

# **Little Creek Catchment Floodplain Risk Management Study and Plan**

**Final Summary Report**

**October 2021**



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The preparation of the Study and 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 Study and 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.

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## ▶▶ TABLE OF CONTENTS

Overview.....	1
The Existing Flooding Problem .....	2
The Potential Future Flood Risk .....	4
Options Considered for Better Managing the Flood Risk .....	4
Evaluation Outcomes for Flood Risk Management Options .....	5
Flood Modification Options.....	5
Property Modification Options .....	6
Response Modification Options.....	6
Floodplain Risk Management Plan.....	9
Glossary .....	16
APPENDIX A.....	22

## ▶▶ LIST OF FIGURES (APPENDIX A)

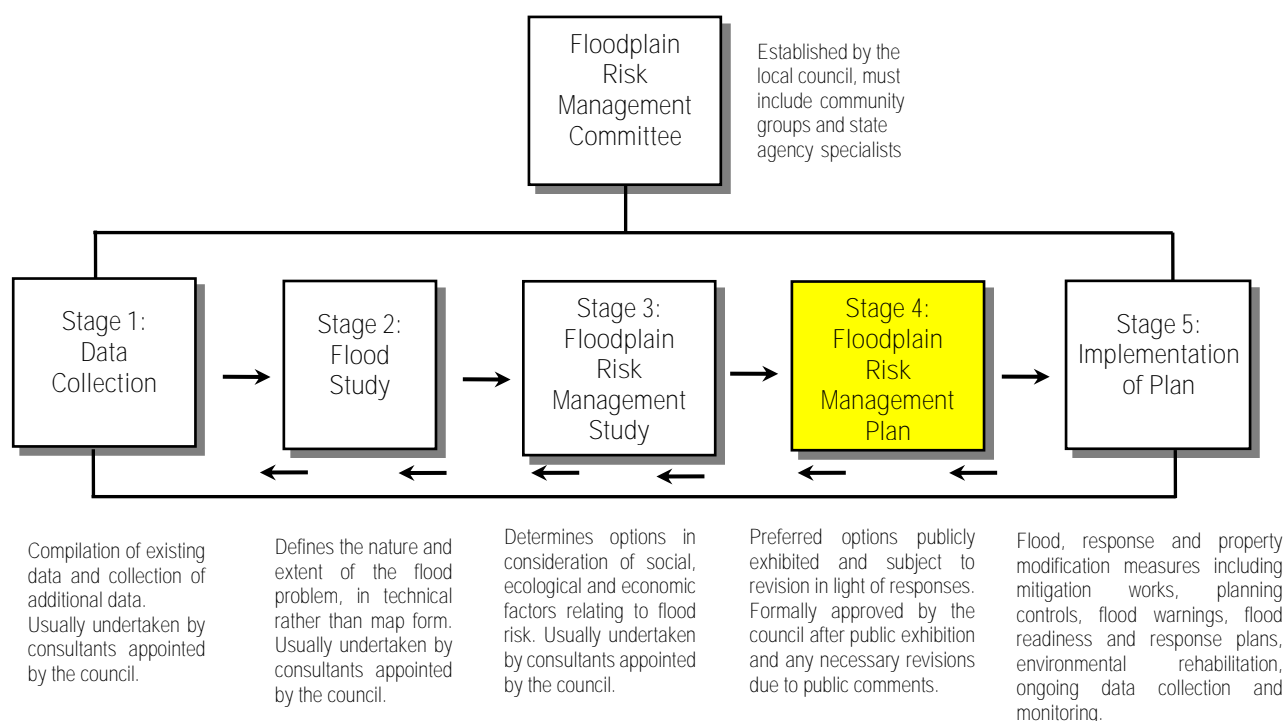
- Figure 1: Little Creek Catchment
- Figure 2: Peak Floodwater Levels for the 1% AEP Flood
- Figure 3: Peak Floodwater Levels for the PMF
- Figure 4: Flood Hazard for the 1% AEP Flood
- Figure 5: Flood Hazard for the PMF
- Figure 6: Flood Planning Area
- Figure 7: Floodplain Risk Management Plan for Little Creek Catchment

## Overview

The Little Creek catchment is located in the Penrith City Council Local Government Area and occupies a total area of 4.65 square kilometres (km<sup>2</sup>). The extent of the catchment is shown on **Figure 1** (enclosed in **Appendix A**) and includes parts of the suburbs of Oxley Park, Colyton, St Marys and North St Marys.

Flooding across the Little Creek catchment has been experienced on a number of occasions. Flooding can occur because of floodwater overtopping the banks of Little Creek or as a result of the capacity of the local stormwater system being exceeded leading to overland flooding.

In recognition of the flooding problems confronting residents and business owners in the Little Creek catchment, Penrith City Council commissioned Catchment Simulation Solutions to prepare a Floodplain Risk Management Study (referred to as the 'Study') and develop a Floodplain Risk Management Plan (referred to as the 'Plan') for the catchment. The Study and Plan form Stage 3 and Stage 4 respectively of the NSW Government's floodplain risk management process, which is outlined below.



As outlined above, the primary goals of the Study and Plan were:

- The Study quantified the nature and extent of the existing and potential future flooding problem and evaluated options that could be potentially implemented to better manage the flood risk.
- The Plan provides a consolidated and prioritised list of options that can be implemented by Penrith City Council and others to manage the flood risk. The list of recommended options in the Plan is based on the evaluation outcomes documented in the Study.

The following document provides a summary of the work that was completed as part of the Study and Plan including the recommended flood mitigation scheme for the Little Creek catchment.

## The Existing Flooding Problem

The nature and extent of the existing flooding problem was quantified using a computer flood model that extends across the full extent of the Little Creek catchment (refer **Figure 1**). The computer flood model was originally developed as part of the ‘*Little Creek Overland Flow Flood Study*’ (WMAwater, 2017). However, the model was updated as part of the current study to better reflect contemporary topographic and development conditions and to also apply the best practice hydrologic procedures detailed in ‘*Australian Rainfall and Runoff – A Guide to Flood Estimation*’ (Ball et al, 2019)

The updated computer model was used to simulate a range of design floods up to and including the Probable Maximum Flood (i.e., from small and frequent floods right up to the largest flood that could occur). A range of information was produced by the flood model to assist in defining the location of flooding ‘trouble spots’. This flood information included the mapping of the flood levels, flood depths, velocities, hazards and hydraulic categories and the definition of the flood planning area.

A copy of the flood level and flood hazard mapping that was produced by the computer flood model for the 1% Annual Exceedance Probability (AEP) (i.e. 100 Year ARI) flood and Probable Maximum Flood (PMF) are provided in **Figure 2** to **Figure 5** in **Appendix A**. The flood hazard mapping describes the potential impact that floodwaters will have on people, vehicles, buildings, and properties in the catchment. A detailed description of the flood hazard categories is provided in **Table 1**.

**Table 1** Description of Adopted Flood Hazard Categories (Geoscience Australia, 2019)

Hazard Category	Description
H1	Generally safe for vehicles, people and buildings. Relatively benign flood conditions.
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.

The Flood Planning Area map is also provided in **Figure 6**.

As shown in **Figure 2** to **Figure 5**, flooding across the catchment can be delineated into two main areas (i.e., upstream and downstream of the railway line). Flooding across the two areas can be characterised as follows:

- Upstream (i.e., south) of the railway line:
  - Flooding generally occurs because of the limited capacity of the underground stormwater drainage network. This results in surcharging flows along roadways and through private properties. There are no formal overland flow routes or easements and, as a result, most of the overland flows are conveyed through private property. Flooding can occur as a result of a variety of different storm durations. However, a storm duration of less than 60 minutes typically produces the worst-case flood conditions across most of the catchment (i.e., short duration rainfall bursts and thunderstorms).
  - Several properties are predicted to be inundated in floods as frequent as the 0.5EY (Events per Year) design flood event. However, more extensive inundation is generally restricted to events greater than the 20% AEP flood.
  - Hazardous flooding conditions are predicted through some areas of 'open space' during the 5% AEP (i.e. 5 Year ARI) flood event. However, the residential areas of the catchment are generally not exposed to hazard conditions that exceed H4 (as described in **Table 1**) during floods up to and including the 0.2% AEP (i.e. 500 Year ARI) flood. Nevertheless, a significant number of residential properties are predicted to be exposed to H5 and H6 (as described in **Table 1**) flooding during the Probable Maximum Flood (PMF) event. This includes a significant area contained between Brisbane Street and Hobart Street.
- Downstream (i.e., north) of the railway line:
  - Floodwaters are generally contained within the main channel or along roadways for all events up to and including the 0.5% AEP (i.e. 200 Year ARI) flood event. During the PMF event, water is predicted to overtop the railway line and spill out into a number of properties immediately downstream of the railway line.
  - Higher hazard areas are typically contained within the creek channel and roadways for events up to and including the 0.5 % AEP event. During the PMF event, the industrial properties immediately downstream of the railway line are exposed to more hazardous flooding conditions (i.e., H4 and H5 hazard).

The results of the flood modelling also demonstrated that:

- During a 1% AEP flood, eighty-three (83) residential properties are predicted to suffer 'external' flood damage (i.e., damage to fences, sheds, garage contents), 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.
- A flood damage assessment was also undertaken to estimate the flood damage costs in the catchment for existing conditions and across the full range of design floods for residential, commercial, and industrial properties. The flood damage assessment estimated a bill of approximately \$3.5 million across the Little Creek catchment should a

1% AEP flood occur. The average annual damage (AAD) for the catchment is predicted to be \$292,000 per annum. Accordingly, if the 'status quo' was maintained and no flood management measures are implemented, 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).

## The Potential Future Flood Risk

Future development across the catchment as well as climate change induced rainfall increases have the potential to further increase the existing flood risk across the Little Creek catchment. More specifically:

- The additional runoff from future development across the catchment has the potential to increase existing 1% AEP flood levels by around 0.05 metres along the main creek line downstream of the railway line as well as the main overland flow path upstream of the railway line. On Hobart Street, flood levels are predicted to increase by more than 0.1 metres.
- A 9% increase in rainfall scenario of climate change is predicted to increase 1% AEP flood levels by between 0.05 to 0.10 metres along Little Creek.
- A 23% increase in rainfall scenario of climate change 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, existing 1% AEP flood levels in Hobart Street are predicted to increase by 0.5 metres.

## Options Considered for Better Managing the Flood Risk

The outcomes of the existing flood risk assessment were used to identify where flood risk management measures should be targeted to manage the flood risk in the Little Creek catchment. This information was used to develop an initial list of flood risk management options. This included:

- **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. A total of twenty-nine (29) flood modification options were initially identified as part of the Study.
- **Property Modification Options**: refers to modifications to planning controls or modifications to individual properties to reduce the potential for inundation in the first instance or improve the resilience of properties should inundation occur. A total of five (5) property modification options were identified as part of the Study.
- **Response Modification Options**: are measures that can be implemented to change the way in which emergency services as well as the public respond before, during and after a flood. A total of ten (10) response modifications were identified as part of the Study.

Each of the options that were identified were evaluated in further detail to determine the feasibility of each option and which options would progress into the Plan. Further details on the evaluation outcomes are summarised below.

## Evaluation Outcomes for Flood Risk Management Options

### Flood Modification Options

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 twenty-nine (29) 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 2** and are denoted FM1 to FM10. Reference is made to Chapter 8 of the Floodplain Risk Management Study for a comprehensive description of the measures.

The 'shortlist' of flood modification options identified in **Table 2** were assessed in detail as part of the Study to determine which would be feasible and move forward for inclusion in the Plan. Each flood modification 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 different 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 2**). 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 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 used to inform a multi criteria assessment (MCA). The MCA assigns an overall 'score' to each option that reflects the full range of evaluation criteria (including tangible and intangible evaluation criteria). The score reflects how well each option performs relative to other options allowing the options to be ranked, which provides valuable insight into implementation priorities as part of the Floodplain Risk Management Plan. The MCA ranking is also provided in **Table 2**.

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.

### Property Modification Options

A total of five (5) planning and property modification options were identified for evaluation as part of the Study and are summarised in **Table 3** and are denoted PM1 to PM5. Reference is made to Chapter 9 of the Floodplain Risk Management Study for a comprehensive description of the measures.

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

- PM1 – Updates to LEP.
- PM2 – Updates to DCP.
- PM3 – Updates to Section 10.7 certificates.

### Response Modification Options

A total of ten (10) response modifications were identified as part of the Study and are summarised in **Table 4** and are denoted RM1 to RM10. Reference is made to Chapter 10 of the Floodplain Risk Management Study for a comprehensive description of the measures.

Based on the outcomes of the evaluation of each response modification option, the following options were selected for inclusion in the Plan:

- RM1 – Community education activities.
- RM2 – Make property level flood information available.
- RM3 and RM10 – Local flood plan updates.
- RM4 - Preparation of residential flood plans
- RM5 - Preparation of business flood plans
- RM6 - Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas

Table 2 Flood Modification Options Assessed in Detail as Part of the Study

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 diameter 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

Table 3 Property Modification Options Assessed as part of the Study

Option ID	Property Modification Option	Description of Option
PM1	Updates to Local Environmental Plan (LEP)	Update Council LEP to reflect the detailed review of the LEP completed as part of the Study. This includes modification of the 'planning flood' in the Flood Planning Level definition from the 1% AEP to 0.5% AEP, to better manage the high flood risk area contained between Brisbane Street and Hobart Street.
PM2	Updates to Development Control Plan (DCP)	Update Council DCP to reflect the detailed review completed as part of the Study.
PM3	Updates to Section 10.7 certificates	Update Council Section 10.7 certificates to include updated flood prone land information generated as part of the current study.
PM4	Voluntary purchase of select properties	Voluntary purchase of select properties in high hazard, floodway areas as per eligibility requirements in NSW Government Guidelines.
PM5	Voluntary House raising of select properties	Voluntary house raising of select properties as per eligibility requirements in NSW Government Guidelines.

Table 4 Response Modification Options Assessed as part of the Study

Option ID	Response Modification Option	Description of Option
RM1	Community education activities	Various community education activities to increase flood awareness and allow residents to be more self-sufficient during future floods.
RM2	Make property level flood information available	Increase the availability and access to the most contemporary property level flood information for all residents and businesses within the LGA to increase flood awareness. An online platform will make this information available in an accessible and consistent framework across all sections of the LGA.
RM3	Local flood plan updates	Update Penrith Local Flood Plan 2017 to take advantage of updated flood information generated as part of the current study.
RM4	Preparation of residential flood plans	Preparation of flood plans by residential property occupiers to identify actions to be taken BEFORE, during and after a flood.
RM5	Preparation of business flood plans	Preparation of flood plans by business owners to identify actions to be taken before, during and after a flood.
RM6	Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas	Develop a strategy to educate the community and establish evacuation protocols for areas exposed to H5 and H6 hazard in the PMF (i.e., Adelaide Street to Hobart Street area).
RM7	Flash flood warning system	Development of a flood warning system (and associated recommendations for supporting infrastructure, such as rain gauges) for the catchment to provide additional evacuation time.

Option ID	Response Modification Option	Description of Option
RM8	Great Western Highway upgrade	Upgrade to Great Western Highway (between Bennet Road and Day Street) to improve level of service.
RM9	Glossop Street upgrade	Upgrade to Glossop Street to improve level of service.
RM10	Local Flood Plan Updated to Accommodate Recovery Planning	Update Penrith Local Flood Plan 2017 to include additional, specific items to further assist emergency services and the community to expedite post-flood recovery.

## Floodplain Risk Management Plan

Based upon the outcomes of the detailed evaluation, the management options outlined in **Table 5**, **Table 6** and **Table 7** are recommended for further investigation and for implementation as part of the Floodplain Risk Management Plan for the Little Creek catchment. The recommended set of management options are also shown on **Figure 4**.

The recommended management options have been prioritised based on a range of criteria including the anticipated benefits afforded by each option (i.e., how effective the option is in reducing existing flood levels and above floor flooding), how easily each option could be implemented, the implementation cost, emergency response benefits as well as the potential social and environmental impacts. The implementation priorities are list in **Table 5**, **Table 6** and **Table 7**.

**Table 5**, **Table 6** and **Table 7** also provide cost estimates for each option, who will be responsible for implementing the option and what other investigations and actions will be required to work towards implementation of each option.

If each of the flood modification options listed in **Table 5** 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.

It is also recommended to consider the property and the response modification measures listed in **Table 6** and **Table 7** to manage the future flood problem in the Little Creek catchment. Implementation of the property and the response modification measures would largely draw upon Penrith City Council and SES available resources.

Table 5 Recommended 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	<ol style="list-style-type: none"> <li>1) Council to coordinate with Transport for NSW (TfNSW) to determine the willingness to be part of the implementation of this option.</li> <li>2) Any future FM1 investigations should include FM8 to ensure downstream properties are not adversely impacted.</li> </ol>	\$0.6 million	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	<ol style="list-style-type: none"> <li>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.</li> <li>2) If the above discussions yield a positive outcome, survey of existing services should be collected.</li> <li>3) A hydraulic assessment should be completed to determine the optimal drainage configuration between Hobart Street and Plasser Crescent (taking into account any constraints identified during stages 1 and 2).</li> </ol>	\$1 million	Council and Sydney Trains	=3	Medium

Flood Modification Option		Description of Option	Required Actions	Cost Estimate	Implementation Responsibility	MCA Ranking	Priority
			<ul style="list-style-type: none"> <li>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.</li> <li>5) Pending a successful economic outcome, detailed construction plans can be prepared, funding can be sought, and the option can be potentially implemented</li> </ul>				
FM4	Canberra Street, Sydney Street and Brisbane Street Stormwater Upgrades	Provide new 1.2m diameter stormwater pipes along Canberra Street, Sydney Street and Brisbane Street plus new stormwater inlets	<ul style="list-style-type: none"> <li>1) Survey of existing services in the area of the new pipe alignment should be collected.</li> <li>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.</li> <li>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.</li> </ul>	\$1.3 million	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	<ol style="list-style-type: none"> <li>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.</li> <li>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.</li> <li>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.</li> </ol>	\$0.9 million	Council	1	High

Table 6 Recommended Property Modification Options

Property Modification Option		Description of Option	Required Actions	Cost Estimate	Implementation Responsibility	Priority
PM1	Changes to LEP	Update Council LEP to reflect the detailed review of the LEP completed as part of the Study. This includes modification of the 'planning flood' in the Flood Planning Level definition from the 1% AEP to 0.5% AEP to better manage the high flood risk area contained between Brisbane Street and Hobart Street.	<ol style="list-style-type: none"> <li>1. Council planners to consolidate the LEP update recommendations from all recent floodplain risk management studies and plans (including this Plan) within the LGA</li> <li>2. Council to prepare planning proposal and undertake various exhibition and review processes to prepare updated LEP</li> </ol>	\$20k	Council	High
PM2	Changes to DCP	Update Council DCP to reflect the detailed review completed as part of the Study.	<ol style="list-style-type: none"> <li>1. Council to consolidate the DCP recommendations contained in this Plan along with other recent floodplain risk management studies and plans within the LGA.</li> <li>2. Council to prepare draft DCP and complete exhibition processes to prepare updated DCP</li> </ol>	\$40k	Council	High
PM3	Update Section 10.7 Certificates	Update Council Section 10.7 certificates to include updated flood prone land information generated as part of the current study.	<ol style="list-style-type: none"> <li>1. Council to update Section 10.7 certificates to reference the updated design flood information generated as part of the Floodplain Risk Management Study</li> </ol>	\$6k	Council	High



Table 7 Recommended Response Modification Options

Response Modification Option		Required Actions	Cost Estimate	Implementation Responsibility	Priority
RM1	Community education strategy	<ol style="list-style-type: none"> <li>1. SES to prepare FloodSafe documents for the local area to provide general flood education information (focussing on overland flooding).</li> <li>2. SES to develop a range of messaging that can be disseminated to the community via media agencies (both print and online)</li> </ol>	\$20k up front and \$5k bi-annually.	SES and Council	High
RM2	Make property level flood information available	<ol style="list-style-type: none"> <li>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.</li> <li>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.</li> <li>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.</li> </ol>	\$20k for required IT infrastructure. \$30k for compiling required datasets and website interface.	Council	High (mapping updates) & Medium (for online mapping portal)
RM3 & RM10	Local flood plan updates to accommodate response and recovery planning	<ol style="list-style-type: none"> <li>1. SES to update LFP (Local Flood Plan) to include information from recently completed flood studies, floodplain risk management studies and actual floods.</li> <li>2. SES consider include additional, specific items in the LFP to further assist emergency services and the community to expedite post-flood recovery.</li> </ol>	\$40k	SES	High
RM4	Home flood plans	<ol style="list-style-type: none"> <li>1. Council and SES could assist in 'prefilling' some of the required information for the preparation</li> </ol>	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 Council	High
RM6	Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas	<ol style="list-style-type: none"> <li>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.</li> <li>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.</li> <li>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.</li> <li>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.</li> </ol>	\$30k	SES and Council	Medium

## Glossary

<b>annual exceedance probability (AEP)</b>	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 <sup>3</sup> /s has an AEP of 5%, it means that there is a 5% chance (that is one-in-20 chance) of a 500 m <sup>3</sup> /s or larger events occurring in any one year (see ARI).
<b>Australian Height Datum (AHD)</b>	a common national surface level datum approximately corresponding to mean sea level.
<b>average annual damage (AAD)</b>	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.
<b>average recurrence interval (ARI)</b>	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.
<b>catchment</b>	the land area draining through the mainstream, as well as tributary streams, to a particular site. It always relates to an area above a specific location.
<b>disaster plan (DISPLAN)</b>	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.
<b>discharge</b>	the rate of flow of water measured in terms of volume per unit time, for example, cubic metres per second (m <sup>3</sup> /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).
<b>effective warning time</b>	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.
<b>emergency management</b>	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.

<b>flash flooding</b>	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.
<b>flood</b>	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.
<b>flood awareness</b>	Awareness is an appreciation of the likely effects of flooding and a knowledge of the relevant flood warning, response and evacuation procedures.
<b>flood education</b>	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.
<b>flood fringe areas</b>	the remaining area of flood prone land after floodway and flood storage areas have been defined.
<b>flood liable land</b>	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).
<b>flood mitigation standard</b>	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.
<b>floodplain</b>	area of land which is subject to inundation by floods up to and including the probable maximum flood event, that is, flood prone land.
<b>floodplain risk management options</b>	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.
<b>floodplain risk management plan</b>	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.
<b>flood plan (local)</b>	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.

<b>flood planning area</b>	the area of land below the FPL and thus subject to flood related development controls.
<b>flood planning levels (FPLs)</b>	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.
<b>flood proofing</b>	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.
<b>flood prone land</b>	land susceptible to flooding by the PMF event. Flood prone land is synonymous with flood liable land.
<b>flood readiness</b>	Readiness is an ability to react within the effective warning time.
<b>flood risk</b>	<p>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.</p> <p><u>existing flood risk</u>: the risk a community is exposed to as a result of its location on the floodplain.</p> <p><u>future flood risk</u>: the risk a community may be exposed to as a result of new development on the floodplain.</p> <p><u>continuing flood risk</u>: 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.</p>
<b>flood storage areas</b>	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.
<b>floodway areas</b>	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.

<b>freeboard</b>	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.
<b>hazard</b>	<p>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.</p> <p>Definitions of high and low hazard categories are provided in Appendix L of the <i>Floodplain Development Manual (2005)</i>.</p>
<b>historical flood</b>	a flood which has actually occurred.
<b>hydraulics</b>	term given to the study of water flow in waterways; in particular, the evaluation of flow parameters such as water level and velocity.
<b>hydrograph</b>	a graph which shows how the discharge or flood level at any particular location varies with time during a flood.
<b>hydrology</b>	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.
<b>local overland flooding</b>	inundation by local runoff rather than overbank discharge from a stream, river, estuary, lake or dam.
<b>local drainage</b>	smaller scale problems in urban areas. They are outside the definition of major drainage in this glossary.
<b>mainstream flooding</b>	inundation of normally dry land occurring when water overflows the natural or artificial banks of a stream, river, estuary, lake or dam.
<b>major drainage</b>	<p>councils have discretion in determining whether urban drainage problems are associated with major or local drainage. Major drainage involves:</p> <ul style="list-style-type: none"><li>• 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</li><li>• 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</li><li>• major overland flowpaths through developed areas outside of defined drainage reserves; or</li></ul>

- 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*).

<b>risk</b>	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.
<b>runoff</b>	the amount of rainfall which actually ends up as streamflow, also known as rainfall excess.
<b>stage</b>	equivalent to water level (both measured with reference to a specified datum).
<b>stage hydrograph</b>	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.
<b>sub-daily rainfall gauge</b>	Also referred to as a 'pluviometer' or 'tipping bucket' gauge. Automated rainfall gauge that reports rainfall at small time increments
<b>TUFLOW</b>	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.
<b>velocity</b>	the speed or rate of motion ( <i>distance per unit of time, e.g., metres per second</i> ) in a specific direction at which the flood waters are moving.
<b>water surface profile</b>	a graph showing the flood stage at any given location along a watercourse at a particular time.
<b>wind fetch</b>	the horizontal distance in the direction of wind over which wind waves are generated.

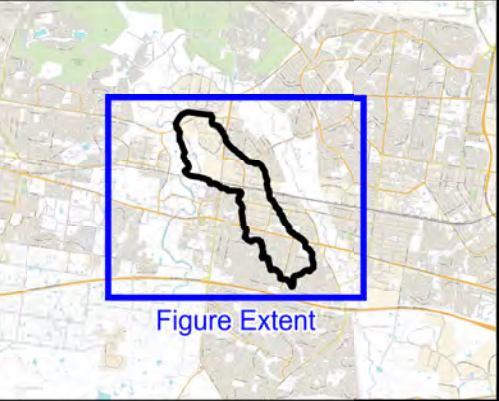
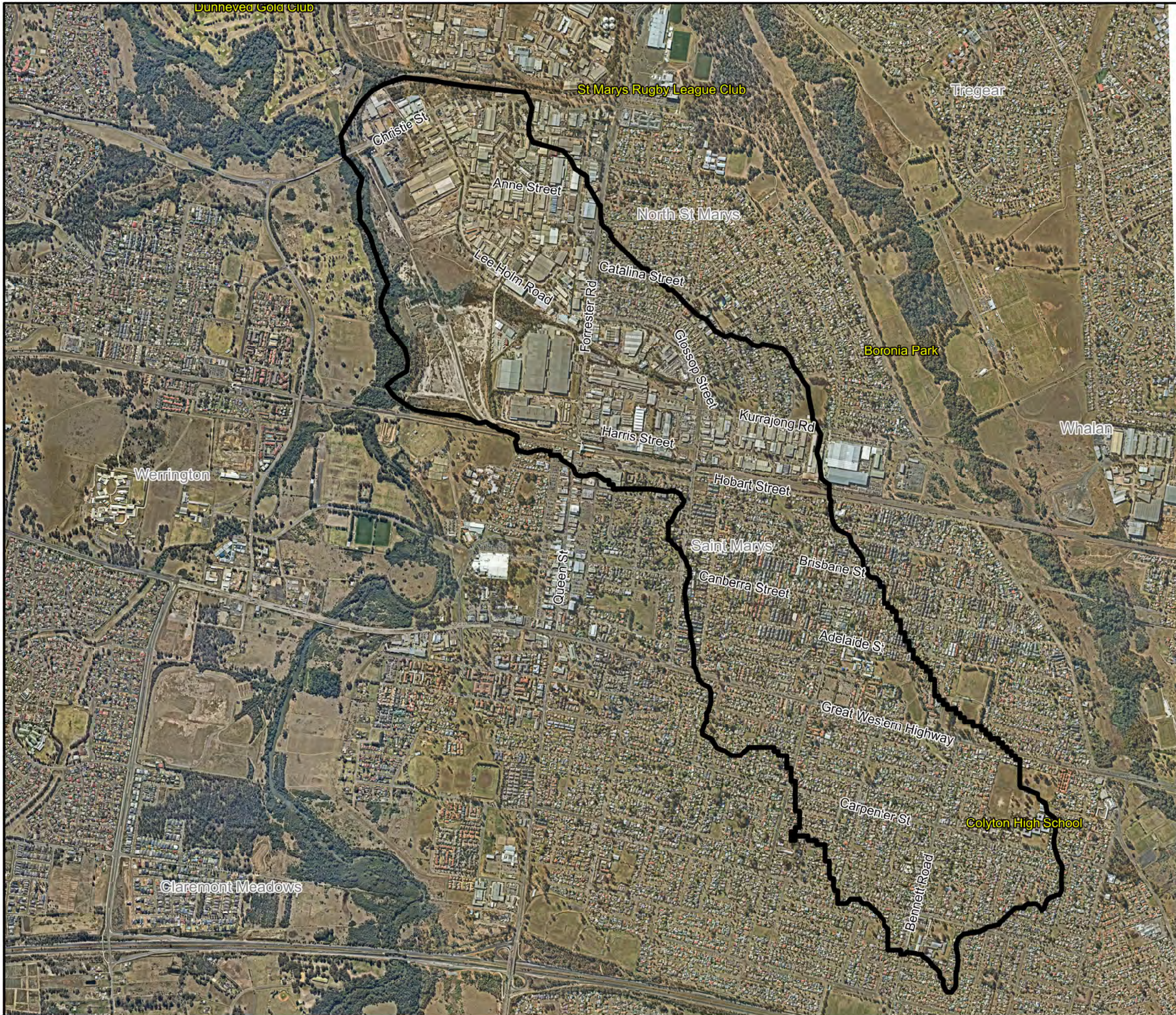


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# APPENDIX A

## FIGURES

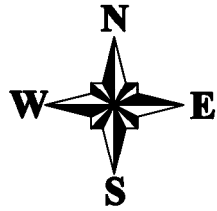
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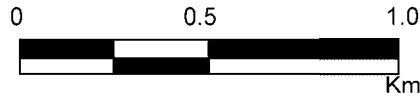
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 Catchment Boundary

Notes:

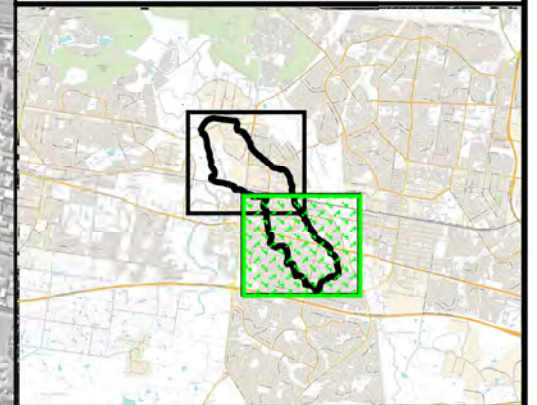


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**Figure 1:  
Little Creek  
Catchment**

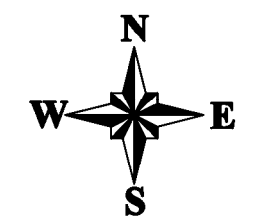
**Little Creek Catchment Flood Risk Management Study and Plan**



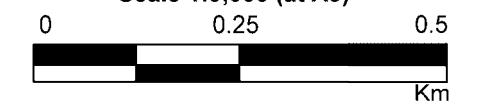
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	Peak Flood Level Contour
Peak Flood Level (mAHD)	
	25
	30
	35
	40
	45
	50
	55

Notes:

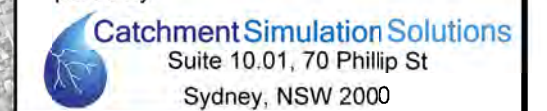


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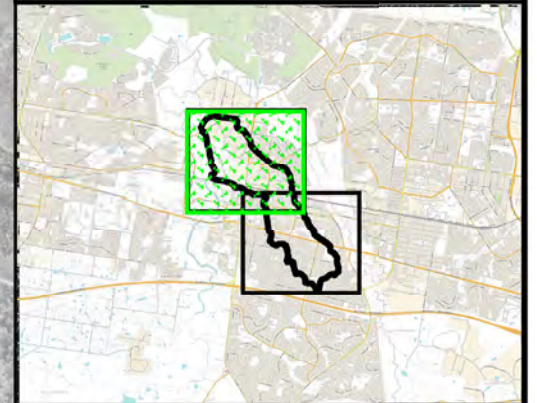
**Figure 2.1**  
**Peak Floodwater Levels for the 1%AEP Flood**

Prepared By:











File Name: Figure 2 Peak Floodwater Levels for the 1%AEP Flood.wor

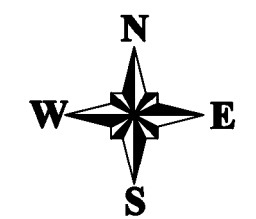




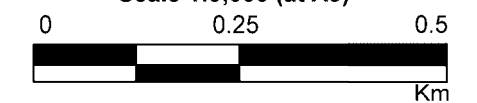
**LEGEND**

	Peak Flood Level Contour		
Peak Flood Level (mAHD)			
	25		45
	30		50
	35		55
	40		

Notes:




Scale 1:9,000 (at A3)



**Figure 2.2**  
**Peak Floodwater Levels for the 1%AEP Flood**

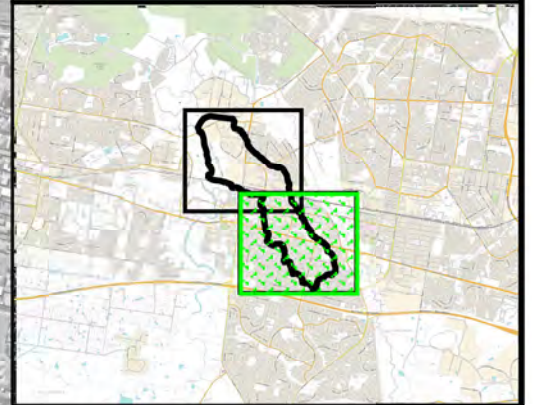
Prepared By:

 **Catchment Simulation Solutions**  
Suite 10.01, 70 Phillip St  
Sydney, NSW 2000









File Name: Figure 2 Peak Floodwater Levels for the 1%AEP Flood.wor



**Little Creek Catchment Floodplain Risk Management Study and Plan**



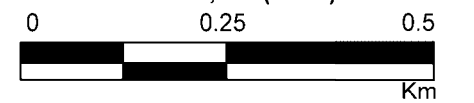
**LEGEND**

	Peak Flood Level Contour
Peak Flood Level (mAHD)	
	25
	30
	35
	40
	45
	50
	55

Notes:

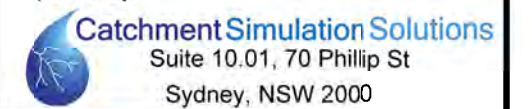


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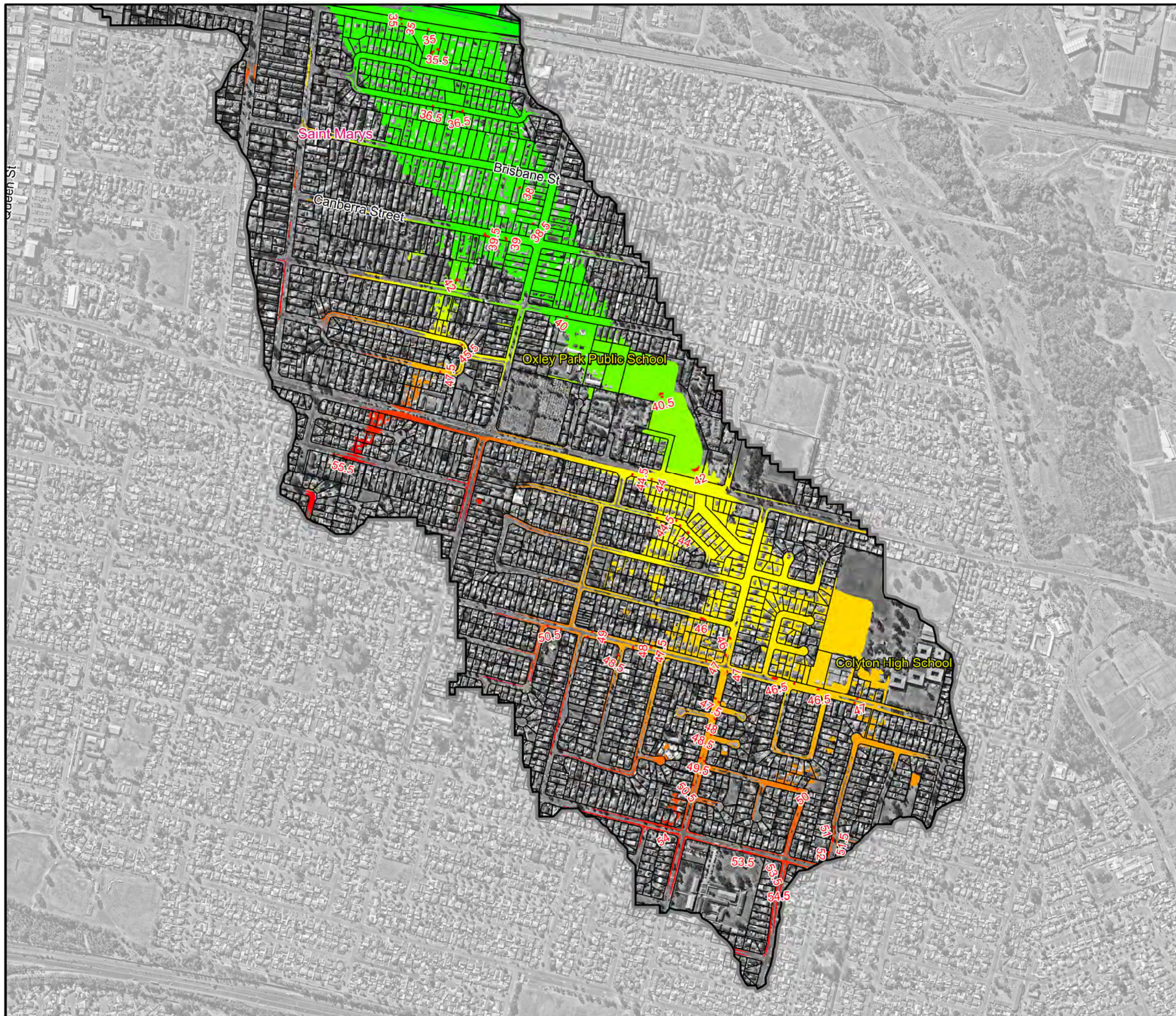


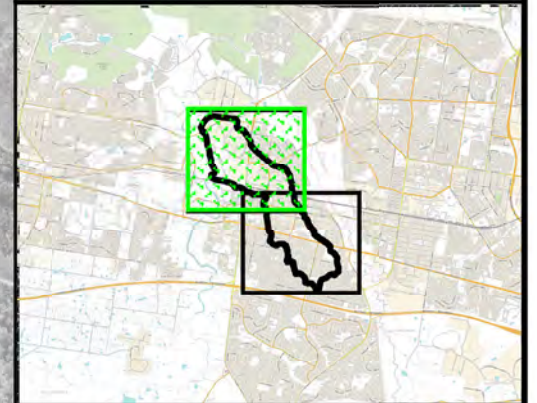
**Figure 3.1**  
**Peak Floodwater Levels for the PMF**

Prepared By:











File Name: Figure 3 Peak Floodwater Levels for the PMF.wor

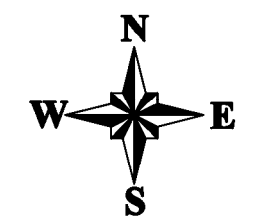




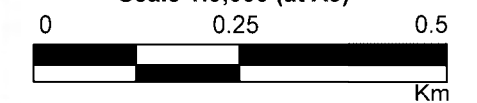
**LEGEND**

	Peak Flood Level Contour		
Peak Flood Level (mAHD)			
	25		45
	30		50
	35		55
	40		

Notes:

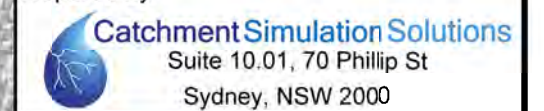


Scale 1:9,000 (at A3)



**Figure 3.2**  
**Peak Floodwater Levels for the PMF**

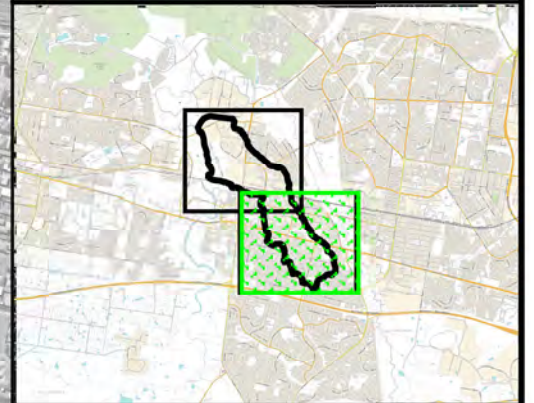
Prepared By:



File Name: Figure 3 Peak Floodwater Levels for the PMF.wor



**Little Creek Catchment Flood Risk Management Study and Plan**



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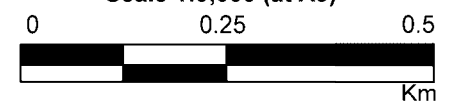
Hazard Categories

- 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:

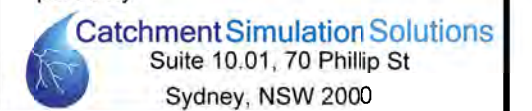


Scale 1:9,000 (at A3)



**Figure 4.1**  
**Flood Hazard for the 1% AEP Flood**

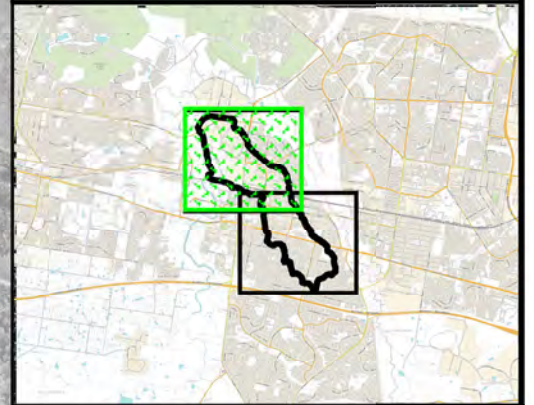
Prepared By:



File Name: Figure 4 Flood Hazard for the 1% AEP Flood.wor



**Little Creek Catchment Flood Risk Management Study and Plan**



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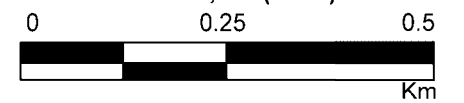
Hazard Categories

- 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:




Scale 1:9,000 (at A3)



**Figure 4.2**  
**Flood Hazard for the 1% AEP Flood**

Prepared By:

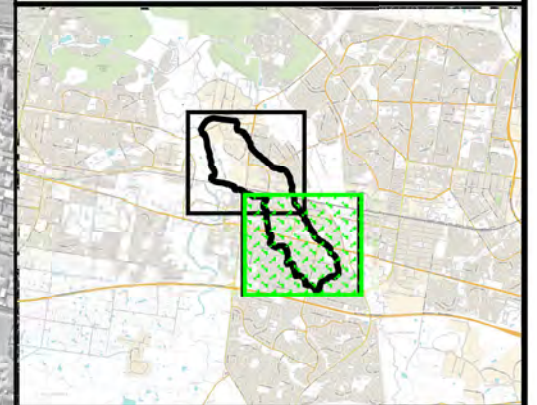
 **Catchment Simulation Solutions**  
Suite 10.01, 70 Phillip St  
Sydney, NSW 2000

File Name: Figure 4 Flood Hazard for the 1% AEP Flood.wor





**Little Creek Catchment Floodplain Risk Management Study and Plan**

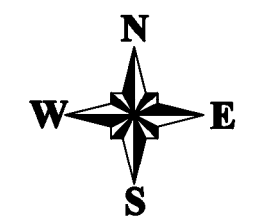


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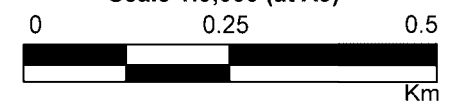
Hazard Categories

- 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:




Scale 1:9,000 (at A3)

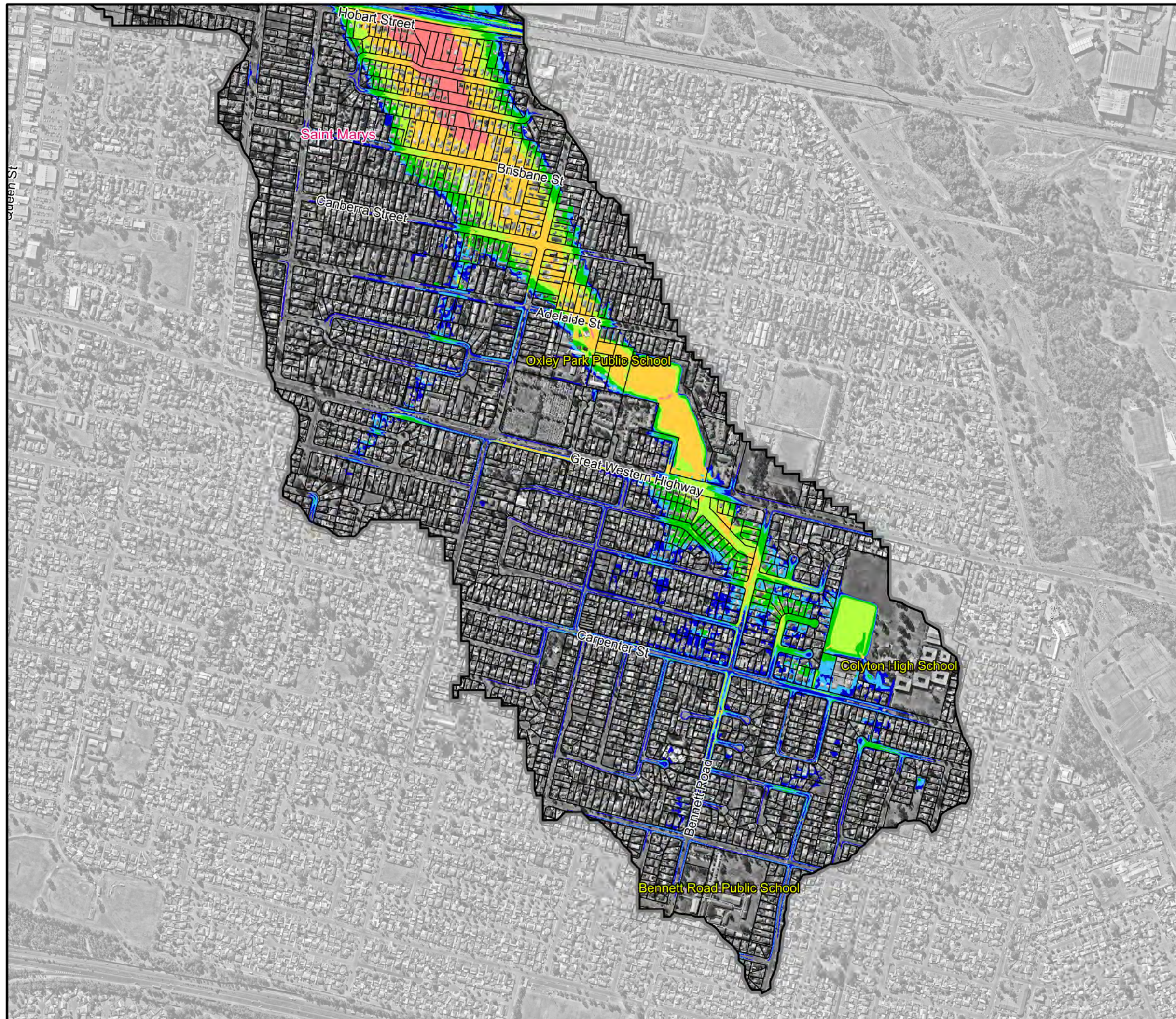


**Figure 5.1**  
**Flood Hazard for the PMF**

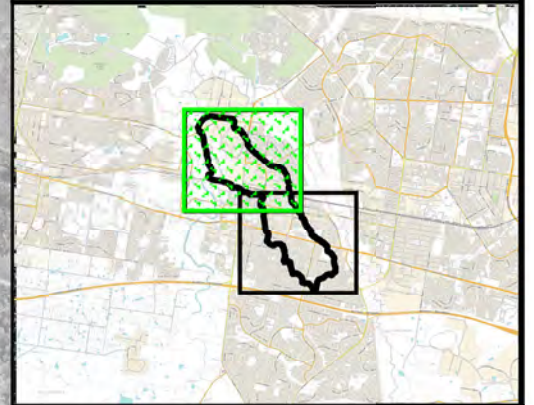
Prepared By:

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File Name: Figure 5 Flood Hazard for the PMF.wor



**Little Creek Catchment Floodplain Risk Management Study and Plan**



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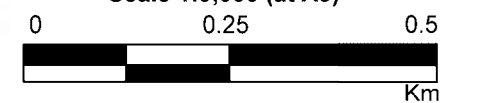
Hazard Categories

- 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:




Scale 1:9,000 (at A3)



**Figure 5.2**  
**Flood Hazard for the PMF**

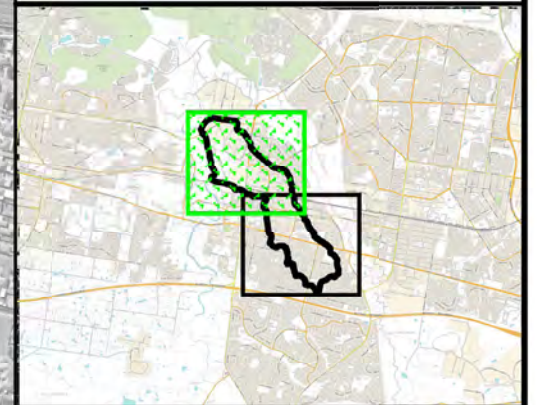
Prepared By:

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File Name: Figure 5 Flood Hazard for the PMF.wor



**Little Creek Catchment Flood Risk Management Study and Plan**



**LEGEND**

-  Study Area
-  Existing FPA #
-  Recommended FPA \*

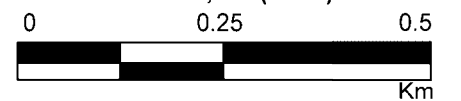
Notes:

# Existing FPA is based on the 1% AEP flood + 0.5m freeboard.

\* Recommended FPA is based on the 1% AEP flood (or 0.5% AEP flood in Brisbane St to Hobart St area + 0.5m freeboard or properties exposed to H4 internal hazard during the PMF.




Scale 1:9,000 (at A3)

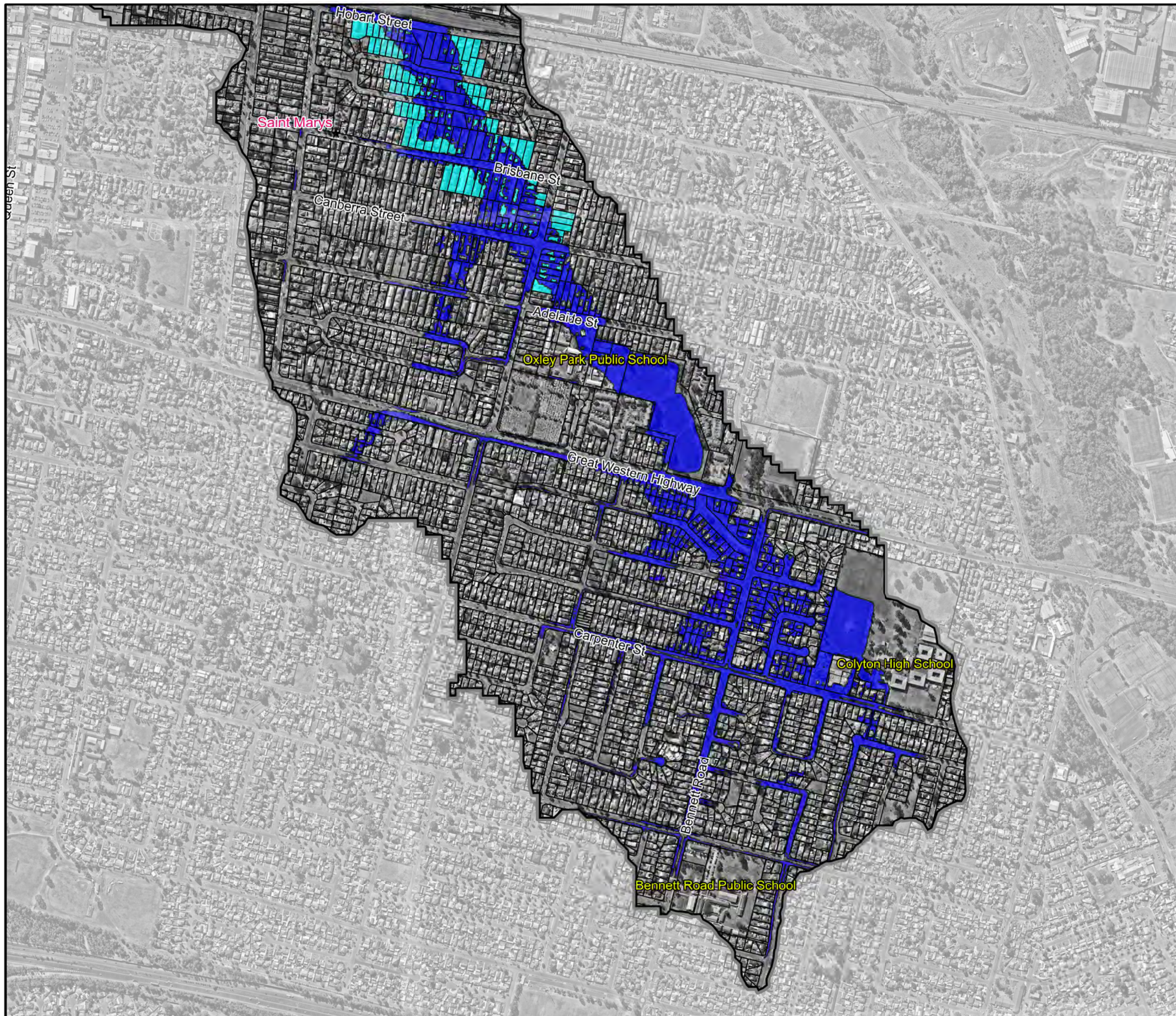


**Figure 6.1**  
**Flood Planning Area**

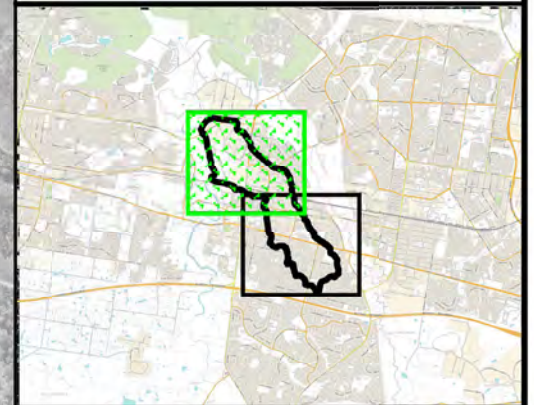
Prepared By:

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Sydney, NSW 2000




File Name: Figure 6 Flood Planning Area



**Little Creek Catchment Flood Risk Management Study and Plan**



**LEGEND**

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-  Existing FPA #
-  Recommended FPA \*

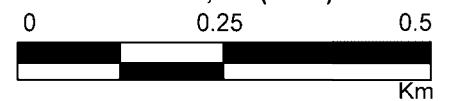
**Notes:**

# Existing FPA is based on the 1% AEP flood + 0.5m freeboard.

\* Recommended FPA is based on the 1% AEP flood (or 0.5% AEP flood in Brisbane St to Hobart St area + 0.5m freeboard or properties exposed to H4 internal hazard during the PMF.



Scale 1:9,000 (at A3)

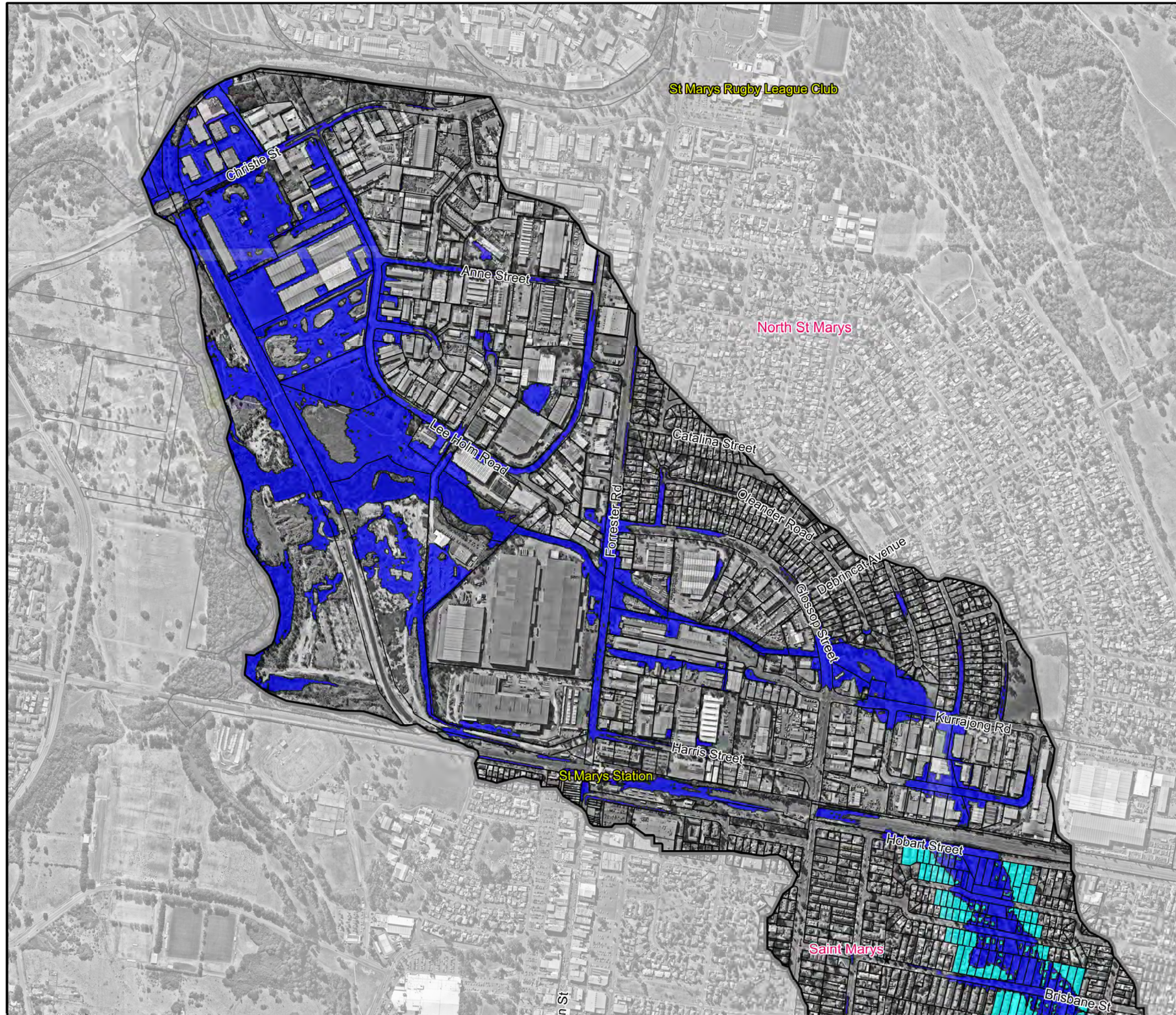


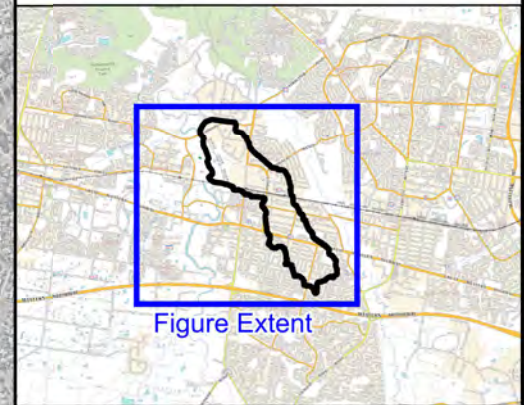
**Figure 6.2**  
**Flood Planning Area**

Prepared By:




 **Catchment Simulation Solutions**  
Suite 10.01, 70 Phillip St  
Sydney, NSW 2000

File Name: Figure 6 Flood Planning Area

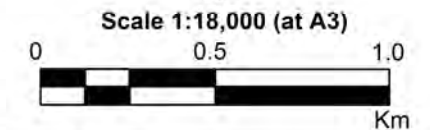




**LEGEND**

-  Study Area
-  1% AEP Flood Extent
-  PMF Extent

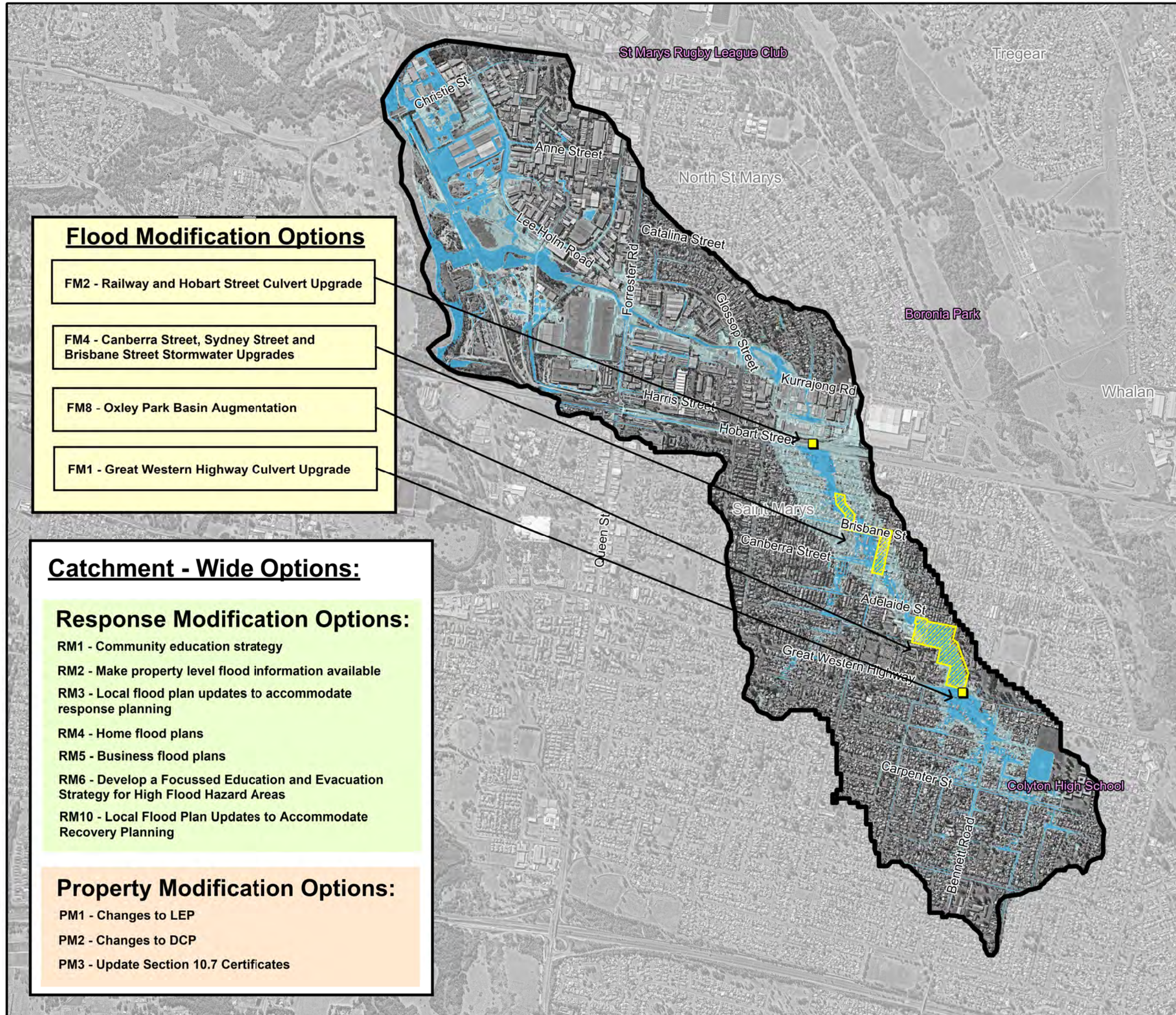
Notes:  
Please refer to the Little Creek Floodplain Risk Management Plan report for further information on each flood risk mitigation measure.



**Flood Mitigation Options**

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File Name: Flood Mitigation Options.wor



**Flood Modification Options**

FM2 - Railway and Hobart Street Culvert Upgrade

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

FM8 - Oxley Park Basin Augmentation

FM1 - Great Western Highway Culvert Upgrade

**Catchment - Wide Options:**

**Response Modification Options:**

- RM1 - Community education strategy
- RM2 - Make property level flood information available
- RM3 - Local flood plan updates to accommodate response planning
- RM4 - Home flood plans
- RM5 - Business flood plans
- RM6 - Develop a Focussed Education and Evacuation Strategy for High Flood Hazard Areas
- RM10 - Local Flood Plan Updates to Accommodate Recovery Planning

**Property Modification Options:**

- PM1 - Changes to LEP
- PM2 - Changes to DCP
- PM3 - Update Section 10.7 Certificates