PENRITH CITY COUNCIL

Little Creek Catchment

Floodplain Risk Management Plan

Final Report

October 2021

Catchment Simulation Solutions

Little Creek Catchment

Floodplain Risk Management Plan

Final Report

Client	Client Representative
Penrith City Council	Elias Ishak

REVISION / REVIEW HISTORY

Revision #	Description	Prepared by	Reviewed by
1	Preliminary draft report for Council review	D. Tetley	C. Ryan
2	Draft report incorporating preliminary Council feedback	D. Tetley	C. Ryan
3	Draft report for public exhibition	D. Tetley	C. Ryan
4	Final report	D. Tetley	C. Ryan

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Catchment Simulation Solutions

Suite 1, Level 10
70 Phillip Street
Sydney, NSW, 2000

(02) 8355 5500 david.tetley@csse.com.au

(02) 8355 5505 www.csse.com.au

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Penrith City Council
601 High Street, Penrith NSW 2750
council@penrithcity.nsw.gov.au
(02) 4732 7777

Acknowledgement
Penrith City Council has prepared this document with financial assistance from the NSW Government through its Floodplain Management Program. This document does not necessarily represent the opinions of the NSW Government or the Department of Planning Industry and Environment.

The preparation of the Plan was steered by Penrith City Council Floodplain Risk Management Committee whose members include councillors, council staff, community representatives and representatives from state agencies and adjacent councils. The Plan is the culmination of many months of investigation, analysis and flood modelling, which has been supported by valuable contributions from representatives of the Floodplain Risk Management Committee, community of Penrith and Penrith City Council.

It has been prepared by incorporating contributions from individuals from the local community and key stakeholders. Contributions from members of the Floodplain Risk Management Committee have been essential to the formation of management strategies that have been considered as part of the Plan and are greatly appreciated. The collegial manner in which input has been provided to the project from representatives from the Penrith City Council has been critical to its success.

Disclaimer

EXECUTIVE SUMMARY

The Little Creek catchment is located in the Penrith City Council Local Government Area and occupies a total area of 4.65 km^2. The extent of the catchment is shown on **Figure 1** and includes parts of the suburbs of Oxley Park, Colyton, St Marys and North St Marys.

The catchment is highly urbanised and many of the original creeks and gullies have been built over and replaced by stormwater pipes. During heavy rainfall in the catchment, there is potential for the capacity of the stormwater system to be overwhelmed leading to overland flooding. There is also potential for water to overtop the banks of Little Creek and inundate the adjoining floodplain.

The 'Little Creek Catchment Floodplain Risk Management Study' (Catchment Simulation Solutions, 2021) involved a detailed assessment of the flood risk across the catchment. This included quantifying the risk that floodwaters pose to people, buildings, vehicles, and other properties within the catchment as well as the potential economic impact of flooding.

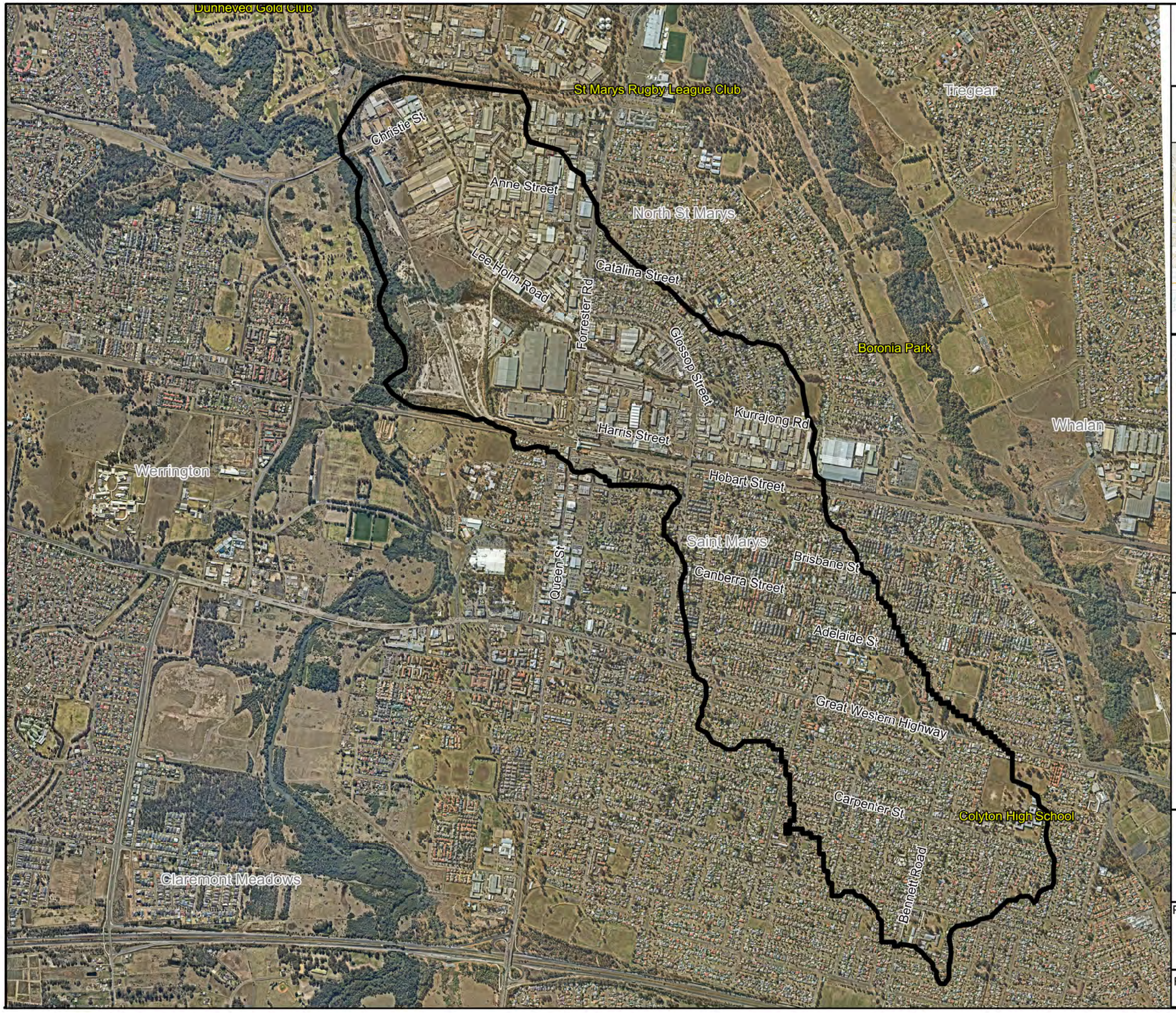
The Study also evaluated a range of options that could be potentially implemented to better manage the flood risk. This included structural options such as stormwater upgrades as well as non-structural options such as modifications to planning documents.

The outcomes of the Floodplain Risk Management Study serve as the basis for the recommendations documented in this Floodplain Risk Management Plan. A summary of all options that are recommended for implementation or further investigation as part of the Plan are summarised in **Table 1**. The recommended options are also shown on **Figure 2**. Further information on each option including costs and implementation responsibility is also provided in **Table 1**. **Table 1** also included the multi-criteria assessment (MCA) ranking for each flood modification option so the implementation priorities can be understood.

If each of the flood modification (i.e., structural) options are implemented, the capital cost is expected to be about $3.9 million. However, total flood damages would be reduced by about $2.6 million over the next 50 years.

Despite the significant capital outlay that would be required to implement the Plan, the reduced frequency and severity of flooding would provide a range of non-monetary benefits to the local community including less frequent and less deep inundation of local roads (including the major thoroughfare of the Great Western Highway) and less disruption, inconvenience and anxiety associated with frequent inundation.

Implementation of the flood modification options will reduce the frequency and depth of inundation but will not eliminate the potential for inundation completely. Therefore, it will be necessary to also implement the remaining non-structural (i.e., planning and emergency response) options to help ensure the continuing and future flood risk is also managed. This would largely draw upon Penrith City Council and SES resources and this time commitment is estimated to require an additional $170,000.



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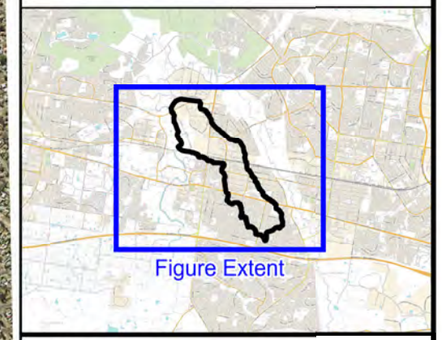
Little Creek Catchment Floodplain Risk Management Study and Plan



LEGEND

Catchment Boundary

Notes:

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Scale 1:18,000 (at A3)

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Km

Figure 1: Little Creek Catchment

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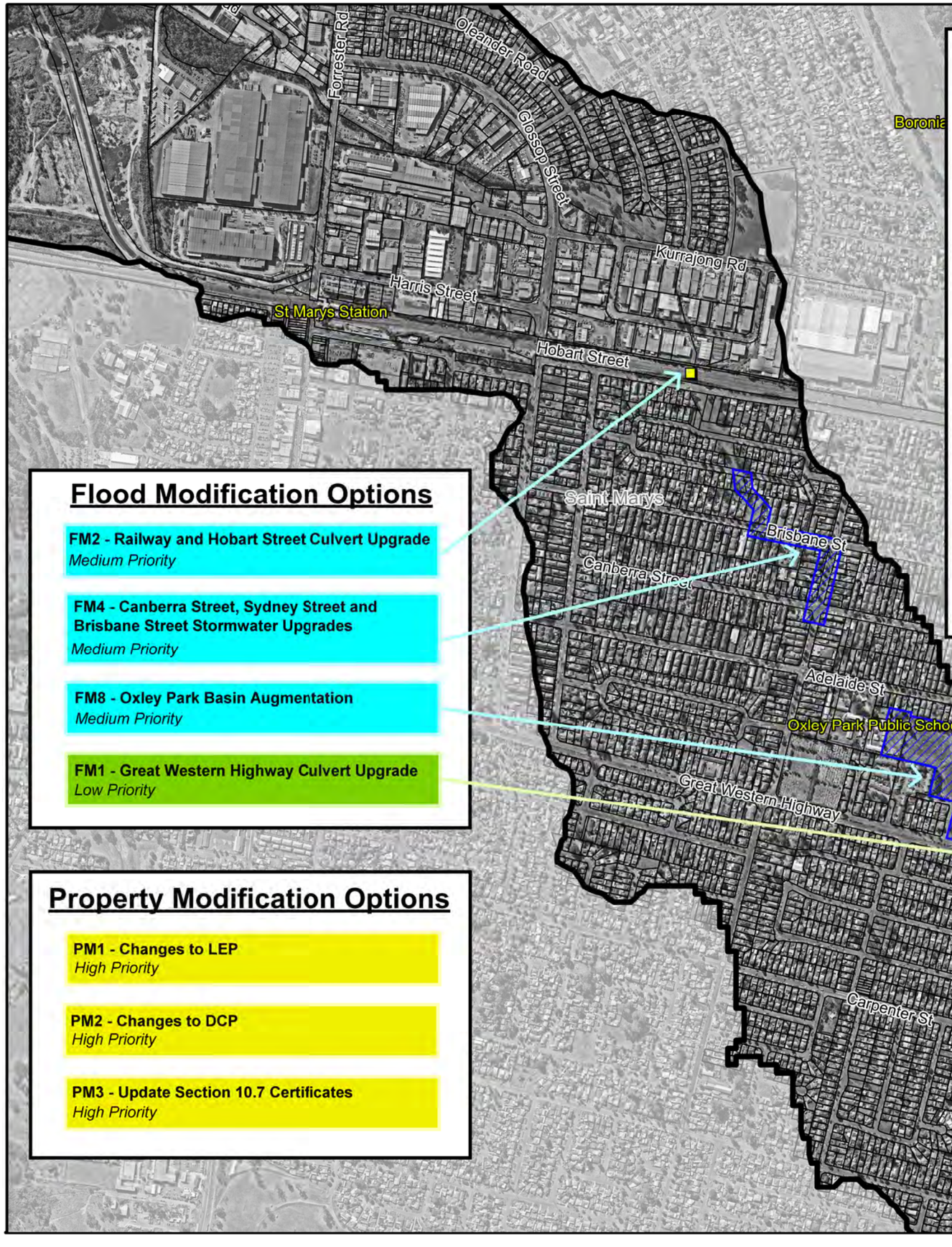
Sydney, NSW 2000

File Name: Little Creek Catchment.wor



Flood Modification Options

FM2 - Railway and Hobart Street Culvert Upgrade
Medium Priority

FM4 - Canberra Street, Sydney Street and Brisbane Street Stormwater Upgrades
Medium Priority

FM8 - Oxley Park Basin Augmentation
Medium Priority

FM1 - Great Western Highway Culvert Upgrade
Low Priority

Property Modification Options

PM1 - Changes to LEP
High Priority

PM2 - Changes to DCP
High Priority

PM3 - Update Section 10.7 Certificates
High Priority

Response Modification Options

RM1 - Community education strategy
High Priority

RM2 - Make property level flood information available
Medium Priority

RM3 - Local flood plan updates to accommodate response planning
High Priority

RM4 - Home flood plans
High Priority

RM5 - Business flood plans
High Priority

RM6 - Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas
Medium Priority

RM10 - Local Flood Plan Updates to Accommodate Recovery Planning
High Priority

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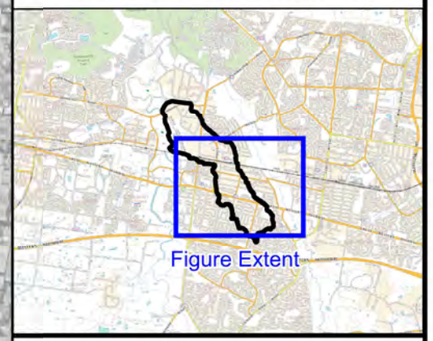
Little Creek Catchment Floodplain Risk Management Study and Plan



LEGEND

- High Priority Option
- Medium Priority Option
- Low Priority Option
- Culvert Upgrades
- Stormwater Upgrades

Notes:
Please refer to the Little Creek Floodplain Risk Management Plan report for further information on each flood risk mitigation measure.

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Scale 1:11,000 (at A3)

0 0.25 0.50
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Figure 2: Floodplain Risk Management Plan for Little Creek Catchment

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File Name: Figure 2 Floodplain Risk Management Plan for Little Creek Catchment.wor

Table 1 Recommended Floodplain Risk Management Options

#	Option Description	Report Section	Estimated Cost	Implementation Responsibility	MCA Rank	Priority
Flood Modification Options						
FM1	Great Western Highway Culvert Upgrade	3.1	$0.6 million	Penrith City Council and Transport for NSW	4	Low
FM2	Railway and Hobart Street Culvert Upgrade	3.3	$1 million	Penrith City Council and Sydney Trains	=3	Medium
FM4	Canberra Street, Sydney Street and Brisbane Street Stormwater Upgrades	3.4	$1.3 million	Penrith City Council	=3	Medium
FM8	Oxley Park Basin Augmentation	3.5	$0.9 million	Penrith City Council	1	High
Property Modification Options						
PM1	Changes to LEP	4.1	$20k	Penrith City Council	-	High
PM2	Changes to DCP	4.2	$40k	Penrith City Council	-	High
PM3	Update Section 10.7 Certificates	4.3	$6k	Penrith City Council	-	High
Response Modification Options						
RM1	Community education strategy	5.1	$20k up front and $5k bi-annually.	SES and Penrith City Council	-	High
RM2	Make property level flood information available	5.2	$20k for required IT infrastructure. $30k for compiling required datasets and website interface.	Penrith City Council	-	Medium
RM3 + RM10	Local Flood Plan updates to accommodate response planning and Accommodate recovery planning	5.3	$40k	Penrith City Council	-	High
RM4	Home flood plans	5.4	Residents and business owner's time. Plus, approximately $10k for Council and SES time	Individual home and business owners with assistance from SES and Penrith City Council	-	High
RM5	Business flood plans				-	High
RM6	Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas	5.5	$30k	SES and Penrith City Council	-	Medium

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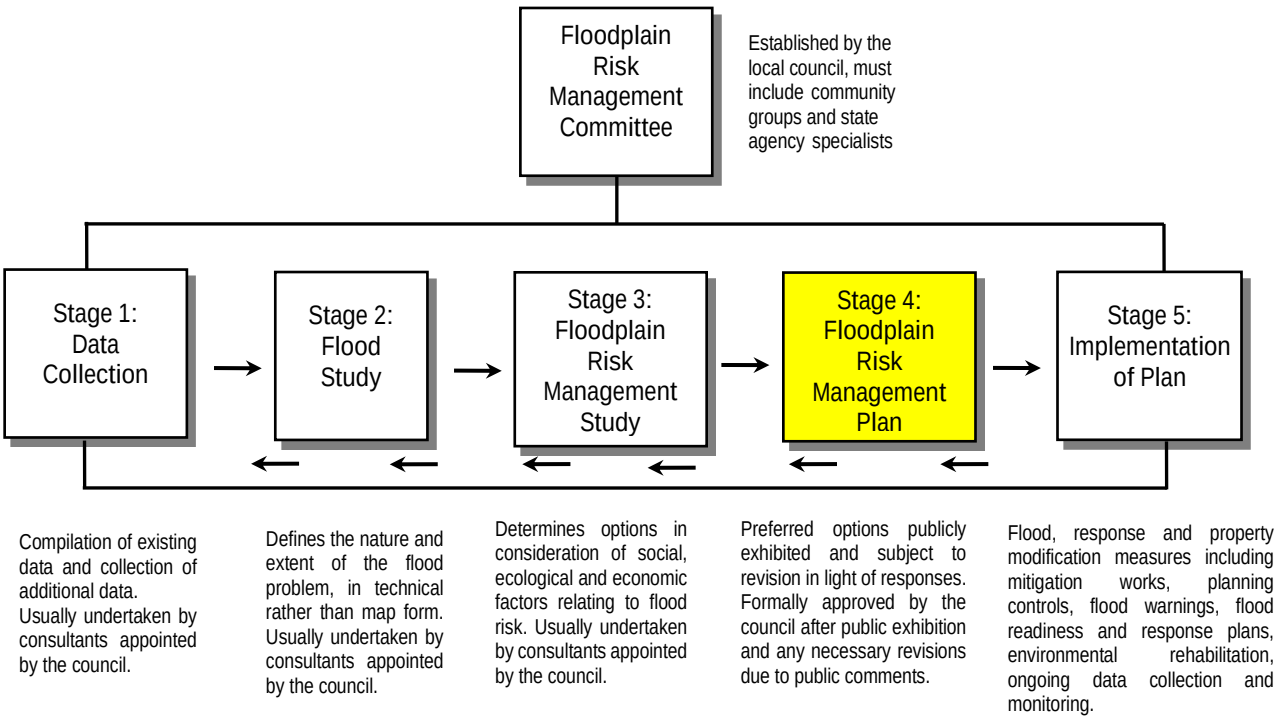
1 OVERVIEW

1.1 The Floodplain Risk Management Process

The '*Little Creek Catchment Floodplain Risk Management Plan*' has been prepared in accordance with the requirements of the NSW Government's '*Floodplain Development Manual' (NSW Government, 2005).* The '*Floodplain Development Manual*' (2005) guides the implementation of the State Government's *Flood Policy*. The *Flood Policy* is directed towards providing management and mitigation measures to existing flooding problems in developed areas and ensuring that new development is compatible with the flood hazard and does not create additional flooding problems in other areas. The Policy is defined in the NSW Government's '*Floodplain Development Manual' (NSW Government, 2005)*.

Under the Policy, the management of flood liable land remains the responsibility of Local Government. However, the State Government provides specialist technical advice to assist Local Government in its floodplain management responsibilities and subsidies to councils to complete the floodplain management process including implementation of flood mitigation works, if feasible, to alleviate existing problems.

The Policy provides for technical and financial support by the State Government through the floodplain risk management process which is outlined below.



The Floodplain Risk Management Plan represents Stage 4 of the Floodplain Risk Management process. The Plan provides a targeted list of options that can be implemented by Council and others to manage the flood risk in the Little Creek catchment, based on the outcomes of the broader Floodplain Risk Management Study.

1.2 Risk Management Approach

The primary goal of the Floodplain Risk Management Plan is to provide a consolidated list of measures that can be implemented moving forward to better manage the existing and potential future flood risk. In this regard, it is first necessary to quantify the existing flood risk and identify locations within the catchment where this risk is considered to be unacceptable. A comprehensive assessment of the flood risk was completed as part of the Floodplain Risk Management Study and a summary of the outcomes of this assessment is provided in Chapter 2 of this report.

The options that are recommended for flood risk management have been grouped into one of three distinct categories, which are detailed below:

- **Flood Modification Options**: are measures that aim to modify existing flood behaviour, thereby, reducing the extent, depth and velocity of floodwater across flood liable areas. Each flood modification option is prefixed with an "FM" identifier and the recommended flood modification options are presented in Chapter 3.
- **Property Modification Options**: refers to modifications to planning controls and/or modifications to individual properties to reduce the potential for inundation in the first instance or improve the resilience of properties should inundation occur. Each property modification option is prefixed with an "PM" identifier and the recommended property modification options are presented in Chapter 4.
- **Response Modification Options**: are measures that can be implemented to change the way in which emergency services as well as the public responds before, during and after a flood. Each response modification option is prefixed with an "RM" identifier and the recommended response modification options are presented in Chapter 5.

A suggested implementation strategy for the Plan is also provided in Chapter 6. It outlines implementation priorities for each of the recommended options along with responsibilities and estimated costs. The implementation strategy is only for this catchment area. However, these projects will need to compete with other recommended flood mitigation projects throughout the LGA for funding.

2 THE EXISTING FLOOD RISK

2.1 Catchment Description

The Little Creek catchment is located in the Penrith City Council (PCC) Local Government Area and occupies a total area of 465 hectares (i.e. 4.65 km^2).

The catchment upstream (i.e., south) of Kurrajong Road predominately comprises residential development and is drained by a constructed stormwater system. There are no formal overland flow paths or drainage easements across this section of the catchment. The stormwater system conveys runoff in a northerly direction into the Little Creek channel which commences on the northern side of Kurrajong Road (near its intersection with Plasser Crescent). Little Creek drains in a westerly direction and into South Creek.

The catchment is traversed by several important transportation links including the Great Western Highway and the Western Railway Line which both run across the catchment in an east to west direction. The embankments of the Great Western Highway and the Western Railway Line form a notable overland flow impediment with the Western Railway Line, in particular, being elevated more than 6 metres above the adjoining terrain.

The catchment has a history of flooding, with severe flooding having been experienced in August 1986 and October 1987. The most recent significant flood in the catchment occurred in March 2014.

2.2 The Existing Flood Risk

2.2.1 Flood Hazard

Computer flood modelling of the Little Creek catchment was completed as part of the 'Little Creek Catchment Floodplain Risk Management Study' (Catchment Simulation Solutions, 2021). This involved simulating a range of hypothetical "design" floods that included the 1% AEP event (also referred to as the 1 in 100 year flood) and the probable maximum flood (PMF), which is the largest flood that could occur.

The estimated water depths and velocities from each design flood simulation were used to map flood hazard categories. As shown in **Plate 1** and described in **Table 2**, the hazard categories assess the potential vulnerability of people (including children and the elderly), cars and structures based upon the depth and velocity of floodwaters at a particular location.

The flood hazard mapping for the 1% AEP flood is provided in **Figure 3** and the flood hazard mapping for the PMF is provided in **Figure 4**.

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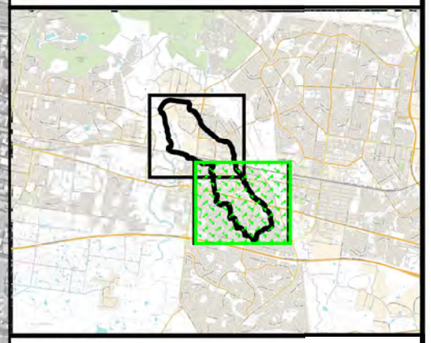
Little Creek Catchment Flood Risk Management Study and Plan



LEGEND

Hazard Categories

- H1 - Generally Safe
- H2 - Unsafe for small vehicles
- H3 - Unsafe for vehicles, children and elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people and vehicles. Buildings require special design
- H6 - Unsafe for people and vehicles All buildings vulnerable to failure

Notes:

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Scale 1:9,000 (at A3)

0 0.25 0.5 Km

Figure 3.1
Flood Hazard for the 1% AEP Flood

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File Name: Figure 3 Flood Hazard for the 1% AEP Flood.wor

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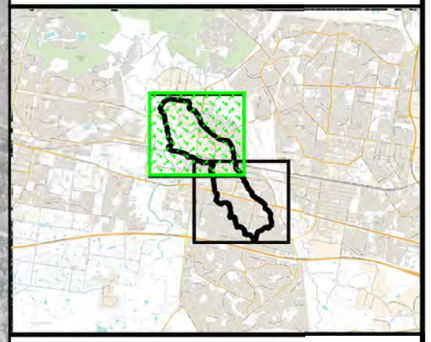

LEGEND

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Notes:

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Scale 1:9,000 (at A3)

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Figure 3.2
Flood Hazard for the 1% AEP Flood

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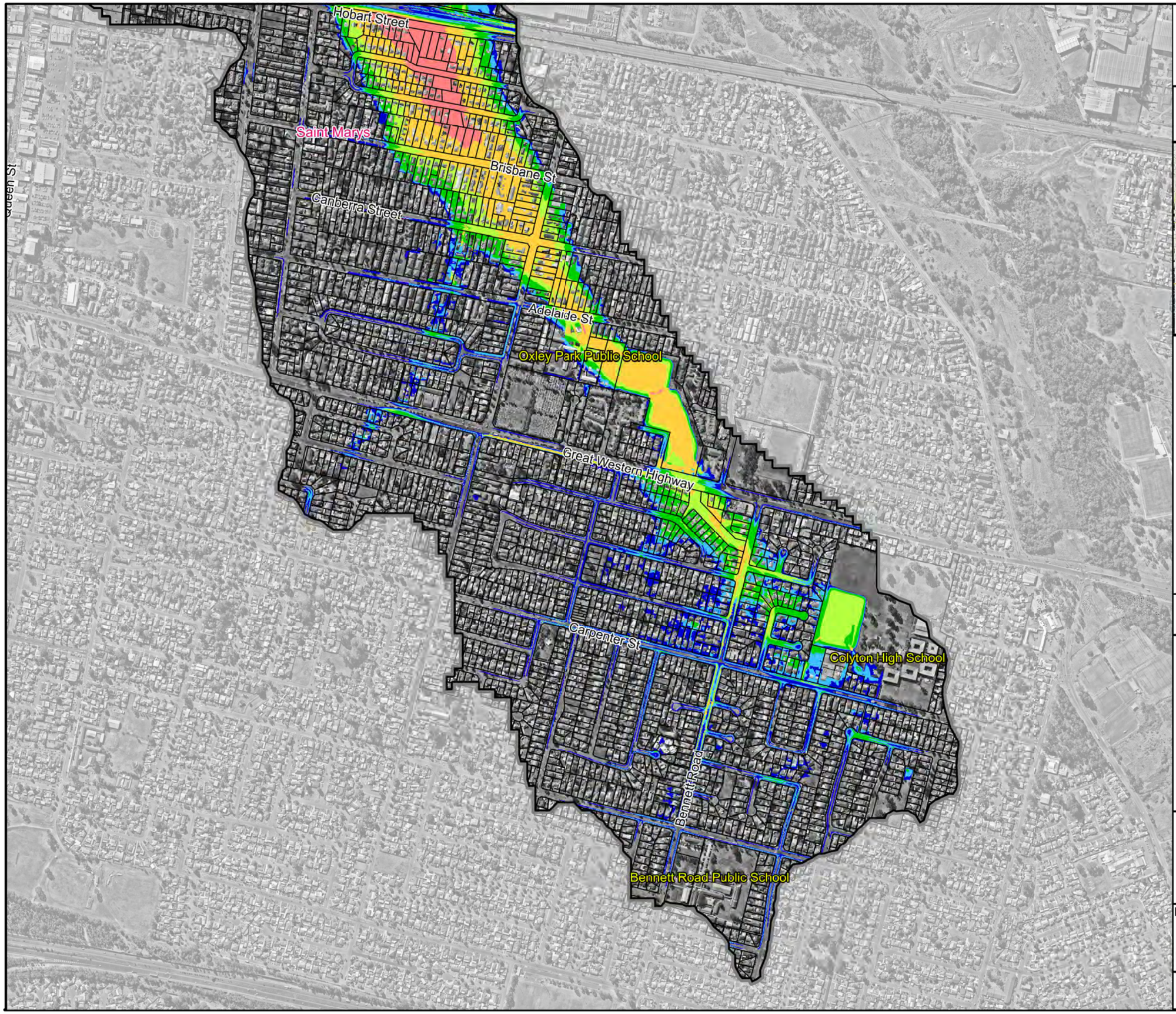
File Name: Figure 3 Flood Hazard for the 1% AEP Flood.wor



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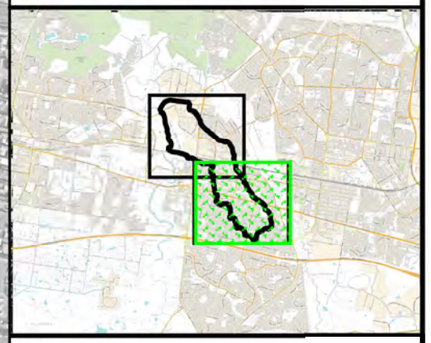

LEGEND

Hazard Categories

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- H3 - Unsafe for vehicles, children and elderly
- H4 - Unsafe for people and vehicles
- H5 - Unsafe for people and vehicles. Buildings require special design
- H6 - Unsafe for people and vehicles All buildings vulnerable to failure

Notes:

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Figure 4.1
Flood Hazard for the PMF

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File Name: Figure 4 Flood Hazard for the PMF.wor

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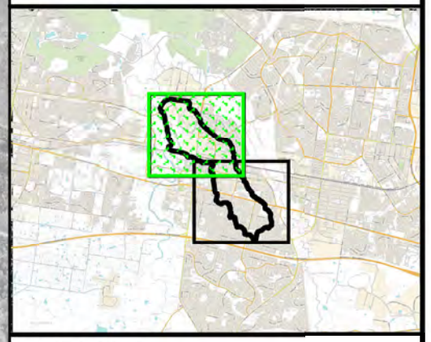

LEGEND

Hazard Categories

- H1 - Generally Safe
- H2 - Unsafe for small vehicles
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Notes:

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Scale 1:9,000 (at A3)

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Figure 4.2
Flood Hazard for the PMF

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Sydney, NSW 2000

File Name: Figure 4 Flood Hazard for the PMF.wor

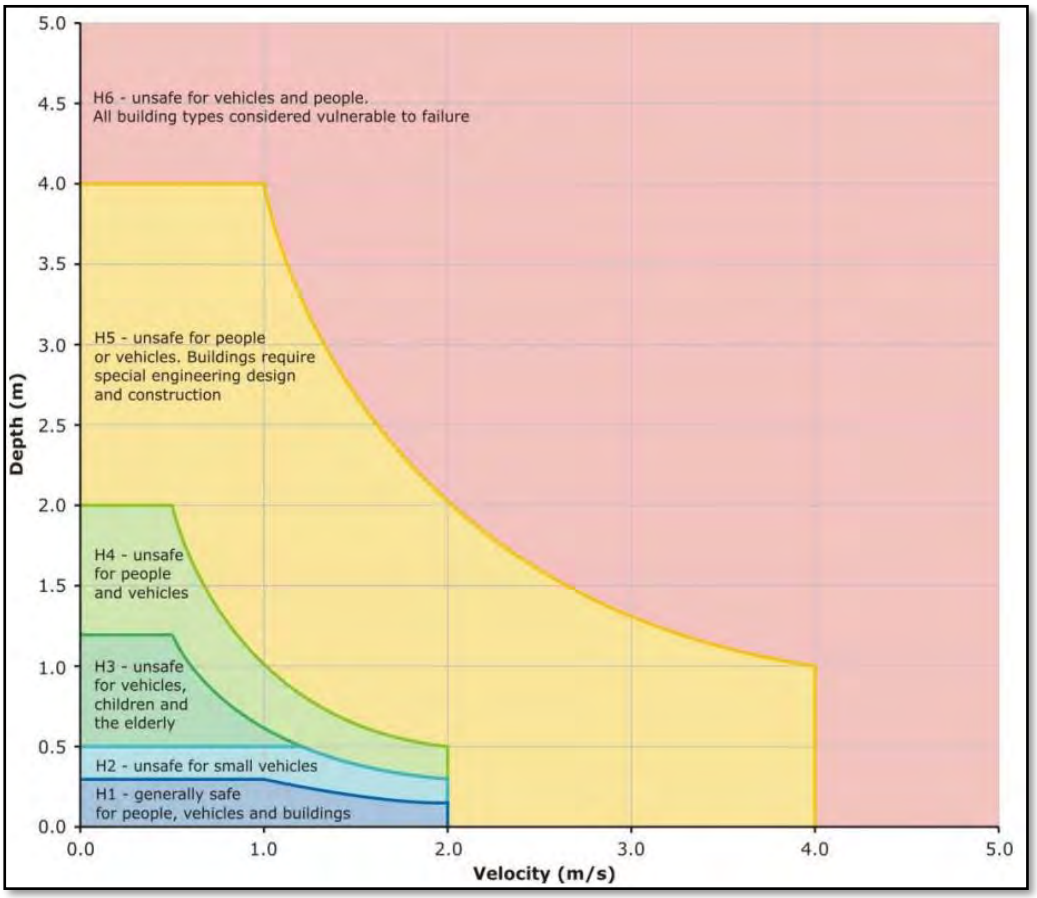

Plate 1 **Flood Hazard Vulnerability Curves (Geoscience Australia, 2019)**

Table 2 **Description of Adopted Flood Hazard Categories (Geoscience Australia, 2019)**

Hazard Category	Description
H1	Generally safe for vehicles, people and buildings. Relatively benign flood conditions. No vulnerability constraints
H2	Unsafe for small vehicles
H3	Unsafe for vehicles, children and the elderly
H4	Unsafe for vehicles and people
H5	Unsafe for vehicles and people. All building types vulnerable to structural damage. Some less robust building types vulnerable to failure
H6	Unsafe for vehicles and people. All building types considered vulnerable to failure.

Figure 3 shows that very few habitable areas are predicted to be exposed to a significant flood hazard during the 1% AEP event. Nevertheless, several roadways (including the Great Western Highway) are predicted to be unsafe for vehicles at the peak of the 1% AEP flood. Sections of Hobart Street are predicted to experience up to H4 hazard immediately upstream of the

railway line. Sections of Kenny Avenue, Thompson Avenue, Brisbane Street and Canberra Street are also expected to experience up to H3 hazard.

There is a noticeable increase in flood hazard between the 1% AEP flood and PMF (refer **Figures 3** and **4**). More specifically, during the PMF, a large area upstream (south) of the railway line is predicted to be exposed to H5 and H6 hazard conditions. Therefore, there is potential for structural damage to buildings and other infrastructure in this area during the PMF. Of particular note are properties located in the following H5 or H6 areas:

- Hobart Street between Sydney Street and Australia Street.
- Kenny Avenue between Sydney Street and Australia Street.
- Thompson Avenue between Sydney Street and Australia Street.
- Brisbane Street between Sydney Street and Australia Street.
- Canberra Street between Perth Street and Australia Street.
- Western side of Lee Holm Drive.
- Christie Street between Lee Holm Drive and the bridge over South Creek.

2.2.2 Economic Impact

The results of the design flood simulations were also used to prepare flood damage cost estimates so that the potential economic impact of flooding could be understood. The flood damage assessment is intended to estimate flood damage costs across the catchment for existing conditions across the full range of design floods for residential, commercial and industrial properties as well as infrastructure. This includes damage associated with above floor inundation as well as damage to properties even when above floor flooding is not predicted (i.e. when only the yards of the properties are flooded).

The flood damage estimates were prepared for each potentially flood liable property in the catchment by comparing the design flood level estimates with the floor levels for each property to determine an above floor flooding depth for each design flood. The above floor flooding depths were then combined with flood damages curves (relationships that describe the typical damage cost relative to the depth of above floor flooding) to provide a flood damage estimate for each property for each design flood.

As part of the damage cost calculations, the number of properties subject to above floor inundation during each design flood was calculated (this includes both above floor flood damage and damage from yard flooding or external damage). This information is summarised in **Table 3**.

The number of properties subject to external flood damage are also listed in **Table 3**. External damage includes damage to items such as fences, sheds and garages.

Table 3 shows that during the 1% AEP flood, eighty-three (83) residential properties are predicted to suffer external flood damage, and an additional twenty-four (24) properties are predicted to experience above floor inundation. During the PMF, one hundred and twelve (112) residential properties are predicted to incur external flood damage, with a further three hundred and seven (307) residential properties inundated above floor level. Thirteen (13)

commercial and industrial properties are expected to be inundated during a 1% AEP design flood, with seventy-six (76) predicted to incur damage during the PMF.

Table 3 Number of Properties Subject to Above Floor Inundation and Property Damage

Flood Event	Residential		Commercial and Industrial		Total Number	
	External Damage Only	Above Floor Inundation	External Damage Only	Above Floor Inundation	External Damage Only	Above Floor Inundation
0.5EY	8	0	2	2	10	2
20% AEP	21	0	3	3	24	3
10% AEP	34	1	3	3	37	4
5% AEP	49	6	4	4	53	10
2% AEP	78	16	13	13	91	29
1% AEP	83	24	13	13	96	37
0.5% AEP	99	28	13	13	112	41
0.2% AEP	106	45	18	18	124	63
PMF	112	307	76	76	188	383

The damage estimates for each design flood for existing conditions are summarised in **Table 4**. It indicates that if a 1% AEP flood were to occur, nearly $3.5 million worth of damage could be expected. Two thirds of these damage costs would be incurred across residential properties. **Table 4** also shows that the flood damage cost would increase to more than $50 million if a PMF was to occur.

Table 4 Summary of Flood Damages for Existing Conditions

Flood Event	**Flood Damage Costs** ($ millions)			Incremental Contribution to Average Annual Damage
	Residential	Commercial and Industrial	Total Damages	
0.5EY	0.06	0.01	**0.07**	$9,819
20% AEP	0.20	0.02	**0.22**	$42,551
10% AEP	0.37	0.07	**0.44**	$32,956
5% AEP	0.73	0.12	**0.85**	$32,397
2% AEP	1.83	0.88	**2.71**	$53,424
1% AEP	2.48	0.97	**3.45**	$30,797
0.5% AEP	3.02	1.06	**4.08**	$18,840
0.2% AEP	4.13	1.36	**5.49**	$14,364
PMF	37.58	13.35	**50.93**	$56,397
			TOTAL AAD	**$291,545**

The damage estimates were also used to prepare an Average Annual Damage (AAD) estimate for each property. The AAD takes into consideration the frequency of a particular flood occurring and the damage incurred during that event to estimate the average damage that is likely to occur each year, on average. The AAD for the Little Creek catchment was estimated to be just under **$292,000**. Accordingly, if the "status quo" was maintained and no flood management measure is undertaken, residents and business owners within the catchment as well as infrastructure providers, such as Penrith City Council, would likely be subjected to cumulative flood damage costs of around $292,000 per annum (on average).

It should be noted that all damage costs are estimates only. Actual damage costs during future floods may vary depending on the magnitude of the flood and the types of properties impacted.

2.3 The Potential Future Flood Risk

2.3.1 Future Catchment Development

The Little Creek catchment is already largely developed and does not include large greenfield areas that have the potential to be developed in the future. However, there are some isolated, undeveloped lots that do have future development potential. The remaining residential areas within the catchment also have the potential to be further developed in the future based upon current land use zonings defined in the Penrith LEP 2010 (e.g., granny flats).

This future development has the potential to alter existing flood behaviour which may impact on the existing flood risk across the catchment. Accordingly, additional analysis was completed as part of the Floodplain Risk Management Study to quantify the potential impacts that future development may have on the flood risk in the study area.

The results of the simulations showed that during the 1% AEP flood, the additional runoff under future catchment conditions has the potential to increase existing flood levels by around 0.05 metres along the main creek line downstream of the railway line as well as the overland flowpath upstream of the railway line. However, on Hobart Street, flood levels are predicted to increase by more than 0.1 metres over a significant number of residential properties. Accordingly, future catchment development does have the potential to increase the existing flood risk across the catchment and is anticipated to increase flood risk in areas that are already experiencing frequent flooding problems.

2.3.2 Climate Change

An assessment of the potential impact that climate change may have on the existing flood risk was also completed as part of the Floodplain Risk Management Study. This involved assessing the impacts that a 9% increase and a 23% increase in existing 1% AEP rainfall would have on existing flood levels as per guidance provided in 'Australian Rainfall and Runoff' (Ball et al, 2019).

A 9% increase in rainfall is predicted to increase 1% AEP flood levels by between 0.05 to 0.10 metres along the main alignment of Little Creek. Immediately upstream of the railway line (including Hobart Street), flood levels are predicted to increase by 0.2 metres.

A 23% increase in rainfall is predicted to increase existing 1% AEP flood levels by between 0.1 and 0.2 metres at most locations along Little Creek. There are greater localised impacts upstream of some of the larger culverts, including upstream of Glossop Street, upstream of the railway line, and at the intersection of Sydney Street and Brisbane Street. In particular, flood levels in Hobart Street are predicted to increase by 0.5 metres.

Accordingly, the outcomes of the climate change assessment show that increases in rainfall have the potential to increase the flood risk across much of the catchment. The area around Hobart Street is particularly sensitive to increases in rainfall.

2.4 Summary of Flooding "Trouble Spots"

There are a number of areas within the Little Creek catchment that have the potential to experience significant property damage and risk to life during floods within the catchment. These areas include:

- Hobart Street, between Sydney Street and Australia Street – this area presents the most significant flood risk in the catchment, particularly during larger floods such as the PMF where H6 hazard conditions are predicted in some locations.
- Bennett Road between Bentley Street and the Great Western Highway – Bennet Road is a significant transportation link and is exposed to H3 and localised areas of H4 hazard during the 1% AEP flood. During the PMF, localised areas (including the front yards of some adjacent properties) are exposed to H5 hazard.
- Great Western Highway between Bennett Street and Marsden Road – this is the major east to west transportation link in the catchment and is predicted to be cut during floods as frequent as the 5% AEP event. Up to H3 hazard is predicted during the 1%AEP flood which is sufficient to mobilise vehicles. Extensive H4 hazard is predicted during the PMF.
- Oxley Park Public School: An overland flow path extends through the northern parts of the school during the 1% AEP flood, and this includes small areas of H3 which would pose a threat to children. During the PMF, H5 hazard is predicted in some locations which would not only pose a significant risk to children and school staff but could also result in structural damage to buildings. Due to the vulnerability of children to the impacts of flooding, the school is one of the higher flood risk areas within the catchment.
- Adelaide Street between Bayton Street and Sydney Street. – areas of H3 hazard are predicted during the 1% AEP while extensive areas of H4 and H5 hazard are predicted during the PMF.
- Canberra Street near Sydney Street intersection – H3 hazard is common within the roadway during the 1% AEP flood and H5 hazard is common during the PMF across multiple adjacent residential properties.
- Brisbane Street between Sydney Street and Australia Street – localised areas of H4 hazard are predicted during the 1% AEP flood within the road reserve. Numerous properties adjacent to Brisbane Street would be exposed to H5 hazard during the PMF.

- Glossop Street between Kurrajong Road and Debrincat Avenue. Glossop Street is the main north to southern transportation link in the catchment. It is predicted to be cut by floodwaters during a 2% AEP flood. H3 hazard is predicted across the road during the 1% AEP flood while H5 hazard is predicted during the PMF.
- Forrester Road between Harris Street and Glossop Street – The road is predicted to experience H4 hazard during the 1% AEP flood which increases to H5 hazard during the PMF.
- Lee Holm Road - Extensive ponding is predicted at the sag point in Lee Holm Drive. Although not particularly fast moving, the floodwater depths are predicted to produce extensive H3 hazard during the 1% AEP flood and H4 hazard during the PMF. Adjoining industrial properties are also be predicted to experience H4 hazard.

3 FLOOD MODIFICATION OPTIONS

3.1 Overview

3.1.1 Flood Modification Options Considered

The outcomes of the existing flood risk assessment were used to develop an initial list of twenty nine (29) flood modification options that could be potentially implemented to better manage the existing flood risk in the Little Creek catchment. The list of options that were initially considered included:

- Detention basins.
- Culvert and bridge upgrades.
- Stormwater upgrades.
- Creek and channel modifications.
- Topographic modifications.
- Levee modifications.

It was not feasible to undertake a detailed assessment of all twenty-nine (29) flood modification options as part of the Study. Therefore, a qualitative assessment of each potential option was completed to assess the potential feasibility of each option and to determine which measures showed merit for further detailed assessment. The full list of options that were initially considered are provided in the Study and the final list of flood modification options that were selected for detailed assessment are provided in **Table 5** and are denoted FM1 to FM10.

3.1.2 Detailed Option Assessment Approach

The "shortlist" of flood modification options identified in **Table 5** were subsequently assessed in detail as part of the Study to determine which would likely be feasible and move forward for inclusion in the Plan. Each option was assessed against a range of criteria, as detailed below:

- Hydraulic Factors: Each option was included in an updated version of the computer flood model and was used to re-simulate flood behaviour with the option in place. This allowed the hydraulic benefits (i.e., reductions in flood levels) afforded by each option across difference parts of the catchment to be quantified.
- Financial Feasibility: Concept design plans were prepared for each option which allowed preliminary implementation cost estimates to be prepared. The results from the computer model simulations were also used to prepare updated flood damage cost estimates for each option. This allowed the 'benefits' of each option to be quantified (in terms of a reduction in flood damage costs) and compared to the implementation cost of each option (refer **Table 5**). This allowed a monetary benefit to cost ratio (BCR) to be prepared for each option. A BCR of more than 1 indicates the economic benefits are predicted to outweigh the implementation cost while a BCR of less than 1 indicates that there will still be a financial benefit, but it will not be sufficient to cover the implementation cost. The BCR for each option is also summarised in **Table 5**

Table 5 Summary of Economic Outcomes for Flood Modification Options

Flood Modification Option		Description of Option	Economic Impact			Multi Criteria Assessment Ranking
			Cost of proposed work ($ millions)	Reduction in Flood Damage Costs ($ millions)	Benefit Cost Ratio	
FM1	Great Western Highway culvert upgrade	Replace the existing triple 1.5 metre diameter culverts with three 1.5m wide by 1.8m high box culverts	0.62	0.35	0.6	4
FM2	Railway and Hobart Street culvert upgrade	Replace existing pipe, box & arch culverts between Hobart St and Plasser Cres with 2.7m wide x 2.1 m high box culvert	1.03	0.93	0.9	=3
FM3	Glossop Street culvert upgrade	Replace existing 5 cell 1.5m wide by 0.9m high box culverts with four 4.2m wide by 1.2 high box culverts	0.74	0.01	Less than 0.1	7
FM4	Canberra Street, Sydney Street and Brisbane Street stormwater upgrades	Provide new 1.2m dia stormwater pipes along Canberra Street, Sydney Street and Brisbane Street plus new stormwater inlets	1.29	0.82	0.6	=3
FM5	Glossop Street stormwater upgrades	Upgrade existing stormwater pipes and pits and provide new pipes and pits near Glossop Street “sag” point	0.77	0.00	0.0	8
FM6	Lee Holm Drive stormwater upgrades	Duplicate stormwater system capacity between Lee Holm Drive and Little Creek	Not calculated	Not calculated	Not calculated	9
FM7	Colyton High School Basin Augmentation	Provide additional storage volume within existing High School basin	1.38	1.25	0.9	6
FM8	Oxley Park Basin Augmentation	Provide additional storage volume in existing detention basins located between Great Western Highway and Oxley Park Public School	0.53	0.56	0.8	1
FM9	Great Western Highway Median Modification	Remove a section of median strip at low point in Great Western Highway)	Not calculated	Not calculated	Not calculated	5
FM10	Combined Option #1	FM1: Great Western Highway culvert upgrade + FM2: Hobart Street and Railway culvert upgrade + FM5: Jamison Road Basin + FM4: Canberra Street, Sydney Street and Brisbane Street stormwater upgrades + FM8: Oxley Park Basin Augmentation	3.88	2.55	0.7	2

- Change in Above Floor Flooding: The results from the updated flood modelling were also used to quantifying the change in the number of buildings subject to above floor inundation with each option in place during each design flood.
- Emergency Response Impacts: This assessment focussed on the ability of each option to result in less frequent and deep inundation of roads which would provide improved opportunities for vehicular evacuation.
- Technical Feasibility: An assessment of any technical impediments was completed for each measure to determine if there would be any "showstoppers" that may render the option impractical.

The outcomes of the options evaluation were subsequently used to inform a multi criteria assessment (MCA). The MCA attempts to assign a "score" to each option that reflects a considered evaluation of the full range of evaluation criteria (including tangible and intangible evaluation criteria). The individual scores for each evaluation criteria can be summed to provide an overall score for each option that reflects how well each option performs relative to other options and provides valuable insight into potential implementation priorities as part of the Floodplain Risk Management Plan.

Based on the outcomes of the MCA, the following options were selected to move forward into the Plan:

- FM1 – Greater Western Highway Culvert Upgrade.
- FM2 – Railway and Hobart Street Culvert Upgrade.
- FM4 – Canberra Street, Sydney Street and Brisbane Street Stormwater Upgrade.
- FM8 – Oxley Park Basin Augmentation.

A summary of key assessment outcomes for each recommended option are provided in the following sections.

3.2 FM1 – Great Western Highway Culvert Upgrade

Description: Replace the existing triple 1.5 metre diameter culverts with three 1.5m wide by 1.8m high box culverts

Priority: Low

Estimated Cost: $620,000

Implementation Responsibility: Penrith City Council and Transport for NSW

NOTE: FM8 should be implemented prior to FM1 to ensure no adverse impacts across downstream properties

Option FM1 targets reducing the severity of flooding across the Great Western Highway as well as across adjoining properties to the south of the highway. This would involve replacing the existing triple 1.5 metre diameter culverts that drain beneath the highway with three 1.5m wide by 1.8m high box culverts.

It is expected that the culvert upgrade would cost around $600,000 to implement.

FM1 is predicted to afford the following benefits:

- Flood damages costs would be reduced by around $350,000 over the next 50 years.
- Three (3) fewer properties would be exposed to above floor flooding in a 5% AEP flood and two (2) fewer properties would be exposed to above floor flooding during the 1% AEP flood. A summary of the change in number of properties impacted by above floor flooding during each design flood is provided in **Table 6**.
- At least 1 west-bound lane of the highway would remain open during floods up to the 2% AEP flood (currently the highway is cut during a 5% AEP flood).

Therefore, FM1 is predicted to afford some significant financial and emergency response benefits for the Great Western Highway as well as properties located south of the highway.

However, implementation of FM1 in isolation is predicted to direct additional water downstream (i.e., north) of the highway. During the 1% AEP flood, the additional flows are predicted to produce flood level increases (typically about 0.05 metres) across multiple properties located between the Oxley Park Public School and the intersection of Sydney Street and Canberra Street. Therefore, it is important that FM1 is not implemented before FM8 (discussed in Section 3.5) to ensure the adverse flood impacts are avoided.

The Great Western Highway is operated by Transport for NSW (TfNSW). Therefore, coordination with TfNSW would be required for this option to proceed.

Overall, FM1 was ranked fourth as part of the multi criteria assessment. It performed well in reducing above floor flooding but did not perform as well as other options in hydraulic performance (notably the flood level increases that are predicted across some properties). There will also be a need to to implement other options prior to FM1 to ensure no adverse flood impacts occur across any properties. As a result, it is suggested that FM1 is targeted as a longer term and lower priority option. However, it is recommended that Council initiate discussions with Transport for NSW to gain an understanding of their willingness to participate in the process. It is also recommended that FM1 be considered with FM8 as part of future detailed hydraulic and concept design assessments to confirm FM8 can suitably mitigate the additional flow that is directed through the FM1 culverts.

3.3 FM2 – Railway and Hobart Street Culvert Upgrade

Description: Replace existing pipe, box & arch culverts between Hobart St and Plasser Cres with 2.7m wide x 2.1 m high box culvert

Priority: Medium

Estimated Cost: $1 million

Implementation Responsibility: Penrith City Council and Transport for NSW

Table 6 Change in Number of Properties Subject to Above Floor Flooding for Each Recommended Flood Modification Option

Flood Modification Option	Change in Number of Properties with Above Floor Inundation*			
	20% AEP	5% AEP	1% AEP	PMF
Culvert and Drainage Upgrades				
FM1 - Great Western Highway culvert upgrade	0	-3	-2	0
FM2 – Railway and Hobart Street culvert upgrade	0	-1	-2	-1
FM4 - Canberra Street, Sydney Street and Brisbane Street stormwater upgrades	0	-1	-2	0
Basin upgrades				
FM8 - Oxley Park Basin Augmentation	0	0	-1	2
Combined Option				
FM10 – FM1 + FM2 + FM4 + FM8	0	-3	-6	-2

NOTE: * A negative value indicates the option is predicted to reduce the number of properties subject to above floor flooding and a positive value indicates the option is predicted to increase the number of properties subject to above floor flooding.

Table 7 Change in Number of Properties Subject to Below Floor (i.e., Yard) Flooding for Each Recommended Flood Modification Option

Flood Modification Option	Change in Number of Properties with Below Floor Inundation*			
	20% AEP	5% AEP	1% AEP	PMF
Culvert and Drainage Upgrades				
FM1 - Great Western Highway culvert upgrade	0	0	1	0
FM2 – Railway and Hobart Street culvert upgrade	0	-3	-1	-3
FM4 - Canberra Street, Sydney Street and Brisbane Street stormwater upgrades	-7	-7	-1	0
Basin upgrades				
FM8 - Oxley Park Basin Augmentation	0	0	-2	0
Combined Option				
FM10 – FM1 + FM2 + FM4 + FM8	-7	-6	-4	-3

NOTE: * A negative value indicates the option is predicted to reduce the number of properties subject to below floor flooding and a positive value indicates the option is predicted to increase the number of properties subject to below floor flooding.

FM2 would involve upgrading the existing pipe and culvert system from Hobart Street, across the railway line to Plasser Crescent. The upgrades would include:

- Replacing the existing 6.3m x 3.3m trapezoidal grate on the northern side of Hobart Street with a larger 7m x 3.5m rectangular grate.
- Regrading the area around the Hobart Street inlet pit to direct water off the road into the larger pit.
- Replacing the four existing 1.2 metre diameter pipes beneath Hobart Street with four 1.35m diameter pipes.
- Replacing the existing 2.44m diameter pipe between Hobart Street and the railway with a 2.7m wide x 2.1 m high box culvert.
- Replacing the existing trapezoidal culvert beneath the railway with a 2.7m wide x 2.1 m high box culvert.

It is expected that FM2 would cost just over $1 million to implement.

FM2 is predicted to afford the following benefits:

- Flood damages costs would be reduced by around $930,000 over the next 50 years. This provides a monetary benefit to cost ratio of just under one (1).
- Flood levels in Hobart St are predicted to reduce by around 0.3 metres during a 5% AEP flood and 0.2 metres during a 1% AEP flood.
- Three (3) fewer properties would be exposed to above floor flooding in the 5% AEP event, and there would be two (2) fewer properties with above floor flooding in the 1% AEP event.
- A summary of the change in number of properties impacted by below floor (i.e., yard) flooding is provided in **Table 7**. It shows that inundation would be completely removed from three (3) properties in the 5% AEP flood, one (1) property during the 1% AEP flood and three (3) properties in the PMF.

The culvert upgrades extend through the existing railway embankment. Therefore, Sydney Trains will need to be engaged in further feasibility discussions.

Overall, FM2 affords some significant benefits across one of the most significantly flood-affected areas within the Little Creek catchment. It is also predicted to provide a benefit to cost ratio near 1 and ranked as the equal third most favoured options as part of the multi-criteria assessment. As a result, this option is considered suitable for further investigations and potential implementation. The following tasks are recommended to progress this option further:

1) Council to initiate discussions with Sydney Trains to gain an understanding of their willingness to contribute to the implementation process and understand any constraints within railway land that may limit the feasibility of the option.
2) If the above discussions yield a positive outcome, survey of existing services should be collected.

3) A hydraulic assessment should be completed to determine the optimal drainage configuration between Hobart Street and Plasser Crescent (taking account of any constraints identified during steps 1 and 2).
4) Detailed concept design plans and cost estimates should be prepared for the preferred design option. A revised economic assessment should be completed to confirm the economic performance of the option.
5) Following a successful economic outcome, detailed construction plans can be prepared, final cost estimates can be prepared, funding can be sought, and the option can be potentially implemented.

3.4 FM4 – Canberra Street, Sydney Street and Brisbane Street Stormwater Upgrades

Description: Provide new 1.2m diameter stormwater pipe along Canberra Street, Sydney Street and Brisbane Street plus new stormwater inlets to drain runoff into new pipe.

Priority: Medium

Estimated Cost: $1.3 million

Implementation Responsibility: Penrith City Council

FM4 would involve upgrading and expanding the stormwater system in the vicinity of Canberra Street, Sydney Street and Brisbane Street. This would aim to capture and direct a greater proportion of flow below ground, thereby reducing overland flow depths and extents.

A cost estimate for FM4 was prepared and indicates that it is likely to cost in the order of $1.3 million to implement. This makes it the most expensive of the options that are recommended in the Plan. Due to the high capital cost, this option may need to be targeted as a longer-term strategy.

FM4 is predicted to afford the following benefits to the Little Creek catchment:

- Flood level reductions of at least 0.15 metres are predicted during the 20% AEP flood from the intersection of Canberra and Sydney Streets downstream to Hobart Street. Similar flood level reductions are predicted in the 1% AEP flood, but the reductions are predicted to extend further upstream to Adelaide Street.
- Existing flood damages would be reduced by more than $800,000 over the next 50 years.
- One (1) fewer property would be exposed to above floor flooding in the 5% AEP event, and there would be two (2) fewer properties with above floor flooding in the 1% AEP event (refer **Table 6**).
- Inundation would be completely removed from seven (7) properties in the 20% AEP and 5% AEP floods, and one (1) property during the 1% AEP flood (refer **Table 7**).

- Sydney Street and Brisbane Street are currently predicted to be cut in a 0.5EY (i.e., a 2 year flood) event. But with FM4 in place, this is predicted to increase to a 10% AEP flood and 20% AEP flood respectively.

Overall, FM4 affords some notable reductions in flood levels and extents across a large section of the catchment benefits. Although the stormwater upgrades do not extend as far north as Hobart Street, the option is still predicted to afford flood level reductions in the Hobart Street area by more efficiently capturing stormwater runoff from the upstream catchment. As a result, it ranked equal third in the multi-criteria assessment.

The following tasks are recommended to progress this option further:

1) The proposed pipe alignment extends across or near to six (6) different utilities and services. These services will have a significant impact on the cost and overall feasibility of the option. Therefore, it is recommended that a survey of existing services in the area should be undertaken.
2) Concept design options should be explored taking account of the services information. This should be supported by a hydraulic assessment and the preparation of revised cost and flood damage estimates for each design option.
3) Detailed construction plans should then be prepared for the preferred concept design option. This should be supported by a detailed cost estimate so that funding for the option can be sought.

3.5 FM8 – Oxley Park Basin Augmentation

Description: Provide additional storage volume in existing detention basins located between Great Western Highway and Oxley Park Public School. This will include lowering the existing basin inverts and increasing the height of basin walls.

Priority: Medium

Estimated Cost: $900,000

Implementation Responsibility: Penrith City Council

NOTE: FM8 should be implemented prior to FM1 to ensure no adverse impacts across downstream properties

FM8 would involve providing additional storage capacity within the existing Oxley Park detention basins that are located between the Great Western Highway and Oxley Park Public School. This would include elevating the downstream basin wall, reducing the elevation of the invert of the basins and including an additional basin wall within the southern basin (i.e., creating a total of three (3) interconnected basins). A formal spillway will also be incorporated in the wall of the downstream most basin to direct any overtopping water into the car park area of the Oxley Park Public School rather than towards school buildings. This flow path will be further reinforced by completing minor regrading within the north-eastern corner of the public school to help direct flows through the school car park.

It is expected that FM8 would cost around $900,000 to implement. This includes a capital cost of $600,000 plus $300,000 for a dam break study and ongoing inspections to ensure the integrity of the basins are maintained over its design life (this is discussed further below).

FM8 is predicted to afford the following benefits:

- Flood damage costs would be reduced by around $800,000 over the next 50 years. This provides a monetary benefit to cost ratio of 0.8.
- Flood level reductions of more than 0.1 metres are predicted through the school and Adelaide Street properties during the 1% AEP flood. Reductions of just under 0.1 metres are predicted across a similar area during the PMF.
- One (1) fewer property would be exposed to above floor flooding (refer **Table 6**) and inundation would be completely removed from two (2) properties in the 1% AEP flood (refer to **Table 6** and **Table 7**).
- The extent of H5 hazard across the school during the PMF would be reduced, thereby reducing the potential for damage to school buildings during this extreme flood.
- FM8 will offset the flood level increases that are predicted if only FM1 is implemented.

Due to the proximity of the basins to Oxley Park Public School as well as downstream residential properties, there is a risk that failure of one or more basins could lead to loss of life or significant damage and financial impacts. As a result, the basin would likely need to be "declared" under the NSW Government's Dams Safety program. This would initially involve a dam or basin break study to establish a basin failure consequence category and then regular inspections of the basin to ensure integrity is maintained over its design life.

Overall, FM8 affords some significant reductions in flood levels and flood hazard during large floods across one of the most vulnerable facilities in the catchment (i.e., Oxley Park Public School). It is also predicted to offset the adverse flood impacts that are predicted if FM1 was implemented in isolation. Therefore, it is critical that FM8 is implemented before FM1. FM8 was also ranked first overall as part of the multi-criteria assessment.

The following tasks are recommended to progress this option further:

1) Council to initiate discussions with the Department of Education over Oxley Park Public School to explain their flood exposure and to seek input into the option and the works that would need to be completed on school grounds.
2) If the above discussions yield a positive outcome, concept design options should be explored. This should aim to maximise the hydraulic benefits across the school and downstream properties while avoiding adverse flood impacts across private property (the design option explored as part of the Floodplain Risk Management Study resulted in a 0.01 metre increase in flood level across two (2) residential properties in Whitcroft Place during the PMF).
3) Detailed construction plans should then be prepared for the preferred concept design option. This should be supported by a detailed cost estimate so that funding for the option can be sought and the option can move towards implementation.

3.6 Other Options

Other options investigated as part of the Floodplain Risk Management Study were also found to afford some notable reductions in flood levels and extents. Council and asset owners (e.g., TfNSW) should consider these options for implementation as part of their ongoing works programs, asset replacement, road upgrades etc. These options include:

- FM3: Glossop Street culvert upgrade.
- FM5: Glossop Street stormwater upgrades.
- FM6: Lee Holm Drive stormwater upgrades.
- FM9: Great Western Highway median modifications.

Further information of each of these options is provided in the Floodplain Risk Management Study.

4 PROPERTY MODIFICATION OPTIONS

4.1 PM1 – Updates to Local Environmental Plan

Description: Updates to Local Environmental Plan (specific details are provided below)

Priority: High

Estimated Cost: $20,000 (within Council's Operational Budget)

Implementation Responsibility: Penrith City Council

A comprehensive review of Penrith City Council's Local Environmental Plan (LEP) 2010 was completed and the outcomes of this review are documented in the Floodplain Risk Management Study. Based upon this review, it is recommended that any future updates of the LEP consider the following changes to better manage the flood risk across the full range of potential floods:

- Include properties in Brisbane Street to Hobart Street that are currently located outside the flood planning area but are exposed to greater than H4 hazard in the PMF within the flood planning area. This could be accomplished by adopting the 0.5% AEP event rather than the 1% AEP event as the "planning flood" in this area. Adoption of the 0.5% AEP flood as the planning flood is discussed further below.
- Make the flood planning area map publicly available in a logical and easy to find location. It is recommended that these are provided as a separate document to the gazetted Penrith LEP 2010 maps so they can be updated as frequently as required when updated flood study and floodplain risk management study information becomes available.
- The existing Clause 7.2 of Penrith LEP 2010 currently states "This clause applies to land at or below the flood planning level", with the flood planning level defined as "the level of the 1:100 ARI flood event plus 0.5 metres freeboard". The current definition of the flood planning event and freeboard does not allow flexibility in defining the flood planning level throughout the different catchments in the LGA, should this design flood and freeboard not be appropriate (e.g., Hobart Street area where a larger planning flood may be desirable, as discussed in more detail below). A potential option for providing more flexibility in the description of the flood planning level is:
  - ***flood planning level*** *means the level of a 1:100 ARI (average recurrence interval) flood event plus 0.5 metres freeboard or other design flood or freeboard as determined by an adopted floodplain risk management plan by the Council, prepared in accordance with the NSW Government's Floodplain Development Manual.*
- More flexibility can be incorporated into Clause 7.2 by redefining how land subject to this clause is selected. Currently, the clause employs the following wording:
  (a) land at or below the flood planning level,
  (b) land identified as "Flood planning land" on the Clause Application Map.

Suggested changes to the wording in the existing clause to provide more flexibility are provided below:

(a) land at or below the flood planning level,

or

(a) land at or below the flood planning level, and
(b) land identified as "Flood planning area" on the flood planning area map.

- Include an additional "Floodplain Risk Management" clause in the LEP (i.e., Clause 7.3) which would relate to the areas between the flood planning area and the edge of the floodplain (i.e., PMF extent).

A review of Council's current Flood Planning Level (i.e., 1% AEP flood plus 0.5 metres freeboard) was completed as part of the Study. This determined that the 0.5 metre freeboard would be suitable for accounting for uncertainty in the flood level estimates across the catchment. However, a larger design flood (i.e., the 0.5% AEP flood) was considered more appropriate than the 1% AEP flood as the "planning flood" for the higher flood risk area contained between Brisbane Street and Hobart Street. Therefore, a modified flood planning area map based on a 'hybrid' planning flood level (i.e., 0.5% AEP between Brisbane Street and Hobart Street and the 1% AEP flood across the balance of the catchment) should be considered.

The process of updating an LEP can be time consuming as it requires extensive review and exhibition periods. However, discussions with Council planners indicate that there are plans to update the LEP soon. As a result, it is recommended that the LEP updates be pursued as a short term, high priority option.

As a starting point, it is recommended that Council planners consolidate the LEP update recommendations from all recent floodplain risk management studies and plans within the LGA. This will form the basis for preparing a planning proposal which will then be forwarded onto DPIE for review and begin the various exhibition and review processes that will culminate in the preparation of an updated LEP.

4.2 PM2 – Updates to Development Control Plan

Description: Updates to Development Control Plan (specific details are provided below)

Priority: High

Estimated Cost: $40,000 (within Council's Operational Budget)

Implementation Responsibility: Penrith City Council

A review of the Penrith Development Control Plan (DCP) 2014 was completed and a detailed discussion on the outcomes of this review are documented in the Floodplain Risk Management Study. Based upon this review, it is recommended that any future updates of the DCP consider the following changes to better manage the flood risk across the full range of potential floods:

- Clear prescriptive controls with defined thresholds for acceptable planning and development applicants.
- Clearly defined flood planning level, including the defined flood event and freeboard, for the various development categories, such as residential, commercial, industrial, vulnerable and critical infrastructure.
- Consideration of the full range of design flood events, up to and including the PMF, for strategic planning purposes, and for vulnerable developments and critical infrastructure.
- Provide updated H1-H6 flood hazard mapping from this study and other recently adopted floodplain risk management plans in the LGA and consideration of the use of flood planning constraint categories (FPCC) mapping.
- Clear controls for change of use and concessional development in flood prone areas.
- Clear controls for filling in the floodplain, based on catchment wide analysis.
- Minimising the potential for increased flood risk via increased density as a result of redevelopment of a site located in the floodplain. This could be potentially achieved by including a control prohibiting more intensive land uses within the PMF extent or, as a minimum, within the FPA.
- The DCP does not currently include considerations for flood mitigation works. Flood mitigation works may have a flood planning level that is higher or lower than the proposed residential flood planning level and should be determined via a merits-based assessment. The full range of design flood events should be used when assessing the potential failure of the flood mitigation works.

The Study has identified a significant flood hazard during the PMF, which affects a number of properties located between Adelaide Street and Hobart Street. Additional development controls for such high hazard areas are recommended for inclusion in the DCP. The general controls for the DCP can be derived from the site specific controls provided below for the high hazard area between Adelaide Street and Hobart Street:

- Include an elevated mezzanine level or second storey as part of any new development in the Adelaide Street and Hobart Street area. This is intended to allow for vertical evacuation if safe evacuation from the dwelling cannot be completed.
- A requirement that all bedrooms be located on the second storey for residential dwellings. This is intended to ensure that residents would remain safe should a large flood occur at night when they are asleep.
- Inclusion of a balcony on the second level to allow emergency boat rescue in emergencies (e.g., medical emergency) or should the area be isolated for an extended period.
- Engineering report to certify that the structure can withstand the forces of floodwater, debris and buoyancy up to and including a PMF plus freeboard.

Discussions with Council planners indicate that there are plans to update the DCP in the near future. Therefore, it is recommended that the DCP updates are commenced as a high priority option.

It is suggested that Council consolidates the DCP recommendation contained in this Study and Plan along with other recent floodplain risk management studies and plans within the LGA. This will serve as a starting point for updating the DCP. Although the DCP must also undergo review and exhibition periods, these are not as exhaustive as the LEP (typically DCP amendments must be exhibited for a minimum of 28 days).

4.3 PM3 – Updates to Section 10.7 Certificates

Description: Update Section 10.7 certificate to reference updated design flood information generated as part of the current study.

Priority: High

Estimated Cost: $6,000 (within Council's Operational Budget)

Implementation Responsibility: Penrith City Council

It is recommended that Council update Section 10.7 certificates to reference the updated design flood information generated as part of the Floodplain Risk Management Study. This will help to ensure that the most up-to-date information is available and used for properties located within the Little Creek catchment.

This needs to be implemented in addition to the other changes identified in the preceding sections of this report regarding the updating of the LEP and DCP.

5 Response Modification Options

5.1 RM1 – Community Education Strategy

Description: Develop local FloodSafe documents and develop educational messages targeting dangerous behaviours during a flood

Priority: High

Estimated Cost: $20,000 up front. Follow up required to maintain awareness and would cost approximately $5,000 bi-annually.

Implementation Responsibility: SES with assistance from Penrith City Council

An effective community education program is often the most effective emergency response planning strategy as it allows individuals to become more self-sufficient and less reliant on emergency services.

It is recommended that the preparation of the FloodSafe documents for the local area to provide general education information will be further considered by SES. The documents could be developed to be generic enough to indicate how residents can plan for floods even if their property is not flood prone, what to do during a flood, such as evacuation routes and centres, and what options are available to residents and business owners to assist with post-flood recovery.

It is also recommended that the SES consider a range of messaging that can be disseminated to the community via media agencies (both print and online). Samples of potential messages are provided in the Floodplain Risk Management Study that target dangerous behaviour (i.e., warning against driving, walking or playing in floodwaters) and overland flooding (i.e., advising flooding can occur away from creeks and rivers). Given the significant flood risk in the Hobart Street area, messaging related to extreme flooding could also be a worthwhile reminder.

The above education recommendations are intended to be generic enough to allow application across overland flooding areas in the broader LGA. In addition to these more general education activities, it is recommended that targeted education be completed for particularly high-risk sections of the catchment. This is discussed further in Section 5.5.

5.2 RM2 – Make Property Level Flood Information Available

Description: Develop a standardised approach for presenting flooding information across all catchments and work towards incorporating available flood information into an online flood portal

Priority: High (presentation of flood information) and Medium (online flood portal)

Estimated Cost: Approximately $20k for required IT infrastructure. Approximately $30k for compiling required datasets and website interface.

Implementation Responsibility: Penrith City Council

A starting point for improving people's readiness for floods is to help them better understand how they could be directly affected by floods. Knowing how their house or business could be directly affected by floods is more likely to cut through the scepticism that can grow when communities are not flooded for some years.

Penrith City Council currently makes a range of flood information available on its website. However, there is a lack of consistency in how flood information across different catchments is presented. If Council would like to continue to use the website and PDF mapping as their preferred approach for providing flood information to the community, they could consider arranging for future studies to provide mapping at a consistent scale (e.g., 1:5,000) and provide standard mapping outputs in a consistent colour scheme. In the short term, Council could consider using their internal GIS resources to prepare a standardised set of maps based on the GIS outputs that have been produced as part of each study.

However, over the medium to long term, there would be value in collating the available spatial flood outputs that are generated as part of flood studies and floodplain risk management studies and incorporating this information on an online mapping webpage. This would help to ensure that:

- All available flood information is provided on a single webpage.
- Results are presented in a consistent manner regardless of who completed the study.
- There are no scaling issues as the community can use the interface to zoom in and out, as required.

There is also potential to include other flood information and links such as Bureau of Meteorology warnings, live information on nearby rain gauges, and the latest advice from relevant organisations such as the SES and TfNSW. Therefore, if well maintained, a website can serve as a central repository for a range of contemporary flood information.

The mapping page could include design flood depths, flood levels and flood hazard. This would assist with providing owners or purchasers of property in the catchment with the flood information related to flood constraints. Together with the planning controls recommended for the DCP, this flood data would assist the property development process in the LGA.

Discussions with Council indicate that consolidating of all flood data and development of an online mapping page are currently under consideration. It is recommended that Council continue with the development of this online mapping taking on board the recommendations provided above.

5.3 RM3 – Local Flood Plan Updates to Accommodate Response Planning

Description: Update Penrith Local Flood Plan (LFP) to align with new SES LFP template and to incorporate the review findings documented in the Floodplain Risk Management Study

Priority: High

Estimated Cost: Approximately $40k when combined with FM10

Implementation Responsibility: SES

The *Penrith City Local Flood Plan* (NSW SES, 2012) (LFP) was reviewed and the outcomes of this review are summarised in the Floodplain Risk Management Study. This review identified areas of the LFP requiring revision, especially to Volume 2, which needs to be updated to include information from recently completed flood studies and floodplain risk management studies along with actual floods.

The LFP does not include any consideration of the Little Creek catchment or local overland flooding in the Penrith LGA, so it is currently not representing the full range of flood risks throughout the LGA.

Flood intelligence generated as part of the current study that could be incorporated into the LFP includes:

- Design flood extents, depths, velocities, hazard and warning times;
- Predicted building inundation in design floods up to PMF;
- Predicted road inundation in design floods up to PMF; and
- Evacuation constraints in design floods up to PMF.

It is recommended that SES will further consider the suggested updates to the LFP based upon the recommendations documented in this study as well as other recently adopted floodplain risk management plans for other catchments in the LGA.

5.4 RM4 and RM5 - Flood Emergency Response Plans

Description: Promote the preparation of Home and Business Emergency Flood Plans. Council and SES could assist preparation of the plans by "prefilling" some of the required information.

Priority: High

Estimated Cost: Home and business owners' time. Penrith City Council and SES time (Council and SES time input equates to approximately $10,000)

Implementation Responsibility: Individual home and business owners with assistance from SES and Council

It is unlikely that many residential, commercial or industrial properties within the flood prone areas have formal flood emergency response plans. Accordingly, the preparation of home and business flood plans is encouraged as a way of making the broader community more "flood aware" and allowing the community to be more proactive during future floods and less reliant on emergency services. The plan should set out protocols to follow by the household or business before, during and after a flood to help minimise damages and the potential for risk to life at the property level. The Flood Plans in this catchment should clearly highlight the roads vulnerable to flooding in the area (e.g., Great Western Highway, Hobart Street, Glossop Street) and the need to stay off flooded roads.

The SES has developed an online Home Emergency Plan website that can guide homeowners through the development of the plan:
http://www.seshomeemergencyplan.com.au/index.php

The SES has also developed a Business FloodSafe Toolkit to assist with the preparation of Business FloodSafe plans. These can be completed either online or as a hardcopy (see http://www.floodsafe.com.au/what-floodsafe-means-for-you/business).

A SES Business Breakfast could also be hosted to promote the development of Business FloodSafe Plans, with sufficient Council and SES staff present to help guide business owners through the process.

As the evacuation strategy for most properties will be very similar, the SES with assistance from Council, could potentially "pre-fill" much of the information necessary which will improve the chances of a successful implementation of this option across the catchment.

It is difficult to mandate the preparation of the flood plans in the first instance and then ensure flood plans are reviewed and updated. It is suggested that Penrith City Council could send out reminders (e.g., as part of rates letters) regularly (suggested every 2 years) to encourage existing owners and renters to prepare plans in the first instance and remind them to update the plans regularly. Regular notifications such as this would also assist in ensuring that plans are prepared if the property changes hands.

5.5 RM6 – Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas

Description: SES, with the assistance of Penrith City Council, to arrange targeted education activities to highlight nature and extent of flood risk. SES to consider setting up communication groups with high-risk sections of the community to assist in providing additional advice before and during a flood and promote more efficient evacuation processes.

Priority: High

Estimated Cost: Approximately $30,000 (within SES's and Penrith City Council's Operational Budget)

Implementation Responsibility: SES with assistance from Penrith City Council

A number of residential properties located between Adelaide Street and Hobart Street at St Marys are predicted to be exposed to at least H5 external hazard, or H4 hazard inside of buildings (or both) during the PMF. These properties are likely to be unsafe during a PMF and evacuation is considered to be the best risk reduction measure for these properties during large floods.

However, the large number of buildings potentially impacted by unacceptably high hazard during the PMF coupled with short warning times means that emergency services may be unable to assist residents with evacuation. Although, residents could "self-evacuate", this is not encouraged as attempting to evacuate too late may expose people to an even higher flood hazard than if they were to remain in their homes. Therefore, it is considered that the safest option is to continue to rely on the SES to facilitate safe evacuation from high risk areas.

However, due to the minimal warning times, residents in high risk areas will need to be ready to promptly act on an evacuation order issued by the SES. Therefore, it is important that residents in the high flood hazard areas are aware of their potential flood exposure and are ready to evacuate on short notice.

As outlined in Section 5.2, a starting point for improving people's readiness for floods is to help them better understand how they could be directly affected by floods. Although the general education strategies summarised in Section 5.1 are also relevant to this area, a more targeted education strategy is considered necessary to assist the community in better understanding the unique severity of flooding that could be experienced in the area during the PMF. This will likely require one-on-one interaction with households from SES (with potential support from Council staff) to present the available information, answer questions and assist in the preparation of flood emergency response plans.

A "meet the street" event (potentially in the area of open space on the southern side of the low point in Hobart Street) held by SES could also have value where the flood risk could be explained with the assistance of flood maps and animations produced as part of the current study. This may also assist in establishing a greater sense of community and begin "planting the seeds" for establishing communication groups across the higher risk sections of the catchment, to assist in promoting more coordinated evacuation efforts.

To assist in flood preparedness efforts, it is recommended that households in the high-risk area prepare emergency kits. The emergency kits include items that will be important during a flood should services be disrupted (e.g., torches, batteries) along with a list of essential items that will need to be included should evacuation be required (e.g., medications, drinking water, baby supplies). The emergency kit will assist in expediting evacuation efforts.

Given the limited amount of advanced warning time, it is recommended that the SES explore opportunities to establish a "communication group" for the local high-risk area (e.g., SMS, Facebook group, Viber or WhatsApp group). This would allow for rapid communication between the SES and households and would assist in promoting more efficient evacuation efforts.

There may also be benefits in exploring an automated alert system. Although a formal flood warning system is unlikely to be viable for the catchment, the installation of a sub-daily (i.e., "tipping bucket" type) rainfall gauge in the upper catchment may assist in providing additional guidance on when evacuation may be required. The gauge could be set up with a telemetry system with predefined rainfall triggers that could send an automated message (via the Facebook or WhatsApp groups discussed above), phone call and or text message to potentially vulnerable properties.

5.6 RM10 – Local Flood Plan Updates to Accommodate Recovery Planning

Description: Local Flood Plan to reflect additional flood recovery responsibilities for various agencies

Priority: High

Estimated Cost: Approximately $40k when combined with FM3

Implementation Responsibility: SES (although providers of essential facilities and services including Council, Sydney Water, DPIE would be called upon to assist with the post flood recovery efforts)

The *Penrith City Local Flood Plan* (NSW SES, 2012) (LFP) sets out the responsibilities of various agencies in post-flood recovery. Recovery, as outlined in the LFP, largely rests with the SES with assistance from other agencies, as required.

It is suggested that additional, specific items could be included in the LFP to further assist emergency services and the community to expedite post-flood recovery, including:

- Council and Sydney Water to ensure vital facilities such as water and sewer are restored and operational;
- Council to aid in removing waste and debris as part of clean-up activities;
- Appropriate agencies to ensure vital utilities such as communication, power and gas are restored and operational;
- Appropriate agencies to offer welfare assistance and counselling services; and
- Council (with potential support from DPIE) to record post-flood information to assist in future updates and calibration of flood models and flood studies.

5.7 Other Options

Some other options that were investigated yielded some notable emergency response improvements. However, they also produced adverse flood impacts across some properties. Therefore, they are not recommended for implementation in their current form but should be considered as part of any future road upgrades or in combination with other flood modification options. This includes:

- RM8 – Raising of Great Western Highway; and
- RM9 – Raising of Glossop Street.

Further details on each of the above options is provided in Floodplain Risk Management Study.

6 IMPLEMENTATION, MONITORING AND REVIEW

6.1 Implementation Plan

The recommended options have been prioritised according to how easily each option could be implemented and the anticipated benefits afforded by each option (i.e., options that are relatively straight forward to implement and have a significant benefit have been assigned a high priority).

However, it should be noted that the Plan and the suggested implementation priorities presented in this report can be considered draft in nature. Ultimately, implementation of the plan is the responsibility of Council and emergency services. These agencies will need to make decisions on how to coordinate and prioritise the various recommendations in the Plan. Factors that may influence the implementation and prioritisation of the recommendations may include:

- How effective the options are at reducing the flood risk.
- What resources are required to implement the option.
- What resources are available to implement the option.
- What constraints might need to be addressed to implement the option (and whether any constraints might prevent implementation all together)

A suggested implementation plan for the flood modification options, property modification options and response modification options is provided in **Table 8**, **Table 9** and **Table 10** respectively. The tables summarise the implementation priorities, responsibilities, and estimated costs.

6.2 Costs and Funding

The total capital cost to implement the Plan is expected to be about $3.9 million. In addition to the capital costs, some options will incur ongoing maintenance costs. As noted in **Table 8**, many of the options will require an investment in time from various agencies including Penrith City Council and the State Emergency Service in addition to monetary contributions.

Funding for implementation of the plan could be potentially obtained from the following sources:

- NSW State Government's Floodplain Management Grants (through DPIE)
- Penrith City Council's capital and operating budgets
- Section 7.11 (formally Section 94) contributions
- Commonwealth Government's Natural Disaster Resilience Program
- Volunteer labour from community groups

It is expected that most of the recommended options will be eligible for funding through the NSW State Government's Floodplain Management Grants on a 2:1 basis (State Government : Council). This can include additional investigations, design activities as well as construction.

However, funding under this program cannot be guaranteed as funding must be distributed to competing projects across the state. Furthermore, the NSW Government's Floodplain Management Grants are primarily available to manage risk to residential properties and are generally not awarded to manage the flood risk to commercial and industrial properties. It should also be noted that ongoing costs (e.g., maintenance) will generally be the responsibility of Council.

6.3 Review of Plan

It is important that the Floodplain Risk Management Plan is continually reviewed and updated over time to ensure that it evolves with the catchment and takes advantage of any improvements in flood knowledge, such as new flood studies, historic floods or information on climate change.

As a minimum, it is recommended that the Plan be revisited after 5 years.

Table 8 Implementation Plan for Flood Modification Options

Flood Modification Option		Description of Option	Required Actions	Cost Estimate	Implementation Responsibility	MCA Ranking	Priority
FM1	Great Western Highway Culvert Upgrade	Replace the existing triple 1.5 metre diameter culverts with three 1.5m wide by 1.8m high box culverts	1) Council to coordinate with Transport for NSW (TfNSW) to determine the wiliness to be part of the implementation of this option. 2) Any future FM1 investigations should include FM8 to ensure downstream properties are not adversely impacted.	$0.6 million	Penrith City Council and Transport for NSW	4	Low
FM2	Railway and Hobart Street Culvert Upgrade	Replace existing pipe, box & arch culverts between Hobart St and Plasser Cres with 2.7m wide x 2.1 m high box culvert	1) Council to initiate discussions with TfNSW to gain an understanding of their willingness to contribute to the implementation process and understand any constraints within railway land that may limit the feasibility of the option. 2) If the above discussions yield a positive outcome, survey of existing services should be collected. 3) A hydraulic assessment should be completed to determine the optimal drainage configuration between Hobart Street and Plasser Crescent (taking account of any constraints identified during stages 1 and 2).	$1 million	Penrith City Council and Sydney Trains	=3	Medium

Flood Modification Option		Description of Option	Required Actions	Cost Estimate	Implementation Responsibility	MCA Ranking	Priority
			4) Detailed concept design plans and cost estimates should be prepared for the preferred design option. A revised economic assessment should be completed to confirm the economic performance of the option. 5) Pending a successful economic outcome, detailed construction plans can be prepared, funding can be sought, and the option can be potentially implemented				
FM4	Canberra Street, Sydney Street and Brisbane Street Stormwater Upgrades	Provide new 1.2m dia stormwater pipes along Canberra Street, Sydney Street and Brisbane Street plus new stormwater inlets	1) Survey of existing services in the area of the new pipe alignment should be collected. 2) Concept design options should be explored taking account of the services information. This should be supported by a hydraulic assessment and the preparation of revised cost and flood damage estimates for each design option. 3) Detailed construction plans should then be prepared for the preferred concept design option. This should be supported by a detailed cost estimate so that funding for the option can be sought.	$1.3 million	Penrith City Council	=3	Medium

Flood Modification Option		Description of Option	Required Actions	Cost Estimate	Implementation Responsibility	MCA Ranking	Priority
FM8	Oxley Park Basin Augmentation	Provide additional storage volume in existing detention basins located between Great Western Highway and Oxley Park Public School	1) Council to initiate discussions with Oxley Park Public School to explain their flood exposure and to seek input into the option and the works that would need to be completed on school grounds. 2) If the above discussions yield a positive outcome, concept design options should be explored. This should aim to maximise the hydraulic benefits across the school and downstream properties while avoiding adverse flood impacts across private property. 3) Detailed construction plans should then be prepared for the preferred concept design option. This should be supported by a detailed cost estimate so that funding for the option can be sought.	$0.9 million	Penrith City Council	1	High

Table 9 Implementation Plan for Property Modification Options

Property Modification Option		Required Actions	Cost Estimate	Implementation Responsibility	Priority
PM1	Changes to LEP	1. Council planners to consolidate the LEP update recommendations from all recent floodplain risk management studies and plans (including this Plan) within the LGA 2. Council to prepare planning proposal and undertake various exhibition and review processes to prepare updated LEP	$20k	Penrith City Council	High
PM2	Changes to DCP	1. Council to consolidate the DCP recommendation contained in this Plan along with other recent floodplain risk management studies and plans within the LGA. 2. Council to prepare draft DCP and complete exhibition processes to prepare updated DCP	$40k	Penrith City Council	High
PM3	Update Section 10.7 Certificates	1. Council to update Section 10.7 certificates to reference the updated design flood information generated as part of the Floodplain Risk Management Study	$6k	Penrith City Council	High

Table 10 Implementation Plan for Response Modification Options

Response Modification Option		Required Actions	Cost Estimate	Implementation Responsibility	Priority
RM1	Community education strategy	1. SES to prepare Floodsafe documents for the local area to provide general flood education information (focussing on overland flooding). 2. SES to develop a range of messaging that can be disseminated to the community via media agencies (both print and online)	$20k up front and $5k bi-annually.	SES and Penrith City Council	High
RM2	Make property level flood information available	1. Council to consider arranging for future studies to provide flood mapping at a consistent scale and provide standard mapping outputs in a consistent colour scheme 2. Council to consider using their internal GIS resources to prepare a standardised set of maps based on the GIS outputs that have been produced as part of each study. 3. Council to collate the available spatial flood outputs that are generated as part of flood studies and floodplain risk management studies and incorporate information on an online mapping webpage to serve as a central repository for flood information.	$20k for required IT infrastructure. $30k for compiling required datasets and website interface.	Penrith City Council	High (mapping updates) & Medium (for online mapping portal)
RM3 & RM10	Local flood plan updates to accommodate response and recovery planning	1. SES to update LFP to include information from recently completed flood studies and floodplain risk management studies and actual floods. 2. SES consider include additional, specific items in the LFP to further assist emergency services and the community to expedite post-flood recovery.	$40k	Penrith City Council	High
RM4	Home flood plans	1. Council and SES could assist in “prefilling” some of the required information for the preparation	Residents and business owner’s	Individual home and business owners with	High

Response Modification Option		Required Actions	Cost Estimate	Implementation Responsibility	Priority
RM5	Business flood plans	of the Home and Business Emergency Flood Plans	time. Plus, approximately $10k for Council and SES time	assistance from SES and Penrith City Council	High
RM6	Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas	1. SES to conduct one-on-one interaction with households (with potential support from Council staff) to present the available flood information, answer questions and assist in the preparation of flood emergency response plans. 2. A "meet the street" event can be organised where the flood risk could be explained with the assistance of flood maps and animations produced as part of the current study. 3. SES is recommended to explore opportunities to establish a "communication group" for the local high-risk area to allow for rapid communication between the SES and households and assist in promoting more efficient evacuation efforts. 4. SES might be able to explore an automated alert system where a sub-daily rainfall gauge could be set up with a telemetry system with predefined rainfall triggers that could send an automated message, phone call and or text message to potentially vulnerable properties.	$30k	SES and Penrith City Council	Medium

7 REFERENCES

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8 GLOSSARY

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. Eg, if a peak flood discharge of 500 m^3/s has an AEP of 5%, it means that there is a 5% chance (that is 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.
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.
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).
effective warning time	The time available after receiving advice of an impending flood and before floodwaters prevent appropriate flood response actions being undertaken. The effective warning time is typically used to move farm equipment, move stock, raise furniture, evacuate people and transport 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, or local overland flooding associated with major drainage before entering a watercourse, or coastal inundation resulting from super-elevated sea levels or waves overtopping coastline defences excluding tsunami.
flood awareness	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 under the leadership of the SES.
flood planning area	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 (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.
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.
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. They are described below. 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. For a town protected by levees, the continuing flood risk is the consequences of the levees being overtopped. For an area without any floodplain risk management measures, the continuing flood risk is simply the existence of its flood exposure.
flood storage areas	those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood. The extent and behaviour of flood storage areas may change with flood severity, and loss of flood storage can increase the severity of flood impacts by reducing natural flood attenuation. Hence, it is necessary to investigate a range of flood sizes before defining flood storage areas.
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	provides reasonable certainty that the risk exposure selected in deciding on a particular flood chosen as the basis for the FPL is actually provided. It is a factor of safety typically used in relation to the setting of floor levels, levee crest levels, etc. Freeboard is included in the flood planning level.

hazard	a source of potential harm or a situation with a potential to cause loss. In relation to this study the hazard is flooding which has the potential to cause damage to the community. Definitions of high and low hazard categories are provided in Appendix L of the *Floodplain Development Manual* (*2005*).
historical flood	a flood which has actually occurred.
hydraulics	term given to 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 flood level at any particular location varies with time during a flood.
hydrology	term given to 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. 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; 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; or - major overland flowpaths through developed areas outside of defined drainage reserves; or - the potential to affect a number of buildings along the major flow path.
computer models	the mathematical representation of the physical processes involved in runoff generation and stream flow. These models are often run on computers due to the complexity of the mathematical relationships between runoff, stream flow and the distribution of flows across the floodplain.

minor, moderate and major flooding	Both the State Emergency Service and the Bureau of Meteorology 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 or evacuation of some houses. Main traffic routes may be covered. major flooding: Appreciable urban areas are flooded or extensive rural areas are flooded. Properties, villages and towns can be isolated.
peak discharge	the maximum discharge occurring during a flood event.
probable maximum flood (PMF)	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 possible 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 (PMP)	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 annual exceedance probability*).
risk	chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. In the context of the manual 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.
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.

sub-daily rainfall gauge	Also referred to as a "pluviometer" or "tipping bucket" gauge. Automated rainfall gauge that reports rainfall at small time increments
TUFLOW	is a 1-dimensional and 2-dimensional flood simulation software. It simulates the complex movement of floodwaters across a particular area of interest using mathematical approximations to derive information on floodwater depths, velocities and levels.
velocity	the speed or rate of motion (*distance per unit of time, e.g., metres per second*) in a specific direction at which the flood waters are moving.
water surface profile	a graph showing the flood stage at any given location along a watercourse at a particular time.
wind fetch	the horizontal distance in the direction of wind over which wind waves are generated.