exceeding 1.5m/s across Evan Street.

The flow path running north-west from Jipp Street causes above floor flooding in 19 houses with depths up to 1m before it joins the above described flow path upstream of the intersection of Lethbridge Street and Castlereagh Street.

The section of Lethbridge Street between O'Farrell Lane and Castlereagh Street experiences peak velocities of 3m/s, although depths are below 0.4m. Between Lethbridge and Tindale Street there are seven commercial buildings with above floor flooding in this event, including the Penrith RSL building.

The overland flow continues west through The Broadway and Union Lane, where there are 13 commercial buildings with above floor flooding.

Further downstream, part of the floodwaters that run through The Broadway veer south towards the intersection of Derby Street and Station Street. These are in part captured in the Showground channel, and in part diverted south along Station Street to Nepean Square's car park, to eventually gather in the southern branch of the Showground Channel. Along this path flood depths are relatively low and there is only one dwelling with above floor flooding in Station Street.

Union Lane Car Park is reached by part of the overland flow path arriving from The Broadway and continuing west in Union Road. In this event a large proportion of the car park becomes flooded with depths exceeding 0.5m, and floodwaters run through the three arcades through the commercial buildings at the northern end of the car park to reach High Street.

At the northern end of the catchment, in Henry Street and Belmore Street, flood depths and velocities are moderate, with the exception of the intersection of Evan Street and Henry Street where depths peak at about 0.5m and velocities exceed 1m/s, making the intersection unsuitable for road traffic. The flood extent in Belmore Street car park increases.

At the north-west corner of the study area, north of the railway, the electricity substation experiences depths up to 1m. Flood depth increases to over 2m at the low point of Mulgoa Road's underpass.

East of Nepean Square the model shows three well defined overland flow paths, namely:

- A flow path running north along Woodriff Street;
- A flow path running from the southern end of Castlereagh Street to Brown Street and from there to Stafford Street. This reaches a hazard equal to H3 and cause above floor flooding in 3 houses;
- A more significant flow path north of Stafford Street, from Castlereagh Street to Brown Street and Woodriff Street. Here floodwaters cut through several residential properties and build up at the low point in Brown Street until they reach a level sufficient to exceed the topographic level at the northern end the road and continue towards Woodriff Street. Here most houses in Brown Street are flood affected and their egress is cut, however the model shows that only one house on Brown Street and one more house closer to Woodriff Street have above floor flooding.

Further south, the intersection of Mulgoa Road and Jamison Road is cut with peak depths of 0.45m.

c) PMF

In the PMF, flood behaviour upstream of Woodriff Street is not dissimilar to that of more frequent events, although all the overland flow paths observed in the 1% AEP increase in depth, velocity and extent. Aside from this, a few new flow paths develop at several locations and join the main flow paths shortly after they originate, but these are relatively shallow with low velocities and as such do not significantly affect the overall flood risk footprint.

The northern flow path running south west from Parker Street and Barber Avenue in this event reaches depths of 1m upstream of Lethbridge Street, with average velocities through the residential properties of about 1m/s. Along the roads however velocities increases to peaks of 2m/s (Barber Avenue and Lethbridge Street) and 3.5m/s in Hope Street. Overland flooding on Hope Street begins just downstream of Parker Street and joins the main flow path at the intersection with Colless Street.

The southern flow path reaches depths between 1.5m and 2m upstream of Colless Street, and over 2m downstream of it. Velocities are up to 1-1.5m/s within residential lots and up to 3.5m/s along sections of Rosedale Avenue, Stafford Street and Colless Street.

Doonmore Street is cut by floodwaters between 1.5m and 2m deep and with velocities peaking at 2.5m/s. Downstream of the road, where the canal enters the first culvert, peak depths and velocities reach values of 2.3m and 2m/s respectively. The area affected by flooding extends north to reach Lethbridge Street which experiences velocities in excess of 1.5m/s upstream of Evan Street. Velocity increases significantly downstream of Evan Street, with the model showing maximum values in excess of 4.5m/s at the intersection with Castlereagh Street.

The flow path running north-west from Jipp Street reaches velocities of 2m/s in Evan Street and Stafford Street, and peaks at over 3m/s in Hand Avenue. Depths in this section are generally below 1m.

Here the flow path continues west in Lethbridge Street and north in Castlereagh Street, then west in Tindale Street, Master Place and High Street. In this area, while depths are generally below 05.m, velocities are significant, particularly in Lethbridge Street (4m/s), Tindale Street (3m/s) and High Street (2m/s).

Downstream of Woodriff Street, all roads and most properties within the study area flood. Flow velocities are higher along roads, and in this section of the study area are generally between 1m/s and 2m/s. There are however isolated locations with peak velocities exceeding 3m/s. These include the intersection of The Broadway and Station Street, the western end of Rodley Avenue, and at the intersection of Jamison Road and Woodriff Street.

Flood depths are generally below 1m, however they reach and exceed 1.5m at those locations affected also in more frequent events. These include the western end of Jane Street, High Street (downstream of Station Street), Union Lane Car Park, Rodley Avenue, Nepean Square and Jamison Road.

7.1.2 Nepean River Flooding

Floodwaters from the Nepean River first approach the study area by backing up Peach Tree Creek. The industrial area in the north western corner of the study is the first area to be flooded which occurs when the river reaches about 25m AHD at the Penrith Gauge at Victoria Bridge which is just above the 2% AEP level in the Nepean River. By the time the water level reaches 26m AHD the whole of the industrial area in the north west corner of the study area is inundated, the railway underpass on Mulgoa Road is under water and floodwaters are starting to enter the electricity substation. This is around the 1% AEP Nepean River flood level.

Once it has reached 27m AHD, the levees along the river have been overtopped and floodwaters flow freely from the river towards the study area. Mulgoa Road is inundated along most of its length within the study area, the whole substation is flooded, water has backed up along Showground Channel and flooded residential areas between it and Rodley Avenue and water has travelled up Jane Street, Henry Street and High Street as far as Station Street. This is a bit higher than the largest flood recorded which occurred in 1867. There is sedimentary evidence in Fairlight Gorge that at least one flood has exceeded this level.

As water levels in the river rise they will progressively flood more and more of the study area moving eastward. The level of the PMF is about 31.5m AHD and flooding would extend east into the study area as far as Castlereagh Street.

7.1.3 Classification of Flood Behaviour

While mapping flood extents, depths and velocities is useful, some form of classification of flood behaviour is required for determining what hazard flooding poses and what are appropriate land uses in the floodplain. This was done by means of:

- hydraulic flood hazard classification;
- hydraulic function classification; and
- emergency response classification.

a) Hydraulic Hazard Categories

Hydraulic hazard is a parameter defined to encapsulate a measure of the potential damage that floodwaters can cause to life and property. Hydraulic hazard is obtained as the product between flow velocity and depth.

The NSW Floodplain Development Manual (2005) distinguishes high hazard, low hazard and a 'transitional' hazard using peak flood depths, velocities and depth-velocity product. This can be considered to be a provisional flood hazard categorisation as it does not consider a range of other factors that influence flood hazard. Therefore provisional hazard categorisation should be used in conjunction with the following factors to determine true hazard categories:

- Extent of flood;
- Effective warning time;
- Flood preparedness;
- Rate of rise of floodwaters;
- Duration of flooding;
- Evacuation problems;
- Effective flood access; and
- Type of development.

For the purposes of the Penrith CBD Floodplain Risk Management Study, consideration was given to a more finely divided hydraulic hazard classification presented in ARR (2019). This combined previous research on the impact of floodwaters on the stability of people, vehicles and buildings to generate a comprehensive hydraulic hazard classification. This classification includes six categories, ranging from H1 (no restrictions), to H6 (not suitable for people, vehicles or buildings). These six hydraulic hazard categories are shown in Figure 5.

The hazard classification of the study area is shown in Map 21 to 23 (Vol. 2).

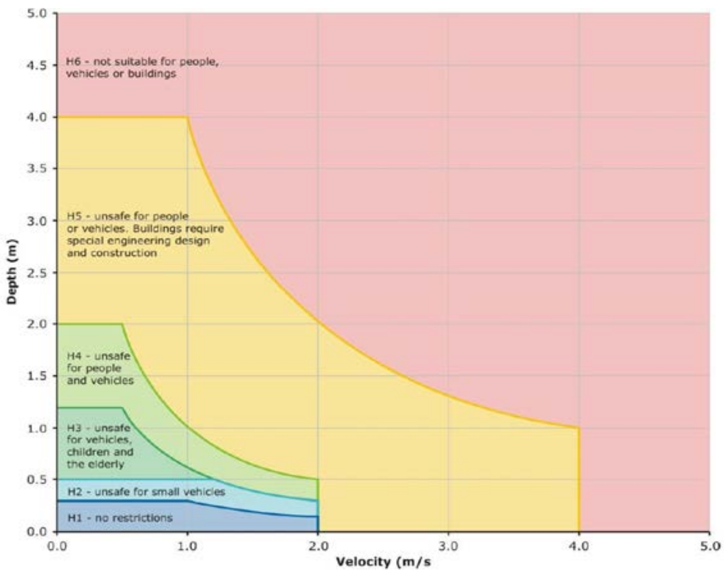

Figure 5. Hydraulic Hazard Categories (ARR, 2019)

b) Hydraulic Categories

Hydraulic classification divides the floodplain according to its hydraulic function. The NSW *Floodplain Development Manual* (2005) recommends three hydraulic categories: floodway, flood storage and flood fringe.

It is not feasible to provide explicitly quantitative criteria for defining floodways, flood storage areas and flood fringe areas, as the significance of such areas is site specific. The following semi-quantitative definitions are set out in the NSW *Floodplain Development Manual* (NSW DPINR, 2005):

- Floodways – areas conveying a significant proportion of the flood flow and where even partial blocking would cause a significant redistribution of flood flow or a significant increase in flood levels.
- Flood storage areas – those areas outside floodways which, if completely filled with solid material, would cause peak flood levels to increase anywhere by more than 0.1 m and/or would cause the peak discharge anywhere downstream to increase by more than 10%.
- Flood fringe areas – the remaining area of land affected by flooding, after floodway and flood storage areas have been defined. Development in flood fringe areas would not have any significant effect on the pattern of flood flows and/or flood levels.

In this study the hydraulic classification was achieved by generating a base case based on the following assumptions in the 1% AEP event:

- Flood Fringe Areas are those with a hazard level of H1 or H2;
- Flood Storage Areas have hazard levels of H3 and H4;
- Floodways have hazard levels of H5 or H6.

The base case was then fine-tuned with a location-specific analysis of the flood model results based on expert judgment. The resulting classification is shown in Map 24, (Volume 2).

c) Emergency Response Classification

In addition to a classification of floodwaters based on hydraulic function and hydraulic hazard, flood risk to people can be further described using the NSW SES's Flood Emergency Response Planning (ERP) Classification of Communities (DECC, 2007b), or the similar Flood Emergency Response Classification of the Floodplain proposed by AIDR (2017).

These classifications provide a way to measure the relative vulnerability of communities when they are responding to a flood threat, which is from immediately before to immediately after the flood.

During a flood, a community is deemed more vulnerable if evacuation, resupply and rescue operations are difficult. The NSW SES's ERP classification proposes to use the PMF to identify and map the following categories of land (in order of significance from higher to lower risk):

- Low Flood Islands (LFI) and Low Trapped Perimeters (LTP)
- High Flood Islands (HFI) and High Trapped Perimeters (HTP);
- Areas with Overland Escape Route (OER);
- Areas with Rising Rd Access (RRA);
- Indirectly Affected Areas.

Flood Islands are defined as inhabited or potentially habitable areas of high ground within a floodplain linked to the flood- free valley sides by a road across the floodplain and with no alternative overland access. The road can be cut by floodwater, closing the only evacuation route and creating an island. After closure of the road the only access to the area is by boat or by aircraft. Flood Islands include High Flood Islands (HFI) – and Low Flood Islands (LFI).

Low flood islands are those areas where the escape routes are cut before premises are inundated, but as floodwaters rise there is insufficient area, or no land, on which to shelter and they are eventually overwhelmed by floodwaters. People trapped in LFI are at life risk and the only safe response option is to evacuate early (i.e. before they are surrounded by floodwaters) or to take shelter at the higher levels of buildings, provided that these are above the PMF level and can withstand the forces of a PMF.

High flood islands are those areas whose escape routes are cut by floodwaters but there is sufficient available high ground for occupants of the isolated area to retreat to should floodwaters continue to rise and enter their building. Late evacuation is not a safe option for people isolated in HFIs, and resupply and rescue operations can be difficult.

Trapped Perimeter Areas are defined as habited or potentially habitable areas at the fringe of the floodplain where the only practical road or overland access is through flood prone land and unavailable during a flood event. The ability to retreat to higher ground does not exist due to topography or impassable structures. Trapped Perimeter Areas are similar to Flood Islands, and can also be classified in high and low, depending on whether these are completely submerged with floodwaters in the PMF.

Areas with Overland Escape Routes (OER) are areas whose road access gets cut in the PMF but from which evacuation is possible by walking or driving overland to higher ground.

Areas with Rising Road Access (RRA) are areas whose access road rises steadily uphill and away from floodwaters. Even though these areas will eventually flood in the PMF, evacuation can take place by vehicle or on foot along the road as floodwater advances.

“Indirectly affected areas” are areas outside the extent of flood-prone land which may be indirectly affected by the flooding because of impacts on infrastructure such as the transport network.

The extent of flood-prone land within the CBD catchment was classified using the guidance provided by the NSW SES’s ERP. This was done to provide information to the NSW SES, and to support the identification of risk “hotspots”, in which local flood mitigation measures may be required (see Section 9).

However, because the NSW SES ERP classification was created to encompass response options to mainstream riverine flooding such as that created by the Nepean River, a simplification of the approach was required to address local flooding in the CBD. Namely, the analysis identified and mapped buildings within high and low flood islands, as well as buildings with rising road access.

Indirectly affected areas were assumed to be all areas within the CBD that are not affected by local flooding in the PMF.

Trapped Perimeter Areas and OER were not mapped because this would have required recognising all possible barriers to evacuation including small-scale items such as property fences, which in an evacuation would become an obstacle for children, elderly people or people with disabilities.

The use of the ERP classification in catchments affected by local flooding is further complicated by the fact that every building surrounded by floodwaters in the PMF is, from a practical point of view, a flood island in itself. Due to the lack of flood warning and high rate of rise of floodwaters in the CBD, in most instances building occupants will not think of evacuating until floodwaters reach their doorsteps or start entering the building. By that time all the building evacuation routes will likely be already cut and evacuation will be impossible, unless the occupants make the decision of walking or driving through floodwaters, which the NSW SES strongly advises against.

While buildings with above floor flooding in the PMF may be considered Low Flood Islands, buildings that are isolated by floodwaters but whose floor area is not completely submerged (e.g. because there is no above floor flooding) fulfil the definition of High Flood Island.

The flood model results show that in the lower part of the CBD, downstream of Castlereagh Street, all roads flood in the PMF, and they do so before most buildings start experiencing any above floor flooding. As such, the large majority of buildings downstream of Castlereagh Street were classified as flood islands.

Risk to people in this area is further exacerbated by mainstream flooding from the Nepean River, which in the PMF extends up to Woodriff Street and Lawson Street (Map 7, Vol. 2). For the purpose of further prioritising risk to people in this area, subsets of the main flood island that become isolated in local events more frequent than the local PMF were identified and mapped. These are referred to as “high risk flood islands”.

In the upper part of the catchment, flood behaviour is such that several buildings may have rising road access to flood free ground. For instance, this applies to the area between Castlereagh Street and Doonmore Street, where floodwaters rising from the canal running at the back of the residential properties may “push” the building occupants to higher ground. However, as previously noted, it is unlikely that the building occupants would think of evacuating before they see floodwaters inside the building, and at that point any attempt to evacuate would be too dangerous.

As such, even in the upper part of the catchment, all buildings surrounded by floodwaters in the PMF were conservatively assumed to be flood islands, and only those that maintain flood free access to higher ground at the peak of the flood were classified as having rising road access.

To distinguish between low and high flood islands it was assumed that if the modelling showed a building experienced any above floor flooding during a PMF then it was a low flood island. Again this is conservative as there are many buildings which would be flooded at ground level but which have a habitable floor level above the PMF and in that sense could be considered high flood islands.

The resulting emergency response classification map is shown in Map 25 (Vol. 2).

8 FLOOD RISKS

8.1 RISK TO BUILDINGS

To be able to determine how best to manage overland flooding in the Penrith CBD catchment, it is first necessary to understand the impacts of flooding.

This section explains how the results of the Penrith CBD Flood Study, whose modelling was revised as part of this study, were combined with other information to estimate direct and indirect flood damages to residential and non-residential properties. This information guided the identification of flood risk "hotspots", where flood mitigation may be beneficial.

8.1.1 Building Database

A building database was prepared to better understand the spatial distribution of building inundation, and to quantify the impacts of overland flooding in Penrith CBD. This will also facilitate an economic appraisal of floodplain management options.

For each building, the following data was obtained:

- **Address and Location** (spatial coordinates);
- **Building Use**, classified in the following categories: Residential (R), Commercial (C), Industrial (I), Education (E), Health (H), Police Station (PS), Emergency Services (ES);
- **Ground Level,** intended as the topographic elevation of the ground at a given point on the building perimeter;
- **Floor Height,** the vertical distance between the same point on the building perimeter and the lowest habitable floor level;
- **Floor Level,** intended as the topographical elevation of the lowest habitable floor level of each dwelling;
- **Flood Levels,** intended as the peak flood level at the building perimeter in each design event as calculated by the flood model;
- **Number of Dwellings** within each residential building;
- **Number of Storeys** (in each dwelling);
- **Area** of Building Footprint.

The following sections describe how this data was obtained, and the assumptions that were made.

8.1.2 Available Data

The following data was made available by Council at the beginning of the project and was used to inform the damages assessment exercise:

- Access to recent high resolution aerial imagery provided by Six Maps (https://maps.six.nsw.gov.au/);
- The 2011 LiDAR survey of the study area;
- GIS cadastral mapping;
- The outcomes of a preliminary building damages assessment undertaken as part of the Penrith CBD Flood Study (Cardno, 2015). These included a database of flood affected buildings within the CBD in GIS format, as well as the estimated damages for each design flood event. However, after an extensive review of this dataset, Molino Stewart deemed the available building database to be unreliable and agreed with Council that a new updated database was required.

A new building database for Penrith CBD was generated by combining data collected in the field and Molino Stewart's Nepean River Floodplain Building Database.

a) Molino Stewart's Nepean River Floodplain Building Database

i) Description of the Database

In 2013, as part of a study to assess flood risk reduction options for the Warragamba Dam for Infrastructure NSW, Molino Stewart generated a GIS database of all buildings within the Nepean River floodplain. A detailed description of the database is provided in Appendix B.

ii) Database Updates and Amendments

Molino Stewart's dataset included all the information required for each building within the extent of the Nepean River floodplain. However, the ground level and the floor level within the Penrith CBD study area were updated using the 2011 LiDAR Digital Elevation Model (DEM) provided by Penrith City Council, because:

- The 2011 LiDAR was a more accurate DEM than the one used in Molino Stewart's database; and
- For consistency with the revised flood models, which were built using the 2011 LiDAR DEM.

In addition to this, the database was updated as follows:

- Any new buildings that were constructed after Molino Stewart's database was created were added in. The relevant data was obtained from Google Street View and the aerial imagery;
- Where individual buildings had been replaced by apartment blocks, the relevant data was updated for each additional dwelling;
- The assumption that all non-residential buildings had their ground floor at ground level was considered appropriate for commercial and industrial premises, but not for the remaining non-residential uses (i.e. education buildings, hospitals, police stations and emergency services facilities). Of these, only seven education buildings were identified in the area covered by Molino Stewart's database (i.e. six daycare centres and a TAFE building), and the relevant floor height was modified to an average value of 0.15m based on visual inspection through Google Street View.

b) Field Surveys

Molino Stewart's existing building database provided the required information only for buildings located in the western part of the CBD (i.e. within the Nepean River floodplain). For the remaining buildings there was no reliable pre-existing information, and a field survey was required.

A total of 357 residential, commercial and industrial buildings were surveyed in the field. Some of these buildings contained multiple dwellings per building and so the data was entered in the GIS in the form of a point layer, where each point represented a dwelling. For each dwelling, the required information was collected as follows:

- Address: from desktop review;
- Spatial Coordinate: from aerial imagery;
- Floor Height. This was obtained in the field by counting the number of steps to enter the building or the number of bricks between the ground and the ground floor (under the assumption that the height of each step and brick are 17 cm and 8.6 cm respectively, as per the Building Code of Australia). It should be noted that floor height can vary significantly across the building footprint depending on where this is measured, because most buildings are not located on perfectly level ground. To ensure that the measured floor height was accurate, the surveys were undertaken using mobile GIS devices showing a footprint of the buildings to be surveyed. In this map, each dwelling was represented by a point, which was positioned along the building perimeter at a location clearly identifiable when observing the building from the street. These points were used as a reference during the field surveys to measure the floor

height. Dwellings at the second storey of apartment blocks were assumed to have a floor height of 2.6m above the ground floor level, similarly to Molino Stewart's Nepean River Database;

- Number of Storeys: from field inspection;
- Land Use: from field inspection;
- Number of dwellings within each building (if residential): from field inspection;
- Ground Level: extracted from the 2011 LiDAR DEM using the same co-ordinates used to measure Floor Height;
- Floor Level: obtained summing Ground Level and Floor Height.

8.1.3 Flood Levels

Flood levels were obtained from the revised flood model outputs for each dwelling and non –residential buildings. This was achieved by:

- generating the "peak of peaks" flood level (i.e. the maximum flood level for a range of flood durations across the study area) for each design flood event;
- cleaning the "peak of peaks" water surface by removing the first 0.15m of water depth and any "puddles" smaller than 100m^2;
- removing any model artefacts. In some cases, rain on grid models tend to generate artefactual "crowns" of water around each building footprint. This water is not representative of what would happen in a real flood event and may lead to overestimating flood affectation. This artefact was removed by "clipping" the model's peak of peaks water surface using an edited version of the building footprint polygon layer. Namely, all building footprints were buffered outwards by 2m (i.e. the size of a grid cell in the model), before being used to clip the modelled water surface;
- using a GIS zonal statistics tool to calculate the maximum flood level within a distance of 3m from the building footprint for each design flood event,, and transferring this value to the point representing each dwelling or non-residential building.

8.1.4 Finalisation of the Building Database

The final building database was created in the form of a GIS layer of points, where each point was representing a dwelling (or a non-residential building) within the PMF extent. Although a polygon layer representing buildings was also available from the Flood Study (Cardno, 2015), the point layer was deemed more practical because:

- the methodology used to survey the floor height was based on points; and
- Molino Stewart's Nepean River Database was primarily available in point format.
- The area of each building footprint, which was also required to estimate flood damages, could be extracted from the polygon layer from Cardno (2015) and transferred to each point.

8.2 DAMAGES ASSESSMENT

8.2.1 Types of Flood Damage

The definitions and methodology used in estimating flood damages are well established. Figure 6 summarises all the types of flood damages examined in this study. The two main categories are tangible and intangible damages. Tangible flood damages are those that can be more readily evaluated in monetary terms. Intangible damages relate to the social cost of flooding and are more difficult to quantify in monetary terms and often difficult to quantify using other metrics.

Tangible flood damages are further divided into direct and indirect damages. Direct flood damages relate to the loss (or loss in value) of an object or a piece of property caused by direct contact with floodwaters, flood-borne debris or sediment deposited by the flood. Indirect flood damages relate to loss in production or revenue, loss of wages, additional accommodation costs and living expenses, and any extra outlays that occur because of the flood.

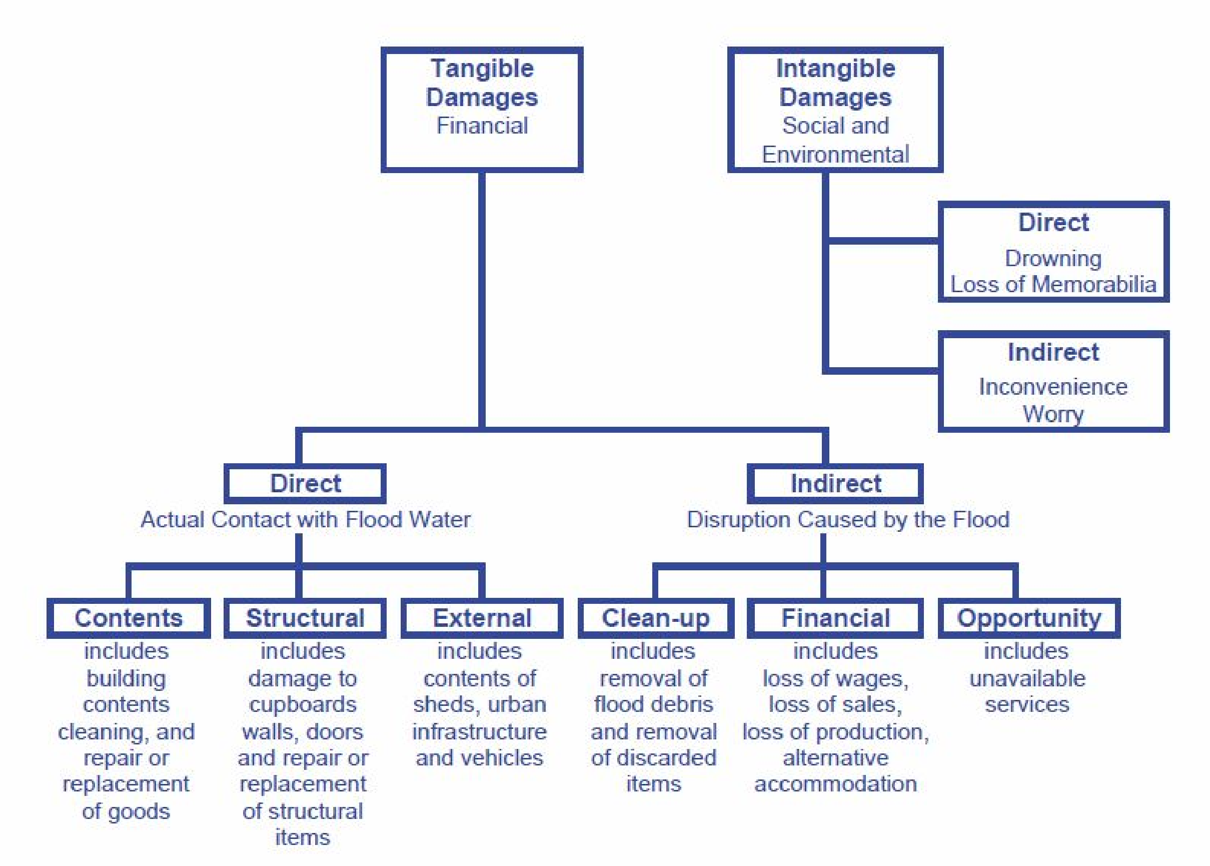

Figure 6. Types of flood damage

Source: Floodplain Development Manual (DIPNR, 2005)

8.2.2 Flood Damages Calculations

Direct flood damages have been estimated by applying one of several stage-damage curves to every building included in the database. These curves relate the amount of flood damage that would potentially occur at different depths of inundation, for a particular building type, both residential and non-residential.

a) Residential

i) Direct Damages

In October 2007, the then Department of Environment and Climate Change, now Department of Planning, Industry and Environment (DPIE), released guidelines to facilitate a standard methodology for assessing residential flood damages (DECC, 2007a). It is a requirement of DPIE grant funded projects that the DPIE standard procedure be employed in order that the merits of funding flood mitigation projects can be compared consistently across NSW.

The DPIE method can be applied using a dedicated computational tool, provided in the form of an MS Excel spreadsheet. The tool requires some boundary parameters to tailor the calculations to the characteristics of each particular study area. The parameters used in this study for all flood ranges and dwelling sizes are shown in Table 3. The rationale for each of these is as follows.

Buildings

- Regional cost variation factor. Penrith LGA was assumed to be part of the Sydney metropolitan area and therefore a value of 1 was adopted;
- Post late 2001 Adjustment. This value was calculated as the May 2018 AWE of 1206.9 (all employees average weekly total earnings) divided by the November 2001 AWE of 673.6 (both of which were taken from the ABS website in 2018). The value obtained is 1.79. (We note that the DPIE spreadsheet has a November 2001 value of 676.4. If this value were used it would have given an adjustment factor of 1.78, which is not significantly different to the value adopted);
- Post Flood Inflation Factor. We selected the factor value recommended by DPIE for small scale impacts in a regional city, given the depths of inundation are unlikely to cause significant structural damage;
- Typical duration of immersion. This value would vary based on the size of the flood and the location of the dwelling in the landscape, however in the worst case scenario the duration is unlikely to exceed 3 hours, and would be generally shorter. We note that this value does not affect directly the calculations, but is used as a reference to determine building and contents damage repair limitation factors;
- Building damage repair limitation factor. DPIE's suggested range is 0.85 (for short immersion time) to 1.00 (for long immersion time). Based on the assumption that duration is unlikely to exceed 3 hours, the lower range limit was adopted;
- Typical House Size. The average house size was obtained as an average value of all the dwellings within the extent of flood prone area.

Contents

- Average Contents Relevant to Site. The recommended average contents value from the spreadsheet was adopted (While it is acknowledged that the standard contents stage-damage curves may under-report damage to contents given an increasing use of technology in houses, they were adopted in this study without modification);
- Contents Damage Repair Limitation Factor. The DPIE suggested range is 0.75 (for short immersion time) to 1.00 (for long immersion time). Based on the assumption that duration is unlikely to exceed 3 hours, the lower range limit was adopted;
- Level of flood awareness. A low flood awareness is assumed as per the DPIE guideline;
- Effective warning time. Given the flashiness of inundation in the catchment, zero effective warning time is assumed;
- Typical table bench heights. 0.9 metres is the adopted typical table bench height.

Additional Factors

- External damage. The guideline value of $6,700 (2001 value) was used. The spreadsheet inflates this to 2018 dollars ($11,993) based on changes in AWE;
- Clean-up costs. The guideline value of $4,000 was used (2001 value). The spreadsheet inflates this to 2016

dollars ($7,160) based on changes in AWE;

- Likely time in alternative accommodation. Given typically shallow inundation, dwellings are unlikely to be uninhabitable for a prolonged period following the flood. A period of two weeks has been adopted;
- Additional accommodation costs /loss of Rent. The guideline value of $220 per week was used (2001 value). The spreadsheet inflates this to 2017 dollars ($394 per week) based on changes in AWE.

Two Storey House Building & Contents Factors

- Second storey floor level. The standard floor level of a second storey was assumed to be 2.6 metres above the ground floor level. For additional storeys we have assumed 2.6m;
- Flood depth adjustment factors. The DPIE guideline and spreadsheet recommend different factors to be applied to two storey houses, depending upon whether or not the water overtops the second storey. It recommends that 70% be used if the water is below the first floor level and 115% if it is above. Alternative values cannot be justified, so the recommended values are used.

The DPIE spreadsheet also requires that the flood level for each design scenario is entered for each building. The maximum flood level impacting each building was extracted from the flood model results by applying a 2m buffer around the building footprint and selecting the maximum flood level within the buffered area.

The resultant stage-damage curves (for residential buildings) are shown in

Figure 7.

Table 3. DPIE input values used for all flood ranges and dwelling sizes

Input Field	Input values
Regional cost variation factor	1.00
Post late 2001 adjustments	1.79
Post-flood inflation factor	1.00
Typical duration of immersion	< 3 hours
Building damage repair limitation factor	0.85
Typical House Size	240 sq.m.
Average Contents Relevant to Site	$57,750*
Contents damage repair limitation factor	0.75
Level of flood awareness	Low
Effective warning time	0 hours
Typical table bench height	0.90
External damage	$6,700*
Clean Up Costs	$4,000*
Likely time in alternative accommodation	2 weeks
Additional accommodation costs	$220*/week
Up to second floor level	2.6m
Second storey floor level	2.6m
Flood depth adjustment factor	70% for two storey house where second storey not flooded
Flood depth adjustment factor	115% for two storey house where second storey flooded

* 2001 dollar values as per DPIE spreadsheet before application of AWE inflation factor

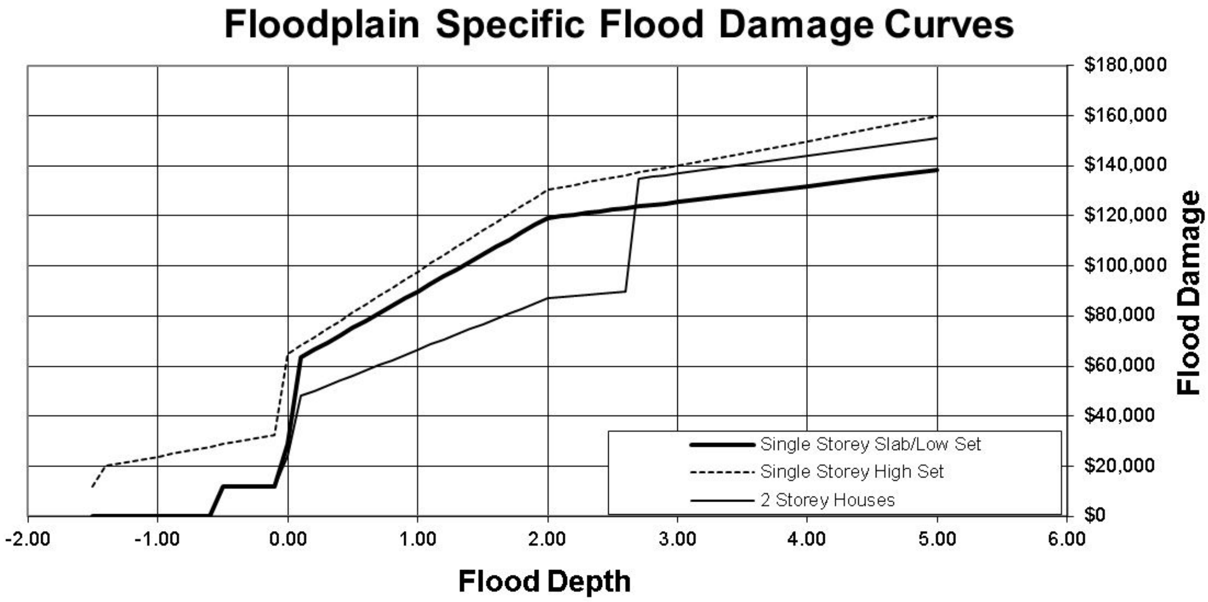

Figure 7. Residential stage-damage curves for Penrith CBD

ii) Indirect Damages

For the residential sector, indirect damages include clean-up costs, the costs of alternative accommodation, the costs of moving, loss of wages and additional living expenses. A number of methods have been put forward for estimating these costs either individually or in aggregate.

The simplest method used has estimated indirect damages as a percentage of direct damages. Past research into the percentages assumed has indicated ranges of between 5% and 40% depending on what was included in the damage estimates (for example, the lower end of the range excluded clean-up costs) and the scale of the flood impacts.

The DPIE damage calculation spreadsheet includes an allowance for alternative accommodation and an allowance for clean-up costs, with the recommended clean-up cost being $4,000 (2001 dollars). This value was adjusted to 2018 dollars, which produced a value of $7,160, and was used to estimate clean-up costs in this study area for each building experiencing external damages.

With regard to alternative accommodation, DPIE's recommended value of $220/week (inflated to $394 in 2018 dollars) was also used in this study, assuming that alternative accommodation will be required for 2 weeks.

Together these two contributions to indirect residential damages make up a total cost of $7,948, which is the same for every home irrespective of the depth of flooding which it experiences or the frequency of the event. Due to the relatively low flood depth that would be observed in the study area, this cost was considered a realistic estimate of residential indirect costs per building.

Clean-up costs for residential damages are based on the opportunity costs of people involved (wage rate or average weekly earnings for time lost at work) and the cost of materials required (BTE, 2001). Clean-up time for residential damages is highly variable and depends on an individual's experience with flooding and what the clean-up involves. BTE (2001) recommends around $330 (in 1999 dollar values) for residential clean-up expenses plus 20 days for clean-up time. Reese and Ramsay (2010) estimate clean-up costs by multiplying clean-up time by an hourly labour rate ($20/hr) for residential properties. Using these assumptions, if 20 days times $20/hr times 8 hours of work per day were used as a reference, after multiplying this (i.e. $3,200) for the 2018/2010 AWE, we would obtain a cost of $3,953. This, when summed to $650 (which is obtained by inflating the clean-up expenses of $330 with the 2018/1999 AWE), would give a final clean-up cost of $4,603, which compares to the $7,160 allowed for by DPIE.

The maximum and minimum residential damages in the study area range from about $29,173 to $119,915 if we ignore those which have external damage only. If we consider that the cost of indirect damages estimated as $7,948 is included in these figures, then the direct residential damages in each event range from approximately $21,173 to $111,967. This means the indirect damages of about $8,000 represent between 37% and 7% of the direct damages respectively. While 7% is consistent with research findings, figures closer to the 37% mark are higher than average. However in the study area there are several buildings which are affected only by very shallow flooding. For these buildings direct damages are very low, and indirect costs for items such as clean-up and alternative accommodation become may become proportionately very high.

b) Non-Residential Properties

i) Direct Damages

Presently there is no adopted industry standard suite of stage-damage curves for calculating direct commercial and industrial flood damages in Australia.

The most widely adopted stage-damage functions in Australia are those developed for the ANUFLOOD model, developed in 1983 and revised in 1994. Many studies have used the ANUFLOOD functions with adjustment factors to derive current values, based on CPI or AWE inflation.

Other studies in Australia adopt the FLDAMAGE model developed by Water Studies in 1992. FLDAMAGE is similar to ANUFLOOD in that it derives an estimate of total flood damages for inundated buildings by applying stage-damage curves appropriate to each type of property.

Both of these sets of stage damage curves were derived from data collected following Australian floods in the 1970s and 1980s when the contents of commercial and industrial premises were very different to today.

An international literature search has shown that the most up to date stage damage curves have been developed by the Flood Hazard Research Centre (FHRC, 2013) at Middlesex University in the UK. These stage-damage curves are based on field observations made in the UK between 2003 and 2005. As such, they provide a contemporary evaluation of the damage to buildings and building contents. They are referred to as FLOODSite MCM.

The MCM curves represent a great diversity of commercial, industrial and other building uses. However, it is noted that commercial and industrial building uses often change so to apply specific curves to individual buildings in the Penrith CBD may not be accurate over time.

Therefore for this study six different stage-damage curves for non-residential premises were used: commercial, industrial, education facilities, healthcare facilities, emergency services and police stations. The relevant stage damage curves are shown in Figure 8.

The commercial and industrial curves are derived from average values across the full range of MCM commercial and industrial curves respectively, which the other categories used the actual MCM curves. The original MCM curves were converted to Australian dollars and adjusted to 2018 values.

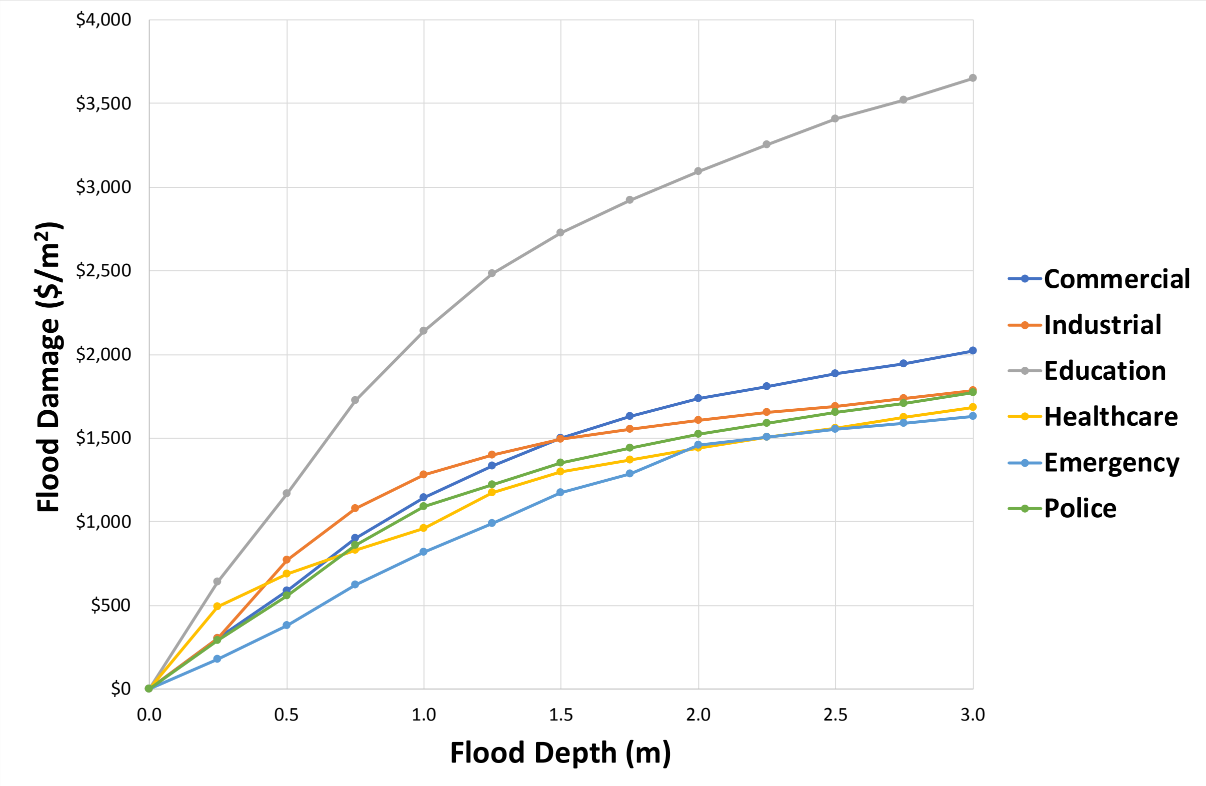

Figure 8. Commercial and industrial stage damage curves

ii) Indirect Damages

Indirect business damages include:

- removal and storage costs;
- clean-up costs;
- payments to workforce for unproductive work;
- extra payments to the workforce (e.g. additional staff or overtime) to make up for lost production or to maintain production;
- costs of transferring production including use of alternative premises or less efficient plant, equipment or systems;
- long term efficiency losses;
- losses to customers;
- loss of production in non-flooded businesses due to interruption of workforce, supplies or sales;
- downturn in trade due to changed regional expenditure patterns caused by flooding;
- loss of business confidence through cancellation of contracts;
- loss of market position and possible closure of business.

There are several methods which have been suggested to estimate indirect commercial and industrial damages, either in part or in aggregate.

The Bureau of Transport Economics (BTE, 2001) cites NRC (1999) as international evidence that indirect costs increase as a proportion of total disaster costs with the size of disaster. It also notes that estimation of indirect damages as a percentage of total direct damages is common but varies widely as there is no simple relationship between the two types of damages.

In a review of flood damages research undertaken for the Warragamba Flood

Mitigation Dam EIS (Sydney Water, 1995), indirect damages for commercial and industrial properties ranged from 25% to 150% of direct damages, depending on the type of business and flooding severity. The higher values were derived from research in Nyngan following the flood there in 1990 which resulted in much of the town being flooded, the entire town being evacuated for three weeks and spending patterns being highly abnormal when people returned. This is unlikely to be the case in Penrith CBD.

QNRM (2002) recommends the ANUFLOOD model estimations of indirect commercial damages as 55% of direct commercial damages. Bewsher Consulting (2003) cites studies that suggest an estimate for indirect commercial/industrial damages as 5% of actual direct damage for every day of trading that is lost. In later studies, Bewsher Consulting (2011a & b) calculated the indirect commercial damages as 20% of direct commercial damages, in keeping with advice from DPIE. This was in a flash flood catchment where part of a shopping precinct would be flooded and is perhaps analogous to Penrith CBD, but not necessarily the industrial premises.

In contrast to residential clean-up costs, the clean-up costs for commercial and industrial damages are estimated by BTE (2001) as ranging between $2,000 and $10,000 (in 1999 dollars) and clean-up times to be between only 1 and 3 days.

Reese and Ramsay (2010) estimate clean-up costs for commercial and industrial buildings by multiplying clean-up time by an hourly labour rate ($80/hr and $45/hr respectively).

Disruption to business involves the estimation of value added foregone, or loss in profits, not including the value of lost sales or stock (EMA, 2002; BTE, 2001; QNRM, 2002). This value is influenced by the length of disruption, whether the business can be transferred within or beyond the affected area and availability of alternative resources (BTE, 2001; Scawthorn et al., 2006). Smith (1979) estimated the cost of lost business accounting for 67% of indirect commercial damages and 71% of indirect industrial damages.

Reese and Ramsay (2010) measure business disruption by functional downtime and loss of income. Functional downtime is assessed as the time (in days) the business cannot operate and is scaled according to a building damage threshold of 10%. Loss of income is ascertained by determining daily income per employee.

Given the large number and diverse types of commercial and industrial premises across the CBD it is not practical to estimate functional downtime and loss of income per business therefore the indirect losses have been estimated as a percentage of direct losses.

We recommend that 20% of direct costs be used for commercial premises as per the earlier DPIE advice to Bewsher Consulting. We also recommend that 50% be used for the industrial premises as many have specialist equipment which is not quickly replaceable.

c) Other Types of Damage

In some floodplain risk management studies, an estimate of 15% of total residential and commercial/industrial damages has been added to make a provision for damages to infrastructure.

Some studies also include a tangible estimate (sometimes 20-25% of total residential and commercial/ industrial damages) in an attempt to measure intangible, social damages. These include the impacts of flooding on health – physically and emotionally. DPIE has also indicated that this is an acceptable approach in NSW.

Consistently with previous work, this study considered:

- a damage to infrastructure equal to 15% of total residential and commercial/ industrial damages, and

- a social/intangible damage estimated to be 25% of total residential and commercial/industrial damages.

d) Economic Analysis

An economic appraisal is required for all proposed capital works in NSW, including flood mitigation measures, in order to attract funding from the State Government's Capital Works Program. The NSW Government has published a Treasury Policy Paper to guide this process: *NSW Government Guide to Cost-Benefit Analysis* (NSW Treasury, 2017).

An economic appraisal is a systematic means of analysing all the costs and benefits of a variety of proposals. In terms of flood mitigation measures, benefits of a proposal are generally quantified as *the avoided costs associated with flood damages*. The avoided costs of flood damage are then compared to the capital (and on-going) costs of a particular proposal in the economic appraisal process.

Average annual damage (AAD) is a measure of the cost of flood damage that could be expected each year by the community, on average. It is a convenient yardstick to compare the economic benefits of various proposed mitigation measures with each other and the existing situation. Figure 9 describes how AAD relates to actual flood losses recorded over a long period. For the current study, AAD is assessed using the potential damages derived for each design event, under the assumption that there would be no flood damages in events as frequent as the 50% AEP.

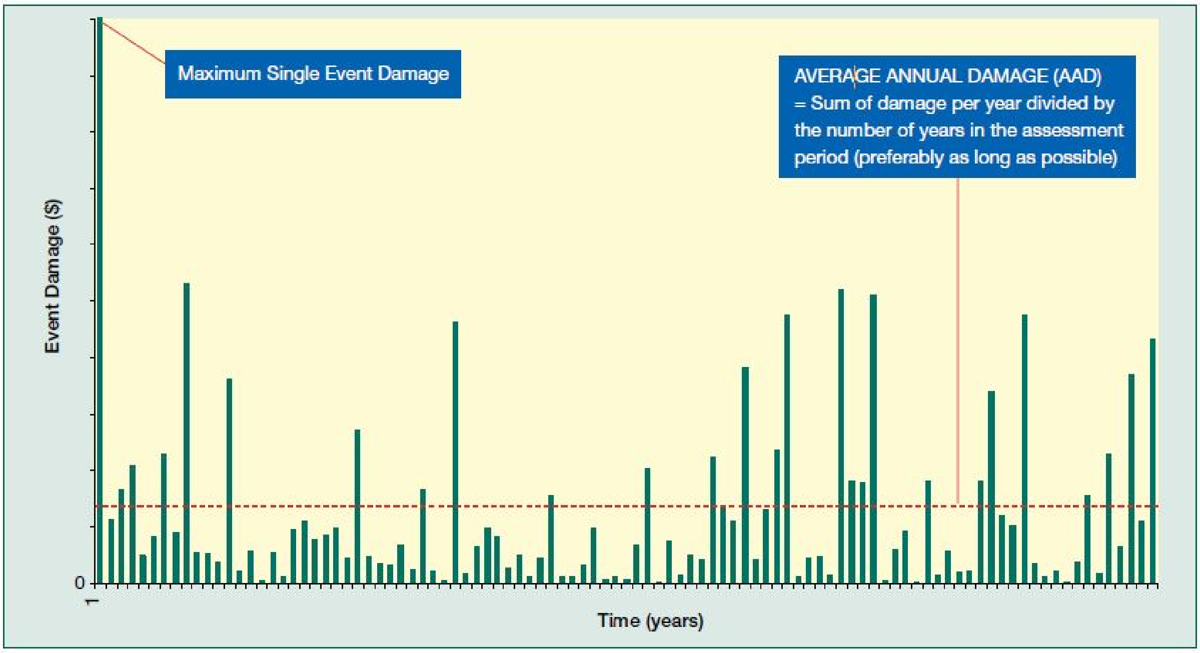

Figure 9. Randomly occurring flood damage as annual average damage (HNFMSC, 2006)

The present value of flood damage is the sum of all future flood damages that can be expected over a fixed period (typically between 20 and 50 years) expressed as a cost in today's value. The present value is determined by discounting the future flood damage costs back to the present day situation, using a discount rate (typically 7%).

A flood mitigation proposal may be considered to be potentially worthwhile if the benefit–cost ratio (the present value of benefits divided by the present value of costs) is greater than 1.0. In other words, the present value of benefits (in terms of flood damage avoided) exceeds the present value of (capital and on-going) costs of the project.

However, whilst this direct economic analysis is important, it is not unusual to proceed with urban flood mitigation schemes largely on social grounds, that is, on the basis of the reduction of intangible costs and social and community disruption. In other words, the benefit–cost ratio could be calculated to be less than 1.0.

8.2.3 Flood Damages Results

a) Tangible Damages

Calculated flood damages and AAD for the study area are summarised in Table 4 (residential properties) and

Table 5 (non-residential properties), and the AAD spatial distribution is shown in Map 26 (Vol. 2) and Map 27 (Vol. 2). Distinctive features include:

- The annual average damage is about $3 million for residential properties and over $12 million for non-residential properties, which is a measure of the cost of flood damage that could be expected each year, on average, by the community;
- Total damages for non-residential properties are higher than residential properties in each AEP event, with the gap increasing as the flood probability decreases. This is due to two main reasons: (a) the relatively high commercial and industrial floor surface area in the core of the CBD, particularly north west and south east of the intersection of High Street and Woodriff Street, where flood depth and velocity are the highest; and (b) the fact the commercial and industrial properties have generally a lower floor level than residential ones.

Table 4. Tangible Flood damages and average annual damage for residential properties

Event	Number of Dwellings with Flood Damages (FD)	Number of buildings with Above Floor Flooding (AFF)	Total $m (Includes Direct & Indirect Damages)
20% AEP	234	52 (22% of FD)	$6,872,141
10% AEP	282	70 (25% of FD)	$8,753,057
5% AEP	361	105 (29% of FD)	$11,667,738
2% AEP	416	125(30% of FD)	$13,765,511
1% AEP	455	164 (36% of FD)	$15,931,137
0.5% AEP	529	201 (38% of FD)	$19,552,450
PMF	1095	785 (72% of FD)	$64,523,474
		AAD total $m	$3,151,440

Table 5. Tangible Flood damages and average annual damage for non-residential properties

Event	Number of buildings with Flood Damages	Direct Damages $m	Indirect Damages $m	Total $m
20% AEP	17(100% of FD)	23,246,062	$4,881,437	$28,127,499
10% AEP	22 (100% of FD)	$24,664,333	$5,548,192	$30,212,525
5% AEP	28 (100% of FD)	$32,265,103	$7,068,346	$39,333,449
2% AEP	58 (100% of FD)	$44,452,158	$9,505,758	$53,957,916
1% AEP	65 (100% of FD)	$65,146,412	$13,644,608	$78,791,020
0.5% AEP	75(100% of FD)	$70,549,198	$14,725,168	$85,274,366
PMF	199(100% of FD)	$250,674,626	$53,952,618	$304,627,244
			AAD total $m	$12,329,478

b) Building Inundation

Table 4 and Table 5 summarise the number of residential and non-residential buildings affected by Above Floor Flooding (AFF) in relation to the total number of buildings with Flood Damages (FD) (i.e. with damages but not necessarily with AFF).

Results show that 52 dwellings are exposed to AFF in the 20% AEP event, with the number increasing to 164 in the 1% AEP event and 785 in the PMF. For non-residential buildings, only 17 are affected by AFF in the 20% AEP event, 65 in the 1% AEP event and 199 in the PMF.

Even though the number of non-residential properties with AFF is significantly smaller than the residential ones in each design flood event, non-residential properties are proportionately significantly more affected.

In fact, Table 4 and Table 5 show that, if we exclude the PMF, 20% to 40% of dwellings with FD would also experience AFF, while for non-residential properties this ratio is consistently 100% because these were assumed to have their floor level at ground level.

In addition to this, the geographical distribution of non-residential properties differs from that of residential ones, with many large non-residential buildings located in the lower part of the catchment, where depths and durations are generally higher.

Table 6 and Table 7 provide an appreciation of the depth of above floor inundation for the 1% AEP event and PMF, respectively. For the 1% AEP event, 95% of all dwellings subject to AFF are inundated to relatively shallow depths (<0.25m). The equivalent statistic for non-residential buildings is 30%. Only four residential buildings and five non-residential buildings are estimated to be inundated above floor to depths exceeding 1.0m in the 1% AEP. In the PMF, 26% of all dwellings subject to AFF are inundated to relatively shallow depths (<0.5m). The equivalent statistic for non-residential buildings is 20%, with almost 67% affected by depths above floor exceeding 0.5m and 35% by depths exceeding 1m.

It should also be noted that the model indicates that 52 residential buildings and 17 non-residential buildings would experience above floor flooding in events as frequent as the 20%AEP These figures should be regarded as the worst case scenario for the following reasons:

- Private stormwater systems are not included in the flood model and these are likely to be able to manage excess flooding in frequent events;
- In many instances, floodwaters running along a flow path may “touch” only a corner of a building. In these cases, even if the peak flood level exceeds the building floor level, floodwaters may not be able to enter the building (if there are no openings such as doors in the corner affected by flooding) and would cause only minor damage to the building exteriors.

Table 6. Number of buildings by above floor depth in the 1% AEP event

1% AEP event	0-0.25m	0.25-0.5m	0.5-0.75m	0.75-1.0m	1.0-1.25m	>1.25m
Residential	109	42	9	0	3	1
Non-Residential	20	20	15	5	2	3

Table 7. Number of buildings by above floor depth in the PMF

PMF	0-0.25 m	0.25-0.5 m	0.5-0.75m	0.75-1.0m	1.0-1.25 m	>1.25 m
Residential	208	259	125	75	56	62
Non-Residential	40	26	31	32	18	52

c) Building Failure

The tangible damage stage damage curves are principally related to contents damage with an allowance for repairs to the building structure such as relining of walls etc. However, they do not account for the losses incurred if the forces of floodwaters and debris loads cause such significant structural damage that the building needs to be completely rebuilt.

According to the national flood hazard guidelines (ARR, 2019), buildings affected by floodwaters with a hazard level of H5 would need a qualified engineer to assess their capability to withstand the flood forces, while buildings exposed to a flood hazard equal to H6 should not be considered safe regardless.

The number of buildings exposed to hazard levels H5 and H6 in the PMF is shown in Table 8.

Importantly, Table 8 shows that no properties are completely surrounded by floodwaters classified as H6 or H5, and the number of properties touched by floodwaters classified as H6 is very small. Nonetheless, the risk posed to the structural integrity of these buildings should be considered when planning the emergency response strategy.

Table 8. Buildings at risk of structural failure in the PMF (flood hazard classified according to ARR, 2019)

PMF event	Flood Hazard = H5	Flood Hazard = H6
Dwellings touched by highly hazardous floodwaters	315	35
Non residential buildings touched by highly hazardous floodwaters	69	5

d) Infrastructure Damages

An allowance has been included for infrastructure damages. This includes the cleaning and repair of roads, drains and creeks, parks and recreational facilities, water and sewage infrastructure, gas and electricity infrastructure and telecommunications infrastructure.

As set out in Section 8.3.2.c), an allowance has been made for these damages by estimating them to be 15% of total residential and commercial/industrial damages.

These damages are summarised for each event in Table 9.

e) Intangible Damages

Intangible damages can include the loss of pets and memorabilia which are worth more to people than their replacement value, financial hardship caused by flood losses, the stress and anxiety caused by experiencing flooding and dealing with its direct and indirect impacts, health impacts from coming into direct contact with floodwaters as well as stress induced illnesses or exacerbation of existing health conditions.

To some extent these damages will be proportional to the number or premises experiencing flooding. Those numbers can act as a surrogate for estimating the relative intangible impacts of the different magnitude floods.

As set out in Section 8.3.2.c), a dollar value has been set for the intangibles by estimating them to be worth 25% of total residential and commercial/industrial damages.

These damages are summarised for each event in Table 9.

Table 9. Estimates of infrastructure and intangible damages

Event	Total residential and non-residential damages $m	Infrastructure Damages (15%) $m	Intangible Damages (25%) $m	TOTAL $m
20% AEP	$34,767,415	$5,215,112	$8,691,854	$48,674,382
10% AEP	$38,350,257	$5,752,538	$9,587,564	$53,690,359
5% AEP	$46,562,610	$6,984,392	$11,640,653	$65,187,654
2% AEP	$63,284,849	$9,492,727	$15,821,212	$88,598,789
1% AEP	$88,759,516	$13,313,927	$22,189,879	$124,263,323
0.5% AEP	$98,864,171	$14,829,626	$24,716,043	$138,409,840
PMF	$958,403,968	$143,760,595	$239,600,992	$1,341,765,556
AAD total $m	$11,413,402	$1,712,010	$2,853,350	$15,978,762

8.3 RISK TO CRITICAL INFRASTRUCTURE

Map 28 (Vol. 2) shows the location of critical infrastructure and vulnerable buildings across the CBD. These are distributed in the north-western part of the study area and in most instances are not affected in the 1% AEP event. The following critical buildings and infrastructure were identified:

- Penrith's transmission electricity substation, in Museum Drive. The model shows that the switch room building is affected from the 20% AEP event with up to 0.7m of depth. However upon closer inspection the floor level of the building was found to be above the PMF level, making the switch room flood free in any event.

  On the other hand, part of the switchyard is flood affected from the 20% AEP event with depths up to 0.3m, which increase to about 0.65m in the PMF. It is expected that in any flood that threatens to reach the switchyard, this would be shut down for safety reasons, resulting in a black out of the whole area supplied by the substation. This extends north of the CBD and includes the land between the Nepean River and Mulgoa Road, as well as part of the land north of High Street and west of the Northern Road.

  Within the CBD, the station supplies electricity to the commercial and industrial area north of High Street, which includes Westfield and Council's building. As such it is expected that these areas would lose power supply in any local flooding event greater than the 20% AEP. It is noted that at the time this FRMS&P was being undertaken, the substation was undergoing extensive refurbishment works, which may result in a different exposure to local flooding;
- Three Sydney Water wastewater pumping stations, one of which is in High Street, west of the intersection with Castlereagh Street, and two are in Mulgoa Road, at the intersection with Ransley Street. The station in High Street has its car park affected in frequent flood events (from the 5% AEP event), however the facility itself is flood free in the 0.5% AEP event and experiences depths between 0.3m and 0.4m in the PMF, with hazard peaking at H2. The stations in Mulgoa Road are affected from the 5% AEP event with depths below 0.2m. Hazard level remains at H1 (i.e. no restrictions) up to the 2% AEP event included. Flood affectation is still relatively low in the 1% AEP and 2% AEP events, with H2 hazard floodwaters and peak depths around 0.3m. In the PMF the site is traversed by a flow path with hazard levels of H5 and depths exceeding 0.7m;
- Telstra's telephone exchange, located at 90 Henry Street. The model shows that this building is flood affected only in the PMF by above floor depths of about 0.15m. Upon closer examination it was determined that the building floor level is elevated above the ground level by about 0.3m, whereas the flood model assumes that non-residential buildings have their floor at ground level. As such, it was concluded that the telephone exchange building is unlikely to experience any flooding above floor in any event. However this building relies on power supplied by the Penrith transmission substation, which is likely to be shut off in events as frequent as the 20% AEP;
- The Nepean Hospital, in Derby Street east of Parker Street. The model shows local flooding within the hospital lots in events as frequent as the 20% AEP. This is caused by ponding water and is likely to be managed by the building private stormwater system, at least in frequent events;
- The NSW Ambulance station at 668 High Street. The model shows that

this building is flood free in all events but the PMF, when it experiences depth of about 0.6m above floor;

- The NSW Police Station located at 317 High Street. The model shows that this building is flood free in all events;
- The NSW Fire Brigades station at 294 High Street. The model shows that this building is flood free in all events;
- A total of 12 child care centres. Of these five are affected in the PMF only, one is within the Nepean Hospital and the remainder is flood free in all events. None of the flood affected buildings are located within high risk low flood islands, however six of them are in the lower catchment and as such are exposed to flooding from the Nepean River;
- Five schools, of which four are flood free in any event and one (i.e. the Tafe building at 117 Henry Street) is affected only in the PMF
- The Mountainview Nursing Home, at 57 Mulgoa Road. This building is located downstream of the Showground Channel culvert under Mulgoa Road. The model shows no flood affectation of the site in any event but the PMF;
- A total of seven disability services providers. These are all located in the north-west section of the study area and experience above floor flooding in events more frequent than the PMF only in a small number of instances. These buildings provide services such as daily support or work placement and would not have people with disabilities living in the premises.

8.4 RISK TO ROADS AND TRAFFIC

Road closures, in addition to slowing down traffic, may hinder the ability to evacuate from local flooding or from mainstream flooding caused by the Nepean River. Regardless of the nature of flooding, evacuating to flood free ground is the NSW SES's preferred flood response strategy and it relies on the availability of flood-free evacuation routes.

In case the NSW SES issued an evacuation order to escape from flooding from the Nepean River, all the main west to east roads of the CBD study area would become evacuation routes, catering for the CBD population. Some, such as Jamison Road and High Street and Henry Street may take evacuation through traffic from outside the study area. Any local flooding cutting these routes would cause a delay in the evacuation and may prevent some evacuees from escaping the rising floodwaters.

The frequency of road closures due to local flooding within the study areas was mapped by identifying locations where floodwaters are likely to become sufficiently deep or fast to block traffic, in each flood design event.

According to ARR (2019), small vehicles start to become unstable in floodwaters with a hazard level of H2, whereas a hazard level of H1 poses no restrictions to vehicular or pedestrian traffic. As such, the main streets of the study area were mapped as being cut if, in each design event, the model showed floodwaters with hazard levels equal or greater than H2 over the road.

It was also conservatively assumed that a road will be closed when travel in one direction becomes impossible, even if travel in the opposite direction is still possible. This is consistent with the approach adopted by the NSW SES, which requires evacuation routes to be trafficable in both directions to let evacuees out and at the same time provide access for emergency service vehicles.

Map 29 (Volume 2) shows the frequency with which the main roads within the study area are cut by local flooding. The associated table (Table 1, Vol. 2) shows the duration of flooding at or above a hazard level of H2 at each of these locations.

8.4.1 Regional Evacuation Routes

Regional evacuation routes are roads that during an evacuation from the Nepean River will cater for evacuees coming from outside the study area and driving through it, as well as for evacuees leaving the western part of the CBD. These roads include:

- Mulgoa Road, south of the intersection with High Street. This section of the road will cater for the residential areas between the CBD and the Nepean River;
- Jamison Road, up to Parker Street;
- Parker Street, catering for evacuees moving south from Penrith North Industrial Area, Thornton and Penrith CBD. ;
- Evan Street, from the Railway to High Street, catering for evacuees from Penrith North Industrial Area and Thornton These would drive south to the intersection with High Street, then east towards Parker Street;
- High Street, between Evan Street and Parker Street, which in addition to the evacuees mentioned above would cater for people in the CBD.

The analysis of road closure shows that:

- Mulgoa Road is only cut in events greater than the 0.5% AEP between High Street and Ransley Street for up to 1.5 hours. The underpass under the railway is also cut by deep floodwaters from the 5% AEP event for over 5 hours, and in greater events it remains closed to traffic for over 10 hours.
- Jamison Road is cut west of the intersection with Mulgoa Road in the 20% AEP event for up to 0.5 hours, in the 1% AEP for over 3 hours, and in the PMF for over 2 hours. Flooding and this location is further discussed in Section 9 of this report (Hot Spot 1). Jamison Road is also cut between Mulgoa Road and Castlereagh Street in events greater than the 0.5% AEP for up to 1 to 2 hours;
- Parker Street's south bound lanes flood at three locations from relatively frequent events, however at least one of the three lanes remains open to traffic in events greater than the 0.5% AEP flood. In the PMF all south bound lanes are cut by H2 floodwaters for up to 0.5 hours. Flooding at this location is discussed in detail in Section 9 (Hot Spot 8);
- Evan Street is cut at the intersection with Henry Street in the 5% AEP event for a duration of 0.5 hours, and in greater events for a duration of 1 hour;
- High Street does not get cut east of Evan Street and remains generally open to traffic in the 0.5% AEP event. In greater events it becomes completely flooded west of Lawson Street.

The NSW SES would prefer that regional evacuation routes are immune from closure by events up to and including the 0.2% AEP local flood event. As the above analyses show that each of these roads can be cut in more frequent events there either needs to be flood modification works or road works to reduce the frequency of inundation or the NSW SES evacuation planning needs to take into account the potential delays caused by local flooding.

8.4.2 Local Roads

This section discusses the frequency of closure of roads within the CBD that are not regional evacuation routes. These may be used during evacuation from local overland flooding or to reach the regional evacuation routes during a flood from the Nepean River. The main west to east roads are particularly important because they serve both the above mentioned purposes. These include:

- Henry Street, which is cut west-bound at the intersection with Evan Street from the 5% AEP event for 0.5 hours, and for 1 hour in greater events;
- High Street, with remains open to traffic in the 0.5% AEP event;

- Lethbridge Street, which is cut at the intersection with Castlereagh Street in the 5 % AEP for 0.5 hour, and for 1 hour in greater events. It is also cut at several other locations but only in events greater than the 0.5% AEP and for relatively short durations;
- Derby Street, which is only cut in events greater than the 0.5% AEP for durations between and 1.5 hours;
- Stafford Street, which is cut east of the intersection with Colless Street in the 20% AEP event for 1 hour, in the 1% AEP event for 2 hours and in the 0.5 AEP for up to 6 hours. In the PMF, which has generally a shorter duration (although larger extent and depths), this location is cut for about 1 hour.

Additional important local roads include:

- Station Street, cut west of Nepean Square in the 5% AEP for 0.5 hours, in the 1% AE event for 2 hours, in the 0.5% AEP event for 4.5 hours and in the PMF for about 2.5 hours;
- Woodriff Street, which is cut north of Lethbridge Street in the 5% AEP event for 1 hour, and for 1.5 hours in greater events;
- Castlereagh Street, cut north of the intersection with Lethbridge Street in the 5% AEP event and in greater events for 1 to 1.5 hours;
- Evan Street, which in addition to being cut at the intersection with Henry Street is also cut south of Lethbridge Street in the 5% AEP event for 0.5 hours, and for 1 hour in greater events;
- Doonmore Street, cut from the 1% AEP event between Derby Street and Lethbridge Street for 1 hour; and
- Colless Street, cut at the intersection with Hope Street from the 5% AEP event for 1.5hours, and for 2 hours in greater events.

Overall, Map 29 (Volume 2) shows that in the PMF all roads west of Woodriff Street are cut, and that some of these roads start flooding in events as frequent as the 20% AEP. These include Rodley Avenue, which when cut in the 20% AEP event isolates several residential properties in the cul de sac. These may flood in greater events, posing a risk to their occupants who are unlikely to be able to evacuate in time. This is discussed in detail in Section 9 (Hot spot 3).

Additional locations where road flooding poses significant risks include Brown Street, north of the intersection with Stafford Street. While Brown Street does not get cut up to the 0.5% AEP event, floodwaters running at the sides of the street have significant hazard levels from the 20% AEP event and would block evacuation from the adjoining residential properties. This is discussed in detail in Section 9 (Hot Spot 7 and 14).

8.5 RISK TO PEOPLE

The assessment of flood risks to people was informed by the following datasets:

- Maps of the hydraulic hazard categories (Map 21 to 23, Volume 2);
- The Flood Emergency Response Planning Classification Of Communities (DECC, 2007b), which was adapted to the study area as described in Section 7.1.3 and overlaid with the location of dwellings and non-residential buildings experiencing above floor flooding in the PMF (Map 25, Vol. 2);
- Vulnerability mapping, showing the location of vulnerable buildings and the socio-economic vulnerability of the CBD population. The latter was based on the 2016 Australian Bureau of Statistics SEIFA (Socio-Economic Indexes for Areas) Index. SEIFA 2016 consists of four indexes designed to reflect the relative socio-economic disadvantage of the Australian population by aggregating selected indicators from the five-yearly Census. This study utilised the Index of Relative Socio-Economic Disadvantage (IRSD), which was

available at a suitable spatial scale (i.e. the Statistical Area Level 1). The IRSD encompasses variables such as age, socioeconomic status, family status, and proficiency in English language, which were deemed pertinent to the hazard posed by flooding in the study area. The IRSD index is graded into quantiles ranging from 1 (i.e. most disadvantaged) to 5 (i.e. least disadvantaged). Results of the vulnerability assessment are shown in Map 28 (Vol. 2).

The analysis showed that the areas with the highest risk to people within the CBD are:

- The areas classified as "high risk low flood islands" in the lower part of the catchment (Map 25, Vol. 2). At these locations evacuation routes are cut by local flooding in events as frequent as the 20% AEP. Because overland flooding would rise quickly and without any warning, local residents may only realise that a significant flood is ongoing when they see floodwaters entering their properties, but at that point all evacuation routes would already be cut.
- It is reiterated that the area west of Woodriff Street and Lawson Street, in addition to local flooding, is also affected by mainstream flooding from the Nepean River, which further increases risk to people.
- Finally, the flood islands in Rodley Avenue and west of Woodriff Street, have very high socio economic disadvantage scores (i.e. IRSD = 1), which makes them particularly vulnerable to the impacts of flooding.
- Buldings affected by high hazard floodwaters in the upper catchment. East of Woodriff Street, flood behaviour is dominated by well-defined flow paths, which are limited in extent but reach hazard levels of H5 in the 1% AEP event and H6 in greater events. According to ARR (2019), hazard levels of H5 are unsafe for buildings that have not been purposely design to withstand flood forces, and levels of H6 are unsafe for any type of building regardless of the design. Pockets of buildings exposed to H5 and H6 hazards are identified and discussed in Section 9.
- Most buildings in this area are classified as flood islands because they are completely surrounded by floodwaters in the PMF, even though in some instances the building may be reached by floodwaters from the backyard, before the evacuation route at the front is cut. As discussed in Section 8, this assumption was made to account for the lack of flood warning and the quick rate of rise of local flooding, which would most likely result in local residents failing to evacuate before floodwaters start entering the building from the front door.
- In addition to this, the IRSD socio economic disadvantage scores east of Woodriff Street range between 1 and 2 (i.e. high vulnerability).
- The challenges of a timely evacuation, the potential for flood hazards to reach levels sufficiently high to threaten the structural stability of buildings and the relatively high socio economic vulnerability make risk to people at these locations extremely high.

PART C: FLOODPLAIN RISK MANAGEMENT MEASURES

9 FLOOD RISK REDUCTION MEASURES

This section presents the exercise undertaken to identify, evaluate and shortlist appropriate flood risk mitigation options.

9.1 TYPES OF FLOOD RISK MITIGATION

According to the NSW Floodplain Development Manual (NSW, 2005), flood risk mitigation measures fall into three categories:

- Flood modification;
- Property modification;
- Response modification.

9.1.1 Flood Modification

The purpose of flood modification measures is to modify the behaviour of the flood itself by reducing flood levels or velocities or by excluding floodwaters from areas under threat.

Flood modification generally requires the construction of civil works and is usually cost-effective only where there are clusters of properties which would benefit from the same flood modification measure.

Typical examples of flood modification options include the installation or upgrade of stormwater pipes and channels, or the construction of detention basins or levees.

9.1.2 Property Modification

Property modification generally involves measures such as:

- Removing buildings from the area which floods;
- Ensuring floor levels are at a level with a low probability of flooding;
- Constructing with flood compatible building materials.

Property modification can be applied to either existing development or future development. Property modification to existing development involves either:

- Voluntary house raising (VHR). A VHR scheme involves home owners receiving a subsidy from government to lift their existing house to reduce the probability of above floor flooding. Because of the costs and practicalities involved, this type of measure is usually only considered where other types of mitigation options are not applicable or not effective, and only for lightweight buildings (e.g. single storey, clad, timber framed houses).
- Voluntary Purchase (VP) and demolition; VP involves government purchase of a property at market value and then demolishing the building and ensuring no further unsuitable development takes place on the land.
- Renovation with flood compatible building materials or design.

Modification to future development may involve:

- Strategic planning to move inappropriate development away from high flood risk areas;
- Development controls to ensure development, redevelopment or renovation reduce flood risks to an acceptable level for each property which can include, amongst the measures, requirements for minimum floor levels and building material compatibility.

9.1.3 Response Modification

Improved flood response by community members can reduce loss of property and life in floods. In NSW the NSW SES is the lead agency for flood response and flood response measures should be implemented in consultation with NSW SES.

Specific flood response measures may include:

- Improved flood warning including installation of warning systems;
- Improved agency response including closure of high risk roads;
- Options for evacuation;
- Improved community response through community education.

As part of the community engagement component of this FRMS&P, a survey was distributed to the CBD's residents and business owners asking the community views and preferences in relation to each possible flood risk reduction measure. Results of the survey are presented and discussed in Section 4 of this report.

9.2 AREAS REQUIRING FLOOD RISK MITIGATION

Across the CBD flood-prone area there are locations where clusters of assets are impacted by flooding. These locations are herein named "Hot Spots" and may benefit from local flood risk mitigation options.

Based on the outputs of the Flood Study (Cardno, 2015), as well as on historical flood and complaints records, Council identified a preliminary list of flood risk Hot Spots. These are specific locations within the CBD that were known to Council for having shown flooding issues in the past (Map 30, Vol. 2), namely:

1. Jamison Road and Mulgoa Road intersection.
2. Worth Street/ Station Street/ Union Road/ Union Lane/ High Street area.
3. Showground Channel in the area of Rodley Avenue.
4. High Street between Worth Street and Woodriff Street and also in areas around Penrith library and Joan Sutherland Performing Arts Centre
5. Station Street/ Jane Street / Belmore Street area.
6. Henry Street / Evan Street.
7. Nepean Square and K-Mart area between Station Street and Penrith Swimming Centre area.
8. Parker Street / Northern Road.
9. Castlereagh Street/ Evan St / Doonmore Street/ Lethbridge Street area.
10. Penrith RSL area.
11. Doonmore Street/ Colless Street/ Parker Street area including overland flows arriving into the open space near the intersection of Derby Street / Doonmore Street and potential retarding basin within the open space.
12. Entry to Council's main office basement carpark (flooding from Jane Street)in the same location as Penrith Library & Joan Sutherland PA Centre.
13. Flood impacts to the Carpenter site as a result of discharge into Showground Channel via the site.

These locations were validated as part of this FRMS&P after the flood modelling was revised and updated to reduce the computational time and incorporate more recent input data. However, two additional potentially problematic spots were identified, namely:

14. The residential areas east of Nepean Square and K-mart area;
15. The residential area between Stafford and Jipp St.

Specific flood modification options are discussed for each Hot Spot in the next section, while Section 9.4 includes consideration of property modification options (i.e. development controls, strategic planning) and Section 9.5 response modification (i.e. evacuation) that apply either to individual Hot Spots or to the whole catchment area.

9.3 FLOOD MODIFICATION

This section presents the outcomes of the investigations for specific flood modification options that may be used to reduce flood risk at each of the risk Hot Spots

9.3.1 Methodology and Assumptions

A systematic process of investigation was used to determine if flood modification was possible at each Hot Spot, and how this could be achieved.

In doing so, data from the flood model and estimates of building floor levels were used to quantify impacts, prepare concept designs and evaluate costs and benefits of each risk reduction option. It is recognised that these analyses were undertaken using the best available information at the time of publication. The methods used for deriving the data provide approximations suitable for a broad scale catchment wide study to identify locations where there are apparent flood issues which need to be addressed.

At each Hot Spot, the outcomes of the flood model were assessed in detail to understand local flood behaviour and identify the likely cause of the flooding. This included an assessment of flood depths and hazards for different design events.

An analysis of the capacity of the existing pipe network in frequent flood events (i.e. 5% AEP and 20% AEP) was also undertaken to determine whether increased pipe capacities might reduce the frequency of above floor flooding (Map 31 and Map 32, Vol. 2). Where pipe capacity increases would not significantly reduce flood impacts, or were deemed impractical, additional flood modification measures were explored including:

- Diversion of floodwaters around the area impacted or towards the existing stormwater network should this have spare capacity in frequent flood events;
- Detention of floodwaters upstream of the area impacted.

Regardless of the type of flood modification options being assessed, where possible these were designed to manage flooding up to the 10% AEP event in residential areas, and the 2% AEP event in non-residential areas, as per Council's adopted drainage standards in the CBD.

Where none of these would be effective, flood modification options were dismissed as not being a viable option for that Hot Spot.

Where the modelling suggested significant flood risk reduction would be possible, an iterative process of concept design and flood modelling was undertaken until one or more combinations of flow capacity increase, flow diversion and/or flow detention was identified to optimise the reduction in flood impacts.

A concept design of the shortlisted flood modification options was then prepared and used to estimate the costs of construction, operation and maintenance of the required flood modification infrastructure.

The flood damages were then calculated with and without the option in place so that the benefits of the options could be assessed as the resulting reduction in flood damages, namely in Annual Average Damages (AAD).

For each Hot Spot, costs and benefits were then discounted to present time under the following assumptions:

- A life span of 50 years for all structural works;
- A discount rate of 7% (as per NSW Treasury, 2017).

A cost-benefit analysis was then undertaken for each option which compared the present values of the costs with the benefits provided by the implementation of the option, estimated as reduced damages.

Where the economic value of benefits exceeded the costs, i.e., the benefit cost ratio (BCR) exceeded 1.0 then the option was considered to be economically worthwhile. The social and environmental costs and benefits of the option were then investigated and if these costs were not sufficient to outweigh the benefits of the option, the option was recommended for detailed investigation as part of the flood risk management plan.

If the BCR was less than 1.0, the social and environmental costs of the option were considered and if there were substantial non-economic benefits associated with the options, it was recommended for detailed investigation as part of the flood risk management plan. Otherwise it was dismissed as not being a worthwhile option.

9.3.2 Analysis of Options

In this section, the analysis and results of flood modification options are presented for each Hot Spot individually.

a) Hot Spot #1: Jamison Road and Mulgoa Road intersection

i) Flood Behaviour and Risks

Floodwaters are brought to this intersection by an open channel running east to west along Jamison Road (Map 33, Vol. 2). The channel is known as Bazooka Channel. Floodwaters are then conveyed under Mulgoa Road through a culvert (i.e. the Bazooka Culvert), and discharged to Jamison Creek, downstream of the intersection, within the Panthers' site.

The model shows that both lanes of Jamison Road west of the intersection are cut by floodwaters from the 20% AEP event, however most of the road is only affected by floodwaters with hazard equal to H1, which will not cause any significant restrictions to traffic movement. However, the model shows that flooding with H2 hazard may block traffic in the west bound lane for up to 0.5 hours (Map 33, Vol. 2).

However from the 20% AEP event, a flow path develops between Woodriff Street and Mulgoa Road, and runs east to west south of Jamison Rd. Although this flow path is outside the boundary of the study area, it may cause flood damages to some of the residential buildings along the southern side of Jamison Road up to the intersection with Mulgoa Rd.

In the 5% AEP event, the extent of the area flooded in Jamison Road increases, and at the peak of the flood the west bound lanes are entirely affected by H2 floodwaters, which are deemed unsafe for small cars (Map 34, Vol. 2). In this event the road is cut for 2 hours west-bound, although flooding at the side of the road may last for up to 6 hours.

From the 1% AEP event, the flow within the Bazooka channel starts exceeding the capacity of the culvert under Mulgoa Road, which results in floodwaters running in a south-east to north-west direction across Mulgoa Road. Part of this flow continues north along Mulgoa Road, and part goes west through the Panthers' site. In this event, the flood extent in Jamison Road increases further, and the peak hazard does exceeds H2 resulting in the road being cut for 3.5 hours west bound, and 1 hour east bound (Map 35, Vol. 2).

In the PMF (Map 36, Vol. 2) both flood extent and hazard increase significantly, and Jamison Road is cut west and east of the intersection with Mulgoa Road by peak hazard levels ranging between H3 and H5. In the PMF, the intersection is cut by floodwaters with hazard equal or greater than H2 for a duration of 1 hour (east bound lane) and 2 hours (west bound lane).

However, the maximum duration for which this section of Jamison Road is cut by floodwaters with hazard equal or greater than H2, among all the flood events modelled, is the 0.5% AEP event (1.5 hours east bound, and 5 hours west bound).

This intersection is a major evacuation route for flooding from the Nepean River. Since local flooding rises faster than river flooding, there is a risk that the intersection might become cut by overland local flooding during an evacuation triggered for risk of flooding from the Hawkesbury-Nepean river. This would affect the evacuation time availablefor vehicles evacuating from the Peachtree Creek East subsector and Jamison town West subsector.

ii) Analysis of Flood Modification Options

A detailed drainage assessment study was undertaken by J. Wyndham Prince for Panthers Precinct in 2016 (JWP, 2016). The assessment concluded that a series of culverts under Mulgoa Road would better manage flooding from the Bazooka Channel over Mulgoa Road (Figure 10). The report found that in order for this to be achieved, a reshaping of the landform on the eastern side of Mulgoa Road would also be required. The flood difference map for the above described stormwater system upgrades showed that a significant flood level reduction would be achieved up to the 1% AEP event (Figure 11).

Because of its implications on mainstream flood evacuation, the above mentioned flood modification option should also be considered in the Nepean River Floodplain Risk Management Study and Plan.

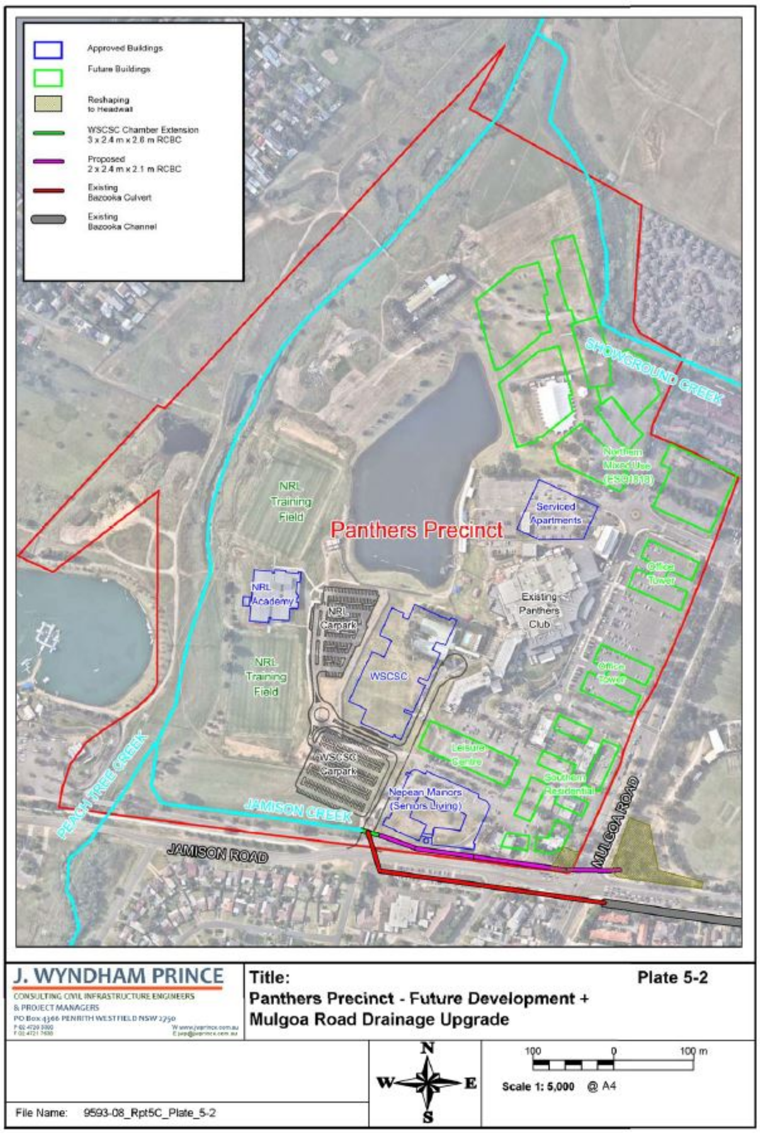

Figure 10. Proposed drainage upgrades at the Mulgoa Rd and Jamison Rd intersection (JWP, 2016)

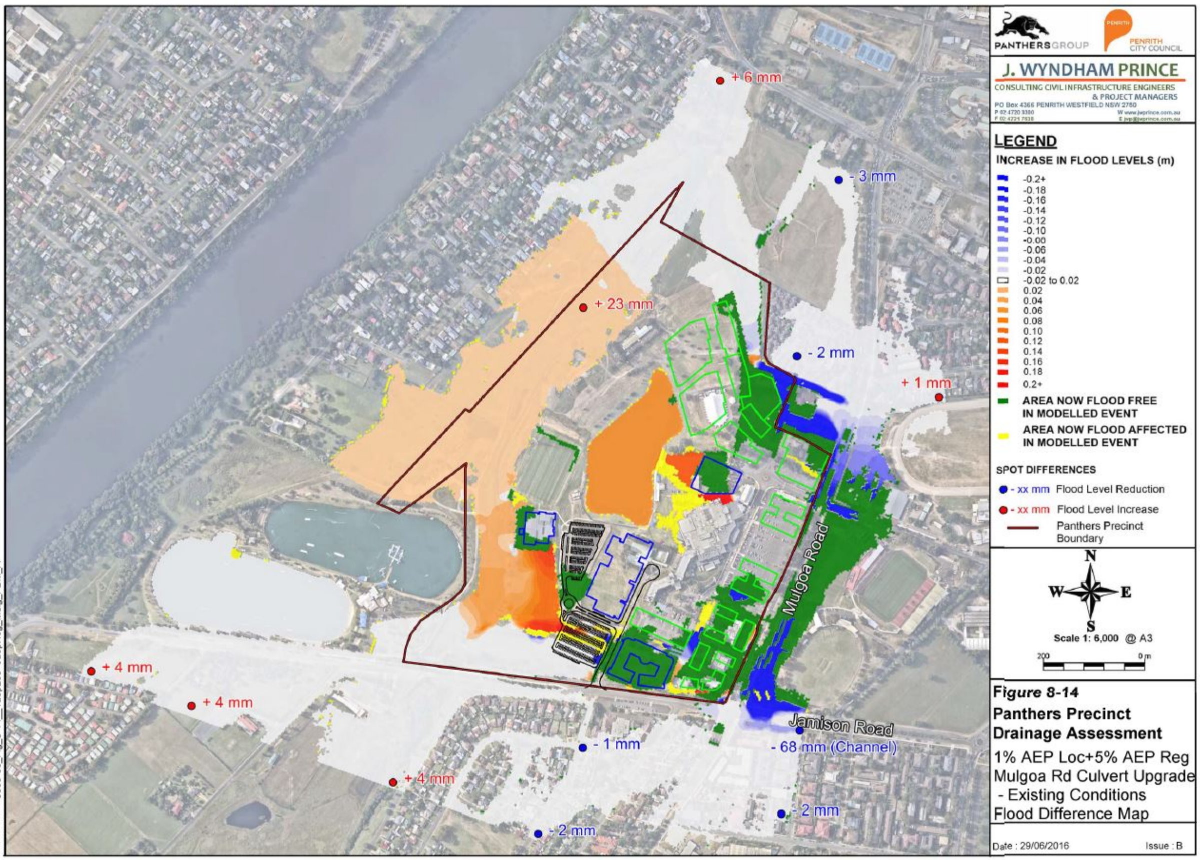

Figure 11. Flood level difference map for the Mulgoa Road upgrades proposed as part of the drainage assessment study for the redevelopment of the Penrith Panthers site (JWP, 2016)

b) Hot Spot #2: Worth Street/ Station Street/ Union Road/ Union Lane/ High Street

i) Flood Behaviour and Risks

Floodwaters are conveyed to this area from the main overland flow path running across the CBD from east to west. This reaches Union Street car park through The Broadway area and across Station Street. In larger events, floodwaters build up in the car park until they enter the arcades connecting the car park to High Street (Map 38, Vol. 2).

In events as frequent as the 20% AEP, the model shows minor flood affectation of Union Road car park, with no significant property impact and durations at or above H2 hazard between 30 minutes and 1 hour at one spot in the eastern part of the car park.

In the 5% AEP event Union Car Park experiences a larger flood extent and parts of Station Street are flooded. Duration above H2 hazard in this event reaches 1.5 hours.

In the 1% AEP event the car park experiences hazardous flooding, and most of the commercial properties between High Street and Union Lane are affected. Flood duration above H2 hazard is around 2 hours.

In the PMF, the car park is entirely flooded and experiences peak hazards between H3 and H4, while Union Road and High Street have hazards peaking at H5. In this event, all the commercial buildings between Union Lane and High Street experience significant depths of flooding above floor. Flood duration above H2 hazard is up to 3.5 hours.

ii) Analysis of Flood Modification Options

A reduction of flood levels in frequent events was sought by testing flood modification options upstream of Union Street car park, and in the car park itself.

Upstream of Union Street car park

As this Hot Spot is located in lower part of the catchment, any flood modification intervention upstream has the potential to affect local flood levels. Specifically, two of the flood modification options that were tested upstream of Hot Spot #2 showed appreciable flood level reductions in frequent events in Union Road car park. These included a detention basin in Hot Spot #9, and measures to divert overland flooding into an existing pipe in Hot Spot #10. These options are described in detail in Section 9.3.2.i and 9.3.2.j respectively.

Within Union Street car park

The network of pits and pipes at the northern end of Union Street car park runs at capacity from the 20% AEP event, while the pipes connecting the car park to Triangle Park culvert in High Street have spare capacity up to the 5% AEP event. An upgrade of the pipes in Union Street car park was firstly considered because it is likely to feed the connection to Triangle Park's culvert more efficiently and decrease flood levels in the car park up to the 5% AEP. Additional flood level reductions were sought by assessing an upgrade of the pipes running from the car park to Triangle Park as Triangle Park's culvert has significant spare capacity even in the 5% AEP event.

The following flood modification configuration was assessed (Map 39, Vol. 2):

- A 0.9m (W) x 0.6m (H) culvert between Union Road and Union Lane catering for the car park;
- 2 x 525mm diameter pipes running under one of the buildings in High Street to drain water from the car park to Triangle Park's culvert.

The flood model showed that these upgrades would significantly reduce flood levels in Union Street car park and for the commercial buildings between Union Lane and High Street up to and including the 1% AEP event.

iii) Evaluation of the Shortlisted Flood Modification Options

Map 40 to Map 42 (Vol.2) show the change in flood levels generated by the shortlisted flood modification option in the 20% AEP event, 5% AEP event and 1% AEP event respectively. A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if this would be economically worthwhile. Table 10 shows a summary of the results for this hotspot (please refer to Appendix C and D for more details).

The cost/benefit analysis showed that flood modification at this location would be economically worthwhile, having a benefit to cost ratio of 4.59. While the option would not reduce the number of buildings flooded in each event, it would reduce the depth of flooding and therefore the damages caused. It would also reduce the cost of vehicles being damaged in the car park.

In terms of social costs, the shortlisted flood modification option would cause only minor inconvenience during construction operations, and these would be temporary.

For these reasons, it is recommended that flood modification be investigated further at this location.

Table 10. Results of Cost Benefit Analysis for Flood Modification Options in Union Street car park

Hot Spot Number	**2**		
Scale of the Problem:	**20% AEP**	**5% AEP**	**1% AEP**
Buildings with AGF	0**	1**	10**
Buildings with AFF	0**	1**	10**
Car Spots affected by Depths >0.5m	0	0	30
Flood Modification Option Proposed	Stormwater System Upgrade		
Benefit/Cost Ratio	4.59		
Total Option Costs (Present Value)	$546,700		
Total Option Benefits (Present Value)	$2,508,301		
AAD per Building (within 1% AEP extent)	Current Condition	$19,285**	
	With Option in Place	$9,215**	
Average Damage per Building (in the 1% AEP event)	Current Condition	$442,028**	
	With Option in Place	$143,741**	
*** = dwellings, ** = non-residential buildings**			

c) Hot Spot #3: Rodley Avenue

i) Flood Behaviour and Risks

The Showground Channel collects water from two main pipes coming from the intersection of Castlereagh Street and Lethbridge Street (Map 43, Vol. 2). The channel runs at capacity in events greater than the 1% AEP. The model shows some flooding ponding at the eastern end of Rodley Avenue and affecting some residential properties from the 20% AEP event, however this is not caused by the Showground Channel overtopping its banks. Duration of flooding above H2 hazard at this location is 1 hour in the 20% AEP event. This part of Rodley Avenue is serviced by a pipe draining water to the Showground Channel, but this is at full capacity in the 20% AEP event.

In the 5% AEP the extent of the flooded area in Rodley Avenue increases and a second flooded area appears west of Worth Street. Flood duration at or above H2 hazard increases to 1.5 hour to 2 hours in the eastern part of Rodley Avenue. Similarly to the 20% AEP event, this flooding is not caused by the Showground

Channel, but more likely by minor local overland flooding running in a north to south direction along Worth Street. The flooded area is also serviced by a pipe directing water to the channel, but this is also at capacity from the 20% AEP event.

In the 1% AEP event flood behaviour remains the same as in more frequent events, although the extent of the flooded areas in Rodley Avenue increases and duration at or above H2 hazard reaches 2 hours. The model does not show any significant overtopping of the Showground Channel up to the 0.5% AEP event.

In the PMF, all the buildings in Rodley Avenue are surrounded by floodwaters and 57 of these experience significant above floor flooding depths. Flood hazard peaks at H5 in Rodley Avenue, while buildings on both sides of the road experience a peak hazard of H4. Flood duration at or above H2 hazard peaks at 4.5 hours in the eastern part of Rodley Avenue, and 3.5 hours in the western part.

Because Rodley Avenue would flood first, egress from all buildings would be cut in events as frequent as the 20% AEP. As such, this area is classified as a Low Flood Island. Furthermore, as these dwellings are at the bottom of the catchment they are amongst the most at risk from Nepean River flooding. It is likely to be flooded in a repeat of the 1867 flood and depths could exceed 4m in a PMF in this area.

Council reported that during the January 2016 flood, floodwaters were sighted moving from the eastern end of the showground channel across Station Street and towards Union Street car park. After that flood, the new pipe connecting the intersection of Castlereagh Street and Lethbridge Street to the channel was put in place, which reduced the amount of overland flow reaching the channel from across Station Street. The model does not show any overland flow path running north-west from the eastern end of the channel in any event but the PMF, which suggests that the new pipe may have addressed this issue.

ii) Analysis of Flood Modification Options

The model suggests that adding capacity to the two pipes running from Rodley Avenue to the Showground Channel may reduce flood impacts locally. The flood modification option that was tested entails the addition of new 375mm pipes to remove water ponding in Rodley Avenue (Map 44, Vol. 2).

iii) Evaluation of the Shortlisted Flood Modification Options

Map 45 to Map 47 (Vol.2) show the change in flood levels generated by the shortlisted flood modification option in the 20% AEP event, 5% AEP event and 1% AEP event respectively. A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if this would be economically worthwhile. Table 11 shows a summary of the results for this hotspot (please refer to Appendix C and D for more details).

Table 11. Results of Cost Benefit Analysis for Flood Modification Options in Rodley Avenue

Total Option Costs	$133,100
Total Option Benefits	$72,411
Benefit/Cost Ratio	0.54

The cost/benefit analysis showed that flood modification at this location would not be economically worthwhile, having a benefit to cost ratio of only 0.54. The shortlisted flood modification options would however reduce the frequency with which Rodley Avenue is cut by floodwaters, therefore alleviating flood risks to people, vehicular traffic and pedestrians. This is particularly important given the need for these areas not to have their evacuation frequently compromised given the risks associated with failing to evacuate in advance of a Nepean River flood.

In consideration of the significant levels of flood risk to people at this location, it is recommended that flood modification is investigated further as part of Council's long term planning strategy for future development or as an evacuation route improvement option as part of the Hawkesbury Nepean Flood Risk Management Strategy.

d) Hot Spot #4: High Street between Worth Street and Woodriff Street

i) Flood Behaviour and Risks

In the 20% AEP event and in the 5% AEP event, the model shows no overland flooding in this section of High Street (Map 48, Vol. 2). While in the 20% AEP event the stormwater system in High Street has spare capacity; in the 5% AEP event there is little to no capacity left.

There are no properties in High Street impacted by flooding in the 20% AEP with the exception of two commercial buildings on the north side of High Street, but these are affected from the back by floodwaters running east to west in Allen Place.

In the 5% AEP the model shows four additional buildings affected by flooding in Allen Place. There are also four commercial buildings at the southern end of the intersection of High Street and Station Street that may experience flooding as a result of floodwaters running north along Station Street and from the Union Road car park. It was then concluded that impacts on these properties do not depend on the performance of the stormwater system in High Street and the four commercial buildings south of High Street may benefit from the flood modification options proposed for Hot Spot 2.

High Street remains flood free up to the 2% AEP event, when minor overland flooding, with hazard levels not greater than H1, starts affecting the section between Riley Street and Station Street.

In the 1% AEP event, the flooded area extends to Triangle Park and connects to the Station Street car park through the arcades going through the commercial properties along the southern side of High Street, but peak depths remain below 300mm and hazards below H1.

In the PMF, all 55 commercial buildings along this section of High Street would experience above floor flooding depths in excess of 1m and would be surrounded by high hazard floodwaters (i.e. H5 in High Street). In this event, flood duration at or above H2 hazard would be between 2 hours and 3 hours.

ii) Analysis of Flood Modification Options

The relatively low flood affectation of this area in frequent events is due to the recently installed High Street culvert extending from Woodriff Street to Triangle Park. This measure was deemed sufficient to control flood risk to property at this location.

e) Hot Spot #5:Station Street/ Jane Street / Belmore Street

i) Flood Behaviour and Risks

From the 20% AEP event, the model shows no significant property or road affectation; however there is water ponding in the car park north of Belmore Street for more than 5 hours, even if the relevant pipe along Belmore Street has significant spare capacity (Map 49, Vol. 2). The flood extent in the car park increases in the 5% AEP event, but the pipe in Belmore Street retains significant spare capacity.

In the 1% AEP most of the car parks floods, with hazard levels peaking at H3 at its southern end. Duration of flooding at or above H2 hazard exceeds 10 hours.

In the PMF, the car park is entirely flooded and all commercial buildings between Henry Street and Belmore Street experience significant above floor flooding depths well in excess of 1m. Flood hazard levels peak at H5 in Belmore Street, while most buildings are affected by H3-H4. Duration of flooding at or above H2 hazard exceeds 10 hours.

ii) Analysis of Flood Modification Options

The model results suggest that the problem of water ponding in the Belmore Street car park in frequent events could be addressed using flood modification by providing access to the pipe that runs along Belmore Street, which has spare capacity at least up to the 5% AEP event. The analysis assessed the addition of a 600mm pipe from the low spot in the car park draining to Belmore Street's pipe (Map 50, Vol. 2).

iii) Evaluation of the Shortlisted Flood Modification Options

Map 51 to Map 53 (Vol.2) show the change in flood levels generated by the shortlisted flood modification option in the 20% AEP event, 5% AEP event and 1% AEP event respectively. A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if this would be economically worthwhile. Table 12 shows a summary of the results for this hotspot (please refer to Appendix C and D for more details).

Table 12. Results of Cost Benefit Analysis for Flood Modification Options in Belmore Street car park

Total Option Costs	$70,400
Total Option Benefits	$7,728
Benefit/Cost Ratio	0.11

The cost/benefit analysis showed that flood modification at this location would not be economically worthwhile, having a benefit to cost ratio of only 0.11. However it should be emphasized that at locations where risk to property is only driven by damage to parked vehicles, the benefit to cost ratio is affected by larger variability as damages to cars are strictly dependent on the car value and how full the car park is when the flooding occurs. Risk to people who may attempt to drive their cars through hazardous floodwaters also requires consideration.

As such, given the relatively low cost of construction of this option and ease of implementation, it is recommended that it is investigated further as part of Council's long term planning strategy for future development.

f) Hot Spot #6: Henry Street / Evan Street

i) Flood Behaviour and Risks

From the 20% AEP event there is a flow path running east to west along Henry Street to the intersection with Evan Street (Map 54, Vol. 2). From here floodwaters veer north-west to affect the intersection, the lot at 57 Henry Street which is currently an unused school, and the commercial buildings further downstream. Duration of flooding at or above H2 hazard peaks at 0.5 hours in the west bound lane of Henry Street, immediately downstream of the intersection with Evan Street. However, the lane is not cut in this event and a relatively normal traffic flow is still possible.

In the 5% AEP event, a larger flood extent affects the intersection of Evan Street and Henry Street. The flood hazard level ranges between H1 and H2, and the west bound lane of Henry Street is cut for up to 1 hour. The flow path then continues to affect the unused school grounds and the above mentioned commercial buildings. The latter starts experiencing medium hazard floodwaters (i.e. hazard = H3) from the 1% AEP event, and the main commercial building has above floor flooding from the same event. IN this event, the intersection of Henry Street and Evan Street is likely to be close to traffic for up to 1 hour.

In the PMF, north of the railway, around Haynes Street and the Crescent, floodwaters build up against the railway embankment until they eventually go through at a low point between Blaxland Avenue and Hemmings Street. This creates a high hazard flow path running north-east to south-west through the lot at 39-49 Henry Street towards the intersection of Evan Street and Henry Street, where it joins floodwaters running west along Henry Street. From here, floodwaters continue in west direction across Evan Street to affect the two commercial buildings mentioned above plus an additional building.

In the PMF the intersection of Henry Street and Evan Street is entirely flooded and traffic is likely to be blocked for about 1 hour.

Flood hazard peaks at H5 within the lots at 39-49 Henry Street and 57 Henry Street, as well as at the commercial centre and in Henry Street. All buildings experience above floor flooding in the PMF.

While the lot at 39-49 Henry Street has its access to Henry Street cut from the 1% AEP event, the lot at 57 Henry Street and the three commercial buildings have flood free access to Henry Street up to the PMF.

ii) Analysis of Flood Modification Options

The pipe running along Henry Street veers north-west upstream of the intersection with Evan Street, crossing the lot at 39-49 Henry Street, then it is joined by a pipe running north along Evan Street. The resulting pipe then heads west across the school to join a larger set of pipes in front of the commercial centre. The model shows that a section of the pipe in Henry Street, the pipe in Evan Street and another section of the pipe within the school grounds are at capacity from the 20% AEP event, whereas the downstream pipe system starting in front of the commercial centre has spare capacity in the 5% AEP event.

At the time this study was undertaken; two rezoning proposals had been submitted for the lots at 39-49 Henry Street and 57 Henry Street to modify the land use to High Density Residential from Mixed Use and Commercial Core respectively. The proposal for 57 Henry Street included a plan to upgrade the local stormwater system, with a pipe running around the proposed building footprint, and discharging into a section of the existing pipe within the same lot, before this connects to the downstream stormwater system running in front of the commercial centre.

The flood modification option tested included implementing the proposed stormwater upgrades at 57 Henry Street, but with the following modifications:

- Increased pipe capacity to drain water from the intersection between Evan Street and Henry Street to the new pipe within the lot at 57 Henry Street;
- Increased capacity of the section of pipe within the lot at 57 Henry Street connecting to the downstream stormwater system.

The design and dimensions of this upgrade are shown in Map 55 (Vol. 2).

Another option that was assessed was to connect the pipes at the intersection between Evan Street and Henry Street with the pipes downstream in Henry Street, which has spare capacity in frequent events. However, this would require maintaining the east to west pipe gradient across the terrain hump west of the intersection, which was deemed impractical.

iii) Evaluation of the Shortlisted Flood Modification Options

Map 56 to Map 58 (Vol.2) show the change in flood levels generated by the shortlisted flood modification option in the 20% AEP event, 5% AEP event and 1% AEP event respectively. A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if this would be economically worthwhile in existing conditions. These do not include the proposed development at 39-49 Henry Street and at 57 Henry Street. Table 13 shows a summary of the results for this hotspot (please refer to Appendix C and D for more details).

Table 13. Results of Cost Benefit Analysis for Flood Modification Options in Hot Spot 6 in current conditions

Total Option Costs	$1,376,100
Total Option Benefits	$238,726
Benefit/Cost Ratio	0.17

The cost/benefit analysis showed that, in current conditions, flood modification at this location would not be economically worthwhile, having a benefit to cost ratio of only 0.17. This means that the benefits for the existing commercial buildings downstream of 57 Henry Street in terms of reduction of flood damages would be outweighed by the costs of the pipe capacity upgrade.

However, the rezoning proposal for the lot at 57 Henry Street will require an upgrade of the local pipe capacity to ensure that the relevant development conditions (i.e. flood planning levels) are met, regardless of the extent to which these benefit other existing buildings.

In addition to this, the proposed flood modification options will decrease the frequency with which Henry Street and Evan Street are cut from the 20% AEP to the 5% AEP, therefore providing benefits to traffic flow.

Given that this intersection is part of the evacuation route for regional flood evacuation traffic from North Penrith as well as from parts of the CBD, the closure of this intersection by local flooding could compromise regional flood evacuation for the Nepean River.

In terms of social costs, the shortlisted flood modification option would cause only minor inconvenience during construction operations, and these would be temporary.

Finally, the rezoning proposals provide an opportunity to fund the proposed flood modification options through developer contribution.

For these reasons, it is recommended that the proposed flood modification options are investigated further at this location and are considered as part of Council's long term planning strategy for future development.

Upon seeing the results of the flood modification option presented above, Council requested an alternative design of the new upgraded pipe, capable of achieving comparable flood level reductions at the intersection of Evan Street and Henry Street, but adding draining capacity for the site at 39-49 Henry Street, so that it would benefit both proposed developments and would reduce flood risks to traffic and pedestrians in Henry Street. The alternative pipe upgrade design is shown in Map 59 (Vol.2).

g) Hot Spot #7 and #14: Nepean Square, K-Mart area and residential properties between Woodriff Street and Castlereagh Street

Hot Spot #7 (Map 60, Vol. 2) and #14 (Map 61, Vol. 2) are discussed jointly in this section because of their proximity and the similarity of flood behaviour.

i) Flood Behaviour and Risks

At this location, in the 20% AEP event there is minor flood affectation of the car park surrounding the commercial centre in Nepean Square, especially at its south-western end. Here hazard levels range between H1 and H2, which may be sufficient to cause damage to some of the parked cars. This is caused by a flow path running north-east along Woodriff Street and partly veering north-west to traverse the car park. The commercial centre is only affected along its eastern wall, where floodwaters coming from Woodriff Street and veering left build up against the building wall. Here, flood hazard levels are mostly H2. Here, flood duration above H2 hazard peaks at 3.5 hours, however this is likely to be shorter because of the contribution of the car park private stormwater system, which is not considered in the flood model.

There are a 1.05m diameter pipe and a 1.1x2.4 m culvert running from Woodriff Street to Station Street, under the commercial centre. While the pipe is at full capacity in the 20% AEP event, the culvert has about a 20% residual capacity.

There is a second minor flow path running south-east to north-west between Castlereagh Street, Brown Street and Woodriff Street, which affects some of the residential properties south of Stafford Street.

In addition to this, at the low point of Brown Street, north of Stafford Street, there is a relatively large flooded area, which in this event does not cause any appreciable damage to the adjacent residential properties.

The pipes along Woodriff Street have spare capacity up to the commercial centre, and north of this point run close to full capacity.

In the 5% AEP event, flood extent in the car park increases, however flood hazard remains generally below H2 throughout the area. The flow path running along Woodriff Street starts receiving floodwaters from Stafford Street.

The pipes on Woodriff Street still have some minor spare capacity south of the car park. Several residential properties between Brown Street and Woodriff Street start experiencing external damages, however only two dwellings have above floor flooding. There is a pipe running from Castlereagh Street to Woodriff Street across this spot but this is at full capacity from the 5% AEP event. The culvert running under the commercial centre has virtually no residual capacity in this event.

Flood duration above H2 hazard exceeds 10 hours in the car park, but as previously noted this is a conservative estimate because it does not consider the car park private stormwater system. In Brown Street there are now more houses isolated by hazardous floodwaters for up to 1.5 hours.

In the 1% AEP event, flood hazard reaches level H3 in the car park, east of the commercial centre and in Brown Street. A total of eight properties between Castlereagh Street and Woodriff Street experience above flood flooding (four of these are south of Stafford Street and four north).

Flood duration at or above H2 hazard exceeds 12 hours in the car park, and reaches 2.5 hours in Brown Street

In the PMF, all roads at this location flood with average hazards ranging between H2 and H5, but mostly H3. Peaks of H5 hazard are observed in Stafford Street and in Woodriff Street, along the eastern side of the commercial centre in Nepean Square.

Flood duration at or above H2 hazard is generally up to1.5 hours in most roads, but it exceeds 2.5 hours in Brown Street.

Of the 193 residential buildings located between Woodriff Street and Castlereagh Street, south of Derby Street and north of Jamison Road, 162 experience above floor flooding. The maximum depth above floor is 0.75m.

Almost all buildings in Brown Street are located in Low Flood Islands and would have their escape routes cut in frequent events before they are eventually affected by flooding (Map 25, Vol. 2). There is a low point in Brown Street, north of Stafford Street, where residential buildings begin to be isolated by floodwaters in events as frequent as the 20% AEP.

ii) Analysis of Flood Modification Measures

An assessment of the private stormwater system of the commercial centre and the relevant car park was undertaken to understand if this would be able to drain the flooding shown by the model. The assessment confirmed this hypothesis.

With regard to flood affectation of the residential properties east of Woodriff Street, the only option to reduce flood levels in frequent events would be to increase the capacity of the pipe running from Castlereagh Street to Woodriff Street, as well as the downstream pipe/culvert system running under the commercial centre. These are all at full capacity, or close to being at full capacity, in the 20% AEP event. However, this option was not modelled because:

- At this location there are no properties experiencing above floor flooding in the 20% AEP event and only two properties with above floor flooding from the 5% AEP event. As such flood modification at this location is likely to bring only minor benefits;
- The practical and financial implications of running a new pipe under multiple residential lots and the shopping centre would offset the benefits in terms of reduction of flood impacts.

However, given the significant risk to people and frequency of road flooding at this location, it is recommended that Council considers upgrading the stormwater system between Castlereagh Street to Woodriff Street, and from Woodriff Street to Station Street as part of Council's long term planning strategy for future development.

In addition to this, the block between Nepean Square and Jamison Road has been rezoned as High Density Residential. This presents an opportunity to introduce flood modification measures as part of this redevelopment to reduce the amount of water running north along Woodriff Street and eventually affecting Nepean Square. This would likely free some capacity of the culvert running under the commercial centre and potentially reduce flood levels at the residential properties in Woodriff Street.

h) Hot Spot #8: Parker Street/ Northern Road drainage

i) Flood Behaviour and Risks

In the 20% AEP event there is minor flooding of three spots along two of the three southbound lanes of Parker Street (Map 62, Vol. 2), namely:

- between Jamison Road and Stafford Street;
- north of Stafford Street; and
- at the intersection with Barber Avenue.

At all these locations, hazard levels are below H1 in one of the two lanes affected and overall below H2. While each location is serviced by a pipe, these are at already at full capacity in the 20% AEP event. At the southern end of Parker Street there is a residential property with above floor flooding in the 20% AEP event.

In the 5% AEP event, flood extent increases at each of the above mentioned spots, and while it remains confined to two south bound lanes at the two southern spots, it now affects all south-bound lanes at the intersection with Barber Avenue. However, here flood hazard does not exceed H1 in one of the three lanes affected, which may remain open to traffic. Overall, similarly to the 20% AEP event, flood hazard remains below H2 at all affected spots in Parker Street and duration at H2 hazard is not greater than 0.5 hours.

In this event, the number of residential properties experiencing above flood flooding increases to three.

In the 1% AEP event, the peak hazard level increases to H2-H3 (i.e. unsafe for people and vehicles), but the flood extent still does not affect the north bound lanes of Parker Street, and .the western south-bound lane at the intersection with Barber Avenue is only affected by H1 floodwaters (i.e. no restrictions). Flood duration at or above H2 hazard in the eastern lanes peaks at 1 hour.

At the southern end of the road, there are now four buildings with above floor flooding.

In larger events, the western south-bound lane of Parker Street maintains conditions suitable (although not ideal) for vehicular traffic up to the 0.5% AEP, while in the PMF flood hazard reaches significant levels and traffic southbound is blocked, although for only about 30 minutes.

The number of buildings in Parker Street with above floor flooding in the PMF increases to 16.

In all events the model shows significant flooding of the Nepean Hospital car park, however this is likely to be managed by the hospital private drainage system, which is not considered in the flood model.

ii) Analysis of Flood Modification Measures

Parker Street remains trafficable northbound in any event, and southbound the hazard level does not exceed H2 (i.e. unsafe for small cars) in all lanes in any event but the PMF. As flood modification is typically effective only in frequent events, it is not recommended at this location to reduce the frequency with which Parker Street is cut.

Parker Street is a major evacuation route in case of mainstream flooding from the Nepean River. As such there is a concern that the road may become cut by local flooding while an evacuation from the Nepean River is ongoing.

While any flood modification intervention at this location is unlikely to change to a significant extent the frequency with which Parker Street is cut, the model shows that the three northbound lanes would be trafficable in all events.

Furthermore, one of the south bound lanes would be trafficable at least up to the 0.5% AEP event, and in greater events would be cut by floodwaters and become unsafe for small vehicles (i.e. H2) for no longer than 30 minutes. Should this occur while an evacuation from the Nepean River is ongoing, there would still be an opportunity for the NSW SES to temporarily provide contraflow traffic in one or two of the northbound lanes.

It is emphasised that this would only be required in the unlikely circumstances that significant local flooding occurs while an evacuation from the Nepean River is taking place, and that even under these circumstances the contraflow would be necessary for no longer than 30 minutes.

If the NSW SES does not find this solution acceptable then improvements to the drainage under Parker Street may need to be considered as part of the Hawkesbury Nepean Flood Risk Management Strategy.

i) Hot Spot #9: Castlereagh Street/ Evan Street / Doonmore Street Lethbridge Street

i) Flood Behaviour and Risks

This is a major area of concern in Penrith CBD (Map 63, Vol. 2). A large flow path originates north of the intersection of Derby Street and Doonmore Street. The flow path continues within an open canal which runs west past Doonmore Street among several residential properties, most of which are unit blocks. About 100m east of Evan Street the canal enters a culvert and resurfaces 20m past the road. It then continues in a westerly direction for 90m and re-enters a culvert which runs under several residential lots up to the intersection of Lethbridge and Castlereagh Street, where it connects to a new pipe draining to the Showground Channel.

The canal is overtopped at several locations in events as frequent as the 20% AEP, more significantly upstream of the two culverts whose capacity is insufficient in the 20% AEP event.

This causes above floor flooding in two buildings upstream of Evan Street and two unit blocks south west of the intersection of Lethbridge Street and Castlereagh Street. Flood hazard reaches H3 across many residential properties.

Flood duration at or above H2 hazard is overall around 1 hour, but at locations where floodwaters pond or build up against buildings it reaches 4 hours.

In the 5% AEP event there are eight dwellings with above floor flooding east of Evan Street and 13 dwellings downstream. Flood hazard reaches peaks of H4 in proximity of the canal. Evan Street is cut by floodwaters with a hazard level of H2. Flood duration above H2 hazard now peaks at 5 hours at some isolated spots, however it remains below 1 hour elsewhere.

In the 1% AEP event the number of dwellings with above floor flooding increases to 49, and flood hazard reaches H4 at several locations. In this event Lethbridge Street is cut by floodwaters with hazard H5. Flood duration above H2 hazard is about the same observed in the 20% AEP.

In the PMF there are 118 dwellings with above floor flooding, with depths above floor up to 2m. Of these, 97 are affected by floodwaters with hazard of H5, which poses a significant risk to their structural stability and to the safety of the occupants. In any design event most of the affected buildings have rising road access to flood-free land. Flood duration above H2 hazard is about the same observed in the 20% AEP.

ii) Analysis of Flood Modification Options

The flow path originates in the park located at lot 135 Derby Street, north of Spence Park. The flood modification option that was assessed entails the construction of a 6,200 m^3 detention basin at this location (Map 64, Vol. 2).

iii) Evaluation of the Shortlisted Flood Modification Options

Map 65 to Map 67 (Vol.2) show the change in flood levels generated by the shortlisted flood modification option in the 20% AEP event, 5% AEP event and 1% AEP event respectively. A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if this would be economically worthwhile in existing conditions. Table 14 shows a summary of the results for this hotspot (please refer to Appendix C and D for more details).

The cost/benefit analysis showed that, in current conditions, flood modification at this location would be economically worthwhile, having a benefit to cost ratio of 5.96.

In terms of social costs, the shortlisted flood modification option would cause only minor inconvenience during construction operations, and these would be temporary. In the long term the detention basin would still be able to be used for passive recreation as it currently is although flood risks to park users would be increased.

However, the assessment identified the following Threatened Ecological Communities (TECs) within the park where the detention basin would be built:

- Forest Red Gum PCT 835 (River-Flat Eucalypt Forest on Coastal Floodplains of the New South Wales North Coast, Sydney Basin and South East Corner Bioregions, an Endangered Ecological Community - EEC); and
- Grey Box PCT849 (Cumberland Plain Woodland in the Sydney Basin Bioregion, a Critically Endangered Ecological Community - CEEC).

Council will need to assess the proposed flood mitigation works under Part 5 of the EP&A Act. As part of the assessment process, the impacts of the removal of this vegetation would be assessed and appropriate mitigation or offset measures considered

In conclusion, the proposed flood modification option offers a very high benefit cost ratio. Social costs at this location are negligible and can be reduced if appropriate action is taken during design and construction. However, there are environmental impacts which would have to be further investigated and mitigated.

Table 14. Results of Cost Benefit Analysis for Flood Modification Options in Hot Spot 9

Hot Spot Number	9				
Scale of the Problem:	20% AEP		5% AEP		1% AEP
Buildings with AGF	103* 10**		139* 17**		238* 34**
Buildings with AFF	8* 10**		24* 17**		58* 34**
Flood Modification Option Proposed	Detention Basin				
Benefit/Cost Ratio	5.96				
Total Option Costs (Present Value)	$1,175,900				
Total Option Benefits (Present Value)	$7,010,355				
AAD per Building (within 1% AEP extent)	Current Condition			$2,819*	$49,581**
	With Option in Place			$2,311*	$41,644**
Average Damage per Building (in the 1% AEP event)	Current Condition			$16,705*	$429,080**
	With Option in Place			$15,110*	$423,107**
* = dwellings, ** = non-residential buildings					

j) Hot Spot #10: Penrith RSL

i) Flood Behaviour and Risks

Penrith RSL is located north-west of the intersection of Lethbridge Street and Castlereagh Street, and immediately downstream of Hot Spot #9. As such flood behaviour at this location is driven by the overland flow path discussed in the previous section, which goes past the intersection of Lethbridge and Castlereagh Street, then runs around the eastern and northern wall of the RSL in Castlereagh Street and in Tindale Street respectively.

In the 20% AEP event only the section of Castlereagh Street between Lethbridge and Tindale Street is affected, with flood hazard below H2. In this event the RSL would not experience above floor flooding (Map 68, Vol. 2).

In the 5% AEP event the flow path runs around the RSL in Castlereagh Street and Tindale Street, with hazard levels between H2 and H3. The model results suggest that in this event floodwaters would be at the same level of the RSL floor, however no above floor flooding would occur.

In this event Castlereagh Street is cut for up to 1 hour north of the intersection with Lethbridge Street. Lethbridge Street is cut upstream of the above mentioned intersection for 0.5 hours.

In the 1% AEP event, flood extent, depth and velocity would further increase, and flood hazard would peak at H4 at a few isolated spots around the RSL. In this event the building is likely to experience mild above floor flooding (the model shows a depth above floor of 0.11m).

In this event flood duration above H2 hazard in Castlereagh Street is the same as in the 20% AEP event, however Lethbridge Street is now cut for 1 hour.

In the PMF the RSL become surrounded by floodwaters and experiences above floor depths of 1.3m. Hazard levels peak at H5 in Lethbridge Street but are mainly H2-H3 around the RSL in Castlereagh and Tindale Street.

All streets around the RSL flood for about 1 hour. Floodwaters build up at the back of buildings in Woodriff Street for up to 4 hours.

The model shows significant affectation of the commercial area downstream of the RSL in Tindale Street and along The Broadway. Here there are eight buildings with AFF in the 20% AEP, 14 buildings with AFF in the 5% AEP and 32 buildings with AFF in the 1% AEP.

ii) Analysis of Flood Modification Options

Council recently installed a pipe running from the intersection of Castlereagh Street and Lethbridge Street which discharges to the Showground Channel. This pipe runs parallel to a smaller, older pipe, whose connections to the surrounding pits were cut when they were redirected to the new pipe. Both pipes start from a culvert located south of the intersection of Castlereagh and Lethbridge Street.

The culvert collects stormwater from a pipe catering for the upstream residential area between Castlereagh Street, Lethbridge Street, Derby Street and Evan Street. The capacity of this pipe is exceeded from the 20% AEP event, which results in a significant overland flow path through the intersection of Castlereagh Street and Lethbridge Street. This flow path runs past the culvert and affects several residential and non-residential buildings downstream of the RSL, eventually reaching Union Street car park.

The flood modification option tested at this location entails measures to divert the overland flow path towards the culvert, redirecting part of the flow to the Showground Channel. The analysis of the pipe residual capacity shows that the older of the two pipes draining to the Showground Channel has spare capacity up to the 5% AEP event, and the Showground Channel has capacity up to and including the 1% AEP event.

The following options were assessed:

(a) regrading the land between Lethbridge Street and the culvert,

(b) adding a new pipe from Lethbridge Street to the culvert;

(c) adding a water diversion device or a grated pit across Lethbridge Street; and

(d) a local capacity increase of the y-shaped pipe system draining water from the intersection of Castlereagh Street and Lethbridge Street to the old pipe discharging to the Showground Channel (Map 69, Vol. 2).

Upon further analysis option (a) was deemed impractical due to the local topography and existing development and was not investigated further. Option (b), (c) and (d) were retained and their combined effect on flood levels was assessed with the flood model.

Option (b) was achieved by adding a new 1,200mm pipe draining water from O'Farrell Lane to the Lethbridge Street/Castlereagh Street culvert.

The water diversion device mentioned in Option (c) (e.g. a speed hump) was positioned across Lethbridge Street, immediately downstream of the pits feeding the pipe described in option (b). Should the speed hump be deemed impractical, it could be replaced by a grated pit across Lethbridge Street.

The model showed that this configuration of options would produce significant flood level reductions at the RSL building and in the commercial area downstream of it. In addition to this, a substantial contribution to the reduction of flood levels at this location (and further downstream) would be provided by the detention basin tested to address flood affectation in Hot Spot #9.

Specifically, an analysis of differential flow rates and depths produced individually by the detention basin at Hot Spot #9 and the flood diversion at Hot Spot #10 was undertaken. The analysis showed that, on average, in the most frequent AEP events flood depth reductions downstream of the intersection of Lethbridge Street and Castlereagh Street are generated in equal proportions by the detention basin and flood diversion at Hot Spot #10.

iii) Evaluation of the Shortlisted Flood Modification Options

Map 65 to Map 67 (Vol.2) show the change in flood levels generated by the shortlisted flood modification option in the 20% AEP event, 5% AEP event and 1% AEP event respectively. A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if this would be economically worthwhile in existing conditions. Table 15 shows a summary of the results for this hotspot (please refer to Appendix C and D for more details).

The cost/benefit analysis showed that, in current conditions, flood modification at this location would be economically worthwhile, having a benefit to cost ratio of 22.68. The unusually high ratio score is due to the fact that flood modification at this location would require minimal works as it would make use of already existing and underutilised stormwater infrastructure.

In terms of social costs, the shortlisted flood modification option would cause only minor inconvenience during construction operations, and these would be temporary.

In conclusion, the proposed flood modification options at this location were deemed worth further investigation.

*Table 15. Results of Cost Benefit Analysis for Flood Modification Options in Hot Spot 10**

Hot Spot Number	**10**					
Scale of the Problem:	**20% AEP**		**5% AEP**		**1% AEP**	
Buildings with AGF	13*	9**	21*	15**	45*	32**
Buildings with AFF	0*	9**	2*	15**	4*	32**
Flood Modification Option Proposed	Flood Diversion into Existing Pipe					
Benefit/Cost Ratio	22.68					
Total Option Costs (Present Value)	$210,100					
Total Option Benefits (Present Value)	$4,765,854					
AAD per Building (within 1% AEP extent)	Current Condition	$1,081*	$51,112**			
	With Option in Place	$923*	$35,997**			
Average Damage per Building (in the 1% AEP event)	Current Condition	$8,939*	$447,357**			
	With Option in Place	$6,858*	$443,978**			
*** = dwellings, ** = non-residential buildings**						

*Includes benefits to development downstream of Penrith RSL

k) Hot Spot #11: Doonmore Street/ Colless Street/ Parker Street

i) Flood Behaviour and Risks

This Hot Spot occupies most of the upper part of the catchment (Map 70, Vol. 2). Two independent overland flow paths develop at the northern and southern end of Parker Street and run south-west and north-west respectively across several residential properties, until they merge east of Doormore Street. Both flow paths run along an existing series of pipes, however these are nearly at full capacity from the 20% AEP event.

Northern Flow Path

The model suggests that the northern flow path may cause above floor flooding in the 20% AEP event in six buildings that are part of the same residential development, located south-west of the intersection of Parker Street and Barber Avenue.

Past this point, this flow path cuts south-west across two residential blocks, crossing Lethbridge Street first and reaching the intersection of Hope Street and Colless Street. Two of the affected residential properties between Lethbridge Street and Hope Street experience above floor flooding from the 5% AEP event, and a third one from the 1% AEP event. The flow path then continues west along Hope Street until it reaches the park north-east of the intersection of Derby street and Doonmore Street.

In the PMF, floodwaters reach hazard levels of H4-H5 along Hope Street and 89 dwellings experience above floor flooding. All affected buildings have rising road access to flood free ground.

Southern Flow Path

The southern flow path originates in Parker Street, between Jamison Road and Stafford Street. It then runs north-west to reach Rosedale Avenue. From here it continues to cross Stafford Road and Colless Street.

It then cuts across several residential properties between Colless Street and Doonomore Street and runs through Spence Park and Derby Street until it joins the northern flow path in the park north east of the intersection of Derby Street and Doonmore Street.

Between Parker Street and Colless Street the model results suggest that five dwellings experience above floor flooding in the 20% AEP event, while ten additional dwellings from the 5% AEP event. Downstream of Colless Street more residential properties are affected, with 13 dwellings experiencing above floor flooding in the 20% AEP event, three additional dwellings from the 5% AEP event and nine more dwellings from the 1% AEP event.

While the pipe upstream of Colless Street is at full capacity in the 20% AEP event, the pipe downstream of Colless Street has significant spare capacity in the 5% AEP event.

In the PMF, floodwaters reach hazard levels of H4-H5 and 96 dwellings experience above floor flooding. Of these, 42 are affected by hazard levels of H5 and may become structurally unstable. All affected buildings have rising road access to flood free ground.

At this Hot Spot flood duration above H2 hazard is on the order of 1 to 2 hours in all events. There are however localised peaks of 4 to 5 hours from the 5% AEP event at the back of some houses in Colless Street and upstream of Spence Park.

ii) Analysis of Flood Modification Options

A pipe capacity upgrade was initially assessed for both flow paths. However, the one addressing the northern flow path was not deemed worth further investigations because:

- above floor flooding occurs in frequent events in only a few buildings, located predominantly at the top of the catchment where pipe capacity increases will be of minimal benefit;

- the existing pipes are at full capacity from the 20% AEP event along the whole length of the flow path, reducing flood levels for the affected buildings would require upgrading the pipe capacity from Parker Street to Doonmore Street. Given the significant length of this section and the fact that it runs entirely across residential lots, the costs of constructions would be significantly higher than the benefits that would likely be obtained;
- This area is zoned as High Density Residential and as such is likely to undergo extensive redevelopment. This may provide an opportunity to upgrade the stormwater system along the whole length of the flow path as part of the redevelopment and to ensure building floor levels are appropriate to the flood risk.

With regard to the southern flow path, a pipe capacity upgrade was deemed necessary only in the section between Rosedale Avenue and Colless Street, because downstream on this point the existing pipes have significant spare capacity. As such, the following pipe capacity upgrade was assessed in detail:

- Addition of a 1.2m (w) x 0.6m culvert from Rosedale Avenue to Stafford Street and Colless Street (Map 71, Vol. 2).

iii) Evaluation of the Shortlisted Flood Modification Options

Map 72 to Map 74 (Vol.2) show the change in flood levels generated by the shortlisted flood modification option in the 20% AEP event, 5% AEP event and 1% AEP event respectively. A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if this would be economically worthwhile. Table 16 shows a summary of the results for this hotspot (please refer to Appendix C and D for more details).The cost/benefit analysis showed that, in current conditions, flood modification at this location would be economically worthwhile, having a benefit to cost ratio of 2.2.

In terms of social costs, the shortlisted flood modification option would cause only minor inconvenience during construction operations, and these would be temporary.

In conclusion, the proposed flood modification options were deemed worth further consideration.

Table 16. Results of Cost Benefit Analysis for Flood Modification Options in Hot Spot 11

Hot Spot Number	11		
Scale of the Problem:	**20% AEP**	**5% AEP**	**1% AEP**
Buildings with AGF	25r*	34*	41*
Buildings with AFF	16*	27*	34*
Flood Modification Option Proposed	Stormwater System Upgrade		
Benefit/Cost Ratio	2.2		
Total Option Costs (Present Value)	$1,257,300		
Total Option Benefits (Present Value)	$2,764,499		
AAD per Building (within 1% AEP extent)	Current Condition	$13,277*	
	With Option in Place	$9,876*	
Average Damage per Building (in the 1% AEP event)	Current Condition	$57,523*	
	With Option in Place	$43,458*	
*** = dwellings, ** = non-residential buildings**			

l) Hot Spot #12: Entry to Council's main office basement carpark in Jane Street.

i) Flood Behaviour and Risks

At this location the flooding is caused by water running off Jane Street, ponding against the northern wall of Council's building and running down the car park exit ramp. This generates a relatively large puddle outside the building from the 20% AEP which would likely cause flooding of the car park itself (Map 75, Vol. 2). The car park entry is currently protected by a manually operated flood gate, which in past floods was not closed in time due to the lack of warning for local flooding.

The model shows that floodwaters pond at the car park entrance for over 10 hours in all events greater than the 20% AEP, however the effect of the building private stormwater system is not considered, therefore the actual flood duration is likely to be shorter.

ii) Analysis of Flood Modification Options

This issue of floodwaters entering the car park could be addressed at least in the most frequent events by replacing the manual flood gate with an automatic one, triggered by a water level detector.

m) Hot Spot #13: Carpenter Site flooding from Showground Channel

i) Flood Behaviour and Risks

The Carpenter Site is bounded on its western side by the Showground Channel and by Mulgoa Road on its eastern side. The site is outside the study area, however it was included in the analysis to assess the suitability of the existing culvert on the Showground Channel under Mulgoa Road. The model does not show any significant flooding of the site caused by the Showground Channel up to the 0.5% AEP event included (Map 76, Vol. 2). It also does not show signs of insufficient capacity of the Showground Channel culvert under Mulgoa Road, which does not cause overtopping in the 0.5% AEP event.

North of the above mentioned culvert, the model shows water ponding at a low point nearby the residential lots at 8 and 10 John Tipping Grove, with possible above floor flooding from the 20% AEP event. However this was deemed unlikely to reflect an actual risk to the building at 8 John Tipping Grove, because this was recently redeveloped and built at the flood planning level. Similarly, the lot at 10 John Tipping Grove is currently under construction. In addition to this, the model shows two houses with above floor flooding from the 5% AEP event, north and south of the above mentioned lots respectively.

At this location there is a second smaller culvert under Mulgoa Road, draining water to the Carpenter Site from a pipe running along John Tipping Grove. The model shows that this pipe is at full capacity in the 20% AEP event.

ii) Analysis of Flood Modification Options

The model shows that the existing culvert under Mulgoa Road provides sufficient capacity to avoid overtopping of the Showground Channel up to the 1% AEP event, upstream and downstream of Mulgoa Road. This is consistent with findings of the Peach Tree & Lower Surveyors Creek Flood Study, adopted by Council.

The proposed flood modification options upstream of the Channel (i.e. Hot Spot #2, Hot Spot #3) are likely to increase the flow in the Showground Channel, however the flood model results show that even in this case there would be no affectation of the site up to the 0.5% AEP event included, and that the existing culvert under Mulgoa Road would provide sufficient capacity.

With regard to flood affectation in John Tipping Grove, a preliminary analysis shows that this may be reduced by increasing the capacity of the local pipe and the relevant culvert under Mulgoa Road. However this option was not modelled because only two buildings would have reduced frequency of above floor flooding, making flood modification at this location unlikely to be economically worthwhile.

However it is recommended that Council considers exploring this option further as part of Council's long term planning strategy for future development, as it would reduce the frequency with which the road floods and, as a consequence, risks to traffic, pedestrians and local residents. This would also reduce the risk of local road flooding preventing these dwellings at the lowest end of the catchment from being able to evacuate from a Nepean River flood.

n) Hot Spot #14: Residential area east of Nepean Square and k-Mart

This Hot Spot was discussed jointly to Hot Spot #7.

o) Hot Spot #15: Residential Area between Stafford Street and Jipp Street

i) Flood Behaviour and Risks

An overland flow path develops in Jipp Street from the 20% AEP event and runs west towards Evan Street (Map 77, Vol. 2). It then cuts north across some residential properties causing above floor flooding in four of these in the 20% AEP.

From here, the flow path continues to the intersection of Evan Street and Stafford Street, then runs west in Stafford Street and before reaching Hand Avenue cuts north again across the adjacent residential block.

The flow path then crosses Hand Avenue about half way through it, and continues north across more residential properties at the intersection with Derby Street. Here the model shows one dwelling with above floor flooding in the 20% AEP event, and seven other dwellings from the 5% AEP event.

The whole flow path runs along an existing pipe, however most of this is at full capacity in the 20% AEP event.

Flood duration above H2 hazard is up to 1 hour in the 20%, with a peak at the back of some houses downstream of Stafford Street. In the 20% AEP duration increases to 1.5 hours and Hand Avenue is cut for about 0.5 hours. In the 1% duration reaches 2.5 hours in Jipp Street and downstream of Stafford Street. Hand Avenue is cut for about 1 hour.

In the PMF a total of 46 dwellings experience above floor flooding. Of these, 37 are single storey buildings, and 30 are affected by a hazard level of H5 which may undermine their structural stability. Flood duration above H2 hazard is overall between 30 minutes and 1 hour.

ii) Analysis of Flood Modification Options

Given the high number of residential properties with above floor flooding in frequent events, flood modification is likely to bring significant benefits at this location.

The area does not offer opportunities for flood detention; therefore flood modification can be achieved only though an upgrade of the pipe capacity. As such, the following flood modification option was assessed for this site (Map 78, Vol. 2):

- Addition of a 600mm diameter pipe at the western end of Jipp Street, fed by two pits on the northern side of the street;
- The pipe mentioned above feeds a 600mm diameter double pipe system in Evan Street, which then continues west in Stafford Street up to the intersection with Hand Avenue;
- In Hand Avenue, an additional 600mm diameter pipe is added for the whole length of the street. The triple pipe then continues west in Derby Street and cuts north between two residential properties to join the existing stormwater system.

iii) Evaluation of the Shortlisted Flood Modification Options

Map 79 to Map 81 (Vol.2) show the change in flood levels generated by the shortlisted flood modification option in the 20% AEP event, 5% AEP event and 1% AEP event respectively. A cost-benefit analysis was undertaken for the shortlisted flood modification option to assess if this would be economically worthwhile. Table 17 shows a summary of the results for this hotspot (please refer to Appendix C and D for more details).

The cost/benefit analysis showed that, in current conditions, flood modification at this location would be economically worthwhile, having a benefit to cost ratio of 2.79.

In terms of social costs, the shortlisted flood modification option would cause only minor inconvenience during construction operations, and these would be temporary.

In conclusion, the proposed flood modification options were deemed worth further consideration.

Table 17. Results of Cost Benefit Analysis for Flood Modification Options in Hot Spot 15

Hot Spot Number	15		
Scale of the Problem:	**20% AEP**	**5% AEP**	**1% AEP**
Buildings with AGF	12*	31*	34*
Buildings with AFF	6*	15*	19*
Flood Modification Option Proposed	Stormwater System Upgrade		
Benefit/Cost Ratio	2.79		
Total Option Costs (Present Value)	$1,674,200		
Total Option Benefits (Present Value)	$4,671,789		
AAD per Building (within 1% AEP extent)	Current Condition	$9,001*	
	With Option in Place	$4,411*	
Average Damage per Building (in the 1% AEP event)	Current Condition	$46,214*	
	With Option in Place	$23,518*	
*** = dwellings, ** = non-residential buildings**			

9.4 PROPERTY MODIFICATION

Property modification options can be used to reduce flood risks to existing or future development.

9.4.1 Existing buildings

House raising or voluntary purchase were deemed unsuitable across the CBD due to the nature of the development and flood behaviour. As such property modification measures for existing buildings were assessed only when these could reduce risk to people. There are two ways in which existing buildings might be modified to reduce risks:

a) Elevated refuge

Where hazardous flooding could enter a building, and evacuation to flood free ground cannot be achieved safely, the provision of a refuge above the reach of floodwaters may be a viable means of keeping people beyond the reach of floodwaters. This might be through provision of a mezzanine level in a commercial or industrial building or the construction of a second storey on a residential building.

Such provisions cannot be mandated by Council nor does Council or DPIE provide funding for their construction. Any decision to provide such a building modification measure to reduce flood risks would be entirely up to the property owner. Factors that owners might want to take into consideration in such a decision are:

- The probability that hazardous flooding will enter the building;
- The probability that the building will be occupied when it floods;
- The duration of the flooding;
- The mobility of occupants and their ability to reach an upper level;
- The potential loss of electricity supply during a flood;
- The stability of the building during high hazard flooding;
- The cost of providing the building modification;
- The value the modification adds to the overall property value.

While the option analysis in this FRMS&P does not evaluate the provision of refuges as a property modification measure, it does provide information about flood behaviour and potential property impacts which can be used by property owners to inform their own investigations.

It is stressed that in the western end of the catchment consideration also needs to be given to the risks posed by flooding from the Nepean River when property owners evaluate the benefits of modifying their existing building with a refuge.

b) Building strengthening

Sheltering within a building beyond the reach of floodwaters may not be safe if the building becomes structurally unstable due to the impacts of flooding. There may therefore be benefits in strengthening a building to reduce risk to the occupants. As with the provision of elevated refuges, such building modifications would neither be mandated nor funded by Council.

When assessing the costs and benefits of such building modifications, a property owner should consider, amongst other factors:

- The potential hydrostatic, dynamic and debris loads might place on a building;
- The probability that such loads will be imposed on the building;
- The probability that the building will be occupied when it floods;
- The cost of providing the building modification;
- The value the modification adds to the overall property value.

The discussion of Hot Spots provides information about the current estimated flood risks which can be used by property owners as a starting point for their own investigations. Again it is stressed that in the western parts of the catchment the impacts of Nepean River flooding also needs to be taken into account.

9.4.2 Future Buildings

Flood risks to future development can be managed through appropriate provisions in Council's planning instruments. This can include strategic planning of flood prone areas and the inclusion of development controls for flooding.

Redevelopment may reduce flood risks in multiple fashions, including:

- Changing landuses over time to be compatible with flood risks;
- By building at the flood planning level (i.e. level of the 1% AEP event plus

freeboard), where this condition is currently not satisfied by existing development;

- At some locations, building at the flood planning level will provide protection against events less frequent than the 1% AEP, including the PMF (Map 82, Vol. 2);
- By employing flood-proof building design solutions and construction materials;
- By adopting locality specific development controls to address the variability of flood risks and urban landscape within the study area.

a) Rezoning

Changing land zonings to encourage development which is more compatible with the flood risks is one way of reducing flood risk.

Currently within the study area there are significant areas zoned Commercial Core, Mixed Use, High Density Residential, Medium Density Residential, Low Density Residential and Recreation (Map 6, Vol. 2). There are no planning imperatives to change the extent of these zonings but to meet State Government and Council dwelling and job targets for the CBD more intense development than is currently permitted within some of these zones may be necessary.

Council has advised that throughout the CBD most of the land use zones set in PLEP (2010) have significant spare capacity for new development within the existing zonings, pending compatibility with regional flood evacuation requirements. This provides an opportunity to address flood risks to property or people as part of the redevelopment process but this would be achieved through modifying development controls within these zones rather than changing zone boundaries.

Consideration was given to whether the rezoning of some additional areas for open space would enable the removal of development from areas of highest risk.

However, most of the high hazard flood areas are either narrow linear strips in the upper catchment which would require the acquisition of numerous properties or they are wide expanses in the lower catchment which are close to or in the commercial core of the CBD. In the latter case they would not be suitable for conversion to open space for other planning reasons. Furthermore, Nepean River flooding poses a much greater risk to the lower catchment and would be the predominant driver of any land use or zoning changes. Rezoning was therefore not considered further as part of this study.

b) Amendments to Planning Instruments

Development controls provide the opportunity to reduce flood risks when buildings are being built, renovated or extended. Penrith's provisions with regards to flooding can be found in two related documents:

- Penrith LEP 2010; and
- Penrith DCP 2014.

The LEP and DCP provisions warrant review. This would provide an opportunity to update and rationalise the controls relating to both overland flow funding (the subject of this study) and riverine flooding. The revised controls should continue to be structured to ensure they can be applied across the LGA and not just the study area.

Generally, matters that could be addressed in a review of the DCP include removing superfluous references to historical flood context and studies and structured to trigger consideration of a range of currently accepted flood planning matters such as:

- Site and Floor levels
- Building materials
- Structural soundness
- External Flood Effects
- Emergency Management
- Environmental Management

In conjunction with the review of the DCP it would be important to provide an up-to-date comprehensive set of flood maps. The LEP presently provides flood mapping that partly covers areas of the LGA with regard to riverine flooding. It is recommended that these flood maps be rationalised and updated to include both riverine and overland flow flooding information.

Flood mapping for planning purposes can take two forms:

1. Maps used to guide planners as part of a strategic planning exercise can vary and be quite detailed but need to present the full range of flood risks up to and including a PMF, so that a proper risk management approach can be applied. These maps can comprise a series of maps depicting different aspects of flood behaviour that occur at different return frequencies. "Australian Disaster Resilience Handbook 7 Managing the Floodplain: A Guide to Best Practice in Flood Risk Management in Australia" (AIDR 2017) and accompanying Guidelines provide a pertinent methodology for preparing maps for this purpose, which have been adopted as part of this study. Handbook 7 and accompanying guidelines also provide direction on how to apply such mapped information to the planning process. Within a strategic planning context FRM is considered together with all relevant planning considerations to determine the optimum planning outcome for an area.

2. Maps produced to trigger the requirement for different planning approvals and considerations to be made when assessing an application. These maps are normally included within an LEP or DCP. In the case of Penrith Council has included such maps in the LEP.

Flood maps for planning purposes, in particular for the second purpose which have more direct and enduring availability, are important as they provide a readily accessible format for the community to be informed about where Council has identified a flood risk that could require consideration for planning approval purposes. The need for consideration can vary depending on the location within the floodplain and the type of development. This enables the community and consent authorities to be informed in regard to flood risks when making property related decisions.

While the principal purpose of flood maps for such planning purposes is to trigger approval requirements, they should always be presented so not to misrepresent the existence of flood risks irrespective of whether an approval requirement is triggered. This is important to ensuring the public is fully informed of known flood risks for making personal decisions and to be flood aware during more extreme floods.

A simple and clear approach for formatting flood planning maps is to divide the floodplain into areas which pose a similar level of risk to urban land uses. An emerging convention is to map the following flood risk precincts related to both riverine and overland flow flooding (being the type of flooding relevant to this study):

- **High** – this would be where there is a significant risk of building collapse, evacuation constraints, unmanageable impact on others &/or unsustainable risk to communities and most uses would be restricted.
- **Medium** – where there is a high risk of flood damages without substantial modifications to building structures & other planning controls.
- **Low** – where the risk of damages are low modifications to building structures are not cost effective, and consequently development controls would be applied to few highly vulnerable land uses (such as schools, certain seniors living developments or hospitals) and to identify areas subject to potential evacuation requirements.
- **Overland Flow** – this precinct could identify those areas subject to overland flow flooding where flood extents and depths are confined, and planning controls should consequently be less complex or

onerous. In some cases, such as the Penrith CBD, this flood precinct would overlap with the riverine flood risk precincts.

Flood maps produced for planning assessment purposes can be used to trigger approval pathways and different controls for different types of development depending on which flood risk precinct a site is located within. The severity of the controls can be adjusted to reflect the flood risk precinct and vulnerability of the proposed land use. The maps could also be designed to align the high hazard categories referred to in the Codes SEPP with the high flood risk precinct to provide a simple and consistent flood planning map for the LGA.

Where definitive flood study information is not available but flooding is identified as a potential issue, the DCP should trigger a requirement. Control C of clause C3.5 of the DCP currently specifies submission requirements in such situations.

The standard LEP and associated guidelines do not specify whether flood maps used to trigger approval pathways and development considerations must be embodied within the LEP. The current practice across NSW varies. Incorporation of flood maps into an LEP provides clarity and certainty as to where flood related considerations apply to development where flood data is comprehensively available for riverine and overland flow flooding, but otherwise can misrepresent the actual situation and be administratively cumbersome as flood maps require constant updating.

The alternatives to the LEP adopting flood maps for planning purposes would be to adopt the flood maps as part of a standalone maps set or as part of the DCP. As a standalone maps set, format and updating of the flood maps is easiest as additional or revised flood modelling becomes available. The adoption of flood maps as part of the DCP, provides greater flexibility in format and ease for updating compared to when part of an LEP, and provides some administrative rigour including a public consultation process that can provide a checking step and added weight in the DA assessment process.

The adoption of the flood maps as part of the DCP is recommended as the preferred approach. This will require all flood relating mapping to be simultaneously stripped from the LEP and all definitions and LEP clauses such as clause 7.2(2)(b) that refer to flood mapping to be reworded to refer to maps that are contained within the DCP as may be amended from time to time.

Where definitive flood study information is not available but flooding is identified as a potential issue, the DCP should trigger a requirement. Control C of clause C3.5 of the DCP currently specifies submission requirements in such situations.

Clause 7.2(2)(a) of the LEP presently provides a reference to land at or below the FPL in order to trigger considering flood risk when assessing DAs, for situations where not triggered by mapping. Such a fall back mechanism should be retained. At present the FPL trigger level is the 1% AEP flood plus 0.5m freeboard. This can be adequate for overland flow flooding the subject of this study but would not likely be adequate for riverine flooding, particularly given the flood depth range and evacuation issues associated with Hawkesbury Nepean River flooding. An alternate approach to establishing the triggers for consideration of flood risks as part of the DA assessment process is outlined in the following section.

c) Flood Planning Levels (FPLs) and Flood Planning Area

The FDM (pg.21) defines FPLs and flood planning area (**FPA**) as follows:

flood planning levels (FPLs) are the combinations of flood levels (derived from significant historical flood events or floods of specific AEPs) and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans. FPLs supersede the "standard flood event" in the 1986 manual.

flood planning area [is] the area of land below the FPL and thus subject to flood related development controls. The concept of flood planning area generally supersedes the "flood liable land" concept in the 1986 Manual.

Consistent with the above definition, the FDM facilitates the adoption of multiple FPLs. This is current best practice as it would allow the adoption of different FPLs to target different components of a development (eg habitable, non-habitable floors, carparking, entry to basement car parking, private open space, etc) as well as managing different land uses with different vulnerability to flood hazards (eg seniors housing, standard residential or commercial/industrial). Different FPLs can also be used for other purposes such as to define the standard to which buildings need to be certified as structurally sound, the level at which flood compatible materials need to be installed, or the extent of the floodplain to be considered when assessing external flood impacts. This enables the application of a risk management approach to planning.

However, the definition of flood planning area implies the adoption of a single 'flood planning area" for planning purposes which had in past years become common practice, but is not best practice or the only approach adopted by other planning authorities across NSW or Australia.

Consequently the preferred and recommended approach is to adopt multiple FPLs and flood planning maps with a series of flood risk precincts as described above as part of Council's DCP revision. The aggregated area covered by all flood risk precincts is effectively the FPA.

To avoid conflict with the 2007 Flood Planning directive (PS 07 003), clause 7.2 of the LEP can, for example, be rephrased to apply to residential development only when located in high and medium flood risk precincts (defined to ensure their extent do not cumulatively exceed the 1% AEP flood plus 0.5m flood extent). Alternatively, an exceptional circumstances case could be made to the relevant state government agencies to allow clause 7.2 of the LEP to apply to all forms of development across the whole of the floodplain (i.e. up to the PMF). The case for exceptional circumstances would be more relevant to Nepean River flooding, particularly to ensure evacuation issues are addressed, as opposed to overland flow flooding which is the focus of this FRMS and FRMP.

A recommendation for this FRMP is the inclusion of an Overland Flow flood risk precinct as part of the mapping of the FPA. The overland flow flood risk precinct could be mapped to include the 1% AEP flood level plus 0.5m freeboard (Map 83, Vol.2). This would be consistent with the 2007 Flood Planning directive (PS 07 003), and the current provisions of clause 7.2 of the LEP. As the depth of overland flow flooding is typically minimal compared to riverine flooding, it is recommended that the FPA not exceed the PMF extent.

Separate to the definition of the FPA, it would be appropriate to revise the FRM development DCP controls, which should be reliant on multiple FPLs. The types of land uses and development components that could be subject to differential FPLs are:

- *Sensitive land uses* – seniors living housing, centre based child care centres and public buildings and community facilities likely to be required to be operational during a flood emergency.
- *Other Land Uses* – including standard residential, commercial and industrial and those not included as sensitive land uses.
- Basement parking.
- *Peripheral areas* - Non-habitable floors, external parking, private open space.
- *Concessional cases* – Minor extensions (the greater of 30m^2 or 10% of existing floor space), where required to maintain the heritage significance of a building, or for a maximum of

50% of the total floor space of commercial premises where required to provide for pedestrian access from a public area or pedestrian footpath.

The followings are provisionally recommended FPLs for the above having regard to existing controls and directives, the Codes SEPP and generally accepted practice. These recommendations are cognisant that as the range of depths of overland flooding for different floods is typically low compared to riverine flooding, the more commonly applied 0.5m freeboard can be excessive.

For example, Map 15 in Volume 2 shows that over most of the study area the depth of flooding outside of the stormwater channels is less than 0.5m deep in the 1% AEP flood. Freeboard is included in planning controls to account for uncertainties in flood modelling, localised flood level irregularities due to hydraulic surface features and building obstructions, and waves generated by wind and vehicle wash.

A freeboard of about 0.5m is appropriate where flood depths and flows are considerable and there is wide open space for wind induced waves to occur such as on the Nepean River. However, it is unlikely that the combination of factors above is likely to result in the flood depth more than doubling what has been modelled. Accordingly, a freeboard of 0.3m would be more appropriate in areas affected by overland flooding.

Table 18 provides a list of recommended FPLs taking the above into consideration.

Table 18. Recommended FPLs for Overland Flooding

Land use/ development component	Floor/ Ground Level FPL
Sensitive Land Use	PMF or 1% AEP plus 0.5m freeboard if PMF is not exceeded
Other Land Uses	1% AEP plus 0.3m freeboard
Basement Car Parking	To be protected from inundation up to the 1% AEP plus 0.3m freeboard.
Concessional cases	At least 150mm above the footpath level and no lower than the existing floor level on site, or in the entrance area of adjoining properties.

d) Other Planning Controls

In regard to other generally accepted flood planning controls the following are recommended for consideration:

- *Flood compatible materials* - These should be required up to the minimum habitable floor level in all developments so that no significant damage is caused to buildings in events more frequent than the design level event.
- *Structural soundness* – to withstand the forces of a flood up to the flood planning levels for all land uses. This would be consistent with the minimum requirements of the Building Code of Australia. In the case of sensitive land uses or where the building is required for sheltering in place where deemed appropriate in the LGA structural soundness should be provided to the PMF.
- *External flood effects* - the development should not materially increase flood effects elsewhere

having regard to the loss of flood storage and changes in flood levels and velocities caused by alterations to the flood conveyance. An engineer's report and flood modelling may be required by Council where the potential flood effects are significant and incapable of assessment based on existing information.

- *Emergency Management* - Reliable access for pedestrians or vehicles is required from the building, commencing at a minimum level equal to the lowest habitable floor level to an area of refuge above the PMF level.
- *Internal Warning Systems* - Basement car parking, not protected from inundation from floods up to a PMF should be fitted with adequate visual and audible warning systems, signage and rising pathways to exits. This is to provide for evacuation in case of inundation in an extreme flood.
- *Environmental Management* - An area should be available to store goods above the 1% AEP flood level plus freeboard. No storage of materials below the design floor level, which may cause pollution or be potentially hazardous during any flood, should be permitted.

The abovementioned controls are widely adopted throughout NSW, particularly in the urban areas of Sydney. The response of developers to these controls however have sometimes resulted in unintended consequences which have had other undesirable effects.

For example, to meet minimum floor level requirements the ground floor level of buildings is raised above street level. This can not only have a visual impact on the street scape but also create problems if the ground floor is occupied by shops as they do not have ground level access from the footpath.

Similarly, an option to prevent external flood effects can be to elevate the lowest floor level above the ground to allow the flow of flood waters through the site. Such an option must also be acceptable having regard to aesthetics, building functionality and security. That is, the consequent building form must resolve the appearance of the undercroft, be acceptable in regard to height and streetscape, and be compatible with adjoining development and the locality in regard to character and amenity considerations.

Examples of design solutions to these flood planning controls are illustrated in Figure 12.

In some LGAs development controls permit commercial development (particularly shops) at ground level below the FPL provided that there is an elevated mezzanine within the premises. The mezzanine level must be above the FPL, and the most valuable contents should be placed here. For example a restaurant may have its seating at street level but its kitchen on a mezzanine above the FPL. In this way the shop front addresses the streetscape but flood damages are minimised. This might be an appropriate planning control for Penrith CBD.

The requirement for access to an area of refuge above the PMF level can be achieved in a number of ways. For example the refuge would be required in a location external to the floodplain for riverine flooding, and consequently must be consistent with the SES Local Flood Plan. Such is the case in the western parts of the CBD study area.

In areas subject to only overland flow flooding (the eastern parts of the study area), evacuation from the floodplain may not be a reasonable expectation due to limited warning time and access roads being flooded before the building is threatened.

In situations where shelter in place is deemed acceptable by Council and the SES, a minimum refuge size above the PMF level should be specified commensurate with the number of occupants likely to be in the building. The PMF refuge should be equipped to provide for the basic needs of occupants for the expected duration of isolation during a flood. A Flood Emergency Response Plan might be required in the case of large residential flat buildings or commercial complexes.

Figure 12.Examples of ground floor levels raised to meet minimum floor level and flood flow requirements.

e) Recommendations

The aforementioned recommendations are provisional in order that some sensitivity testing of the FPLs and other planning controls can be undertaken to confirm the practicality of their implementation within the study area and across the LGA. While not essential, it would be preferable that a single set of development controls be adopted in the DCP for all land affected by overland flow flooding in the LGA, as opposed to having different controls in each catchment. That analysis is beyond the scope of this study.

It is also noted that large parts of the CBD study area are impacted by Nepean River flooding and the risks imposed by it may override local flood considerations when developing planning controls for some parts of the CBD.

While this FRMS and FRMP is prepared specifically in regard to overland flow flooding in Penrith CBD, it would be desirable that the recommendations are implemented holistically with a review of the LEP and DCP FRM provisions regarding all forms of flooding. The FRM development controls that should be applied to development on any individual site should be the more stringent required in regard to either overland flow flooding or riverine flooding. Table 19 summarises some of the key information required to underpin the identification of appropriate development controls based upon flood risk and other considerations at each of the hotspots identified in this study.

9.5 RESPONSE MODIFICATION

9.5.1 Background and Scope

Response modification options aim to reduce flood risks to people by changing their behaviour before, during and after a flood emergency.

As discussed throughout this FRMS&P, Penrith CBD may face flood emergencies arising by two types of flooding:

- Local overland flooding, which is addressed by this FRMS&P, and
- Mainstream flooding from the Nepean River, which in a PMF would affect the part of the CBD west of Castlereagh Street and Lawson Street (Map 7, Vol.2).

While mainstream flooding is not included in the scope of this FRMS&P, its implications in terms of emergency management and response modification are such that it needs to be considered in conjunction with local flooding.

There are three flood emergency scenarios that could present in the lower part of the CBD:

- Mainstream flooding from the Nepean River, without local overland flooding in the CBD;
- Mainstream flooding from the Nepean River, with local overland flooding in the CBD occurring at the same time; and
- Local overland flooding, occurring without mainstream flooding from the Nepean River.

The response strategy for mainstream flooding from the Nepean River is set in the Hawkesbury Nepean Flood Plan (HNFESP) (NSW SES, 2015). Due to the potential scale and duration of this type of flooding, evacuation is the only acceptable response, and it is managed by the NSW SES at the State level. Should the NSW SES obtain information that Nepean River flooding is likely to affect Penrith CBD, an evacuation order would be issued and communicated by the NSW SES directly to residents and workers within the areas affected. The order would be issued with sufficient lead time to allow for an orderly and safe evacuation process.

In case an evacuation order is issued when there is no local flooding affecting the roads of the CBD, evacuees would be able to leave the areas at risk before evacuation routes are cut.

However, should the evacuation order be issued while a major local flooding is ongoing, there would be a delay in the evacuation due to the fact that many roads in the CBD may already be cut.

As such, the time at which the evacuation order is issued by the NSW SES should allow for delays due to the risk of local flooding. This issue is currently being considered as part of the Hawkesbury Nepean regional evacuation model, and accurate estimates of the duration of road closures due to local flooding are required to quantify possible evacuation delays. This FRMS&P provides this information in Section 8 and Map 29 (Vol. 2), for each local flooding design event and for all the main roads within the CBD.

The implications of local flooding in Penrith CBD however go beyond the risk of delaying the Nepean River regional evacuation timeline.

As discussed in detail in Section 8 of this report, local flooding alone could cause significant risks to life throughout the study area. Floodwaters would rise fast and without any warning. In a local flood rising as fast as the PMF, most roads would be cut with hazardous floodwaters within 30 minutes from the beginning of the rainfall, and before most buildings would experience any flooding at all.

Map 25 (Vol.2) shows that most of the flood affected buildings within the study area could be considered flood islands, and only a small proportion would maintain rising road access to flood free land at the peak of the PMF (local flooding). For these reasons, it is not unreasonable to assume that, in most instances, people would not think of leaving their buildings before these starts flooding, but by that time all evacuation routes would likely be already cut.

Leaving a building when this is surrounded by hazardous floodwaters is dangerous, and the NSW SES strongly advises against walking or driving through floodwaters of any depth.

The only alternative to evacuation, when this carries excessive risks, is to take shelter within buildings above the reach of floodwaters and wait until these have receded (Shelter in Place – SIP). The risks of SIP are summarised in Section 4 of this report. These could be addressed by means of locality-specific development controls to ensure that:

- The building is structurally stable up to the PMF. It should be emphasised that if the building is affected by floodwaters with a hazard level of H5, structural stability could only be achieved through special engineering design and construction;
- The building has a safe shelter above the reach of the PMF. Where this condition is not satisfied, for example in the case of single storey buildings

in low flood islands, SIP could only be made possible through redevelopment or second storey-additions.

Establishing whether and where within the study area evacuation is a response to local flooding more or less appropriate than SIP goes beyond the scope of this report. Instead, this FRMS&P aims to provide the NSW SES with sufficient factual information on the risks associated with both strategies, so that these can be evaluated as part of the preparation of the Penrith CBD Local Flood Plan.

In addition to the description of flood risks at each Hot Spot, Table 19 summarises key information that may provide guidance in identification of appropriate Hot Spot response strategies.

9.5.2 Analysis of Options

In general terms, and regardless of the response strategy (i.e. evacuation or SIP), flood emergency response outcomes can be improved by means of:

- A flood warning system;
- Appropriate response planning; and
- Raising community awareness of flood risks.

This section provides an evaluation of these response modification options in the context of local flooding throughout the CBD catchment.

a) Flood Warning for Local Flooding

The flood modelling and mapping undertaken by Council provides information about the possible extent and impacts of local flooding. It is preferable for people to have specific information about the flood they are actually responding to. This is only possible with a flood forecasting system.

The Bureau of Meteorology is responsible for flood forecasting in Australia but does not provide a flood forecasting service where flood warning times are less than six hours (deemed a 'flash flood'), such as in Penrith CBD. As such the Bureau of Meteorology will not provide flood forecasts.

The Bureau will provide severe weather warnings for the area generally and may warn of the chance of flash flooding. This, followed by the commencement of heavy rain, is the only warning which the area will receive, and there would be no indication as to how severe it might get.

Council could choose to install its own flash flood alerting system in the catchment and the Bureau provides councils with guidance to do that. However, the characteristics of the catchment is such that at most locations east of Castlereagh Street, in a flood rising as quickly as the PMF there would be less than 15 minutes between the commencement of rainfall and the commencement of flooding in the streets. Similarly, most roads in the area west of Castlereagh Street would begin to flood within 30 minutes from the beginning of the rainfall. As such, a Council operated catchment wide flood warning system is not seen as a practical response modification option.

b) Emergency Response Plans

The NSW SES is the lead agency for response to flood events and accordingly has a local flood emergency response plan for Penrith LGA.

The 2012 Penrith City Local Flood Plan covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding from the Hawkesbury Nepean River within the whole Penrith City LGA.

From September 2015, with the release of the new Hawkesbury Nepean Flood Plan (HNFESP), all types of mainstream flood events in the Hawkesbury Nepean floodplain are to be managed at the State level, while the scope of local flood plans is limited to local creeks flooding and overland flooding. However, the 2012 Penrith City Local Flood Plan does not address local overland flooding.

The NSW SES has advised that the next edition of Penrith Local Flood Plan will address only local flooding including overland flooding. As such, it is recommended that the outcomes of this study are incorporated into the new Plan. It is also recommended that Council provides the information contained in this study related to emergency management (e.g. local catchment flooding cutting regional evacuation routes) to the NSW SES, so that this can be considered in the regional HNV flood evacuation Plan.

Businesses and households can also develop their own flood emergency response plans which are specific to their own circumstances to reduce the direct and indirect impacts of flooding on them. The NSW SES has produced templates to assist with this task and the information in this floodplain risk management study can also assist in the regard. Some property owners and occupiers may need to obtain more specific local flood data from Council

c) Raising Community Awareness of Flood Risks

Community awareness of flood risk may be raised by making sure that:

- Flood risks to individual properties are adequately communicated to the property owners and users. This can be achieved through Section 10.7 Planning Certificates;
- The community is aware of what to do before, during and after a flood emergency.

i) Section 10.7 Planning Certificates

It is recommended that Council's current format and wording of Planning Certificates be reviewed to provide standardised notations that can be applied across the LGA based on whether:

- Land is subject to riverine or overland flow flooding;
- Flood data is reliable or not; and
- Flood data is available or not.

This review should be undertaken in conjunction with the preparation of flood planning maps as recommended in section 9.4.2.

For the purposes of the study area, it is expected that the currently used precautionary note regarding the potential inaccuracies of past overland flooding studies will become superfluous as a consequence of the more accurate information derived as part of this study.

While the revised wording of Council Section 10.7(2) Certificates notifications should be undertaken with regard to all flood related risks, not just overland flow flooding the subject of this report, some guiding principles are recommended below.

The certificates should differentiate between nominated types of "residential development" as outlined in Schedule 4 of the EP&A Regulations and all other development when stating as to whether they would be subject to flood related planning controls on the particular site the subject of the certificate. Such certificates should also adopt the following principles:

- All properties noted as being subject to flood controls would also be noted as "flood control lots" for the purposes of the Codes SEPP.
- Where flood risk precinct (FRP) mapping has been undertaken the applicable FRP could be noted, with an explanation as to its meaning and application under the DCP provisions.
- Where Council is unsure of whether a property contains flood liable land (due to the lack of any flood investigations and mapping in particular areas) a general notation to this effect can be placed with an explanation that a flood study could identify that the land is subject to flooding, in which case flood related controls would apply.

Section 10.7(5) Certificates could provide further detailed information for individual properties where available. At a minimum the existence of a flood study, or FRMS and FRMP, once prepared and being used by Council officers (in draft or final form), should be noted on these certificates. The flood studies should be available on Council's website and in hard copy format.

Appropriate wording for the notifications should be determined based on legal advice. This should occur concurrently with the adoption of the new DCP provisions. More than half of the flood fatalities in Australia are caused by people voluntarily entering flood waters either by driving on flooded roads, walking through floodwaters or recreating in floodwaters. Some fatalities have been caused by people being caught unexpectedly by fast flowing and quickly rising floodwaters entering the buildings which they occupy.

ii) Improving Response to Flood Emergencies

There are several ways in which Council can assist people to respond appropriately:

- Strategic planning and development controls which minimises the chance of above floor flooding in buildings;
- Encouraging people with single storey homes which have a significant risk from above floor flooding to add a second storey;
- Working with the NSW SES to encourage the preparation of household and business flood emergency response plans using NSW SES tools and templates;
- Building and using networks ('social capital') and self-help relationships (e,g. between neighbours) in the community to enable preparedness, response and recovery;
- Building the capacity of leaders in the community (e.g. Penrith CBD Corporation) to motivate preparedness behaviours;
- Provide information in community languages and through existing community networks to maximise the number of people reached.

It is recommended that all of the above be investigated in consultation with the NSW SES as part of an ongoing community flood response and education strategy.

Table 19. Summary of Hot Spot information

	LEP Zoning	Redevelopment Potential?	FPL above the PMF?	Affected by Nepean River Flooding?	ERP Classification from local flooding	Structural Stability up to PMF?
Hot Spot 1	-	-	-	Yes	-	-
Hot Spot 2	Mixed Use	Yes*	No	Yes	Low Flood Island	H5 hazard **: special engineering design required
Hot Spot 3	High Density Residential	Yes*	No	Yes	High Risk Low Flood Island, isolated from 20% AEP event	Yes
Hot Spot 4	Mixed Use	Yes*	No	Yes	Low Flood Island	H5 hazard**: special engineering design required
Hot Spot 5	-	-	-	No	-	-
Hot Spot 6	Mixed Use and Commercial Core –	Subject to rezoning proposal to High Density Residential	No	No	Low Flood Island	H5 hazard: special engineering design required
Hot Spot 7 and 14	Medium Density Residential	Yes*	No	Yes	High Risk Low Flood Island, isolated from 20% AEP event	Yes
Hot Spot 8	Medium Density and High Density	Yes	Yes	No	Low Flood Island	Yes

	LEP Zoning	Redevelopment Potential?	FPL above the PMF?	Affected by Nepean River Flooding?	ERP Classification from local flooding	Structural Stability up to PMF?
	Residential					
Hot Spot 9	High Density Residential	Yes	No	No	Low Flood Island**, Rising Road Access**	H5 hazard**: special engineering design required
Hot Spot 10	Mixed Use	Yes	Yes	No	High Risk Low Flood Island, isolated from 0.5% AEP event	H5 hazard**: special engineering design required
Hot Spot 11	High Density Residential and Medium Density Residential	Yes	Yes**	No	Low Flood Island**, Rising Road Access**	H5 hazard **: special engineering design required
Hot Spot 12	-	-	-	Yes	-	-
Hot Spot 13	-	-	-	Yes	-	-
Hot Spot 14	Refer to Hot Spot 7					
Hot Spot 15	Medium Density Residential	Yes	Yes**	No	Low Flood Island**, Rising Road Access**	H5 hazard **: special engineering design required

* pending regional evacuation capability requirements ** applies to some of the buildings within the Hot Spot

PART D: FLOODPLAIN RISK MANAGEMENT PLAN

10 FLOODPLAIN RISK MANAGEMENT PLAN

10.1 OBJECTIVE

The overall objective of the Penrith CBD Floodplain Risk Management Plan (FRMP) is to develop a long-term approach to flood and floodplain management that addresses the existing and future flood risks in accordance with the general desires of the community and in line with the principles and guidelines laid out in the NSW Floodplain Development Manual.

This will ensure that the following broad needs are met:

- Reduce the flood hazard and risk to people and property, now and in the future; and
- Ensure floodplain risk management decisions integrate economic, environmental and social considerations.

10.2 RECOMMENDED MEASURES

The recommended measures for the FRMP have been selected from the suite of flood risk options introduced, discussed and evaluated in Section 9. These options were shortlisted for detailed investigation in the FRMP after an assessment of their impact on flood risk, as well as consideration of economic, environmental and social factors. The recommended measures are summarised in Table 20 and in Map 84 (Vol.2).

10.3 PLAN IMPLEMENTATION

10.3.1 Costs

The total capital cost of implementing the Plan to reduce risk to residential and commercial property is about $6.4M, including flood modification options having a benefit to cost ratio smaller than 1.0. These are included, despite the low benefit to cost ratio, because of their social benefits (i.e. reduction of risk to life and road closure). Overall, if all of the flood modification options are implemented it would yield damage savings of at least $22M, resulting in an overall benefit-cost ratio of about 3.4. It would reduce the number of dwellings that the model shows as flooded above floor in the 100 year ARI flood by 33, and where there would still be above flood flooding the depth would be significantly reduced.

Also, there would be significant intangible benefits associated with the recommended flood modification options, as well as with the proposed amendments to planning instruments and development controls, emergency management planning and community flood awareness and readiness.

It should be noted that even when the benefit to cost ratio analysis suggests that an option is economically viable, there may be significant practical difficulties in its implementation. These may include social or environmental impacts that are not considered in the benefit to cost ratio, because of their intangible nature. Table 20 lists the social and environmental impacts and implications for each option.

10.3.2 Resourcing

Plan implementation will be dependent on adequate resourcing. Potential contributors of resources include:

- Penrith City Council – financial resources from capital and operating budgets, staff time;
- NSW State Government – financial grants for investigations, mitigation works and programs, DPIE and NSW SES staff time;
- Commonwealth Government – financial grants for investigations, mitigations works and programs;

- Developers – through Development Contribution Plans (CP);
- Property owners – building modifications
- Community – volunteer time.

10.4 PLAN MAINTENANCE

A FRMP plan is never truly finished. The Penrith CBD FRMP should be regarded as a dynamic instrument requiring review and modification over time. Catalysts for change could include flood events, revised flood modelling, better information about potential climate change flood impacts, social changes, legislative and planning changes or variations to the availability of funding. In any event, a thorough review every five years is warranted to ensure the ongoing relevance of the Plan.

It is envisaged that the Plan will be implemented progressively over a 5 to 10 year timeframe. The timing of the proposed works and measures will depend on the overall budgetary commitments of Council and the availability of funds from other sources.

Table 20. Summary of recommended flood risk reduction measures

Report Section	Hot-spot	Floodplain Management Measures	Location	Respons-ibility	Total Cost	Benefit to Cost Ratio	Resourcing	Feasibility	Social and Environmental Implications	Priority within Flood Modification
		FLOOD MODIFICATION MEASURES								
9.3.2.a	1	Local pipe capacity upgrades of culvert underneath Mulgoa Road, as designed and assessed in JWP (2016).	Mulgoa Road and Jamison Road intersection	NSW RMS	n.a.	n.a.	Potentially a combination of Council funds, State and Federal Government grants, or developer Contribution Plans	Subject to detailed design and costings	SOCIAL Closing the intersection between Mulgoa Road and Jamison Road would have significant impact on the local traffic flows during construction. However, these impacts would be temporary. Reduced risk of closure of a regional flood evacuation route. ENVIRONMENTAL Nothing of significance	6
9.3.2.b	2	Pipe capacity upgrade	Union Lane Car Park	Council	$546,700	4.59	Potentially a combination of Council funds, State and Federal Government grants, or developer Contribution Plans	Subject to detailed engineering investigations and costings	SOCIAL Closure of the Car Park during construction would have moderate impacts on car parking spots availability and local traffic. However, these impacts would be temporary. ENVIRONMENTAL Nothing of significance	3
9.3.2.c	3	Pipe capacity upgrade	Rodley Avenue	Council as part of the long term planning strategy for future development	$133,100	0.54	Potentially a combination of Council funds, or developer Contribution Plans	Subject to detailed engineering investigations and costings	SOCIAL Reduction of frequency of road flooding, risk to vehicular and pedestrian traffic. Reduction of frequency of isolation of houses in Rodley Avenue. Reduced risk of entrapment by local flooding during a Nepean River evacuation. No significant impacts. ENVIRONMENTAL Nothing of significance	9
9.3.2.e	5	Pipe capacity upgrade	Belmore Street car park	Council as part of the long term planning strategy for future development	$70,400	0.11	Potentially a combination of Council funds and TfNSW as the car park is used by commuters	Subject to detailed engineering investigations and costings	SOCIAL Reduced risk to people who may attempt to drive their cars through hazardous floodwaters. Reduced flood damage to parked vehicles ENVIRONMENTAL Nothing of significance	10
9.3.2.f	6	Pipe capacity upgrade	Evan Street and Henry Street:	Council	$1,376,100	0.17	Developer Contribution Plans	Subject to detailed engineering investigations and costings	SOCIAL Reduced risk to people and frequency with which Henry Street and Evan Street are cut from the 20% AEP to the 5% AEP, therefore providing benefits to traffic flow and regional evacuation from Nepean River flooding ENVIRONMENTAL Nothing of significance	8

9.3.2.f	7 and 14	Council to assess the merits of increasing the capacity of the pipes between Castlereagh Street and Woodriff Street, and under the commercial centre in Nepean Square.	Residential area east of Nepean Square	Council as part of the long term planning strategy for future developm ent	n.a	n.a.	Potentially a combination of Council funds, or developer Contribution Plans	Subject to detailed engineering investigations and costings	SOCIAL Reduced risk to people isolated in Low Flood Islands in Brown Street, benefits to local traffic ENVIRONMENTAL Nothing of significance	7
9.3.2.i	9	Detention basin	Park at the intersection between Doonmore Street and Derby Street	Council	$1,175, 900	5.96	Potentially a combination of Council funds, State and Federal Government grants, or developer Contribution Plans	Subject to detailed engineering investigations and costings and environmental approvals for vegetation removal	SOCIAL Minor inconvenience during construction and maintenance. Minor change to flood risks to park users ENVIRONMENTAL Removal of mapped Threatened Ecological Communities (TECs) within the park where the detention basin would be built	2
9.3.2.j	10	flow diversion into existing underutilised pipe draining to Showground Channel	Lethbridge Street and Castlereagh Street	Council	$210,1 00	22.68	Potentially a combination of Council funds, State and Federal Government grants, or developer Contribution Plans	Subject to detailed engineering investigations and costings.	SOCIAL Closing the intersection between Lethbridge Street and Castlereagh Street would have significant impact on the local traffic flows during construction. However, these impacts would be temporary. ENVIRONMENTAL Nothing of significance	1
9.3.2.k	11	pipe capacity upgrade	Rosedale Avenue to Colless Street	Council	$1,257, 300	2.2	Potentially a combination of Council funds, State and Federal Government grants, or developer Contribution Plans	Subject to detailed engineering investigations and costings.	SOCIAL Closing the local roads would have minor impact on the traffic flows during construction. These impacts would be temporary. ENVIRONMENTAL Nothing of significance	5
9.3.2.l	12	Council replacing the manual flood gate at the car park entrance with an automatically operated one	Council's main office, entrance in Jane Street	Council	$70,00 0	n.a.	Council funds	No feasibility impediments	SOCIAL Nothing of significance ENVIRONMENTAL Nothing of significance	12
9.3.2.m	13	Council to assess the merits of a pipe capacity upgrade between John Tipping Drive and the Carpenter Site, including culvert under Mulgoa Road	John Tipping Drive	Council as part of the long term planning strategy for future developm ent	n.a.	n.a.	Potentially a combination of Council funds, or developer Contribution Plans	Subject to detailed engineering investigations and costings.	SOCIAL Reduction of frequency of road flooding, risk to vehicular and pedestrian traffic. ENVIRONMENTAL Nothing of significance	11

9.3.2.o	15	Pipe capacity upgrade	Jipp Street to Derby Street	Council as part of the long term planning strategy for future developm ent	$1,674, 200	2.79	Potentially a combination of Council funds, State and Federal Government grants, or developer Contribution Plans	Subject to detailed engineering investigations and costings.	SOCIAL Closing the local roads would have minor impact on the traffic flows during construction. These impacts would be temporary. ENVIRONMENTAL Nothing of significance	4
		PROPERTY MODIFICATION MEASURES								
Report Section		**Floodplain Management Measures**	**Location**	**Respon-sibility**	**Total Cost**	**Benefit to Cost Ratio**	**Resourcing**	**Feasibility**	**Social and Environmental Implications**	**Priority within Property Modification**
9.4		Acknowledge and address flood risk through redevelopment where possible	All Hot Spots except HS1	Council and private citizens	included in costs of redevelopment	n.a.	Developer construction costs	n.a.	n.a.	3
9.4		Use locality specific development controls to reduce risk to life and property	All Hot Spots except HS1	Council	included in costs of redevelopment	n.a.	Developer construction costs	n.a.	n.a.	4
9.4.2		Development Controls: Council undertakes a comprehensive review of the DCP (PDCP 2014); DCP to include comprehensive set of flood maps. DCP to generate flood risk zoning addressing mainstream and overland flood risks. DCP to use controls reliant on the adoption of multiple FPLs in the LEP.	Whole Catchment	Council	$30,000	n.a.	Council	n.a.	n.a.	1
9.4.2		Development Controls: Consider amending the LEP to include provision for variable FPLs. Consider applying for “exceptional circumstances” to ensure variable FPL is consistent with 2007 Flood Planning directive (PS 07 003)	Whole Catchment	Council	included in DCP review costs above	n.a.	Council	The DCP makes reference to the use of variable freeboard in locations where Council has assessed the risk of lesser freeboard to be acceptable below the FPL	n.a.	2

		RESPONSE MODIFICATION MEASURES									
Report Section		**Floodplain Management Measures**	**Location**	**Respon-sibility**	**Initial Cost**	**Whole of Life Cost**	**Benefit to Cost Ratio**	**Resourcing**	**Feasibility**	**Social and Environmental Implications**	**Priority within Response Modification**
9.5.2.b		Council to provide the NSW SES with information on risks to people, property and duration of road closure caused by local flooding so that these can be implemented in the development of the new Penrith CBD Local Flood Plan	Whole Catchment	Council and NSW SES	included in cost of developing the new Penrith CBD Local Flood Plan	n.a.	n.a.	NSW SES	n.a.	n.a.	1
9.5.2.b		Council to work with the NSW SES to encourage the preparation of Emergency Response Plans for businesses and households where appropriate	Whole Catchment	Council and NSW SES	Included in cost of education strategy	$0	n.a.	Council and NSW SES	n.a.	n.a.	4
9.5.2.c		Council to consider revising wording and format of Section 10.7 Planning Certificates to better communicate flood risks to property owners	Whole Catchment	Council	$10,000	$0	n.a.	Council	n.a.	n.a.	3
9.5.2.c		Council to work with the NSW SES to develop and implement a community education strategy to encourage appropriate responses.	Whole Catchment	Council and NSW SES	$20,000	$2,000 p.a.	n.a.	Council and NSW SES	n.a.	n.a.	2

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APPENDIX A– GLOSSARY AND ABBREVIATIONS

This Floodplain Risk Management Study utilises the terminology used in the NSW *Floodplain Development Manual* (2005). The following Glossary is drawn from that Manual.

acid sulfate soils	These are sediments which contain sulfidic mineral pyrite which may become extremely acid following disturbance or drainage as sulfur compounds react when exposed to oxygen to form sulfuric acid.
annual exceedance probability (AEP)	The chance of a flood of a given or larger size occurring in any one year, usually expressed as a percentage. For example, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (i.e., a one-in-20 chance) of a 500 m^3/s or larger events occurring in any one year (see ARI).
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level.
average annual damage (AAD)	Depending on its size (or severity), each flood will cause a different amount of flood damage to a flood prone area. AAD is the average damage per year that would occur in a nominated development situation from flooding over a very long period of time.
average recurrence interval (ARI)	The long-term average number of years between the occurrence of a flood as big as or larger than the selected event. For example, floods with a discharge as great as or greater than the 20 year ARI flood event will occur on average once every 20 years. ARI is another way of expressing the likelihood of occurrence of a flood event.
BoM	Bureau of Meteorology
catchment	The land area draining through the main stream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
Consent authority	The council, government agency or person having the function to determine a development application for land use under the EP&A Act. The consent authority is most often the council, however legislation or an EPI may specify a Minister or public authority (other than a council), or the Director General of DPI, as having the function to determine an application.
Development	Defined in Part 4 of the EP&A Act: **Infill development**: refers to the development of vacant blocks of land that are generally surrounded by developed properties and is permissible under the current zoning of the land. Conditions such as minimum floor levels may be imposed on infill development **New development**: refers to development of a completely different nature to that associated with the former land use. For example, the urban subdivision of an area previously used for rural purposes. New developments involve re-zoning and typically require

	major extensions of existing urban services, such as roads, water supply, sewerage and electric power. **Redevelopment:** refers to rebuilding in an area. For example, as urban areas age, it may become necessary to demolish and reconstruct buildings on a relatively large scale. Redevelopment generally does not require either re-zoning or major extensions to urban services.
Disaster plan (DISPLAN)	A step by step sequence of previously agreed roles, responsibilities, functions, actions and management arrangements for the conduct of a single or series of connected emergency operations, with the object of ensuring the coordinated response by all agencies having responsibilities and functions in emergencies.
Discharge	The rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m^3/s). Discharge is different from the speed or velocity of flow, which is a measure of how fast the water is moving for example, metres per second (m/s).
EP&A Act	The Environmental Planning & Assessment Act, the principal planning legislation in NSW.
EPI	Environmental Planning Instrument – a generic term for the suite of planning documents specified under the Environmental Planning & Assessment ACT and includes State Environmental Planning Policies (SEPP), Local Environmental Plans (LEP) and Development Control Plans (DCP).
Ecologically Sustainable Development (ESD)	Using, conserving and enhancing natural resources so that ecological processes, on which life depends, are maintained, and the total quality of life, now and in the future, can be maintained or increased. A more detailed definition is included in the Local Government Act, 1993.
Effective warning time	The time available after receiving advice of an impending flood and before the floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to raise furniture, evacuate people and their possessions.
Emergency management	A range of measures to manage risks to communities and the environment. In the flood context it may include measures to prevent, prepare for, respond to and recover from flooding.
Flash flooding	Flooding which is sudden and unexpected. It is often caused by sudden local or nearby heavy rainfall. Often defined as flooding which peaks within six hours of the causative rain.
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 local overland flooding associated

	with major drainage before entering a watercourse, and/or coastal inundation resulting from super-elevated sea levels and/or waves overtopping coastline defences excluding tsunami.
Flood awareness	Flood awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
Flood education	Flood education seeks to provide information to raise awareness of the flood problem so as to enable individuals to understand how to manage themselves and their property in response to flood warnings and in a flood event. It invokes a state of flood readiness.
Flood fringe areas	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood liable land	Is synonymous with flood prone land, i.e., land susceptible to flooding by the PMF event. Note that the term flood liable land covers the whole floodplain, not just that part below the FPL (see flood planning area).
Flood mitigation standard	The average recurrence interval of the flood, selected as part of the floodplain risk management process that forms the basis for physical works to modify the impacts of flooding.
Floodplain	Area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
Floodplain risk management options	The measures that might be feasible for the management of a particular area of the floodplain. Preparation of a floodplain risk management plan requires a detailed evaluation of floodplain risk management options.
Floodplain risk management plan	A management plan developed in accordance with the principles and guidelines in this manual. Usually includes both written and diagrammatic information describing how particular areas of flood prone land are to be used and managed to achieve defined objectives.
Flood plan (local)	A sub-plan of a disaster plan that deals specifically with flooding. They can exist at state, division and local levels. Local flood plans are prepared by the SES.
Flood planning area (FPA)	The area of land below the FPL and thus subject to flood related development controls.
Flood planning levels (FPLs)	Are the combinations of flood levels and freeboards selected for floodplain risk management purposes, as determined in management studies and incorporated in management plans.
Flood proofing	A combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding, to reduce or eliminate

	flood damages.
Flood prone land	Land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
Flood readiness	Readiness is an ability to react within the effective warning time. (see flood awareness)
Flood refuge	In an industrial or commercial situation: an area used for offices or to store valuable possessions susceptible to flood damage in the event of a flood.
flood risk	Potential danger to personal safety and potential damage to property resulting from flooding. The degree of risk varies with circumstances across the full range of floods. Flood risk in this manual is divided into 3 types, existing, future and continuing risks: **Existing flood risk:** the risk a community is exposed to as a result of its location on the floodplain. **Future flood risk:** the risk a community may be exposed to as a result of new development on the floodplain. Continuing flood risk: the risk a community is exposed to after floodplain risk management measures have been implemented.
Flood storage areas	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 aligned with naturally defined channels. Floodways are areas that, even if only partially blocked, would cause a significant redistribution of flood flow, or a significant increase in flood levels.
Freeboard	It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc.
Habitable room	In a residential situation: a living or working area, such as a lounge room, dining room, rumpus room, kitchen, bedroom or workroom.
Hazard	A source of potential harm or a situation with a potential to cause loss. In relation to this manual the hazard is flooding which has the potential to cause damage to the community. Two levels of hazard are usually adopted in floodplain risk management planning: **High hazard:** possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty in wading to safety; potential for significant structural damage to buildings. **Low hazard:** should it be necessary, truck could evacuate people and their possessions; able-bodied adults would have little difficulty in wading to safety.

Hydraulics	The study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
Hydrograph	A graph which shows how the discharge or stage/flood level at any particular location varies with time during a flood.
Hydrology	The study of the rainfall and runoff process; in particular, the evaluation of peak flows, flow volumes and the derivation of hydrographs for a range of floods.
Local overland flooding	Inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
Local drainage	Smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
Major drainage	Councils have discretion in determining whether urban drainage problems are associated with major or local drainage. For the purposes of this study, major drainage involves: the floodplains of original watercourses (which may now be piped, channelised or diverted), or sloping areas where overland flows develop along alternative paths once system capacity is exceeded; and/or water depths generally in excess of 0.3m (in the major system design storm as defined in the current version of Australian Rainfall and Runoff). These conditions may result in danger to personal safety and property damage to both premises and vehicles; and/or major overland flowpaths through developed areas outside of defined drainage reserves; and/or the potential to affect a number of buildings along the major flow path.
Minor, moderate and major flooding	Both the SES and the BoM use the following definitions in flood warnings to give a general indication of the types of problems expected with a flood: **Minor flooding**: causes inconvenience such as closing of minor roads and the submergence of low level bridges. The lower limit of this class of flooding on the reference gauge is the initial flood level at which landholders and townspeople begin to be flooded. **Moderate flooding**: low-lying areas are inundated requiring removal of stock and/or evacuation of some houses. Main traffic routes may be covered. **Major flooding**: appreciable urban areas are flooded and/or extensive rural areas are flooded. Properties, villages and towns can be isolated.

Modification measures	Measures that modify either the flood or the property or the response to flooding. There are three generally recognised ways of managing floodplains to minimise the risk to life and to reduce flood losses: By modifying the response of the population at risk to better cope with a flood event (Response Modification); by modifying the behaviour of the flood itself (Flood Modification); and by modifying or removing existing properties and/or by imposing controls on property and infrastructure development (Property Modification).
Peak discharge	The maximum discharge occurring during a flood event.
Probable maximum flood	The PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions. Generally, it is not physically or economically viable to provide complete protection against this event. The PMF defines the extent of flood prone land, that is, the floodplain. The extent, nature and potential consequences of flooding associated with a range of events rarer than the flood used for designing mitigation works and controlling development, up to and including the PMF event should be addressed in a floodplain risk management study.
Probable maximum precipitation	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends (World Meteorological Organisation, 1986). It is the primary input to PMF estimation.
Probability	A statistical measure of the expected chance of flooding (see AEP).
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In this context, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
SES	State Emergency Service
stage	Equivalent to water level (both measured with reference to a specified datum).
stage hydrograph	A graph that shows how the water level at a particular

	location changes with time during a flood. It must be referenced to a particular datum.
survey plan	A plan prepared by a registered surveyor.
water surface profile	A graph showing the flood stage along a watercourse at a particular time.

APPENDIX B – MOLINO STEWART BUILDING DATABASE

The database was created by reviewing, updating and expanding a pre-existing building database, generated by Australian National University (ANU) in 1988 as part of the 1988 Warragamba Flood Mitigation Dam EIS (Mitchell McCotter, 1995).

The survey included over 15,000 of the urban residential buildings and over 3,600 commercial buildings within the Hawkesbury Nepean floodplain. It also included more than 1,000 rural residential dwellings in the more populated non-urban areas.

The ANU database spatial accuracy was assessed against the most recently available aerial photographs which, at the time the 2013 work was undertaken, were from 2011, and significant adjustments to the database were made. In addition to this, because the ANU dataset did not include many newer subdivisions, those that were visible in the aerial photographs were digitised and added to the database. New buildings were identified using a combination of information from aerial photographs, Google Street View, and cadastral boundary files. The database was updated with the following building attributes:

Address

Address information including house number, street and suburb was assigned to each building using a combination of Property lot information, Google Maps and Google Street View.

Floor Height

To determine the floor height the following methods were used.

Google Street View was used to estimate the floor height of almost half of the new residential buildings. The floor height assigned to each dwelling was measured as the distance between the ground and any of the following surfaces, determined by which was most visible:

- The door most visible from the road;
- The surface of a veranda or deck on the first storey;
- The bottom edge of the house (this was mostly used for older houses where the above features were not visible from the road, but it was possible to estimate the height of the dwelling above the ground based on the bricks or stumps supporting the dwelling).

The floor height was estimated utilising a number of different indicators which could be seen in Google Street View. Where bricks were present, they were used to estimate the height raised and the presence of stairs was also used as an indicator of height raised.

Where dwellings were raised high enough that a garage had been built or cars had been parked in the space underneath, the floor height was recorded as 2.6 metres.

Where none of the above measurement methods could be applied, the floor height was estimated based on the height relative to nearby objects which were visible in Google Street View such as cars, caravans or people.

In some cases, it was not possible to determine the floor height of buildings from the images available in Google Street View. This was due to factors such as intervening vegetation, topography and the distance of some dwellings from the road.

A set of assumptions were developed which could be used to assign floor height information to the buildings which could not be inspected using the method above. These assumptions were based on the average floor height measured in Windsor, South Windsor, and a section of Rifle Range Road in Bligh Park during field surveys undertaken by Bowdens Group Australia Pty Ltd and the age of the buildings. The surveys were made using a vehiclemounted mobile laser to collect a three dimensional LIDAR image. The assumptions can be summarised as follows:

- It was assumed that residential buildings originally surveyed by ANU had a floor height of 0.6m above ground. This corresponded to the median height of older buildings in the survey
- In urban areas, the dwellings that would have been built since the ANU survey were assigned the modern median height raised value of 0.3 metres.
- In rural areas the dwellings were a mix of ages. In these areas the height raised value of 0.6 metres was used (it should be noted that this assumption does not apply to any of the buildings in Penrith CBD, which are classified as urban).
- All non-residential buildings were assumed to have their ground floor at ground level. This included also educational buildings, hospitals, police stations and emergency services buildings.

Storeys

Google Street View, dwelling shadows, and roof shape were used to determine the number of storeys for many of the residential dwellings in rural areas and all dwellings in urban areas.

APPENDIX C - FLOOD MODIFICATION COSTING

Costing Assumptions:

The rates are based on the following:

- Australian Construction Handbook, 2017
- Estimates from recent drainage projects in Sydney and Melbourne
- 30% used for contingency

- Typical works under the preliminary total :

Project management & supervision
Site compound
Mobilisation
Demobilisation
OH&S allowances
Site survey
Works as executed
Services location
Erosion sediment and control
Traffic management
Engineering inspection and testing
Insurances and security

HS3

Cost Item	Cost	
Preliminaries	$	33,000
Drainage Network Upgrade Works	$	60,000
Contigency	$	28,000
Total	**$**	**121,000**

HS2

Cost Item	Cost	
Preliminaries	$	33,000
Drainage Network Upgrade Works	$	349,000
Contigency	$	115,000
Total	**$**	**497,000**

HS6

Cost Item	Cost	
Preliminaries	$	210,000
Drainage Network Upgrade Works	$	752,000
Contigency	$	289,000
Total	**$**	**1,251,000**

HS11

Cost Item	Cost*	
Preliminaries	$	287,000
Drainage Network Upgrade Works	$	592,000
Contigency	$	264,000
Total	**$**	**1,143,000**

HS 10

Cost Item	Cost*	
Preliminaries	$	33,000
Drainage Network Upgrade Works	$	114,000
Contigency	$	44,000
Total	**$**	**191,000**

HS15

Cost Item	Cost*	
Preliminaries	$	287,000
Drainage Network Upgrade Works	$	884,000
Contigency	$	351,000
Total	**$**	**1,522,000**

HS9

Cost Item	Cost*	
Preliminaries	$	210,000
Retarding Basin	$	612,000
Contigency	$	247,000
Total	**$**	**1,069,000**

HS5

Cost Item	Cost*	
Preliminaries	$	33,000
Drainage Network Upgrade Works	$	16,000
Contigency	$	15,000
Total	**$**	**64,000**

*all estimated costings throughout this report are preliminary estimates only at the concept design stage. They do not include engineering or design fees and any figures quoted would be subject to the applicable GST. This will need to be reassessed during later design stages.

APPENDIX D – COST / BENEFIT ANALYSIS

Hot Spot Number	Description of Flood Modification Option		Dwellings Annual Average Damage (AAD)	Dwellings AAD plus allowance for intangible and infrastructure damages	Non Residential AAD	Non Residential AAD plus allowance for intangible and infrastructure damages	Cars AAD	Total AAD	Net Present Value of Total AAD	Option's Economical Benefits	Net Present Value of Total Option Cost	Benefit/Cost Relative to current condition
2	Union Lane Car Park: pipe capacity upgrade	Current Condition	$0	$0	$177,838	$248,973	$12,320	$261,293	$3,605,838			
		With Flood Modification	$0	$0	$55,651	$77,912	$1,620	$79,532	$1,097,537	$2,508,301	$546,700	4.59
3	Rodley Avenue: pipe capacity upgrade	Current Condition	$64,930	$90,902	$0	$0		$90,902	$1,254,448			
		With Flood Modification	$61,182	$85,655	$0	$0		$85,655	$1,182,036	$72,411	$133,100	0.54
5	Belmore Street car park: pipe capacity upgrade	Current Condition	$0	$0	$0	$0	$2,980	$2,980	$41,124			
		With Flood Modification	$0	$0	$0	$0	$2,420	$2,420	$33,396	$7,728	$70,400	0.11
6	Evan Street and Henry Street: pipe capacity upgrade	Current Condition	$0	$0	$558,508	$781,911		$781,911	$10,790,367			
		With Flood Modification	$0	$0	$546,151	$764,612		$764,612	$10,551,641	$238,726	$1,376,100	0.17
9	Doonmore Street and Derby Street: detention basin	Current Condition	$651,785	$912,499	$1,668,200	$2,335,481		$3,247,980	$44,822,118			
		With Flood Modification	$530,774	$743,084	$1,426,357	$1,996,899		$2,739,983	$37,811,763	$7,010,355	$1,175,900	5.96
10	Lethbridge Street and Castlereagh Street: flow diversion into existing underutilised pipe draining to Showground Channel	Current Condition	$58,672	$82,141	$1,668,200	$2,335,481		$2,417,621	$33,363,175			
		With Flood Modification	$53,836	$75,370	$1,426,357	$1,996,899		$2,072,270	$28,597,321	$4,765,854	$210,100	22.68
11	Rosedale Avenue to Colless Street: pipe capacity upgrade	Current Condition	$580,913	$813,278	$0	$0		$813,278	$11,223,239			
		With Flood Modification	$437,823	$612,952	$0	$0		$612,952	$8,458,740	$2,764,499	$1,257,300	2.20
15	Jipp Street to Derby Street: pipe capacity upgrade	Current Condition	$313,605	$439,047	$0	$0		$439,047	$6,058,849			
		With Flood Modification	$71,794	$100,512	$0	$0		$100,512	$1,387,060	$4,671,789	$1,674,200	2.79