Final FRMS&P Report

5B6BWhites Creek and Johnstons Creek Flood Risk Management Study and Plan

304600164

Prepared for

Inner West Council

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R001	21/05/2021	Stage 1 Draft Report	MG	SC
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R005	9/08/2024	Final FRMSP	AP, AC, HR & MG	TWG (NSW DCCEW and IWC)

Foreword

The primary objective of the NSW Flood Prone Land Policy 2021 is to reduce the impact of flooding and flood liability on communities and individual owners and occupiers of flood prone property, and to reduce private and public losses resulting from floods, utilising ecologically positive methods wherever possible.

The previous policy formed part of the New South Wales (NSW) Floodplain Development Manual (FDM) in 2005. Recently, two changes have occurred in flood risk management in NSW:

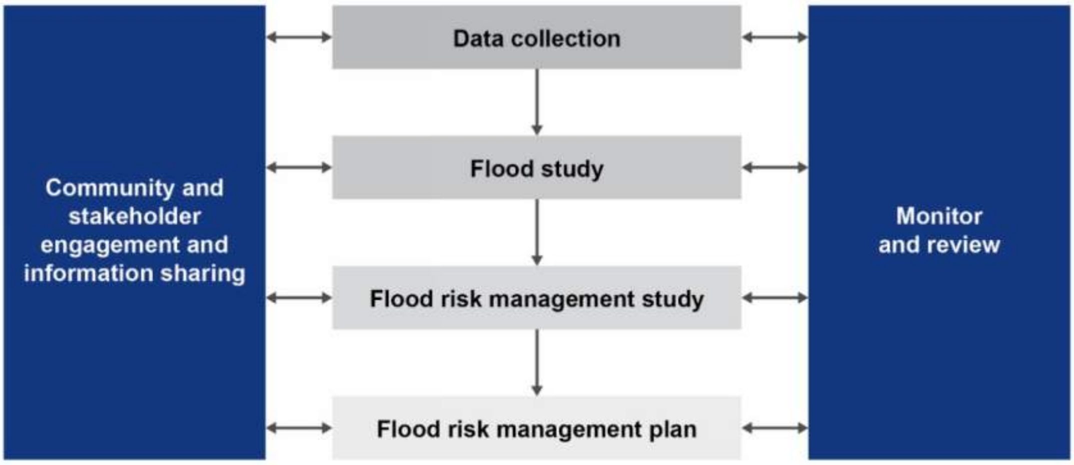
> The 2021 Flood Prone Land Package Update was released in July 2021. The Flood Prone Land package included a new planning direction, planning circular, guideline, standard flood-related Local Environment Plan (LEP) instruments, and several planning legislation changes.

> The finalised and gazetted Flood Risk Management (FRM) Manual was adopted on 30 June 2023. The Manual replaces the FDM 2005 and a number of previous technical guides. The manual provides advice to local councils on the management of flood risk in their local government areas through the flood risk management framework and flood risk management process. This update builds on the 2005 manual and guides. It considers lessons learnt from floods and the application of the flood risk management process and manual since 2005. It considers a range of work on managing natural hazards across government, including relevant national and international frameworks, strategies and best practice guidance. Accompanying the manual is eight FRM Guidelines that comprise a new toolkit to provide guidance for local councils and their consultants.

Under the 2021 policy, councils are primarily responsible for managing flood risk to reduce the risk to life, property damage and other impacts in their local government areas. The State Government subsidises flood management measures to alleviate existing flooding problems and provides specialist technical advice to assist councils in the discharge of their flood risk management responsibilities. The Commonwealth Government also assists with the subsidy of floodplain modification measures. The new policy identifies the following flood risk management 'process' for the identification and management of flood risks:

1. Data Collection - Aims to gather the information needed to support the study being undertaken.
2. Flood Study - Aims to define flood behaviour in sufficient detail to support the understanding and management of flood risk.
3. *Flood Risk Management Study (FRMS) - Provides the basis for examining and recommending FRM measures to manage risks to the existing and growing community, people and built environment. The measures aim to limit the residual flood risk to the community and how this may change over time.*
4. *Flood Risk Management Plan (FRMP) - Builds on the recommendations of the FRM study by clearly outlining council's decision on how it intends to effectively manage flood risk in the study area.*

This Whites Creek and Johnstons Creek Flood Risk Management Study and Plan falls within steps 3 and 4 in the FRM process and has been developed from the previous Flood Study, completed in 2017. An illustration of the FRM process from the FRM Manual is shown below. Beyond the FRM process, councils must also implement, review and update the studies.



Executive Summary

Stantec Australia Pty Ltd (formerly Cardno) was commissioned by Inner West Council ('Council', or IWC) to undertake a Flood Risk Management Study and Plan (FRMS&P) for the Whites Creek and Johnstons Creek Study Areas. The Study Areas are focused around the portions of the two creek catchments that are contained within the former Marrickville Council LGA, south of Parramatta Road.

Community Consultation

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

The consultation strategy has been divided into three key sections:

> Consultation in FRMS&P development: This occurs during the initial stages of the project (**Section 1.4)** and involves both informing the community and stakeholders of the project and gathering information on existing flooding issues and suggestions for flood risk management options.

> Review of possible flood management options with key stakeholder groups including Council Engineers, Council Planners, NSW SES, NSW DCCEW and community representatives within Council's Flood Risk Management Advisory Committee.

> Public exhibition of Draft FRMS&P: This occurs in the final stage of the project, with comments sought from the community and stakeholders on the Draft FRMS&P report with this input reviewed and incorporated into the final FRMS&P.

Across the initial consultation period, information regarding the project was advertised on Councils website on the Your Say portal. Outcomes from the initial consultation included, there were 650 views of the project page, initiated by 501 unique visitors. The total viewing time of project information was approximately 7 hours. Two persons contributed to the interactive map. There were three attendees relevant to the Whites Creek and Johnstons Creek study area at the three in-person sessions.

For the public exhibition period in June and July 2024, there were approximately 23 recorded responses across this Study and Whites Creek and Johnstons Creek FRMSP through Your Say uploads (3 submissions and 1 questionnaire response), phone calls (4), and emails (4), along with two in-person sessions (11 attendees). Across all response methods, 1 comment (Your Say upload) related to Alexandra Canal FRMSP. All other responses were related to Whites Creek and Johnstons Creek catchment areas.

Common concerns in public exhibition related to localised stormwater issues not within the scope of flood risk, i.e. maintenance or drainage issues to be addressed by means of temporary solutions prior to the implementation of mitigation options or otherwise captured under Council's capital works. Specifically relating to identified options, comments were received in relation to flooding:

> In the junction of Gladstone Street and Phillip Street in Enmore; Salisbury Road, Camperdown near Church Street; Salisbury Lane, Stanmore near the inlets to the Johnstons Creek, Stafford Street, Stanmore; and Australia Street, Newtown in the Johnstons Creek Catchment; and

> Corunna Street in the Whites Creek catchment.

These comments from the community have been considered and accounted for in the final reporting for the Study and Plan.

Impact of Flooding

The number of flood affected properties for five design events are summarised in the below table. Two forms of property tagging analysis have been considered – tagging of properties with any flood affectation and tagging of properties where the flood extent covers at least 10% of the property area, as was applied under the Johnstons Creek Flood Study.

A review of the number of properties affected between the "10% affectation" and the "any affectation" scenarios, and the relative flood hazard affecting these properties, it was considered that the 10% affectation scenario sufficiently addressed the flood risk, requiring no updates to the flood affected lot tagging currently adopted by Council.

Property Tagging	Base Case Flood Affected Property				
	20% AEP	5% AEP	2% AEP	1% AEP	PMF
Flood Affected	770	1006	1107	1197	1906
>10% Area Affectation	197	300	368	409	913
				Total Properties in Catchment	6976

In the PMF event using the 10% property area approach, there are a total of 913 flood affected properties, or 14.2% of the total 6434 properties in the study area. In the 1% AEP the total number of affected properties is 409, or 6.3% of all properties.

With respect to economic impacts of flooding in the study area, the total Average Annual Damage (AAD) for Whites Creek is over $2 million. More than half (58%) of this AAD is a result of the most frequent 20% AEP event, with the next most frequent event, the 5% AEP contributing a further 26% of the AAD. The less frequent events, the 2% and 1% AEP and PMF provide between 2 – 7% of AAD contribution.

For Johnstons Creek, the total AAD is over $28.8 million. Similar to Whites Creek, over half (57%) of this AAD is a result of the most frequent 20% AEP event, with the next most frequent event, the 5% AEP contributing 27% of the AAD. The less frequent events, the 2% and 1% AEP and PMF provide between 3 – 7% of AAD contribution. Though these events result in far higher flood damage totals, particularly the PMF event, their relatively low likelihood means they contribute less to the AAD.

Therefore, as it relates to damages and AAD, structural flood risk management options that reduce flood damages for the most frequent 20% AEP event are expected to provide the biggest benefits to AAD reductions. The following tables are summarised AAD calculations for Whites Creek and Johnstons Creek respectively.

Whites Creek

AEP	Probability	Total Damages	AAD Contribution	AAD Contribution %
20%	0.20	$3,063,904	**$1,242,852**	58%
5%	0.05	$4,464,671	**$566,565**	26%
2%	0.02	$4,784,009	**$140,084**	7%
1%	0.01	$5,404,352	**$51,276**	2%
PMF	0.0000001	$24,166,397	**$147,706**	7%
Total AAD			**$2,148,483**	

Johnstons Creek

AEP	Probability	Total Damages	AAD Contribution	AAD Contribution %
20%	0.20	$40,992,067	**$16,541,136**	57%
5%	0.05	$62,615,455	**$7,809,006**	27%
2%	0.02	$73,588,421	**$2,060,652**	7%
1%	0.01	$82,892,052	**$783,517**	3%
PMF	0.0000001	$247,421,259	**$1,649,915**	6%
Total AAD			**$28,844,226**	

Flood Emergency Response Review

Due to the short duration of both the critical storm affecting the catchment and the time to peak flood depth, there is limited opportunity to stand up an emergency management centre and begin directed evacuation of residents prior to the onset of flooding. Based on a detailed review of flood emergency response provisions and the flash flooding nature of the study area, it is unlikely, almost impossible, that SES doorknocked evacuation will be able to effectively evacuate residents prior to flooding. From this review, potential measures have been identified that could improve flood emergency response potential for the study area:

> Improved flood awareness – Limited knowledge of an individual's potential risk from flooding and the associated lack of planning can cause significant delays to community evacuation due to both acceptance and lag time. A comprehensive flood awareness program for the Study Area, educating residents of the

seriousness of the flood risk and the flash flooding nature of the catchment could improve the flood risk to the community.

> Alternative flood warning systems- There are noted difficulties of flood warning systems in flash flooding environments. As forecasting and modelling technology improves, options may be considered for the development of flood warning systems for the Study Area, particularly in the emergency management hotspot areas.

> Self-managed evacuation - Where SES assisted evacuation is not an option, self-managed evacuation is a potential alternative. This describes where people make their own decision to evacuate earlier and move to alternate accommodation, using their own transport. These plans would typically be prepared using information available from Council and with support of the local SES unit, using SES templates such as FloodSafe. The advantage of this approach would be that people can evacuate more quickly than SES assisted evacuation, and as a result reduces the strain on SES and does not rely on a centralised evacuation order. However, self-managed evacuation can also pose a risk if not conducted in an appropriate way. Residents could place themselves at higher risk for example if they evacuate to a location which is even more flood affected, drive through flood waters, or could increase traffic congestion if the wrong route is selected.

Flood Planning Review

The outcomes of the flood planning review were as follows:

> Compared to the requirements for planning proposals outlined within the 2021 Flood Prone Land Policy Update, the current development controls are generally in agreement.

> Compared to the Flood Planning Constraints Categories (FPCC) approach from the 2023 Flood Risk Management (FRM) Manual Guide FB01, current Flood Risk Precincts of the Development Control Plan (DCP) are generally aligned however potentially adopting FPCC offers some potential benefits. These benefits include splitting the current High risk precinct into FPCC1 and FPCC2 where development can be precluded in FPCC1 and more tailored controls can be applied to FPCC2 areas.

> Compared to the requirements for Flood Impact Risk Assessment (FIRA) from the 2023 FRM Manual Guide LU01. Generally, the current development controls are in agreement with the proposed requirements in the guide with some exceptions:

  - The current controls do not require consideration of climate change in assessments.
  - The current controls do not specify flood impacts be considered not just for flood levels but also duration, velocity, evacuation, flood function or hazard categorisation.
  - The current controls do not specifically require a consideration of residual risk of proposed developments to confirm if flood risk is lower than existing based on proposed risk management measures for developments.

Ultimately the current development controls are considered suitable, and generally in accordance with recent guidance both within the 2021 Flood Prone Land Policy Update and the 2023 FRM Manual Guide LU01. However, there are some minor alterations listed in the bullet points above that may improve an applicant's understanding of the controls and provide a more comprehensive assessment of flood risk in future development submissions.

Flood Risk Management Options Background

Three main types of Flood Risk Management (FRM) options were considered:

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

> Property modification measures – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than necessarily modify the flood behaviour, these options aim to modify properties (both existing and future) so that there is a reduction in flood risk.

> Emergency response modification measures – Emergency response modification measures aim to reduce the consequences of flood risks. These measures generally aim to modify the behaviour of people during a flood event.

The assessment of FRM options should consider inputs from people in the community, the economy, social and cultural aspects, services to the community and the natural environment. Relating to the development of FRM options, the following stages were applied in this project:

> Option identification and preliminary option assessment and optimisation – The identification of an inclusive range of FRM options to address local or broad FRM issues for the existing community and new development. Having identified the FRM issues to address and an inclusive range of FRM options worthy of consideration, the viability of these options were discussed with Council, the Committee and other stakeholders in several workshops to determine if they warranted more detailed assessment.

> Detailed option assessment – Detailed assessment and subsequent optimisation of FRM options and packages of options needs to consider their costs, benefits and disbenefits in managing risk. The detailed assessment included flood modelling of options, damages assessment of option benefits, preliminary costing and a Multi-Criteria Assessment (MCA) that considers a broad range of factors quantitatively or qualitatively.

> Recommendation in FRM studies and decision-making in FRM plans.

Detailed Assessment of Options

Following the preliminary option assessment, twenty options were selected for detailed assessment, with the final options listed in the table below.

Option Type	Option ID/Name
Flood Modification (FM)	JC1 v1 – Fowler Street, Camperdown Drainage Upgrade
	JC1 v2 – Fowler Street, Camperdown Detention Basin
	JC5 – Bridge Road, Stanmore Drainage Upgrade
	JC6 v1 – Bridge Road, Stanmore Channel Regrading
	JC6 v2– Bridge Road, Stanmore Channel Widening
	JC7 – Bridge Road, Stanmore Detention Basin
	JC10 – Trafalgar Street, Petersham Drainage Upgrade
	JC13 – Gladstone Street, Enmore Drainage Upgrade
	JC14 – Railway Avenue, Stanmore Road Regrading
	JC15 – Probert Street, Newtown Drainage Upgrade
	JC18 v1 – Kingston Road, Camperdown Drainage Upgrade
	JC18 v2 – Kingston Road, Camperdown Drainage Upgrade
	JC20 – Lennox Street, Newtown Drainage Upgrade
	JC23 – Clarendon Lane, Stanmore Drainage Upgrade
	WC1 – Margaret Street, Petersham Drainage Upgrade
Property Modification (PM)	PM6 – Targeted Stormwater Maintenance
Emergency Management Modification (EM)	EM2 – Review of Local Flood Planning and Information Transfer to NSW SES
	EM3 – Community Flood Awareness
	EM5 – Flood Markers and Signage
	EM6 – Flood Data and Debrief

The detailed assessment of these 20 FRM options was conducted including:

> Hydraulic modelling of five design events – 20%, 5%, 2%, 1% AEP and PMF (for FM options),

> Flood damages benefits assessment (for FM options) involving adopting water level impact results compared to the existing flood damages to determine the potential benefits of the option in the 5 modelled events. The AAD of damage benefits were calculated and the Net Present Worth (NPW) of benefits for all options were calculated assuming a 5% discount rate and 30 year life cycle for the option.

> Cost estimation was conducted for all options for both capital and ongoing / maintenance costs. The process for capital cost estimation was based on quantities for construction estimated from preliminary design for the 15 FM options as they were modelled in the TUFLOW model. Unit rates were initially estimated by Stantec and reviewed and updated by Council staff in some instances to match current cost rates for the local area. A 50% contingency has been applied to all estimates given uncertainty on eventual design refinement and quantities. For other measures (EM and PM), costs were estimated only on the basis of cost to implement and were done for the purpose of comparison in the multi-criteria assessment. The total cost of the options was calculated for Net Present Worth using a 5% discount rate and an implementation period of 30 years.

> Benefit Cost Ratio - The economic evaluation of each option was performed by considering the reduction in the amount of flood damages incurred for the design events and then comparing this value with the cost of implementing the option. The benefit-cost ratio provides an insight into how the damage savings from a measure relate to its cost of construction and maintenance. Where the benefit-cost ratio is greater than one (BCR >1) the economic benefits are greater than the cost of implementing the measure. For all FM options it is possible to quantify, at least at a high-level both damage benefits and costs of implementation for each option, therefore a BCR is able to be calculated. For PM and EM options, the damage benefits are not easily quantifiable, though there would be some economic benefits of these options in the form of reduced risk to life and resultant reduction in flood damage for loss of life. Therefore in lieu of any damage benefit information, the economic analysis of these options has assumed that BCR is 1.0. The Benefit Cost Ration outcomes for all detailed options have been summarised in the table below.

Option	NPW of AAD Reduction Benefits	NPW of Cost of Implementation of Option	Benefit Cost Ratio
JC1 v1– Fowler Street, Camperdown Drainage Upgrade	$1,578,818	$397,097	3.98
JC1 v2– Fowler Street, Camperdown Detention Basin	$2,952,404	$2,625,485	1.12
JC5 – Bridge Road, Stanmore Drainage Upgrade	$2,176,794	$7,938,503	0.27
JC6 v1 – Bridge Road, Stanmore Channel Regrading	$7,181,786	$1,911,058	3.76
JC6 v2– Bridge Road, Stanmore Channel Widening	$7,403,263	$5,456,303	1.36
JC7 – Bridge Road, Stanmore Detention Basin	$7,632,909	$1,386,777	5.50
JC10– Trafalgar Street, Petersham Drainage Upgrade	$60,783	$704,768	0.09
JC13 – Gladstone Street, Enmore Drainage Upgrade	$6,582,822	$1,646,592	4.00
JC14 – Railway Avenue, Stanmore Road Regrading	$5,299,041	$2,247,616	2.36
JC15 – Probert Street, Newtown Drainage Upgrade	$1,774,388	$452,519	3.92
JC18 v1 – Kingston Road, Camperdown Drainage Upgrade 1	$3,216,878	$368,877	8.72
JC18 v2 – Kingston Road, Camperdown Drainage Upgrade 2	$4,690,901	$1,198,241	3.91
JC20– Lennox Street, Newtown Drainage Upgrade	$8,366,172	$2,300,761	3.64
JC23 – Clarendon Lane, Stanmore Drainage Upgrade	$324,555	$401,322	0.81
WC1 – Margaret Street, Petersham Drainage Upgrade	$4,990,924	$2,356,821	2.12
PM6 – Targeted Stormwater Maintenance	*	$5,719,990	1.0*
EM2 – Review of Local Flood Planning and Info Transfer to NSW SES		$137,794	1.0*

Option	NPW of AAD Reduction Benefits	NPW of Cost of Implementation of Option	Benefit Cost Ratio
EM3 – Community Flood Awareness		$751,761	1.0*
EM5 – Flood Markers and Signage		$265,294	1.0*
EM6 – Flood Data and Debrief		$275,587	1.0*

*In lieu of benefit values for EM & PM options, due to flood risk reduction BCR value assumed to be 1.0

The BCR results show that of flood risk management options:

> Eight (8) options have BCR values over 3.0, therefore the costs are significantly lower than the calculated benefits.

> Two (2) options have BCR values over 1.5 to 3.0, therefore the costs are lower than the calculated benefits.

> Eight (8) options have BCR values over 0.5 to 1.5, therefore the costs are comparable to the calculated benefits, five (5) such options are EM and PM options with assumed BCR of 1.0.

> Two (2) options have BCR values less than 0.5, therefore the costs are significantly higher than the calculated benefits.

Option PM6 is for the targeted increased maintenance of the stormwater network. Inner West Council, in accordance with its responsibility as owner of the majority of the drainage assets within the study area, has a significant maintenance schedule already in place for all of its stormwater assets. This includes timely responses to community requests or notes relating to any drainage blockage or damage. Option PM6 involves potential additional targeted maintenance of greater frequency than is currently applied at key locations. The potential benefits of the PM6 option for targeted stormwater maintenance was assessed using modelling assuming no blockage of pipes. This is a best-case scenario, that in reality is unlikely to be achievable. Nevertheless, it does provide an indication of areas of potential benefits, even if the scale of benefits may exceed expected outcomes. Therefore, due to this uncertainty, the modelling outcomes in the form of damage benefits were not applied to the BCR outcome for this option PM6.

Multi-Criteria Assessment

To assist Council in identifying the FRM options that provide the most benefits for the society, environment and economy, all options need to be compared against each other based on factors relevant to the study area. Evaluating what constitutes an appropriate strategy for floodplain management is a significant analytical and policy challenge. Such challenges have led to the exploration of alternative policy analysis tools, one being Multi Criteria Assessments (MCA). The goal of MCA is to attempt to directly incorporate multiple values held by community and stakeholders into the analysis of management alternatives while avoiding the reduction of those values into a standard monetary unit. In doing so, one can consider different FRM options in the context of economic criteria as well as other criteria such as social, or environmental aspects. Community and stakeholders can also assign explicit weights to those values to reflect their preferences and priorities. Therefore, MCA provides opportunities for the direct participation of community and stakeholders in the analysis.

An MCA approach has been used for the comparative assessment of all options identified. Each option is given a score according to how well the option meets specific considerations. To keep the scoring system simple a framework has been developed for each criterion.

The selection of criteria and weighting has been completed by involving the technical working group (TWG). A scoring system with 11 criteria (five economic, four social and two environmental) was established for each criterion with scores ranging from +2 for options that represented a significant improvement on existing conditions for any given criteria, to -2 for options that represented a significant worsening of existing conditions. It is noted that for two criteria (Benefit-Cost Ratio and Reduction in Risk to Property or damage) scoring systems was based on quantifiable assessment outcomes, for all other criteria scoring was more qualitative, although supported by sound judgement.

The highest scoring options typically fall into one of two categories:

> Relatively cost-effective FM) options consisting of drainage upgrades that provide significant flood risk reduction benefits (with the exception of the Bridge Road detention basin option).

> EM options which offer significant flood risk reduction with relatively minor cost. Three of the top seven MCA scoring options are EM options.

The lowest scoring options are typically FM options that do not provide significant flood risk reduction benefits relative to their cost, complexity or other issues. The lowest 5 scoring options are all FM options.

Implementation Plan

The list of recommended management options has been transformed into an implementation plan provided in the table below. It lists the following information relevant to the implementation of each adopted FRM option:

- Type and sub-catchment location of option and MCA score;
- The priority for implementation (high, medium, or low) and rank as an outcome of the FRMS&P;
- An estimate of implementation costs including capital and ongoing costs per annum;
- Potential funding mechanism or organisation; and
- Required economic assessment level during Investigation and Design (I&D) stage.

The flood risk management options identified in the below table represent a capital cost of approximately $17.6M, with the flood modification options making up $17.0M of this cost. High priority options have combined capital costs of $5.9M.

It is noted that the implementation plan does not outline a specific timeframe for the implementation of each project. Plan has not been explicitly identified. Rather, the implementation plan provides a body of projects to inform future advocacy, budgeting, and planning in order that Council may be able to undertake works in a prioritised manner as funding becomes available or other opportunities arise in a specific location associated with a proposed option.

Option ID	Option Type	MCA Weighted Score	Option Rank	Implementation Priority	Capital Costs (incl. GST)	Ongoing Costs (p.a incl. GST)	Economic Assessment Level for I&D
Option JC15 – Probert Street, Newtown Drainage Upgrade	Flood Modification (FM)	1.25	1	High	$ 440,990	$ 750	Level 1 (FRMS&P)
Option JC7 – Bridge Road, Stanmore Detention Basin	FM	1.15	2	High	$ 1,317,600	$ 4,500	Level 2 (Detailed damages)
EM2 – Review of Local Flood Planning and Info Transfer to NSW SES	Emergency Management (EM)	1.10	3	High	$ 22,500	$ 7,500	Level 1
Option JC20 – Lennox Street, Newtown Drainage Upgrade	FM	1.10	3	High	$ 2,266,173	$ 2,250	Level 2
Option JC13 - Gladstone Street, Enmore Drainage Upgrade	FM	1.05	5	High	$ 1,612,003	$ 2,250	Level 2
EM3 – Community Flood Awareness	EM	0.95	6	High	$ 60,000	$ 45,000	Level 1
EM5 – Flood Markers and Signage	EM	0.95	6	High	$ 150,000	$ 7,500	Level 1
Option JC14 - Railway Avenue, Stanmore Road Regrading	FM	0.85	8	Medium	$ 2,247,615	$ -	Level 2
Option JC18 v1 - Minor Kingston Road, Camperdown Drainage Upgrade 1	FM	0.75	9	Medium	$ 368,876	$ -	Level 1
Option JC6 v1 - Bridge Road, Stanmore Channel Upgrade (Re-grading North)	FM	0.70	10	Medium	$ 1,899,528	$ 750	Level 2
PM6 – Targeted Stormwater Maintenance	Property Modification (PM)	0.65	11	Medium	$ 349,367	$ 349,367	Level 1
Option JC23 - Clarendon Lane, Stanmore Drainage Upgrade	FM	0.55	12	Medium	$ 378,263	$ 1,500	Level 1
Option JC18 v2 - Major Kingston Road, Camperdown Drainage Upgrade 2	FM	0.55	12	Medium	$ 1,198,240	$ -	Level 2
Option JC1 v2 - Fowler Street, Camperdown Detention Basin	FM	0.50	14	Medium	$ 2,533,250	$ 6,000	Level 2
EM6 – Flood Data and Debrief	EM	0.45	15	Low	$ 45,000	$ 15,000	Level 1
Option WC1 - Margaret Street, Petersham Drainage Upgrade	FM	0.40	16	Low	$ 2,356,821	$ -	Level 2
Option JC1 v1 -Fowler Street, Camperdown Drainage Upgrade	FM	0.35	17	Low	$ 397,097	$ -	Level 1
				Total	**$ 17,643,323**	**$ 442,367**	

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Appendices

Tables

Figures

Abbreviations

1D	One-dimensional
2D	Two-dimensional
ABS	Australian Bureau of Statistics
AEP	Annual Exceedance Probability
AHD	Australian Height Datum
AHIP	Aboriginal Heritage Impact Permit
ARI	Average Recurrence Interval
AR&R	Australian Rainfall and Runoff
ASS	Acid Sulfate Soils
BCR	Benefit Cost Ratio
BoM	Australian Bureau of Meteorology
DAWE	Australian Department of Agriculture, Water and Environment.
DCCEW	NSW Department of Climate Change, Energy and Water
DCP	Development Control Plan
DEM	Digital Elevation Model
DPHI	NSW Department of Planning, Housing and Infrastructure
ELVIS	Elevation Information System
EPA	NSW Environmental Protection Authority
EPBC Act	Environment Protection and Biodiversity Conservation Act 1999
FDM	Floodplain Development Manual
FRM	Flood Risk Management
FRMS&P	Flood Risk Management Study and Plan
FPL	Flood Planning Level
FPA	Flood Planning Area
GIS	Geographical Information Systems
IFD	Intensity-Frequency-Duration
IWC	Inner West Council
LEP	Local Environment Plan
LGA	Local Government Area
LIDAR	Light Detection and Ranging
NPV	Net Present Value
NSW	New South Wales
PCT	Plant Community Types
PMF	Probable Maximum Flood
PMST	Protected Matters Search Tool
SEPP	State Environmental Planning Policy
SES	NSW State Emergency Service
TEC	Threatened Ecological Community

Glossary

Acid Sulfate Soils (ASS)	Acid sulfate soils (ASS) are naturally occurring sediments and soils containing iron sulfides (mostly pyrite). When these sediments are exposed to the air by excavation or drainage of overlying water, the iron sulfides oxidise and form sulphuric acid. ASSs are widespread among low lying coastal areas of NSW, in estuarine floodplains and coastal lowlands.
Annual Exceedance Probability (AEP)	The probability of an event occurring or being exceeded within a year. For example, a 5% AEP flood would have a 5% chance of occurring in any year. An approximate conversion between ARI and AEP is provided.
Australian Height Datum (AHD)	A standard national surface level datum approximately corresponding to mean sea level.
Average Recurrence Interval (ARI)	The long-term average period between occurrences equalling or exceeding a given value. For example, a 20 year ARI flood would occur on average once every 20 years.
Cadastre, cadastral base	Information in map or digital form showing the extent and usage of land, including streets, lot boundaries, water courses etc.
Catchment	The area draining to a site. It always relates to a particular location and may include the catchments of tributary streams as well as the main stream.
Design flood	A significant event to be considered in the design process; various works within the floodplain may have different design events. E.g. some roads may be designed to be overtopped in the 1% AEP flood event.
Development	The erection of a building or the carrying out of work; or the use of land or of a building or work; or the subdivision of land.
Discharge	The rate of flow of water measured in terms of volume over time. It is to be distinguished from the speed or velocity of flow, which is a measure of how fast the water is moving rather than how much is moving.
Elevation Information System (ELVIS)	ELVIS was launched by Geoscience Australia in 2016 to replace the existing National Elevation Data Framework (NEDF) and to open access to elevation datasets to a wider user base. With the online ELVIS portal, users can now easily download continent-wide elevation data.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood prone land after floodway and flood storage areas have been defined.
Flood hazard	Potential risk to life and limb caused by flooding.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Flood Risk Management Plans encompass all flood prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.

Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood Planning Area (FPA)	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels (FPLs)	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also take into account the social, economic and ecological consequences associated with floods of different severities. Different FPLs may be appropriate for different categories of land use and for different flood plains. The concept of FPLs supersedes the "Standard flood event" of the first edition of the Manual. As FPLs do not necessarily extend to the limits of flood prone land (as defined by the probable maximum flood), floodplain management plans may apply to flood prone land beyond the defined FPLs.
Flood storages	Those parts of the floodplain that are important for the temporary storage of floodwaters during the passage of a flood.
Floodway areas	Those areas of the floodplain where a significant discharge of water occurs during floods. They are often, but not always, aligned with naturally defined channels. Floodways are areas which, even if only partially blocked, would cause a significant redistribution of flood flow, or significant increase in flood levels. Floodways are often, but not necessarily, areas of deeper flow or areas where higher velocities occur. As for flood storage areas, the extent and behaviour of floodways may change with flood severity. Areas that are benign for small floods may cater for much greater and more hazardous flows during larger floods. Hence, it is necessary to investigate a range of flood sizes before adopting a design flood event to define floodway areas.
Geographical Information Systems (GIS)	A system of software and procedures designed to support the management, manipulation, analysis and display of spatially referenced data.
High hazard	Flood conditions that pose a possible danger to personal safety; evacuation by trucks difficult; able-bodied adults would have difficulty wading to safety; potential for significant structural damage to buildings.
Hydraulics	The term given to the study of water flow in a river, channel or pipe, in particular, the evaluation of flow parameters such as stage and velocity.
Hydrograph	A graph that shows how the discharge changes with time at any particular location.
Hydrology	The term given to the study of the rainfall and runoff process as it relates to the derivation of hydrographs for given floods.
Low hazard	Flood conditions such that should it be necessary, people and their possessions could be evacuated by trucks; able-bodied adults would have little difficulty wading to safety.
Mainstream flooding	Inundation of normally dry land occurring when water overflows the natural or artificial banks of the principal watercourses in a catchment. Mainstream flooding generally excludes watercourses constructed with pipes or artificial channels considered as stormwater channels.
Management plan	A document including, as appropriate, both written and diagrammatic information describing how a particular area of land is to be used and managed to achieve defined objectives. It may also include description and discussion of various issues, special features and values of the area, the specific management measures which are to apply and the means and timing by which the plan will be implemented.
Mathematical/computer models	The mathematical representation of the physical processes involved in runoff and stream flow. These models are often run on computers due to the complexity of the mathematical relationships. In this report, the models referred to are mainly involved with rainfall, runoff, pipe and overland stream flow.
Overland Flow	The local runoff, travelling through properties and /or roads, before it discharges into a stream, river, estuary, lake or dam.
Peak discharge	The maximum discharge occurring during a flood event.

Probable maximum flood (PMF)	The flood calculated to be the maximum that is likely to occur.
Probability	A statistical measure of the expected frequency or occurrence of flooding. For a more detailed explanation see AEP and Average Recurrence Interval.
Risk	Chance of something happening that will have an impact. It is measured in terms of consequences and likelihood. For this study, it is the likelihood of consequences arising from the interaction of floods, communities and the environment.
Runoff	The amount of rainfall that actually ends up as stream or pipe flow, also known as rainfall excess.
Stage	Equivalent to 'water level'. Both are measured with reference to a specified datum.
Stage hydrograph	A graph that shows how the water level changes with time. It must be referenced to a particular location and datum.
Stormwater flooding	Inundation by local runoff. Stormwater flooding can be caused by local runoff exceeding the capacity of an urban stormwater drainage system or by the backwater effects of mainstream flooding causing the urban stormwater drainage system to overflow.
Topography	A surface which defines the ground level of a chosen area.

1 Introduction

Stantec Australia Pty Ltd (formerly Cardno (NSW/ACT) Pty Ltd) ('Stantec') was commissioned by Inner West Council ('Council') to undertake a Flood Risk Management Study and Plan (FRMS&P) for the Whites Creek and Johnstons Creek Study Area (**Figure 2-1**). The Study Area is within the Inner West Local Government Area (LGA), located approximately 4km southwest of the Sydney Central Business District (CBD). The Study Area is focused on the portions of Whites Creek and Johnstons Creek located south of Parramatta Road. The remaining areas of these catchments north of Parramatta Road were previously reviewed as part of the Leichhardt Flood Risk Management Study and Plan (Cardno, 2017). **Figure 2-2** outlines the division of the creek catchments between this study and the areas previously completed by Inner West Council and City of Sydney Council, which have been excluded from this study. The Study Area is roughly between Crystal Street in the west and Missenden Road and King Street in the East, extending as far up as Parramatta Road, and south to some areas of Enmore Road and Cambridge Street.

This report is the Final FRMS&P report for Whites Creek and Johnstons Creek, incorporating comments from stakeholder agencies and the comments received from the community during public exhibition.

1.1 Study Context

As outlined within the Floodplain Risk Management (FRM) Manual 2023, like all councils in NSW, Inner West Council is responsible for local land use planning including management of both mainstream and overland flooding within the LGA. In response to the objectives of the New South Wales (NSW) Government's Flood Prone Land Policy, Council has an ongoing commitment to reduce the impact of flooding and flood liability on individual owners and occupiers of flood prone property, and to reduce public losses resulting from floods, utilising ecologically positive methods wherever possible.

Through the Department of Climate Change, Energy and Water (DCCEW, formerly Department of Planning and Environment, DPE) and the State Emergency Service (SES), the NSW Government provides specialist technical assistance to local government on all flooding and land use planning matters. The FRM Manual 2023 guides councils in the strategic management of flood risk across their LGAs through the FRM framework. This supports councils in meeting their responsibilities for a range of FRM activities and their strategic consideration of flooding.

The FRM process is a key element of the FRM framework. Studies and plans under the process support the understanding of flooding, the examination of measures to manage flood risk and informed decisions on how to manage flood risk into the future. They also support the consideration of flooding in broader activities under the FRM framework. The FRM process progresses through four (4) steps in an iterative process:

1. Data Collection
2. Flood Study
3. ***Flood Risk Management Study***
4. ***Flood Risk Management Plan***

The study currently being undertaken addresses steps three and four of the process. The Whites Creek and Johnstons Creek Flood Study was prepared in 2017 by WMAwater for Inner West Council and provides the second step listed above to define the flood behaviour in the Study Area. The Flood Study form the basis of the flood data used for this FRMS&P.

1.2 Study Objectives

The primary objective of this study is to develop a Flood Risk Management Study & Plan that addresses the existing, future and continuing flood problems, considering the potential impacts of climate change, in accordance with the NSW Government's Flood Prone Land Policy and the FRM Manual 2023.

The specific project objectives are to:

- Review the Whites Creek and Johnstons Creek Flood Study (WMAwater 2017) in accordance with the updated requirements of AR&R 2019 and any recent changes in topography in the Study Area;
- Review Council's adopted flood planning area mapping;
- Review the existing emergency response situation and limitations;
- Review effectiveness of current flood management measures;
- Identify floodplain management measures aimed at reducing the social, environmental and economic impacts of flooding and the losses caused by flooding on development and the community, both existing and future;
- Examination of the existing flood warning systems, community flood awareness and emergency response measures in the context of the NSW State Emergency Service's (SES's) developments and disaster planning requirements;
- Reduce the flood hazard and risk to people and property in the existing community and to ensure future development is controlled in a manner consistent with the flood hazard and risk (taking into account the potential impacts of climate change);
- Reduce private and public losses due to flooding; and
- Establish a program for implementation and suggest a mechanism for the funding of the plan which should include funding sources, priorities, staging, funding, responsibilities, constraints, and monitoring.

1.3 Flood Risk Management Principles

Beyond the specific objectives of this study listed above, the FRM Manual 2023 outlines ten (10) principles for flood risk management in NSW:

1. Establish sustainable governance arrangements,
2. Think and plan strategically,
3. Be consultative,
4. Make flood information available,
5. Understand flood behaviour and constraints,
6. Understand flood risk and how it may change,
7. Consider variability and uncertainty,
8. Maintain natural flood functions,
9. Manage flood risk effectively, and,
10. Continually improve the management of flood risk.

The objectives of this study align with these principles, and through the proposed study methodology attempts to account for all of these principles, either directly or indirectly.

1.4 Project Summary

The Whites Creek and Johnstons Creek Flood Risk Management Study and Plan project include the following stages:

- Stage 1 – Data Collection and Review;
- Stage 2 – Additional Data Collection;
- Stage 3 – Community Engagement;
- Stage 4 – Options Identification and Assessment;
- Stage 5 – Draft Flood Risk Management Study and Plan;
- Stage 6 – Public Exhibition of Study and Plan; and
- Stage 7 – Completion of Flood Risk Management Study and Plan.

The Whites Creek and Johnstons Creek Flood Risk Management Study and Plan has been undertaken across seven stages, outlined in the sections below:

- Study Area description including topography, flora and fauna, heritage, demographics (**Section 2**);
- Initial data collection and review process including review of the Flood Study model in accordance with the updated analysis of ARR2019 (**Section 3**);
- Summary of the community consultation process including public exhibition in June and July 2024 (**Section 4**);
- Existing flood risk review including flood planning review (**Section 5**), economic impacts of flooding (**Section 6**), and a flood emergency response review (**Section 7**).
- Summary of flood modification options development and selection of detailed options (**Section 8**).
- Description of detailed assessment of options including modelling, cost estimation, damages benefits and Multi-Criteria Assessment (MCA) (**Section 9**), and implementation program for these detailed options to provide Council guidance on the future implementation of these options (**Section 10**).

2 Study Area Description

2.1 Catchment Background

Johnstons Creek has a total catchment area of approximately 460 ha which drains into Rozelle Bay. The catchment includes suburbs of Newtown, Camperdown, Stanmore, Annandale, Forrest Lodge and Glebe. The catchment area comprises of LGAs under the control of:

- Inner West Council (352 ha); and
- The City of Sydney (108 ha).

Whites Creek has a total catchment area of approximately 262 ha which drains into Rozelle Bay. The catchment includes suburbs of Petersham, Stanmore, Leichardt, Annandale and Lilyfield. It is all contained within the Inner West LGA (formerly Marrickville LGA). The Study Area is wholly urbanised, mostly consisting of residential areas characterised by detached or terraced houses. There are also large open space areas such as Camperdown Park, O'Dea Reserve, Camperdown Memorial Park, Maundrell Park and Weekly Park.

The catchment is highly modified by human activity, with a high proportion of impermeable, hardstand areas. Water drains from the Study Area via council stormwater drainage systems which include covered channels, in-ground pipes, culverts and kerb inlet pits, and via Sydney Water's two major trunk drainage systems, one for each catchment. The trunk drainage systems discharge into Rozelle Bay from a combination of open and covered channels. The Study Area for this FRMS&P, shown in **Figure 2-1**.

2.1.1 History of the Catchment and Flooding

Located in one of the older areas of Sydney, the Study Areas were first settled in the early 19th Century. The original natural drainage system comprised rock gullies draining to small pockets of mangroves along the shoreline at the head of various bays. As development proceeded, the natural drainage lines were subsumed into the constructed drainage system of open channels. Eventually, by the late 19th Century, much of the channel system was progressively covered over and piped, with much of the original system forming the backbone of the present-day stormwater drainage system.

Given the age of the existing stormwater drainage network, there is a prevalence of antiquated drainage systems. In many streets, underground pipe systems do not exist, and in their place are high kerbs and/or dish gutters to convey the stormwater, with minor converter networks only located beneath intersections to carry stormwater below the road at the intersection.

Where there are existing drainage pipelines within the street, many of these pipelines are running at capacity by the 50% AEP and 20% AEP flood events, resulting in high volumes of surface flows. It is further noted that, most of the urban development within the Study Area took place prior to the major and minor drainage system design concept of Australian Rainfall and Runoff (AR&R). The resulting subdivision patterns and housing types has led to a lack of formal overland flowpaths with limited or, in some cases, no opportunity for overland drainage of adjacent low points within the street network. Consequently, many un-drained sag points result in localised flooding.

Historical records indicate flooding within the Johnstons Creek and Whites Creek catchments at many locations for events in excess of the 50% AEP. Some of the major storm events in the catchment include June 1949, November 1961, March 1975, November 1984, January 1991, February 2001, October 2014 and April 2015. Flooding within these catchments is typically dominated by flash flooding, with limited warning times available between the start of rainfall and peak flood depths, with some roads and properties within the lower areas of the catchment becoming cut off or isolated due to rising flood waters.

2.1.2 Topography

The topography of the Johnstons Creek and Whites Creek Study Area is shown in **Figure 2-1**. The Johnstons Creek catchment has a ridgeline that runs along the southern, eastern and western boundaries of around 45 m Australian Height Datum (m AHD) in elevation, which slopes down to low-lying areas in the northern portion that are adjacent to Johnstons Creek with an elevation of approximately 0-5 mAHD.

Whites Creek catchment, to the north-west of the Johnstons Creek catchment, is similar with a ridgeline along the southern, eastern and western boundaries, with the low-lying areas located in the north. The ridgeline along the southern boundary separates the Johnstons Creek catchment from Marrickville Valley catchment.

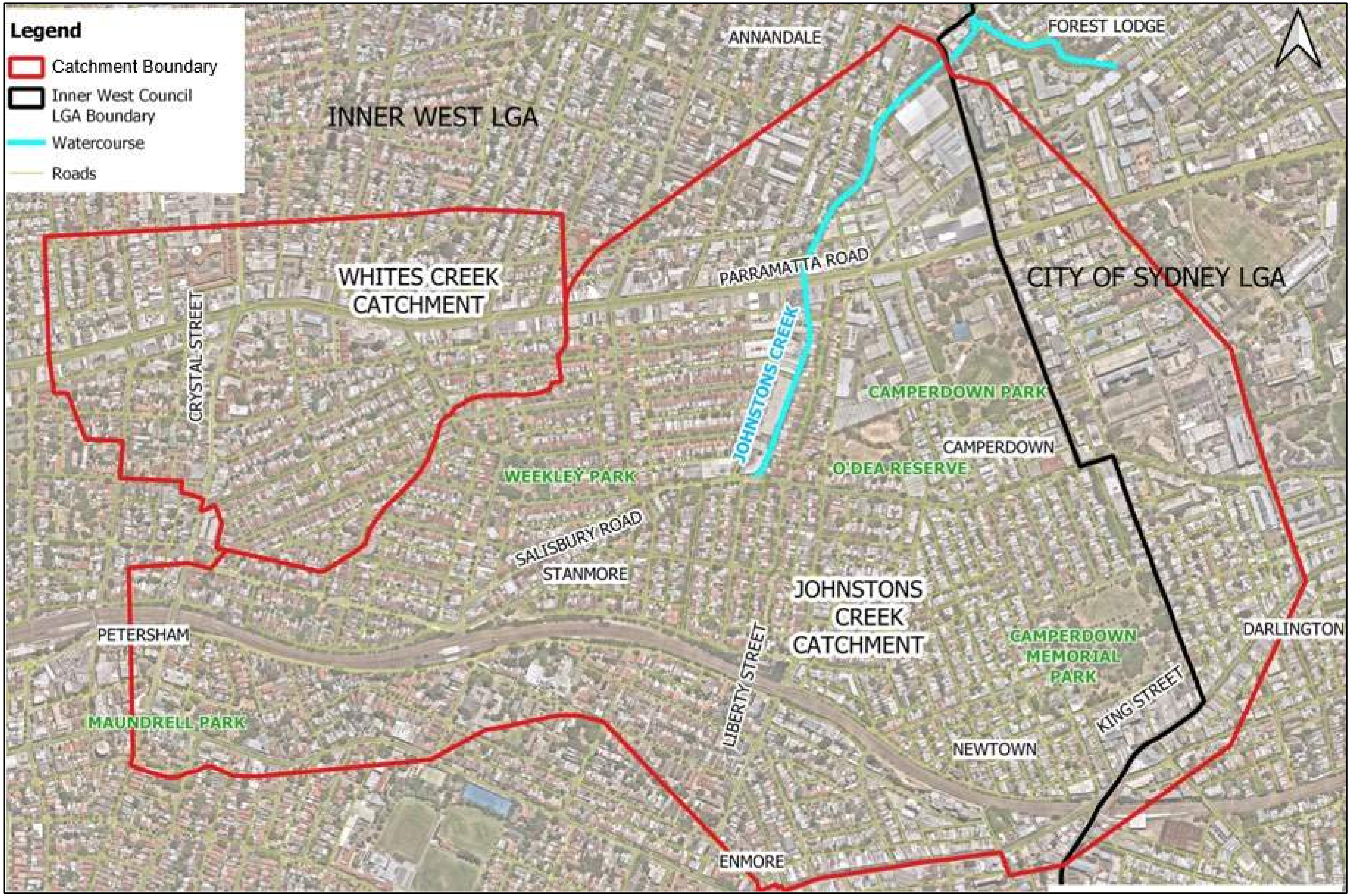

Figure 2-1 Whites Creek and Johnstons Creek Catchment and Study Area

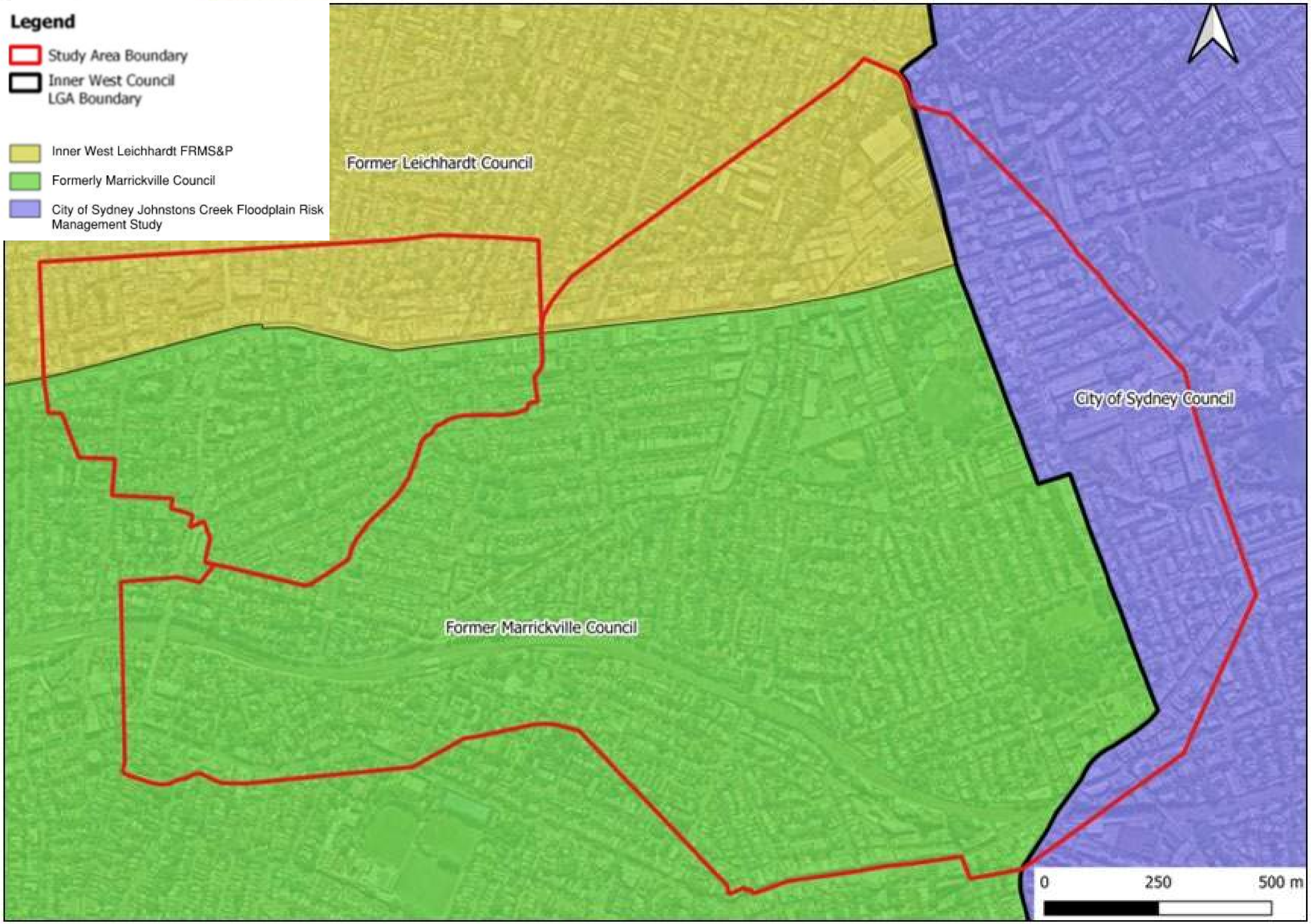
Legend
Study Area Boundary
Inner West Council LGA Boundary
Inner West Leichhardt FRMS&P
Formerly Marrickville Council
City of Sydney Johnstons Creek Floodplain Risk Management Study
Former Leichhardt Council
City of Sydney Council
Former Marrickville Council
0
250
500 m

Figure 2-2 Whites Creek and Johnstons Creek Study Areas Located within the Former Marrickville LGA South of Parramatta Road and West of Mallett Street and Church Street

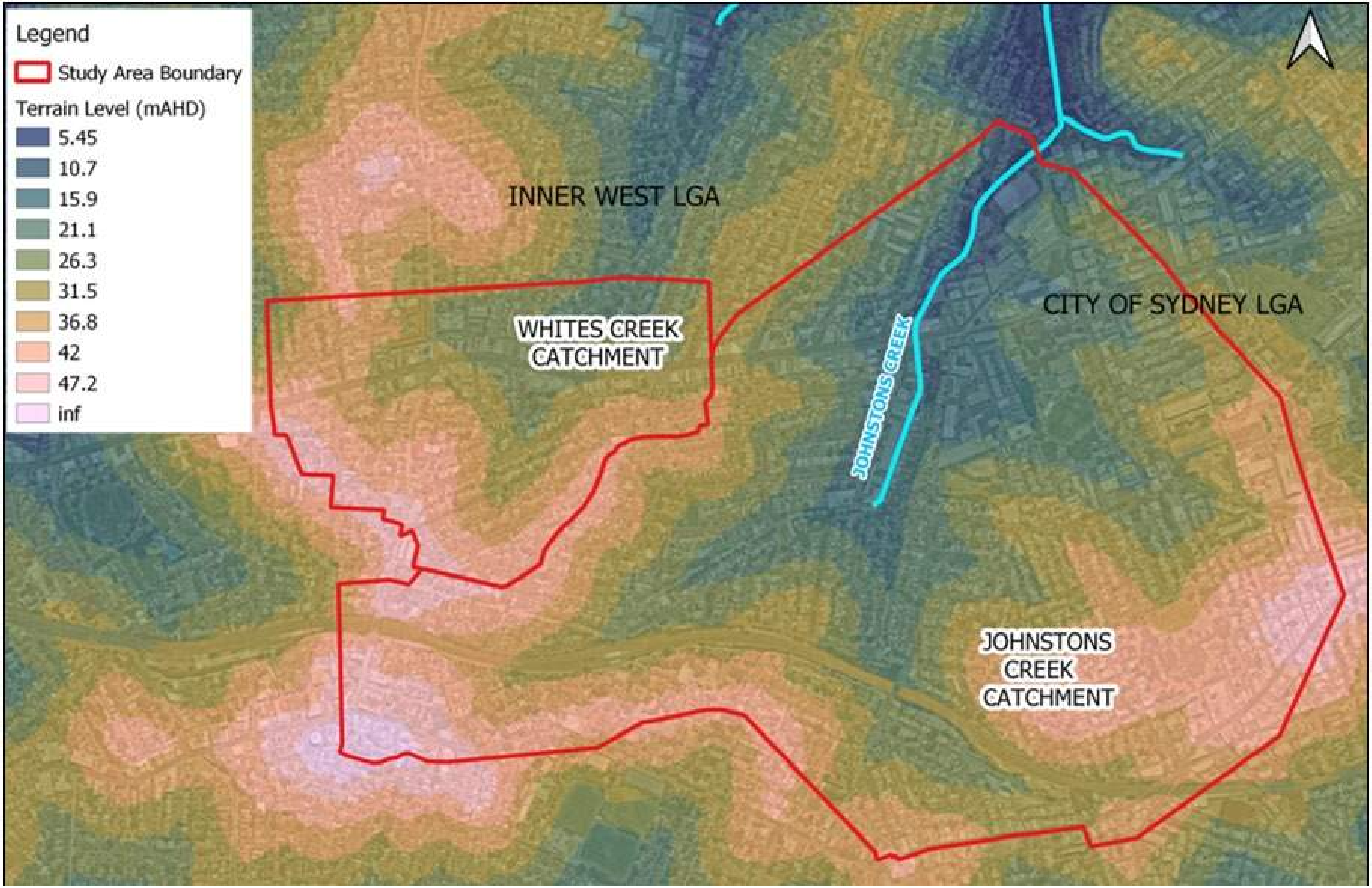

Figure 2-3 Topography of Whites Creek and Johnstons Creek Study Area

2.1.3 Soil Erosion Potential

A review of soil landscapes from eSpade (DPIE, 2021) indicated that the catchment contains two soil landscape groups; Blacktown and Gymea soils. The majority of the Study Area is likely to be underlain by Blacktown soils, which are characterised by shallow to moderately deep red and brown soils on crests, upper slopes and well-drained areas and yellow soils on lower slopes and in areas of poor drainage. Some areas in the northern portion of the Study Area could be underlain by Gymea soils which are characterised by shallow to deep yellow sands on shale lenses.

Blacktown soils are considered to minimal erosion potential as most of the surface is covered by tiles, concrete, bitumen or turf. Soil erosion potential for Gymea soils is high for unsealed surfaces with no stabilising vegetative cover.

2.1.4 Acid Sulfate Soils

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

Potential ASS within the former Marrickville LGA are classified into five land classes with each land class indicating the depth where potential ASS may occur. Development consent is required for work in those five classes as described in **Table 2-1**.

Table 2-1 Acid Sulfate Soil Land Classes (Source: Marrickville LEP 2011)

Class	Works
1	Any works.
2	Works below the natural ground surface. Works by which the watertable is likely to be lowered.
3	Works more than 1 metre below the natural ground surface. Works by which the watertable is likely to be lowered more than 1 metre below the natural ground surface.
4	Works more than 2 metres below the natural ground surface. Works by which the watertable is likely to be lowered more than 2 metres below the natural ground surface.
5	Works within 500 metres of adjacent Class 1, 2, 3 or 4 land that is below 5 metres Australian Height Datum and by which the watertable is likely to be lowered below 1 metre Australian Height Datum on adjacent Class 1, 2, 3 or 4 land.

2.1.5 Contaminated Land

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

The NSW Department of Planning, Industry and Environment (DPIE) regulates contaminated land sites and maintains a record of written notices issued by the NSW Environmental Protection Authority (NSW EPA) in relation to the investigation or remediation of site contamination. Searches were undertaken of the online Contaminated Land Record and the List of NSW Contaminated Sites notified to the EPA on 18 March 2021. A total of four premises were listed within the Study Area:

- O'Dea Reserve, Salisbury Lane, Camperdown;
- Adjacent to Former Service Station, 79 Wilson Street, Newtown;
- Former Service Station, 81 Wilson Street, Newtown; and
- Aluminium Enterprises, 46 Brocks Lane, Newtown.

The first three of these sites have been formerly regulated under the *Contamination Land Management Act 1997* and the last site has had contamination addressed via the planning process. It is important to note that there are limitations to the registers and there may be contaminated sites that are not listed.

2.2 Threatened Flora and Fauna

A review of DPIE's vegetation mapping for the Sydney Metropolitan Area (NSW OEH, 2016) characterised the vegetation within the Study Area as Urban Exotic / Native (refer **Figure 2-4**). A search of the Australian Department of Agriculture, Water and Environment Protected Matters Search Tool (DAWE, 2021a) for matters listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) was undertaken on 17 March 2021 adopting a 5 km buffer. The PMST indicated that ten threatened ecological communities (TECs) are likely to, or may, occur in the area, namely:

- Coastal Swamp Oak (*Casuarina glauca*) Forest of New South Wales and SouthEast Queensland ecological community (Endangered under the BC Act and EPBC Act);
- Coastal Upland Swamps in the Sydney Basin Bioregion (Endangered under the BC Act and EPBC Act);
- Cooks River/Castlereagh Ironbark Forest of the Sydney Basin Bioregion (Endangered under the BC Act and Critically Endangered under the EPBC Act);
- Eastern Suburbs Banksia Scrub of the Sydney Basin Bioregion (Critically Endangered under the BC Act and Endangered under the EPBC Act);
- River-flat eucalypt forest on coastal floodplains of southern New South Wales and eastern Victoria (Endangered under the BC Act and Critically Endangered under the EPBC Act); and
- Turpentine-Ironbark Forest of the Sydney Basin Bioregion (Critically Endangered under the BC Act and EPBC Act);
- Castlereagh Scribbly Gum and Agnes Banks Woodlands of the Sydney Basin Bioregion (Critically Endangered under the BC Act and Endangered under the EPBC Act);
- Shale Sandstone Transition Forest of the Sydney Basin Bioregion (Critically Endangered under the BC Act and EPBC Act);
- Upland Basalt Eucalypt Forests of the Sydney Basin Bioregion (Endangered under the EPBC Act); and
- Western Sydney Dry Rainforest and Moist Woodland on Shale (Endangered under the BC Act and Critically Endangered under the EPBC Act).

A search of the DPIE BioNet database was undertaken to assess the potential for threatened species to occur within the Study Area listed under the NSW *Biodiversity Conservation Act 2016* (BC Act) and/or EPBC Act. A total of 97 threatened flora species have been recorded in the LGA, and 108 threatened and migratory fauna sightings have been recorded in the LGA, consisting of:

- Six amphibian species;
- Five reptiles species;
- 70 bird species;
- 23 mammal species;
- Three gastropod species; and
- One insect species.
- Of these, the following species have records in the Study Area:
- *Pteropus poliocephalus* (Grey-headed Flying Fox) listed as vulnerable under BC Act and EPBC Act;
- *Perameles nasuta* (Long-nosed Bandicoot) listed as endangered under the BC Act; and
- *Ptilinopus superbus* (Superb Fruit Dove) listed as vulnerable under the BC Act.

The search identified 21 TECs listed under the BC Act that are known to occur within the LGA, although based on the DPIE vegetation mapping (refer **Figure 2-4**), it is unlikely any of these occur in the Study Area. The potential impacts on vegetation and threatened species that occur or have the potential to occur within the Study Area should be considered in the development and implementation of any proposed flood modifications options or flood protection works.

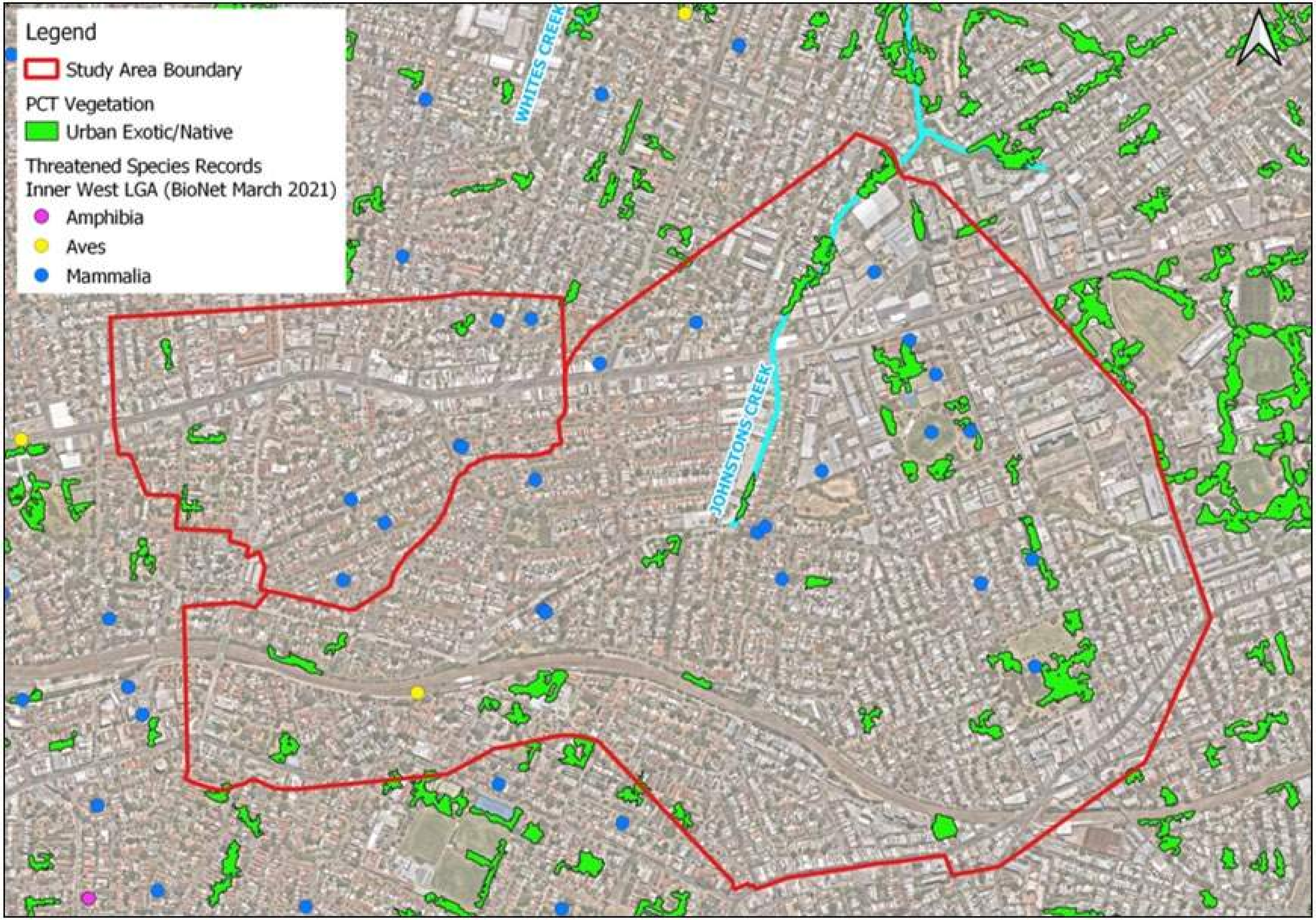

Figure 2-4 Mapping of Whites Creek and Johnstons Creek Biodiversity Constraints

2.3 Heritage

2.3.1 Aboriginal Heritage

Australia contains many different and distinct Aboriginal and Torres Strait Islander groups, each with their own culture, language, beliefs and practices (AIATSIS, 2021). The Inner West LGA is situated on the traditional land of the Gadigal and Wangal peoples of the Eora nation. The Study Area is located on Gadigal land.

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

All Aboriginal sites are protected under the *National Parks and Wildlife Act 1974* (NPW Act) and therefore any floodplain management options that have potential to impact on protected sites should be assessed via the Aboriginal cultural heritage due diligence assessment process detailed in the *Due Diligence Code of Practice for the Protection of Aboriginal Objects in New South Wales* (DECCW, 2010). Impacts to sites should be avoided in the first instance. In the event a management option would impact an item or site listed under the NPW Act, an Aboriginal Heritage Impact Permit (AHIP) must be sought from DPIE.

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

2.3.2 Non-Aboriginal Heritage

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

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

- Australian Heritage Database which incorporates World Heritage List; National Heritage List; Commonwealth Heritage List (DAWE, 2021b);
- State Heritage Register (DCCEW, 2021b); and
- Local Council Heritage as listed on the *Marrickville Local Environmental Plan 2011* (Marrickville Council, 2011a).
- Based on a search of the State Heritage Register (DPIE, 2021) a total of 55 items were found in the IWC LGA were identified as being listed under the NSW *Heritage Act 1977*, with an additional 29 identified as being listed by Sydney Water under Section 170 of the Act. One state heritage items have been identified to be within the Study Area:
- Stanmore Railway Station Group (SHR no. 01251 and Marrickville LEP I248).

There are more than 300 items of local significance and 36 Heritage Conservation Areas listed on the *Marrickville Local Environmental Plan 2011*, with numerous items within the Study Area.

Where it is proposed to undertake works that either directly or indirectly impact on a locally listed heritage item or site, the proponent must refer to the *Marrickville Local Environmental Plan 2011* and Part 8 of the *Marrickville Development Control Plan 2011* for heritage provisions and development guidelines relating to locally listed heritage items.

Figure 2-5 shows Whites Creek and Johnstons Creek Heritage Constraints.

Figure 2-5 Mapping of Whites Creek and Johnstons Creek Heritage Constraints

2.4 Demographic Profile

Knowledge of the demographic character of an area assists in the preparation and evaluation of floodplain management options that are appropriate for the local community. For example, in the consideration of emergency response or evacuation procedures, information may need to be presented in a range of languages and/or additional arrangements may need to be made for less mobile members of the community who may not be able to evacuate efficiently.

Demographic data for the Marrickville and Camperdown area, sourced primarily from the Australian Bureau of Statistics (ABS), was reviewed to gain an appreciation of the social characteristics of the area. The most recent Australian Census was undertaken by ABS in 2016, so this data has been used in the assessment.

The Study Area comprises the Marrickville, Sydenham and Petersham Statistical Area 3 (SA3) and Newtown, Camperdown, Darlington Statistical Area 2 (SA2). All, or part, of the following suburbs are located within the Study Area:

- Enmore;
- Newtown;
- Stanmore;
- Camperdown;
- Petersham;
- Lewisham; and
- Annandale.

Census data showed that the population of the Marrickville, Sydenham and Petersham SA3 in 2016 was approximately 54,609, with a median age of 35 years, which is lower than the median for NSW (38 years). Approximately two thirds of the people living in the Marrickville area are aged between 15-54 years, which suggests that the community is likely to be generally able-bodied and able to evacuate effectively. However, very young children (0-4 years) and the elderly (>75) make up approximately 11% of the population (approximately 5,900 people) so it is important to consider these members of the community in flood risk management planning.

Census data showed that the population of the Newtown, Camperdown and Darlington SA2 in 2016 was approximately 24,839, with a median age of 30 years, which is lower than the median for NSW (38 years). Approximately 80% of the people living in the Camperdown SA3 area are aged between 15-54 years, which suggests that the community is likely to be generally able-bodied and able to evacuate effectively. However, very young children (0-4 years) and the elderly (>75) make up approximately 6% of the population (approximately 1,445 people) so it is important to consider these members of the community in flood risk management planning.

English was the only language spoken in nearly two-thirds (62%) of homes in the Marrickville SA3. Other languages spoken at home included Greek (5.2%), Vietnamese (4.6%), Arabic (1.9%), Portuguese (1.9%) and Cantonese (1.7%). English was the only language spoken in nearly two-thirds (68%) of homes in the Camperdown SA3. Other languages spoken at home included Mandarin (6.6%), Cantonese (1.6%), Spanish (1.2%), Greek (1.2%) and French (0.9%). This suggests that language barriers (e.g. during evacuation, or for flood education) have the potential to be an issue for some households. The inclusion of multi-lingual brochures and personnel may be required in this instance.

Consideration of house prices in Newtown, Camperdown, Stanmore, Annandale and Petersham may assist in the calculation of economic damages incurred during a flood event. According to data from realestate.com.au (realestate.com.au, 2021) the average median property prices across the Study Area are approximately $1,615,000 for houses and $785,000 for units.

3 Review of Available Data

3.1 Whites Creek and Johnstons Creek Flood Study

The Johnstons Creek and Whites Creek Flood Study was completed in 2017 on behalf of Inner West Council formerly Marrickville Council by WMAwater. The Flood Study defined flood behaviour in the catchment for the 50%, 20%, 10%, 2% and 1% Annual Exceedance Probability (AEP) design storms, and the Probable Maximum Flood (PMF). The 2017 Flood Study modelling forms the basis for this Flood Risk Management Study. Further details on the hydrological and hydraulic modelling approaches are discussed below.

3.1.1 Flood Study Approach

Hydrological models were built in DRAINS for each catchment to create flow boundary conditions for input into the hydraulic (TUFLOW) model by using design rainfall patterns specified in AR&R 1987 to produce runoff hydrographs.

The Johnstons Creek model included 240 sub-catchments with an average size of 1.1 ha for a total area of 2.5 km^2, while the Whites Creek model included 48 catchments with an average size of 1.5 ha for a total area of 0.7 km^2. Impervious surface area was determined based on the proportion of sub-catchment area allocated to a number of land use categories, with each category having an estimated impervious percentage based on aerial observation of a representative area. Rainfall losses were modelled using the Horton loss method – with an initial loss of 1.0 mm and a continuing loss of 5.0 mm were adopted.

Comparison with a DRAINS model of the nearby Rose Bay Catchment from a previous study was undertaken to verify the hydrological models. Specific yield (peak discharge divided by upstream catchment area) comparison was undertaken and the Johnstons Creek and Whites Creek catchment models were found to have comparable yields.

The availability of high-quality LIDAR data meant that the Study Area was suitable for 2D hydraulic modelling to assess flood behaviour, with the TUFLOW package being adopted in this case due to wide acceptance in Australia and to ensure consistency with other flood studies previously completed within the (former) Marrickville Council LGA. A separate TUFLOW model was prepared for Johnstons Creek and Whites Creek. The hydraulic models use the runoff hydrographs from the hydrology model as boundary conditions in order to provide estimates of flood depths, velocities and hazard within the Study Area. The models were used to define flood behaviour for the 50%, 20%, 10%, 5%, 2% and 1% AEP flood events and the Probable Maximum Flood (PMF).

The TUFLOW model boundaries are shown in **Figure 2-1**. The TUFLOW model boundary includes the eastern portions of Johnstons Creek catchment, however as these are part of City of Sydney LGA, these areas are not included in the Study Area and will not be considered for flood mitigation options. The Johnstons Creek 2D model had a total area of 2.6 km^2, being approximately bounded at four corners by Missenden Street to the east, Enmore and Stanmore Roads to the south, the Booth St / Mallet St intersection to the north, and Crystal St to the West. The Whites Creek 2D model had a total area of 0.6 km^2 and is approximately bounded by Lorna Lane to the south, and extends to the north an additional 250m past the Study Area boundary of Parramatta Road to include portions of the downstream catchment.

A grid with 2 m by 2 m cell size was adopted for both models in order to provide sufficient detail for roads and overland flow paths. The grid sampled terrain from a 1 m by 1 m DEM generated from LIDAR data (see **Section 3.2** for further discussion). For inflows, local runoff hydrographs were extracted from the DRAINS model and applied to the 2D domain of the TUFLOW model at the downstream end of the sub-catchments. A height versus time boundary was applied to the downstream boundaries (located north of Paramatta Road) of both models to both the 1D and 2D domain.

Roughness coefficients for different flow paths were adopted based on site inspection and correspondence to similar environments, and consistency with ARR 2016 revision guidelines. Buildings and other structures were incorporated into the models based on footprints derived from aerial photography, and modelled as flow path obstructions, while bridges were modelled as 1D features within open channels. All pipes equal to or smaller than 300mm in diameter were assumed to be fully blocked and not included in the Flood Study model. The catchment drainage systems defined in each model included 652 pipes, 659 pits / nodes, and 111 open channel segments for Johnstons Creek, and 114 pipes and 120 pits / nodes for the Whites Creek model.

The joint hydrologic / hydraulic model was calibrated based on the 25th April 2015 event by comparing flood affectation at various locations based on photographs acquired from community consultation and council database flooding complaints. The model was found to effectively replicate some degree of flood affectation at the locations. Comparison was also carried out with previous studies for verification purposes.

Sensitivity analyses were conducted for the 1% AEP and 5% AEP models based on hydrologic routing lag, Manning's roughness values, pipe blockage, and climate change both rainfall increase (10%, 20%, and 30%).

Design storm result analysis and mapping included peak depths, levels and velocities. The analysis also included a pipe capacity assessment. In addition, the 20% AEP, 5% AEP, 1% AEP and PMF events also had provisional hydraulic hazard, hydraulic categorisation (floodway, flood storage, and flood fringe) and the 1% AEP and PMF events also had flood emergency response classifications.

A provisional Flood Planning Area (FPA) and Flood Control Lot tagging was conducted for the Study Area. The report also briefly summarised the relevant flood development controls for the Study Area.

Eleven flooding hotspots were identified in the Flood Study, 10 within Johnstons Creek and one within Whites Creek which were:

- Hotspot 1 – Parramatta Road, Bridge Road and Cardigan Street, Stanmore;
- Hotspot 2 – Salisbury Road near Stafford Street, Stanmore;
- Hotspot 3 – Salisbury Road, Camperdown;
- Hotspot 4 – Mallett Street, Fowler Street and Gibbens Street, Camperdown;
- Hotspot 5 – Cardigan Street, between Salisbury Road and Railway Avenue, Stanmore;
- Hotspot 6 – Liberty Street, Bedford Street and Railway Avenue, Stanmore;
- Hotspot 7 – Lennox Street and Australia Street, Newtown;
- Hotspot 8 – Trafalgar Street near Crammond Park, Petersham;
- Hotspot 9 – Probert St and Probert Ln (near St Marys St), Newtown;
- Hotspot 10– Australia St and Denison St (near Camperdown Park), Camperdown; and
- Hotspot 11 – Parramatta Road near Phillip Street, Stanmore (Whites Creek catchment).

Refer to **Section 7.5** for maps of the hotspot locations.

3.1.2 Flood Study Data Provided

As part of project inception, Inner West Council provided Stantec with the following data related to the Johnstons Creek and Whites Creek Flood Study (WMAwater, 2017):

- LIDAR data collected in 2013 and obtained from the Land and Property Information (LPI) division of the NSW Government Department of Finance, Services and Innovation. Open water and vegetation also tend to affect the accuracy of LIDAR data. A 1 m x 1 m Digital Elevation Model (DEM) was constructed from the LIDAR to form the basis of the TUFLOW model; and
- Ground and floor level survey at select locations from the previous Whites Creek, Johnstons Creek North, Johnstons Creek South (Dalland and Lucas, 1996, 1998 and 1999) and Johnstons Creek West (Stantec, 2008) studies were used to verify the LIDAR data and was found to have an average elevation difference of 0.01 m in the Johnstons Creek catchment and -0.02 m in the Whites Creek catchment.
- In addition to these Flood Study model terrains, Stantec sourced several other LiDAR and DEM datasets for this study. Detailed review of the following LiDAR sources has been conducted (refer to **Section 3.6.2**):
- LiDAR points provided by Council from an unknown source and date covering part of the Study Area;
- The ELVIS - Elevation and Depth - Foundation Spatial Data website was accessed with two datasets available from the website. The files appear to have been recorded on the following dates:
    - 2013-04-10 – 1m x 1m ASC grid data set in 2km x 2km with an accuracy of 0.3m (95% Confidence Interval) vertical and 0.8m (95% Confidence Interval) horizontal in GDA94 and MGAz56; and
    - 2020-05-10 - 1m x 1m TIFF data set in 2km x 2km with an accuracy of 0.3m (95% Confidence Interval) vertical and 0.8m (95% Confidence Interval) horizontal in GDA2020 and MGAz56.

3.2 Survey Information

The Flood Study model (WMAwater, 2017) was constructed utilising the following available data:

- LIDAR data collected in 2013 and obtained from the Land and Property Information (LPI) division of the NSW Government Department of Finance, Services and Innovation. Open water and vegetation also tend to affect the accuracy of LIDAR data. A 1 m x 1 m Digital Elevation Model (DEM) was constructed from the LIDAR to form the basis of the TUFLOW model; and
- Ground and floor level survey at select locations from the previous Whites Creek, Johnstons Creek North, Johnstons Creek South (Dalland and Lucas, 1996, 1998 and 1999) and Johnstons Creek West (Stantec, 2008) studies were used to verify the LIDAR data and was found to have an average elevation difference of 0.01 m in the Johnstons Creek catchment and -0.02 m in the Whites Creek catchment.
- In addition to these Flood Study model terrains, Stantec sourced several other LiDAR and DEM datasets for this study. Detailed review of the following LiDAR sources has been conducted (refer to **Section 3.6.2**):
- LiDAR points provided by Council from an unknown source and date covering part of the Study Area;
- The ELVIS - Elevation and Depth - Foundation Spatial Data website was accessed with two datasets available from the website. The files appear to have been recorded on the following dates:
    - 2013-04-10 – 1m x 1m ASC grid data set in 2km x 2km with an accuracy of 0.3m (95% Confidence Interval) vertical and 0.8m (95% Confidence Interval) horizontal in GDA94 and MGAz56; and
    - 2020-05-10 - 1m x 1m TIFF data set in 2km x 2km with an accuracy of 0.3m (95% Confidence Interval) vertical and 0.8m (95% Confidence Interval) horizontal in GDA2020 and MGAz56.

3.3 GIS Data

As part of project inception, Inner West Council provided Stantec with the following GIS data for the study:

- Local Environment Plan (LEP) land use zone mapping and Acid Sulfate Soil (ASS) layer;
- LGA Boundary layer;
- LiDAR data from an unknown source and date covering part of the Study Area;
- Stormwater pit and pipe network;
- State Environmental Planning Policy (SEPP) 2016 Coastal Management layer; and
- Aerial imagery from an unknown source and date.

Aside from these GIS layers, provided by Council during the early stages of the project, various other publicly available GIS layers were sourced by Stantec for this study including high quality aerial imagery from NearMap (2021) recorded at various periods for the Study Area and its surrounds. This aided in not only providing details about the current site, but also the historical site at the time of the Flood Study. Another example is the various flora and fauna and heritage GIS databases described in **Section 2**.

3.4 Site Inspection

Site inspections of the Study Area were conducted by Stantec representatives on 12 May 2021. In total, 33 different sites within the Study Area were visited, all in areas identified as flood affected based on Flood Study outcomes. The location of the sites visited is shown in **Figure 3-1**. The site visits provided the opportunity to review the following:

- Review flood hotspots identified in the Flood Study (WMAwater, 2017), and the flood study model results compared to the observed topography and layout of the site;
- Review of site layouts and the elevations of floor levels for buildings in the vicinity of flooded areas to help inform the development of a floor level survey scope;
- Noting of the current development of the Study Area with some of the changes in sites discussed further in **Section 3.6.2** and **Section 3.6.3**; and
- Initial review of opportunities and constraints for potential future flood mitigation options.

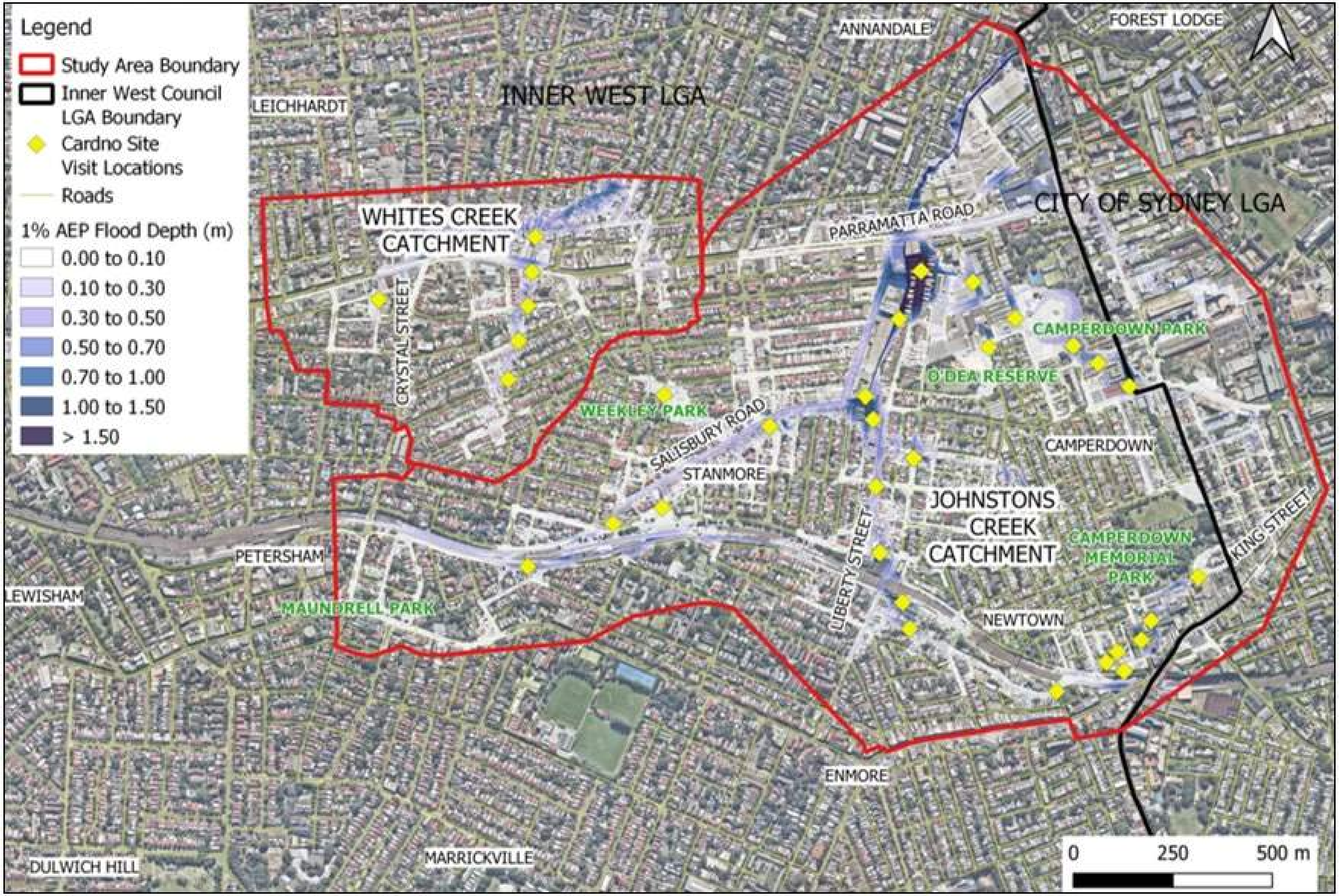

Figure 3-1 Site Locations for Whites Creek & Johnstons Creek Study Area Visited by Stantec on 14/05/2021, with Underlay of Peak 1% AEP Depth Results from the Flood Study (WMAwater, 2017)

3.5 Floor Level Survey

Floor level survey was prepared for the Whites Creek and Johnstons Creek catchment as part of this Study. In total, 403 floor levels were surveyed. For flood affected buildings that did not have surveyed levels from the survey, floor levels were estimated as discussed further in **Section 6.2.3**.

3.6 Flood Study Model Review and Update

Since the completion of the Johnstons Creek and Whites Creek Flood Study in 2017, several developments have occurred in both floodplain management guidance and standards and in the Study Area itself. These changes have the potential to impact the suitability of the Flood Study model in accurately representing the Study Area and its flood behaviour. Therefore, in order to confirm the potential impacts of these changes, a model review process has been conducted accounting for these changes in updated 1% AEP and 5% AEP models. The following model updates were included in this review process:

- Adoption of the AR&R 2019 design rainfall method as opposed to the AR&R 1987 method adopted in the Flood Study model;
- Updates to the model topography to reflect development and changes in the Study Area post-2013; and,
- Updates to the model building polygons to reflect development and changes in the Study Area post-2013.

These updates are detailed further in the following sections with model outcomes from this review discussed in **Section 3.6.4**.

3.6.1 AR&R 2019 Design Rainfall Update

3.6.1.1 Background

An important change has occurred in the development of flood estimation in Australia, with the release of Australian Rainfall and Runoff 2016 (AR&R 2016). On 25 November 2016, Geosciences Australia announced that:

> *The AR&R 2016 Guidelines have now been officially finalised, providing engineers and consultants with the guidance and datasets necessary to produce more accurate and consistent flood studies and mapping across Australia, now and into the future.*

Following this, the AR&R 2019 update was released which included minor updates to AR&R 2016 without changes to the edition. There are specific changes to the methodology for estimation of flood behaviour compared to the AR&R 1987 methodology that was adopted in the Whites Creek and Johnstons Creek Flood Study (WMAwater, 2017). These include:

- Rainfall – the Bureau of Meteorology (BoM) has re-analysed all the Intensity-Frequency-Duration (IFD) parameters across Australia, incorporating 30 further years of data and many more rainfall stations. The method of derivation has also changed, meaning the previously used IFD coefficients have been updated. It is also noted that the standard reporting for storm duration has been reduced;
- Design Storms – AR&R 2019 recommends the utilisation of a suite of design rainfall temporal patterns, with ten patterns for each Annual Exceedance Probability (AEP) and duration of event;
- Storm Loss Rates – AR&R 2019 recommends the use of initial and continuing loss rates for design storms, and is no longer recommending the use of runoff coefficients for hydrological modelling. The loss rates provided are also for the entire storm, as opposed to the burst losses adopted in AR&R 1987; and
- Storm Loss Rates – AR&R 2019 provides for the use of three types of area when assessing loss rates - directly connected impervious areas, indirectly connected impervious areas and pervious areas. The document also provides guidance as to the calculation of these areas.

3.6.1.2 Design Rainfall Update

In AR&R 1987, there was a single temporal pattern defined for each storm burst duration of interest. This limited the number of runs required to identify the critical storm burst duration within a catchment. In AR&R 2019, ten temporal patterns are provided for each storm burst duration.

As part of this model review, all ten temporal patterns were run for each storm burst duration and the median peak flow was determined at each location of interest. It is noted that this requires a ten-fold increase in hydrological assessments to identify the critical storm burst duration, which may vary depending on location within the catchment. Furthermore, no single temporal pattern will give the median peak flow and that rather the temporal pattern (which gives the peak flow closest to, but higher than, the median flow) has been adopted for assessment purposes.

As part of this model review, the DRAINS model from the Johnstons Creek and Whites Creek Flood Study was updated to AR&R 2019 rainfall for the 1% AEP (1 in 100 year), and 5% AEP (1 in 20 year) events. Two DRAINS models were prepared as part of the Flood Study, one for Johnstons Creek and one for Whites Creek.

For the Johnstons Creek model, for the 1% AEP and 5% AEP, all ten temporal patterns were prepared for the 20, 30, 45, 60, and 90 minute storms. Compared to the AR&R 1987 critical duration of 60 minute, these modelled durations provided sufficient scope to encompass any potential shift in critical duration as part of the AR&R 2019 update.

For the Whites Creek model, the smaller catchment size means that the AR&R 1987 has a relatively shorter critical duration of 20 minutes. For the 1% AEP and 5% AEP all ten temporal patterns were prepared for the 10, 20, 30, and 45 minute storms. Due to the expected shorter critical duration for this catchment these modelled durations provided sufficient scope to encompass any potential shift in critical duration as part of the AR&R 2019 update.

3.6.1.3 Review of Rainfall Loss Approach

AR&R 2019 recommends the use of the initial / continuing loss approach, whereas the Flood Study model used Horton Loss model which is the default loss model for DRAINS with ILSAX hydrology. Stantec conducted a review of the adopted Horton losses from the Flood Study compared to an equivalent initial / continuing loss approach as recommended in AR&R 2019.

The equivalent initial / continuing losses suitable for the Study Area were concluded to be:

- 1% AEP – initial loss 6.4 mm and continuing loss 0.7mm / hour;
- 5% AEP - initial loss 8.5 mm and continuing loss 0.7mm / hour.

The losses were adopted using the Antecedent Moisture Condition (AMC) of 3.0 as adopted in the Flood Study model. In addition, a sensitivity check to an AMC of 3.5 was conducted. The outcomes of the total loss comparison showed for both AMC 3.0 and 3.5 total losses are similar for the shorter durations such as the 10 and 20 minute events. However, as the burst duration increases the Horton Losses becomes higher than that estimated by the Initial-Continuing loss model.

Nevertheless, the comparison shows that the choice of loss model is unlikely to make a significant difference to model results the critical duration was assumed to be relatively short, the catchments are highly impervious so rainfall losses have less affect, and the rainfall excess is much higher than the losses for the 5% & 1% AEP events.

Therefore, the Horton loss curves from the Flood Study model were retained within the review models.

3.6.1.4 Review of Other Model Assumptions

Stantec also conducted a high-level review of other Flood Study model components. It was found that the model set-up was generally appropriate including surface roughness, impervious percentage, and pit and pipe modelling. For time of concentration calculation, the Kinematic Wave equation was adopted which is generally not typically utilised for large, piped catchments, however as calculated travel times are in the appropriate range, this was not considered a concern.

3.6.2 Topography Review and Update

Since the Flood Study model was completed, the catchment has undergone a substantial amount of change and development. As covered in **Section 3.2**, the Flood Study model terrain was based on LiDAR data recorded in 2013, sourced from the ELVIS website from 10 April 2013. A review was undertaken to assess the adequacy of the model terrain by comparing to newer LiDAR data collected May 10, 2020 sourced from the ELVIS website (refer to **Section 3.2** for further details).

Comparing the Flood Study model terrain to the newer DEM showed that the terrain differences between 2013 and 2020 data are largely within +/- 0.2 metres outside of building footprints, with some notable exceptions where significant development has occurred. A comparison of Flood Study model terrain and 2020 LiDAR data is included in **Figure 3-2**.

For Johnstons Creek & Whites Creek Study Area the significant terrain differences outside of building footprints appear to be:

- The 2020 data appears to have the bridge over the railway line at Newtown train station. As the bridge would present a negligible flow restriction, it is suitable for the railway line be modelled in the 2D domain of the model and the bridge structure over the highway was disregarded. This was the approach adopted within the Flood Study model therefore no change to the model terrain was required;
- There are narrow sections of significant differences along the perimeters of the rail corridor. Council had noted that there has not been any major recent works along this corridor to suggest these differences reflect changes in topography from 2013 to 2020. Therefore, these differences are presumably due to slight spatial misalignments in the data sets with the steep sides of the corridor resulting in differences. It is not clear upon review that either the 2013 or 2020 are particularly misaligned along this rail corridor more than the other;
- It also appears that the elevated Stanmore station platform has been recorded in the 2013 LiDAR but not the 2020 LiDAR, as this is a solid, permanent structure the 2013 LiDAR is better in this instance; and
- There are significant differences for a site north of Parramatta Road near the corner of Alexandra Drive and Booth Street due to a new building on this site (discussed further in **Section 3.6.3**).

Therefore, it appears there are only minor terrain differences from 2013 to 2020 LiDAR within the Johnstons Creek and Whites Creek Study Area due to development or alteration of sites over that period. It appears that significant terrain differences between the two data sets can be explained by slight misalignment and recording differences, with no clear indication that the 2013 data is in poorer condition than the 2020 data.

As it is not clear that the 2020 terrain provides better accuracy than the 2013 terrain, the Flood Study model terrain was thus retained in the updated Flood Study Model for Johnstons Creek and Whites Creek Study Area.

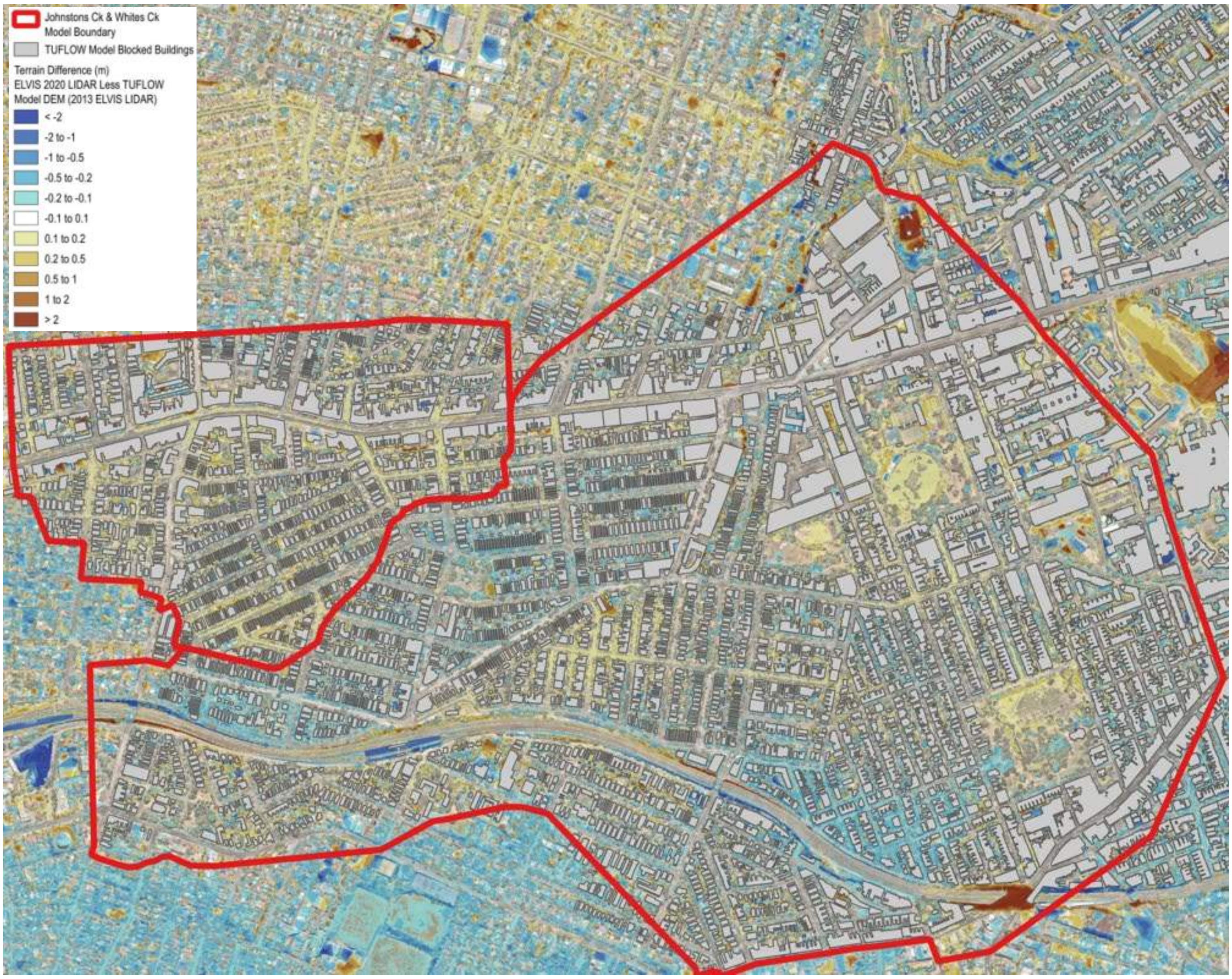

Figure 3-2 Terrain Differences - 2020 LiDAR Less 2013 LiDAR Used in the Whites Creek and Johnstons Creek Flood Study with Labels of Key Sites

3.6.3 Model Building Polygon Review and Update

The Johnstons Creek and Whites Creek Flood Study model assumed full blockage of building footprints by removing building polygons from the 2D terrain of the model. Generally, this approach is considered appropriate. A review was conducted of building footprints from the Flood Study TUFLOW model and more recent 2020 Geoscape building footprints provided by DCCEW, offering a detailed and more up-to-date dataset. Review of the building polygons layer showed that in most instances the polygons align with buildings shown in the aerials, but there were particular instances where this is not the case.

There are presumably two reasons for building polygons not matching building locations in latest available aerials:

- The base data used in the model building polygon layer did not include some areas. The main example of this is where an area of historical buildings along Susan Street in the northern reaches of the Johnstons Creek Study Area have not been included in the polygon layer, presumably because data was not available at this location. Review of the model set-up and results suggest these buildings are only on the fringe of the Johnstons Creek floodplain, however they have been added to the updated model;
- There has been development since the Flood Study with new or removed buildings in the area. Instances of potential new buildings and extended buildings in Johnstons Creek and Whites Creek that have been added to the updated model include:
  - A new building was constructed on a site north of Parramatta Road near the corner of Alexandra Drive and Booth Street. This site is outside the main flood extents but near an overland flow inflow point, though flows do not interact with the site significantly. Nevertheless, the polygon was added to the model;
  - A new building complex has been constructed on the west side of Camperdown Park oval which was added to the updated model;
  - There has been significant redevelopment of sites associated with Royal Alfred Hospital. These sites are within City of Sydney LGA however had potential to alter overland flow downstream within the Inner West LGA, therefore these changes were added to the updated model;
  - In the centre of the Whites Creek catchment just south of Parramatta Road in the middle of the flowpath, an existing car dealership building was expanded. The previous flowpath underneath the building (8m x 0.6m) has been retained in the new building as confirmed on review of design plans for the development approval. This building polygon in the model was expanded;
  - A building fronting Parramatta Road on the north side has been removed in Whites Creek catchment; and
  - Other minor redevelopment sites that are in the floodplain throughout both catchments have been added in such as garages and new and altered building footprints. These site changes were reviewed using latest available aerial imagery compared to historical aerials from the time of the Flood Study.

3.6.4 Model Review Results – Johnstons Creek

The model updates discussed in the above sections were incorporated into a Johnstons Creek review model for the 1% AEP and 5% AEP events, with the outcomes of this modelling summarised in the following sub-sections.

3.6.4.1 Critical Duration

For both the 1% AEP and 5% AEP events, all ten temporal patterns were prepared for the 20, 30, 45, 60, and 90 minute storms. Of the ten temporal patterns for each duration, the median pattern was selected for each duration, and then these duration median results were combined to create the peak flood results. The critical durations for the 1% AEP and 5% AEP from the updated modelling is shown in **Figure 3-3** and **Figure 3-3** respectively.

The critical duration for the majority of the Study Area is the 30 minute storm for the 1% AEP, and the 45 minute for the 5% AEP. For some disconnected ponding areas and for the downstream portion of the Study Area north of Parramatta Road the longer duration storms are critical. Compared to the Flood Study AR&R 1987 critical duration of 60 minute, the shorter critical duration for AR&R 2019 is in keeping with Stantec's past experience on updates to AR&R 2019 where the critical duration has been found to almost always shortens.

3.6.4.2 Peak Water Level Differences

A comparison of peak water level differences for the updated AR&R 2019 model compared to the Flood Study AR&R1987 model for the 1% AEP and 5% AEP from the updated modelling is shown in **Figure 3-5** and **Figure 3-6** respectively.

The results show that throughout the Study Area, the proposed revision to AR&R 2019 has resulted in reductions in peak water level results for both the 1% AEP and 5% AEP throughout the Johnstons Creek catchment. These reductions in peak water level results are in keeping with Stantec's past experience on updates to AR&R 2019, where the severity of peak flooding was almost always reduced as a result of AR&R 2019 updates.

Water level reductions from the Flood Study results are not significantly different for the majority of the Study Area, typically anywhere from -0.01 metres to -0.2 metres for both the 1% AEP and 5% AEP events. The section of Johnstons Creek south of Parramatta Road has more significant reductions of greater than 0.5 metres. It is expected that this is due to this location being the confluence of most runoff from the site resulting in the reductions being more pronounced at this location.

The terrain and building polygon changes do not result in any significant areas of water level increases, the only example is in the immediate vicinity of the new building west of Camperdown Park oval where there are minor localised increases. Therefore updated model results suggest that site changes post-2013 do not have a significant impact on flood behaviour within the Study Area.

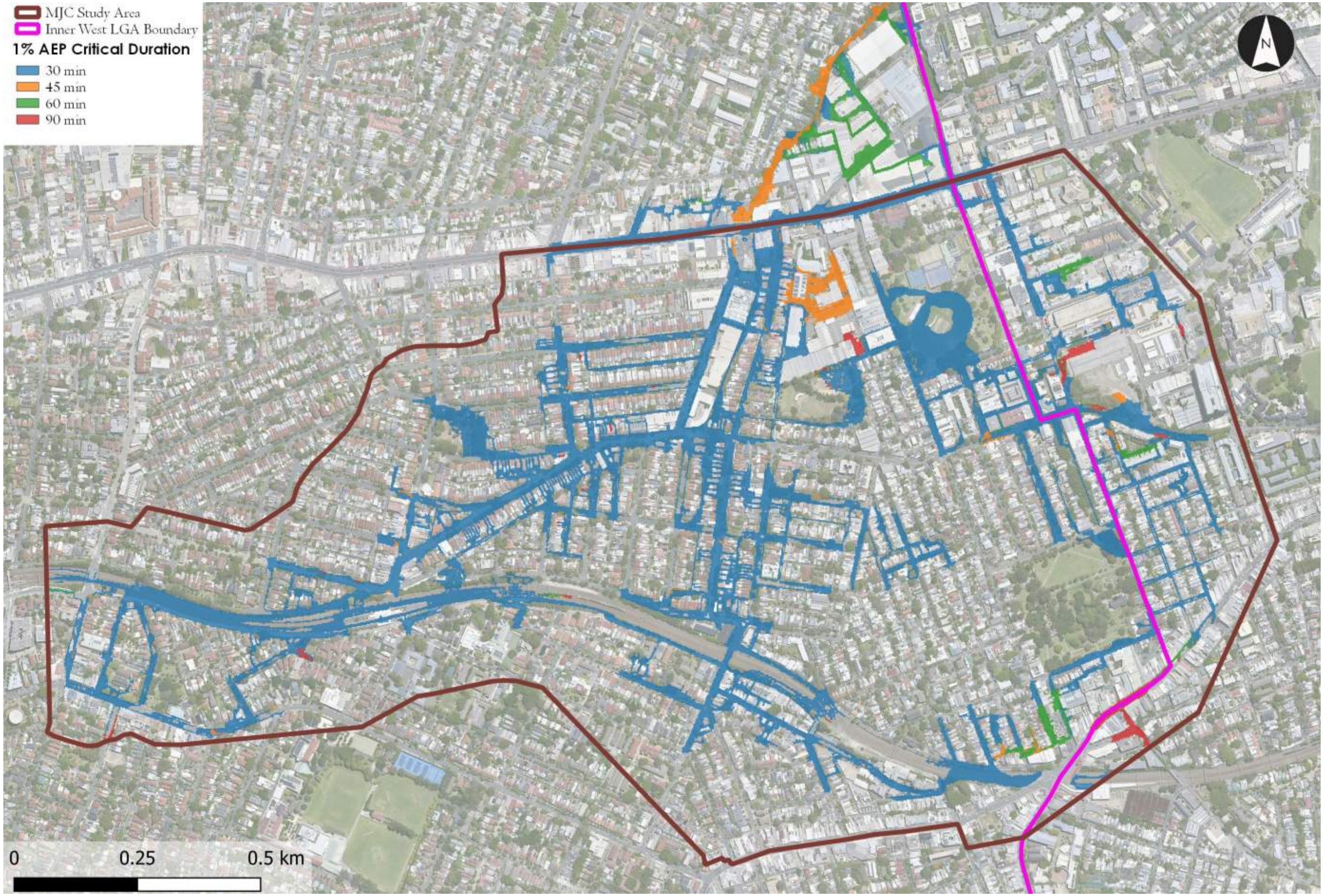

Figure 3-3 1% AEP Critical Duration Storms for Updated Model for Johnstons Creek Study Area Based on AR&R 2019 Design Rainfall Updates

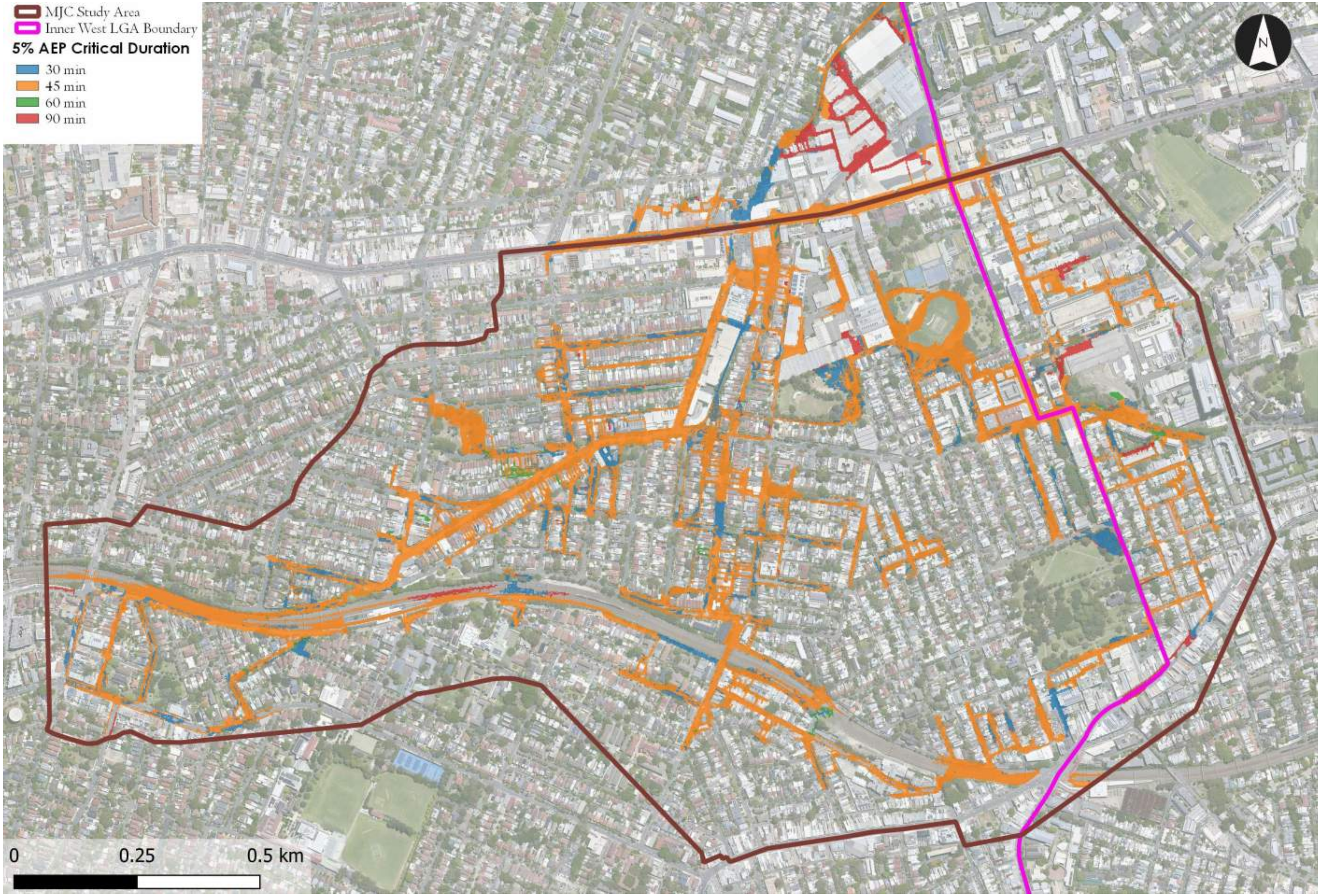

Figure 3-4 5% AEP Critical Duration Storms for Updated Model for Johnstons Creek Study Area Based on AR&R 2019 Design Rainfall Updates

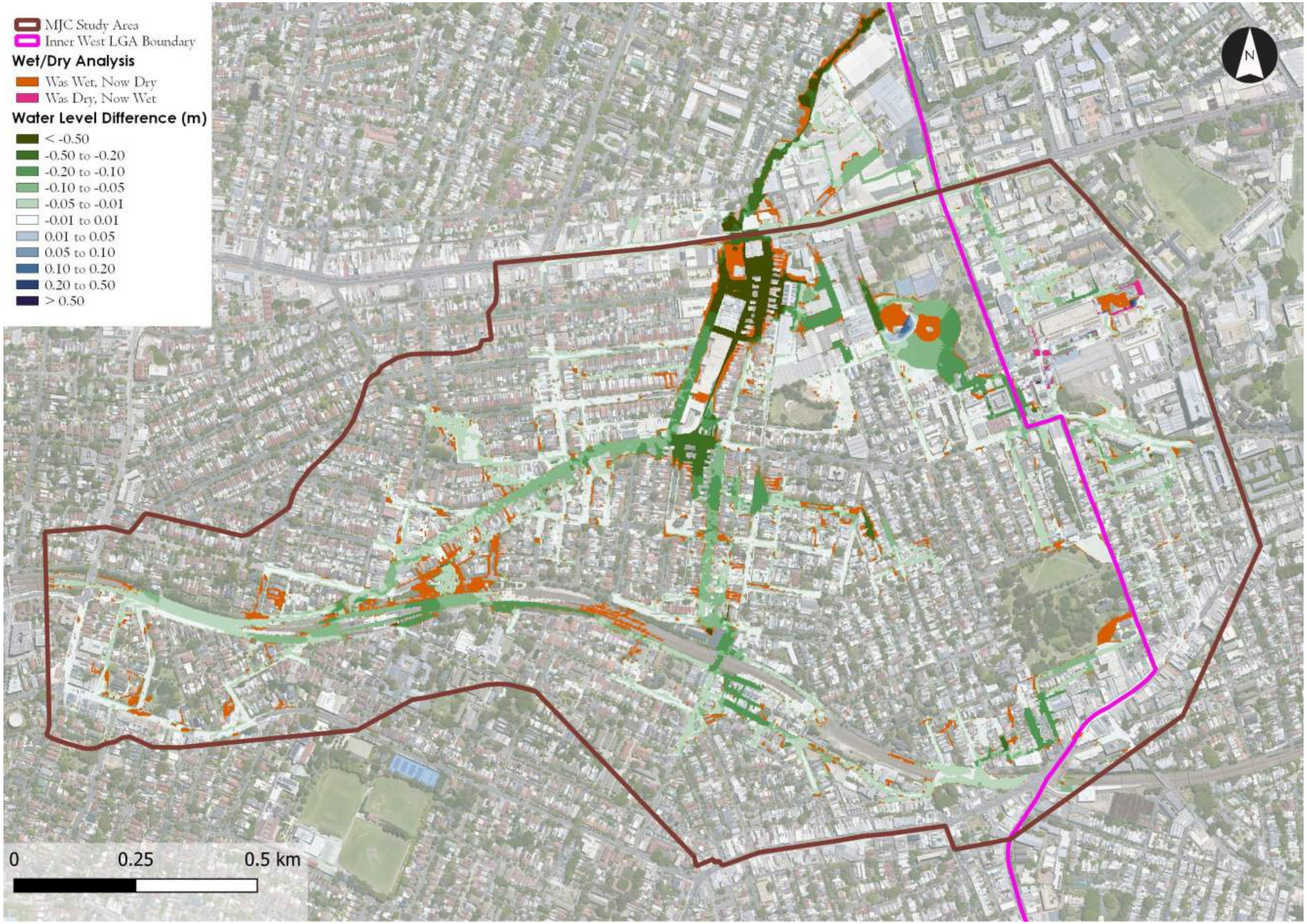

Figure 3-5 1% AEP Peak Water Level Differences – Johnstons Creek - Updated AR&R 2019 Model Less Flood Study AR&R 1987

Figure 3-6 5% AEP Peak Water Level Differences – Johnstons Creek - Updated AR&R 2019 Model Less Flood Study AR&R 1987

3.6.5 Model Review Results – Whites Creek

The model updates discussed in the above sections were incorporated into a Whites Creek review model for the 1% AEP and 5% AEP events, with the outcomes of this modelling summarised in the following sub-sections.

3.6.5.1 Critical Duration

For both the 1% AEP and 5% AEP events, all ten temporal patterns were prepared for the 10, 20, 30, 45, and 60 storms. Of the ten temporal patterns for each duration, the median pattern was selected for each duration, and then these duration median results were combined to create the peak flood results. The critical durations for the 1% AEP and 5% AEP from the updated modelling are shown in **Figure 3-7** and **Figure 3-8** respectively.

The critical duration for the majority of the upper catchment the 20 minute storm for the 1% AEP, and the 10 minute for the 5% AEP. For the downstream portion of the Study Area north of Parramatta Road the 30 minute storm is critical for both the 1% AEP and 5% AEP events. Compared to the Flood Study AR&R 1987 critical duration of 20 minute, the critical duration for AR&R 2019 is comparable.

3.6.5.2 Peak Water Level Differences

A comparison of peak water level differences for the updated AR&R 2019 model compared to the Flood Study AR&R1987 model for the 1% AEP and 5% AEP from the updated modelling is shown in **Figure 3-9** and **Figure 3-10** respectively.

The results show that throughout the Study Area, the proposed revision to AR&R 2019 has resulted in reductions in peak water level results for both the 1% AEP and 5% AEP throughout the Whites Creek catchment. These reductions in peak water level results are in keeping with Stantec's past experience on updates to AR&R 2019, where the severity of peak flooding was almost always reduced as a result of AR&R 2019 updates.

Water level reductions from the Flood Study results are not significantly different for the majority of the Study Area, typically anywhere from -0.01 metres to -0.2 metres for both the 1% AEP and 5% AEP events.

The terrain and building polygon changes for the most part do not result in any significant areas of water level increases. The only notable example is a result of the building removal for the north fronting of Parramatta Road, which has opened up a new ponding location for waters to access the rear of these properties. This results in some area of newly flooded area at the rear of the properties. However given this is in the upper portion of the catchment and the flooding is minor it is not seen as a significant change.

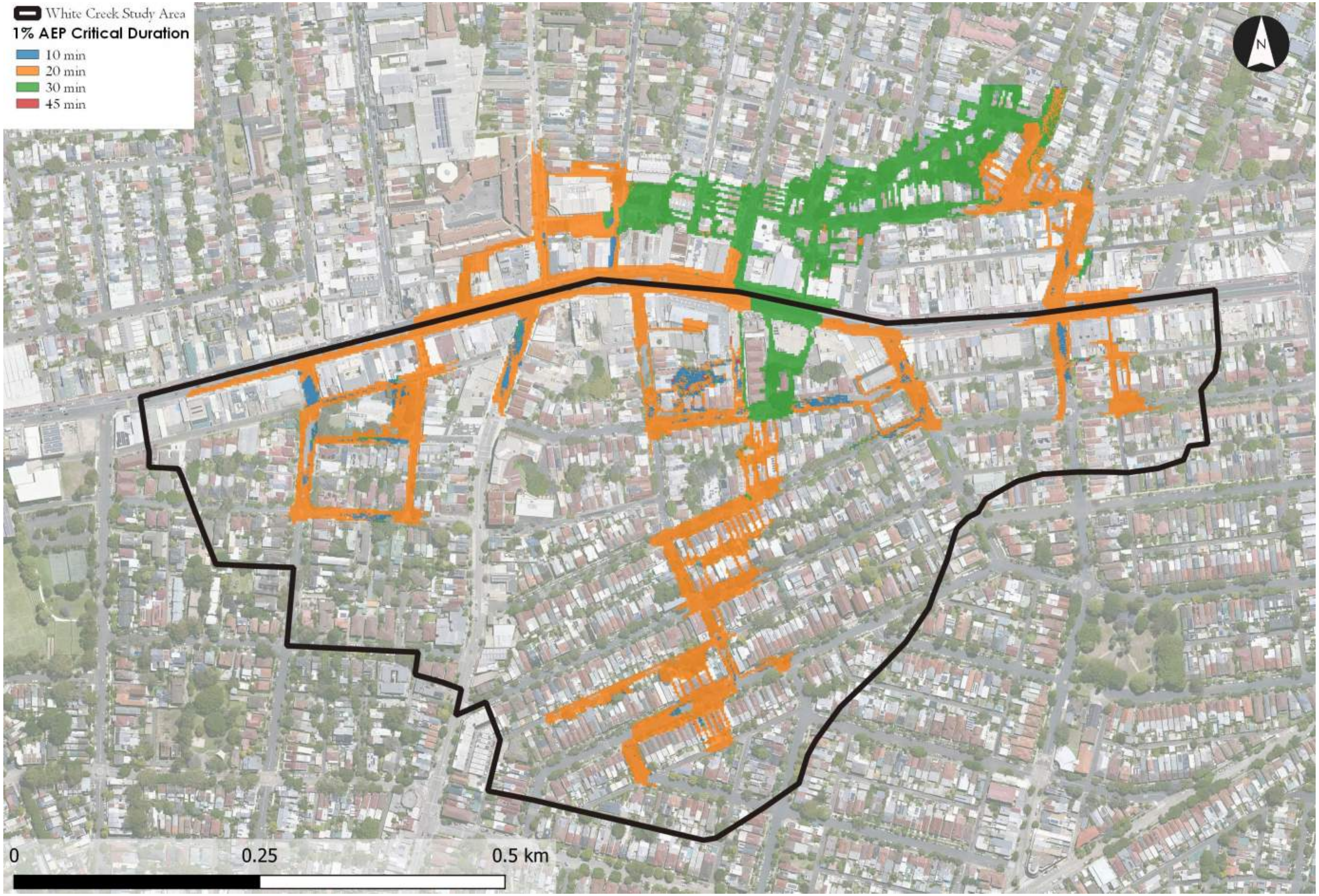

Figure 3-7 1% AEP Critical Duration Storms for Updated Model for Whites Creek Study Area Based on AR&R 2019 Design Rainfall Updates

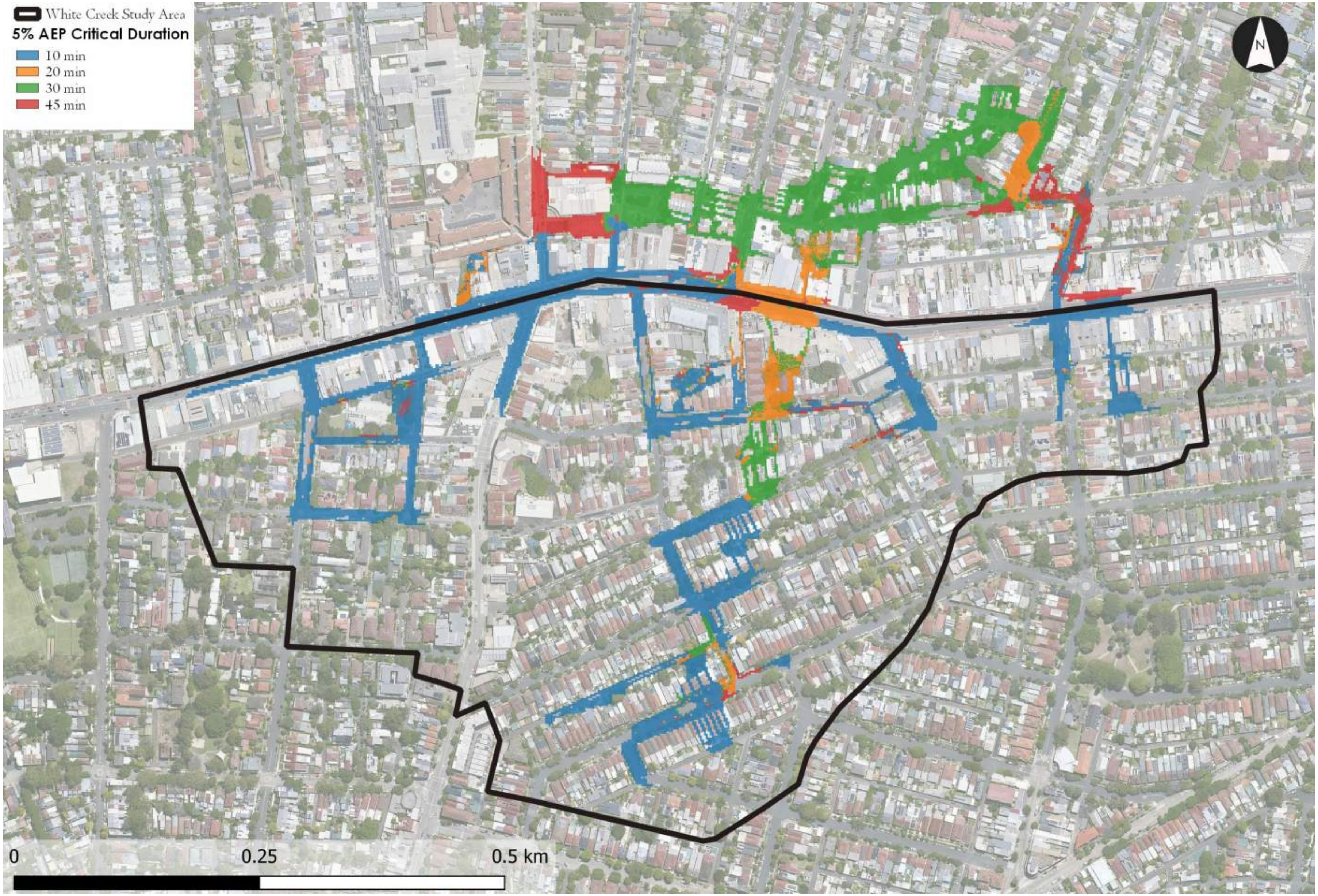

Figure 3-8 5% AEP Critical Duration Storms for Updated Model for Whites Creek Study Area Based on AR&R 2019 Design Rainfall Updates

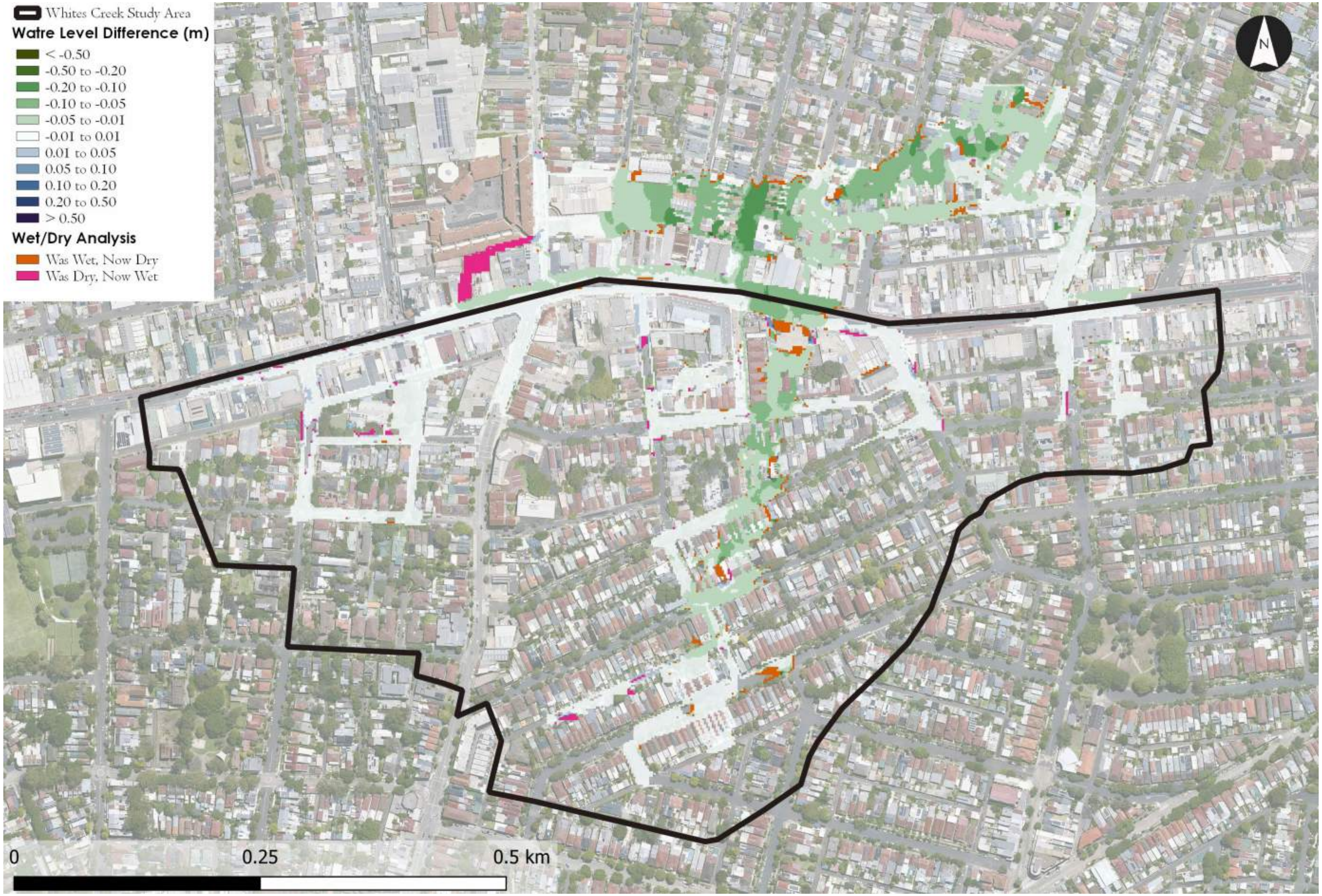

Figure 3-9 1% AEP Peak Water Level Differences – Whites Creek - Updated AR&R 2019 Model Less Flood Study AR&R 1987

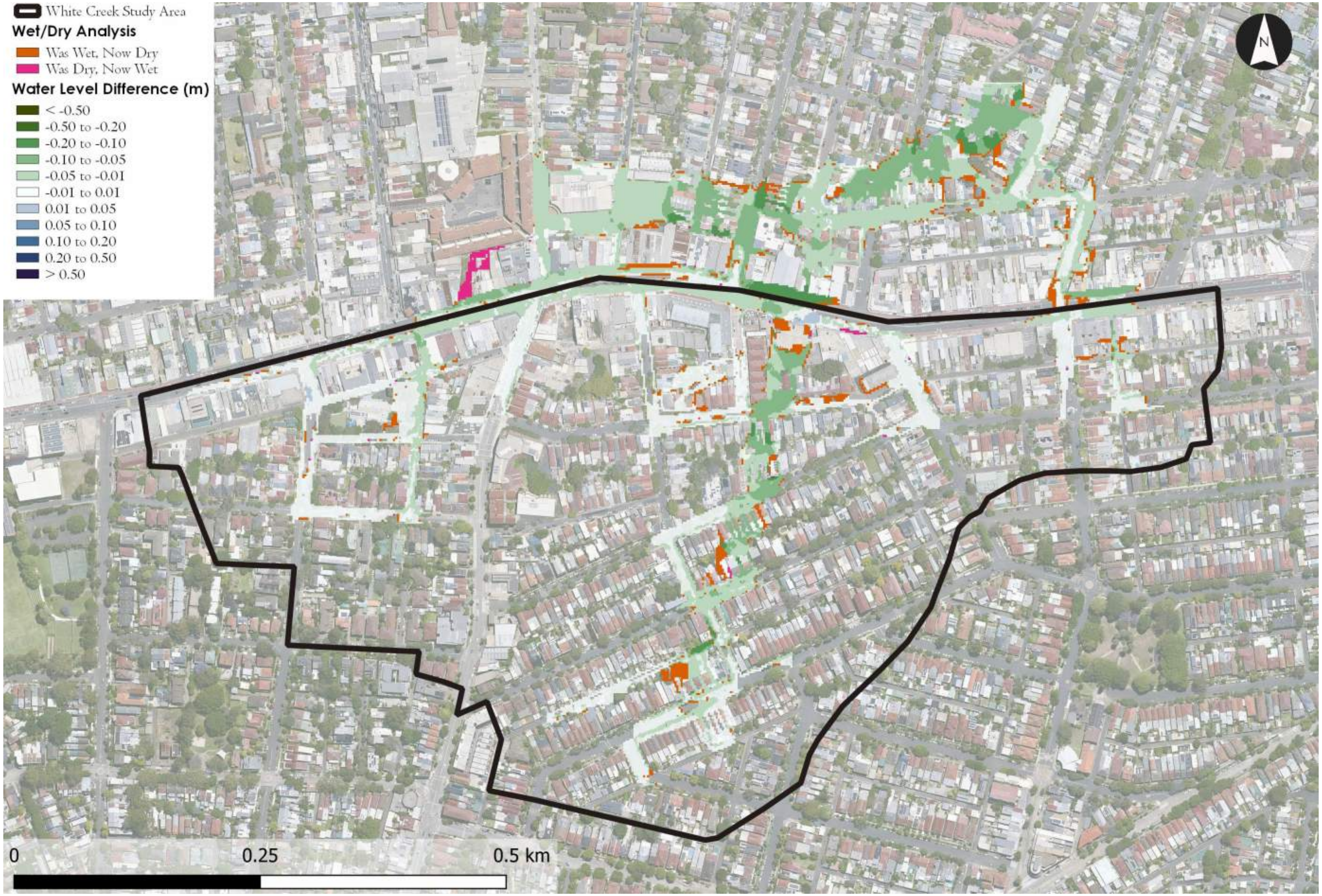

Figure 3-10 5% AEP Peak Water Level Differences – Whites Creek - Updated AR&R 2019 Model Less Flood Study AR&R 1987

4 Consultation

4.1 Consultation Process

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

The consultation strategy has been divided into three key sections:

> Consultation in FRMS&P development: This occurred during initials stages of the project (**Section 1.4)**-and involved both informing the community and stakeholders of the project and gathering information on existing flooding issues and suggestions for flood risk management options.

> Review of possible flood management options with key stakeholder groups including Council Engineers, Council Planners, NSW SES, NSW DCCEW and community representatives within Council's Flood Risk Management Advisory Committee.

> Public exhibition of Draft FRMS&P: This occurred in the final stage of the project, with comments sought from the community and stakeholders on the Draft FRMS&P report with this input reviewed and incorporated into the final FRMS&P.

The strategy has been developed in accordance with the IAP2 Quality Assurance Standard and the Inner West Council Community Participation Plan.

4.2 Consultation Plan and Engagement Techniques

A consultation plan was developed in the preliminary stages of this project involving the development of several engagement techniques to achieve the objectives of the two stages of the consultation process. Details of the plan are provided below in **Table 4-1**.

Table 4-1 Consultation Plan

Task	Description	Expected Outcome
Press Release	Stantec will draft a press release for Council's consideration and publication.	> Public awareness of the study. > Assist in engagement with the community through the newsletter/questionnaire, workshops and public exhibition. > Assist in the public acceptance of the study outcomes and implications for development and flood risk management in the future.
Stakeholder Consultation – Council	Relevant Council staff attended the inception meeting to discuss various input to the study and the proposed study approach. Key stakeholders will be consulted in an option development workshop to receive feedback on the preliminary options list.	> All available information is utilised in the preparation of the flood study. > Modelling incorporates the high risk areas. > Council objectives are achieved by the study.
Stakeholder Consultation – Flood Advisory Committee	Stantec will attend and present at four stakeholder meetings (which may include Flood Advisory Committee as deemed suitable) throughout the study.	> Update FRAC on the FRMS&P process. > Provide an opportunity for input from the FRAC on the mitigation options.
Stakeholder Consultation – Agencies	Stantec will contact relevant agency stakeholders (e.g. NSW SES, TfNSW) via letter and follow up email and/or phone.	> Inform the agencies of the study. > Obtain relevant information. > Provide an opportunity for input from the relevant agencies.

Task	Description	Expected Outcome
Community Newsletter and Questionnaire	Stantec will draft a newsletter and questionnaire for Council's consideration. Once finalised Council will print and distribute to target properties within the catchment. Responses will be via a reply-paid envelope. The brochure and survey will also be made available online by Council.	> Inform the community about the study and provide background information. > Identify community concerns and awareness > Gather information from the community on potential flood mitigation options. > Develop and maintain community confidence in the study results.
Website	Council will host a dedicated "Your Say" website for the project. The website will be utilised for media release, online newsletter and questionnaire providing residents with an opportunity to locate the area of flooding on a GIS based system and upload an associated photos/videos they may wish to share.	> Collaborative community engagement process. > Provide community opportunities to provide input/feedback. > Provide key information to the community.
Community Workshops	Stantec will prepare materials for and present at 2 community workshops. One workshops will be undertaken during Stage 2 of the study to get community feedback on the preliminary flood options, the other during Public Exhibition (see below).	> Provide the community with an opportunity to comment on flood mitigation options and an understanding of the outcomes of the Draft Study and Plan.
Public Exhibition Period	Stantec to draft a press release for Council's consideration and publication.	> Inform the community of the draft Study and Plan and invite submissions. > Inform the community of the workshop.
	Council will arrange for the public exhibition of the Draft Flood Risk Management Study and Plan. One community workshop will be undertaken during the public exhibition to present the outcomes of the study and receive feedback from the community.	> Provide an opportunity for the community to review and provide comment on the Draft Study and Plan.

4.3 Council Engagement

Given Inner West Council's role in commissioning this FRMS&P, it is important that Stantec maintain constant engagement with Council's project manager throughout the project. Furthermore, NSW Department of Climate Change, Energy and Water (DCCEW) have maintained an active role in project supervision throughout the project. Council engagement has been maintained through the following:

- An online project inception meeting was held on 12 January 2021 with Council and Stantec representatives in attendance. The inception meeting signified the commencement of the project and provided an opportunity for Council to outline the objectives and expectations for the study, and to provide initial guidance and direction.
- Meetings occurred as required between 2021 and 2022 as the project reached critical milestones and review points, however there were delays associated with COVID and the 2022 Flood Response.
- Fortnightly online project update meetings have been conducted since project recommenced model changes and option analysis on 24 January 2023 with Council, DCCEW and Stantec's project manager in attendance as well as other Stantec staff as needed. The update meetings have provided an opportunity for Stantec to update Council on the ongoing status of the project, and to ask Council for any clarifications or queries that arise during the project.
- Ongoing weekly option development and review workshops with Stantec and Council's technical working groups were held from August through to October. The list of attendees included Council's project managers and NSW DCCEW representatives for the project), as well as relevant stakeholders from technical teams in Council. The goal of the meetings was to seek feedback on the preliminary list of options and refine and identify a set of detailed options for assessment.

- Workshops were held on 13 and 27 July 2023 with Stantec, DCCEW, SES, City of Sydney Council and Council strategic, engineering and planning representatives to present an overview of the FRMS&P and the initial preliminary flood mitigation options.
- Additional weekly workshops were held with Council’s project team and NSW DCCEW representatives during option development and modelling to review option outcomes and refinement of options. This allowed the options to be developed in light of Council and DCCEW preferences and advice.

4.4 Flood Risk Management Committee

One of the primary mechanisms by which the study team engaged in consultation with key stakeholders and the community is via the Inner West Flood Management Advisory Committee (FMAC) convened by Council. The Committee includes membership by the following individuals:

- Local community representatives,
- Local business representatives,
- Staff from Inner West Council who have involvement in the study including coordinators, managers, strategic planners, and engineers.
- SES representatives,
- Floodplain Engineer from NSW DCCEW.

The first FRAC meeting for the project was held mid-2022 to discuss the progress of the project and to present the outcomes of the Stage 1 report.

Further meetings were undertaken throughout 2023 to review, seek input, and shortlist proposed flood mitigation and management options for detailed assessment and costings.

The Draft FRMS&P was presented to the Committee for feedback and support for community exhibition in early 2024. The meeting provided an opportunity for the FRM Committee members to ask questions about the FRMS&P. During the meeting the committee endorsed this report to go on public exhibition.

Next FRM Committee meeting will present outcomes of the public exhibition, the comments received from the community and how these were applied to the Final FRMS&P report. This meeting is planned for 24 July 2024 prior to potential Council endorsement and adoption of the final study.

4.5 Initial Consultation

The initial consultation period was held from 7 March 2023 to 6 April 2023. The initial consultation period for this project was run jointly with the Alexandra Canal FRMS&P project. During this period the following materials were made available to the community:

> A dedicated community engagement page for the catchment on Council's Your Say website.was posted for the project,to inform the community about the project and for feedback. The text for the Your Say page has been included in **Appendix A**.

> Press release information for the study was posted to Council’s social media and to Council’s newsletter.

> Introductory letters were mailed to all owners and occupants of flood affected properties in the study area, which involved mail out to approximately 2,700 properties. The resident letter template provided an introduction to the study, and a link to the Your Say page for further information and a link to complete the online survey. The letter text is included in **Appendix A**.

> A resident online survey / questionnaire was hosted by Council through an online portal, with links to the online survey provided on the project’s Your Say page. The survey text is included in **Appendix A.**

Three in-person information sessions were hosted by Council and attended by Stantec flood engineers and Council representatives. Notification of the in-person sessions was posted on the Your Say page and in the introductory letter (for the first session). The details for the three sessions were:

> St Peters Town Hall, 39 Unwins Bridge Road, St Peters on 15 March 2023 from 12.00 – 3.00pm

> St Peters Town Hall, 39 Unwins Bridge Road, St Peters on 15 March 2023 from 5.00 – 8.00pm

> Marrickville Pavilion, 313 Marrickville Road, Marrickville on 20 March 2023 from 12.00 – 3.00pm

4.5.1 Consultation Response Outcomes

Across the initial consultation period, there were 3 community attendees relevant to the Whites Creek and Johnstons Creek study area to the three in-person information sessions.

One of the 3 attendees was a resident from outside of the study area and asked questions about the flood modelling project. The other two attendees raised matters related to the study area, including one from Enmore as their area had been identified as a hot spot and mitigation options considered. A resident from Stanmore showed flood maps of the area and discussed flooding history, clarified that this is a FRMS&P study not to re-assess existing flood behaviour, clarified that DCP requirements were not applicable to existing dwellings, only the portion of new development, hence the reason the existing structure did not need to be raised in recent alterations.

With respect to Your Say outcomes from the initial consultation, there were 650 views of the project page, initiated by 501 unique visitors. The total viewing time of project information was approximately 7 hours. Two persons contributed to the interactive map, including:

> a submission noting that their property was located at the intersection of Salisbury Rd and Mallet St had experienced previous severe water damage of the lift pit and passenger lift infrastructure as a result of flooding at the intersection, incurring repairs and maintenance costs to the residents.

> a submission noting that road and footpaths on Lennox St Newtown are regularly flooded, even during moderate rainfalls and attached a photo from 2 April 2023 showing overflowing drains and gutters.

The adopted Flood Study was downloaded 49 times.

4.5.2 Online Survey Outcomes

Five community members shared their experiences of flooding via the online survey.

- 100% of respondents (5 of 5) were owner occupiers,
- 80% of respondents (4 of 5) declared that other parts of their neighbourhood had flooded since living/working in the catchment area,
- 80% of respondents (4 of 5) believed the flooding disrupted their daily routine,
- While 20% of respondents (1 of 5) suggested they believed lack of capacity in the stormwater network (e.g. pits and pipes) caused drainage systems to surcharge and backflow, 80% of respondents (4 of 5) believed other reasons were are the main cause of flooding in their area,
- 60% of respondents (3 of 5) would prefer management options of
  - culvert / bridge / increasing pipe size and/or capacity, and
  - and planning and flood related development controls to ensure future developments does not add to the existing flood risk.
- 80% of respondents (4 of 5) are concerned about the uncertainty of future climates and the possible impacts on flooding in their area,
- 100% of respondents (5 of 5) believed the climate is changing,
- 60% of respondents (3 of 5) are concerned about the impact of an uncertain climate on future flooding in the study areas,
- 100% of respondents (5 of 5) believe Council should be addressing the impacts of an uncertain future climate on flooding,
- 100% of respondents (5 of 5) gave permission for Stantec or Council to contact them to discuss the information they have provided Council.

4.6 Public Exhibition Period

The public exhibition period is an important stage of any regional Flood Study or FRMS&P as it provides the community and stakeholders the opportunity to provide comment and feedback on the draft outcomes of the study prior to finalisation.

The public exhibition period for this study was conducted from 4 June to 12 July 2024, a period of 5 weeks. The public exhibition period for this project was run jointly with the Whites Creek and Johnstons Creek FRMS&P During this period the following materials were made available to the community:

> An updated Your Say page was posted for the project, with links to the draft final FRMS&P report including appendices, background information for the study, frequently asked questions, an interactive map showing 1% AEP flood extents and sub-catchment boundaries, a study timeline, details of in-person sessions and a feedback submission section for any comments.

> Notification letters were mailed to all owners and occupants of flood affected properties in the study area (including the 1 in 100 Annual Exceedance Probability (AEP) flood extent and the Probable Maximum Flood (PMF) extent), which involved an extensive mail out. The letter notified of the draft report completion, and provided a link to the Your Say page for further information and details of the two in-person sessions.

> Four in-person information sessions were hosted by Council and attended by Stantec flood engineers and Council representatives. The details for the four sessions were (set-ups for both sessions shown in **Figure 4-1**):

  - Thursday 13 June 2024, 5-8pm, Marrickville SES, 17 Railway Road, Sydenham
  - Thursday 20 June 2024, 5-8pm, Marrickville SES, 17 Railway Road, Sydenham
  - Monday 24 June 2024, 1:30-4:30pm, The Pavilion, Marrickville Library
  - Tuesday 2 July 2024, 1:30-4:30pm, The Pavilion, Marrickville Library.

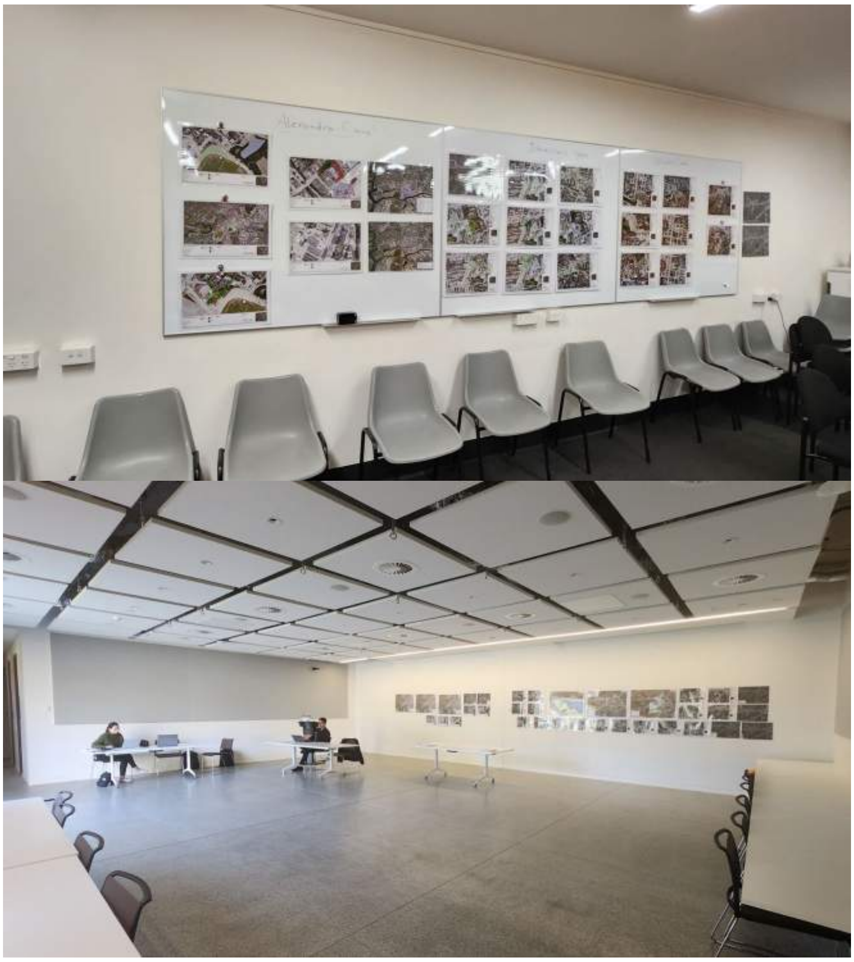

Figure 4-1 Public Exhibition In-Person Setups for Marrickville SES (Above) and The Pavilion, Marrickville Library (Below)

Public exhibition materials remained on display for SES representatives and volunteers in between the two Marrickville SES sessions (from 13 to 20 June 2024) as shown in **Figure 4-2**, including copies of the report, images of the mitigation options and mapping overview.

Figure 4-2 Public Exhibition In-Person Setup on display at Marrickville SES from 13 to 20 June 2024

4.6.2 Public Exhibition Response Outcomes

Across the public exhibition period there were 23 recorded responses across both Alexandra Canal FRMSP and Whites Creek and Johnstons Creek FRMSP through one of four response methods:

> Phone calls to Council by 4 different respondents in relation to the public exhibition of the study

> Your Say comment uploads (3 participants) and Your Say questionnaire responses (1 participant) by 4 total participants

> Email responses submitted to Council by 4 respondents

> 11 in-person attendees at the information sessions. These attendees consisted of 1 at the first session, 2 at the second, 7 at the third, and 1 at the fourth session.

Across all response methods, 1 comment (Your Say upload) related to Alexandra Canal FRMSP. All other responses were related to Whites Creek and Johnstons Creek catchment areas.

Although this represents a total of 23 engagements, it should be noted a number of households made several engagements for some households, most commonly residents attending in-person sessions often completed another form of response such as a Your Say written response or email.

With respect to Your Say outcomes from the public exhibition period, there were a total of 708 visits across both Alexandra Canal FRMSP and Whites Creek and Johnstons Creek FRMSP project pages. 459 of these visits were for Whites Creek and Johnstons Creek FRMSP. Additionally, there were 68 downloads of the main report along with 15 views of Appendix C (Emergency Management Maps), 18 views of Appendix D (Preliminary Flood Options Maps), 12 views of Appendix E (Detailed Flood Options Maps) and 27 views of Appendix F (MCA Scoring and Implementation).

During the public exhibition period, Council provided stakeholders with the draft final FRMSP report. As part of this engagement,

> One comment was received from Sydney Water regarding the number of overfloor flooded buildings reported. A clarifying response was provided to Council via an email, to be passed onto Sydney Water.

> Council Strategic Planning team commented on the report. Clarifying responses were provided to Council via an email, and updates to the report were made where necessary.

4.6.3 Summary of Public Comments

The most common concerns received across the various forms related to the following:

> Localised stormwater issues not within the scope of flood risk, i.e. maintenance or drainage issues to be addressed by means of temporary solutions prior to the implementation of mitigation options or otherwise captured under Council’s capital works

> General enquiries either outside of the catchment subject areas or requesting information about the FRSMP and the proposed mitigation options.

Specifically relating to the flood risk management options, the following comments were received during public exhibition:

> A concern was raised about flooding in the junction of Gladstone Street and Phillip Street in Enmore. The attendee communicated that the flooding was caused by insufficient drainage on King Street. There is a valid flood risk concern to properties further downstream of this intersection, which are subject to low flood island effects. These properties have been assessed to benefit from Option JC13. However, at the intersection where the concern was raised, the observed H5 hazard category within a 1% AEP event is contained within the road corridor. It is also understood that the further upstream King Street is a TfNSW owned asset. Due to these factors affecting feasibility comparative to flood risk benefits, it is unlikely for further proposed solutions in this location to be scored favourably in terms of CBR and MCA.

> A concern was raised about flooding to a property on Salisbury Road, Camperdown near Church Street in the Johnstons Creek catchment. There is a valid flood risk concern to these properties due to the trapped low point with H4-H5 hazard category of flooding within a 1% AEP event. No solution was proposed during option development due to high level feasibility issues resulting from the limited diameter of downstream pipes. It is noted that the subject pits are part of Council's capital works program, and that Council is currently progressing longer term feasibility assessments as part of a separate study. In the meantime, Council may implement an interim approach to mitigate flooding in the short-term including investigating the inlet capacity at that location.

> A concern was raised about Salisbury Lane, Stanmore near the inlets to the Johnstons Creek stormwater channel. The attendee provided images showing flooding of the street, caused by the invert levels of the inlet pipes sitting above the existing street surface level. The subject location is mostly H2 hazard, with minor spots of H3-H4 within a 1% AEP event. The feedback provided by the attendee merits public safety concerns, and it is understood that Council will investigate inlet capacity or drainage upgrades in this area separate from the FRMSP and as part of their capital works.

> Two concerns were raised regarding flood risk classification, insurance premiums and property values in the Johnstons Creek catchment. The community members for these areas did not consider their property to be flood affected. The Flood Study model has been reviewed as part of the FRMSP, and the assumptions used were found to be generally reasonable in line with industry best practice and guidelines. It is noted that these types of concerns relate to the previous Flood Study process where flood affectation of properties was assessed, whereas the focus of the FRMS&P engagement was on the proposed flood risk management options. On Australia Street, there is a proposed JC20 drainage upgrade option directly benefiting the affected properties in this subject area, which are subject to H4 hazard category of flooding within a 1% AEP event.

> A concern was raised regarding Corunna Street in the Whites Creek catchment. The attendee suggested the installation of raingardens additional to the proposed WC1 drainage upgrade option. The option types (i.e. drainage upgrade, road regrading, detention basin, etc) were developed with consideration of feasibility, cost and likelihood of scoring favourably in terms of CBR and MCA. The introduction of a raingarden, though may slow flows and improve water quality treatment in higher frequency events, is not likely to cause reductions to flooding downstream in larger rare events such as the 1% AEP. Council may wish to consider the benefits of installing raingardens as part of a separate feasibility study or included within the capital works program.

5 Flood Planning Review

5.1 Flood Affected Properties

A review of flood affected properties has been considered for the study area with a review of changes considered compared to the previous Flood Study property tagging.

The updated property list adopted the original Flood Study model results in creating flood extents. These flood extents apply the flood extent trimming of 0.15 metres depth. This more effectively removes minor sheet flows and shallow overland flows. A comparison of 1% AEP flood extents with and without the 0.15m depths filter is shown in **Figure 5-1**. The comparison shows that the untrimmed flood extents are significantly more widespread than the extents trimmed to 0.15 metre depth, showing there is significant areas of shallow sheet flow modelled in the TUFLOW model.

The number of floods affected properties for five design events are summarised in **Table 5-1** for Whites Creek and Johnstons Creek. Two forms of property tagging analysis have been considered:

> Any flood affectation of the property

> Flood extent covers at least 10% of the property area,

As has been adopted in other study areas by Council, the use of the 10% area tagged approach has been preferred. In the PMF event using the 10% property area approach, there are a total of 913 flood affected properties, or 14.2% of the total 6434 properties in the study area. In the 1% AEP the total number of affected properties is 409, or 6.3% of all properties.

Table 5-1 Flood Affected Property Numbers for Private and Developed Properties (Excluding Parkland Sites) for All Design Flood Events for Base Case Flood Extents

Property Tagging	Base Case Flood Affected Property				
	20% AEP	5% AEP	2% AEP	1% AEP	PMF
Flood Affected	770	1006	1107	1197	1906
>10% Area Affectation	197	300	368	409	913
				Total Properties in Catchment	6976

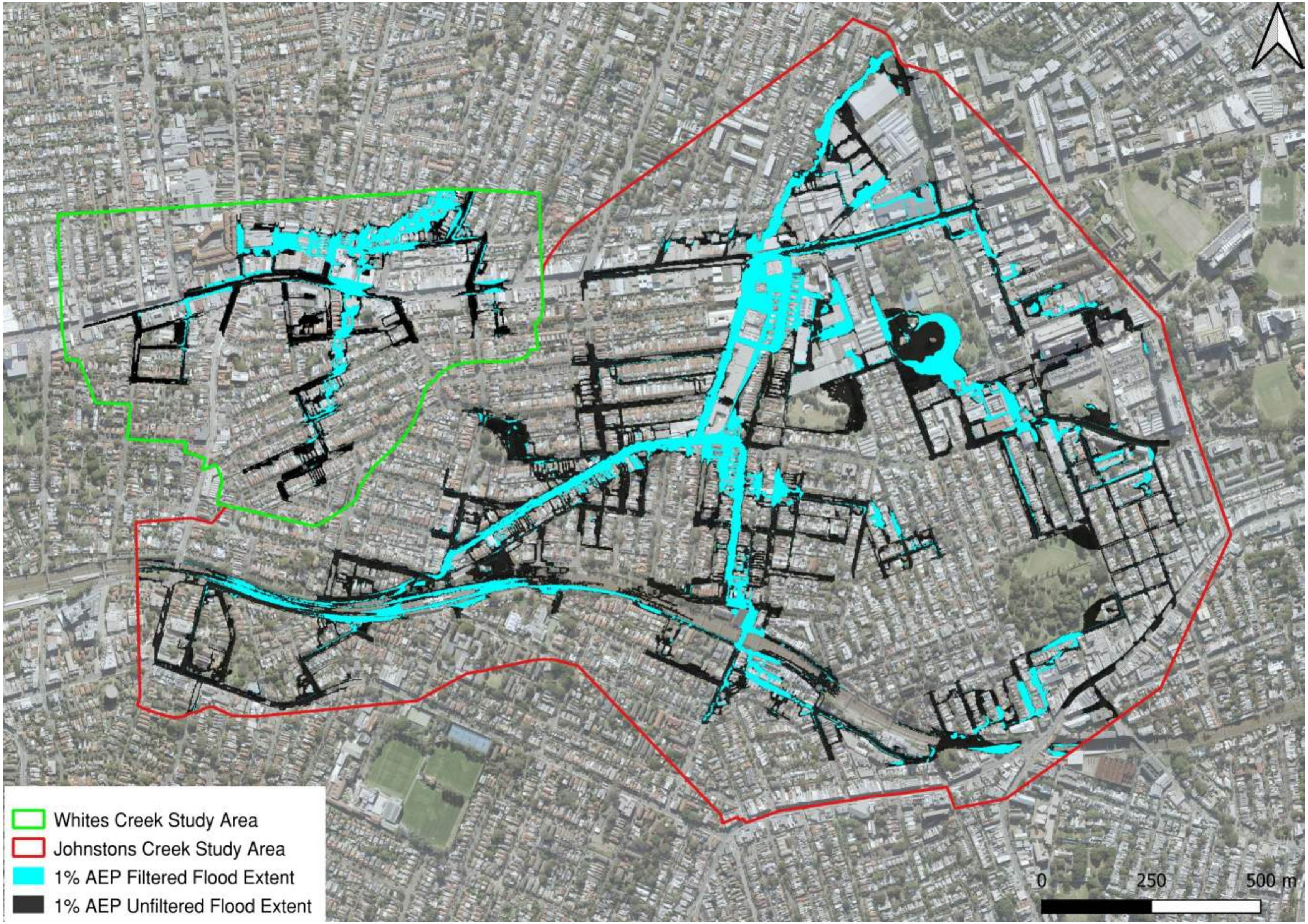

Figure 5-1 Comparison of 1% AEP Flood Extents With and Without 0.15m Depth Filter Applied

5.2 Relative Vulnerability for Development Types

The relative vulnerability of development types and their users to flooding should be considered in decision-making as it can influence risk to the community. Vulnerability to flooding can vary between development types and their typical users.

The 2023 FRM Manual guideline for Flood Impact and Risk Assessment (Flood Risk Management Guide FU01) in Table 6 provides a useful resource in providing a high-level summary of flood risk for different development types of users, buildings and their contents for the same flood exposure. The summaries from this guideline for development types relevant to this Study Area have been included in **Table 5-2**.

It is noted this guidance is a generalisation for development types, and the flood risk of any development will depend on site specifics and details of the development, not just these broad vulnerability assessments. However, this provides a useful resource in understanding the relevant flood risk of different land uses. It should be consulted in the review of current land uses and future development potential in the following sections."

Table 5-2 Relative Flood Risk & Vulnerability of Land Uses for the Same Flood Exposure (Source: NSW DCCEW, FRM Guide FB01)

Type of Use	Relative Risk Compared to Low Density Residential			Comment
	Users	Buildings	Contents	
Low Density Residential	Base	Base	Base	This is used as a baseline for considering relative impacts in other land uses
Medium/high density	Higher	Lower	Lower	Due to the higher density more people are involved but the buildings may be more structurally resistant to flooding. Contents may be less exposed to flooding as they may be over multiple levels
Emergency response management facility	Lower	Lower	Lower	Lower density of development and people
Aged care facility	Higher	Lower	Higher	Users on average more vulnerable in evacuation. Building may be structurally stronger. Potential for high value medical equipment
School	Higher	Lower	Lower	Users on average more vulnerable in evacuation. However, evacuation arrangements likely to be in place. Buildings and contents generally lower value
Correctional facility	Higher	Lower	Lower	May have challenges in the relocation of users therefore continued operation preferable. This relies on accessibility for staff and utility services. Buildings and contents expected to be generally of lower vulnerability
Commercial	Higher	Lower	Varies	Employees may be able to be trained to assist in response to flooding. Higher density of customers, who are likely to be unfamiliar with location or flood issue and therefore more vulnerable. Buildings expected to be generally of lower vulnerability. Contents varies substantially depending on the specific business
Industrial	Lower	Lower	Varies	Employees may be able to be trained to assist in response to flooding, customer density low, but they are likely to be unfamiliar with location or flood issue. Buildings expected to be generally of lower vulnerability. Contents varies substantially depending on the specific business
Hazardous/ offensive industry	Lower	Lower	Higher	Employees may be able to be trained to assist in response to flooding, customer density low, but they are likely to be unfamiliar with location or flood issue. Buildings expected to be generally of lower vulnerability. However, the impacts of hazardous or offensive materials could be significant and need to be considered. This may require management measures such as avoidance of flood-affected areas or effective containment of hazardous or offensive materials to limit impacts on the community or environment
Recreation	Lower	Lower	Lower	Occupied less and may be weather influenced but could be higher density of people when in use. Users often unfamiliar with flooding in the location. Buildings and contents expected to be generally of lower vulnerability or value

5.3 Future Development Potential in Flood Affected Land

5.3.1 Proposed Future Development Sites

In the preliminary stages of the project, Council reviewed submitted planning proposals within the study area and no planning proposal was currently active within the study area.

5.3.2 Future Planning Proposal Requirements

In mid-2021, NSW DCCEW released a new Flood Prone Land Policy Update. Included within this policy is a draft set of standard flood-related clauses for Local Environment Plans (LEPs) to assist local Councils. In addition, the update package included a local planning directive outlining flooding requirements in consideration of planning proposals.

A summary of the key requirements of the local planning direction for planning proposals and their relevance to the future development potential of Whites Creek and Johnstons Creek Catchment is included in **Table 5-3**.

To assist in the discussion of planning proposal requirements related to floodway and high hazard areas, these two maps for the 1% AEP have been overlaid on current land use zoning as shown in **Figure 5-3** and **Figure 5-4** respectively.

The outcomes from **Table 5-3** suggest that development and particularly potential intensification should be prioritised in the flood free portions of the study area where possible. However, the high-level review suggests there is still redevelopment potential within parts of the floodplain.

The guide on flood risk of development types summarised in **Section 5.2**, should be reviewed as a general guide when assessing potential future changes in land use in the floodplain.

Table 5-3 Planning Proposal Requirements and Relevance to Whites Creek and Johnstons Creek Catchment

Planning Proposal Requirement	Relevance to Whites Creek and Johnstons Creek Catchment
A planning proposal must not rezone land within the flood planning area from Recreation, Rural, Special Purpose or Environmental Protection Zones to a Residential, Business, Industrial or Special Purpose Zones.	Based on this requirement there is limited development potential for the flood affected portions of sites that are currently zoned as recreation or special purpose including parts of Stanmore Baptist Church, All Saints Anglican Church, Uniting Church in Australia as well as any zoned Council park sites.
A planning proposal must not contain provisions that apply to the flood planning area which:	
▪ permit development in floodway areas,	Assumed to be the 1% AEP floodway. As shown in **Figure 5-3** the floodway extents in the study area affect various residential areas, business and industrial areas as well as neighbourhood and local centres. Several areas of the Whites Creek and Johnstons Creek catchments may be limited by this requirement.
▪ permit development that will result in significant flood impacts to other properties,	This requirement would need to be assessed through flood impact assessments on a site-by-site basis with detailed assessment of proposed development plans
▪ permit development for the purposes of residential accommodation in high hazard areas,	Assumed to be the 1% AEP high hazard. As shown in **Figure 5-4** there are residential and business areas affected by high flood hazard, which may impact potential redevelopment of these sites in the study area.
▪ permit a significant increase in the development and/or dwelling density of that land,	This requirement will need to be considered in potential intensification of development in the floodplain. It is possible that intensification in flood affected areas may be feasible if flood risk is suitably addressed. However potential intensification should be prioritised in flood free portions of the study area.
▪ permit development for the purpose of centre-based childcare facilities, hostels, boarding houses, group homes, hospitals, residential care facilities, respite day care centres and seniors housing in areas where the occupants of the development cannot effectively evacuate,	These vulnerable development types should not be proposed within the 1% AEP floodplain where possible. As discussed further in **Section 7.3.2**, there are a number of these existing vulnerable developments within the floodplain, the alteration of these sites to improve flood risk should be considered.
▪ are likely to result in a significantly increased requirement for government spending on emergency management services, flood mitigation and emergency response measures, which can include but are not limited to the provision of road infrastructure, flood mitigation infrastructure and utilities, or	Further review of flood emergency management concerns for the study area is included in **Section 7**. Development potential in identified flood emergency hotspots should be avoided based on this requirement. That is unless a potential redevelopment could justifiably be shown to reduce the emergency response burden for an existing site.
▪ permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.	This may be of concern for the light industrial zoned, flood affected areas in the Johnstons Creek catchment.
A planning proposal must not contain provisions that apply to areas between the flood planning area and probable maximum flood to which Special Flood Considerations apply which include items listed above.	Similar to the above response, vulnerable developments should not be prioritised within PMF affected lands where possible. This also relates to critical infrastructure types for flood emergencies (refer to **Section 7.3**).
For the purposes of preparing a planning proposal, the flood planning area must be consistent with the principles of the FRM Manual 2023 or as otherwise determined by a Flood Risk Management Study or Plan adopted by the relevant council.	The flood planning level should be maintained at the 1% AEP plus 0.5 metre freeboard as in the Inner West LEP and is recommended in the current Flood Prone Land Policy Update. There is no clear evidence that flood behaviour in the study area would justify an alternative FPL.

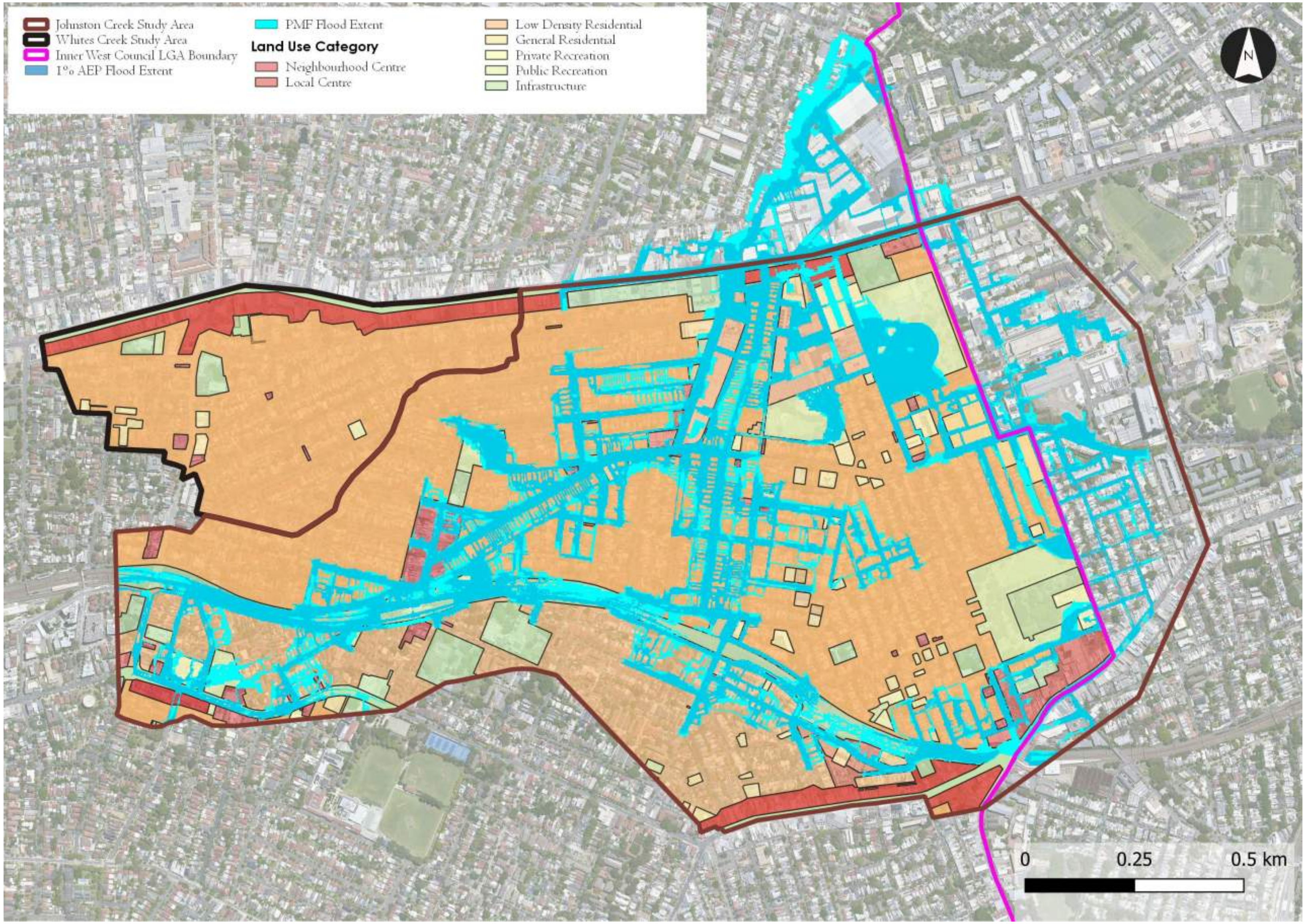

Figure 5-2 Current Land Use Zoning with 1% AEP and PMF Extents

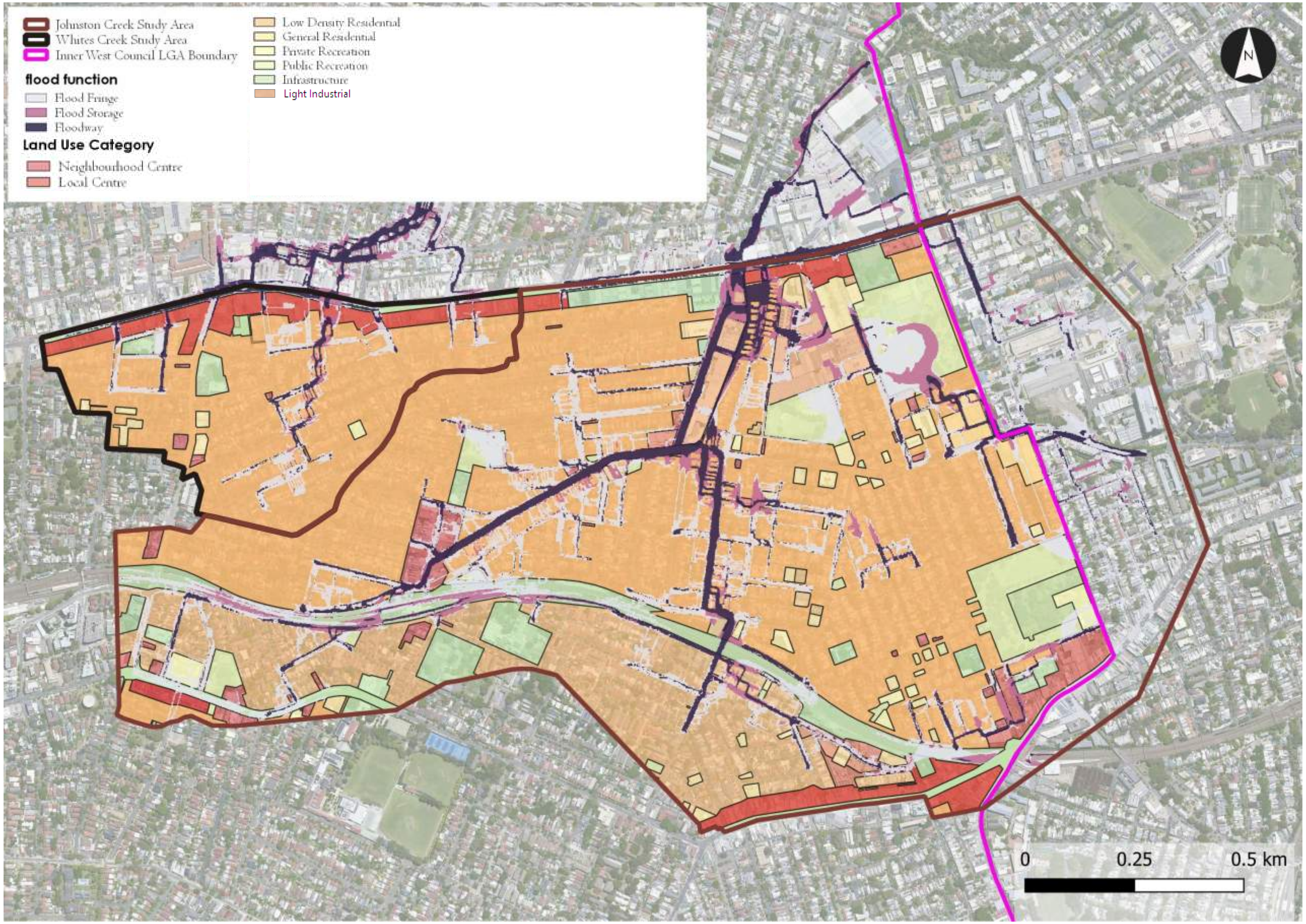

Figure 5-3 1% AEP Flood Function with Floodway on Current Land Use Zoning

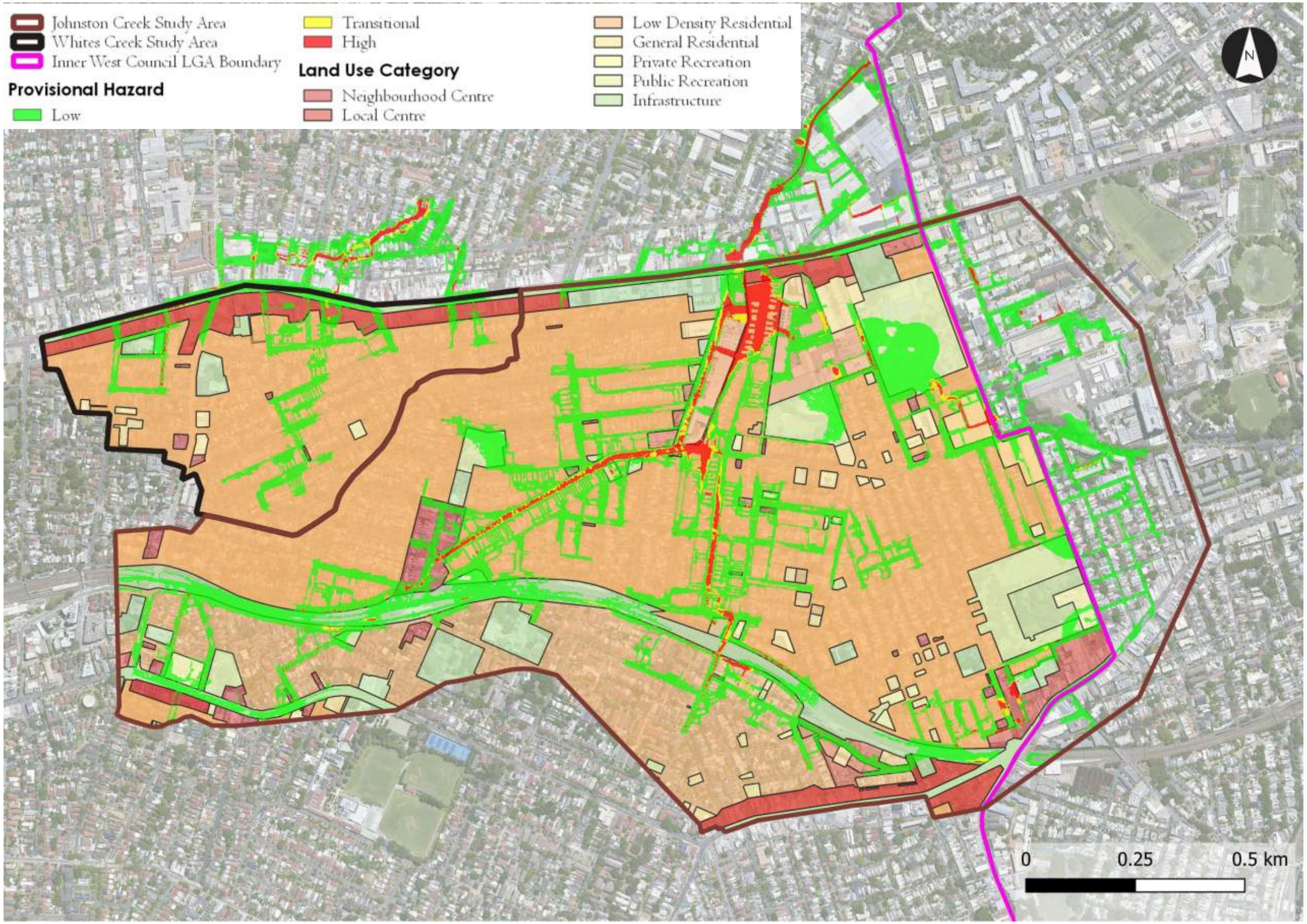

Figure 5-4 1% AEP Provisional Hazard with High Hazard on Current Land Use Zoning

5.4 Flood Related Development Controls

The Whites Creek Catchment and Johnstons Creek Catchment are located in the Inner West LGA where development is controlled through the Local Environment Plans (LEP) and Development Control Plan (DCP). The following sub-sections summarise the flood-related development controls for these documents and provide recommendations.

5.4.1 Local Environment Plan

The Whites Creek Catchment and Johnstons Creek Catchment lie within the Inner West LGA, therefore the relevant document is the Inner West Local Environmental Plan 2022.

As noted in previous sections, in mid-2021, NSW DCCEW released a new Flood Prone Land Policy Update. Included within this policy is a draft set of standard flood-related clauses for Local Environment Plans (LEPs) to assist local Councils. The 2021 package establishes two different categories, and two associated standard Local Environment Plan (LEP) clauses where flood-related development controls may be applied / considered. These are:

> Flood Planning Areas (FPAs): The ‘flood planning’ LEP clause is mandatory and the LEPs of all Councils in NSW were amended on 14 July 2021,

> Special Flood Considerations (SFCs): The ‘special flood consideration’ LEP clause is optional, and Councils decide whether to adopt this clause or not. If Councils choose to adopt the optional standard instrument SFC provision, it must be adopted without variation but subject to any relevant direction in the standard instrument (cl 4(2), SI order).

5.4.1.1 Mandatory LEP Clause - Flood Planning Area

Clause 5.21 outlines the requirements for developments in the FPA which is all land under Flood Planning Level (FPL), which in accordance with the FRM Manual 2023 is typically defined by the 1% AEP (1 in 100 AEP) event with a 0.5 metre freeboard. Councils are permitted to propose alternate FPLs, however they are required to demonstrate and document the merits of any decision based on a risk management approach. The land this clause applies to is essentially unchanged from the previous standard LEP clause.

The main updates to the mandatory standard flood related clause include:

> Several new objectives have been added to the updated text including a reference to cumulative impacts, enabling safe and appropriate uses of land, and enabling safe evacuation from the land,

> The requirements for development consent have been updated with reference to:

  - Compatibility to flood function (floodway, flood storage and flood fringe),
  - No offsite flood impacts and the impact of the development on projected changes to flood behaviour (accounting for climate change),
  - There is a reference to safe occupation and efficient evacuation of people and not to exceed the capacity of existing evacuation routes for the surrounding area. Similarly, also stated in the clause is whether the development incorporates measures to minimise the risk to life and ensure the safe evacuation of people in the event of a flood,
  - The intended design and scale of buildings resulting from the development, and the potential to modify, relocate or remove buildings resulting from development if the surrounding area is impacted by flooding.

Review of the draft Inner West LEP shows that the wording of the flood planning section 6.3 reflects this updated wording as is mandatory.

5.4.1.2 Optional LEP Clause – Special Flood Considerations

A new optional flood clause 5.22 has been added to the update called the 'Special Flood Considerations' (SFC) clause. The clause applies to all land between FPA and the PMF, an area that was not covered within the previous standard LEP clause. The types of development this optional clause would apply to includes vulnerable developments and critical infrastructure. In relation to the Special Flood Considerations (SFC) Clause 5.22, as stated within the guideline document:

….this is an optional provision of the Standard Instrument and Councils have the discretion whether to adopt the clause in a LEP in their LGA, provided they have appropriate information and justification to support the flood related development controls. Studies under the FRM process, as well as emergency management planning processes and relevant strategies and plans developed by NSW Government may provide information and support justification for the adoption of the clause.

Inner West Council has adopted the optional LEP clause 5.22 for land between the FPA and the PMF. Therefore, both LEP clauses 5.21 and 5.22 for the FPA and the PMF will be applicable.

5.4.2 Current Development Control Plan

The Whites Creek Catchment and Johnstons Creek Catchment lies within the former Marrickville Council LGA, therefore the relevant document was the Marrickville DCP 2011. This review relates to the Marrickville DCP 2011, Part 2.22 - Flood Management.

Section 2.22.2 – Land Affected complements Clause 6.3 (Flood planning) (currently Clause 5.21) of Inner West Local Environmental Plan 2022 (Inner West LEP 2022). It applies to:

> land identified on the DCP 2011 Flood Planning Area Map (**Figure 5-5**). Flood planning area include:
  - Flood planning area (Cooks River) that land likely to be affected by the 1% AEP flood, factoring in a rise in sea level of 400mm to the year 2050, (plus 500mm freeboard) of the Cooks River; and
  - Flood planning area (Overland Flow) that identifies land (in accordance with Council's Flood Tagging Policy) likely to be affected by the 1% AEP flood associated with various locations affected by local overland flooding.

> land identified as being flood liable land on the DCP 2011 Flood Liable Land Map (**Figure 5-6**). Flood liable land identifies land within a flood planning area, and land likely to be affected by the probable maximum flood (PMF) of the Cooks River. This means that the map identifies some land as being within the Cooks River PMF area, but not within the Cooks River 100-year flood (plus 500mm freeboard) area.

It should be mentioned that he Marrickville DCP 2011 incorporates twelve amendments. Amendment No. 7 relates to amendments to Part 2.22 – Flood Management, to incorporate an updated Flood Planning Area Map and an updated Flood Liable Land Map, came into force on 6 July 2018.

Flood classifications have been applied to parts of the Flood Planning Area (Cooks River). The flood classifications are:

> Low hazard: Should it be necessary, people and their possessions could be evacuated by truck. Able bodied adults would have little difficulty wading out of the area.

> High hazard: Possible danger to life, evacuation by truck difficult, potential for structural damage, and social disruption and financial losses could be high.

> The identified areas, and their flood classifications, are:
  - Riverside Crescent/Tennyson Street area (Marrickville and Dulwich Hill): Low hazard to high hazard.
  - Illawarra Road/Wharf Street area (Marrickville): Low hazard to high hazard.
  - Carrington Road area (Marrickville): Low hazard.
  - Bay Street area (Tempe): Low hazard to high hazard.

Flood management controls apply as follows:

> For land in a flood planning area, the controls apply to all development that requires development consent.
> For land that is flood liable land, but that is not in a flood planning area (land within the Cooks River PMF), the controls also apply to caravan parks, childcare centres, correctional centres, emergency services facilities, hospitals, residential accommodation (except for attached dwellings, dwelling houses, secondary dwellings and semi-detached dwellings), and tourist and visitor accommodation.

The development controls for the former Marrickville LGA (the DCP 2011) are derived from a development nature approach. The procedure to determine what controls apply to proposed development involves:

> Section 2.22.5 of the DCP identifies the category of the development which are grouped into the following:
  - New residential development
  - Residential development – minor additions
  - Non-habitable additions or alterations
  - New non-residential development
  - Non-residential development – additions
  - Change of use of existing buildings
  - Subdivision
  - Filling of land within the Flood Planning Area
  - Land uses on flood liable land identified on the DCP 2011 Flood Liable Land Map
  - Garages, carports, open car parks and basement garages.

There are twenty-nine development controls. **Table 5-1** indicates which flood management control applies to which type of development. Flood management controls are provided in **Appendix B**.

Table 5-4 Development Relevant Flood Management Controls

Development	Flood Management Control
General (applicable to all types of development)	C1, C2, C3, C4
New residential development	C5, C6, C7
Residential development – minor additions	C8, C9, C10
Non-habitable additions or alterations	C11, C12
New non-residential development	C13, C14
Non-residential development – additions	C15, C16
Change of use of existing buildings	C17, C18
Subdivision	C19, C20
Filling of land within the Flood Planning Area	C21
Land uses on flood liable land identified on the DCP 2011 Flood Liable Land Map	C22, C23, C24
Garages, carports, open car parks and basement garages	C25, C26, C27, C28, C29

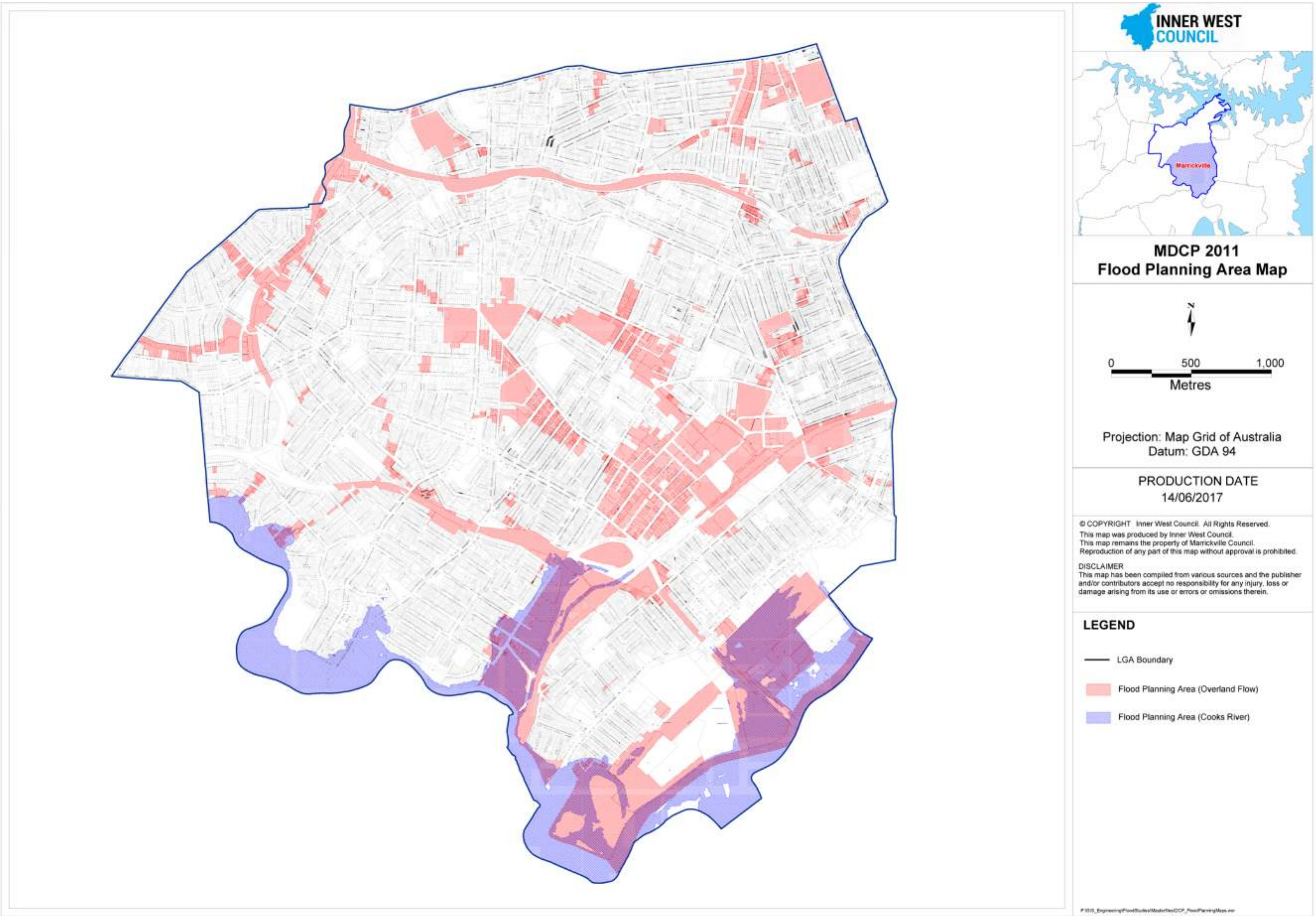

Figure 5-5 Marrickville DCP 2011 Flood Planning Area Map

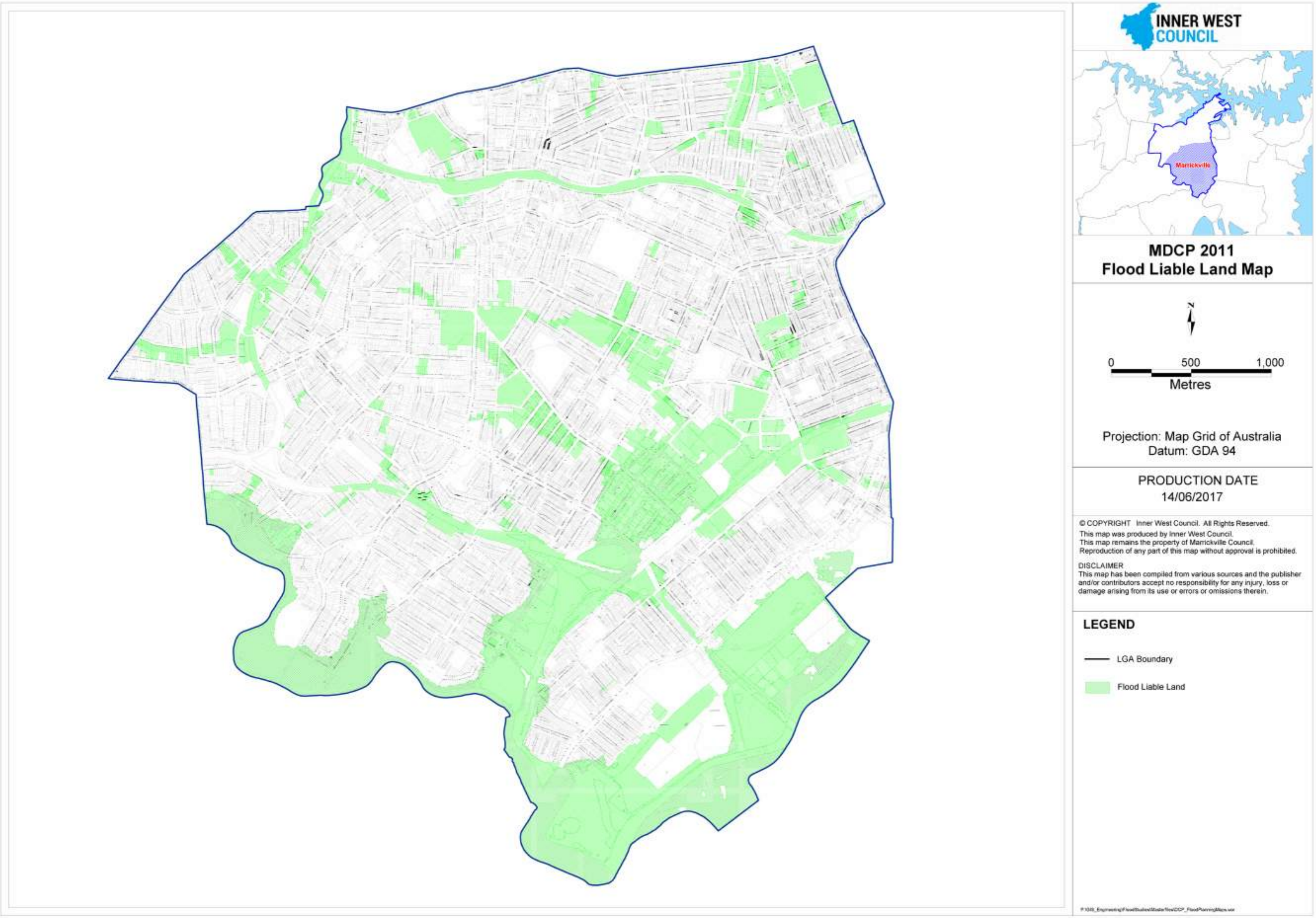

Figure 5-6 Marrickville DCP 2011 Flood Liable Land Map

5.4.3 Flood Impact and Risk Assessment Requirements

More recent guidance for applicant flood impact assessments is included within the 2022 FRM Manual guideline for Flood Impact and Risk Assessment (Flood Risk Management Guide FU01). The guideline provides details on the preparation of both simple and detailed Flood Impact and Risk Assessment (FIRA) for developments. The recommended preparation of a FIRA for developments should consider (as outlined in Section 3 of the FU01 guide):

> Proposed development: The proposed development needs to be shown with the necessary detail.

> Existing and developed model scenarios: The consent authority will need to ensure that flood modelling and/or analysis is sufficient to identify and assess the existing flood conditions and to determine post developed flood impacts and risks. Assessment needs to consider the key details of the final proposal, including development type and density (changing runoff characteristics), infrastructure, proposed modification to waterways or floodplain landform or vegetation.

> Impacts to be addressed: The consideration of development impacts is recommended to extend beyond flood level impacts only, with the table of impacts recommended to consider provided in **Table 5-5** below.

Table 5-5 Typical considerations when assessing impacts due to development (Source: NSW DCCEW, FU01 Guide)

Key considerations	Reasons for considering
Flood level change	• May increase inundation and damage to existing development • May inundate additional existing development • May create new or larger floodways or flowpaths • May isolate new areas
Change in duration of flooding	• May increase damage • May increase duration of isolation
Velocity change	• May increase scour potential and/or damage to buildings
Change in warning and evacuation time	• May decrease available warning time and time available for evacuation
Change in frequency of inundation	• Properties may become flood affected in more frequent events • Access may be cut more frequently • Areas may be isolated more frequently
Flood function categorisation change	• May change categorisation (e.g. flood storage to floodway) and change impacts on flooding on existing development
Hazard categorisation change	• May reduce safety to vehicles, people or buildings

> Managing residual flood risk: In many situations there will be opportunities to limit the increase in risk due to development, however, available options will vary depending on the stage and scale of the development being considered. Typical risk considerations include the risks to people, property and infrastructure, including the ability of the occupants to respond in an emergency. Residual risks will remain after management measures and development controls have been applied. A list of measures available to minimise the increase in flood risk to large and small-scale development are in **Table 5-6**.

Table 5-6 Typical measures to minimise impacts due to development (Source: NSW DCCEW, FU01 Guide)

Multi-lot, large-scale development	Individual, small-scale development
Include strategic management considerations and measures: • avoid floodways and flowpaths • avoid other highly flood constrained areas • provide management measures to manage risks to existing development • consider compatibility of land uses/ development types with the flood constraints on the land • determine and apply controls required to manage risk to the development and its users • consider emergency response issues and options and provide management measures consistent with advice from emergency services	Generally: • avoid floodways and flowpaths • avoid other highly flood constrained areas • apply controls to manage the risk to the development and its users: • management and design measures • structural considerations • floor level controls

The guide notes that documentation should ensure the intent of the approval is clear and maintained for the life of the approved development. This may include the need for conditions that consider:

> Limiting impacts and risks posed to the development and future occupants to ensure these have been appropriately managed. Consent conditions are to incorporate the key requirements to ensure these aspects are addressed. This may include the need to apply flood related controls such as those that nominate minimum fill or floor levels, structural considerations, management measures, address site egress, ensure the safety of occupants during flooding, and restrict unapproved modification to key elements of the development as approved in the consent.

> Management measures required to be considered in a staged manner as necessary to manage risks to the existing community.

> Inclusion of all design reports and drawings in the consent to ensure these are consistent with key parameters used in post development modelling and analysis that formed the basis of the FIRA.

> Modification of key design features of the development that may alter flood behaviour. This may require an additional approval with supporting modelling and/or reporting to ensure impacts of post developed flood risks are either in accordance with the original approval or are within the tolerable levels as defined by the consent authority.

> How risks and impacts of the development change with future climatic conditions.

> Any other specific requirements for consideration by the proponent to manage flood risk.

5.4.4 Conclusion of Review of Development Controls

Upon review of the flood-related development controls within the formerly Marrickville DCP 2011, the following general comments are noted:

> Compared to the requirements for planning proposals outlined within the 2021 Flood Prone Land Policy Update (refer to **Section 5.3.2**), the current development controls are generally in agreement with one exception:
  - The controls do not permit (only) filling of floodways or high flood hazard areas. Regarding the policy requirement for no residential accommodation in high hazard areas, there is a relevant control for new residential development enforcing flood free access must be provided where practicable.
  - The controls require filling of land within the Flood Planning Area (Control C21)
    - not increase flood levels by more than 10mm,
    - not increase downstream velocities by more than 10%,
    - not redistribute flows by more than 15%,
    - the potential for cumulative effects of possible filling proposals in that area is minimal,
    - the development potential of surrounding properties is not adversely affected by the filling proposal,
    - not increase the flood liability of buildings on surrounding properties, and
    - no local drainage flow/runoff problems.

> This is similar to requirements within the policy.
  - Requirements for storage of goods and hazardous materials is consistent.
  - Emergency management requirements are similar, though the controls are more prescriptive outlining refuge and evacuation requirements more specifically which is beneficial to aid applicants.
  - There is not a control that does not permit vulnerable and critical developments below the PMF level, similar to the requirements of the policy relating to these types of developments. Consideration should be given to amending the DCP to specifically address flood risk in vulnerable and critical developments,

> Compared to the requirements for FIRA from the 2022 FRM Manual Guide FU01. Generally, the current development controls are in agreement with the proposed requirements in the guide with some exceptions:
  - The current controls do not require consideration of climate change in assessments.
  - The current controls do not specifically require a consideration of residual risk of proposed developments to confirm if flood risk is lower than existing based on proposed risk management measures for developments.

> The development matrix approach offers a simple platform to be able to apply development controls specific to development types.

Ultimately, the current controls are generally fit for purpose, some alterations to the current development controls should be considered to bring it in accordance with recent guidance both within the 2021 Flood Prone Land Policy Update and the 2022 FRM Manual Guide FU01. This may include the following key changes from the bullet points above:

> setting controls to allow for no new residential accommodation in high hazard areas in accordance with the policy requirement,

> setting controls to reduce flood hazard and associated risk to existing residential accommodation in high hazard areas,

> setting controls that consider the higher flood risk of vulnerable and critical developments below the PMF level, and

> consideration of climate change in assessments.

6 Economic Impact of Flooding

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

Table 6-1 Types of Flood Damages

Type	Description
Direct	Building contents (internal) Structural damage (building repair) External items (vehicles, contents of sheds, etc.)
Indirect	Building contents (internal) Structural damage (building repair) External items (vehicles, contents of sheds, etc.)
Intangible	Social (increased levels of insecurity, depression, stress) Inconvenience (general difficulties in post-flood stage)

The direct damage costs, as indicated in **Table 6-1**, are just one component of the entire cost of a flood event. There are also indirect costs. Together, direct, and indirect costs are referred to as tangible costs. In addition to tangible costs, there are intangible costs such as social distress. The flood damage values discussed in this report are the tangible damages and do not include an assessment of the intangible costs which are difficult to calculate in economic terms.

The purpose of a flood damage assessment is to support decision-making on FRM options. It provides the basis for understanding the scale of benefits or disbenefits FRM measures may have on flood damages to the community. The damage assessment is not intended to be a precise estimate of damage at a given location. Rather, it is intended to provide a reasonable understanding of the relative scale of damage across the study area (focusing on aspects that will be materially changed by FRM measures) and how this may be altered with the implementation of FRM measures.

6.2 Input Data

6.2.1 Building Footprints

The primary flood damage calculation relates to building damages, being structural, contents, relocation, and clean-up costs. Therefore, building damages have been calculated for each individual building footprint, based on the building footprint layer provided by NSW DCCEW.

Commonly in the past flood damages were calculated on a per property basis rather than a per building basis. The adopted damage per building calculation provides a more accurate determinant of flood affectation due to the following reasons:

- Properties may have multiple buildings in the one property therefore damages can be calculated per building and added together,
- Flood model results can be considered only within the building footprints to provide a more accurate localised picture of flood affectation. On a property basis, flooding far removed from building footprints may misrepresent flood affectation near the building where the majority of flood damages are caused.

Therefore, the bulk of flood damages calculation has been conducted based on NSW DCCEW building footprints. The exception is for external (garden) damage which has been considered on a per property basis and then added to the cumulative building damages for each property to create a combined total damage.

6.2.2 Building Types

The adopted damages approach allows for unique classification of flood damages based on the type of building that were able to be determined for each building across the study area. Building types were derived for each building footprint based on building type provided in the NSW DCCEW footprint layer and confirmed through site visit observations, and Google Streetview observations. For example, all 1% AEP flood affected residential classed properties were inspected from site visit photos or Google Streetview to confirm if they were single or double storey. The building types were classified as follows:

> Residential building types:
  - Single storey:
  - Double storey,
  - Multi-unit,
  - Townhouse.
> Non-residential building types:
  - Low to medium being restaurants, cafes, offices, surgeries, retail outlets, service stations, hardware stores,
  - Default average,
  - Medium to high being chemists, electrical goods, bottle shops, electronics.
> Public buildings:
  - School
  - Hospital
  - Other

Note that all secondary buildings such as garden sheds and garages in residential properties were excluded from damages calculations. In total, when removing secondary buildings there were a total of 909 buildings assessed in the flood damages calculation across the catchment.

The number of dwellings per building footprint were also estimated based on aerial images, site visit observations and Google Streetview. In addition, residential properties were grouped by size with small being less than 135 m^2, medium being between 135 – 200 m^2, default being between 200 – 230 m^2 and large being 230 m^2 or greater.

6.2.3 Floor Levels

Floor levels for all building footprints have been adopted in the damages calculation through one of two methods:

- Based on floor levels survey for the building for surveyed buildings in the study area. The floor level survey data is summarised in **Section 3.5**.
- For non-surveyed buildings, the following floor level estimation process was applied:
  - The average ground level for the building footprint was calculated using the TUFLOW model terrain.
  - Using Google Streetview, an approximate floor height above ground levels was estimated. This floor height was typically 0.15 metres for slab-on-ground type construction, 0.3 metres for normal construction and 0.6 metres for higher suspended floor type buildings.
  - The estimated floor level was calculated from average ground floor of the building footprint plus the approximate floor height above ground.

6.2.4 Hydraulic Model Results

To inform the flood damages calculation, a range of base case model results were assessed for all five design flood events, 20%, 5%, 2% and 1% AEP and PMF events. The results were applied as max values across the building footprints:

- Maximum water levels for footprints were determined for each design event,
- Maximum depth results for footprints were determined for each design event, and,
- Maximum H1-H6 hazard category within the footprint were determined for each design event.

In addition, to inform external (garden) damage calculation, the maximum flood depth for properties were calculated for each design event.

6.3 Flood Damages Methodology

Flood damages can be assessed by several methods including the use of computer programs such as FLDamage or ANUFLOOD, or via more generic methods using spreadsheets. For the purposes of this project, the recently released 2023 Flood Damages Tool (DT01) prepared by NSW DCCEW as part of the FRM Manual 2023 has been adopted for calculation of building damages, with external damages calculated using in-house spreadsheet analysis as summarised in the following sub-sections.

6.3.1 New Flood Damages Tool

This flood damages analysis has been based on the Flood Damages Tool (DT01) prepared by NSW DCCEW as part of the FRM Manual 2023. The damages tool is supported by Section 3 of the Flood Risk Management Measures - Flood Risk Management Guide MM01 which provides background and guidance on the use of the tool.

The methodology outlined within the damages tool is an improved and more detailed calculations than previous damages tools. The damages tool DT01 provides the following advantages over past damages tools provided by the NSW Government:

- It provides not only residential damages for single and double storey houses similar to past tools, but it also provides damages curves for commercial and public infrastructure buildings and specific public buildings,
- The methodology also allows for calculation of risk to life projected costs based on the H1-H6 hazard categorisation of the building,
- It allows for damages estimation based on building footprint areas providing additional detail in analysis.

Therefore the DT01 damages tool was ultimately considered suitable for adoption in this study.

6.3.2 Calculation Parameters

The damages tool DT01 curves are derived for late 2019, and as part of this Study were updated to represent late 2022 dollars (only quarter 1 2023 inflation data available at the time of this report).

General recommendations in the damages tool and guideline are to adjust values in residential damage curves by Consumer Price Index (CPI). The most recent data for CPI from the Australian Bureau of Statistics at the time of the assessment was for March 2023. Therefore, all ordinates in the residential flood damage curves were updated to March 2023 dollars (CPI 132.7) from December 2023 dollars (CPI 130.9).

Consequently, all ordinates on the damage curves were increased by 1.38% compared to the curves presented in the flood damages tool DT01.

6.3.3 Damage Curves for Overfloor Flooding Depths

Residential and non-residential flood damages are generally assessed based on assessments of structural damage, damage to contents, external damage, relocation costs and clean-up costs. In limited cases, the additional damage costs related to structural integrity due to building failure may also warrant consideration. The adopted flood damages curves for residential single and double storey buildings for the various building sizes are shown in **Figure 6-2** and **Figure 6-2** respectively.

Further details about the formulation of the residential damage curves adopted in the flood damages tool DT01 are included in Section 3.1 of Flood Risk Management Guide MM01.

Non-residential flood damage curves including commercial / industrial and public buildings are shown in **Figure 6-3**. Further details about the formulation of the non-residential damage curves adopted in the flood damages tool DT01 are included in Section 3.2 of Flood Risk Management Guide MM01.

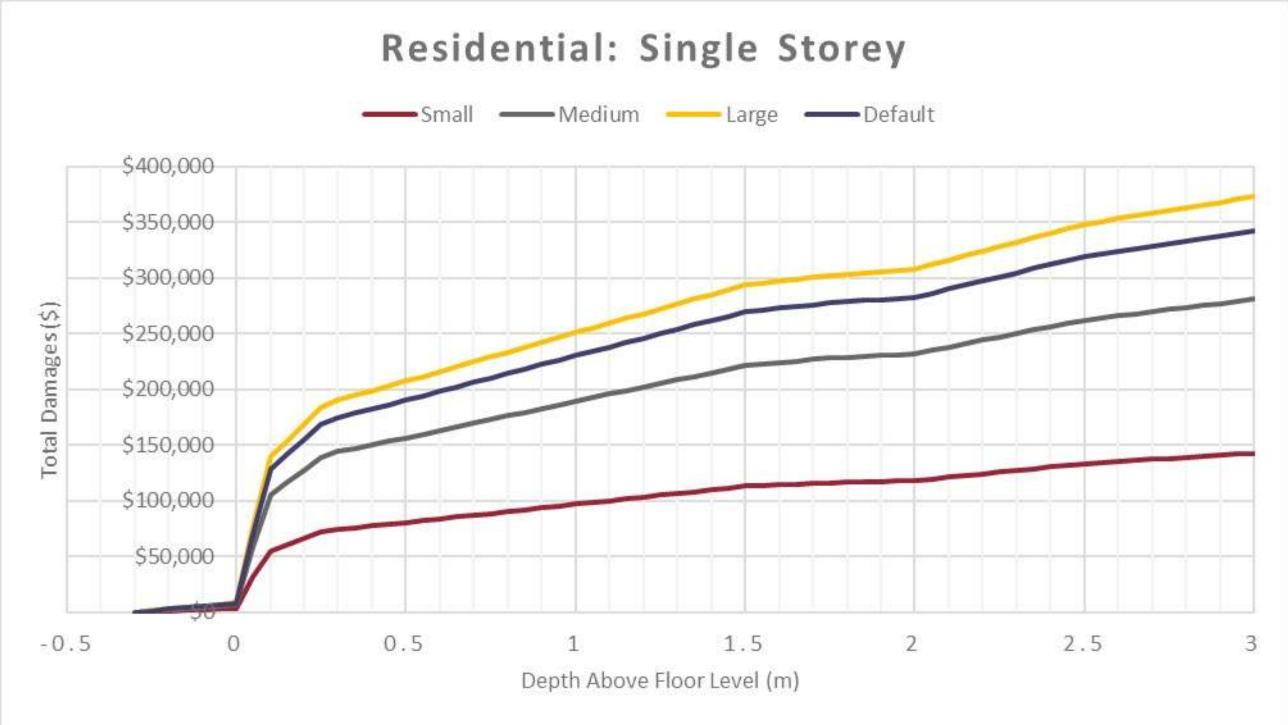

Figure 6-2 Adopted Damage Curves for Residential Single Storey (Source: DT01 Damages Tool)

Figure 6-3 Adopted Damage Curves for Residential Double Storey (Source: DT01 Damages Tool)

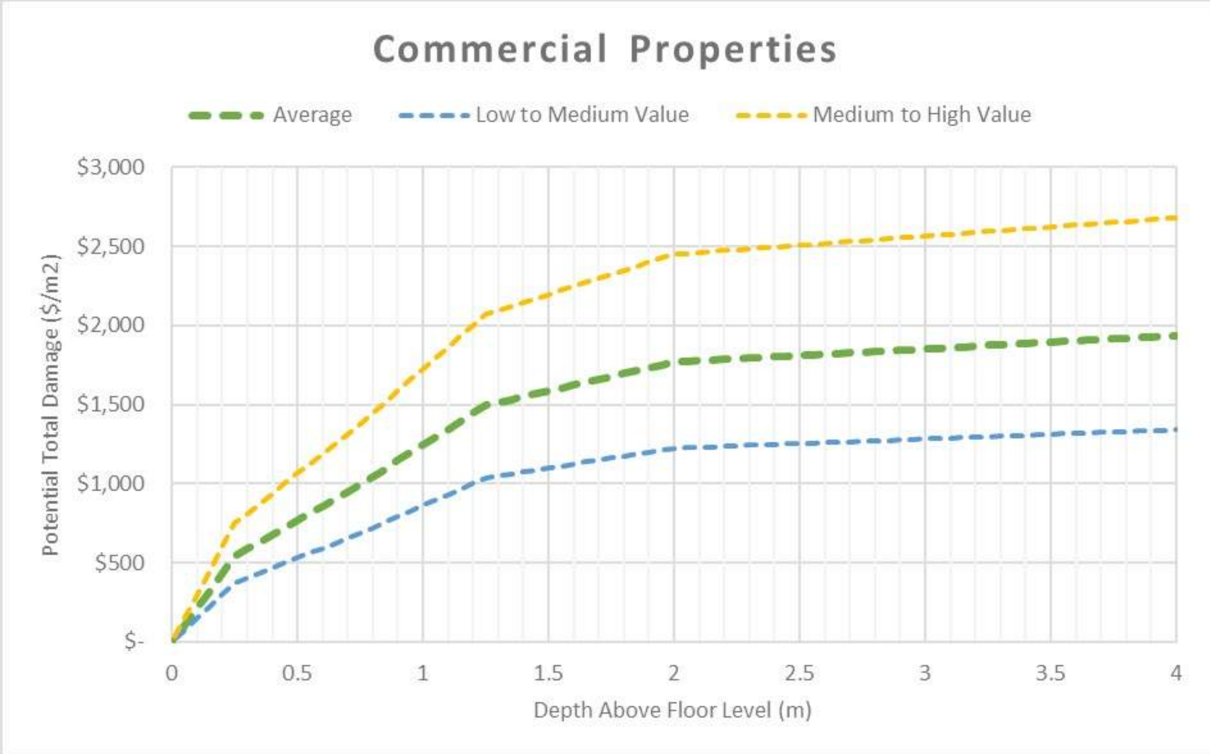

Figure 6-4 Adopted Damage Curves for Commercial and Public Buildings (Source: DT01 Damages Tool)

6.3.4 Property Based Damages Calculation

A fixed external damage of $17,234 in 2023 dollars ($17,000 in 2022 dollars) is to be used for each dwelling site and for each site that contains multi-unit dwellings. This is used when flood depths above the ground level adjacent to the building are at least 0.3 metres or are above the habitable floor level of the house.

The trigger for these external damages has been based on average ground levels around the buildings, if the depth results exceed the threshold of the 0.3 metres, then the fixed damage rate has been applied to each property. The basis for external damage calculation has been based on the building footprint layer, and not based on a property layer. Therefore no external damage has been applied to properties without a building.

6.3.5 Adopted Input Parameters

The flood damages tool DT01 provides numerous input parameters to tailor the flood damages analysis. The tool and associated guide provide advice with respect to default values. The input parameters for this flood damages assessment are as follows:

- Actual to potential ratio = 0.9 (default)
- Regional uplift factor = 1.00 (default for Sydney region)
- Infrastructure damages uplift = 10% of residential damages (default)
- Damages downscale for townhouses and units = 30% (default)
- Internal / contents rate = $550 / m^2 (default)
- Residential clean-up costs = $4,500 / property (default)
- Non-residential indirect costs = 30% of direct actual damages, clean-up costs and loss of trading (default).

With respect to risk to life damages calculations, the equations adopted within the flood damages tool DT01 are summarised in **Figure 6-4**.

$$Injuries = 2 \cdot N_z \times \frac{HR \cdot AV}{100} \cdot PV$$

$$Fatalities = 2 \cdot N(I) \times \frac{HR}{100}$$

$$Hazard\ Rating\ [HR] = d \times (v + 0.5)$$

Where,

N_z	Population living in the floodplain
HR	Hazard Rating (Table 12-6)
AV	Area Vulnerability (Table 12-7)
PV	People Vulnerability = {% residents suffering any long-term illness, % aged 75+}
N(I)	Number of injuries
d	Depth of flooding (m)
v	Velocity of floodwaters (m/s)

Figure 6-5 Flood Risk to Life Damages Calculations (Source: NSW DCCEW, 2023)

The adopted flood risk to life parameters are as follows:

The adopted flood risk to life parameters are as follows:

- Estimated cost per fatality = $5,300,000 (default taken from the Office of Best Practice Regulation (Australian Government)
- Estimated cost per injury = $52,962 (default taken from the Office of Best Practice Regulation (Australian Government)
- N(z) average people per household = 2.1 (default from ABS)
- Speed of onset = 3 (rate of rise is less than 1 hour)
- Primary nature of area = 2 (detached residential dwellings)
- Flood Warning Factor = 3 (calculated from P1, P2 and P3)
- Area Vulnerability (AV) = 8
- People Vulnerability = 36% (default)

6.4 Flood Damages Outcomes

6.4.1 Total Damages

The total damages have been calculated for all design events, 20%, 5%, 2%, and 1% AEP and the PMF event. The results are tabulated in **Table 6-2** and **Table 6-3** show that the damages total for Whites Creek and Johnstons Creek respectively. The tabulated results also show the building and external damages.

As it relates to contributions from building and external damages, the external component makes up only a fraction (8.25% – 13.5%) in Whites Creek and (7.7% – 13.1%) in Johnstons Creek of the total damages, with the vast majority being building related damages including structural, risk to life, contents, relocation etc.

The total damage values and number of affected properties / buildings, and average depth of flooding for the 20%, 5%, 2%, and 1% AEP events are shown **Table 6-2** and **Table 6-3**.

Table 6-2 Existing Total Damages Summary for Design Flood Events for Whites Creek Study Area

Event	Damage Type	Total Damages	Number of Overfloor / Overground Flooded	Avg. Overfloor/ Overground Depth (m)
20% AEP	Building	$2,343,533	39	0.10
	External	$720,371	83	0.34
	Total	$3,063,904		
5% AEP	Building	$3,687,428	48	0.13
	External	$777,243	97	0.34
	Total	$4,464,671		
2% AEP	Building	$3,930,937	52	0.14
	External	$853,071	99	0.36
	Total	$4,784,009		
1% AEP	Building	$4,456,495	59	0.15
	External	$947,857	105	0.37
	Total	$5,404,352		
PMF	Building	$21,749,361	160	0.35
	External	$2,417,036	202	0.61
	Total	$24,166,397		

Table 6-3 Existing Total Damages Summary for Design Flood Events for Johnstons Creek Study Area

Event	Damage Type	Total Damages	Number of Overfloor / Overground Flooded	Avg. Overfloor/ Overground Depth (m)
20% AEP	Building	$36,477,108	272	0.16
	External	$4,514,960	545	0.36
	Total	$40,992,067		
5% AEP	Building	$57,005,721	340	0.22
	External	$5,609,735	633	0.41
	Total	$62,615,455		
2% AEP	Building	$67,308,868	391	0.24
	External	$6,279,554	680	0.43
	Total	$73,588,421		
1% AEP	Building	$76,299,705	419	0.27
	External	$6,592,346	726	0.44
	Total	$82,892,052		
PMF	Building	$234,467,979	835	0.44
	External	$12,953,280	1139	0.63
	Total	$247,421,259		

6.4.2 Average Annual Damage

Average Annual Damage (AAD) is calculated using a probability approach based on the flood damages calculated for each design event. These damage curves attempt to define the damage experienced on a property for varying depths of flooding. The total damage for a design event is determined by adding all the individual property damages for that event. AAD attempts to quantify the flood damage that a floodplain would receive on average during a single year. It does this using a probability approach.

While the PMF event has a theoretical probability of 0% of occurring, to inform the calculation of AAD a representative probability of 0.0000001 (or 0.00001%) has been adopted for the PMF event (equivalent to a 10,000,000 year ARI event). This is based on guidance from AR&R Book 8 – Estimation of Very Rare to Extreme Events which notes this as the equivalent recurrence event for catchment less than 100 km^2. Through this method, the PMF accounts for extremely rare flood events in the AAD calculation.

For the most frequent event, the 20% AEP event, a lower bound flood damages estimate is required for the next most frequent event. In the DT01 tool it has been assumed that the total damages in the 100% AEP event will be $0 creating the lower bound of the AAD curve as per the default set-up of the tool.

The AAD calculation for the Whites Creek and Johnstons Creek catchment is summarised in **Table 6-4** and **Table 6-5.**

Table 6-4 Whites Creek Average Annual Damage Summary for Design Flood Event Contributions

AEP	Probability	Total Damages	AAD Contribution	AAD Contribution %
20%	0.20	$3,063,903.96	**$1,242,852.12**	58%
5%	0.05	$4,464,671.08	**$566,565.20**	26%
2%	0.02	$4,784,008.54	**$140,083.55**	7%
1%	0.01	$5,404,351.73	**$51,276.34**	2%
PMF	0.0000001	$24,166,396.99	**$147,705.89**	7%
Total AAD			**$2,148,483.10**	

Table 6-5 Johnstons Creek Average Annual Damage Summary for Design Flood Event Contributions

AEP	Probability	Total Damages	AAD Contribution	AAD Contribution %
20%	0.20	$40,992,067.07	**$16,541,136.30**	57%
5%	0.05	$62,615,455.20	**$7,809,005.61**	27%
2%	0.02	$73,588,421.34	**$2,060,651.80**	7%
1%	0.01	$82,892,051.58	**$783,517.49**	3%
PMF	0.0000001	$247,421,258.99	**$1,649,914.99**	6%
Total AAD			**$28,844,226.18**	

The total AAD for the Whites Creek is over $2 million. Nearly half (58%) of this AAD is a result of the most frequent 20% AEP event, with the next most frequent event, the 5% AEP contributing 26% of the AAD. The less frequent events, the 2% and 1% AEP and PMF provide between 2 – 7% of AAD contribution. By looking at Johnstons Creek result we can determine that the total AAD is over $28.8 million. Also, nearly half (57%) of this AAD is a result of the most frequent 20% AEP event, with the next most frequent event, the 5% AEP contributing 27% of the AAD. The less frequent events, the 2% and 1% AEP and PMF provide between 3 – 9% of AAD contribution. Though these events result in far higher flood damage totals, particularly the PMF event, their relatively low likelihood means they contribute less to the AAD.

Therefore, as it relates to damages and AAD, structural flood risk management options that reduce flood damages for the most frequent 20% AEP event are expected to provide the biggest benefits to AAD reductions.

7 Flood Emergency Response Review

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

The primary strategy for the NSW State Emergency Service is horizontal evacuation of people to an area outside of the effects of flooding that has adequate facilities to maintain the safety of the community. However, during flash floods this may not be possible due to the short warning times.

The emergency response provisions for Inner West Council are outlined in the Inner West Local Emergency Management Plan (EMPLAN) and overseen by the Local Emergency Management Committee. Under the provisions of the EMPLAN, NSW SES are appointed as the lead agency for response to Flooding Emergencies. The NSW SES, in conjunction with the Inner West LEMC is responsible for the preparation and management of the Inner West Council Flood Emergency Sub Plan. These documents are intended to provide information to residents and other authorities relating to identified evacuation centres, evacuation procedures, as well as actions and responsibilities in the event of flooding. A review of these available documents is included in **Section 7.1**. There is also a review of available flood emergency response advice in flash flooding situations in **Section 7.2**.

In addition, a review of the flood emergency response potential for the Whites Creek and Johnstons Creek catchments summarised below including key emergency management locations (**Section 7.3**), current and possible flood warning systems (**Section 7.6**), evacuation timeline review (**Section 7.4**), potential for shelter-in-place refuge (**Section 7.6**), and a summary of flood emergency response hotspots (**Section 7.5**).

7.1 Emergency Flood Management Documentation

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

The Inner West catchment is located within the Sydney Metropolitan Emergency Management Region. This region encompasses 8 Local Government Areas of Sydney bounded by Woollahra, Waverley and Randwick to the east and Sutherland Shire to the southwest. The relevant local area with respect to SES emergency planning is the Inner West Local Government Area (LGA).

7.1.1 Local Flood Plan

In December 2021 the SES released Volume I the Inner West Flood Emergency Sub Plan covering operations for flooding within the Inner West Council LGA. Volume I of the plan outlines emergency management arrangements for prevention, preparation, response and initial recovery for flooding in the Inner West LGA.

The local strategies for flood emergency response outlined within Volume I were divided into the four stages of emergency management, prevention / mitigation, preparation, response, and recovery operations. In response to strategies a range of recommended actions are nominated for SES to achieve these strategies. The total number of strategies is 32 and 136 actions, spread across the four stages of emergency management as follows:

- Prevention / mitigation – 2 strategies and 4 actions.
- Preparation – 6 strategies and 22 actions.
- Response – 23 strategies and 105 actions.
- Recovery – 1 strategy and 5 actions.

7.1.2 Local EMPLAN

Inner West Council has established a Local Emergency Management Committee to carry out emergency management as the responsible authority for the Inner West local government area. This committee is responsible for an all-agencies comprehensive approach to emergency planning to prepare the community for disasters. Committee members include Emergency Services and agencies with functional responsibilities.

Inner West Emergency Management Plan has recently been published by NSW SES.

7.1.3 Regional and State Documents

The relevant regional and state emergency management documents are as follows:

- Sydney Metropolitan Region Emergency Management Plan – January 2022
- NSW State Flood Plan – December 2021
- NSW State Emergency Management Plan – December 2018.

The various documents provide more useful information in relation to the roles and responsibilities of various stakeholders in both general emergencies (EMPLANs) and specifically for flood emergencies (Flood Plans).

7.2 Guidance on Emergency Response in Flash Flooding

7.2.1 AFAC Guideline for Emergency Response in Flash Flood Events

In April 2018, the Australasian Fire and Emergency Service Authorities Council (AFAC) released the *Guideline on Emergency Planning and Response to Protect Life in Flash Flood Events*. This guideline for flash flood events provides a useful insight into the position of the national emergency services authorities' council, of which NSW SES is a member. The guideline reflects a consensus on best practice for managing flash flooding, focussing on risk to life. The AFAC define flash flooding as:

> *Flash flooding can be defined as flooding that occurs within six hours or less of the flood-producing rainfall within the affected catchment. This may result in isolation of individuals and communities as time to warn and respond to flash flooding is limited.*
>
> *Flash flood environments are characterised by the rapid onset of flooding from when rainfall begins (often within tens of minutes to a few hours) and by rapid rates of rise and by high flow velocity. The duration of flash flooding is often relatively short by comparison to riverine floods.*

The discussion of flood timing for the Whites Creek and the Johnstons Creek study area (**Section 7.4.2**) shows the entire floodplain is flash flooding based on the above definition, making this guideline relevant to the catchment.

7.2.2 Guidance on Flood Emergency Response Potential in Flash Flood Environments

Effective evacuation typically requires lead times of longer than just a couple of hours and this creates a dilemma for flash flood emergency managers. The following excerpt from the AFAC guideline outlines the dilemma as it relates to the suitability of evacuation and shelter-in-place potential in flash flood environments:

> *Because of the rapid onset of flash flooding and associated high velocity floodwaters, up to 75% of flash flood deaths occur while people are outside buildings attempting to leave or return, and directly exposed to floodwater.*
>
> *This suggests that if evacuation has not occurred prior to the arrival of floodwater, taking refuge inside a building may generally be safer than trying to escape by entering the floodwater. However, some deaths – 25% of the total – occur among people trapped inside buildings. Details are not well documented, and these deaths could be the result of the building filling with flood water to a depth occupants cannot survive or because those trapped inside are swept away when the building fails. Other causes of death could be serious injury or an emergency medical condition while access to emergency assistance is compromised. Fires might also break out in buildings surrounded by floodwater, in which case occupants might not be able to evacuate as they would usually do.*
>
> *For these reasons, remaining in buildings likely to be affected by flash flooding is not low risk and should never be a default strategy for pre-incident planning or incident action planning, even if the buildings are considered likely to withstand the impact of flash flooding. Where the available warning time and resources permit, evacuation should be the primary response strategy.*

This conclusion is similar to advice provided by NSW SES representatives for past studies within Sydney:

> *The NSW SES considers evacuation as the primary response strategy during flooding to protect the at-risk community. This strategy relies on the principles for evacuation that include:*
>
> - *Evacuation completed in sufficient time before the onset of a flood is the safest emergency management strategy.*
> - *The primary method of evacuation should be by vehicle where feasible with pedestrian evacuation as a backup option.*

- *Evacuation must not require people to drive or walk through flood water.*
- *The best vehicular evacuation routes are vehicular escape routes that rise steadily and lead away from the flood.*
- *For existing communities, a strategy of having occupants shelter in place may be acceptable, where the decision to evacuate is left too late, as long as the buildings they inhabit are out of the floodwater or are structurally sound.*
- *Emergency management strategies must consider expected human behaviour and the expected range of severity of hazards*
- *Sheltering in place should only be a strategy where the risk if staying is lower than the risk of evacuating.*

The SES's position, continues to be that isolation is dangerous from the moment it commences and the longer the isolation continues, the more opportunity there is for an emergency to develop.

Additionally, secondary emergencies such as fires and medical emergencies may occur in buildings isolated by floodwater. During flooding it is likely there will be a reduced capacity for relevant emergency service agencies to respond. Even relatively brief periods of isolation, in the order of a few hours, can lead to personal medical emergencies.

While the preferred method of emergency response throughout NSW is for evacuation to be assisted and directed by the SES, there are certain emergency situations where there is limited time available to prepare and facilitate a staged evacuation as preferred. One such example is flash flooding where the rate of rise of floodwaters is extremely fast and the ability for SES to co-ordinate a regional evacuation strategy is not possible.

7.2.3 Guidance for New Developments in Flash Flood Environments

Given the life risk posed by flash flooding and the inherent limitations on how it can be managed, the AFAC guideline recommends new development areas:

- *be designed within the limits of existing flash flood forecast capability,*
- *facilitate rapid and safe evacuation from flash flood prone locations,*
- *account for the likelihood that some people might become trapped inside buildings, and*
- *involve a thorough understanding of how people will behave in a flash flood event and their risks*.

This conclusion is similar to advice provided by NSW SES staff for past studies for new developments:

- *No increase to the existing risk to life and evacuation or reduces the current continuing or residual risk to life.*
- *Where evacuation cannot be accomplished and 'shelter in place' is proposed, then development that will increase the risk to life of future occupants and increase reliance on emergency services should not be permitted. Development strategies relying on deliberate isolation or sheltering in buildings surrounded by flood water are not equivalent, in risk management terms, to evacuation.*

Self-evacuation of the community should be achievable in a manner which is consistent with the NSW SES's principles for evacuation.

It should be made very clear that in relation to the strategy of sheltering in place the SES has done some work with several councils which have flash flood risk over large urban areas. In this existing flash flood context, and only in that context, it has been recognised that causing residents to attempt to evacuate at the time flash flooding is occurring, could be a serious risk to life. Only in areas where urban redevelopment cannot be prevented under existing planning policy, it has therefore been proposed that the DCP (that applies) for any new or redeveloped dwelling will require an internal refuge area above the level of the PMF (Opper and Toniato, 2008).

7.3 Emergency Management Locations

7.3.1 Emergency Services Locations

Emergency services locations are considered critical during flooding if the infrastructure is relied upon for emergency management on a regional scale or pose a significant hazard to surrounding areas. Therefore, these types of emergency services have been mapped at a regional scale around the Whites Creek and Johnstons Creek Catchment as shown in **Figure 7-1**. This map has also been included in **Appendix C**.

The following emergency services have been mapped in the region around this catchment:

- Hospitals,
- Ambulance stations,
- Fire stations,
- Police stations, and
- NSW SES facilities.

Within the study areas there is the Newtown Police Station, NSW Newtown Fire Station, Street John Ambulance and King George V building Hospital all located in the Johnstons Creek Catchment. The Newtown Police Station and the NSW Newtown Fire Station site are partially flood affected in the 1% AEP and PMF events While Street John Ambulance is flood free in all the events, also Australia Street is flood free from the south but flooded from the south.

Also shown in **Figure 7-1** with the emergency service locations is the 1% AEP and PMF flood extents, not only for the study area, but for the vicinity of Whites Creek and Johnstons Creek. The flood extents show the regional isolation of the study area from emergency services.

Most roads are isolated from overland flooding from within the Study Areas, then other catchments cause road flooding that would further block access to emergency services during a regional overland flood event. Though it was not possible to show the flood extents outside the LGA, it is assumed that access to emergency services would be similarly restricted for areas outside the LGA. The nearest hospitals would be King George V building and Royal Prince Alfred Hospital Emergency Room in the northeast of study area. It is assumed that there would be no flood free access to these hospitals in the event of a regional flash flooding event from any part of the study area.

7.3.2 Vulnerable Developments

Vulnerable development relates to the increased risk of loss of life to vulnerable people including children, the elderly and disabled in most of these land use types. These demographics have a significantly greater risk to life when exposed to flood hazard. In addition, there is increased risk to life resulting from periods of isolation from medical emergency services due to pre-existing health conditions. Mobility of the related demographics is also compromised which will impede the effectiveness of both emergency response types. Included in these development types are:

- Schools, Preschools, and Childcare centres,
- Aged care facilities and retirement villages,
- Detention Centres – due to the limited mobility of the detained, these sites make flood evacuation much more difficult, and
- Hotels – the lack of local knowledge of hotel guests, coupled with the number of guests needing to be managed by hotel staff mean these are higher risk sites.

These categories of vulnerable developments match those presented in the 2021 Flood Prone Land Policy Update. Further discussion of the relative vulnerability of development types is in **Section 5.2**.

These sites have been mapped for the Study Area in **Figure 7-2**, which is also included in **Appendix C**.

The mapping shows that most vulnerable developments are suitably located in flood free land, with some of these developments partially affected by flooding, with only some locations significantly flood affected. Due to the permissibility of childcare centres, preschools and retirement communities in various land use zonings, the location of vulnerable developments will change over time. This mapping should be reviewed and updated by Council in the future to have a continued understanding of flood risk vulnerable developments.

7.3.3 Current Emergency Management Procedures for Vulnerable Developments

The NSW SES within the Inner West LGA Local Flood Plan provide the following specific actions within **Section 5.8.3** and **Section 5.9.2** as it relates to evacuation of vulnerable developments:

- Health Services Functional Area will coordinate the evacuation of hospitals, health centres and aged care facilities (including nursing homes) in consultation with the NSW SES and Welfare Services.
- School administration offices (Government and Private) will coordinate the evacuation of schools in consultation with the NSW SES and Welfare Services, if not already closed.
- Welfare Services Functional Area will manage evacuation centres for affected residents and travellers in accordance with the Welfare Services Functional Area Supporting Plan.
- Schools Administration (Government and Private) will manage the safety of students directly affected by flooding and will work with the NSW SES in the temporary closure of schools and will coordinate with NSW SES Transport and Welfare Services in the management of school evacuees.

As discussed further in **Section 7.4.6**, the flash flooding nature of the Study Area will make it difficult for SES to coordinate the evacuation of these vulnerable sites within the time available from the onset of rainfall. It is therefore recommended that individual flood response plans are developed for both existing and future vulnerable developments that are flood affected within the study area.

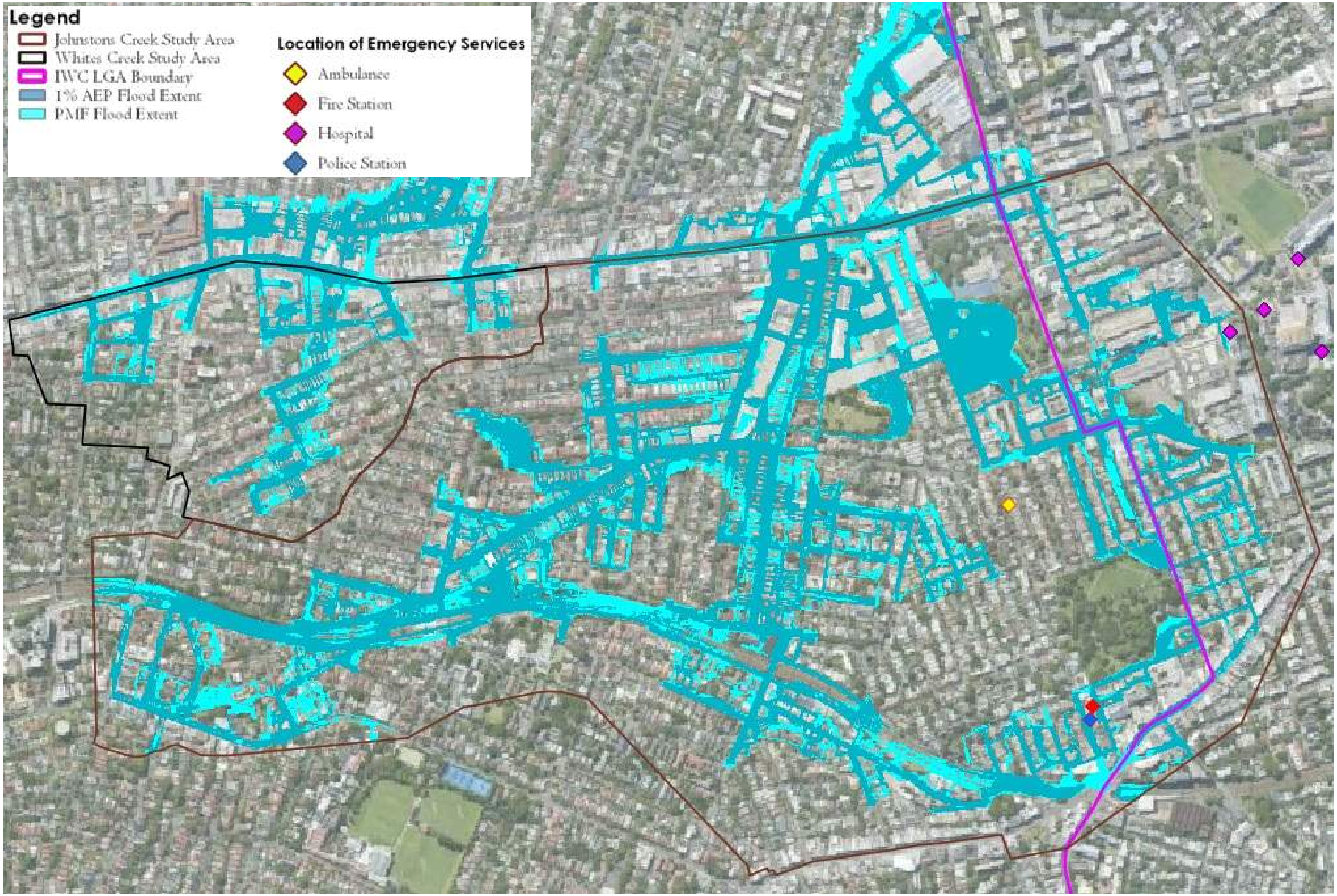

Figure 7-1 Location of Emergency Services in the Region with CBC LGA 1% AEP and PMF Extents

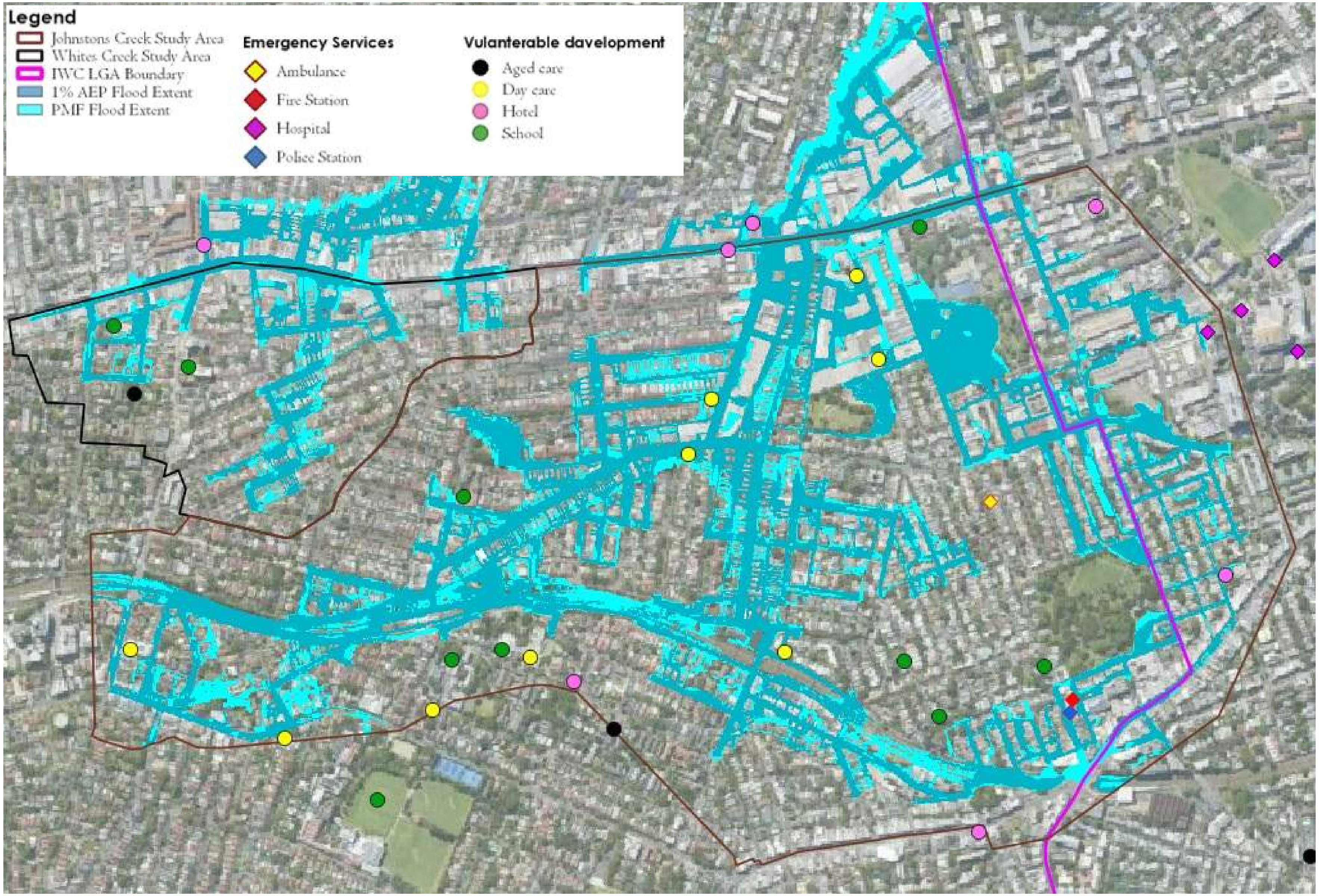

Figure 7-2 Location of Vulnerable Developments and Emergency Services within the Study Area with 1% AEP and PMF Extents

7.4 Evacuation Timeline

7.4.1 Background

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

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

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

Surplus Time = Time Available – Time Required

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

7.4.2 Sub-Catchment Flood Water Levels and Timing

A review of flood timing for the Whites Creek and the Johnstons Creek catchments has been conducted based on the model results for the 20%, 5%, 2%, and 1% AEP and PMF events at two locations. All have a rainfall duration of 1 hour. The flood timing inspection points, shown in **Figure 7-3** include one point on Parramatta Road in Whites Creek catchment and other point is on Salisbury Road in Johnstons Creek. This selected location generally matches the identified emergency hotspots discussed in **Section 7.5**.

7.4.3 Rate of Rise

With regards to rate of rise for the PMF event,

- Parramatta Road site in Whites Creek begins flooding in a couple of minutes after the onset of rainfall, with between 1.5 metres of flooding depth within an hour of the onset of rainfall; and
- Salisbury Road Site in Johnstons Creek begin flooding in 10 minutes after the onset of rainfall, with between 2.5 metres of flooding depth within an hour of the onset of rainfall.

For the 1% AEP and smaller design events,

- Parramatta Road site in Whites Creek begin flooding in a few minutes after the onset of rainfall, with up to 0.7 metre of flooding depth within an hour of the onset of rainfall; and
- Salisbury Road Site in Johnstons Creek begin flooding in 20 minutes after the onset of rainfall, with between 1.5 metres of flooding depth within an hour of the onset of rainfall.

7.4.4 Duration of Flooding

With regards to flooding duration for the PMF event, in Whites Creek and Johnston Creek the model simulation period was set at only 0.5 hours for the model. These short simulation times allow for the peak of flooding to occur, and as shown in **Figure 7-4**, also allow the falling limb of the PMF flood.

For the Parramatta Road Site in the Whites Creek catchment much of the local overland flooding has finished within 0.5 hours of the onset of rainfall. For the 1% AEP and smaller events, the duration of flooding is expected to be less than the PMF, a shown in **Figure 7-4** these events have durations of flooding of less than 1 hour.

For the Salisbury Road Site in the Johnstons Creek catchment the majority of the local overland flooding has finished within 2 hours of the onset of rainfall. For the 1% AEP and smaller events, the duration of flooding is expected to be less than the PMF, a shown in **Figure 7-5** these events have durations of flooding of less than 1.5 hour.

The only locations with risk of longer duration flooding are trapped low points that either have no existing stormwater drainage, or drainage that becomes blocked in the event of flooding. With no mechanism for draining these low points its reasonable that ponding may persist until any blockages are removed. Generally throughout the study area the duration of flooding is expected to typically be sub-daily.

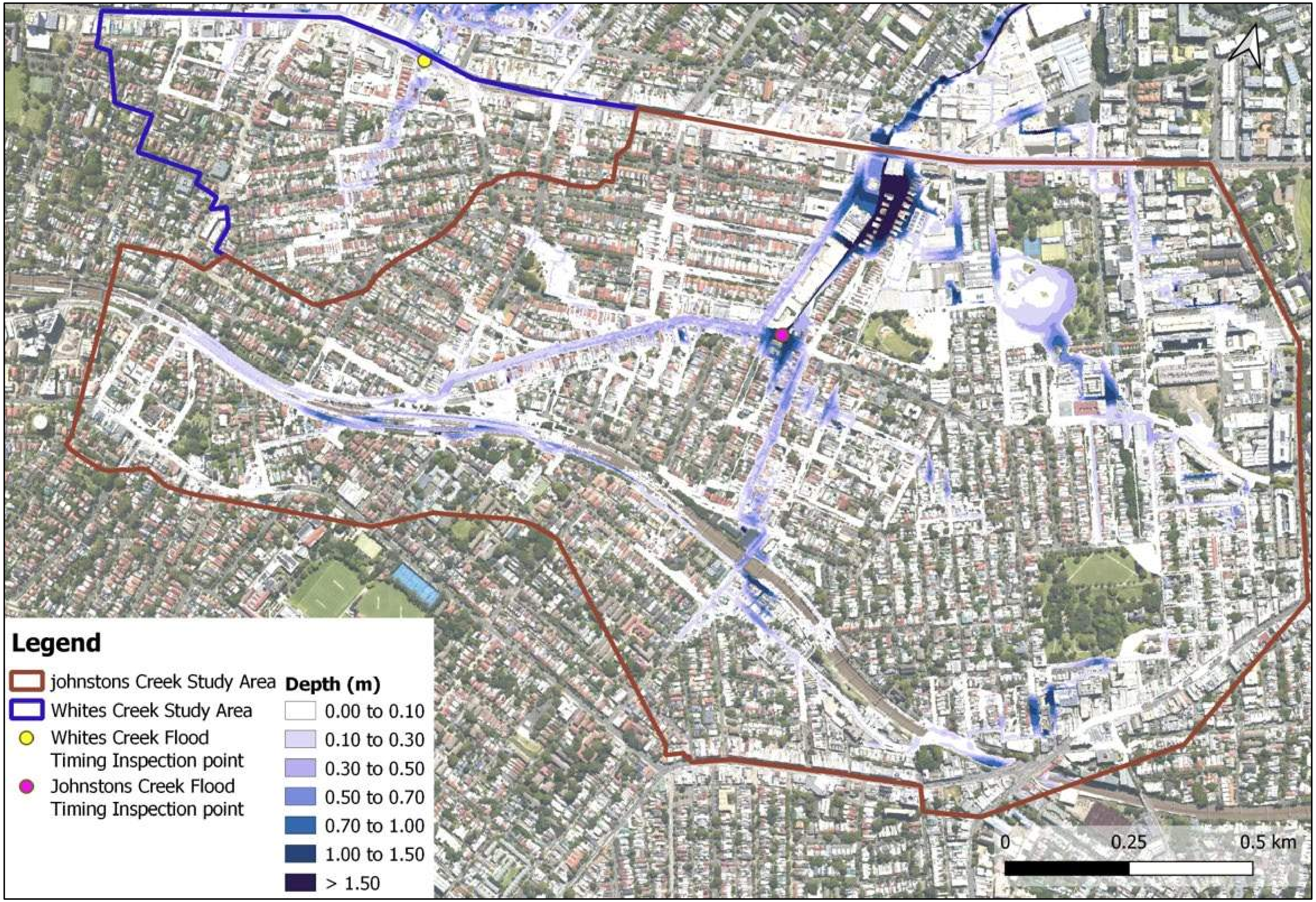

Figure 7-3 Flood Timing Inspection Points with 1% AEP Peak Depth Results

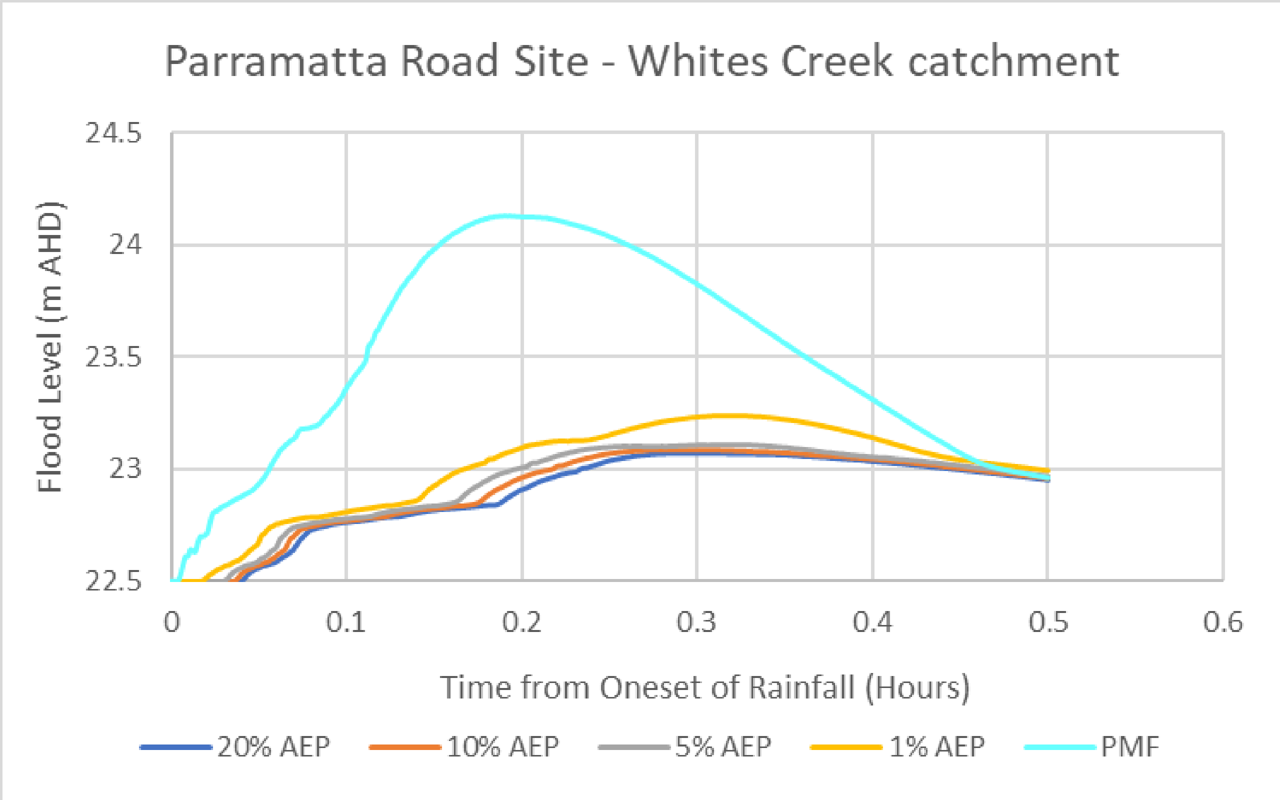

Figure 7-4 Flood Level Time Series Result for Base Case Models for Whites Creek Catchment Location

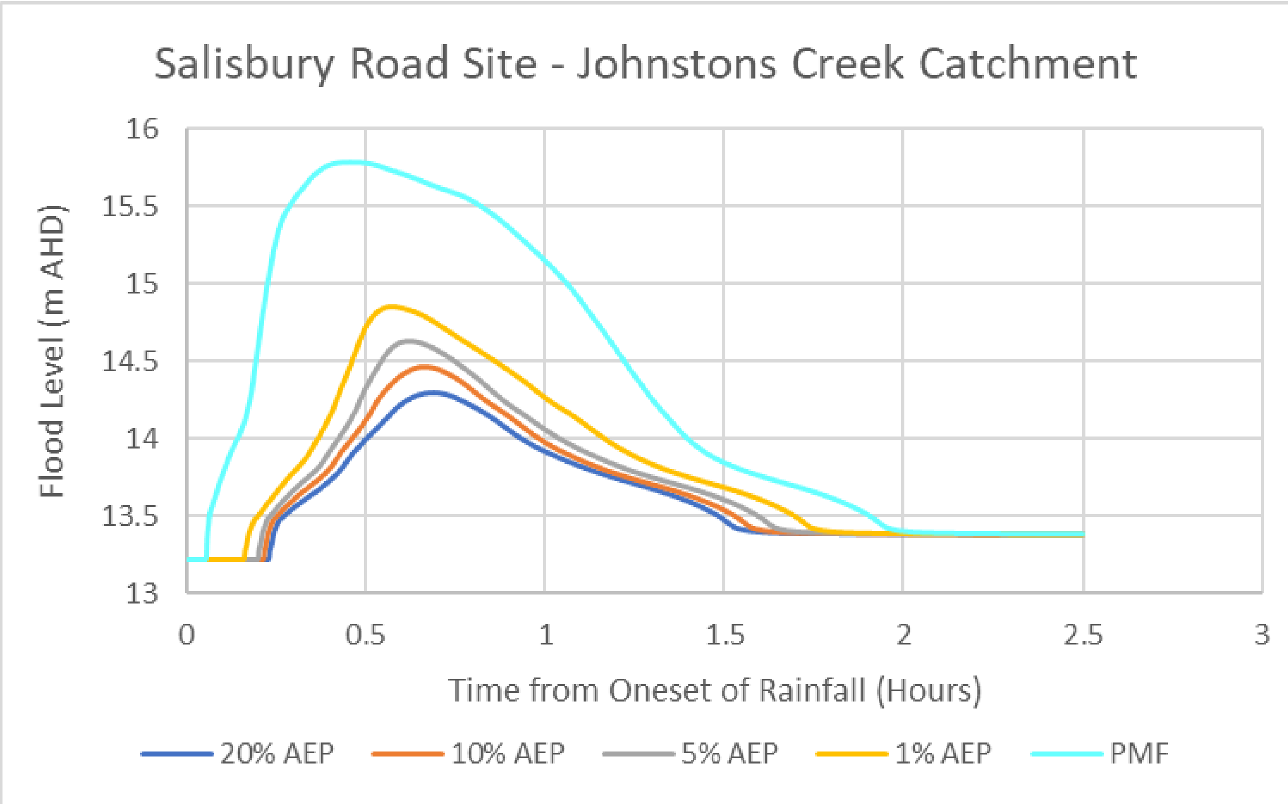

Figure 7-5 Flood Level Time Series Result for Base Case Models for Johnston Creek Catchment Location

7.4.5 Time Available

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

> For the Whites Creek catchment
  - A couple of minutes from the onset of rainfall for the PMF event,
  - A few minutes from the onset of rainfall for the 1% AEP and smaller events.

> For the Johnstons Creek catchment
  - Between 5 – 10 minutes (0.1 hours) from the onset of rainfall for the PMF event,
  - Between 10 – 20 minutes (0.1 – 0.2 hours) from the onset of rainfall for the 1% AEP and smaller events.

Therefore there is very little time available from the onset of storm burst rainfall for evacuation to occur. In addition, the volume of rainfall occurring is extreme in both a 1% AEP and PMF storm. It is unlikely that evacuating during the early stages of a design storm burst rainfall event will be safe as both vehicle safety and pedestrian safety is compromised under such heavy rainfall.

As a result, the only form of flood evacuation trigger for the Study Area that will provide sufficient available time to facilitate evacuation is flood forecasting methods as observed rainfall or flooding means that the opportunity to evacuate low-lying areas has already passed.

7.4.6 Time Required for SES Assisted Evacuation

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

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

Where the following values are recommended:

- Warning Acceptance Factor = 1 hour – accounts for the delay between occupants receiving the evacuation warning and acting upon it.
- Warning Lag Time = 1 hour – an allowance for the time taken by occupants to prepare for evacuation such as packing their belongings etc.
- Travel Time = Variable – the number of hours taken for the evacuation of all vehicles based on road capacity. NSW SES recommend a road lane capacity of 600 vehicles per hour.
- Travel Safety Factor = Variable – added to travel time to account for any delays along the evacuation route for example resulting from accidents.

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

Based on the above contributors, the overall time required for evacuation of the Whites Creek and Johnstons Creek catchments is a minimum of 2.5 hours (2 hours for WAF and WLT and 0.5 hours for mobilisation). It should be noted that this is a low bound estimate, as various factors such as Travel Time, and Travel Safety Factor have been disregarded. This means that in relation to SES doorknocked evacuation for the Study Area, evacuation needs to be triggered at least 2.5 hours prior to a storm burst rainfall event occurring.

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

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

7.5 Emergency Management Hotspots

As part of initial consultation for this project, NSW SES representatives requested emergency management mapping for hotspot areas in the Study Area. These emergency management maps have been provided in **Appendix C**.

The maps include flood information for the 20% and 1% AEP and PMF events to provide the requested information for the full range of design events. The maps provide the following information to assist SES:

- H1-H6 hazard mapping for the three selected design flood events to show areas of vehicular, pedestrian and building instability,
- Estimated overfloor flooding depth in metres for the three selected design flood events to provide an indication of flood risk sites,
- Indicative evacuation routes to flood free land. A distinction has been made between evacuation routes suitable for vehicles which are preferred and pedestrian only evacuation routes, and,

In total, eight emergency management hotspot areas have been identified as shown in **Figure 7-6**, six in the Johnstons Creek catchment and two in the Whites Creek catchment. This figure is also replicated in **Appendix C**.

Potential flood risk management options, particularly emergency management focused options, should prioritise these eight hotspot areas:

- Hotspot 1 – Johnstons Creek area of Stanmore between Parramatta Road, Mallett Street, Salisbury Road, and Northumberland Avenue.
- Hotspot 2 – Johnstons Creek near Stanmore Railway Station, including Salisbury Road between Douglas Street and Lincoln Street.
- Hotspot 3 – Johnstons Creek between Stanmore and Petersham, from Stanmore Road to Douglas St.
- Hotspot 4 – Johnstons Creek areas of Stanmore and Enmore, from Salisbury Road down to Charles St.
- Hotspot 5 – Johnstons Creek area of Enmore between Camperdown Memorial Rest Park/Cemetery and the railway line.
- Hotspot 6 – Johnstons Creek and Church Street, between King Street and Lucas Street.
- Hotspot 7 – Whites Creek area of Petersham between Temple Street and Parramatta Road.
- Hotspot 8 – Whites Creek area of Petersham between Parramatta Road and Fort Street.

Within these hotspot areas, pockets of low flood island properties have been identified to support SES operations. These are the higher risk areas with limited evacuation potential due to flooding of access roads in accordance with the principles of the Flood Emergency Classification of Communities (FERCC) (outlined in Part C of Flood Risk Management Guide EM01), A distinction has been made for low flood islands in industrial land uses where the risk to life may be different than residential land uses.

As noted within AIDR guideline 7.2 that outlines requirements for FERCC there is the following note:

> *The guideline supports decision making at a precinct or community scale, and for rivers and creeks where flow paths can readily be defined. It is not intended for application in local overland flooding at a smaller scale, or to individual structures.*

While the type of flooding in this study area would be defined as overland flooding, the FERCC mapping of specific hotspot areas does help to identify the properties that will have complications with flood emergency response.

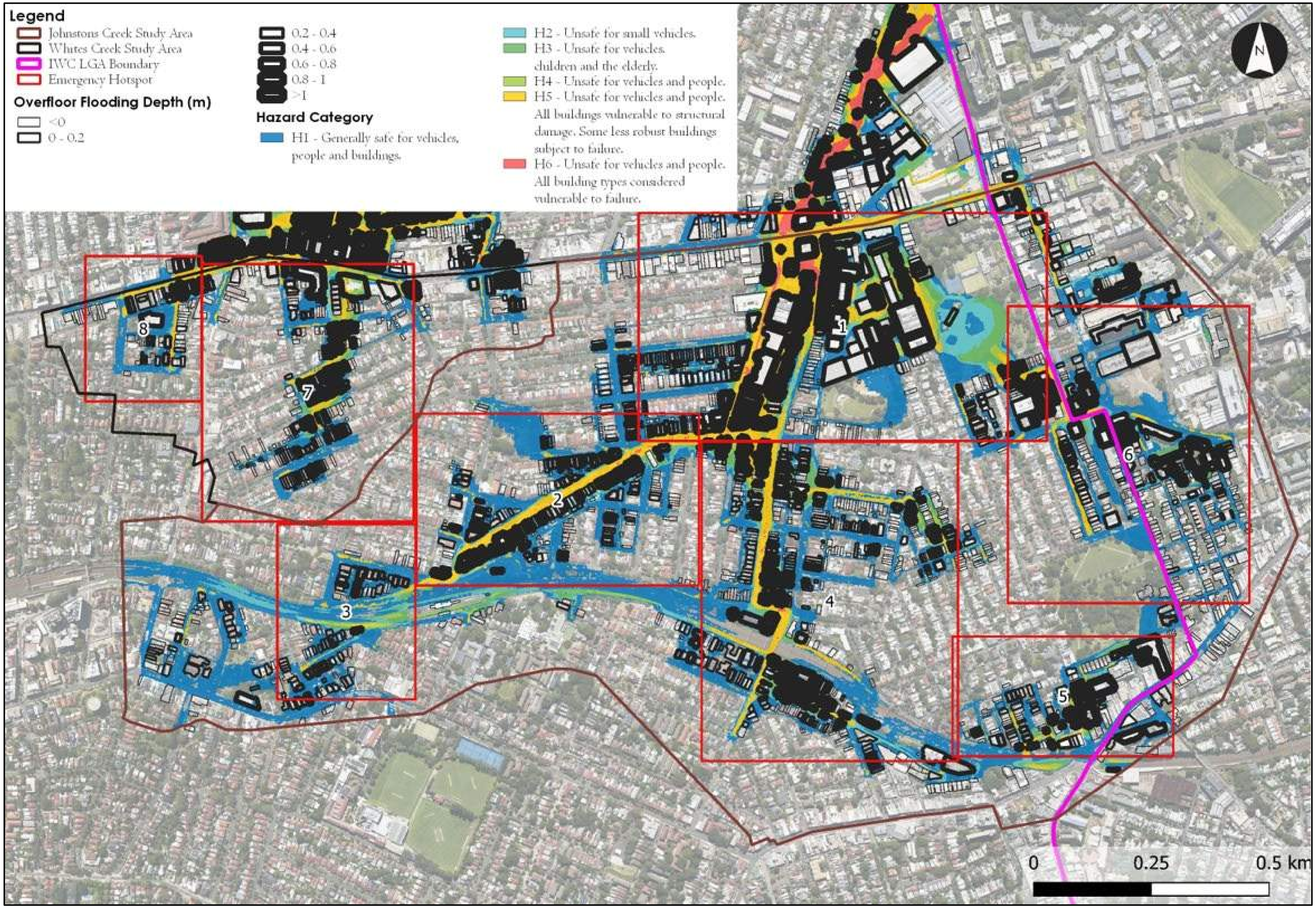

Figure 7-6 Emergency Management Hotspots with PMF H1-H6 Hazard

7.6 Flood Warning Systems

There are two components to a flood warning system:

- Monitoring of weather and flood conditions to decide when emergency response is required,
- Disseminating this information to residents so that evacuation may commence.

These two components of both current and potential flood warning systems are discussed in the following sub-sections.

7.6.1 Current Flood Warning System

The Inner West LGA Flood Emergency Sub Plan (SES, 2021) under Section 5.4 discusses the range of monitoring and alerts currently adopted by the NSW SES in the local area:

- The BoM issues public weather and flood warning products before and during a flood. These may include:
  - Severe Thunderstorm Warnings with reference to heavy rainfall
  - Regional Severe Thunderstorm Warnings with reference to heavy rainfall
  - Detailed Severe Thunderstorm Warnings (for Sydney/Newcastle/ Wollongong) with reference to heavy rainfall,
  - Severe Weather Warnings with reference to heavy rainfall and/or storm surge,
  - Flood Watches, and
  - Flood Warnings.
- In a flash flooding environment, these services can provide pre-emptive warnings of potential flood-causing rainfall, however they are considered less viable for ongoing updates and warnings during a flood event and monitoring of these resources during an event is not considered appropriate. Further discussion of the reasons for this are included in **Section 7.2**.

In addition to these resources that are monitored by the NSW SES, the Flood Plan also notes how these warnings are then disseminated to the community, with the SES providing alerts and flood information through:

- Mobile and fixed public address systems and sirens.
- Two-way radio.
- Emergency Alert (SMS and voice message alerting system).
- Telecommunications (including Auto dial systems).
- Facsimile.
- Standard Emergency Warning Signal.
- Doorknocking.
- Variable message signs.
- Community notices in identified hubs.
- Distribution through established community liaison networks, partnerships, and relationships, and
- NSW SES social media and website.
- NSW SES may seek support from agencies and local Council to share the SES social media messages.
- Road closure information will be provided to the community through Transport for NSW 'Live Traffic' website: www.livetraffic.com or 'Transport InfoLine': 131 500. Also, VMS messaging on roadways may also be used to advise motorists.

Several of these options will provide a useful means of almost instantaneously distributing flood warnings to the community. However, some of these means such as doorknocking and social media posts and community notices are unlikely to have the near instantaneous response needed from the community in flash flooding situations.

7.6.2 Discussion of Flood Warning Systems in Flash Flooding Environments

A summary of the considerations for flood warning systems in flash flooding is contained in the below excerpt from the AFAC guideline for flash flooding:

> *Successful evacuation strategies require a warning system that delivers enough lead time to accommodate the operational decisions, the mobilisation of the necessary resources, the warning and the movement of people at risk.*
>
> *Where pre-incident planning identifies existing warning lead times as being non-existent, too short or based on too much uncertainty, improvements to warning systems within existing hydro-meteorological capability should be a priority.*
>
> *Weather forecasting and flash flood prediction is undergoing continual improvement. This is the result of many factors, including better science and the influence of technology. The advent of faster and more 'accurate' weather and hydrological modelling and enhanced real-time observation systems such as Doppler radar are examples of such advances.*
>
> *However, although forecast 'accuracy' is improving for 24 to 72-hour periods, the near-to-real-time period of one to six hours, the period most relevant to flash flood environments, remains a significant forecasting challenge.*
>
> *Effective evacuation typically requires lead times of longer than just a couple of hours and this creates a dilemma for flash flood emergency managers. Due to the nature of flash flood catchments, flash flood warning systems based on detection of rainfall or water level generally yield short lead times (often as short as 30 minutes) and as a result provide limited prospects for using such systems to trigger planned and effective evacuation.*
>
> *Warning systems based on weather forecast can yield longer lead times but provide only a qualitative assessment of the potential for flash flooding over a broad geographical area. A forecast-based warning also inherently provides less certainty in either the location or rainfall volume from which to derive the expected depth and timing of flash flooding. This makes it difficult to provide timely and accurate advice to at-risk communities about flash flooding, regarding advice about who needs to evacuate and when to evacuate.*
>
> *Initiating evacuation of large numbers of people from areas prone to flash flooding based on these uncertain triggers may be theoretically defensible in a purely risk avoidance context but it is likely to be viewed as socially and economically unsustainable. Frequent evacuations in which no flooding occurs, which statistically will be the outcome of forecast-based warning and evacuation, could also lead to a situation where warnings are eventually ignored by the community.*
>
> *These considerations call for flash flood emergency managers to engage with flash flood prone communities, both to discuss and agree on appropriate triggers for agency-led evacuation, and to educate the community on appropriate behaviour in the event of flash flooding occurring with no or very little warning (including messages about the dangers of late evacuation, and strategies such as moving from unsuitable to suitable buildings).*

Within the Inner West, the constraint in deploying an effective flooding warning system is the time available to obtain and process actual rainfall and runoff data to provide an accurate prediction of flood behaviour in a timely manner to residents. Current technologies do not currently provide sufficient time to record and model potential rainfalls and the resulting impact to in time for sufficient community warning. However, this is an area of advancing technology, and improvements may be possible within a medium timeline.

Consequently, a flood warning system is not recommended as an immediate action for this catchment; however, advancements in technology should continue to be monitored for potential medium to long term implementation in the emergency management hotspots discussed in **Section 7.5**.

7.7 Shelter-in-Place Potential

NSW DPE following consultation with NSW SES have released the Draft Shelter-in-Place Guidelines in December 2022. The principles outlined in the guideline for shelter-in-place reflect those included in **Section 7.2**. Essentially that evacuation is the primary response strategy, however in flash flooding areas where evacuation is not possible, shelter-in-place is an alternative, and a last resort for brownfield and greenfield developments.

The guideline provides a list of requirements for potential shelter-in-place. Some requirements relate to development specific considerations such as access to utilities and power during shelter, a minimum flood space area for shelter, and the storage of food, first aid and other resources. However, there are some requirements that relate to the flood affectation of the area, specifically relating to:

- Stability of shelter-in-place structure,
- The duration of flooding of the refuge area and,
- The feasibility of flood free refuge area.

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

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

As noted within Emergency Management Principle 4 of the 2023 FRM Guide EM01, shelter-in-place should consider the following additional risks for this emergency response type:

- *Isolation – There is no known safe period of isolation in a flood, the longer the period of isolation the greater the risk to occupants who are isolated.*
- *Secondary risks – This includes fire and medical emergencies that can impact on the safety of people isolated by floodwater. The potential risk to occupants needs to be considered and managed.*
- *Consideration of human behaviour – The behaviour of individuals such as choosing not to remain isolated from their family or social network in a building on a floor above the PMF for an extended flood duration, or attempting to return to a building during a flood, needs to be considered when adopting EM strategy.*

7.7.1 Structural Stability

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

Hazard categories H5 and H6 both involve structural instability with lower hazard groups H1-H4 being generally considered in a stable range for structures. Mapping of H1-H6 hazard for the 20% and 1% AEP and PMF events for the emergency hotspots is included in **Appendix C**.

The results show that H6 areas where as guided by the hazard definitions building stability is compromised are generally confined to road reserve, backyards and dedicated waterways and channels.

The extent of H5 areas are where standard buildings may be unstable but buildings designed for flood affectation may be stable based on hazard definitions. The H5 extents are more widespread than H6 but in most locations are not within existing building footprints. At these locations any prospective shelter-in-place refuges would need to be specially engineered to withstand flood forces in the PMF event.

7.7.2 Duration of Flooding

The duration of inundation (the time for which the location is submerged) is guided by the water level time series for the Study Area discussed in **Section 7.4.2**. The analysis shows that the duration of flooding for the Study Area is short with most locations flood free less than 1 hour in Whites Creek and 2 hours in Johnstons Creek after the onset of rainfall for the PMF event. For frequent flood events the duration of flooding is same.

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

> *However, safety of isolation is subjective, and there is no evidence-based method for determining the tolerable duration of isolation that might result from floods. This is to state that the question of what is a safe period of isolation is not resolved.*

Further discussion of duration of isolation is provided within Principle 4 of the 2023 FRM Guide EM01, which notes secondary risks including fire and medical emergencies can impact on the safety of people isolated by floodwater, and consideration of human behaviour in flooding isolation conditions.

7.7.3 Flood Free Refuge

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

PMF peak depths throughout the Whites Creek and Johnstons Creek study area are relatively shallow compared to riverine or mainstream floodplains. In the upper catchment where overland flow typically occurs and fringe areas of the floodplain PMF depths can be less than 0.5 metres, and even lower than the Flood Planning Level (1% AEP plus 500mm freeboard). In these locations it is not onerous at all to require for shelter-in-place refuge above the PMF level.

In some sections of the floodplain, such as the commercial area along Bridge Road in the northern side of the Johnstons Creek catchment, PMF peak depths may be more significant. For these locations, shelter-in-place refuges become more onerous to construct as they will likely require a mezzanine level or a first floor to be constructed. However, such elevated levels are possibly advantageous to future industrial developments in the area assuming that they can be allowed for within height restrictions for the area.

Sections 7.7.1 to 7.7.3 indicate that the SIP (shelter-in-place) and planned vertical refuge in the flood impacted areas of the Whites Creek and Johnstons Creek study area may not possible due to intensity and duration of flooding, though it may be feasible for large portions of the study area. There will be a need for the development of local level resilience at highly impacted properties to address and manage flooding risks. This would include an elevated platform (say 2m) at a flood impacted property based on available space, which could be used by residents to take refuge during flooding events. This will negate the requirements from the SES to mobilise resources and investments. The flood impacted property owners should be incentivised to build such elevated platforms.

7.8 Potential Improvements to Flood Emergency Response

Based on the detailed review of flood emergency response provisions for the Whites Creek and Johnstons Creek catchments, it is unlikely, almost impossible, that SES doorknocked evacuation will be able to effectively evacuate residents prior to flooding. From this review, a number of potential measures have been identified that could improve flood emergency response potential for the study area:

- Self-managed evacuation,
- Improved flood awareness.

These points are discussed further in the following sections.

The potential for early warning systems to reduce the Warning Lag Time is discussed in **Section 7.4**. As noted in this section, current technology does not provide a suitable resource at this time, however newer technologies may provide for rapid modelling and predictions in the mid-term.

Another consideration to improve the emergency timeline is to reduce the Travel Time by utilising a shelter-in-place strategy where evacuation cannot be readily achieved. The suitability of this approach discussed further in in **Section 7.6**. As noted in this section, where structural stability, duration of flooding and flood free refuge are feasible, this may be a potential alternative. It is important to note that all of these potential alternatives are less preferential to SES assisted evacuation, which as per NSW SES and NSW DCCEW guidance is the primary and preferred form of flood emergency response.

These review outcomes have been considered and form the basis of the assessment of Emergency Management (EM) options as discussed in **Section 8.5**.

7.8.1 Self-Managed Evacuation

Where SES assisted evacuation is not an option, self-managed evacuation is a potential alternative. This describes where people make their own decision to evacuate earlier and move to alternate accommodation, using their own transport. These plans would typically be prepared using information available from Council and with support of the local SES unit, using SES templates such as FloodSafe. Self-managed evacuation has a number of advantages:

- People can be evacuated far quicker than SES assisted evacuation as various factors in the evacuation timeline are reduced or removed completely such as accounting for time for SES to mobilise, and doorknocking time.
- Self-managed evacuation reduces the strain on SES resources as part of the floodplain will be evacuated without needing to be doorknocked or otherwise prompted. Also less coordination is required on the part of SES as the scale of the evacuation exercise is lessened by some people being self-reliant.

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

A way for Council to encourage and confirm the adequacy of any self-managed evacuation is through flood emergency response development controls. This could be through implementing requirements for new developments to develop flood emergency response plans particularly large-scale development such as medium and high density residential. Another alternative to improve self-managed evacuation could be requiring site-specific flood warning systems, however these systems typically rely on observed flooding. NSW SES in their advice for this project noted “self-evacuation of the community should be achievable”.

7.8.2 Improved Flood Awareness

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

- Warning Acceptance Factor, accounts for the delay between occupants receiving the evacuation warning and acting upon it. If people are aware of the flood risk of the area that they live in, then it is reasonable to expect that they will acknowledge the seriousness of any flood warning, and perhaps begin evacuating immediately instead of one hour after receiving the warning.
- Warning Lag Time, an allowance for the time taken by occupants to prepare for evacuation such as packing their belongings etc. If residents are aware of the flash flooding nature of the catchment they are in, then they will know that they have very limited time to respond before flooding commences, leaving the majority of their belongings behind to ensure they evacuate as soon as possible for their own safety.

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

The crucial safety message to **not enter floodwaters** is relevant to all community members as flash flooding due to overland flow in heavy rainfall events (also referred to as stormwater flooding) is recognised as a high risk to all road users driving on flooded roads across the LGA.

8 Flood Risk Management Options

8.1 Background

8.1.1 Managing Flood Risk

Risk is a combination of the consequences of flooding and the likelihood of these consequences occurring. Flood risk to the community is not static. It can be influenced by Flood Risk Management (FRM) measures, climate change, and future development. It is important to understand these risks and how they may change over time so that this can be considered in management.

Considering flood behaviour with existing measures in place provides a basis for understanding the residual risk to the community with existing conditions, how risks may change into the future, and making informed management decisions. Flood risk can be categorised as existing, future or residual risk as follows:

- Existing Flood Risk – existing buildings and development on flood prone land. Such buildings and developments by virtue of their presence and location are exposed to an 'existing' risk of flooding,
- Future Flood Risk – buildings and developments that may be built on flood prone land in the future. Such buildings and developments would be exposed to a flood risk when they are built, and
- Residual Flood Risk – buildings and development that would be at risk following the implementation of FRM measures. Unless a FRM measure is designed to the PMF, it may be exceeded by a sufficiently large event at some time in the future, meaning in most instances there is still a residual flood risk.

The alternate approaches to managing risk are outlined in **Table 8-1**. The hierarchy of preferred risk approaches is from top to bottom in the approaches listed in the table. This hierarchy is also referenced within Section 3 of the Flood Risk Management Guide FB01.

Table 8-1 Flood Risk Management Alternatives (Source: SCARM, 2000)

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

The relevant emergency response provisions for Inner West Council are established in the Local EMPLAN by the Local Emergency Management Committee (LEMC). The EMPLAN details the combat agency for each hazard and is an all hazards all agencies approach. It refers to sub plans for hazard specific emergency management arrangements and planning. The flood emergency management arrangements that are outlined in the local flood plan (sub plan) expand on the roles and responsibilities of all local stakeholders including LEMC, and the NSW SES local volunteer unit as the combat agency for flooding, this is relevant once the SES stands up an Incident Management Team (activated) by a weather alert by the Bureau of Meteorology.

On all relevant public websites, members of the community within the PMF floodplain are encouraged to know their risk in relation to their local river level gauge. The AWS flood warnings that are issued provide clear statements for actions through Hazard Watch including for residents to stay informed of messaging based on Bureau warnings and reported flood water levels.

The crucial safety message to **not enter floodwaters** is relevant to all community members as flash flooding due to overland flow in heavy rainfall events (also referred to as stormwater flooding) is recognised as a high risk to all road users driving on flooded roads across the LGA. A valuable output of the FRM process to NSW SES flood intelligence is the mapping and tabulation of inundated roads by elevation and depth of flooding at various design storm events.

8.1.2 Options Development Process

As stated within the FRM Guide MM01 the assessment of FRM options should consider:

- Their practicality and feasibility, including the timeframe within which they may be implemented.
- The social, economic, and environmental costs, benefits and disbenefits of FRM measures.
- The upfront, ongoing and complementary work and lifecycle costs involved in implementation.
- Input from the community and the acceptability of measures to the community.
- Consistency with industry guidance and government direction, policy and guidance.

The assessment of FRM options should consider people in the community, the economy, social and cultural aspects, services to the community and the natural environment. Relating to the development of FRM options, the FRM Guide MM01 recommends the following stages within a FRMS&P:

- Option identification and preliminary option assessment and optimisation – The identification of an inclusive range of FRM options to address local or broad FRM issues for the existing community and new development. Having identified the FRM issues to address and an inclusive range of FRM options worthy of consideration, the viability of these options needs to be tested to determine if they warrant more detailed assessment. This process is summarised within the following sections.
- Detailed option assessment – Detailed assessment and subsequent optimisation of FRM options and packages of options needs to consider their costs, benefits and disbenefits in managing risk. The detailed assessment includes flood modelling of options, damages assessment of option benefits, preliminary costing and a Multi-Criteria Assessment (MCA) that considers a broad range of factors quantitatively or qualitatively.
- Recommendation in FRM studies and decision-making in FRM plans.

8.2 Flood Risk Management Measures

FRM measures (interchangeably referred to as FRM options in this report) which are available for the management of flood risk can be categorised according to the way in which the risk is managed. There are five broad categories outlined within Table 29 of the FRM Guide MM01:

- Flood information - Flood information is essential to understanding flooding. Therefore the continued sourcing of flood information for the study area is considered a stand-alone FRM measure that indirectly influences future flood risk through informing decision-making.
- Flood modification measures – Flood modification measures are options aimed at preventing / avoiding or reducing the likelihood of flood risks. These options reduce the risk through modification of the flood behaviour in the catchment.
- Property modification measures – Property modification measures are focused on preventing / avoiding and reducing consequences of flood risks. Rather than necessarily modify the flood behaviour, these options aim to modify properties (both existing and future) so that there is a reduction in flood risk.
- Emergency response modification measures – Emergency response modification measures aim to reduce the consequences of flood risks. These measures generally aim to modify the behaviour of people during a flood event.
- Environment enhancement – Measures that look to prevent / avoid and reduce consequences of flood risk while also enhance environmental outcomes. Examples include catchment management measures, waterway modification measures, and Water Sensitive Urban Design (WSUD).

8.3 List of Flood Modification Options

Opportunities for potential flood modification options were identified by incorporating the following:

- Observations made during the site visit,

- Comments received by the general public during initial consultation, and by project stakeholders including DCCEW, SES, City of Sydney Council and Council strategic, engineering and planning representatives during several workshops, and the Flood Risk Management Committee. Comment was sought from all of these stakeholders during option identification and development.
- Assessment of the existing terrain, drainage information and 1% AEP and PMF flood hazards provided by Council.

A preliminary and exhaustive list of potential modification options for flood mitigation was developed, with a total of 25 flood modification (structural) options identified within the Whites Creek and Johnstons Creek study area. Mapping of the comprehensive list of options are included within **Appendix D**. The flood modification options have been grouped into the following categories:

- Drainage Upgrade,
- Channel Upgrade,
- Bridge Upgrade,
- Detention Basin,
- Road Regrading,
- Drainage Maintenance.

The number of possible flood modification options and option types that were considered for each catchment are summarised in **Table 8-2**.

Table 8-2 Number of Flood Modification Options by Type and Sub-Catchment

Catchment	Drainage Upgrade	Drainage Maintenance	Channel Upgrade	Detention Basin	Road Regrading	Total
Whites Creek	3	0	0	0	0	**3**
Johnstons Creek	9	1	1	4	7	**22**

These options have been outlined in the following **Figure 8-1** to **Figure 8-7**.

Figure 8-1 Johnstons Creek Hotspots 1 and 6 Mitigation Options

Figure 8-2 Johnstons Creek Hotspot 2 Mitigation Options

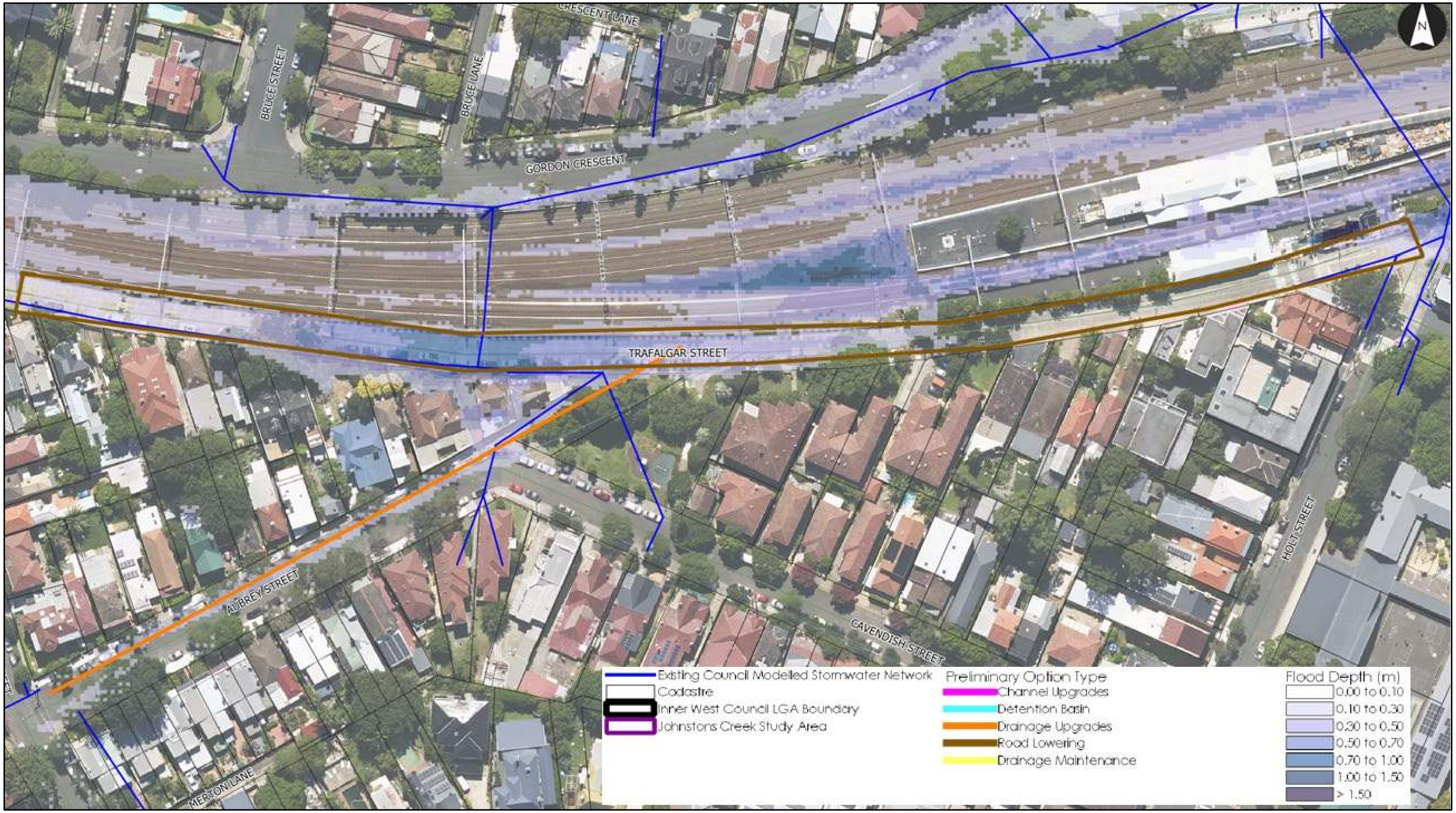

Figure 8-3 Johnstons Creek Hotspot 3 Mitigation Options

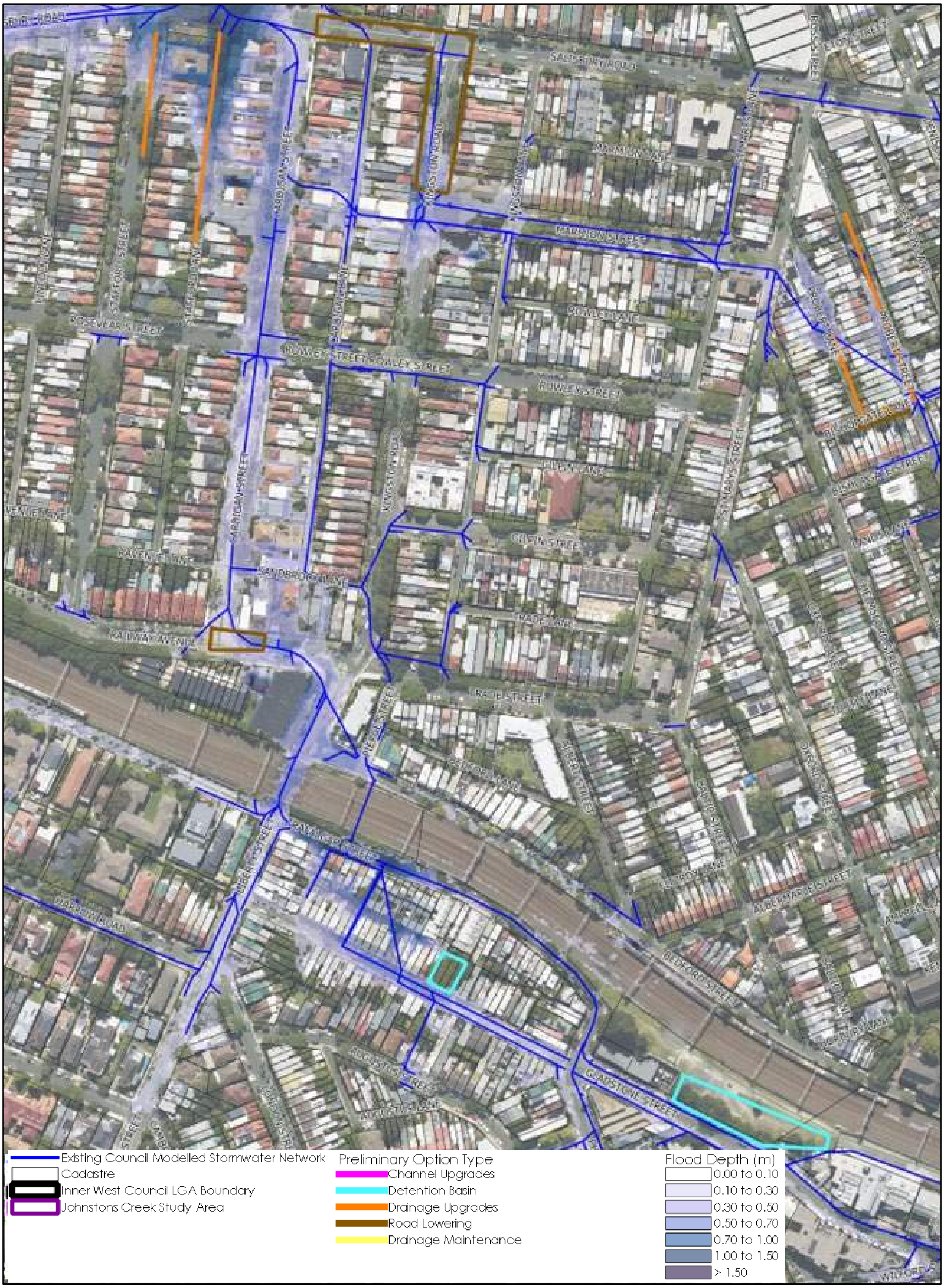

Figure 8-4 Johnstons Creek Hotspot 4 Mitigation Options

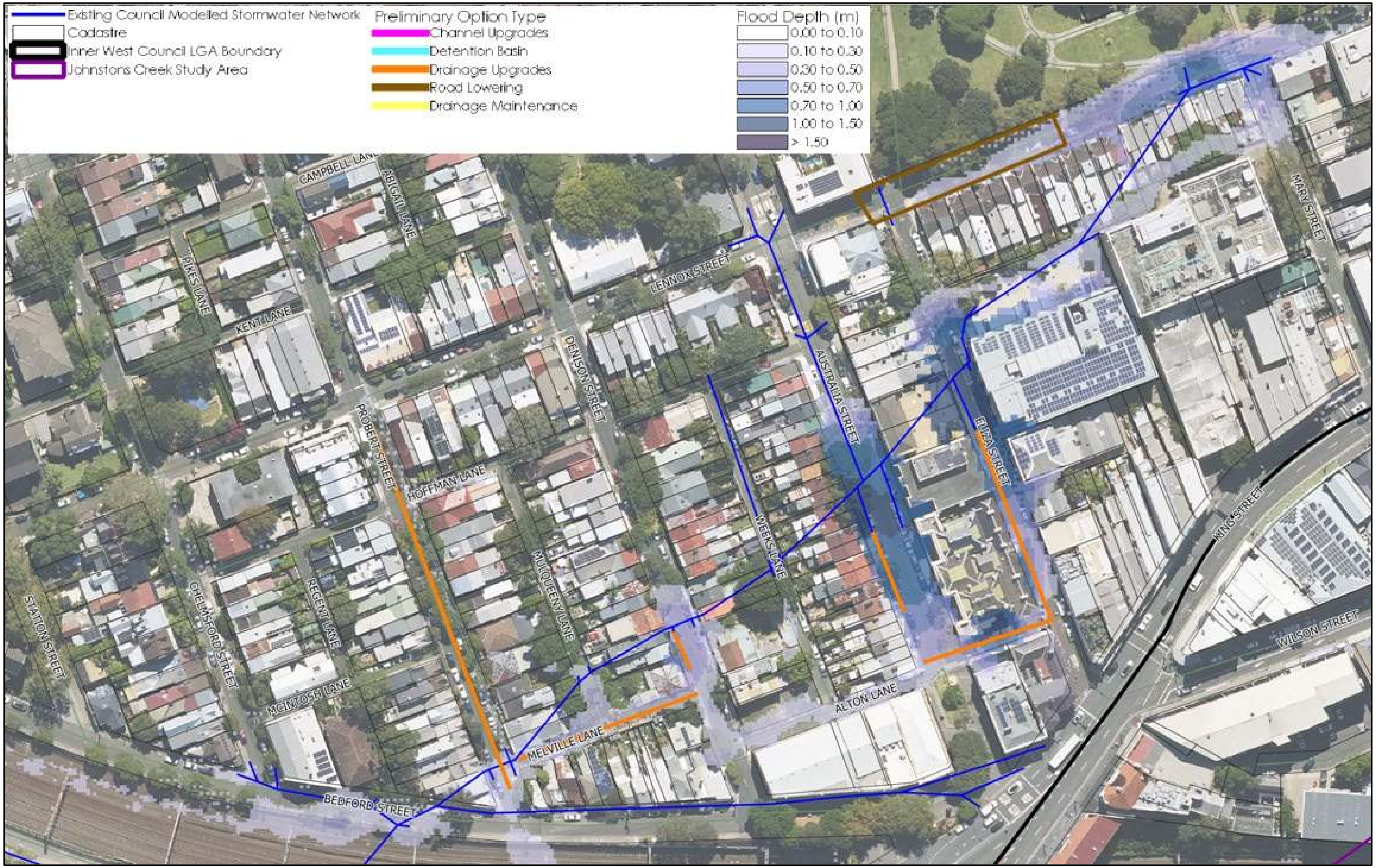

Figure 8-5 Johnstons Creek Hotspot 5 Mitigation Options

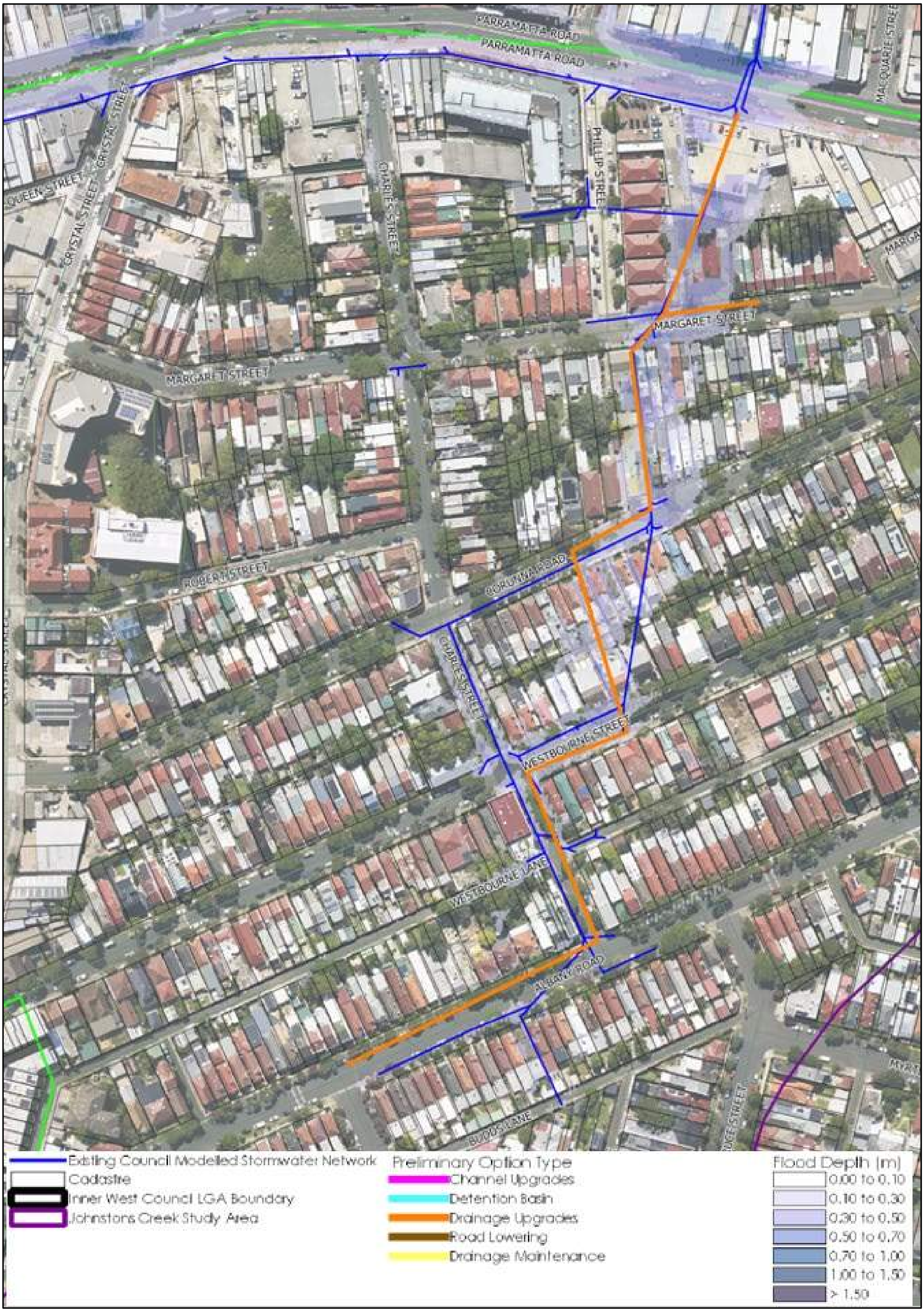

Figure 8-6 Whites Creek Hotspot 7 Mitigation Options

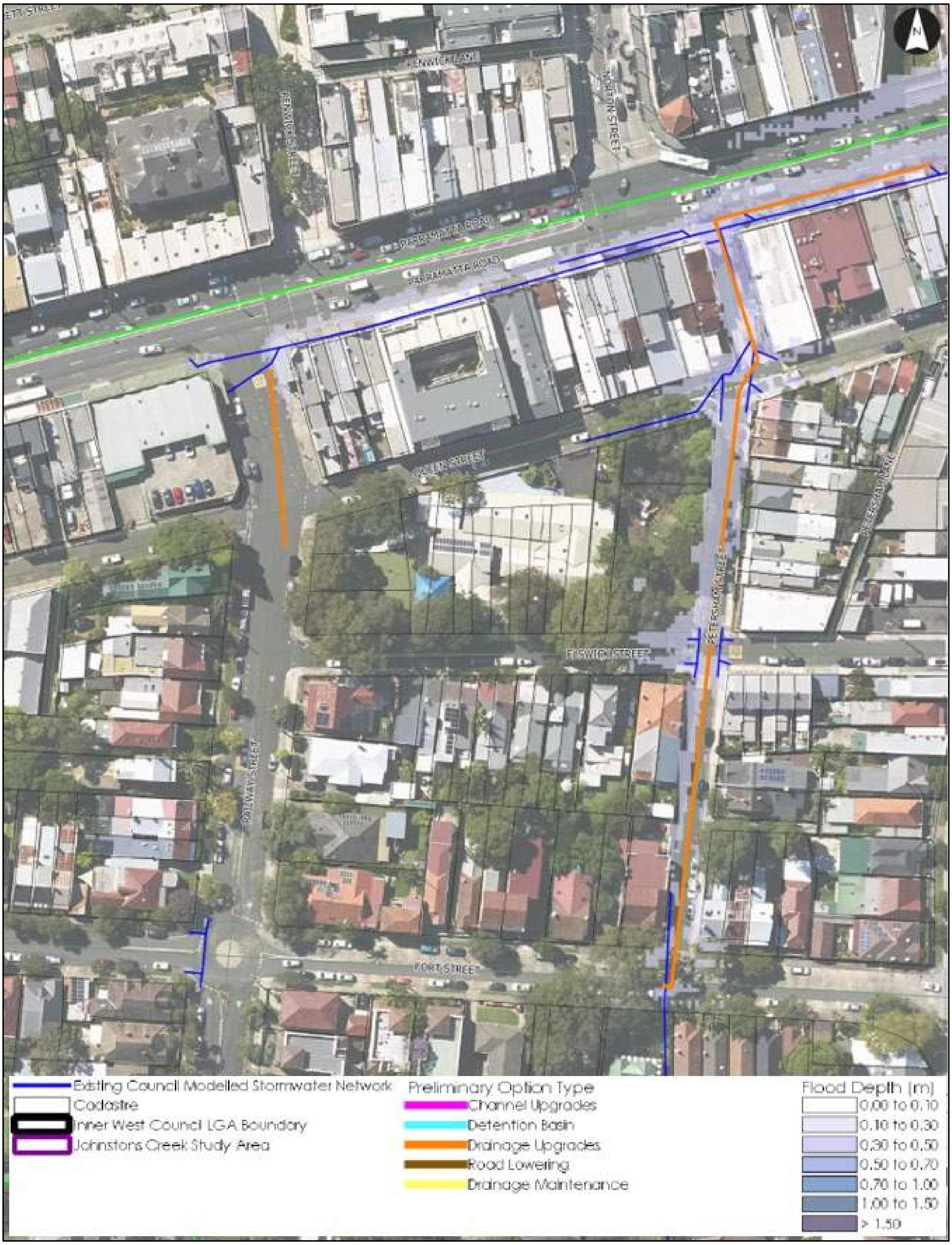

Figure 8-7 Whites Creek Hotspot 8 Mitigation Options

8.4 Preliminary Flood Modification Options

8.4.1 Initial Preliminary Flood Modification Options

The comprehensive list of possible flood modification options and option types that were considered are summarised in **Table 8-3.**

Table 8-3 Comprehensive List of Flood Modification Options

Location	Catchment	Type	Hotspot*	Description
Bridge Road, Stanmore	Johnstons Creek	Drainage Upgrade	1	Improve drainage capacity to better convey water towards the existing channel between Bridge Road and Cardigan Street.
Fowler Lane, Camperdown	Johnstons Creek	Drainage Upgrade	1/6	Improve drainage capacity along Mallett Street and Fowler Lane to reduce flooding impacts to Tooths Place and Fowler Street properties.
Gibbens Street, Camperdown	Johnstons Creek	Road Regrading	1/6	Regrade the existing road to better convey water through to Gibbens Street instead of Fowler Street properties.
Australia Street / Parramatta Road, Stanmore	Johnstons Creek	Road Regrading	1	Regrade the existing Australia Street and Parramatta Road intersection to convey water towards Parramatta Road instead of through properties.
Between Bridge Road and Cardigan Street, Stanmore	Johnstons Creek	Channel Upgrade	1	Improve channel capacity to reduce impacts to surrounding properties.
Camperdown Park, Australia Street, Camperdown	Johnstons Creek	Detention Basin	1/6	Construction of a detention basin to reduce flooding of downstream properties.
Salisbury Road / Douglas Street, Camperdown	Johnstons Creek	Drainage Upgrade	2	Improve drainage capacity to better convey water away from Salisbury Road properties.
Salisbury Road, Camperdown	Johnstons Creek	Drainage Maintenance	2	Carry out routine ongoing maintenance of existing drainage to sustain adequate drainage capacity.
Aubrey Street Trafalgar Street, Petersham	Johnstons Creek	Drainage Upgrade	3	Improve drainage capacity to reduce flooding impacts to the corner of Aubrey Street and Trafalgar Street.
Trafalgar Street, Petersham	Johnstons Creek	Road Regrading	3	Regrade the existing road to prevent ponding near Aubrey Street.
Stafford Street, Stanmore	Johnstons Creek	Drainage Upgrade	4	Improve drainage capacity to reduce water flow through properties.
Stafford Lane, Stanmore	Johnstons Creek	Drainage Upgrade	4	Improve drainage capacity to reduce water flow through properties.
Probert Street / Lane, Newtown	Johnstons Creek	Drainage Upgrade	4	Improve drainage capacity to reduce water flow through properties.
Bishopgate Lane, Camperdown	Johnstons Creek	Road Regrading	4	Regrade the existing road to redirect flow away from properties.
Kingston Road / Salisbury Road, Camperdown	Johnstons Creek	Road Regrading	4	Regrade the existing road to redirect flow away from properties.
Railway Avenue, Stanmore	Johnstons Creek	Road Regrading	4	Regrade the existing road to redirect flow away from properties.
Gladstone Street opp. Philip Lane, Enmore	Johnstons Creek	Detention Basin	4	Construction of a detention basin to reduce flooding of downstream properties.

Location	Catchment	Type	Hotspot*	Description
Gladstone Street adj. Augustus Street, Enmore	Johnstons Creek	Detention Basin	4	Construction of a detention basin to reduce flooding of downstream properties.
Probert Street / Melville Lane, Newtown	Johnstons Creek	Drainage Upgrade	5	Improve drainage capacity to reduce water flow through properties.
Eliza Street / Australia Street, Camperdown	Johnstons Creek	Drainage Upgrade	5	Improve drainage capacity to reduce water flow through properties.
Lennox Street, Newtown	Johnstons Creek	Road Regrading	5	Regrade the existing road to redirect flow away from properties.
Albany Road to Parramatta Road, Stanmore	Whites Creek	Drainage Upgrade	7	Improve drainage capacity to reduce water flow through properties.
Petersham Street, Petersham	Whites Creek	Drainage Upgrade	8	Improve drainage capacity to reduce water flow through properties.
Railway Avenue, Stanmore	Whites Creek	Drainage Upgrade	8	Improve drainage capacity to reduce water flow through properties.

Refer to **Section 7.5 for further details of the hotspot locations.*

Upon Council review, discussions were held to determine which of these preliminary options are to be adopted for further assessment. Details of the selected options are in the below report sections.

8.4.2 Selection of Initial Preliminary Flood Risk Management Options

An initial high-level assessment was carried out for each option based on the following criteria: potential benefits, technical feasibility and costs.

Benefits were assessed based on the expected or potential effects on flood affected areas. The zoning type, number of properties as well as road type/usage were considered. Benefits were categorised as negligible, very low, low, medium and high.

Technical feasibility and cost were assessed based on the specific requirements of each option such as earthworks, roadworks, potential property impacts, length of pipe upgrades, etc. Feasibility and costs were categorised as very low, low, medium and high.

Upon Council review, workshops were held with project stakeholders including DCCEW, SES, City of Sydney Council and Council strategic, engineering and planning representatives during several workshops, and the FRM Committee. The outcome of these discussions was to determine which of these preliminary options are to be adopted for further assessment. Options that scored relatively lower in terms of the above criteria (potential benefits, technical feasibility and costs) were not selected to be progressed.

Out of 23 total FM options (20 for Johnstons Creek and 3 for Whites Creek), 13 were recommended to be progressed to modelling (12 for Johnstons Creek and 1 for Whites Creek). A single Property Modification (PM) option (PM6) for increased drainage maintenance was considered for both study areas. With both PM and FM options the total number of modelled options is 15 (13 for Johnstons Creek and 2 for Whites Creek). The selected preliminary options are in **Table 8-4**. The flood modification options not selected for detailed assessment, including a brief reason, have been summarised in **Table 8-5**.

Table 8-4 List of Modelled Flood Risk Management Options

Option ID/ Location	Type	Number of Modelling Iterations	Continued to Detailed Assessment (Y/N)
JC1 – Fowler Street, Camperdown	Drainage Upgrade/ Detention Basin	5	Yes
JC5 – Bridge Road, Stanmore	Drainage Upgrade	6	Yes
JC6 – Bridge Road, Stanmore	Channel Upgrade	5	Yes
JC7 – Bridge Road, Stanmore	Detention Basin	1	Yes
JC9 – Salisbury Road, Camperdown	Drainage Upgrade	3	No
JC10 – Trafalgar Street, Petersham	Drainage Upgrade	3	Yes
JC13 – Gladstone Street, Enmore	Drainage Upgrade	4	Yes
JC14 – Railway Avenue, Stanmore	Road Regrading	1	Yes
JC15 – Probert Street, Newtown	Drainage Upgrade	2	Yes
JC18 – Kingston Road, Camperdown	Drainage Upgrade	4	Yes
JC20 – Lennox Street, Newtown	Drainage Upgrade	2	Yes
JC23 – Clarendon Lane, Stanmore	Drainage Upgrade	1	Yes
WC1 – Margaret Street, Petersham	Drainage Upgrade	5	Yes
PM6 – Targeted Stormwater Maintenance	Drainage Maintenance	1	Yes

Table 8-5 Options Not Progressed to Detailed Assessment

Location	Catchment	Type	Hotspot*	Reason For Not Progressing
Gibbens Street, Camperdown	Johnstons Creek	Road Regrading	1/6	Relatively low technical feasibility/high cost. Depth of road lowering required to divert flows away from residential properties on Fowler Lane was not feasible.
Australia Street / Parramatta Road, Stanmore	Johnstons Creek	Road Regrading	1	Relatively low technical feasibility/high cost. Length of road lowering and scale of works was significant with an interface with TfNSW road. Potential impacts on properties.
Salisbury Road / Douglas Street, Camperdown	Johnstons Creek	Drainage Upgrade	2	Partially included in JC5 Bridge Road Drainage Upgrade, relatively low technical feasibility Length of pipe upgrades, and limited capacity of downstream Sydney Water channels meant not feasible. Twin existing pipes under road meant limited space for additional capacity.
Salisbury Road, Camperdown	Johnstons Creek	Drainage Maintenance	2	Included in PM6 for assessment on a catchment-wide scale, therefore specific assessment at this high debris location not necessary.
Trafalgar Street, Petersham	Johnstons Creek	Road Regrading	3	Relatively low technical feasibility/high cost. Scale of works required to divert runoff from Aubrey Street around residential properties to Trafalgar Street not considered feasible.
Stafford Street, Stanmore	Johnstons Creek	Drainage Upgrade	4	Partially included in JC18 Kingston Road Drainage Upgrade. Network capacity found to be constrained with no capacity for additional inlet pits, length of pipe upgrades considered not feasible with limited capacity in downstream Sydney Water channels.
Stafford Lane, Stanmore	Johnstons Creek	Drainage Upgrade	4	Partially included in JC18 Kingston Road Drainage Upgrade. Network capacity found to be constrained with no capacity for additional inlet pits, length of pipe upgrades considered not feasible with limited capacity in downstream Sydney Water channels.
Bishopgate Lane, Camperdown	Johnstons Creek	Road Regrading	4	Relatively low technical feasibility/high cost. Depth of cut required to lower road to divert flows away from Probert St not considered feasible. Found that drainage upgrade for additional inlet pit capacity preferred option.
Kingston Road / Salisbury Road, Camperdown	Johnstons Creek	Road Regrading	4	Relatively low technical feasibility/high cost. Length and depth of road lowering to Salisbury Road to divert flows around residential properties was not considered feasible.
Gladstone Street opp. Philip Lane, Enmore	Johnstons Creek	Detention Basin	4	Relatively low technical feasibility/high cost. Rail corridor open space opportunity not deemed feasible for detention basin given potential utilities, contamination and ownership considerations.
Gladstone Street adj. Augustus Street, Enmore	Johnstons Creek	Detention Basin	4	Relatively low technical feasibility/high cost. Bugler playground opportunities not deemed feasible for detention basin given limited volumes and potential utilities, and loss of public space.
Eliza Street / Australia Street, Camperdown	Johnstons Creek	Drainage Upgrade	5	Included in Lennox Street option, rather than upgrading existing line, a diversion of runoff from upstream was deemed the preferred option.
Lennox Street, Newtown	Johnstons Creek	Road Regrading	5	Relatively low technical feasibility/high cost. Length and depth of road lowering to divert flows around properties was not considered feasible.
Petersham Street, Petersham	Whites Creek	Drainage Upgrade	8	Relatively low technical feasibility. Scale of works to increase capacity was not feasible based on existing flood affectation.
Railway Avenue, Stanmore	Whites Creek	Drainage Upgrade	8	Relatively low technical feasibility. Scale of works to increase capacity was not feasible based on existing flood affectation.

8.4.3 Modelling of Preliminary Flood Risk Management Options

The 15 flood risk management options that were selected for preliminary assessment were developed and modelled in the two sub-catchment TUFLOW models for Johnstons Creek and Whites Creek with the following methodology:

- 5 design events were considered: 20% AEP, 5% AEP (DSHHWS), 2% AEP, 1% AEP and PMF.
- The PM6 model scenario involved the unblocking off all pipes from the model. The assumption in this model approach is that improved maintenance would potentially remove blockage of pits and pipes, as a theoretical best-case scenario.
- PM6 was used as a base case for the FM options. Details on the PM6 scenario are in **Section 8.5**. The justification for adopting the PM6 option as the base case for the FM options is the removal of blockage. The FM options rely on the effectiveness of the drainage network, therefore assuming an unblocked condition is considered a suitable basis for assessing potential benefits of any drainage upgrades.
- Each option had a unique model scenario established to account for the proposed option details. Each option model was based off the base case.
- Each option was then initially modelled for the 20% AEP design event, then selected for detailed assessment based on the 20% AEP flood level difference impacts and other opportunities for improvement identified from the model set up.
- Options that were selected for detailed assessment were then progressed to modelling of all 5 design events.
- The methodology for each option accounted for the proposed works in the TUFLOW model as follows:
  - Drainage upgrades were modelled with updates to the 1D network with duplication of pits and pipes, and creation of new pits and pipes. The details of the proposed network were based on review of existing conditions to develop feasible pipe / culvert dimensions, locations, inverts and pit sizes.
  - Channel upgrades were modelled as 1D irregular channel elements with cross sections as per the base case model. Changes to the channel shapes, inverts, and 1D roughness values were applied to represent proposed changes in channel shape and lining.
  - Two types of detention basins were modelled. The inverts of the basins were determined based on review of existing conditions, terrain levels and minimum connection levels to existing stormwater networks.
    - Within the 2D domain of the TUFLOW model with 2D_zshapes applied to create basin shapes
    - Within the 1D pit and pipes network to simulate an underground detention basin, using pit dimensions to set the basin size and a short section of smaller diameter pipe to represent the effects of an overflow weir.
  - Road or surface regrading was modelled in the 2D domain of the TUFLOW model with 2D_zshapes, raising or lowering the existing surface to divert flows away from private property and retention in the road reserve.

8.4.4 Development and Optimisation of Preliminary Flood Modification Options

As per Section 2.2.4 of the FRM Guide MM01, optimisation of options may be used to refine options to improve benefits and reduce costs or disbenefits. This process was conducted for the 4 preliminary flood modification measures developed for this study.

The option as proposed in discussions with Council and NSW DCCEW was initially modelled, and then depending on the outcomes of the initial modelling was often refined and altered to enhance option benefits. In some instances, this led to significant changes in option design through this optimisation process.

Optimisation not only occurred based on maximising flood benefits, but also in response to other factors that were accounted for in the preliminary option development including:

- Maximising the feasibility of the option. This included consideration of the following:
  - Subsurface utility locations, with proposed earthworks avoiding the vicinity of these utilities where possible.

  - Suitable scale of works justifiable based on the anticipated flood benefits, such as downstream pipe sizes and lengths.
  - Land ownership and avoiding works on private lands where possible.
- Considering the relative cost of the option based on the scale of works, this provides an indication of the economic feasibility of the option.
- Reducing flood affectation and flood risk on private properties, particularly residential properties wherever possible. In some instances this resulted in additional flood risk within publicly owned lands such as road reserves and public open spaces.
- Minimising disturbance of ecological communities and minimising tree removal. The types of vegetation on subject sites were guided by site visit observations and Google Streetview.
- Minimising adverse impacts on private properties or non-publicly owned lands. While some options would result in significant benefits for some properties, it was important they not adversely affect other properties.

For the 4 preliminary flood modification options, a summary of the option outcomes considering the above factors was provided to Council and NSW DCCEW for their review. As discussed in the sections below, these factors were assessed in determining the options to carry into detailed assessment.

8.5 Other Preliminary Options

Beyond the 14 flood modification options that were modelled and assessed, a further twelve non-structural preliminary options were considered:

- Six preliminary Property Modification (PM) measures including Voluntary House Raising (VHR), flood proofing, Voluntary Purchase (VP) and two derivatives (land swap and Council redevelopment) and targeted stormwater maintenance. The options are discussed further in **Table 8-6**.
- Six preliminary Emergency Management Modification (EM) measures including flood prediction and warning, review of Local Flood Planning and information transfer to NSW SES, community flood awareness and school education programs, flood markers and signage and flood data and debrief. The options are discussed further in **Table 8-7**. It is noted that comment on these preliminary options was sought from NSW SES representatives to determine their opinion on the proposed Emergency Management options given the relevance to their operations.

These options were developed based on guidance provided within the FRM Guide MM01, the 2023 FRM Manual and based on past experience with option development in other study areas.

In total, 4 EM options and 1 PM options were recommended/selected for detailed assessment.

Table 8-6 Preliminary Property Modification Options

Option ID	Option Name	Description	Recommendation for Detailed Option
PM1	Voluntary House Raising (VHR)	House raising is a measure designed to reduce the incidence of over-floor flooding of existing buildings through works where Council and NSW DCCEW make contributions to the funding the cost of the work. There are a range of factors that contribute to the feasibility of Voluntary House Raising. The scheme should involve raising residential properties above a minimum design level, assumed to be Council's flood planning level (FPL) meaning 1% AEP plus 0.5 metre freeboard. While house raising can reduce the occurrence of overfloor flooding, there are issues related to the practice, including: > The potential for damage to items on a property other than the raised dwelling are not reduced – such as gardens, sheds, garages, granny flats, decks etc.; > Unless a dwelling is raised above the level of the PMF, and proven to be stable in such a flood event, the potential for above floor flooding still exists – i.e. there will still be a residual risk; > Evacuation may be required during a flood event for a medical emergency or similar, even if no overfloor flooding occurs, and this evacuation is likely to be hampered by floodwaters surrounding a property; > Ensure new footings or piers can withstand flood-related forces; and > Potential conflict with height restrictions imposed for a specific zone or locality within the LGA. The Guidelines for voluntary house raising schemes: Floodplain Management Program (NSW DCCEW, 2020) sets out ineligibility criteria for house raising under the Voluntary House Raising (VHR) scheme. In addition, follow up discussions with NSW DCCEW representatives have provided further information as the potential eligibility of properties for a VHR scheme. The adopted eligibility criteria for this FRMS&P based on these resources is as follows: > Must be residential dwellings to be eligible for funding. Commercial and industrial, public buildings or secondary dwellings are not considered eligible. > Properties that would not achieve a positive benefit through damage reduction relative to cost (i.e. benefit-cost ratio less than 1). > The post-raised building must be stable and therefore not be in a high hazard area. As outlined in the guideline this is defined as areas with PMF hazard of H4 or less being eligible. > Building located in 1% AEP floodway areas are not considered eligible as they represent a significant flow obstruction. > Based on NSW DCCEW guidance, house construction of brick or masonry type are not feasible for raising due to the difficulty of raising floors for such structures. Therefore, only fibro or timber type constructed houses are considered eligible. > Funding is only available for properties where the buildings were approved and constructed prior to 1986, when the original Floodplain Development Manual was gazetted by the State Government. Properties built after this date should have been constructed in accordance with the principles in the manual. > Properties which are already benefiting substantially from other floodplain mitigation measures, such as houses already protected by a levee. There are negligible existing flood mitigation measures in the study area. It is assumed that this requirement does not relate to properties that may benefit from one of the FM options proposed within the FRMS&P as these are not currently implemented mitigations.	No Considering the overland flooding nature of the study area, and the limited impact this would provide, and the suitability of the existing housing construction, this option was not considered viable.

Option ID	Option Name	Description	Recommendation for Detailed Option
PM2	Voluntary Purchase (VP)	Voluntary purchase is the optional purchase of pre-selected properties funded jointly by Council and the State Government. It would free both residents and emergency services personnel from the hazard of future floods by removing the risk, and is achieved by the purchase of properties and the removal and demolition of buildings. Properties could be purchased by Council at an equitable price and only when voluntarily offered. Such areas would then need to be re-zoned under the LEP to a flood compatible use, such as recreation or parkland, or possibly redeveloped in a manner that is consistent with the flood hazard (see PM5 below). Voluntary House Purchase is funded by Council with assistance from the State Government. However, due to the relatively expensive nature of such a program, limited availability of Government and/or Council funding can be a major constraint to undertaking Voluntary House Purchases. Typically, only a small number of properties within a floodplain can be considered for Voluntary Purchase, however, more can be assisted if funding is available. The Guidelines for voluntary purchase schemes: Floodplain Management Program (NSW DCCEW, 2020) to assist in determining when and where voluntary purchase schemes may be suitable. The guideline recommends that voluntary purchase be considered where: > There are highly hazardous flood conditions from riverine or overland flooding and the principal objective is to remove people living in these properties and reduce the risk to life of residents and potential rescuers; > A property is located within a floodway and the removal of a building may be part of a floodway clearance program that aims to reduce significant impacts on flood behaviour elsewhere in the floodplain by enabling the floodway to more effectively perform its flow conveyance function; and/or > Purchase of a property enables other flood mitigation works (such as channel improvements or levee construction) to be implemented because the property will impede construction or may be adversely affected by the works with impacts not able to be offset. > Must be residential dwellings to be eligible for funding. Commercial and industrial, public buildings or secondary dwellings are not considered eligible; > Properties that would achieve a positive benefit through damage reduction relative to cost (i.e. benefit cost ratio less than 1).	No Considering the overland flooding nature of the study area, heritage of existing buildings, and likely community expectation, this option was not considered viable.
PM3	Flood Proofing	Flood proofing involves undertaking structural changes and other procedures in order to reduce or eliminate the risk to life and property, and thus the damage caused by flooding. Flood proofing of buildings can be undertaken through a combination of measures incorporated in the design, construction and alteration of individual buildings or structures subject to flooding. It is primarily suited to industrial or commercial properties. Examples of proofing measures include: > All structural elements below the FPL shall be constructed from flood compatible materials. > All structures must be designed and constructed to ensure structural integrity for immersion and impact of debris up to the 100 years ARI flood event. If the structure is to be relied upon for shelter-in-place evacuation, then structural integrity must be ensured up to the level of the PMF. > All electrical equipment, wiring, fuel lines or any other service pipes and connections must be waterproofed to the FPL. The NSW SES Flash Flood Tool Kit (SES, 2012) provides businesses with a template to create a flood-safe plan and to be prepared to implement flood proofing measures.	No Current DCP provisions should address future development. The number of overfloor flooded properties across the LGA would make this type of scheme not feasible.

Option ID	Option Name	Description	Recommendation for Detailed Option
PM4	Land Swap	An alternative to voluntary purchase is the consideration of a land swap program whereby Council swaps a parcel of land outside of the flood prone area, such as an existing park, for a parcel of flood prone land with the appropriate transfer of any existing facilities to the acquired site. After the land swap, Council would then arrange for demolition of the building and have the land re-zoned under the LEP to open space. Since a detailed floor level survey has not been undertaken and over floor flooding has been estimated based on a desktop assessment, it is recommended that Council undertake a detailed floor level survey to validate if properties identified for voluntary purchase are suitable for land swap.	No – Due to lack of available Council owned land, particularly land that is flood free, therefore land swap not feasible.
PM5	Council Re-development	This option also provides an alternative to the Voluntary Purchase scheme. While Council would still purchase the worst affected properties, it would redevelop these properties in a flood compatible manner and re-sell them with a break-even objective.	No - From high level review conducted no properties are immediately apparent for being suitable for a scheme of this type.
PM6	Targeted Stormwater Maintenance	Vegetated roadsides result in significant leaf and branch drop which build up over time and often results in drainage inlet pits blocking rapidly when runoff events occur. This can lead to concentrated and uncontrolled overland flows occurring downslope of these inlets thereby increasing surface flows through streets and private properties. It is recommended that regular street sweeping is undertaken to reduce the potential for the inlets to become blocked and subsequently reduce the frequency of uncontrolled overland flows on streets and through private properties. In addition to regular street sweeping which reduces the potential for inlet pits to become blocked, it is also recommended that stormwater pits in areas subject to flooding are cleaned on a more frequent basis. Suction machines can be used to remove silt and rubbish from the pits. A stormwater maintenance program is currently implemented by Council, with the above tasks routinely conducted. However additional maintenance works could possibly be implemented in the future. It is difficult to quantify the potential benefits that an increased maintenance schedule may have, as the effectiveness of maintenance is reliant on the relative timing of maintenance and flooding. If a flood occurs immediately after a maintenance and cleaning then the benefits in flood reduction may be strongly evident. If flooding occurs after a long period without cleaning then any potential benefits of maintenance would be diminished. Therefore any increase maintenance program should consider the frequency of cleaning and other works. Option PM6 is for the targeted increased maintenance of the stormwater network. Inner West Council, in accordance with its responsibility as owner of the majority of the drainage assets within the study area, has a significant maintenance schedule already in place for all of its stormwater assets. This includes timely responses to community requests or notes relating to any drainage blockage or damage. Option PM6 involves potential additional targeted maintenance of greater frequency than is currently applied at key locations. The potential benefits of the PM6 option for targeted stormwater maintenance would be assessed using modelling assuming no blockage of pipes. This is a best-case scenario, that in reality is unlikely to be achievable. Nevertheless, it does provide an indication of areas of potential benefits, even if the scale of benefits may exceed expected outcomes.	Yes Council currently undertakes maintenance of the stormwater network. The base case model assumes a 100% blockage factor that has been applied to all small diameter pipes. A targeted cleaning program would help reduce the risk of blockage impacting flooding in small diameter pipelines.

Table 8-7 Preliminary Emergency Management Modification Options

Option ID	Option Name	Description	NSW SES Comment	Recommendation for Detailed Option
EM1	Flood Prediction and Warning	The critical duration and response times for the study area floodplain limit the implementation of a flood warning system. The short duration flooding experienced in local systems is not well suited to flood warning systems. Severe weather warnings are likely to be the only assistance for these areas. While flood response times of less than an hour that have been modelled in this study area make any form of warning system seem impossible, there are several factors that may make a scheme worth further investigation: > Flood free land throughout the study area is typically not a long distance. Unlike riverine catchments where the evacuation routes can be kilometres long, as shown in the evacuation route mapping the distance to flood free land does not typically exceed several hundred metres. This means that land above the PMF level could be reached by pedestrians or vehicles in a matter of minutes based on travel time. > Due to the local nature of the flooding, there should be less traffic for evacuation routes as there is not a regional evacuation route that needs to service an entire community. The 2023 FRM Guide EM01 provides advice around the development of a Total Warning System for Flooding (TWSF). The components of a TWSF must be integrated for a system to operate effectively.	Agree that a flood warning system is not feasible. BoM warnings are useful indicators of potential flooding. The NSW SES has adopted the Australian Warning System (AWS) for Riverine Flooding and Tsunami and is planning on extending this to Storms - including Flash flooding	No - A local flood warning system may not be feasible due to the flash flooding nature of the study areas. However, the short distance to flood free land means that any advanced warning may provide improved flood risk for the residents. Not progressed as a detailed option as currently not feasible to implement.
EM2	Review of Local Flood Planning and Information Transfer to NSW SES	Having a robust EM plan that can provide the basis for responding to various scales of flood threat and be altered to fit the particular circumstances of an event can assist with flood preparation, response and recovery. The review of local flood plans should also include: > A review of the current flood warning classifications (minor, moderate and major) for the location relative to the impacts on the community and any associated recommendations. > Clarification of the scale of impacts and the scale of the emergency response required in relation to key events and the associated flood timings so this can inform decisions and logistics. For example, for a levee protected community, having a plan in place on how to respond to floods that do not threaten the levee, threaten to result in minor overtopping of the levee, and for extreme floods that overwhelm the levee and town, can provide flexibility. > A review of other key information in the plan in light of the information in this study. The findings of this FRMS&P are an important source of catchment specific information for the NSW SES and Council. Details of flood risks at specific locations are important for planning of operational tasks and for the future review of the Flood Emergency Sub-Plan. The NSW SES have developed a Flood Risk Management Checklist to clearly establish the current expectations for data developed in the FRM process for the purposes of generating reliable flood intelligence to support flood emergency planning. This is a standard across the board and the checklist	NSW SES is currently revising the way flood planning is addressed in the IW LGA. The current draft VOL 2 of the flood plan is currently on hold and focus is on Pre-Incident Plans (PIPs) for flood rescue hotspots. The planning teams in Marrickville and Ashfield Leichardt units are refining overview documents for hotspot Zones to supplement the PIPs	Yes - Providing outcomes from the FRMS&P to NSW SES is essential.

Option ID	Option Name	Description	NSW SES Comment	Recommendation for Detailed Option
		is normally adopted upon receiving a formal request via the agency referral process. The checklist relates to three categories; Flood Studies, FRMS&P, and Key Flood Risk Management Issues		
EM3	Community Flood Awareness	Flood awareness is an essential component of flood risk management for people residing in the floodplain, it is important to maintain an adequate level of flood awareness during the extended periods when flooding does not occur. A continuous awareness program is required to ensure new residents are informed, the level of awareness of long-term residents is maintained, and to cater for changing circumstances of flood behaviour and new developments. This option would focus on education of the entire LGA with the objective to educate residents that may be in the floodplain at the time of flooding or may attempt to enter floodwaters. There are a broad range of approaches that can be adopted, which all should be done in close consultation with NSW SES: > Develop FloodSafe Brochure and FloodSafe Toolkit > Develop a post-flood data collection strategy > Hold a FloodSafe launch event > Develop a flood information package for new residents. This option however would not necessitate SES involvement in a Council flood awareness program. It is understood that some flood awareness programs are currently adopted in the local area. Collaboration with SES would be advantageous, as the expectation would be that Council could develop a flood awareness program that provides support and supplements SES flood awareness schemes. The implementation of a flood awareness program may be important in supporting other EM options. For example, the development of a flood warning system (option EM1) would require strong flood awareness, and flood signage and markers (option EM5) would provide best benefits if accompanied with a flood awareness program.	NSW SES supports the development of a council flood awareness program, accompanied by measures outlined in EM5	Yes - Recommended outcome of the FRMS&P. Support shown for this option during stakeholder workshop call.
EM4	School Education Program	The SES has developed a tailored program for school children in primary schools. The program, includes teacher's resources, newsletters, activities and games, is designed to deliver knowledge and awareness of floods to young children. SES personnel are also available to visit schools to talk about flooding and flood response. Further details of these programs are available on the SES StormSafe website. Education of parents / carers relating to the flood affectation of the school and the emergency response procedures in place to ensure the safety of their children could be provided directly or through children in the form of brochures etc. Particularly for the study area floodplain it should be reinforced to parents that as all schools have programs in place so they should never enter floodwaters in an attempt to reach their children at school.	NSW SES supports schools who have such programs in place. NSW SES obtains contact details from relevant school authorities.	Supported in Principle Not Recommended for Detailed Analysis – Council can engage and advocate on this matter, however only Considered an SES and Department of Education can take action.

Option ID	Option Name	Description	NSW SES Comment	Recommendation for Detailed Option
EM5	Flood Markers and Signage	While the above public programs can be effective in improving the long-term awareness of flood risk, in the event of flooding these education programs can easily be forgotten. Therefore, flood warning signage can be an effective tool to remind or inform residents of the risks associated with entering floodwaters, and to also provide practical information in the event of flooding such as recommended evacuation routes. Appropriate flood warning signs should be posted at all locations of significant flooding. These signs may contain information on flooding issues or be depth gauges to inform residents of the flooding depth over roads and paths. Also, evacuation route mapping could be provided on these signs to assist residents. In addition, consultation could be conducted with Transport for NSW (TfNSW) to discuss potential flood signage for flood affected regional roads through the study area. Potential flood affected roads for signage and markers may include: > Parramatta Road at the crossing of Johnstons Creek and Whites Creek. This is a potential regional access route for NSW SES operations. > Salisbury Road and Bridge Road in Stanmore at flood affected ponding areas. > Liberty Street railway bridge crossing in Enmore > Lennox Street in Newtown > Fowler Street and Australia Street near Camperdown Oval > Probert Street and Kingston Road ponding areas in Newtown/Camperdown.	NSW SES supports and encourages the adoption of this measure. Many of the roads affected are high traffic through roads and used by non-residents, so local awareness campaigns are not relevant to these road users. Our flood rescue operators also support these measures as they also indicate to responders the depth of water in the area.	Yes - Recommended outcome of the FRMS&P. Support shown for this option during stakeholder workshop call.
EM6	Flood Data and Debrief	A flood event provides an ideal opportunity to capture information on the flood and learn from it. It helps understand the event, the consequences for the community, successes and limitations in current management practices and how the community recovered. Information can be captured in coordinated community surveys. This information should be collated, and a report produced to catalogue what has been captured and its availability and format. The data should be securely stored and made publicly available. The information can be used in both explaining this event to the community and in considering future flood risk, EM and land-use planning decisions within and potentially beyond this community. These tasks are currently part of Council’s requirements for flooding response. It is also noted that post-flood funding is also available from NSW DCCEW.	NSW SES supports this measure and considers this information vital to refining flood planning and response alternatives.	Yes - Recommended outcome of the FRMS&P. While Council already implements a program of post-flood data collection, continued emphasis of the need for such schemes is recommended. Post flood funding available from NSW DCCEW

9 Detailed Assessment of Options

9.1 Options for Detailed Assessment

A total of 20 options were selected for detailed assessment including hydraulic modelling of 5 design events (for 14 Johnstons Creek and 1 Whites Creek FM options and 1 PM option for each study area), damages assessment, cost estimation and Multi-Criteria Assessment (MCA). A summary of the 20 options is included in **Table 9-1**. It is noted that detailed options retained their preliminary option ID, therefore the ID numbering of the detailed option list is non-sequential.

Table 9-1 Description of Options for Detailed Assessment

Option Type	Option ID/Name	Modelled Option
Flood Modification (FM)	JC1 v1 – Fowler Street, Camperdown Drainage Upgrade	Yes
	JC1 v2 – Fowler Street, Camperdown Detention Basin	Yes
	JC5 – Bridge Road, Stanmore Drainage Upgrade	Yes
	JC6 v1 – Bridge Road, Stanmore Channel Regrading	Yes
	JC6 v2 – Bridge Road, Stanmore Channel Widening	Yes
	JC7 – Bridge Road, Stanmore Detention Basin	Yes
	JC10 – Trafalgar Street, Petersham Drainage Upgrade	Yes
	JC13 – Gladstone Street, Enmore Drainage Upgrade	Yes
	JC14 – Railway Avenue, Stanmore Road Regrading	Yes
	JC15 – Probert Street, Newtown Drainage Upgrade	Yes
	JC18 v1 – Kingston Road, Camperdown Drainage Upgrade	Yes
	JC18 v2 – Kingston Road, Camperdown Drainage Upgrade	Yes
	JC20 – Lennox Street, Newtown Drainage Upgrade	Yes
	JC23 – Clarendon Lane, Stanmore Drainage Upgrade	Yes
	WC1 – Margaret Street, Petersham Drainage Upgrade	Yes
Property Modification (PM)	PM6 – Targeted Stormwater Maintenance	Yes
Emergency Management Modification (EM)	EM2 – Review of Local Flood Planning and Information Transfer to NSW SES	No
	EM3 – Community Flood Awareness	No
	EM5 – Flood Markers and Signage	No
	EM6 – Flood Data and Debrief	No

A brief description of the proposed works for the 15 FM options proposed for adoption are summarised in Table 9-2. The layout of these FM options is also included in **Appendix E**.

Of the 15 flood modification options selected for detailed assessment, 14 are within the Johnstons Creek sub-catchment and 1 is within the Whites Creek sub-catchment. The location of the 15 flood modification options is shown in **Table 9-2**.

There are 2 detention basins proposed (one underground storage and one being a retrofit of an existing private carpark), 10 pit and pipe drainage network updates, 2 stormwater channel upgrades, and 1 road regrading projects. Options may have multiple components of the above option types, for example a detention basin option may also incorporate a pit and pipe drainage alteration.

Table 9-2 Description of FM Options for Detailed Assessment

Option ID	Sub-Catchment	Description
JC1 v1 – Fowler Street, Camperdown Drainage Upgrade	Johnstons Creek	Various pits on Australia St, Mallett St, Tooth Pl/Ln, Fowler Ln/St and Deniston St changed to unlimited capacity. Pipe to low point on Australia St upgraded from 0.45m to 0.75m. Drainage line from Fowler Ln/St diverted to the other culvert under Camperdown Oval. Two pipes on Deniston St upgraded from 0.3m to 0.75m.
JC1 v2 – Fowler Street, Camperdown Detention Basin	Johnstons Creek	Proposed underground storage pit under Camperdown Oval (2.5m depth, approximate area of 1700m2), incorporating above drainage upgrades.
JC5 – Bridge Road, Stanmore Drainage Upgrade	Johnstons Creek	Proposed and upgraded drainage throughout Bridge Rd with culvert size of 3.6m x 1.2m connected from the existing Salisbury Road intersection drainage network, pits with unlimited capacity throughout. This option does not include the detention basin in JC7.
JC6 v1 – Bridge Road, Stanmore Channel Regrading	Johnstons Creek	Cross sections and invert levels of the 1D irregular channel lowered to achieve 1% grade both north and south of Parramatta Road.
JC6 v2 – Bridge Road, Stanmore Channel Widening	Johnstons Creek	Channel inverts lowered to 0.5% to 0.7% grade south of Parramatta Road only, with widening to the west of the channel by 3m.
JC7 – Bridge Road, Stanmore Detention Basin	Johnstons Creek	Use of the existing basement at 29-31 Bridge Road as a detention basin (3m depth).
JC10 – Trafalgar Street, Petersham Drainage Upgrade	Johnstons Creek	Pipes on Trafalgar Street (eastbound side) upgraded to 0.9m with 5 pits changed to unlimited capacity and one directional intake only (for model stability).
JC13 – Gladstone Street, Enmore Drainage Upgrade	Johnstons Creek	Various pits along Gladstone St, Trafalgar St, Bedford St and Liberty St changed to unlimited capacity. One 0.3m pipe upgraded to 0.6m and one 1.2m pipe with pit added to a low point on Bedford St. Pipe sizes on Liberty St increased from 0.3m to 0.6m.
JC14 – Railway Avenue, Stanmore Road Regrading	Johnstons Creek	Lowering of the Railway Avenue to redirect flow from properties to the road corridor.
JC15 – Probert Street, Newtown Drainage Upgrade	Johnstons Creek	4 pits on Probert Street changed to unlimited capacity and one pipe with 0.9m diameter added to Probert St.
JC18 v1 – Kingston Road, Camperdown Drainage Upgrade 1	Johnstons Creek	Pits at intersection of Cardigan St and Marmion St changed to unlimited capacity. Two 0.3m pipes upstream of the drainage under private properties upgraded to 0.825m.
JC18 v2 – Kingston Road, Camperdown Drainage Upgrade 2	Johnstons Creek	Including above drainage upgrades, plus drainage under the private properties upgraded to 0.9m x 1.5m culvert and 4 additional pits on Cardigan Street changed to unlimited capacity.
JC20 – Lennox Street, Newtown Drainage Upgrade	Johnstons Creek	Proposed drainage on Australia Street, new 1d network with 0.6m diameter pipes added.
JC23 – Clarendon Lane, Stanmore Drainage Upgrade	Johnstons Creek	5 pits changed to unlimited intake and one 0.3m diameter pipe added on Clarendon Lane.
WC1 – Margaret Street, Petersham Drainage Upgrade	Whites Creek	Various pits on Margaret St, Corunna Rd, Westbourne St and Charles St changed to unlimited capacity. Pipes between Margaret St and Corunna Rd upgraded to 0.9m. Pipes between Parramatta Rd and Margaret St upgraded to 1.8m x 1.2m.

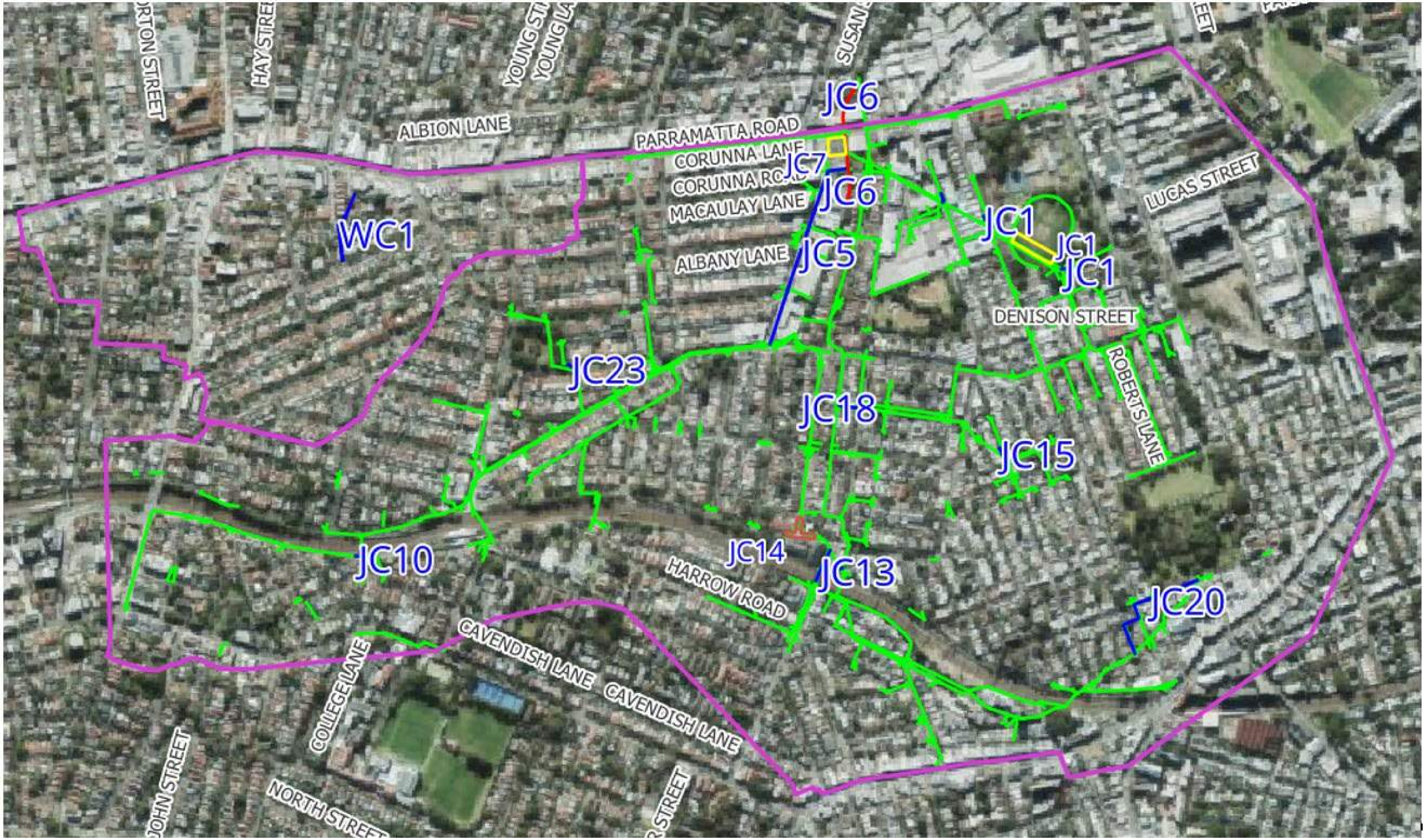

Figure 9-1 Location of 14 Detailed Flood Modification Options for Whites Creek and Johnstons Creek

9.2 Hydraulic Modelling of Options

The hydraulic modelling of detailed flood modification options reflected the model approach adopted for the preliminary options summarised in **Section 8.4.3**. The 13 detailed flood modification options and one property modification option were modelled for five design flood events - the 20%, 5%, 2% and 1% AEP and PMF events.

The review of hydraulic model results for detailed options included water level difference plots for each option compared to the PM6 base case for all 5 design events. The extent and scale of water level reductions and complete removal of flooding informed flood risk improvement conclusions for each option. Flood impact maps for all five modelled options for all five design flood events are included in **Appendix E**.

9.3 Preliminary Costing

Preliminary cost estimates have been prepared for all FM options, which allow for an economic assessment via consideration of the cost of implementation and the associated reduction in flood damages. The process for capital cost estimation was as follows:

- Quantities for construction have been estimated from preliminary design for the 13 FM options as they were modelled in the TUFLOW model. This included cut and fill volumes, disturbance footprint areas, and pipe lengths and diameters.
- Unit rates were initially estimated by Stantec based on past project experience. These unit cost rates were reviewed by Council staff and revised in some instances to match current cost rates for the local area.
- Due to the high-level nature of the estimates, a 50% contingency has been applied to all estimates given uncertainty on eventual design refinement and quantities.

Ongoing maintenance costs of FM Options have been estimated based on expected site conditions post-construction. Typically maintenance works assumed include pit and pipe cleaning, CCTV and mowing and maintenance of open space areas, with only minor expected costs associated. Due to uncertainty on future maintenance requirements and annual costs for Council, a 50% contingency has been applied to ongoing cost estimates as well.

Cost estimates for the Property Modification Option, PM6, the annual drainage maintenance budget for Inner West Council was scaled to the study area as an estimate of potential costs for increased maintenance based on the number of existing stormwater pipes. This amount was applied as both a capital cost and an ongoing maintenance cost for PM6.

For Emergency Management (EM) options, costs were estimated only on the basis of cost to implement, and were done for the purpose of comparison in the multi-criteria assessment. Ongoing costs for EM options were estimated based on expected work needed for each scheme.

Due to uncertainty of potential capital and ongoing costs for all PM and EM options, a 50% contingency has been applied to all, remaining consistent with the assessment of the FM options as well.

A summary of cost estimation outcomes for the 13 FM, 1 PM and 4 EM detailed options are included in **Table 9-3**. All capital and ongoing costs are excluding GST, and account for the 50% contingency.

Table 9-3 Cost Estimates for High-Level Quantitatively Assessed Options

Option	Capital Cost (excl. GST)	Ongoing Annual Cost (excl. GST)*
JC1 v1 – Fowler Street, Camperdown Drainage Upgrade	$397,097	$-
JC1 v2 – Fowler Street, Camperdown Detention Basin	$2,533,250	$6,000
JC5 – Bridge Road, Stanmore Drainage Upgrade	$7,915,444	$1,500
JC6 v1 – Bridge Road, Stanmore Channel Regrading	$1,899,528	$750
JC6 v2 – Bridge Road, Stanmore Channel Widening	$5,444,773	$750
JC7 – Bridge Road, Stanmore Detention Basin	$1,317,600	$4,500
JC10– Trafalgar Street, Petersham Drainage Upgrade	$704,767	$-
JC13 – Gladstone Street, Enmore Drainage Upgrade	$1,612,003	$2,250
JC14 – Railway Avenue, Stanmore Road Regrading	$2,247,615	$-
JC15 – Probert Street, Newtown Drainage Upgrade	$440,990	$750
JC18 v1 – Kingston Road, Camperdown Drainage Upgrade 1	$368,876	$-
JC18 v2 – Kingston Road, Camperdown Drainage Upgrade 2 (with upgrades under private properties)	$1,198,240	$-
JC20– Lennox Street, Newtown Drainage Upgrade	$2,266,173	$2,250
JC23 – Clarendon Lane, Stanmore Drainage Upgrade	$378,263	$1,500
WC1 – Margaret Street, Petersham Drainage Upgrade	$2,356,821	$-
PM6 – Targeted stormwater maintenance	$349,367	$349,367
EM2 – Review of Local Flood Planning and Info Transfer to NSW SES	$22,500	$7,500
EM3 – Community Flood Awareness	$60,000	$45,000
EM5 – Flood Markers and Signage	$150,000	$7,500
EM6 – Flood Data and Debrief	$45,000	$15,000

9.4 Damages Assessment of Options

An assessment of flood damages of the study area for the existing condition was presented in **Section 6**. The 2023 DT01 damage tool provides both a base case tab and an option tab such that damage benefits can be assessed within the tool. The base case is used to compare the performance of modelled options, and through calculation of post-option damages based on hydraulic model results the potential flood damage benefits of each option. The details of all methodology and input data for the option condition damages assessment are unchanged from those summarised in **Section 6**.

The damage assessment for options focussed only on the extent of impacts of the options, not the entire study area, with the total damage benefits calculated from the difference between option and PM6 condition damage totals in these areas of impact.

The new 2023 damages tool optimised external damage calculations by directly assessing them, eliminating the necessity for a separate property layer in the process. The tool features a tab for the base case and an option tab for inputting options data, enhancing the ease of comparing modelled options' performance.

Notably, the total length of assessment utilised a 30-year timeframe, as opposed to the previously employed 50 years, with a discount rate of 5% being considered throughout the analysis in agreement with DT01 defaults.

For PM6, applying existing condition, all pits and pipes were unblocked, achieving the desired PM6 condition to assess the best possible outcomes of increased drainage maintenance. For the PM6 option, the existing case was adopted as the base case. For the FM options, the PM6 condition assessment was used as the base case.

A summary of damage benefit outcomes for the five modelled design flood events (20%, 5%, 2%, and 1% AEP and PMF) for each of the 14 JC options and WC option is included in **Table 9-3** and **Table 9-4**.

The Average Annual Damage (AAD) reduction for each of the options has also been calculated in **Table 9-3** and **Table 9-4**. The total combined AAD benefit of 14 JC options is estimated to be nearly $3.9M per year and for WC option is nearly $320,000 per year.

Reduction in Flood Damages and AAD Associated with each Johnstons Creek Option

Option ID	Total Damages Reduction					Average Annual Damage Reduction
	PMF	1% AEP	2% AEP	5% AEP	20% AEP	
JC1 v1	$312,176	$216,803	$119,176	$20,646	$172,248	$102,704
JC1 v2	$78,827	$392,436	$797,530	$212,980	$277,497	$192,058
JC5	$128,968	$164,075	$352,491	$434,254	$169,430	$141,604
JC6 v1	$1,376,171	$1,203,646	$1,590,679	$1,506,617	$510,676	$467,185
JC6 v2	$1,625,581	$1,605,751	$1,353,928	$1,489,613	$538,691	$481,593
JC7	$149,280	$411,217	$1,357,498	$700,338	$729,992	$496,532
JC10	$0	$6,944	$53,643	$25,872	$879	$3,954
JC13	$2,127,043	$1,184,098	$712,851	$956,963	$555,234	$428,222
JC14	$3,431,063	$397,750	$466,465	$502,598	$489,152	$344,710
JC15	$20,170	$26,655	$142,280	$248,752	$163,320	$115,426
JC18 v1	$144,802	$9,424	$14,515	$35,953	$372,580	$209,263
JC18 v2	$1,010,857	$802,299	$589,819	$693,695	$396,096	$305,150
JC20	$173,057	$403,022	$554,971	$1,124,269	$776,464	$544,231
JC23	$0	$0	$35,676	$0	$37,089	$21,113
Total	$10,577,994	$6,824,120	$8,141,522	$7,952,549	$5,189,347	$3,853,745

Table 9-4 Reduction in Flood Damages and AAD Associated with each WC Option

Option ID	Total Damages Reduction					Average Annual Damage Reduction
	PMF	1% AEP	2% AEP	5% AEP	20% AEP	
WC1	$163,419	$419,958	$369,589	$345,327	$511,240	$324,667

In this process, the overflow depth was calculated utilizing the water level difference between the modelled option and PM6. This involved the addition of the water level difference to the PM6 overflow depth. Finally, to obtain the overflow level, the floor level was added to the calculated overflow depth.

The new 2023 damages tool optimised external damage calculations by directly assessing them, eliminating the necessity for a separate property layer in the process. The tool features a tab for the base case and an option tab for inputting options data, enhancing the ease of comparing modelled options' performance.

Notably, the total length of assessment utilised a 30-year timeframe, as opposed to the previously employed 50 years, with a discount rate of 5% being considered throughout the analysis.

9.5 Benefit-Cost Ratio

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

Table 9-5 summarises the results of the economic assessment of each of the options. The indicator adopted to assess these measures on economic merit is the benefit-cost ratio (BCR), which is based on the net present worth (NPW) of the benefits (reduction in AAD, refer to **Section 9.4**) and the costs (of implementation, refer to **Section 9.3**). In the calculation of NPW, a 5% discount rate and an implementation period of 30 years have been adopted (default values in the 2023 DT01 Damage Tool).

The benefit-cost ratio provides an insight into how the damage savings from a measure relate to its cost of construction and maintenance.

- Where the benefit-cost ratio is greater than one (BCR >1) the economic benefits are greater than the cost of implementing the measure.
- Where the benefit-cost is less than one but greater than zero (0 < BCR < 1) there is still an economic benefit from implementing the measure, but the cost of implementing the measure is greater than the economic benefit.
- Where the benefit-cost is equal to zero (BCR = 0), there is no economic benefit from implementing the measure.

For all FM options it is possible to quantify, at least at a high-level both damage benefits and costs of implementation for each option, therefore a BCR is able to be calculated. For EM and PM options, the damage benefits are not easily quantifiable, though there would be some economic benefits of these options in the form of reduced risk to life and resultant reduction in flood damage for loss of life. Therefore in lieu of any damage benefit information, the economic analysis of these options has assumed that BCR is 1.0.

Table 9-5 Summary of Net Present Worth of Benefits and Costs and Resultant Benefit Cost Ratio

Option	NPW of AAD Reduction Benefits	NPW of Cost of Implementation of Option	Benefit Cost Ratio
JC1 v1– Fowler Street, Camperdown Drainage Upgrade	$1,578,818	$397,097	3.98
JC1 v2– Fowler Street, Camperdown Detention Basin	$2,952,404	$2,625,485	1.12
JC5 – Bridge Road, Stanmore Drainage Upgrade	$2,176,794	$7,938,503	0.27
JC6 v1 – Bridge Road, Stanmore Channel Regrading	$7,181,786	$1,911,058	3.76
JC6 v2– Bridge Road, Stanmore Channel Widening	$7,403,263	$5,456,303	1.36
JC7 – Bridge Road, Stanmore Detention Basin	$7,632,909	$1,386,777	5.50
JC10– Trafalgar Street, Petersham Drainage Upgrade	$60,783	$704,768	0.09
JC13 – Gladstone Street, Enmore Drainage Upgrade	$6,582,822	$1,646,592	4.00
JC14 – Railway Avenue, Stanmore Road Regrading	$5,299,041	$2,247,616	2.36
JC15 – Probert Street, Newtown Drainage Upgrade	$1,774,388	$452,519	3.92
JC18 v1 – Kingston Road, Camperdown Drainage Upgrade 1	$3,216,878	$368,877	8.72
JC18 v2 – Kingston Road, Camperdown Drainage Upgrade 2	$4,690,901	$1,198,241	3.91
JC20– Lennox Street, Newtown Drainage Upgrade	$8,366,172	$2,300,761	3.64
JC23 – Clarendon Lane, Stanmore Drainage Upgrade	$324,555	$401,322	0.81
WC1 – Margaret Street, Petersham Drainage Upgrade	$4,990,924	$2,356,821	2.12
PM6 – Drainage Maintenance		$5,719,990	1.0*
EM2 – Review of Local Flood Planning and Info Transfer to NSW SES		$137,794	1.0*
EM3 – Community Flood Awareness		$751,761	1.0*
EM5 – Flood Markers and Signage		$265,294	1.0*
EM6 – Flood Data and Debrief		$275,587	1.0*

*In lieu of benefit values for EM options, due to flood risk reduction BCR value assumed to be 1.0

The BCR results show that of flood risk management options:

> Eight (8) options have BCR values over 3.0, therefore the costs are significantly lower than the calculated benefits.

> Two (2) options have BCR values over 1.5 to 3.0, therefore the costs are lower than the calculated benefits.

> Eight (8) options have BCR values over 0.5 to 1.5, therefore the costs are comparable to the calculated benefits, five (5) such options are EM and PM options with assumed BCR of 1.0.

> Two (2) options have BCR values less than 0.5, therefore the costs are significantly higher than the calculated benefits.

The PM6 option cannot be easily assessed as the potential benefits of targeted maintenance are difficult to quantify. A sensitivity modelling scenario has been adopted assuming no blockage of pipes as a result of maintenance. This is a best case scenario, that in reality is unlikely to be achievable. Nevertheless, it does provide an indication of areas of potential benefits, even if the scale of benefits may exceed expected outcomes. Therefore, due to this uncertainty, the modelling outcomes in the form of damage benefits were not applied to the BCR outcome for this option PM6.

9.6 Multi-Criteria Assessment

To assist Council in identifying the FRM options that provide the most benefits for the community, all options need to be compared against each other based on factors relevant to the study area.

Evaluating what constitutes an appropriate strategy for floodplain management is a significant analytical and policy challenge. Such challenges have led to the exploration of alternative policy analysis tools, one being Multi Criteria Assessments (MCA). The goal of MCA is to attempt to directly incorporate multiple values held by community and stakeholders into the analysis of management alternatives while avoiding the reduction of those values into a standard monetary unit. In doing so, one can consider different FRM options in the context of economic criteria as well as other criteria such as social, or environmental aspects. Community and stakeholders can also assign explicit weights to those values to reflect their preferences and priorities. Therefore, MCA provides opportunities for the direct participation of community and stakeholders in the analysis.

An MCA approach has been used for the comparative assessment of all options identified using a similar approach to that recommended in 2023 FRM Guide MM01. This approach uses a subjective scoring system to assess the merits of each option. The principal value of such a system is that it allows comparisons to be made between alternatives using a common index. In addition, the MCA makes the assessment of alternatives “transparent” (i.e. all important factors are included in the analysis).

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

Each option is given a score according to how well the option meets specific considerations. In order to keep the scoring system simple a framework has been developed for each criterion.

9.6.1 Development of Criteria

A balanced FRMS&P addresses existing, future and continuing risk to reduce residual risk to a level more acceptable to the community and in doing so generally involves assessing, deciding on and prioritising a range of FRM measures.

One way of considering the outcomes of an MCA of different options or packages of options is the establishment of an options assessment matrix that considers a range of criteria that can influence decision-making. The criteria used can vary with the flood situation and community. Some may not be relevant to the circumstances or the options being considered. In addition, different communities, decision-makers and groups may consider different criteria and specific elements to be more or less important. One way of addressing this variation is to weight the relative importance of these criteria so this can be factored into the assessment.

As per the recommendations of Section 2.2.5 of the FRM Guide MM01, the selection of criteria and weighting should be completed independent of scoring and actively involve the FRM committee and its technical working group (TWG).

There are a total of 11 MCA criteria adopted for this FRMS&P:

- 5 economic criteria – Benefit-cost ratio, risk to property, technical feasibility, implementation complexity, and adaptability/long-term performance
- 4 social criteria – Risk to life, emergency access and evacuation, social disruption and public open spaces, and community and stakeholder support
- 2 environment criteria – Flora and fauna impact and heritage impact.

The criteria weightings provided by Council are summarised in **Table 9-6**.

9.6.2 Criteria Scoring System

A scoring system was established for each criterion with scores ranging from +2 for options that represented a significant improvement on existing conditions for any given criteria, to -2 for options that represented a significant worsening of existing conditions. The scoring system for all 10 criteria are summarised in **Table 9-6**. It is noted that for two criteria (Benefit-Cost Ratio and Reduction in Risk to Property) scoring systems was based on quantifiable assessment outcomes, for all other criteria scoring was more subjective.

Table 9-6 Multi-Criteria Assessment - Scoring System Summary

Category	Criterion	Weighting	Description of Criterion Assessment	Score -2	Score -1	Score 0	Score 1	Score 2
Economic	Benefit-Cost Ratio	20%	The cost effectiveness of the scheme, i.e. the tangible return on investment	0 to 0.25	0.25 to 0.5	0.5 to 1.5	1.5 to 3.0	>3.0
	Reduction in Risk to Property	5%	Based on reduction in AAD, it establishes the tangible benefit of an option	Major increase in AAD (>$200,000)	Slight increase in AAD ($200k to $100k)	Negligible Improvement (less than $100k AAD impact)	Slight decrease in AAD ($200k to $100k)	Major decrease in AAD ($>200,000)
	Technical Feasibility	10%	Establishes the feasibility of options based on likely service constraints, environmental hazards, and programming contingencies such as land acquisition or agreements with external agencies	There are a number of significant factors that pose an impact on the feasibility of the project	There is a single significant factor or multiple smaller factors that pose a potential impact on the feasibility of the project	May or may not be feasible	Likely to be feasible with management of constraints	Very likely to be feasible with no significant restraint
	Implementation Complexity	5%	Ease of constructability within Council's standard Capital Works Planning	Construction timeframe greater than 1 year Project cannot be broken down into sequential components	Construction timeframe greater than	Key components can be completed in isolation within 12 months	Overall construction timeframe less than 12 months Minor components can be staged	Construction timeframe less than 6 months Major components can be staged
	Adaptability and long-term performance	10%	The impact the option will have both in terms of feasibility, benefits and cost over the life of the option, and adaptability to climate change conditions	Significantly diminished performance long-term or under climate change	Slightly diminished performance long-term or under climate change	Unchanged performance long-term or under climate change	Unchanged or improved performance long-term or under climate change with minor ongoing costs	Unchanged or improved performance long-term or under climate change with negligible ongoing costs
Social	Reduction in Risk to Life	15%	The impact on risk to life from the 20% AEP up to the PMF event	Widespread or significant localised increase in risk to life	Localised or slight increase in risk to life	Negligible change in risk to life	Localised or slight reduction of risk to life	Widespread or significant localised reduction of risk to life
	Emergency Access and Evacuation	10%	The impact on the ability to evacuate or for NSW SES or emergency services under extreme flood conditions	Widespread or significant localised impact on evacuation and emergency services	Localised or slight localised impact on evacuation and emergency services	Negligible impact on evacuation and emergency services	Localised or slight improvement for evacuation and emergency services	Widespread or significant localised improvement for evacuation and emergency services
	Social Disruption and Public Open Spaces	5%	The impact of the risk management option on social disruption and the use of public spaces	Significant increase in the frequency of flooding or limitation of the use of a public space or causes significant social disruption	Increase in the frequency of flooding or limitation of the use of a public space or causes social disruption	Negligible impact on public space or social disruption	Reduces the frequency of flooding or provides enhanced use of a public space or causes social benefit	Significantly reduces the frequency of flooding or enhanced use of a public space or causes significant social benefit
	Community and Stakeholder Support	10%	Support for the option based on FRM Committee meeting, stakeholder engagement and community consultation outcomes	Strong opposition to the option in multiple submissions	Slight opposition to the option	No response	Slight support to the option	Significant support to the option
Environment	Impact on Fauna/Flora	5%	Likely impacts on Threatened Ecological Communities and Threatened Species	High negative impact	Slight negative impact	Negligible impact	Some benefit	Considerable benefit
	Impact on Heritage	5%	Impact to Heritage items	Likely impact on State, National, or Aboriginal Heritage item	Likely impact or increased impact on a local heritage item	No impact	Reduces the impact of flooding to heritage item or heritage conservation area	Heritage item no longer flooded

9.6.3 Multi-Criteria Scoring Outcomes

The assignment of a score and brief discussion reasoning for the score for each criterion for all flood modification (FM), property modification (PM), and emergency management (EM) modification options is shown in its entirety in the matrices presented in **Appendix F**.

The unweighted scores of the MCA has a range from 20 to -20 based on 10 criteria each with a score of +2 to -2. The weighted final MCA scores using the criteria weighting (see **Table 9-6**) have a possible range of +2.0 to -2.0. The total weighted and unweighted MCA scores for each detailed option are summarised in **Table 9-7**. The options have been tabulated in order from highest to lowest weighted score.

Due to the relative weighting of the 10 criteria the weighted and unweighted scores for options are not ordered the same. This provides an insight into the significance of appropriate criteria weighting.

Table 9-7 MCA Outcomes for Weighted and Unweighted Scores for Detailed Options

Option ID	Option Type	Total Unweighted Score (from -20 to 20)	MCA Weighted Score	Final Rank
Option JC15 - Probert Street, Newtown Drainage Upgrade	Flood Management (FM)	12	1.25	1
Option JC7 - Bridge Road, Stanmore Detention Basin	Flood Management (FM)	11	1.15	2
EM2 – Review of Local Flood Planning and Info Transfer to NSW SES	Emergency Management (EM)	11	1.10	3
Option JC20 - Lennox Street, Newtown Drainage Upgrade	Flood Management (FM)	10	1.10	3
Option JC13 - Gladstone Street, Enmore Drainage Upgrade	Flood Management (FM)	9	1.05	5
EM3 – Community Flood Awareness	Emergency Management (EM)	10	0.95	6
EM5 – Flood Markers and Signage	Emergency Management (EM)	10	0.95	6
Option JC14 v2 - Railway Avenue, Stanmore Road Regrading	Flood Management (FM)	7	0.85	8
Option JC18 v1 - Minor Kingston Road, Camperdown Drainage Upgrade	Flood Management (FM)	7	0.75	9
Option JC6 v1 - Bridge Road, Stanmore Channel Upgrade (Re-grading North)	Flood Management (FM)	5	0.70	10
PM6 –Targeted stormwater maintenance	Property Modification (PM)	7	0.65	11
Option JC23 - Clarendon Lane, Stanmore Drainage Upgrade	Flood Management (FM)	7	0.55	12
Option JC18 v2 - Major Kingston Road, Camperdown Drainage Upgrade	Flood Management (FM)	3	0.55	12
Option JC1 v5 - Fowler Street, Camperdown Detention Basin	Flood Management (FM)	5	0.50	14
EM6 – Flood Data and Debrief	Emergency Management (EM)	5	0.45	15
Option WC1 - Margaret Street, Petersham Drainage Upgrade	Flood Management (FM)	1	0.40	16
Option JC1 v1 -Fowler Street, Camperdown Drainage Upgrade	Flood Management (FM)	4	0.35	17
JC6– Bridge Road, Stanmore Channel Widening	Flood Modification (FM)	3	0.30	18
JC10– Trafalgar Street, Petersham Drainage Upgrade	Flood Modification (FM)	5	0.15	19
JC5 – Bridge Road, Stanmore Drainage Upgrade	Flood Modification (FM)	0	0.00	20

The highest scoring options typically fall into one of two categories:

- Relatively cost-effective FM) options consisting of drainage upgrades that provide significant flood risk reduction benefits (with the exception of the Bridge Road detention basin option).
- EM options which offer significant flood risk reduction with relatively minor cost. Three of the top seven MCA scoring options are EM options.

The lowest scoring options are typically FM options that do not provide significant flood risk reduction benefits relative to their cost, complexity or other issues. The lowest 5 scoring options are all FM options.

10 Implementation Program

The Flood Risk Management options outlined in **Section 9** are recommended for implementation as an outcome of the Floodplain Risk Management Study. In order to achieve the implementation of relevant management actions, a plan of implementation has been developed as outlined in the following sections.

10.1 Steps to Implementation

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

> Formal adoption of FRMS&P: Following public exhibition and FRM Committee approval, Council will formally adopt the final Flood Risk Management Study and Plan;

> Investigation and Design (I&D) stage – Most options will next require an Investigation and Design (I&D) phase to further refine the design and further confirm the feasibility of the option. An equivalent assessment is a ‘Feasibility Study’ or ‘Scoping Study’ for programs such as the Voluntary House Raising Scheme. These investigation and design assessments for individual projects should build on the assessment undertaken in the FRM plan. The potential steps of the I&D stage may include:

- Prior to the I&D stage, grant funding applications for the I&D assessment may need to be submitted by Council when required.
- Additional investigations may be required to inform feasibility assessment. For example, for Flood Modification options these may include geotechnical investigations, subsurface utility survey, or environmental impact reviews.
- Concept design of the option.
- Detailed design of the option.
- Environmental approvals submissions such as a Review of Environmental Factors (REF) or Environmental Impact Statement (EIS).
- Economic assessment of options (Level 1, Level 2 or Level 3 guided by the framework discussed in the next sub-section) potentially including further detailed damages benefit assessment, or cost estimation compared to the analyses conducted in this FRMS&P.

> Following I&D stage, if required, a grant funding application will need to be submitted to support the implementation / construction of the option.

> Implementation / construction of the flood risk management option.

10.2 Economic Assessment Framework for Options

Where external funding is required, the FRM economic assessment framework, as shown in **Figure 10-1**, provides the basis for further assessment of the FRM measures as part of the investigation and design phases of implementation.

The framework for the economic assessment of FRM measures from the FRM Guide MM01 is shown in **Figure 10-1**. It provides a summary of the economic assessment of FRM options following on from a FRMS&P into Investigation and Design (I&D) stage and into Implementation stage. This provides useful context into the different levels of detailed assessment required for FRM options once they proceed beyond the FRMS&P stage. There are four levels of economic assessment based on this framework:

> Level 1 assessments are the least detailed form of economic assessment. Level 1 assessments include preliminary costing, damages benefit estimation and an MCA including preliminary cost-benefit summary. These Level 1 assessments are applied at the FRMS&P phase for all FRM options, regardless of expected option cost. For FRM options with expected cost less than $1 million, a level 1 assessment is also appropriate at I&D and implementation stage as no grant approval is required. The Level 1 assessment in this FRMS&P for detailed options is summarised in **Section 9.5**.

> Level 2 assessments update the Level 1 economic analysis to include cost estimates from I&D stage. Consider whether additional damage assessment factors (not included but likely to influence the outcome) should be included to improve the Level 1 damage assessment, also consider sensitivity assessment to discount rate, and increases, and decreases in benefits and costs. Level 2 assessments relate to FRM

options with expected value between $1-$5 million. Level 2 assessments require additional reporting incorporated in I&D reporting to support grant application for implementation.

> Level 3 assessments are similar to Level 2 with updating of Level 1 economic analysis to include cost estimates from I&D stage, but with potential to include more detailed techniques for monetary valuation. Use of more detailed assessment techniques for benefits assessment, for example, evacuation modelling may be appropriate to identify risk to life more readily. More detailed sensitivity analyses than Level 2 with a more detailed stand-alone report or appendix to the I&D report to support grant application. Level 3 assessments relate to FRM options with expected value between $5-$10 million.

> For FRM Options with expected value in excess of $10 million, the option must go through a NSW Treasury gateway review process with more detailed economic assessment and reporting required.

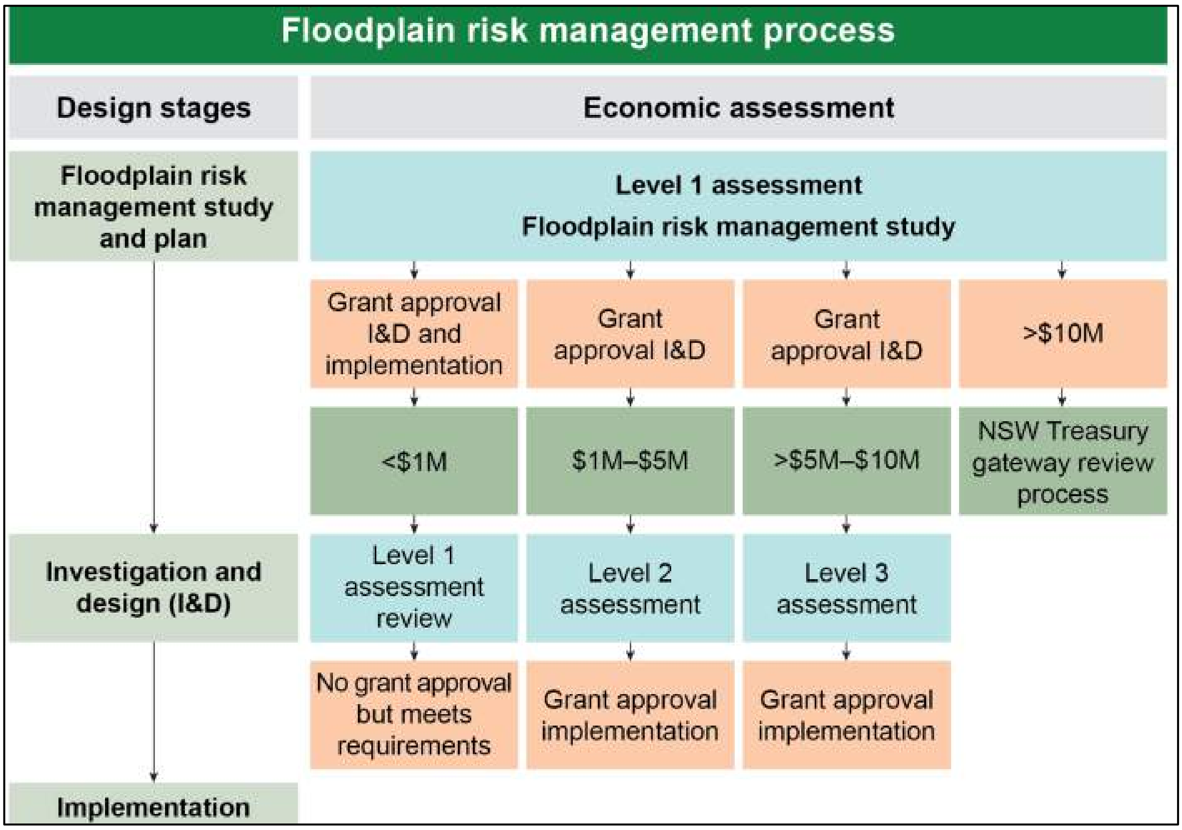

Figure 10-1 Detailed FRM Measure Economic Assessment Framework (Source: FRM Guide MM01)

The expected necessary economic assessment level of each option in this FRMS&P is summarised in the implementation program in **Table 10-1**. The economic assessments will need to be completed during Investigation and Design (I&D) stage for each option.

10.3 Funding Mechanisms for FRM Options

As stated in FRM Guide MM01, FRM plans may recommend a range of implementation measures that are funded through one of the following means:

a. Council funded: Can be implemented within council's own resources, such as updating land-use planning arrangements. Council should progress these measures within their own resources considering the priorities in the plan

b. Funded by Other Agencies: Are the agreed responsibility of, or require agreed input from external parties to implement. Examples include updating EM planning arrangements, or options located within the lands of other stakeholder agencies. Council should work with external parties to support implementation, considering the priorities in the plan.

c. Grant Funded: Will generally require external funding support, such as new or upgraded FRM works, including levees, basins, and flood warning systems. Council will need to apply for these grant funds.

The anticipated funding mechanism for each option adopted within this FRMS&P is summarised in the implementation program in **Table 10-1**. This is an assumed funding source, it is possible that funding sources other than those listed in **Table 10-1** may be considered for any given option at Council's discretion and with the agreement and support from any relevant funding agencies.

10.3.1 Grant Funding

The NSW Government's floodplain management grants support local Councils to manage flood risk. The funding for FRM option implementation from these grants has traditionally comes from two programs:

> NSW Floodplain Management Program, and

> Floodplain Risk Management Grants Scheme (jointly funded by the NSW DCCEW and the Commonwealth Government).

Applications for funding can be made by Council for the implementation of actions identified in a FRMS&P. The information provided in the applications for each management action is used to rank the priority for funding of all actions across NSW. The information presented in this FRMS&P can be used as a starting point to complete the relevant applications for funding.

Sufficient information should be provided in reports to facilitate funding applications for eligible projects under relevant funding programs. Information currently needed to support these applications relates to Council's commitment to FRM, how FRM measures were identified and assessed, community involvement in FRM plan development, and the FRM benefits of the project for the community.

10.4 Ranking and Prioritisation of Options

Based on review of the Multi-Criteria Assessment outcomes summarised in **Section 9.6**, the options have been ranked in order of preference. The MCA scores were combined to produce an options implementation preferences list as shown in **Table 10-1**. As shown in the rank column, this table was ordered based on ranking, from highest ranking to lowest ranking option.

In addition, a priority has been assigned to each of the options to inform the implementation strategy. The priority reflects the recommended urgency of the option from a reduction in flood risk perspective, it is possible that the order of implementation that Council adopts may differ from these priority assignments.

The grouping of options into the three priority categories has been based on the distribution of MCA scoring, with categories set at points of clear delineation of scoring outcomes. There is a MCA score difference of 0.90 from the worst scoring high priority option and the best medium priority option, with a 0.15 score difference from medium to low. The three priority categories are:

> High – Seven options were identified as high priority. Of the high priority options, four are Flood Modification (FM), or structural options and three are Emergency Management (EM) modification options. The range of MCA scores for high priority options is 1.25 to 0.95 (ranks 1-7)

> Medium – Eight options were identified as medium priority. Of the medium priority options, two are Property Modification (PM) options and six are Flood Modification (FM), or structural options. The range of MCA scores for medium priority options is 0.90 to 0.50 (ranks 7-14); and

- Low – Three options were identified as low priority. Of the low priority options, two are Flood Modification (FM), or structural options and two are Emergency Management (EM) options. The range of MCA scores for low priority options is 0.45 to 0.35 (ranks 15-18).

Three Flood Management (FM) options were removed from the implementation plan due to relatively low ranking scores:

- JC6 v1 Bridge Road channel widening upgrade
- JC10 Trafalgar Street drainage upgrade
- JC5 Bridge Road Drainage upgrade.

10.5 Implementation Plan

The list of recommended management options has been transformed into an implementation plan provided in **Table 10-1**. It lists the following information relevant to the implementation of each adopted FRM option:

- Type and sub-catchment location of option and Multi-Criteria Assessment score;
- The priority for implementation (high, medium, or low) and rank as an outcome of the FRMS&P;
- An estimate of implementation costs including capital and ongoing costs per annum;
- Potential funding mechanism or organisation; and
- Required economic assessment level during I&D stage from framework in **Section 10.2**.

The flood risk management options identified in **Table 10-1** represent a capital cost of approximately $17.6M, with the flood modification options making up $17.0M of this cost. High priority options have combined capital costs of $5.9M.

It is noted that the implementation plan does not outline a specific timeframe for each project. Rather, the implementation plan provides a body of projects to inform future advocacy, budgeting, and planning in order that Council may be able to undertake works in a prioritised manner as funding becomes available, or other opportunities arise in a specific location associated with a proposed option.

Table 10-1 Implementation Plan for Whites Creek and Johnstons Creek FRMS&P

Option ID	Option Type	MCA Weighted Score	Option Rank	Implementation Priority	Capital Costs (incl. GST)	Ongoing Costs (p.a incl. GST)	Economic Assessment Level for I&D
Option JC15 - Probert Street, Newtown Drainage Upgrade	Flood Modification (FM)	1.25	1	High	$ 440,990	$ 750	Level 1 (FRMS&P)
Option JC7 - Bridge Road, Stanmore Detention Basin	Flood Modification (FM)	1.15	2	High	$ 1,317,600	$ 4,500	Level 2 (Detailed damages)
EM2 – Review of Local Flood Planning and Info Transfer to NSW SES	Emergency Management (EM)	1.10	3	High	$ 22,500	$ 7,500	Level 1 (FRMS&P)
Option JC20 - Lennox Street, Newtown Drainage Upgrade	Flood Modification (FM)	1.10	3	High	$ 2,266,173	$ 2,250	Level 2 (Detailed damages)
Option JC13 - Gladstone Street, Enmore Drainage Upgrade	Flood Modification (FM)	1.05	5	High	$ 1,612,003	$ 2,250	Level 2 (Detailed damages)
EM3 – Community Flood Awareness	Emergency Management (EM)	0.95	6	High	$ 60,000	$ 45,000	Level 1 (FRMS&P)
EM5 – Flood Markers and Signage	Emergency Management (EM)	0.95	6	High	$ 150,000	$ 7,500	Level 1 (FRMS&P)
Option JC14 - Railway Avenue, Stanmore Road Regrading	Flood Modification (FM)	0.85	8	Medium	$ 2,247,615	$ -	Level 2 (Detailed damages)
Option JC18 v1 - Minor Kingston Road, Camperdown Drainage Upgrade 1	Flood Modification (FM)	0.75	9	Medium	$ 368,876	$ -	Level 1 (FRMS&P)
Option JC6 v1 - Bridge Road, Stanmore Channel Upgrade (Re-grading North)	Flood Modification (FM)	0.70	10	Medium	$ 1,899,528	$ 750	Level 2 (Detailed damages)
PM6 – Targeted stormwater maintenance	Property Modification (PM)	0.65	11	Medium	$ 349,367	$ 349,367	Level 1 (FRMS&P)
Option JC23 - Clarendon Lane, Stanmore Drainage Upgrade	Flood Modification (FM)	0.55	12	Medium	$ 378,263	$ 1,500	Level 1 (FRMS&P)
Option JC18 v2 - Major Kingston Road, Camperdown Drainage Upgrade 2	Flood Modification (FM)	0.55	12	Medium	$ 1,198,240	$ -	Level 2 (Detailed damages)
Option JC1 v2 - Fowler Street, Camperdown Detention Basin	Flood Modification (FM)	0.50	14	Medium	$ 2,533,250	$ 6,000	Level 2 (Detailed damages)
EM6 – Flood Data and Debrief	Emergency Management (EM)	0.45	15	Low	$ 45,000	$ 15,000	Level 1 (FRMS&P)
Option WC1 - Margaret Street, Petersham Drainage Upgrade	Flood Modification (FM)	0.40	16	Low	$ 2,356,821	$ -	Level 2 (Detailed damages)
Option JC1 v1 -Fowler Street, Camperdown Drainage Upgrade	Flood Modification (FM)	0.35	17	Low	$ 397,097	$ -	Level 1 (FRMS&P)
				Total	**$ 17,643,323**	**$ 442,367**	

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11 Conclusions

This Draft Final Flood Risk Management Study and Plan (FRMS&P) report summarises the outcomes of the study undertaken for Inner West Council for Whites Creek and Johnstons Creek Catchments. This includes initial data collection and review process, community consultation, review of the flood study models, existing risk assessments including economic impacts of flooding, flood emergency response review, and flood planning review. It includes a summary of the flood risk management option development process and preliminary option assessment to refine options for adoption. The report also documents the detailed option assessment including modelling, cost estimation, damage benefits assessment, and Multi-Criteria Assessment (MCA) and provides a prioritised list of final options. Finally, the report outlines an implementation program to assist Council in the future implementation of these final options.

The flood study model review process involved the updating of the Flood Study TUFLOW model to account for ARR2019 design rainfall (Flood Study adopted ARR87 rainfall), and updating for present-day terrain in the form of LiDAR. The review concluded that the impacts of the model updates were relatively minor therefore the Flood Study model was appropriate for retention as the base case model for this FRMS&P and the assessment of options.

The flood damages assessment, flood emergency response review and flood planning review all contribute to the understanding of existing flooding as it relates to economic impacts, risk to life, and future development respectively.

A preliminary assessment of flood modification options has also been conducted including flood modelling of Flood Modification (FM) options and consideration of Property Modification (PM) options and Emergency Management Modification (EM) options. In total 37 preliminary options were developed including 25 FM, 6 PM and 6 EM options. From these preliminary options, 20 options have been selected for detailed assessment including 15 FM options, 1 PM options, and 4 EM options.

The detailed option assessment to review the selected final 20 options through flood modelling to assess the impacts of the option, flood damages (both for FM and PM options only, not EM options), cost estimation and Multi-Criteria Assessment (MCA). Three Flood Management (FM) options were removed from the implementation plan due to relatively low ranking scores, leaving a total of 17 options in the implementation plan. The outcomes of the MCA have been applied to the implementation plan including a list of priority options with seven high priority options, seven medium priority options, and three low priority options. Of the high priority options, four are Flood Modification (FM), or structural options and three are Emergency Management (EM) modification options.

The Draft Final FRMS&P report was placed on public exhibition, to receive comments and feedback from the community on the draft outcomes of the study prior to finalisation. The public exhibition period was conducted for a five-week period in June and July 2024. Comments from the community were collated and reviewed and incorporated into the Final FRMS&P report.

12 References

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