Campsie Rezoning - Updated Flood Risk Assessment

Stantec

Prepared for:
Canterbury Bankstown Council

Prepared by:
Martin Griffin & Alireza Pouya

5 September 2024

Project/File:
300204096

Stantec Australia Pty Ltd

Revision	Description	Author	Date	Quality Check	Date	Independent Review	Date
1	For issue to client	AP	3/09/2024	MG	5/09/2024		

The conclusions in the Report titled Campsie Rezoning - Updated Flood Risk Assessment are Stantec's professional opinion, as of the time of the Report, and concerning the scope described in the Report. The opinions in the document are based on conditions and information existing at the time the scope of work was conducted and do not take into account any subsequent changes. The Report relates solely to the specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose, and any unauthorized use or reliance is at the recipient's own risk.

Stantec has assumed all information received from Canterbury Bankstown Council (the "Client") and third parties in the preparation of the Report to be correct. While Stantec has exercised a customary level of judgment or due diligence in the use of such information, Stantec assumes no responsibility for the consequences of any error or omission contained therein.

This Report is intended solely for use by the Client in accordance with Stantec's contract with the Client. While the Report may be provided by the Client to applicable authorities having jurisdiction and to other third parties in connection with the project, Stantec disclaims any legal duty based upon warranty, reliance or any other theory to any third party, and will not be liable to such third party for any damages or losses of any kind that may result.

Prepared by

Signature

Printed Name

Reviewed by

Signature

Martin Griffin

Printed Name

Approved by

Signature

Martin Griffin

Printed Name

Table of Contents

List of Tables

List of Figures

List of Appendices

Acronyms / Abbreviations

1D	One-dimensional
2D	Two-dimensional
AEP	Annual Exceedance Probability
AFAC	Australasian Fire and Emergency Service Authorities Council
AHD	Australian Height Datum
ARF	Areal Reduction Factor
ARI	Average Recurrence Interval
ARR	Australian Rainfall and Runoff
BoM	Australian Bureau of Meteorology
DCP	Development Control Plan
DEM	Digital Elevation Model
DFE	Defined Flood Event
DPHI	NSW Department of Planning and Infrastructure
FDM	Floodplain Development Manual
FRMS&P	Floodplain Risk Management Study and Plan
FRM	Flood Risk Management
FPL	Flood Planning Level
FPA	Flood Planning Area
FSR	Floor Space Ratio
GIS	Geographical Information Systems
HOB	Height of Building
IFD	Intensity-Frequency-Duration
LEP	Local Environment Plan
LGA	Local Government Area
LIDAR	Light Detection and Ranging
NSW	New South Wales
PMF	Probable Maximum Flood
SEPP	State Environmental Planning Policy
SES	NSW State Emergency Service
SFC	Special Flood Consideration

Glossary

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.

AEP	ARI
63.2 %	1 year
39.3 %	2 year
18.1 %	5 year
10 %	10 year
5 %	20 year
2 %	50 year
1 %	100 year
0.5 %	200 year
0.2 %	500 year

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.
Flash flooding	Flooding which is sudden and often unexpected because it is caused by sudden local heavy rainfall or rainfall in another area. Often defined as flooding which occurs within 6 hours of the rain which causes it.
Flood	Relatively high stream flow which overtops the natural or artificial banks in any part of a stream, river, estuary, lake or dam, and/or overland runoff before entering a watercourse and/or coastal inundation resulting from super elevated sea levels and/or waves overtopping coastline defences.
Flood fringe	The remaining area of flood prone land after floodway and flood storage areas have been defined.

Flood hazard	Potential risk to life and limb caused by flooding.
Flood prone land	Land susceptible to inundation by the probable maximum flood (PMF) event, i.e. the maximum extent of flood liable land. Floodplain Risk Management Plans encompass all flood prone land, rather than being restricted to land subject to designated flood events.
Floodplain	Area of land which is subject to inundation by floods up to the probable maximum flood event, i.e. flood prone land.
Floodplain management measures	The full range of techniques available to floodplain managers.
Floodplain management options	The measures which might be feasible for the management of a particular area.
Flood planning area	The area of land below the flood planning level and thus subject to flood related development controls.
Flood planning levels (FPLs)	Flood levels selected for planning purposes, as determined in floodplain management studies and incorporated in floodplain management plans. Selection should be based on an understanding of the full range of flood behaviour and the associated flood risk. It should also consider 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 PMF is the largest flood that could conceivably occur at a particular location, usually estimated from probable maximum precipitation, and where applicable, snow melt, coupled with the worst flood producing catchment conditions.
Probable maximum precipitation (PMP)	The PMP is the greatest depth of precipitation for a given duration meteorologically possible over a given size storm area at a particular location at a particular time of the year, with no allowance made for long-term climatic trends.
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 has previously been engaged by Canterbury-Bankstown Council to prepare a desktop flood planning assessment for Campsie Town Centre (the Precinct). In 2019, Council completed their Local Strategic Planning Statement (known as Connective City 2036). Amongst its many outcomes, the Connective City 2036 recognised Campsie Town Centre as a strategic centre of Canterbury-Bankstown. In line with Connective City 2036, Council had commenced the master planning process for Campsie. The master plan provides the opportunity to co-locate genuine job-generating development with housing, services, utilities and social infrastructure.

The draft Campsie Town Centre Master Plan was initially exhibited publicly from March to June 2021, with an updated Master Plan prepared by September 2021 in response to public submissions. Once the Master Plan was finalised a planning proposal has been prepared that updates the objectives and controls of Council's Local Environmental Plan (LEP) and Development Control Plan (DCP). This is the current status of the project as a pre-Gateway planning proposal. The planning proposal shall then be submitted for gateway determination, public exhibition, finalisation and adoption.

In mid-2021, NSW Department of Climate Change, Energy, Environment and Water (DCCEEW) released a new Flood Prone Land Policy Update. Included within this release was Ministerial Direction 4.1 which outlines the flood assessment requirements for planning proposals. In May 2021, the asset planning stormwater team for Canterbury-Bankstown Council reviewed the proposed Master Plan for Campsie and concluded that the plan was developed generally in accordance with the objectives of the new Flood Prone Land Policy Update. However, the team requested an industry peer review to provide an independent assessment and verification that the site-specific development and rezoning proposed in the Draft Master Plan is consistent with the relevant planning controls and policies. This is the background for the previous engagement of Stantec to prepare the Campsie Town Centre Desktop Flooding Assessment.

A final version of this report was submitted by Stantec to Council on 3 May 2022. Following this, a set of comments from NSW DCCEEW (formerly EHG) for pre-Gateway conditions was received dated 23 September 2022 as an attachment to Draft Gateway comments. A discussion with NSW DCCEEW representatives, Council and Stantec was held on 28 May 2024 to clarify and provide additional scope for the revised Campsie Flood Risk Assessment based on recent updates to guidance.

Based on the above, a scope of works has been developed by Stantec in liaison with Council for the preparation of a revised Flood Risk Assessment for the Campsie Precinct (the Precinct) which is this study (the Study). It is noted that the previous final Flood Planning Assessment forms the initial basis for this revised assessment, with updates to modelling, analysis and reporting to reflect the comments referred to above from Council and DCCEEW. Another key update has been the adoption of flood model results from the combined mainstream and overland flow TUFLOW model for the Cooks River prepared by Stantec on behalf of Canterbury-Bankstown Council (Stantec, 2024). This updated flood data supersedes the data from the original Flood Assessment based on the Flood Study data for Cooks River Mainstream (2009) and Overland Flow (2016) Studies.

1.1 Study Objective and Scope

The overarching objective of this review was to determine the consistency of the flooding assessment for the proposed rezoning (the Campsie Precinct) with the latest available guidance.

The development of the proposed scope has been initially guided by the DCCEEW (formerly EHG) comments received as Appendix A of the Draft Gateway Conditions from September 2022. Subsequent to the 2022 comments provided by DCCEEW in Draft Gateway conditions, a number of changes have occurred in relation to latest available guidance:

- The 2023 Flood Risk Management (FRM) Manual, Guides and Toolkit have been released by the state government. This includes updated guidance on the preparation of a Flood Impact and Risk Assessment, and relating to Emergency Management planning for developments.
- The Draft Shelter-in-Place guideline has been released by NSW DPHI. While not formally adopted, this guideline provides useful information on the requirements for Shelter-in-Place and its adoption for development.
- Planning Circular PS 24-001 released in March 2024 provides further guidance on planning proposal assessments for flooding. As noted within Attachment A of Planning Circular PS 24-001, DPHI recommends planning authorities adopt a risk-based approach to the assessment of planning proposals, local and regional DAs, and SSD and SSI applications.
- Stantec developed a Cooks River TUFLOW model for Canterbury-Bankstown Council as noted above for nearby Master Plan projects, including the Campsie study area in the model extent.

In light of the pre-Gateway submission, NSW DCCEEW noted that a high level flood risk assessment is required, noting:

- Post-development modelling was not required at this stage of the planning proposal process
- Assessment of 1%, 1% AEP climate change (assumed to be for the previously assessed climate change conditions), and PMF events only was appropriate
- Model updates to improve accuracy of the Cooks River model developed by Stantec was not required.

Therefore the scope for this study does not consider the 2022 draft Gateway comments, rather adopting the advice from the meeting on 28 May 2024, where post-development modelling is not required at this stage of the planning proposal. Hence scope of this study includes:

- Update assessment of existing flood risk for the study area using the flood model results and development details
- High-level review compatibility of re-zoned sites in light of existing affectation against the requirements of the Ministerial Direction 4.1 (similar to previous assessment), EM guidance from the FRM Guides, and recent Planning Circular requirements
- High level assessment of flood emergency response potential for the study area

1.2 Study Area

Campsie is a cultural, retail and local employment hub in the CBCity's east that provides cross-regional links to metropolitan centres to the North, East, South and West. The Campsie Precinct study area is bounded by Cooks River along its north and east, properties fronting Canterbury Rd to the south, and Tudor St, Loch St, Bruce Ave, Omaha St, Varidel Ave and Clarence St from the west. The study area for Campsie Precinct is shown in **Figure 1-1**.

Campsie Precinct study area is located 12km from the Sydney Business District, situated at the junction of Inner and Western Sydney. Campsie's neighbouring suburbs are Croydon Park to the north, Ashbury and Canterbury to the east, Clemton Park to the south and Belmore and Belfield to the west. Campsie is centred around a retail and commercial strip running north-south along Beamish Street. The study area is centred around a retail and commercial strip running north-south along Beamish Street. Beamish Street, which is bisected by the T3 Bankstown train line, will be upgraded into a Metro line in 2025. While the train line enables public transport access, it limits North-South connectivity within the study area. The commercial strip contains fine-grain built form with one to two storey buildings together with recent four to six storey shop top housing developments.

Campsie is estimated to have a current population (from 2021 census data) of 26,132 people, with currently 22% of dwellings being detached houses and 78% being apartments / units.

Campsie Town Centre is located along a ridge line largely with north-south orientation, following Beamish Street. The crest line is pronounced between contour level 42m AHD, along Canterbury Road, near the Canterbury Hospital, following north along Beamish Street, and reaching contour level 15m AHD near Eight Avenue intersection with Beamish Street. From here, the topography drops evenly due north to the Cooks River. A second crest line is identified in the topography, running parallel to the main crest line with a north-south orientation. This crest line also originates in the hilltop near Canterbury Hospital extending north along Loch Street, Carrington Street, cut by the train line and extending to Eight Avenue.

Figure 1-1 Campsie Precinct - Study Area

2 Available Data

2.1 Campsie Town Centre Master Plan and Planning Proposal

As briefed in Introduction **Section 1**, the draft Campsie Town Centre Master Plan was initially exhibited publicly from March to June 2021, with an updated Master Plan prepared by September 2021 in response to public submissions. Following the Local Planning Panel's recommendations, Council has undertaken further engagement with the community in early 2022.

2.1.1 Framework

The proposed framework layout is shown in **Figure 2-1.** One of the key drivers for Campsie Town Centre will be growth over the next 20 years (to the year 2036), in population (additional 14,800 residents), housing (additional 6,360 homes), and employment (additional 2,700 jobs). This growth has been addressed through opportunities for additional height and density (Floor Space Ratio, or FSR), ensuring more people are living and working near sustainable transport, jobs and services.

A significant portion of the area is proposed for intensification, particularly in the following:

- The town centre around Beamish Street, extending to the west until Carrington Square;
- The southern area bounded by Claremont St to the north, properties fronting Canterbury Rd to the south and Thorncraft Parade to the west.
- Northern area bounded by Cooks River to the north, Clissold Pde to the south, and Beamish St west.

Generally, the height and density are proposed to be highest in these three main areas. As most of the town is developed already (brownfield), the intensification will most likely be vertical aside from some infill development opportunities.

2.1.2 Proposed Zoning

The existing land use zoning and the proposed land use zoning is shown in **Figure 2-3** and **Figure 2-4**, respectively. As can be seen in the figure, the centre is all mixed use (B4), with the surrounding areas predominantly high density residential, with the exception of the western area which will remain medium density residential and two low-density residential 'special character' areas. Canterbury Rd frontage is proposed to mostly remain a form of commercial land use with some high-density residential frontage added.

The majority of land use for the area has remained unchanged, however there are also significant land use changes proposed. The areas of change are dash-lined areas such as:

- The centre of the Precinct has been defined as B4 mixed use which will enable the co-location of residential and commercial development and support the viability of the commercial retail space and generate employment growth.

- Most of the northern area, referred to as 'Cooks River foreshore' has changed to high density residential from medium-density residential;
- The two special character areas; west of Carrington Square and between Redman St and Canterbury Rd, have been changed to low density residential, with changes to high density residential in adjacent areas.

2.1.3 Character Areas

The Precinct has also been divided into 12 character areas to represent the predominant proposed future development types that are shown in **Figure 2-4**. Some of the key spatial move goals include:

- Define and celebrate unique character areas such as the Beamish St high street (Area 01 in **Figure 2-4**);
- Celebrate and connect to the river through foreshore restoration and development in the area (Area 07);
- More people living and working near the station which is to be replaced by the Campsie Metro Station (Area 01-04, and 08); and,
- Create a health precinct anchored by two hospitals. Leverage the area around Canterbury Hospital (Area 5) to attract and establish health and lifestyle related uses and activities that become unique to Campsie, including investment in allied and private health.

2.1.4 Proposed Changes in Density and Building

The growth of Campsie Town Centre has been addressed in the Campsie Precinct Rezoning Proposal through opportunities for additional height (Height of Building or HOB) and density (Floor Space Ratio, or FSR), ensuring more people are living and working near sustainable transport, jobs and services.

Generally the height and density are proposed to be highest in the heart of the city centre and decrease further away from this central location. As most of the city is developed already (brownfield), the intensification will most likely be vertical aside from some infill development opportunities.

The proposed FSR and HOB for the proposed Campsie Precinct are shown in **Figure 2-5** and **Figure 2-6** respectively. In **Figure 2-5**, red and dark pink colours show the highest level of proposed FSR, while cyan and light yellow colours show the lowest level FSR. In **Figure 2-6**, pale violet and violet colours show the highest level of proposed HOB, while tea green and cyan colours show the lowest level of proposed HOB.

It is noted that intensification is not proposed for large parts of the study area with the north-west and east portions of the study area including no intensification.

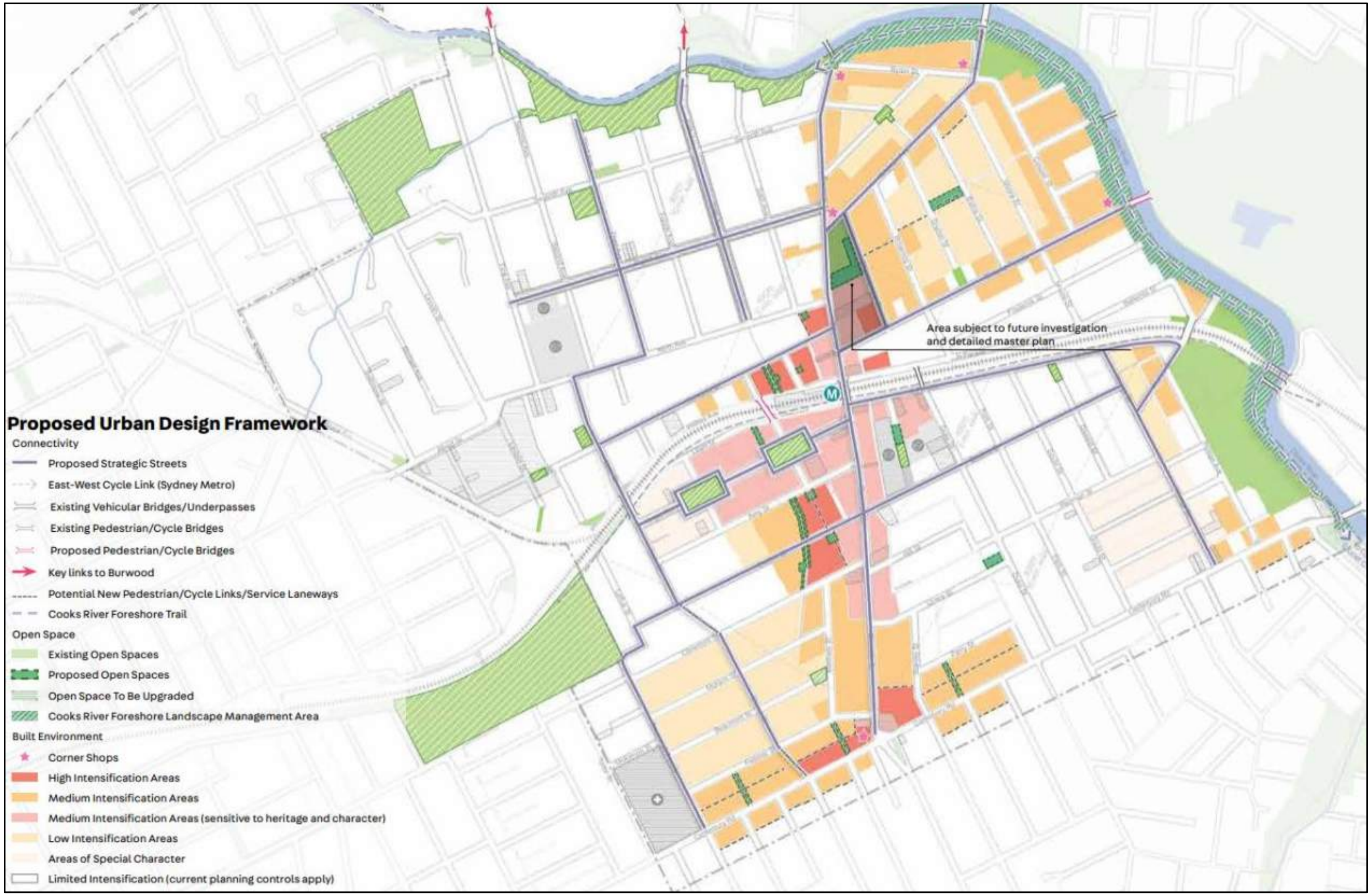


Figure 2-1 Campsie Precinct – Framework Map Showing the Proposed Future Town Layout

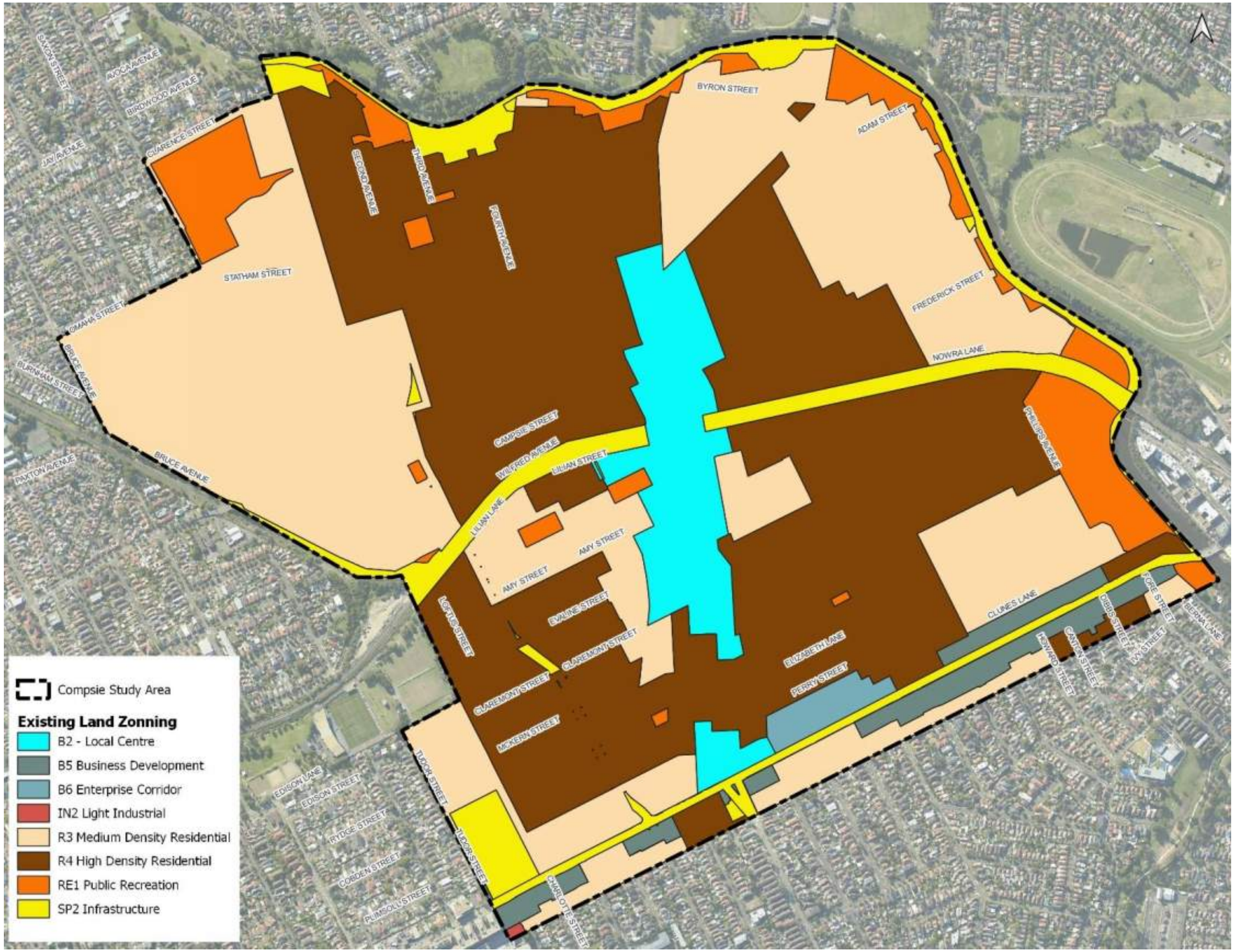


Figure 2-2 Campsie Precinct – Existing Land Use

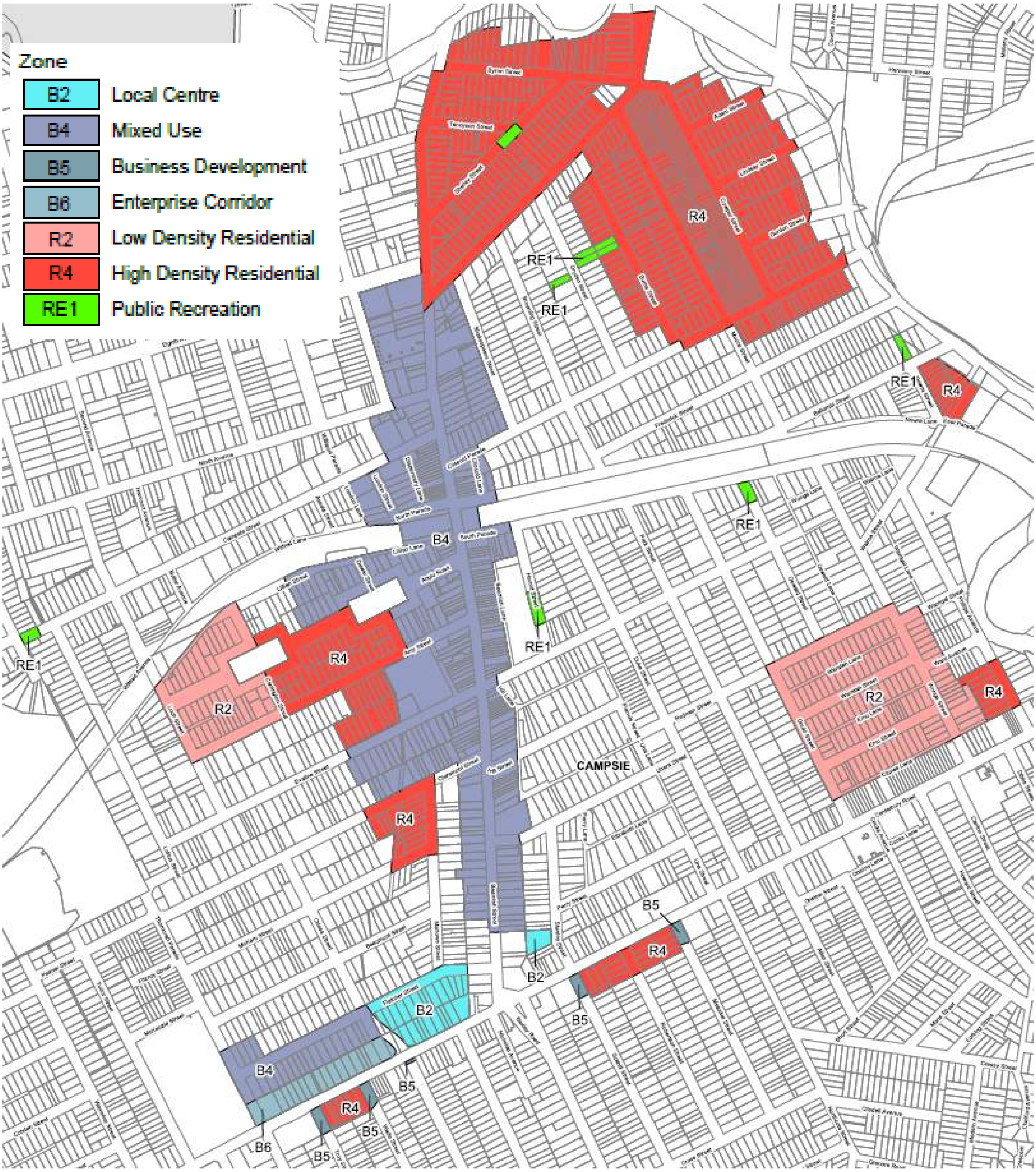


Figure 2-3 Campsie Precinct – Proposed Land Use

Figure 2-4 Campsie Precinct – Proposed Character Areas

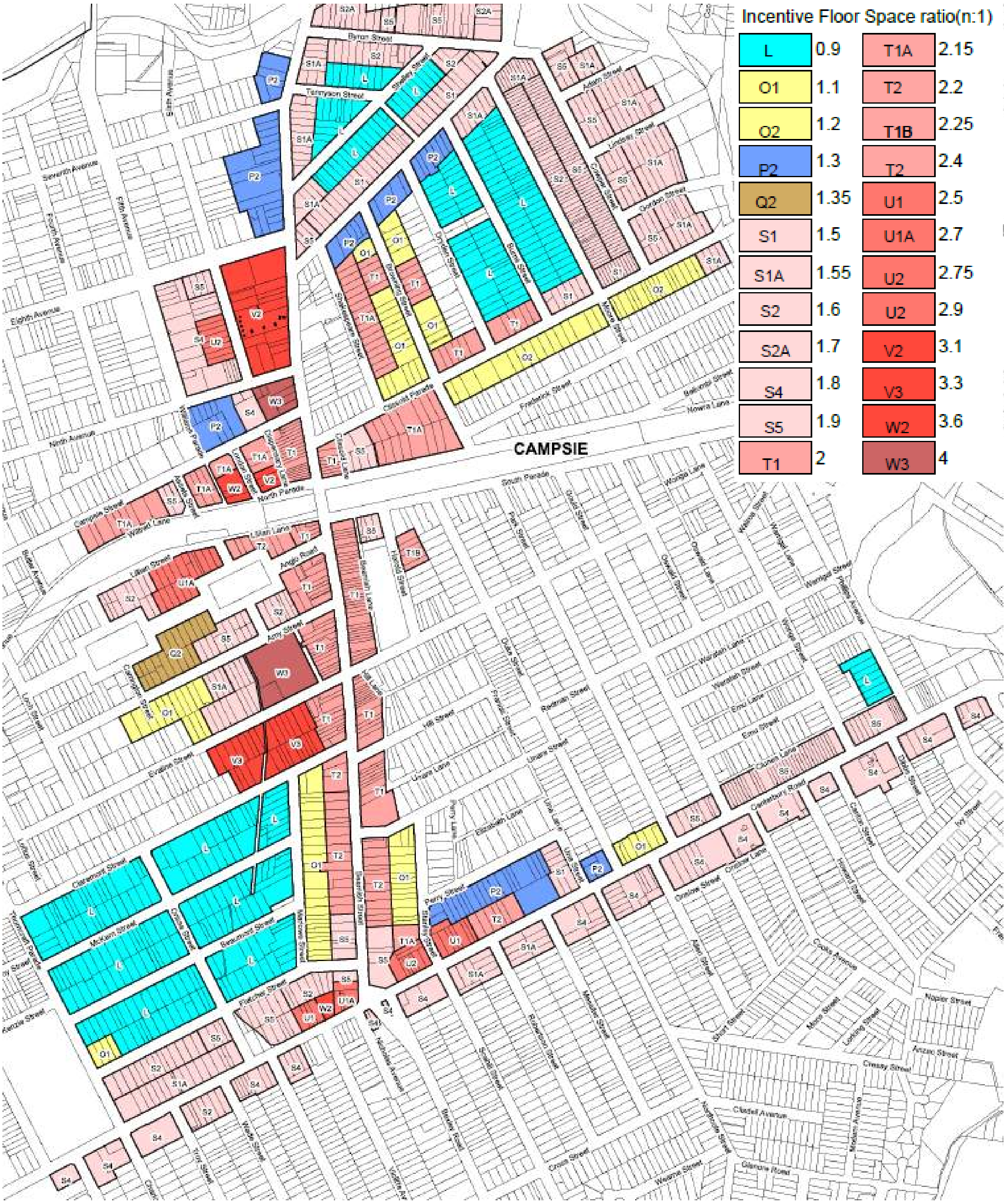


Figure 2-5 Campsie Precinct Rezoning – Proposed FSR

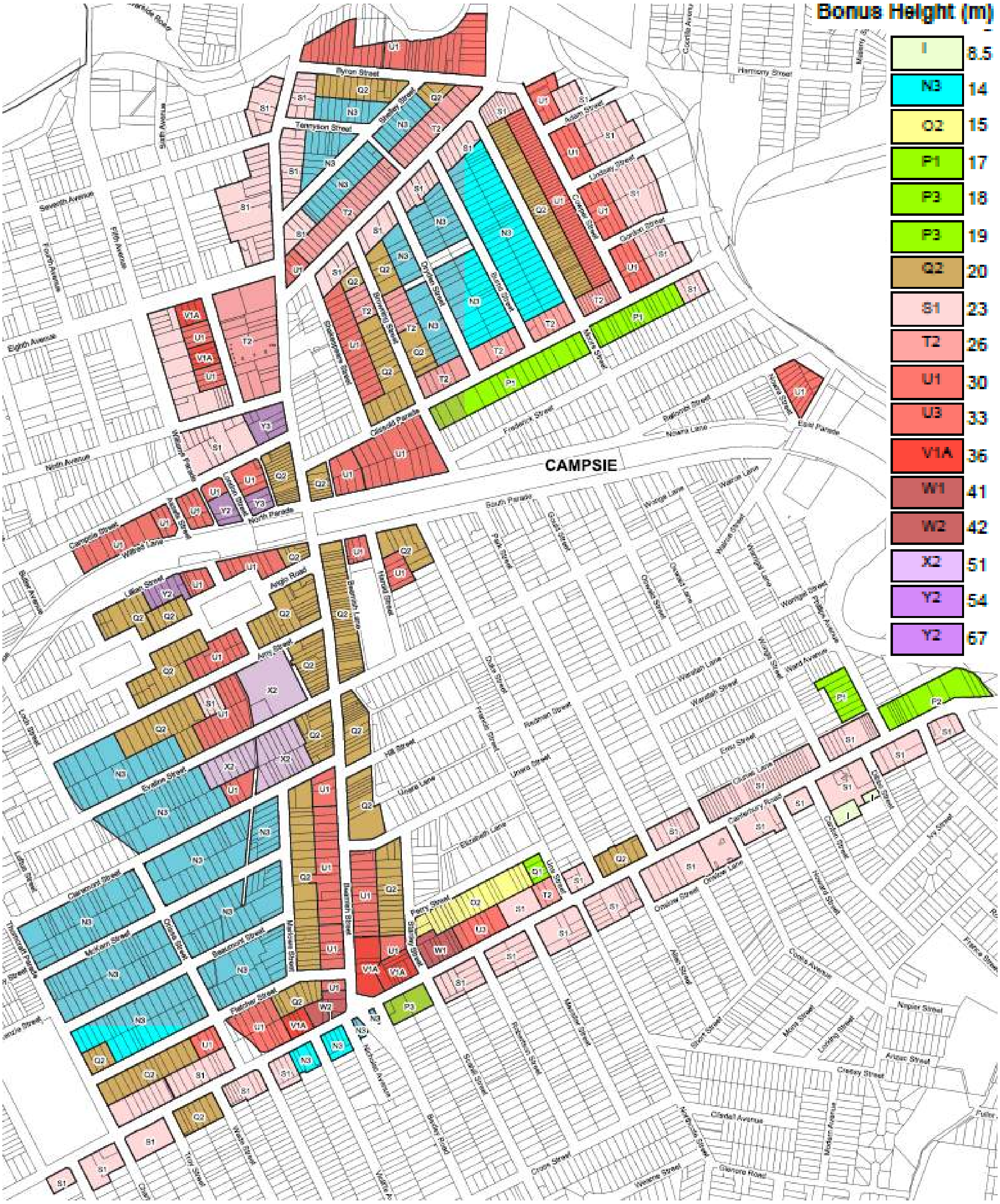


Figure 2-6 Campsie Precinct Rezoning – Proposed HOB

2.2 Previous Flood Studies

The following regional flood studies have been prepared for the Campsie study area:

- Cooks River Flood Study (MWH+PB, 2009)
- Cooks River Final Overland Flow Study (Cardno, 2016)

A brief summary of these studies is included in the following sub-sections.

2.2.1 2009 Cooks River Flood Study

The study prepared by MWH+PB on behalf of Sydney Water investigates flood behaviour throughout the Cooks River catchment. The report and modelling was completed in 2009. The Cooks River Catchment discharges to Botany Bay at Tempe, adjacent to and immediately south of Sydney Airport. The catchment area is approximately 102 km^2 and covers portions of 13 local government areas. The catchment has been extensively developed, with many reaches severely altered by developments, and the channel constrained or diverted from its original alignment. Much of the main channel of the Cooks River is concrete lined, as is Alexandra Canal and many of the Cooks River's tributaries. Wolli Creek and Bardwell Creek are largely natural waterways.

The study provides information on flood conditions throughout the catchment for a range of design floods, including the 2 year, 20 year, and 100 year Average Recurrence Intervals (ARI's) and the PMF.

This study included the analysis of surface runoff across the catchment, flooding within the underground stormwater drainage network, and flood behaviour through the drains and other watercourses towards the lower end of the catchment. A 1D/2D hydraulic TUFLOW hydraulic model was established with a 7m grid cell size based on available LIDAR data. Variable hydraulic roughness was applied with buildings not digitised in the 2D but a composite roughness was adopted for residential and commercial uses. The downstream boundary water levels were derived from tidal and flood conditions within Botany Bay.

With regards to the 1D drainage network, aside from culverts and bridges, the open channels were modelled in the 1D using cross sections spaced roughly every 100 metres.

Information on the extent of flood inundation, and peak water levels was provided for the 2 year, 20 year, 100 year ARI and PMF event. Peak depth of flooding, and velocity of floodwater was provided for the 100 year ARI event only. As it defines existing flood conditions, this study is the equivalent of a Flood Study in accordance with the Flood Risk Management Process.

The hydrologic model was developed using the Watershed Bounded Network Model (WBNM) software program and was used to estimate flood flows within the Cooks River and its tributaries. Design rainfall was assessed using AR&R87 design rainfall depths and patterns, with 2 hour duration assumed critical for all design events. Initial and continuing losses were variable based on pervious (10mm and 2.5mm/hr) and impervious (1.5mm and 0mm/hr) surfaces.

2.2.2 2016 Cooks River Final Overland Flow Study

The study prepared by Stantec (formerly Cardno) on behalf of Canterbury-Bankstown Council (formerly Canterbury Council) investigates overland flow flooding behaviour throughout the Cooks River catchment in the former Canterbury LGA. The report and modelling were completed in 2016.

The study provides information on flood conditions throughout the catchment for a range of design floods, including the 2 year, 5 year, 10 year, 20 year, 50 year and 100 year ARI's and the PMF. Flood behaviour was modelled in a 1D/2D SOBEK hydraulic model for the all design flood events. Model runs were carried out for the rainfall event durations of 15 minutes, 20 minutes, 25 minutes, 30 minutes, 45 minutes, 60 minutes, 90 minutes, 2 hours, 3 hours, 4.5 hours and 6 hours for all AEP events. The PMF event was run for storm durations between 15 minutes and 2 hours.

The model was calibrated to the flood event which occurred on the 14th of October 2014. Hydrology for the model was applied as direct rainfall or rainfall-on-grid in the SOBEK model. Design rainfall was assessed using AR&R87 design rainfall depths and patterns. Initial and continuing losses were variable based on pervious (10mm and 2.5mm/hr) and impervious (1mm and 0mm/hr) surfaces.

Peak water level, depth, and velocity in the study area are determined based on the peak value for each grid cell from all durations modelled in a particular event. As the direct rainfall approach is used, every 2D cell is inundated with some flood depth. A 0.15m depth filter is applied to highlight primary flow paths excluding locations of minor localised runoff depths. As it defines existing flood conditions, this study is the equivalent of a Flood Study in accordance with the Flood Risk Management Process.

2.3 GIS Information

To assist this assessment, Canterbury-Bankstown Council provided GIS information including an updated cadastral layer, existing and proposed land use zoning layers, and combined flood extent mapping for the 1% AEP, 1% AEP + Climate Changes, and PMF events for the entire Local Government Area (LGA). Also Council provided further GIS information including:

- Land Reservation Acquisition (LRA) proposed for the Precinct;
- Base Height of Building (HOB) which is the proposed HOB base for the Precinct;
- Incentive HOB which is an incentive HOB proposed for the Precinct;
- Base Floor Space Ratio (FSR) which is the proposed FSR base for the Precinct; and
- Incentive FSR which is an incentive FSR proposed for the Precinct.

2.3.1 Current Land Use Zoning

Canterbury-Bankstown Council provided Stantec with the current land use zoning layers in GIS to assist with the flood planning review.

2.3.2 LiDAR Topography

The ELVIS - Elevation and Depth - Foundation Spatial Data website was accessed with two datasets available from the website. This data was originally accessed by Stantec for the 2024 Cooks River modelling project. The files appear to have been recorded on the following dates:

- April 2013; and,
- May 2020.

Both files appear to be 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.

Review of the two LiDAR datasets showed that the May 2020 LiDAR data provided the most comprehensive and latest available dataset that covered the entire study area. Therefore, this data set was adopted.

2.3.3 Building Footprints

Canterbury-Bankstown Council provided Stantec access to a geoscape building footprint layer recorded in September 2020. The building footprint database has been prepared on behalf of the NSW Department of Planning and Infrastructure (DPHI). This layer covered the entire Cooks River catchment. The level of detail in the DPHI layer was assessed to be of good quality, relating to recent enhanced sampling techniques. This data was originally accessed by Stantec for the 2024 Cooks River modelling project.

The building footprint layer was provided to Stantec to be adopted in the hydraulic modelling of the area so that the hydraulic obstructions that buildings present in an urban catchment can be accounted for accurately within the model. To represent the high blockage that is caused by buildings, a roughness value of 0.5 was applied to all building footprints.

2.3.4 Pit and Pipe Database

Stormwater pit and pipe data for the catchment provided by Council on 21 June 2022 was used for this assessment. This data was originally accessed by Stantec for the 2024 Cooks River modelling project. From discussions with Canterbury-Bankstown Council representatives it is understood that the pit and pipe data has been recently surveyed as part of an update in Council's information therefore the data is up to date. It is also understood that Council's surveyors were unable to access the rail line corridors therefore details in the database for culverts and pipes within the rail corridor are understood to be unreliable.

- The details provided within the pit and pipe database included:
- For stormwater pits the details included: pit dimensions, if the pit was an inlet type in terms of kerb, inlet or manhole, and on-grade or sag pit, and invert and depth of the pit.
- For pipes / culverts details included dimensions (diameter for pipes and width and height for culverts), and inverts.

3 Flood Modelling

Within the scope for this project was an update of design flood model results for the study area. Stantec reviewed all available data including the models from the two previous Flood Studies. A brief overview of these models is included in **Section 2.2**. While the flood modelling conducted in these two previous studies was in accordance with best practice at the time, there have been developments and improvements in hydrology and hydraulic modelling since these studies were completed. Furthermore, as the study area is affected by both Cooks River mainstream and overland flooding, a consolidated flood model that considered both flooding types was considered necessary.

The adopted methodology for the updated flood model is outlined in **Section 3.1** to **Section 3.6**.

This new TUFLOW model of Cooks River was prepared as part of the *Flood Planning Assessment for Belmore, Lakemba and Canterbury Local Centre Master Plans and Belfield Small Village Centre Master Plan* (Stantec, 2024) and encompasses the Campsie study area as shown in **Figure 3-1**. The model results from this updated hydraulic model have been adopted in this revised assessment for Campsie (where the previous 2022 Campsie flood assessment adopted the previous 2009 and 2016 study results). No updates have been made to date to the TUFLOW model as part of the Campsie project, the model was found suitably detailed for the purposes of this assessment for Campsie. The model set-up summary below has been adapted for the Campsie study area from the summary previously provided in the *Flood Planning Assessment for Belmore, Lakemba and Canterbury Local Centre Master Plans and Belfield Small Village Centre Master Plan* (Stantec, 2024).

The updated flood model has been validated compared to the two previous flood studies as summarised in **Section 3.6**. The updated flood model utilises more contemporary modelling techniques in keeping with current industry best practice. However, the two previous flood studies are relevant as they are still the adopted flood study models for the area, and as they both went through a more rigorous validation and calibration process than was possible for the updated flood model scope. Therefore, a detailed model validation has been conducted to ensure that the updated flood models are suitable in reference to the calibrated and currently adopted flood study models for the catchment.

In addition, in the model methodology section (**Section 3.1**) frequent reference is made to the model set-up relative to these previous flood study models. In these following sections, references to these studies are either '2009 Mainstream Study' referring to the *Cooks River Mainstream Flood Study* (MWH+PB, 2009), or '2016 OLF Study' refers to the *Cooks River Final Overland Flow Study* (Stantec, 2016).

Finally, a summary of the updated design flood model results has been provided in **Section 3.7**.

3.1 Model Methodology

3.1.1 Adopted Model Platform

A TUFLOW 1D/2D hydrology and hydraulic model was established for the catchment as part of the updated flood modelling. TUFLOW is the current industry standard modelling platform within NSW. It is the same platform adopted within the 2009 Mainstream Study, while the 2016 OLF Study adopted a similar 1D/2D model platform in SOBEK.

The hydrology was applied as rainfall-on-grid meaning the flow routing was conducted within the 2D domain of the TUFLOW model. This is a commonly adopted approach for local overland flooding catchments as occurs in this area. For context, the 2016 OLF Study also adopted rainfall-on-grid approach to hydrology, while the 2009 Mainstream Study adopted a conventional hydrology model which then fed into the TUFLOW model.

The updated flood model utilised the Heavily Parallelised Computing (HPC) approach within TUFLOW (also referred to as TUFLOW GPU). This TUFLOW approach uses different computer hardware to TUFLOW classic (also called TUFLOW CPU) which was adopted within the 2009 Mainstream Study model.

The main advantage of TUFLOW HPC is that it provides significantly quicker model run times. HPC provides the ability to run models on Graphics Cards, to achieve significantly shorter model run times, increasing our modelling capabilities to be able to run hydraulic models with higher cell resolution, and across larger extents. Whereas TUFLOW Classic is limited to running a simulation on a single CPU core, HPC provides parallelisation of the TUFLOW model allowing modellers to run a single TUFLOW model across multiple CPU cores or GPU graphics cards (which utilise thousands of smaller CUDA cores).

Given the large catchment area of the Cooks River, and the need for high resolution grid cells as discussed in the sub-sections below, the adoption of TUFLOW HPC was seen as appropriate for this updated flood model. As a result of the changes in processing, the adoption of TUFLOW HPC in the updated flood model results will be a cause for changes in model results when compared to the 2009 Mainstream Study model which utilised TUFLOW classic.

3.1.2 TUFLOW Engine Version

There are relatively frequent updates to the TUFLOW engine versions that help progressively improve modelling in line with improved practices and processing capabilities. The adopted model engine for the updated flood model is one of the most up-to-date versions, 2020-10-AD. There have been a lot of changes in the TUFLOW engines compared to the superseded version from the 2009 Mainstream Study, 2007-07-BF. These version changes mean that it is not possible to replicate previous TUFLOW engine results, and some model result impacts are attributable to the change in model engine. However, given that the latest TUFLOW engines are in theory improvements on earlier versions, it is appropriate to adopt a more recent version.

3.1.3 Model Details

The total two-dimensional (2D) model area for the updated flood model is 2,727.2 ha (27.27 sq. km), with the model boundary layout shown in **Figure 3-1**. The model area has been delineated as follows:

- On the upstream side of Cooks River, the model has been started from near Gregory Street and Cleveland Street in the suburb of Strathfield South.
- On the downstream side of the Cooks River the model has been extended to near the pedestrian bridge for Foord Ave in Hurlstone Park and Waterside Crescent in Earlwood.

- The entire Cooks River catchment between this upstream and downstream end of the model have been included in the model area. This includes the Coxs Creek catchment, and the entire Cup and Saucer Creek catchment which are both major tributaries of the Cooks River. In addition, the catchments of several smaller overland flowpaths have been included in the model area including a flowpath on the north bank of the river in Croydon Park.

The study area is located in the central part of the model area. The model area has been extended far beyond the study areas to include the full catchment flowing to this length of the river.

A grid size of 2m x 2m was adopted for the updated flood model, with a grid cell count of approximately 6.8 million cells. For a TUFLOW classic model this grid cell count would not be functional, however with the adopted TUFLOW HPC the model run times were roughly a day. Therefore this grid cell size provided a balance between achieving an adequate degree of accuracy in the representation of topographic features and providing acceptable run times. Furthermore, this grid size allowed for roadways to be represented by at least two cells.

A time step of 1 second was applied to the 2D component of the model and a time step of 0.5 second for the 1D component. This is within the recommended ranges for 2D for 1D outlined in TUFLOW guidelines.

3.1.4 Topography

The majority of the model 2D grid was based on LiDAR sourced from the ELVIS portal and recorded in May 2020 as discussed further in **Section 2.3.2**. The topography of the TUFLOW model is shown in **Figure 3-2**.

LiDAR data does not detect surface levels at locations that have standing water at the time of survey. Further, where the vegetation is dense or there are building footprints, the LiDAR can only provide a low density of reliable surface survey points. With regards to waterbodies, the key waterbody in the study area is Cooks River itself which has permanent water. Review of the LiDAR data showed that this had caused issues with the surveyed LiDAR levels of the river. Therefore with no bathymetry or hydrographic survey made available for the river, the surface of the river within its banks was simulated as follows:

- Review of the TUFLOW model found that the 2009 Mainstream Study model did have river bathymetry data built into the model. In discussions with Council, it was confirmed this was the best available river bottom information.
- As a result, the 2D outputs of the 2009 Mainstream Study model were trimmed for within the riverbanks along the length of the model area, and this trimmed surface was adopted to represent the river bathymetry in the updated flood model. The extent of this bathymetry data is shown in **Figure 3-2** .

Further review of the LiDAR data showed some deep holes within the surface, some of which were attributable to basement carpark entries, and others to constructions sites with excavation pits. For the basement carpark sites these were assumed to be representative of site conditions therefore the low points in the surface were retained. For construction sites, it was assumed the excavation pits were a temporary condition at the time of survey therefore the holes in the surface for these sites were filled within the model surface.

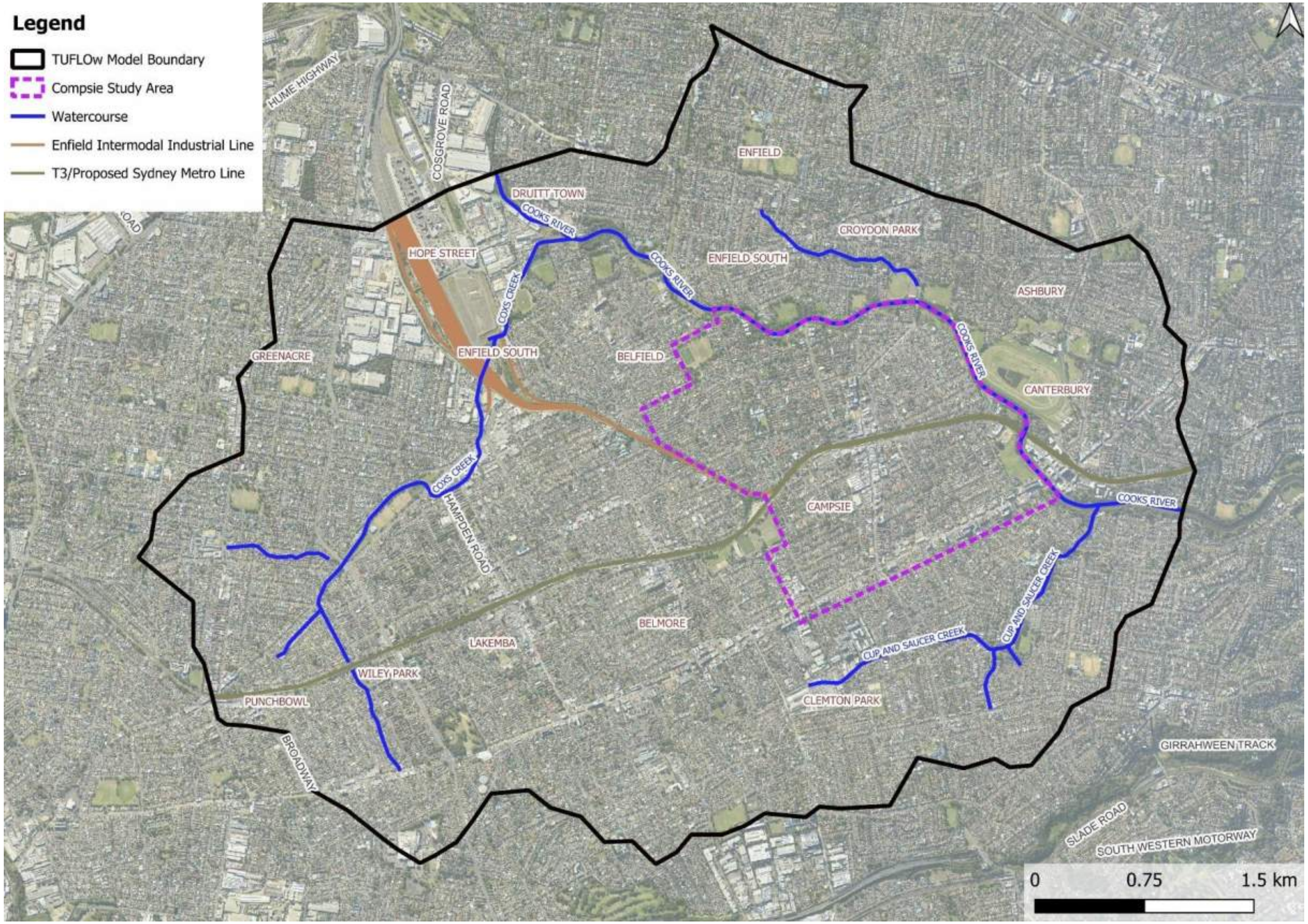


Figure 3-1 TUFLOW Hydraulic Model Boundary

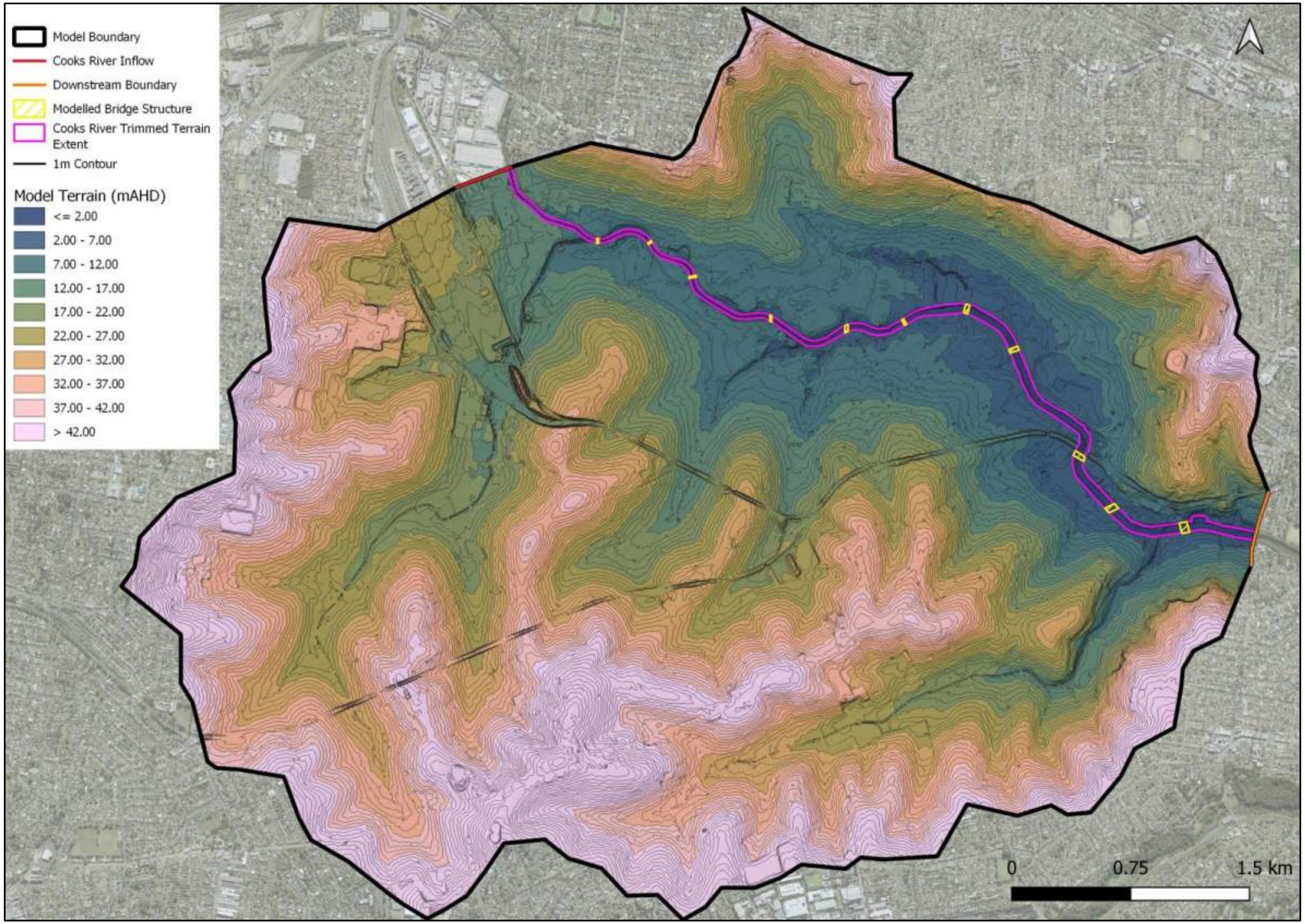


Figure 3-2 Model Topography, River Trimmed Bathymetry Extent, Upstream and Downstream Model Boundaries and Modelled Bridge Structure Locations

3.2 Hydrology Component

3.2.1 Design Flood Event

Three design flood events were identified as relevant to this flood planning review:

- 1% AEP event (1 in 100 year);
- Probable Maximum Flood (PMF); and,
- 1% AEP accounting for the effects of climate change. Upon review of the 2009 Mainstream Study and available data, the following conditions were adopted to simulate climate change:
  - 20% rainfall increase on current climate rainfall (climate change increases intensity of storms); and,
  - 0.55 metre Sea Level Rise (projected ocean conditions in the future as the result of climate change).

3.2.2 Design Rainfall – 1% AEP Event

Design rainfall based on the methodologies described in ARR87, were applied to the catchment centroid for a range of storm durations. The design temporal patterns were adopted from the Intensity Frequency Duration (IFD) curve, which has been extracted from ARR87. The IFD data was obtained from Bureau of Meteorology (BoM) based on the centroid of the model area (-33.9128, 151.0901). The standard ARR87 temporal patterns were applied with hyetographs applied in 5 minutes increments over the storm duration. In this case ARR87 design rainfall was adopted instead of the more recent ARR2019 design rainfall based on advice from Council representatives as Council has typically been retaining ARR87.

A summary of the adopted design rainfall average intensities (in mm/hour) for the updated flood model are included in **Table 3-1**. A comparison has been made to the design rainfall intensities of the two previous flood studies. The 2009 Mainstream Study had slightly higher design rainfall values and the 2016 OLF Study had more similar but slightly higher rainfall as well. The differences in design rainfall are attributable to slight changes in catchment centroid locations in the IFD calculation. Areal Reduction Factors (ARFs) were not considered, similar to the previous flood studies. For the 1% AEP 2 hour, the current study adopted a total rainfall of 115.2mm. In lieu of reporting of rainfall for this specific event, using the below 50 Year 1 hr values, the other study rainfalls for this event should be 1 - 7% higher than the current study for this critical event.

Table 3-1 Adopted ARR87 Design Rainfall Intensities for the Updated Flood Model Compared to Previous Flood Studies

ARI	Duration	Updated Flood Model	2016 OLF Study	2009 Mainstream Study
2 Year	1 hour	37.7	37.89	39.95
2 Year	12 hour	7.88	7.87	7.75
2 Year	72 hour	2.45	2.45	2.4
50 Year	1 hour	78.6	79.68	83.75
50 Year	12 hour	15.9	15.9	15.8
50 Year	72 hour	4.96	4.96	4.81

3.2.3 Design Rainfall – PMF Event

Probable Maximum Participation (PMP) is obtained based on Generalised Short Duration Method (GSDM). The distribution of the rainfall region is shown in **Figure 3-3** with the model area divided into PMP A, B and C ellipses. The majority of the study area is located within ellipse B. The PMF rainfall depths are in **Table 3-2**. Generally, the PMF rainfall depth of ellipsis A is consistent with those adopted in the 2016 OLF Study. However, the 2016 OLF did not apply ellipses meaning overall, PMF rainfall in that model is far greater.

It is noted that all PMF durations up to the 6-hour were simulated for the overland flow hydrology.

Table 3-2 Calculated PMF Rainfall for Ellipses A, B and C all units in mm

Event Duration (hours)	Updated Flood Model PMF Ellipses			2016 OLF Study
	A	B	C	
0.25	157.76	135.02	123.77	150.0
0.5	228.48	200.06	182.08	230.0
0.75	289.00	254.90	231.60	290.25
1	335.24	299.51	277.08	330.0
1.5	382.84	342.24	317.54	379.5
2	427.04	384.00	356.32	430.0
3	454.94	408.62	380.13	N/A
6	597.72	542.50	511.16	N/A

Figure 3-3 Adopted PMP Ellipses for the Updated Flood Model

3.2.4 Rainfall Losses

As the model is a rainfall-on-grid model, initial and continuing rainfall losses were applied to the hydrology component of the TUFLOW 2D model based on pervious and impervious surface types. The pervious and impervious rainfall losses applied to the model are presented in **Table 3-3**. These loss values are consistent with those adopted within the previous flood study models.

Table 3-3 Initial and Continuing Rainfall Losses Adopted in the Updated Flood Model

Surface Type	Initial Loss (mm)	Continuing Loss (mm/hr)
Pervious	10.0	1.5
Impervious	1.0	0.0

These losses were applied through surface material mapping for the TUFLOW 2D model. Eleven different surface materials were mapped in the model area, with a summary of the adopted impervious percentage for each included in **Table 3-4**. The layout of surface material mapping for the model is shown in **Figure 3-4**.

Table 3-4 Surface Types and Assumed Impervious Percentages, Rainfall Losses and Hydraulic Roughness Values

Surface Type	Impervious Percentage	Initial Loss (mm)	Cont. Loss (mm/hr)	Hydraulic Roughness
Residential	35%	6.85	1.625	0.05
Roads	70%	3.7	0.75	0.02
Maintained Grass	0%	10	2.5	0.03
Buildings	100%	1	0	0.5
Commercial	90%	1.9	0.25	0.1
Industrial	100%	1	0	0.03
Park	25%	7.75	1.875	0.03
Waterway	0%	0	0	0.015, 0.02, 0.03
Dense Vegetation	0%	10	2.5	0.06
Open Channel	100%	1	0	0.015
Railway	80%	2.8	0.5	0.02

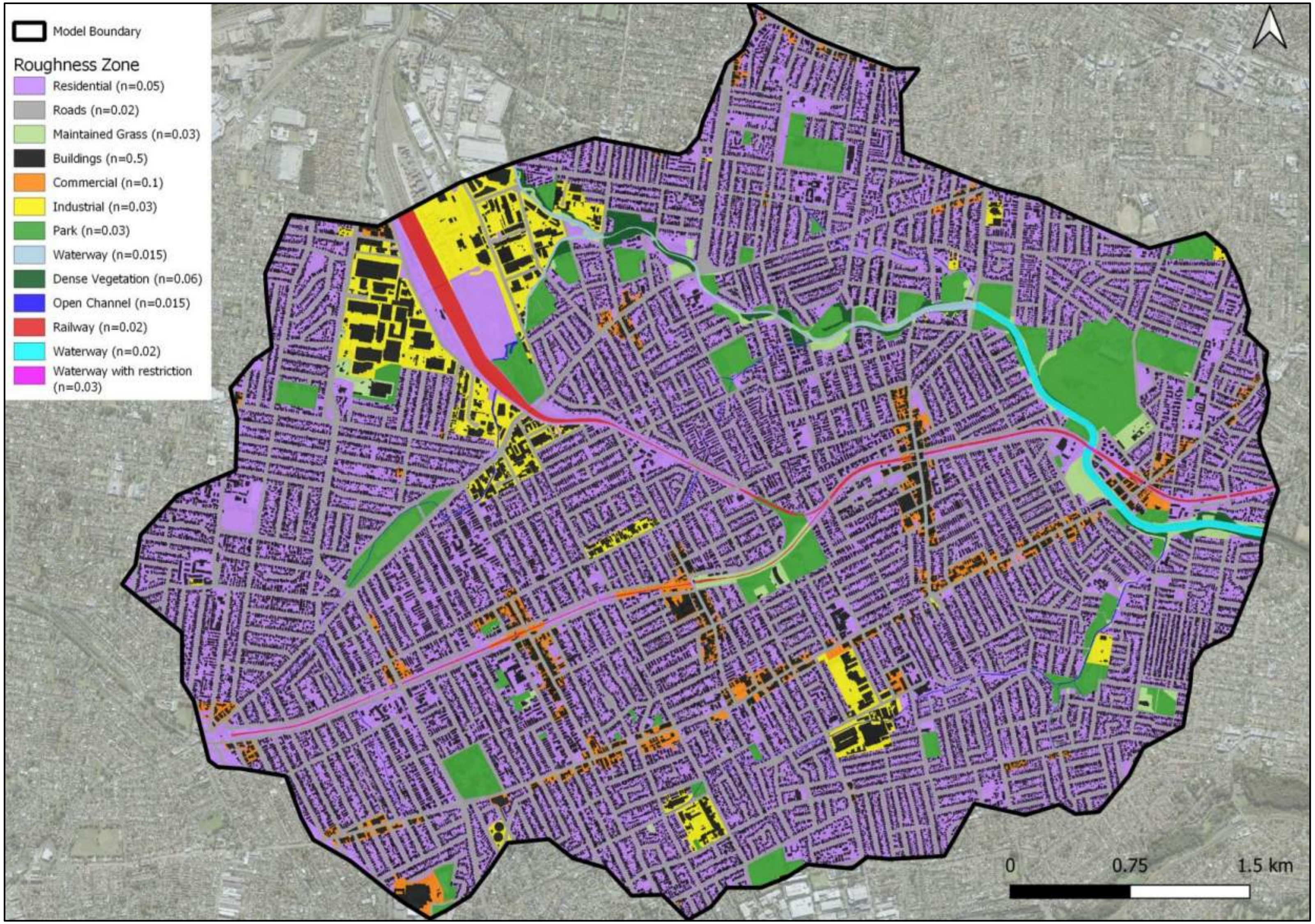


Figure 3-4 Updated Flood Model – Surface Material Types

3.3 2D Hydraulic Component

3.3.1 Hydraulic Roughness

Hydraulic roughness was simulated in the 2D domain of the TUFLOW model using variable Manning's n roughness based on surface types. Using the same surface type mapping from hydrology impervious percentage, roughness values for the surfaces are summarised in Table 3-4. Surface types were mapped using a combination of cadastre for land use types, aerial imagery and site observations. The layout of the surface types is shown in **Figure 3-4**.

For the Cooks River waterway, the roughness values of 0.015 – 0.02 were adopted in accordance with the set-up of the 2009 Mainstream Study model. The difference is that in the 2009 Mainstream Study model, the area of low roughness 0.015 was applied beyond the concrete lined channel, and also applied to the overbank areas which are often heavily vegetated. Given this heavy vegetation, the previously adopted roughness was too low for the observed conditions, as a result revised mapping was applied in the updated model for the Cooks River waterway.

Generally, roughness values have been reviewed and found to be consistent with the 2016 OLF Study model. However, there is one key distinction in surface type mapping, the 2016 OLF Study adopted a composite residential surface type that combined buildings and non-building areas in one layer, with a roughness of 0.3. As detailed building footprint information was available for this updated flood model (see **Section 2.3.3**), buildings were separated in the surface types mapping of the model. To represent the high blockage that is caused by buildings, a roughness value of 0.5 was applied to all building footprints, with the non-building portion of residential areas with a roughness value of 0.05.

3.3.2 Cooks River Bridge Structures

Along the Cooks River waterway, a total of 11 bridge structures were identified that required inclusion within the hydraulic model. Due to the large-scale size of the bridge structures, and as the river has now been modelled within the 2D domain, the bridge structures were also incorporated into the 2D domain. The adopted model approach for bridge structures involved applying a layered polygon that allows for depth varying flow obstructions to be applied to 2D flows. The bridges in the model area were modelled as follows:

- Bridges with multiple cells and piers were modelled with partial blockage to represent the flow obstructions these structures present. For clear span bridges where there is no potential obstruction in the waterway no blockage was applied to this lowest layer;
- The second layer set above the first, represents the bridge deck and was blocked 100%. The obvert and surface level of the bridges (applied as top and bottom layer elevations in the polygon) were determined through review of the bridge details modelled in the 2009 Mainstream Study.
- The third layer represents the bridge surface, with no blockage applied to this layer. While some bridges with railings may present some form of blockage in this layer, the effects were assumed to be negligible.

The bridge structure modelling approach is very different to that applied in the 2009 Mainstream Study model, as that was done in the 1D domain while this updated flood model uses the 2D domain. This change in model approach, combined with improvements in TUFLOW versions from 2007 to 2020 has caused differing model outcomes for the bridge structure modelling. As discussed further in

Section 3.6.2, the 2009 Mainstream Study model appears to apply very high and unrealistic form losses on the bridge structures. This results in pronounced stepped water level results in the previous model. Comparatively, the updated flood model results show a more gradual water level gradient along the river between bridges which is seen as more representative of likely bridge structure influence.

3.3.3 Boundary Condition – Cooks River Flows and Levels

The section of Cooks River from South Strathfield upstream to Hurlstone Park and Earlwood downstream has been included within the TUFLOW hydraulic model. Outside of this portion of Cooks River, the influences of the river floodplain have been accounted for in two boundaries (the location of both are shown in **Figure 3-2**):

- An upstream flow hydrograph boundary that is located in a narrow section of the floodplain near Gregory Street and Cleveland Street; and,
- A downstream water level time series boundary that is located downstream of the Cup and Saucer Creek confluence. The downstream boundary location was assessed to be sufficiently far downstream for boundary conditions to not be significant. A stage-time boundary was adopted to account for any tailwater affects that may be relevant for this section of the Cooks River floodplain.

The inputs to the updated flood model at these two locations was based on model result exports from the previous 2009 Mainstream Study TUFLOW model. Review of previous model results from this study showed that the 2 hour was the critical duration for each of the 3 design flood events; 1% AEP, PMF and 1% AEP climate change (20% rainfall increase and 0.55m SLR). The flow and level results were extracted from the equivalent design event from the previous Flood Study model.

The flow hydrograph and water level time series for Cooks River for input into the updated flood model are presented in **Figure 3-5** and **Figure 3-6** respectively.

One limitation of the modelling is that time series results are only available at the upstream and downstream model boundaries for the 2-hour durations for each event. This is because these were the only results available from the 2009 Mainstream Study model. For the PMF event, all durations up to the 6-hour duration were modelled for the local overland flow catchments in rainfall-on-grid, however for now these long duration events need to partnered with 2-hour event mainstream inputs. In the future this should be corrected with upstream and downstream boundaries to be updated to reflect relevant design events and durations, but for the purposes of this assessment this approach is considered suitable.

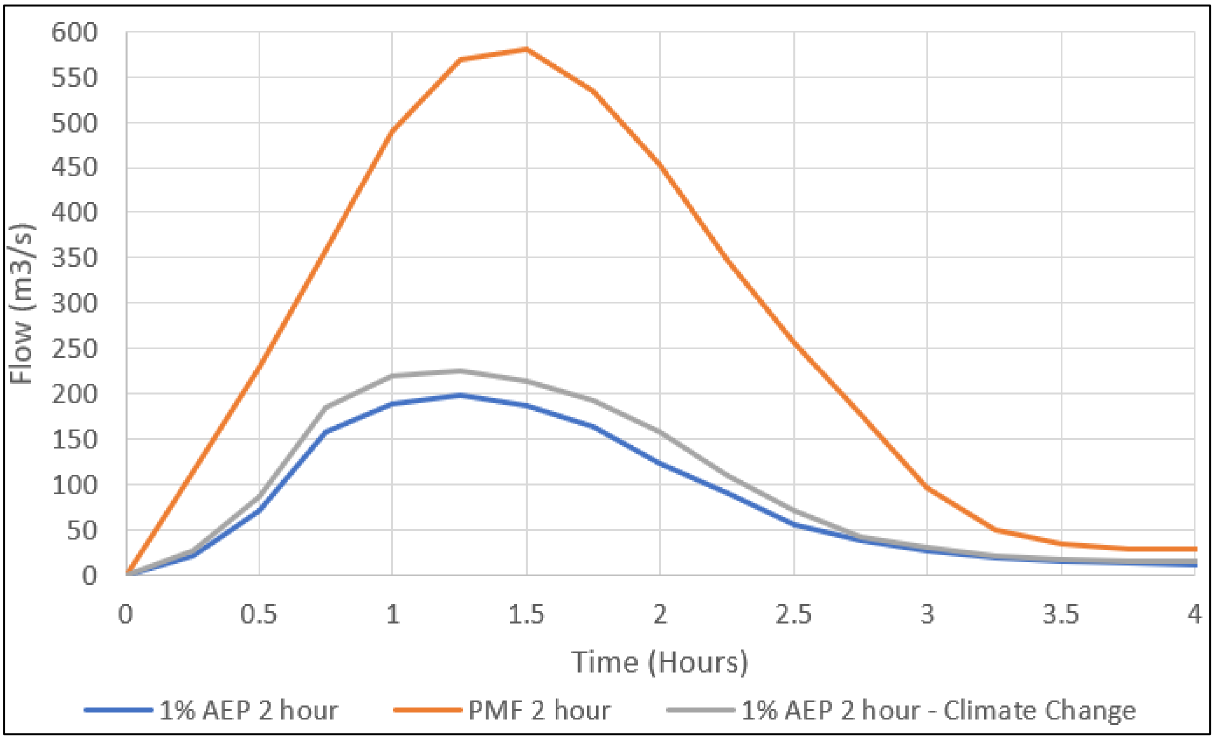


Figure 3-5 Updated Flood Model - Upstream Model Inflows at Cooks River from 2009 Mainstream Study Model

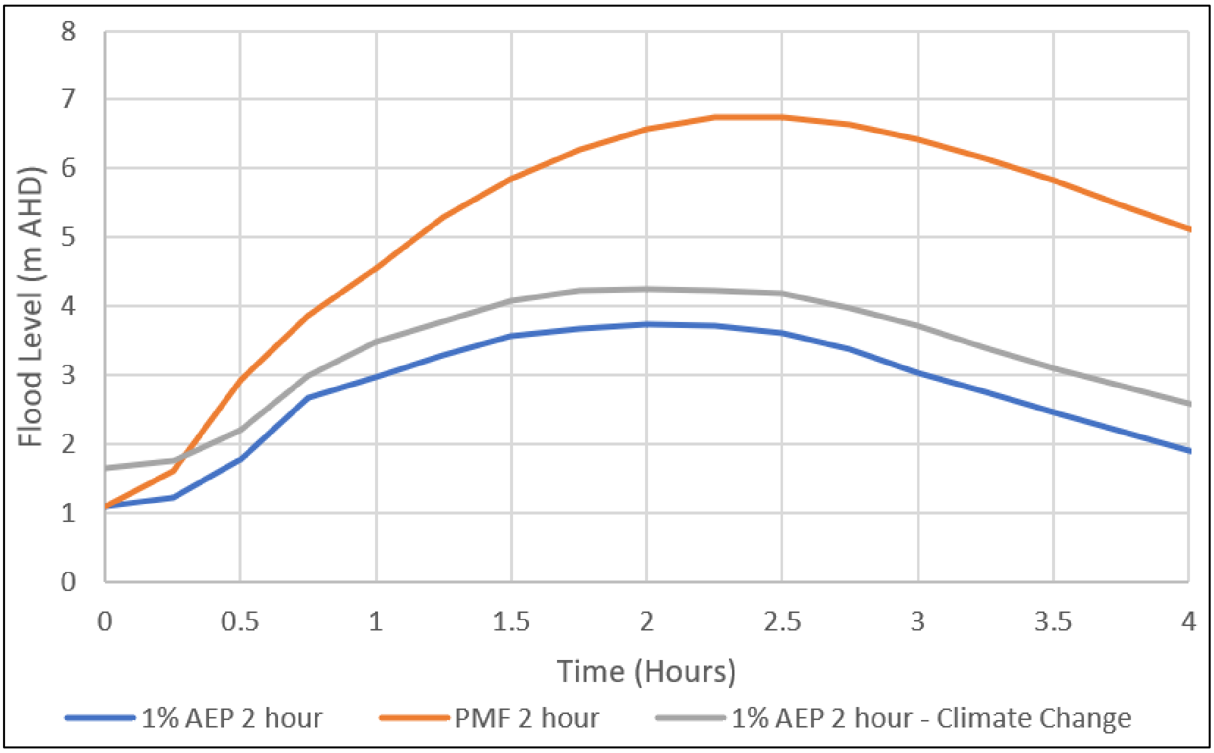


Figure 3-6 Updated Flood Model - Downstream Model Water Level Inputs at Cooks River from 2009 Mainstream Study Model

3.4 1D Hydraulic Component

Within the TUFLOW model, all surface flows have been modelled within the two-dimensional (2D) domain. The one-dimensional (1D) component of the TUFLOW model has been used to model culvert and pipe structures. Council provided GIS layers of the stormwater pit and pipe network as outlined in **Section 2.3.4**.

A detailed review of the provided pit and pipe database was conducted and it was found that the surveyed details generally matched observed conditions from Streetview and the previous OLF Study model. The exception was within the rail corridors, where the observed conditions and the 2016 OLF Study model details in the corridor did not match the database details. In discussion with Council staff, it was confirmed that Council's surveyors were likely not granted access to rail corridors to survey pipes and culverts. Therefore for these corridors it was assumed that the details modelled in the 2016 OLF Study model are the most appropriate representation of these structures, and these details were applied in the updated flood model. The modelling approach for all pipes / culverts was as follows:

- Pipe sizes were applied as per the Council database except for rail corridor pipes where the 2016 OLF Study modelled pipe details were adopted. The modelled pipe / culvert sizes are shown in **Figure 3-7**.
- Entrance and exit loss coefficients of 0.5 and 1.0, respectively, were added to all pipes / culverts.
- A height contraction coefficient of 0.6 and width contraction coefficient of 0.9 were also applied; and,
- A Manning's n value of 0.015 was used for all pipes and culverts.

Pit inlet capacity has been accounted for within the hydraulic model through sizing pits individually and assigning flow rating curves for each pit. The pit rating curves were obtained using the generic rating curve set provided by TUFLOW. These generic rating curves were agreed upon in discussions with Council staff. For stormwater inlet pits, a range of different pit details were available from Council's database including width, length, type (grated inlet, kerb inlet or manhole), kerb length, and configuration (sag or on-grade). The number of potential combinations for all of these different pit details meant that there were too many unique combinations to reasonably establish rating curves for each. Therefore the following standard pit details were adopted in the model, resulting in 37 unique pit types each of which has its own generic rating curve. The various pit sizes from the database were scaled to the nearest standard dimension:

- Three standard pit lengths and widths – 0.45m, 0.9m and 1.8m;
- Five lintel lengths – 1.2m, 1,8m, 2.4m, 3.0m, and 4.2m; and,
- Two entry pit configurations – Sag and on-grade.

Over 3,700 pits were included in the updated model. All pits named 'nodes' in the database with no surveyed details were assumed to be closed manholes and were not modelled as inlet pits in the updated flood model. As shown in **Figure 3-8,** testing of model results found that the sizing of pits, compared to adopting unlimited pit capacity had relative minor impacts on flood behaviour. The reason for the minimal impacts is that pipe capacity is not significantly greater than pit capacity, so with or without pit sizing the system capacity is still low. Within the model all stormwater structures are connected to the 2D grid via SX points or lines which allow flow to transfer between the 1D and 2D domains based on the hydraulic capacity of the pipe.

3.4.1 1D Blockage Factor

All pipes less than 375mm in diameter were assumed to be 100% blocked and were not included in the model. For pipes 375mm diameter and greater, no blockage factor was applied to stormwater pipes / culverts within the model. For the stormwater pit network blockage, factors of 50% for all sag pits and 20% for all on-grade pits in accordance with Council policies. As shown in **Figure 3-8**, testing found that the pit blockage factors had relatively minor impacts on flood results compared to unlimited pit modelling across most flowpaths, as pipe capacity is not significantly greater than pit capacity, so with or without blockage the capacity is low. However there are some specific locations of more significant impacts, near rail and road crossings and other constraint areas.

3.5 Critical Duration

For the 2009 Mainstream Study model, the 2-hour event was critical for both the 1% AEP and PMF events, while for the 2016 OLF Study the 2-hour event was also critical for the 1% AEP, and 15-minute for the PMF. In keeping with these previous studies, modelling showed that the 2-hour was also critical throughout the model area for the 1% AEP. For the PMF event, several events were critical with the 90 minute and 2 hour events adopted as critical durations for the majority of the study area as shown in mapping in **Figure 3-9**. The 30 minute critical areas in the upper catchment were represented by the 90 minute and 2 hour as the water level differences between the events were not significant in these upper lower risk areas.

While not critical events, the 3 hour and 6 hour PMF events were also modelled for the local overland flow catchment in order to assess the maximum duration of flooding at various road locations in the study area.

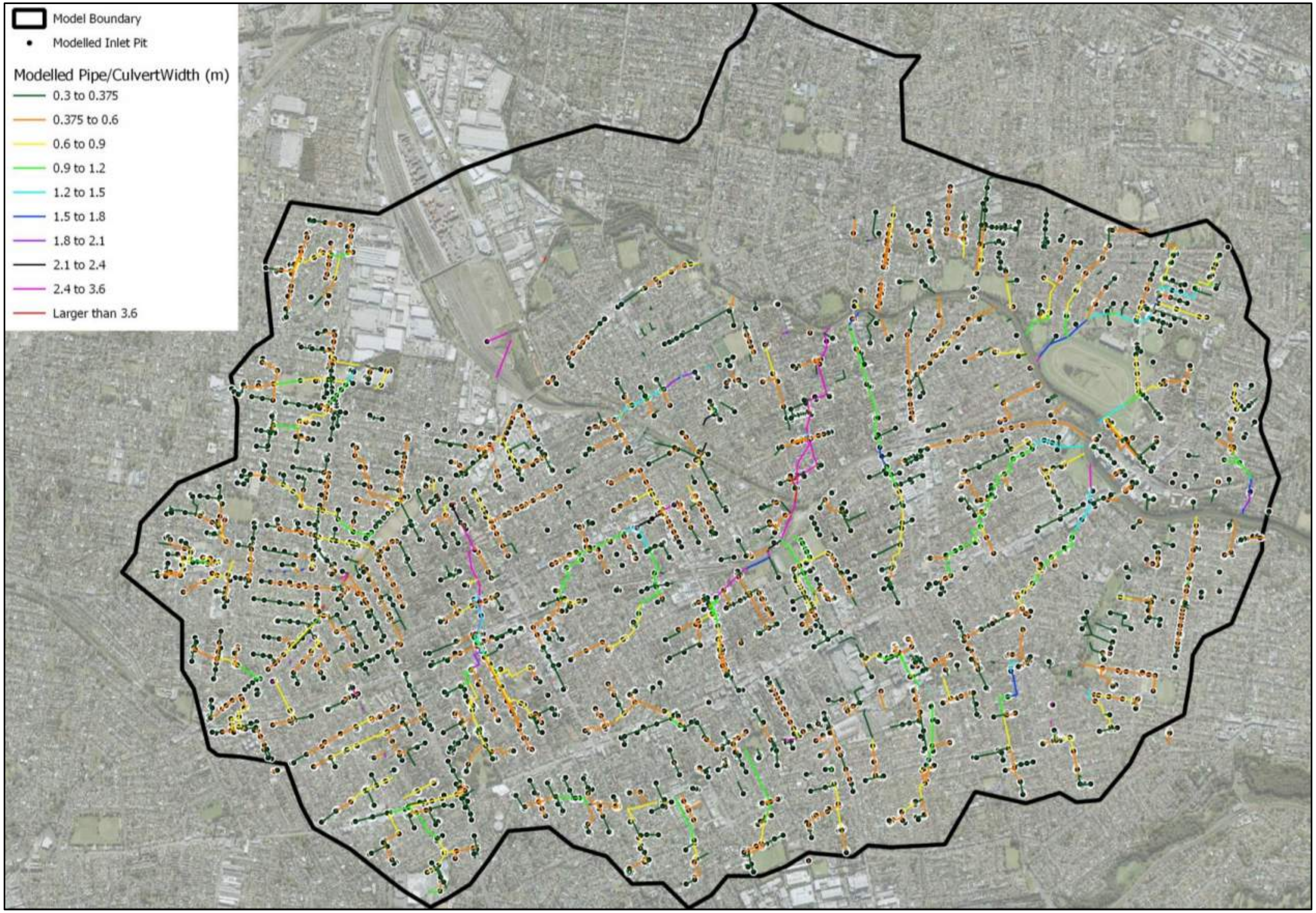


Figure 3-7 Updated Flood Model – 1D Modelled Pit and Pipe Data

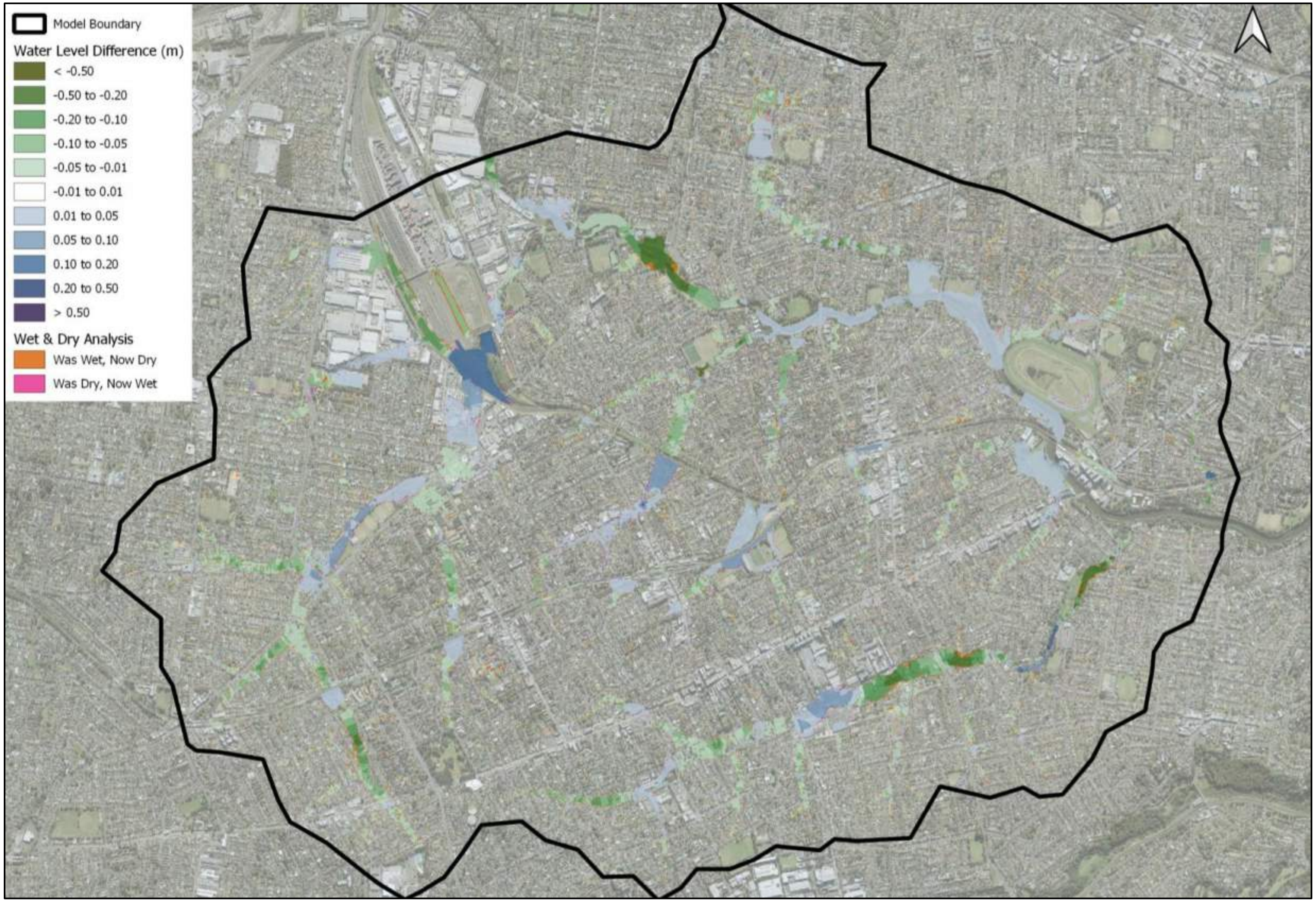


Figure 3-8 Updated Flood Modelling – Sensitivity Testing – 1% AEP 2 hour Water Level Differences (in metres) – Sized and Blocked Pits Less Unlimited Pit Model

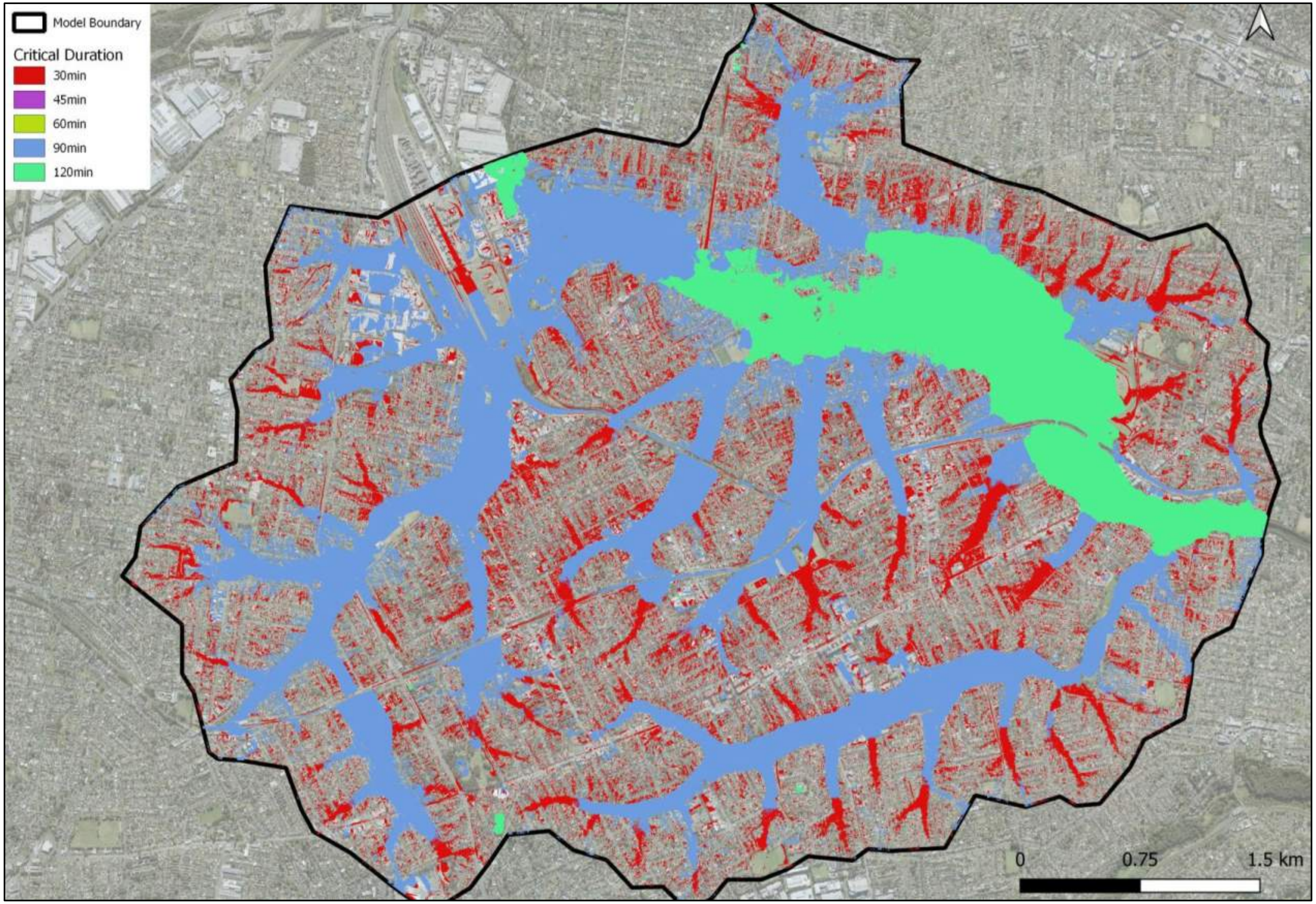


Figure 3-9 Updated Flood Model – PMF Critical Duration Mapping with 90 minute and 2 hour Adopted as Critical

3.6 Model Validation

3.6.1 Changes to Model Approach

As discussed in earlier sections, the updated flood model had a number of differentiations from the 2009 Mainstream Study model and 2016 OLF Study model. The main differences in model results are attributable to the following reasons:

- The TUFLOW version was updated (2020-10-AD from 2007-07-BF in 2009 Mainstream Study) and the model processor type was updated from TUFLOW HPC from TUFLOW classic. These model changes will in turn have impacts on model results, however as these are the more up to date model versions the updates are considered appropriate to be in accordance with latest available practice.
- Compared to the 2016 OLF Study the modelling software was changed from SOBEK to TUFLOW, which is the current industry standard modelling platform in NSW. The change in model software changes computation processes and will influence model results.
- The model terrain was updated from older LiDAR in the two previous models to LiDAR from May 2020, with resulting impacts on hydraulic model behaviour. The more recent LiDAR data was assumed to be more appropriate for adoption in the updated model. For the Cooks River the bathymetry from the 2009 Mainstream Study was retained therefore changes in topography should be minor within the riverbanks.
- Regarding model approach for Cooks River floodplain, the 2009 Mainstream Study adopted a 1D approach to the river and the bridge structures, where the updated flood model simulated both within the 2D domain. The model set-up, with respect to bathymetry and bridge details match those of the 2009 Mainstream Study, however the change in approach from 1D to 2D alters form loss calculations.
- Hydraulic roughness model changes included applying a very high roughness value to building footprints for overland areas, and for the Cooks River floodplain roughness areas were altered to account for banks with heavy vegetation areas more accurately than was done in the previous model.
- The pit and pipe data in the updated flood model is based on recent Council survey database which differs from the previously modelled 2016 OLF Study. The exception is the rail corridors where SOBEK pipe / culvert details from the 2016 OLF Study model have been retained in this model. However, the changes in structure details upstream and downstream of the rail corridors appears to have a significant impact on modelled ponding severity upstream of the rail corridors.
- For the PMF event, the current model adopts ellipses approach, essentially an Areal Reduction Factor (ARF) with reduced rainfall totals in the outer edges of the catchment (refer to **Section 3.2.3**). Conversely the 2016 OLF study adopted constant rainfalls across the study area so the rainfalls for the PMF are greater in the 2016 OLF than the current model, particularly away from the centroid of the catchment.

Generally, it is considered that the updated flood model provides a more detailed analysis that is more in keeping with present-day industry best practice for modelling. Therefore the above changes to the model methodology are considered appropriate, and the following model result comparison discussions should be reviewed in light of this conclusion.

A comparison of peak flow results to 2009 Mainstream Study results has been conducted at three locations: A, B and C, with the locations of these flow review lines shown in **Figure 3-11**. The summary of peak flow results for the two studies is included in **Table 3-5**. The results show that the peak flow results between the two models are in good agreement. For the 1% AEP 2 hour the results are within +/-7% at all three locations.

Table 3-5 Comparison of Peak Flow Results (in m^3/s) for Updated Flood Model and 2009 Mainstream Study

ID	Description	1% AEP 2hour			PMF 2 hour		
		2009 Mainstream	Updated Model	Difference (%)	2009 Mainstream	Updated Model	Difference (%)
A	Upper - 480m Upstream of Cox Creek Confluence	190.5	203.2	6.7%	572.3	637.0	11.3%
B	Mid - 337m Downstream of Brighton Ave Bridge	366.4	346.9	-5.3%	1168.2	1013.4	-13.3%
C	Lower - 125m Downstream of Canterbury Rd Bridge	383.1	370.1	-3.4%	985.2	1035.3	5.1%

A comparison of flow hydrograph results for the 1% AEP 2 hour event between the two studies is shown in **Figure 3-10**. The results show the updated model results are slightly more delayed than the 2009 Mainstream Study with peaks at all three locations being between 10-30 minutes later. The likely reason for this change is the additional lag time in rainfall-on-grid routing compared to traditional hydrology.

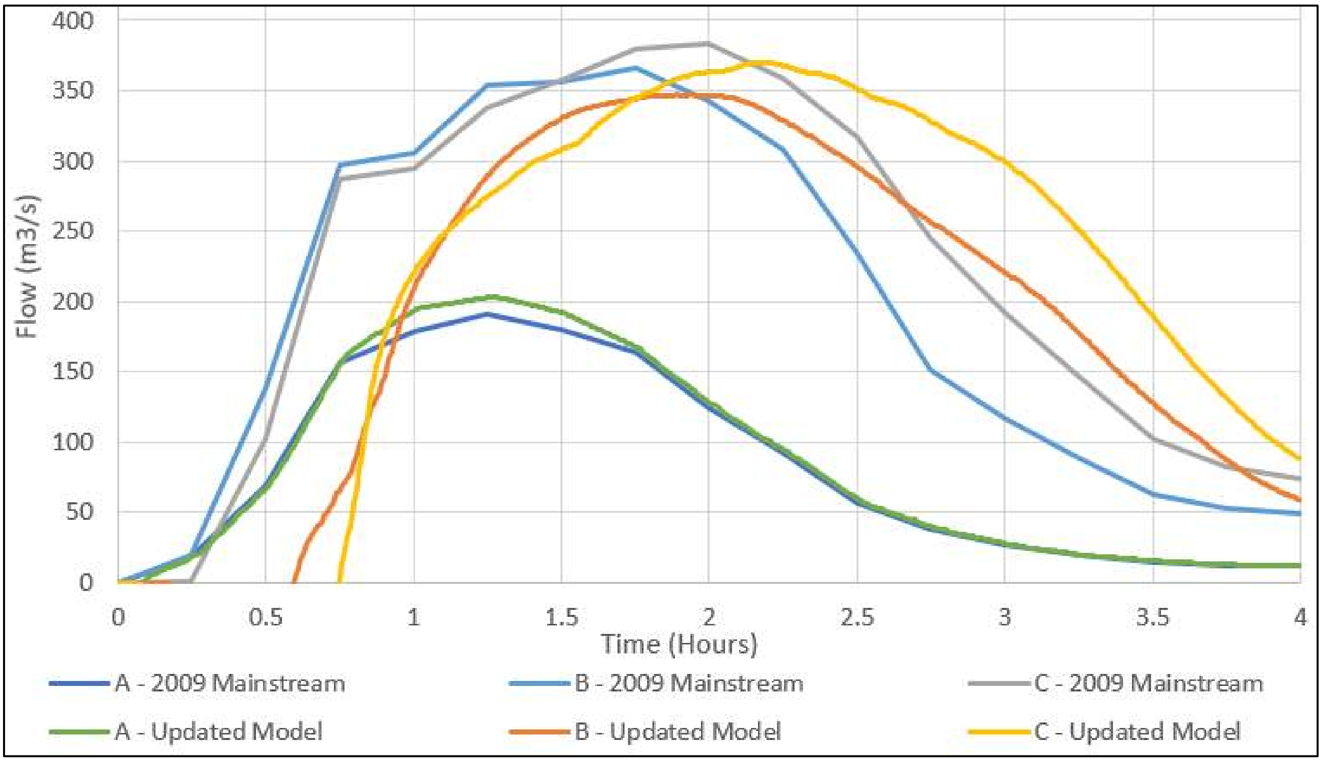


Figure 3-10 Flow Hydrograph Results Comparison – Updated Flood Model and 2009 Mainstream Study

With respect to water level differences between the updated flood model and 2009 Mainstream Study, the following results are presented below:

- An elevation section along the Cooks River centreline has been prepared to compare study model results. The location of the centreline is shown in **Figure 3-11**, while the elevation section plot is shown in Figure 3-12. The elevation section results show that the 2009 Mainstream results has stepped level results along the length of the river, due to large form losses on the eleven bridge structures along the river. Conversely the updated flood model shows a more gradual water level gradient along the river length. Upon review of bridge details, it is expected that most bridges should not present the significant flow obstruction that is suggested in the 2009 Mainstream Study results. With the modelling of the bridges in the 2D of the updated model, it is assumed that less stepped water level gradient is a more realistic model result than the previous 2009 Mainstream results.
- A water level difference plot for updated model less 2009 Mainstream Study model has been presented in Figure 3-13 and Figure 3-14 for the 1% AEP and PMF events respectively. The 1% AEP results show:
  - The upper portion of the model area has water level increases compared to the 2009 Mainstream Study. This is likely due to a more confined channel section in these upper reaches in the 2020 LiDAR, combined with higher roughness values, and different timing of flows arriving from the rainfall-on-grid portion of the Coxs Creek catchment that has a confluence with Cooks River in this upper portion.
  - The middle portion of the model area has water level decreases compared to the 2009 Mainstream Study. This is likely due to the reduced impacts of form losses in the various bridge structures along this section of river, with the largest decreases localised upstream of these various bridge structures.
  - The lower portion has minor water level increases downstream of the rail bridge compared to the 2009 Mainstream Study. This is likely due to changes in flow timing and changes in hydraulic roughness in overbank areas and changes in overbank terrain.

Overall based on the above review, it is concluded that the updated flood model generally shows reasonable agreement with the 2009 Mainstream Flood Study model. The comparison on peak flows, flow hydrographs, and peak water level results shows that the models have relatively modest differences in most instances. In any case, model result differences can be attributed to updates in the modelling approach which are justifiable and that typically provide more detailed modelling techniques in keeping with current best practice.

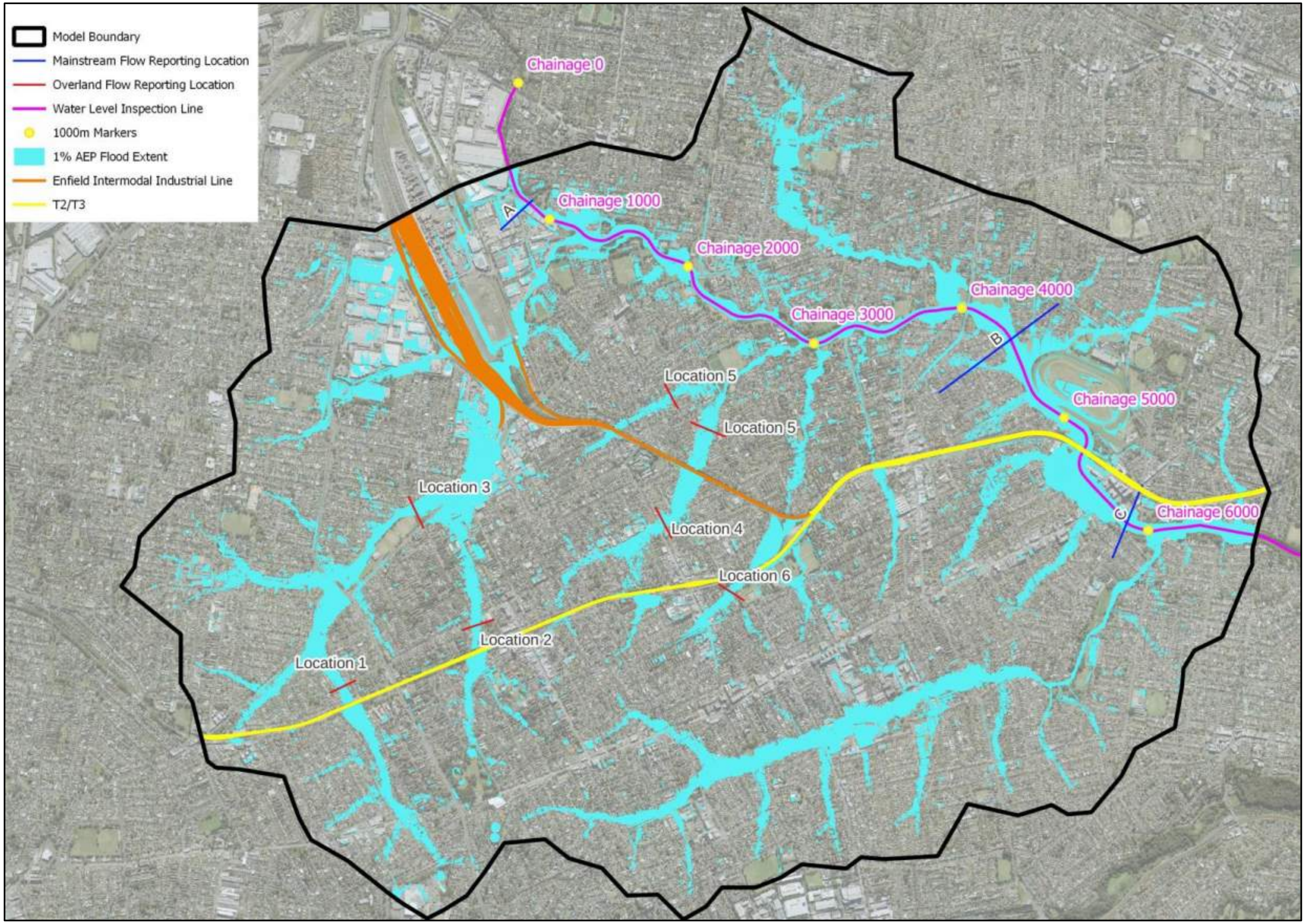


Figure 3-11 Layout of Flow Measurement Lines and Cooks River Long Section Line and Markers

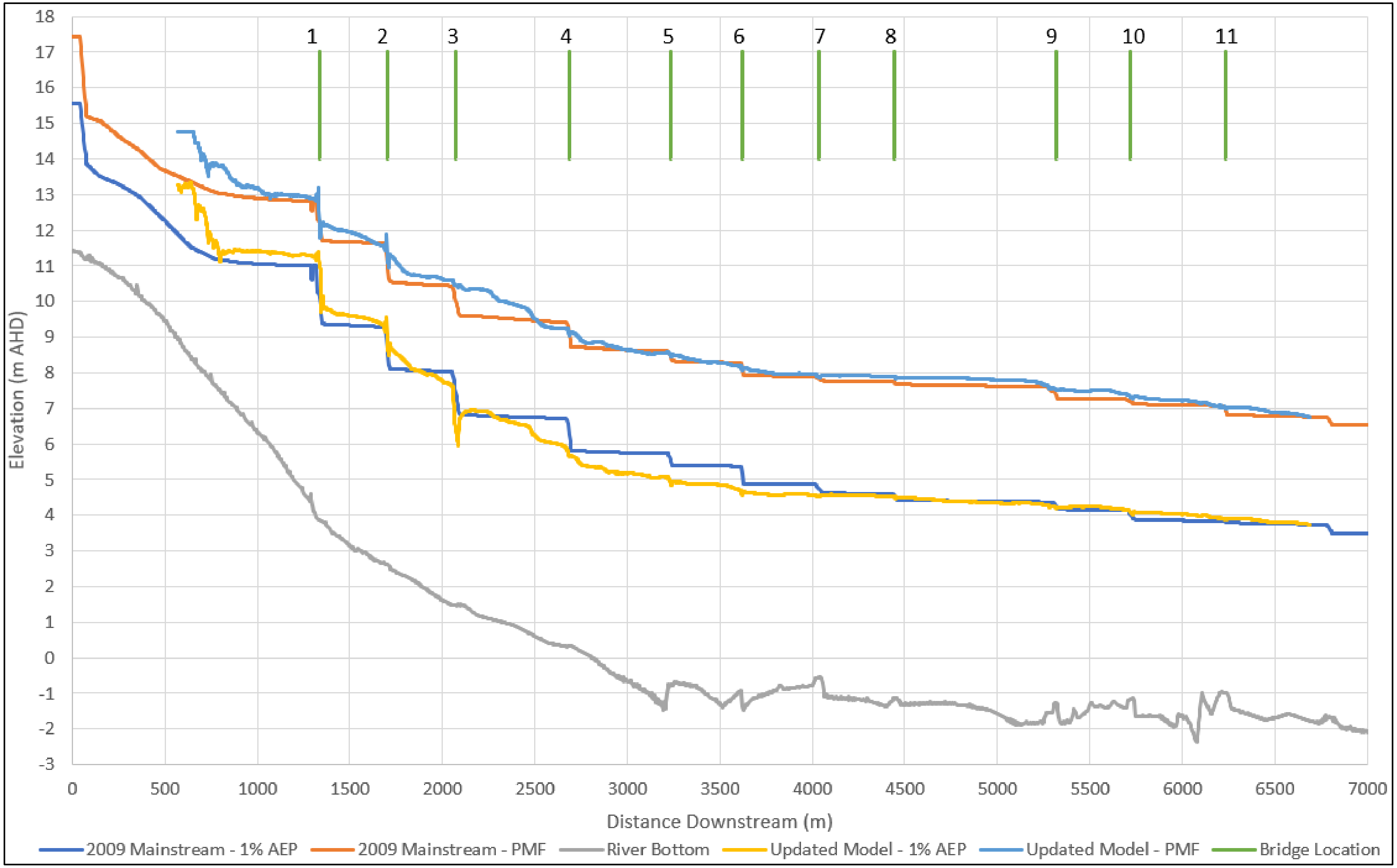


Figure 3-12 Elevation Section for Cooks River from Upstream to Downstream – Peak Water Level Results – Updated Flood Model and 2009 Mainstream Study

Figure 3-13 Peak Water Level Result Differences (in metres) – 1% AEP Event - Updated Flood Model Less 2009 Mainstream Study Model

Figure 3-14 Peak Water Level Result Differences (in metres) – PMF Event - Updated Flood Model Less 2009 Mainstream Study Model

3.6.2 Comparison to 2016 OLF Study Results

A comparison of peak flow results to 2016 OLF Study results has been conducted at six locations: 1-6 with the locations of these flow review lines shown in **Figure 3-11**. The summary of peak flow results for the two studies is included in **Table 3-6**. The results show that the peak flow results diverge significantly from the 2016 OLF Study results at most locations for both 1% AEP and PMF events.

Table 3-6 Comparison of Peak Flow Results (in m^3/s) for Updated Flood Model and 2016 OLF Study

ID	Description	2016 ID	1% AEP 2hour			PMF		
			2016 OLF	Updated Model	Diff (%)	2016 OLF	Updated Model	Diff (%)
1	Urunga Pde	2	36.4	23.9	-34%	51.8	46.3	-10%
2	Lakemba St	4	10.1	7.0	-30%	77.4	23.6	-69%
3	Macdonald St	5	37.4	71.6	92%	252.4	287.6	14%
4	Burwood Rd	7	16.8	20.3	21%	288.5	95.5	-67%
5	Baltimore St	8	35.2	27.6	-22%	363.0	81.9	-77%
6	Myall St	9	20.8	10.8	-48%	114.5	55.9	-51%

With respect to peak depth result differences between the updated flood model and 2016 OLF Study, the depth difference plots have been presented in **Figure 3-15** and **Figure 3-16** for the 1% AEP and PMF events respectively. Comparison should not be made between the two models for all mainstream Cooks River areas as the 2016 OLF model did not model all mainstream inflows as it was outside of the study area for the OLF study. Whereas the current model appropriately models all mainstream inflows which the reason mainstream levels are higher in this model. The main reasons for differences in the 1% AEP results include:

- The most significant depth differences are upstream of rail line culvert crossings. At almost all of these locations, the updated flood model has significantly more ponding upstream of the rail corridor, often within residential neighbourhoods. There are also often significant water level decreases downstream of the crossings. This behaviour clearly shows the flow capacity of the rail line crossings is less in the updated flood model compared to the 2016 OLF Study model. This conclusion is further supported by review of the peak flow results in **Table 3-6**, where locations downstream of rail crossings (locations 1, 2 and 5) all result in significant flow reductions compared to the previous study. It is not clear if the reduced culvert capacity is a result of the modelling platform change, changes in pit and pipe data upstream and downstream, application of pit sizing and blockage, or changes in roughness values. However, these results suggest that the 2016 OLF Study may have underestimated the amount of ponding upstream of almost all rail crossings and how much the rail crossings act as a flow obstruction in the catchment.
- There are other areas of impacts, both increases and decreases which are not near rail corridors and are likely attributable to a range of other model changes discussed in **Section 3.6.1**:
  - Changes in model terrain and as a result flow depths in the 2D domain of the model
  - Change in roughness approach to adopt a high roughness specifically for building footprints
  - Changes in pit and pipe details to reflect those in Councils latest database.

As the areas of depth increases and decreases are generally evenly distributed it confirms that overall, the set-ups with respect to design rainfall amounts and overall flows are similar, however model changes have resulted in significant localised impacts. This conclusion is supported by the 1% AEP peak flow results in Table 3-6, where there are both increases and decreases in peak flows, there is not a consistent flow increase suggesting that flood volumes are higher throughout one model compared to the other.

For the PMF event the main reason for impacts is the areal reduction factor ellipses applied for the current model that were not applied for the 2016 OLF model. This results in less rainfall, particularly in the areas furthest from the centroid of the catchment. This can be seen in **Figure 3-16** where the upper portions of almost all overland flowpaths show reduced flooding, and in the peak flow results in **Table 3-6** where the peak flows are significantly smaller at all locations but one. Downstream the same rail culvert reduced capacities observed in the 1% AEP are also observed in the PMF event with significant increases in ponding depth upstream of all rail crossings.

Overall based on the above review, it is concluded that the updated flood model shows significant local variations from the 2016 OLF Study model. The comparison on peak flows, and peak depth results shows that model changes, particularly reduced rail crossing capacity results in notable local differences. However, as 1% AEP changes are both increases and decreases it suggests that flood volumes are not higher or lower throughout one model compared to the other. These changes are attributed to updates in the modelling approach which are justifiable and that typically provide more detailed modelling techniques.

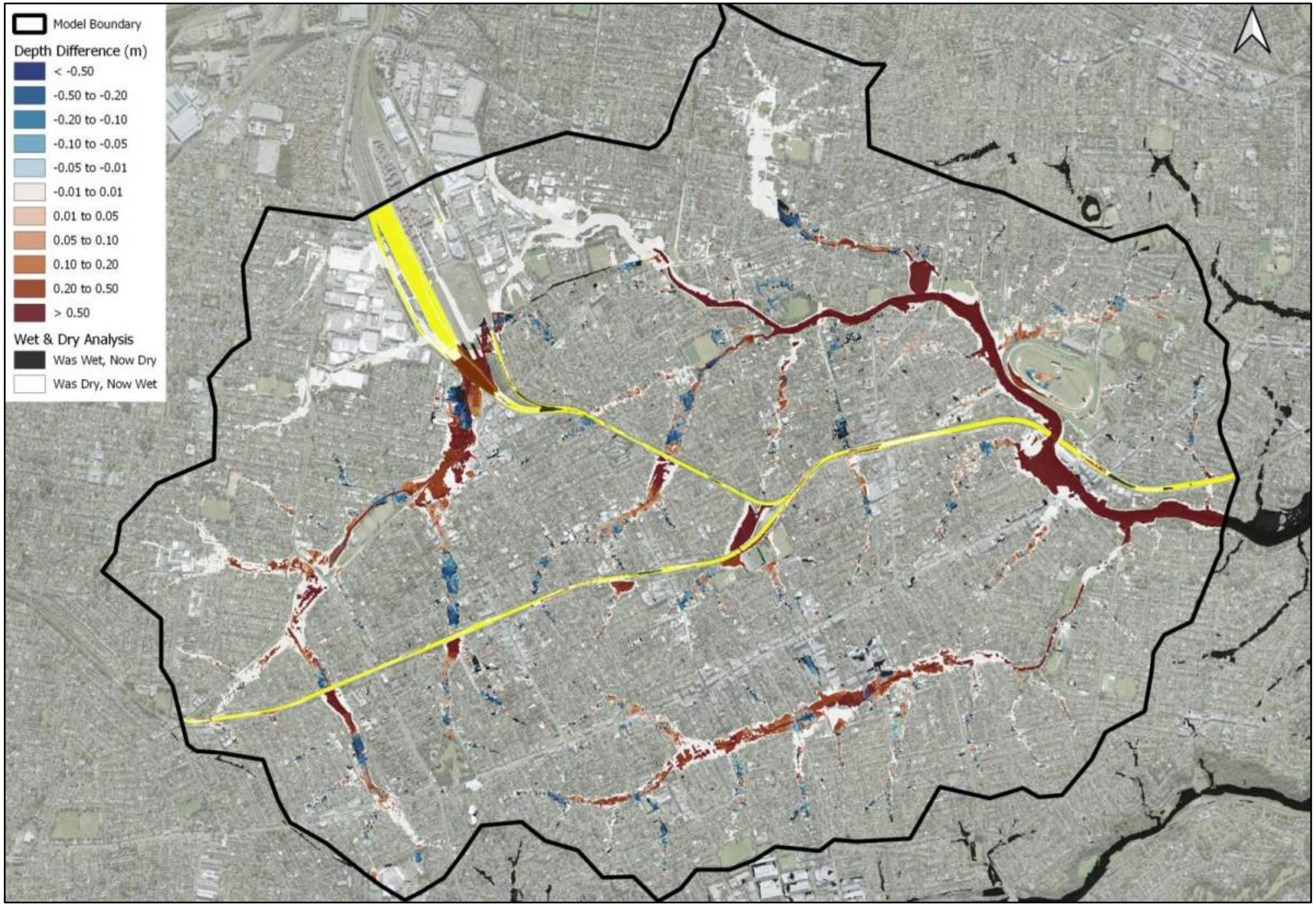


Figure 3-15 Peak Depth Result Differences – 1% AEP Event - Updated Flood Model Less 2016 OLF Study Model

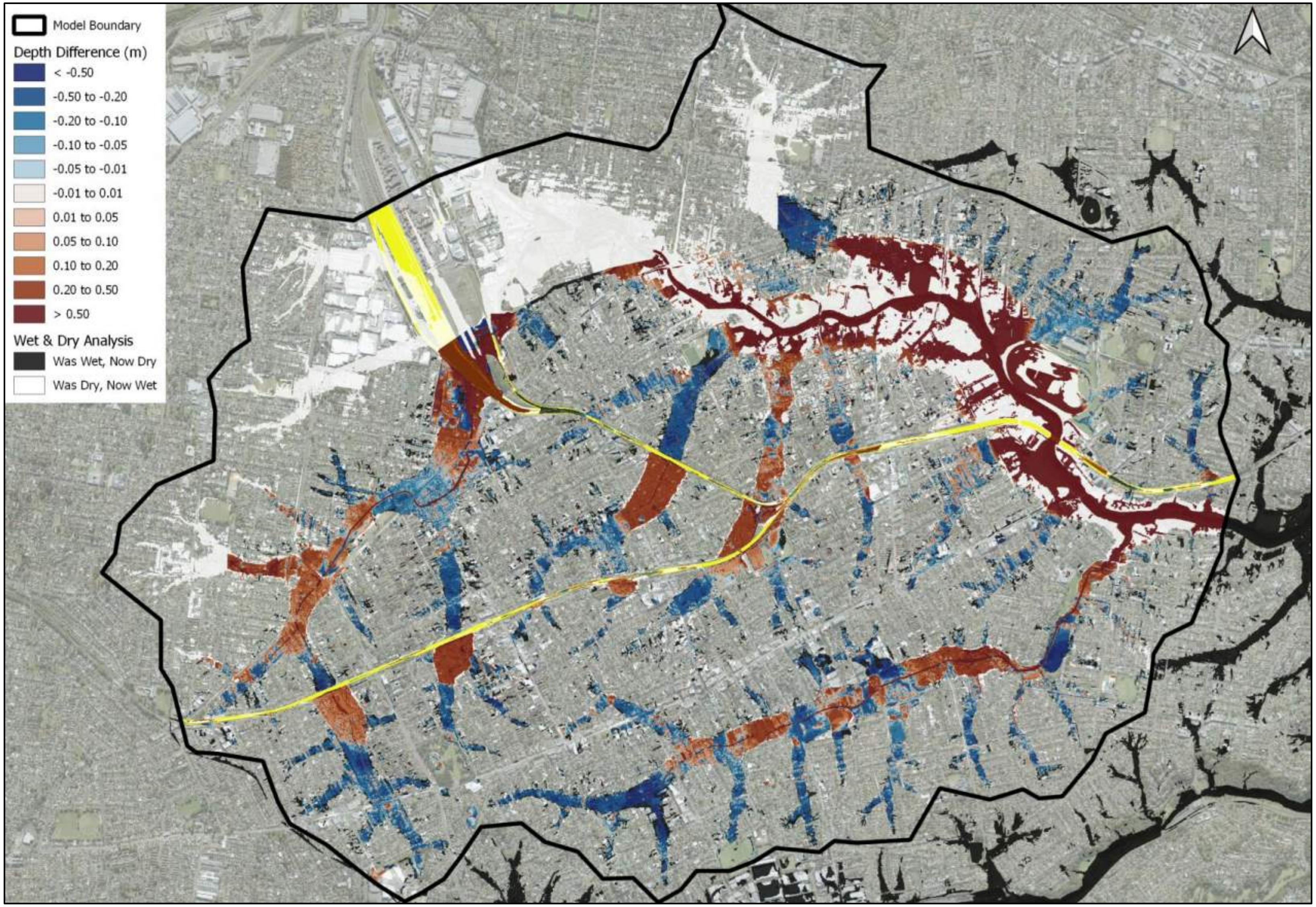


Figure 3-16 Peak Depth Result Differences – PMF Event - Updated Flood Model Less 2016 OLF Study Model

3.7 Flood Model Results

A full set of flood maps have been prepared for the updated flood model for the 1% AEP and PMF events. This full map set has been included within **Appendix A**. The following flood result maps were prepared based on TUFLOW model results:

- Figure 1: 1% AEP Flood Planning Area;
- Figure 2 and 4: Peak depth result mapping for 1% AEP and PMF (in metres);
- Figure 3: Peak depth result mapping for 1% AEP + climate change (in metres);
- Figure 5 and 6: Peak velocity result mapping for 1% AEP and PMF (in metres / second);
- Figure 7 and 8: Provisional hazard mapping (high, transitional and low) for 1% AEP and PMF;
- Figure 9 and 10: H1-H6 hazard mapping for 1% AEP and PMF events;
- Figure 11 and 12: Flood function (floodway, flood storage and flood fringe) for 1% AEP and PMF;
- Figure 13: Water level differences for 1% AEP climate change less 1% AEP.

These model results have been utilised in understanding the existing flood behaviour of the four study areas. The definitions of provisional hazard, H1-H6 hazard and flood function are provided in the following sections.

With respect to 1% AEP climate change impacts, the results in Figure 13 of **Appendix A** show that the water level increases are typically less than 0.5 metres, however often exceeds 0.5 metres for areas adjacent Cooks River. It is expected that the combined effects of 0.55 metres Sea Level Rise and 20% rainfall increase have the biggest impacts within the Cooks River.

3.7.1 Provisional Hazard

Provisional flood hazard is determined through a relationship developed between the depth and velocity of floodwaters and is based strictly on hydraulic considerations.

Historically, the criteria for these relationships have been taken from the NSW FDM (Appendix L; NSW Government, 2005). The Manual defines two major categories for provisional hazard – high and low. A third minor transitional category is also included that requires further investigation of the site in question to define the hazard category. The provisional hazard curves are shown in **Figure 3-17**.

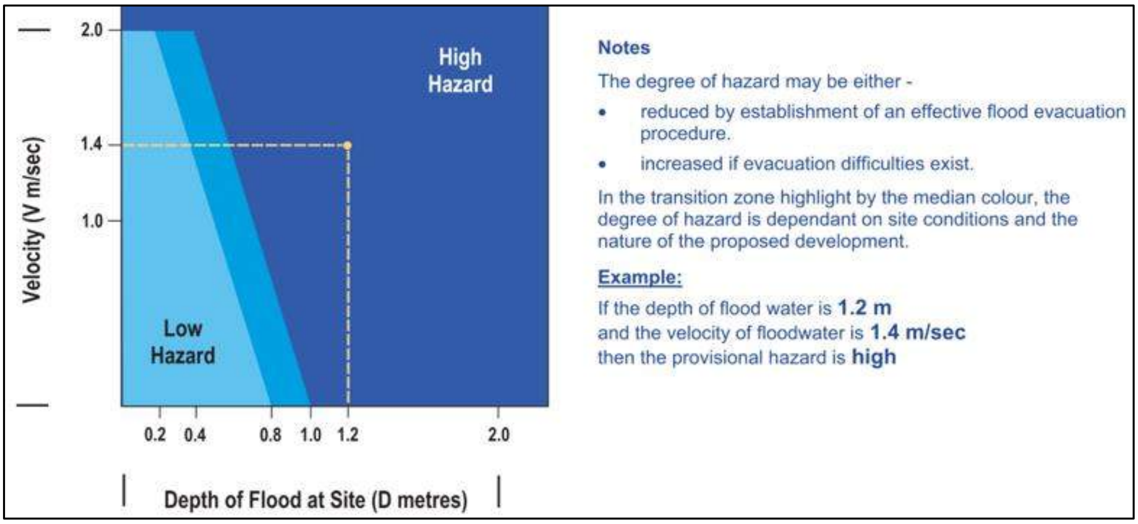


Figure 3-17 Provisional Hazard Curves from Appendix L of the Floodplain Development Manual

3.7.2 H1-H6 Hazard Category

A new method of hazard categorisation has been developed and is included in the 2019 edition of Australian Rainfall & Runoff (Book 6: Flood Hydraulics, Section 7.2.7). The classification is still based on depth and velocity but utilises six categories based on the stability of children, adults, the elderly and vehicles in flood waters. The ARR hazard category curves are shown in **Figure 3-18**.

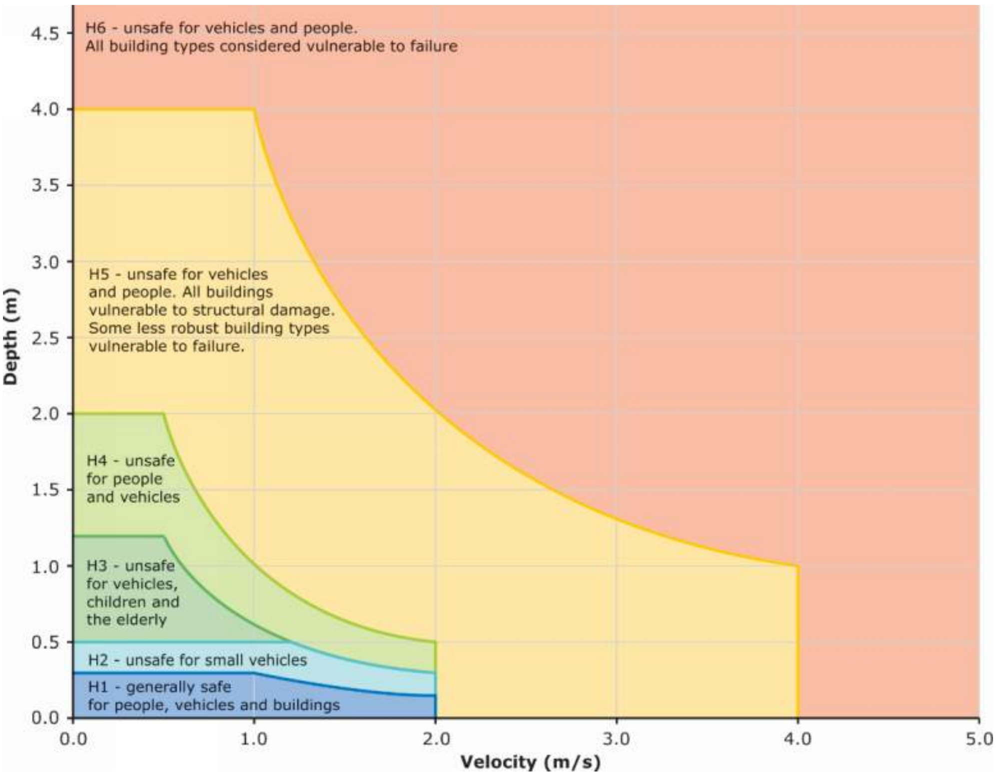


Figure 3-18 H1-H6 Hazard Categories (Source: Section 7.2.7, Book 6, ARR, 2019)

3.7.3 Hydraulic Categories

The 2023 FRM Manual defines flood prone land to be one of the following three hydraulic categories:

- Floodway - Areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas. The following criteria was used to define the floodways for the purposes of this desktop review:
  - Velocity x Depth product greater than 0.25 m^2/s and Velocity greater than 0.25 m/s; or;
  - Velocity is greater than 1 m/s.
- Flood Storage - Areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood Storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%. The criteria used to define the flood storage for the purposes of this desktop review was areas with Depths greater than 0.2 metres.
- Flood Fringe - Remaining area of flood prone land, after Floodway and Flood Storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or levels.

These definitions and thresholds for hydraulic categories described above have been sourced from the *Cooks River Final Overland Flow Study* (Stantec, 2016) and have previously been discussed and approved by Council staff.

3.7.4 Flood Planning Area

As part of this project a preliminary Flood Planning Area (FPA) exercise was conducted where a 0.5 metre freeboard was added to 1% AEP flood levels to determine the Flood Planning Level (FPL) and the mapped area lower than this FPL was approximated. The following trimming process was applied to the FPA extents:

- Trimmed to the PMF extents, as the PMF theoretically represents the maximum extent of flood risk;
- Trimmed to remove all FPA extents that are not in contact with a 1% AEP flood extent and minor manual edits to some areas where the FPA was an unreasonable extension beyond the 1% AEP extent.

The resultant FPA mapping for the four study areas has been presented in figures in later chapters.

4 Flood Planning Requirements

4.1 Relevant Flood Planning Guidance

4.1.1 2023 Flood Risk Management Manual and Toolkit

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 technical 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. Of the eight FRM Guidelines, one provides particularly relevant guidance for this assessment as discussed in **Section 4.1.6**.

4.1.2 2021 Flood Prone Land Policy

The 2021 Flood Prone Land Package was released in July 2021. The Flood Prone Land package includes the following documents:

- A revised s9.1 local planning direction on flooding (Local Planning Direction, or the Act);
- A new planning circular: Considering flooding in land use planning: guidance and statutory requirements (Planning Circular);
- A new guideline: Considering Flooding in Land Use Planning (Guideline);
- Standard Instrument (Local Environmental Plans) Amendment (Flood Planning) Order 2021: two local environmental plan (LEP) clauses which introduces flood related development controls;
- An amendment to clause 7A of Schedule 4 to the Environmental Planning and Assessment Regulation 2000 (the Regulation);
- State Environmental Planning Policy Amendment (Flood Planning) 2021; and,
- Revocation of the Guideline on Development Controls on Low Flood Risk Areas (2007).

The revised flood-prone land package allows a more contemporary approach to better manage flood risk beyond the 1% AEP, including building greater resilience. The package reverses the effects of the 2007 Planning Circular and Guideline on Development Controls on Low Flood Risk Areas, Ministerial Direction No. 4.3 which has restricted Councils in NSW from applying residential development controls on land between the 1% AEP flood extent and the PMF extent.

The update package addresses the key concerns over the safety of people, the management of potential damage to property and infrastructure, and the management of the cumulative impacts of development, particularly on evacuation capacity. A summary of the key outcomes from the package is summarised in the following sub-sections.

4.1.3 Updated Standard LEP Clauses

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).

4.1.3.1 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 2005 FDM 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.

4.1.3.2 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 generally relate to include:

- Sensitive uses that require ongoing functionality during and after a flood event such as hospitals with emergency facilities and emergency services facilities;

- Sensitive uses that require high levels of assistance with evacuation, such as seniors housing, group homes, boarding houses, hostels, caravan parks, educational establishments, centre-based childcare facilities and hospitals;
- Hazardous industries or hazardous storage establishments that require containment of materials in the event of a flood;
- Development that requires risk to life or other safety consideration such as (these examples are listed in the guideline Considering Flooding in Land Use Planning):
  - areas of low probability flood events that have the potential for high consequences (for example, where new floodways develop in low probability floods);
  - where development controls are needed to address risk to life or other safety considerations identified in studies under the FRM process or through the emergency management planning process;
  - areas with evacuation limitations;
  - where increases in dwelling densities would have a significant impact on the ability of the existing community to evacuate using existing evacuation routes within the available warning time;
  - where vertical evacuation for short duration flooding is required such as where the rate of rise of floodwater prohibits safe evacuation from the land;
  - behind flood levees which may have warning and/or evacuation limitations;
  - impacted by either high hazard or/and H4 to H6 hazard vulnerability thresholds in the PMF as defined in the manual or its supporting guides, and unable to safely evacuate;
  - areas indirectly affected by flooding where development may have for example outages of utilities; and
  - areas isolated by floodwaters and/or terrain (such as high flood island or trapped perimeter).

The requirements for development consent for this clause are similar but more limited than the mandatory clause considering safe occupation and efficient evacuation of people in the event of a flood, appropriate measures to manage risk to life, and effects on the environment.

4.1.3.3 Council Consideration of Optional LEP Clause

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.*

In discussions with Canterbury-Bankstown Council's catchment management planning team and stormwater asset planning team it is understood that it is Council's intention not to adopt the optional LEP clause 5.22 for land between the FPA and the PMF. Therefore only the mandatory LEP clause 5.21 for the FPA will be applicable. However, as discussed in the following sub-section, similar provisions for the SFC are still applicable to planning proposals in accordance with the s9.1 Local Planning Direction.

Although the optional SFC clause is unlikely to be adopted by Council, it is still considered relevant as it is generally in accordance with similar provisions for the SFC are applicable to planning proposals in accordance with the s9.1 Local Planning Direction.

4.1.4 Planning Proposal Requirements

The s9.1 Local Planning Direction (now referred to as Ministerial Direction 4.1) applies when an authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land. The key requirements of the local planning direction for planning proposals include:

1. A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy, the principles of the Floodplain Development Manual 2005 (now superseded by the 2023 FRM Manual), the Considering flooding in land use planning guideline 2021, and any adopted flood study and/or floodplain risk management plan adopted by the relevant council.
2. 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.
3. A planning proposal must not contain provisions that apply to the flood planning area which:
    a. permit development in floodway areas,
    b. permit development that will result in significant flood impacts to other properties,
    c. permit development for the purposes of residential accommodation in high hazard areas,
    d. permit a significant increase in the development and/or dwelling density of that land,
    e. 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,
    f. permit development to be carried out without development consent except for the purposes of exempt development or agriculture. Dams, drainage canals, levees, still require consent,
    g. 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
    h. permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.
4. 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 a), b), d), e), f) from item 3 above. An additional requirement for this area is if a planning proposal is likely to affect the safe occupation of and efficient evacuation of the lot.
5. For the purposes of preparing a planning proposal, the flood planning area must be consistent with the principles of the Floodplain Development Manual 2005 (now superseded by the 2023 FRM Manual) or as otherwise determined by a Floodplain Risk Management Study or Plan adopted by the relevant council.

A final section of the direction notes that a planning proposal may be inconsistent with the above terms of the direction only if the planning proposal authority can satisfy the Secretary of the Department of Planning and Environment (or their nominee) that:

> (a) the planning proposal is in accordance with a floodplain risk management study or plan adopted by the relevant Council in accordance with the principles and guidelines of the FDM 2005 (now superseded by the 2023 FRM Manual), or
>
> (b) where there is no council adopted floodplain risk management study or plan, the planning proposal is consistent with the flood study adopted by the council prepared in accordance with the principles of the FDM 2005 (now superseded by the 2023 FRM Manual) or
>
> (c) the planning proposal is supported by a flood and risk impact assessment accepted by the relevant planning authority and is prepared in accordance with the principles of FDM 2005 (now superseded by the 2023 FRM Manual) and consistent with the relevant planning authorities' requirements, or
>
> (d) the provisions of the planning proposal that are inconsistent are of minor significance as determined by the relevant planning authority.

It is noted that subsequent to the July 2021 release of the package, the ministerial direction has since been included within the Local Planning Directions set and has been renamed Section 4.1 Flooding. It is included in Focus Area 4 – Resilience and Hazards. The text of the flooding direction is unchanged from that included in Section 9.1 direction of the July 2021 package.

Local planning direction 9.1 (now Ministerial Direction 4.1) applies when an authority prepares a planning proposal that creates, removes or alters a zone or a provision that affects flood prone land. Upon the future finalisation of the Campsie Town Centre Master Plan, the last stage is the preparation of a planning proposal submission, therefore the planning proposal requirements are particularly relevant to this review. The list of requirements provides clear guidance on what must be considered for a planning proposal as it relates to flood risk.

This list forms the basis for the flood risk review of the Campsie Precinct included in this assessment. Furthermore, the requirements generally address the same objectives as those in the LEP amended clause 5.21.

4.1.5 Planning Circular PS24-001

The recent Planning Circular PS24-001, released in March 2024 outlines existing flood-related planning policies and provides further information and advice on their application in planning. The circular also provides updates on flood-related policy initiatives underway, including action taken in response to the *2022 NSW Flood Inquiry.*

As noted within Attachment A of Planning Circular PS 24-001, DPHI recommends planning authorities adopt a risk-based approach to the assessment of planning proposals, local and regional Development Applications (DAs), and State Significant Development (SSD) and State Significant Infrastructure (SSI) applications. This should include taking into account the flood risk profile of each proposal. Matters to consider include:

- Whether the proposal is in a high-risk catchment (which are Northern Rivers, Hawkesbury–Nepean, Georges, Wilsons, Tweed, Macleay, Richmond, Hunter, Clarence and Shoalhaven Rivers)
- The location of the proposal in relation to flood behaviour and constraints including:
  - Floodway, flood storage area or flood fringe area
  - The hazard vulnerability classification of the land
- Frequency of inundation
- Whether the proposal provides for safe occupation and efficient and effective evacuation in flood events and how it is to be achieved
- Any known evacuation constraints such as the flood emergency response classification for the area and available warning times (including rate of rise and when the evacuation route is cut by floodwater)
- Whether the proposal is for a sensitive or hazardous land use, or other higher risk uses and what controls (if any) are proposed to reduce any identified risks
- Whether there may be adverse flooding impacts on surrounding properties
- Potential impacts of cut and fill and other building works on flood behaviour
- Ability of proposed development to withstand flood impacts.

4.1.6 FRM Guide EM01 – Support for Emergency Management Planning

Section D4 of the FRM Guide EM01 outlines two decision-making frameworks for proposed development:

1. Future community growth directions – This includes identifying areas where new development does not adversely impact on existing development and where flood risks to the new development and its users can be effectively managed. This may inform the making of an LEP by rezoning areas to support greenfield development or redevelopment and the inclusion of development controls required to manage the flood and EM risk to development within these zonings in a DCP.
2. Development consistent with current zonings – This relates to the strategic application of development controls in the DCP in existing zoned and developed areas. For example, controls may be tailored to minimise risk to infill development and ‘one off’ single dwelling redevelopment and their occupants within an area.

Essentially the decision-making framework for type 1 (Figure 20 of the Guide), notes that for any greenfield site or strategic rezoning, shelter-in-place is not preferred and evacuation is the preferred form of emergency response, otherwise ‘reconsider development in this area’. However, the framework for type 2 (Figure 21 of the Guide), notes that any infill development ‘consistent with current zoning’ shelter-in-place may be suitable if ‘consider restricting development types and apply controls’.

In this instance it is assumed that the suitability for this study area be guided by the flood risks associated with shelter-in-place given local conditions.

4.1.7 Draft Shelter-in-Place Guideline

The Draft Shelter-in-Place (SiP) Guideline was prepared by NSW DPHI in 2022. Evacuation constraints are a critical issue when consent authorities are considering development applications, planning proposals and rezonings.

The objective of the guideline, when finalised, is to provide clear and consistent guidance available to consent authorities about when shelter-in-place can be used as an alternative to off-site evacuation for emergency management in flood events.

There are two evacuation options:

- Horizontal - Horizontal evacuation at street level is achieved by vehicle before any roads are cut by floodwaters requiring an understanding of the full range of flood behaviour up to the probable maximum flood (PMF),
- Vertical (shelter-in-place) - Shelter-in-place is the movement of occupants to a building or the occupants remaining in a location that provides vertical refuge on the site or near the site above the PMF level before their property becomes flood-affected.

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.

With respect to guidance for SiP, the guideline notes:

- SIP is an emergency management response, especially when the flood warning time and flood duration are both less than six hours (typically called flash floods)
- Under such circumstances, evacuation via vehicle may not possible. SIP is the last resort evacuation option for development in greenfield and infill areas
- SiP may be used if:
    - The duration for flood inundation is less than six hours
    - The development is not located in an area of high-risk (eg, floodways and H5 or H6 flood hazard areas)
    - Access to on-site systems to provide power, water and sewerage services during and beyond the event for the full range of flooding
    - The location of storage of food, water and medical emergency for SIP purposes should be above the PMF level and available during and beyond the event for the full range of flooding
    - SIP floor level is above PMF
    - SIP provides a minimum floor space per person
    - SIP must be structurally safe and accessible during floods up to the PMF.

The guidance from this draft shelter-in-place guideline has not been formally adopted and therefore is not policy. However, the guidance provides a useful insight into the conditions where shelter-in-place may be required, and the minimum requirements this emergency response may need to consider.

4.1.8 Relevance to Planning Proposals

In accordance with the NSW Flood Prone Land Policy package, in particular the s9.1 Local Planning Direction, planning proposals should consider the following issues (requirements listed in further detail in **Section 4.1.4**):

- Precluding development within high flood risk areas such as floodways or high hazard areas;
- Rezoning and intensification of residential development within the FPA;
- Flood emergency response, in particular evacuation and alternatively shelter-in-place;
- Special flood considerations and additional flood risk for vulnerable developments; and,
- Consideration of any regional flood mitigation measures that could be developed to address future flood risk.

These requirements form the basis for the flood planning review of each study area summarised in the following four chapters of the report. Discussion of these requirements is the basis for identifying land not suitable for intensification or sensitive uses, and developing appropriate planning controls to manage flood prone land.

4.2 Flood Emergency Response

When determining the flood risk to life, the flood hazard in an area does not directly equate to the danger posed to persons on the floodplain. This is due to the capacity for people to respond and react to flooding and to avoid entering floodwaters. This concept is referred to as flood emergency response.

To help minimise the flood risk to future occupants, it is important that developments consider flood emergency response. There are two main forms of evacuation that may be adopted:

- Evacuation: The horizontal evacuation of occupants from the floodplain before the properties and/or evacuation routes becomes flooded;
- Shelter-in-place: The vertical evacuation of occupants in a building to a level higher than the PMF level who then shelter from the flood until it is safe to return to the ground floor and external areas.

Within the NSW Flood Prone Land 2021 package, flood emergency response requirements are included in both the standard LEP clauses (both mandatory and optional) and the planning proposal requirements. It is also discussed in the guideline and other documents in the package. Its significance is that if a suitable flood emergency response is implemented that removes occupants from any flooding, then the residual flood risk of a site can be addressed, even potentially for intensified development on the floodplain.

Effective flood emergency response is developed on a site-by-site basis; therefore it is difficult to assess its feasibility for a high-level planning proposal review such as this. However general commentary on the planning proposal and the opportunities for flood evacuation or shelter-in-place are discussed as follows.

4.2.1 Flood Behaviour

The PMF event is typically adopted as the design event for flood emergency response as it represents the estimated upper limit of flooding albeit extremely rare flooding. The typical AEP of the PMF in urban areas like the study area is 1 in 1 million AEP to 1 in 10 million AEP.

This discussion of flood emergency response in this assessment focusses on the PMF, particularly H1-H6 hazard in this event as these hazard categories relate to vulnerable occupants in the floodplain. As a result PMF H1-H6 hazard mapping has been prepared for the study area included in the next chapters.

Based on NSW SES advice, horizontal evacuation is typically the primary recommended flood emergency response for all new developments on flood prone land. However if horizontal evacuation is not feasible due to flash flooding and the very short warning times then shelter-in-place is a feasible alternative. Particularly if the period of isolation is a matter of hours.

The Australasian Fire and Emergency Service Authorities Council (AFAC) defines flash flooding as:

> *Flash flooding may be defined as flooding that occurs within 6 hours or less of the flood-producing rainfall within the affected catchment. Flash flood environments are characterized by the rapid onset of flooding from when rainfall begins (often within tens of minutes to a few hours) and by rapid rates of rise and by high flow velocity. …..*

Modelling has shown that the critical duration for the Cooks River catchment is 2 hours and similarly the critical duration for overland flooding in the catchment is either 90 minutes or 2 hours. As such, the Cooks River floodplain, with a critical duration of 2 hours is not a typical riverine floodplain with long duration flooding due to its relatively small and steep catchment for a river. Consequently, the study area including Cooks River mainstream areas is classified as a flash flooding environment. The implications of flash flooding for evacuation are discussed as follows.

4.2.2 Evacuation Timeline

The Australasian Fire and Emergency Service Authorities Council (AFAC) defines flash flooding as:

> *Flash flooding may be defined as flooding that occurs within 6 hours or less of the flood-producing rainfall within the affected catchment. Flash flood environments are characterized by the rapid onset of flooding from when rainfall begins (often within tens of minutes to a few hours) and by rapid rates of rise and by high flow velocity. …..*

The flooding affectation of the Cooks River where the Campsie Precinct is located would be defined as ‘flash flooding’ based on the above definition. The NSW SES evacuation timeline assesses the suitability of evacuation based on two considerations:

- Available time: For flood evacuation to be effective, a warning system and procedure needs to be prepared that ensures all occupants can be evacuated prior to flooding occurring. For flash flooding environments such as the Cooks River and overland flooding areas, the amount of time from the onset of rainfall to flooding occurring is typically sub-hourly, which does not provide a sufficient time for horizontal flood evacuation except on the fringes of the floodplain. Also for flash flooding there are not typically stream gauges installed within trunk drainage systems, unlike in large riverine catchments where streamflow gauges can detect flooding in the upper catchment and provide an additional warning time. The only opportunity for advanced warning times would be to implement a system like FloodSmart Parramatta which relies on continuous real-time modelling of forecast rainfall to provide flood warnings. Even then, horizontal evacuation within the study area may be vulnerable to any incidents on evacuation routes which trap drivers and passengers on flooded roads.

- Required time: The time needed to evacuate all occupants considering time for acceptance of occupants of the need to evacuate, travel time, and traffic and other delays. In this instance, as shown in Figure 2 of **Appendix A**, the Cooks River floodplain for the foreshore area and overland flow areas, even in the PMF event is relatively narrow. This is advantageous for evacuation as it means that the distance to land higher than the PMF is short and travel time is also likely to be short, even if pedestrian evacuation is required instead of vehicular evacuation. Review of flood extent mapping suggests most flooded areas can access land above the PMF within several hundred metres of the site along public roads. This is in contrast to large riverine floodplains where land higher than the PMF may be several kilometres away and along heavily used regional evacuation routes which would significantly increase the required time.

For shelter-in-place, the same flash flooding conditions apply as discussed above for horizontal evacuation. However, under shelter-in-place the time required to evacuate vertically within a building to a level higher than the PMF could be several minutes only.

4.2.3 Evacuation Routes

As part of this assessment, evacuation routes have been mapped for the study area. As discussed above a review of PMF extents shows that in most instances land higher than the PMF is typically within several hundred metres of most development sites. Furthermore, it appears that for most of the floodplain, the evacuation routes would be defined as rising road access meaning that evacuation would be along a route where the flood depth progressively decreases as one travels along the evacuation route. This is viewed as a lower flood risk than flood islands where evacuation routes are cut before flooding of the site occurs. In these instances, horizontal flood evacuation is more difficult.

One of the requirements for planning proposals within Ministerial Direction 4.1 is that:

> *… not 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.*

Evacuation for most sites is a short distance away, with limited sites able to access any one of the evacuation routes. However, a consideration is whether it is safer for occupants on levels higher than the PMF to remain safely within a building than to add to the number of persons attempting to evacuate by road. It is possible that the number of vehicles queued on multi-storey basement driveways waiting to exit on to possibly crowded local roads exposes the occupants to greater flood risk than if they remained in place.

Another advantage of multi-storey residential buildings is that a flood emergency response plan is routinely developed for such developments and that the bodies corporate provides a means to implement and maintain the plans.

Under these circumstances, it is possible that intensified development may not cause a significant additional strain on emergency services.

4.2.4 Shelter-in-Place

Shelter-in-Place is considered a feasible emergency response, particularly for multi-storey residential developments such as those proposed within the Precinct. This type of development can elevate the majority of the higher risk residential use above the PMF level and can make allowance for shelter-in-place refuge and vertical evacuation for ground floor occupants. In this way, intensified development offers more shelter-in-place opportunities as it will likely provide more floor space for refuge above the PMF level compared to an existing single storey residential dwelling.

Aside from the timeline considerations discussed above, there are two other key concerns for shelter-in-place - period of isolation and structural stability of the building.

The period of isolation is the amount of time a site would be flooded, stopping occupants in refuge from leaving the property and accessing emergency services in the event of a medical emergency. As the Cooks River mainstream and overland flow floodplains are flash flooding environments (with a 2 hour critical duration), the duration of flooding can often subside as quickly as it occurs, so flooding would be expected to be short. Relative to the isolation period for riverine floodplains that can often exceed multiple days, the risks associated with a sub-daily isolation period are far less. As stated within the Draft Shelter-in-Place guidelines a duration of flooding of 6 hours or less is reasonably considered 'short duration' flooding and appropriate for shelter-in-place.

A detailed review of flood affected road locations has been conducted throughout the study area to confirm the duration of flooding for evacuation routes, To inform this assessment, the PMF 90-minute, 2-hour, 3-hour and 6-hour events have been modelled to assess duration of flooding. Consideration should be given to additional modelling of PMF 12-hour and 24-hour events be considered as part of planning proposal phase.

Considering the non-direct risks of shelter-in-place such as people entering floodwaters, or having a medical emergency and being unable to evacuate should be considered. However comparing the relative risk of the flood affected development sites with flood free development sites in a PMF flash flood:

- For short duration isolation, the direct flood risks to residents on flood free land, or in a multi-storey building above the floodplain are in essence the same, assuming that structural stability can be assured.
- As noted above, due to lack of available time, SES suggested they and other emergency services will be unable to mobilise and coordinate any response until PMF flash flooding has passed. Furthermore, self evacuation to medical services will not be possible as the risks of driving in PMF rainfall, and the widespread nature of PMF flash flooding ensures almost all evacuation routes in the LGA will be flooded. Therefore the temporary isolation of residents from emergency and medical services would apply to both flood affected shelter-in-place residents and flood free properties throughout the study area.
- The risk of some residents entering floodwaters will remain whether residing on flood free land or in a flooded multi-storey development. The flood affectation of the site, the inability to leave the driveway, the ability to establish a site-specific flood emergency response plan, and targeted community education program for residents of flood affected buildings means that it is possible this risk is equal or lessened in buildings surrounded by floodplain.

The H1-H6 hazard category curves presented in **Figure 3-8**, include two hazards that relate to potential structural instability; H5 and H6. Any flood hazard areas less than H5 or H6 should be structurally stable under normal construction. The H1-H6 hazard for the PMF event is included for each of the four study areas in the following chapters. Any proposed development in H5-H6 hazard areas that proposes shelter-in-place should consider special structural design for flood forces in the PMF. Otherwise, the flooding conditions for the study area suggest that structural stability should be readily achieved through appropriate structural engineering design and that shelter-in-place is a feasible flood emergency response.

The above generic discussion of flood emergency response is applicable to the study areas. In addition, any specific flood emergency response areas of concern within the study areas are discussed in further detail in the following chapters.

4.3 Flood Planning Level

4.3.1 Flood Planning Level and Risk Assessment

As noted within the Mandatory LEP Clause of the standard LEP clause (see **Section 4.1.3.1**) the Flood Planning Level (FPL) in accordance with the 2005 FDM 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 current Canterbury-Bankstown LEP adopts the 1% AEP level with a 0.5m freeboard for the entire LGA.

As part of the 2022 Flood Inquiry released by the State Government, ‘finding O’ of the inquiry notes a risk based approach should be used to consider flood planning level, particularly for high risk catchments.

Review of the flooding conditions of the study area suggest that this not significantly high risk catchment relative to other catchments. The flood affectation is in keeping with many other urban overland flow affected catchments in Sydney. The floodplain of the Cooks River does not have as significant riverine flooding severity as other major rivers in the Sydney basin, with the PMF event being between 2-4 metres higher than the 1% AEP. Through appropriate flood response provisions this means that flood risk up to the PMF may more reasonably be managed with less widespread, and no regional evacuation issues in the study area.

This high level risk review supports the Council adoption of a standard 1% AEP plus 0.5m freeboard for FPL across the entire LGA including the study area. The higher risk development types of vulnerable developments are required to consider flood risk up to the PMF level, which in principle is in accordance with the risk based consideration for these types of developments.

NSW DPHI has responded to the recommendations of the inquiry by fully supporting six recommendations and giving in-principle support to the remaining 22, with additional work required for their implementation.

5 Flood Risk Review for Campsie

A review of these flood risk factors for the Campsie Precinct are discussed in the following sections.

5.1 Existing Flood Behaviour Summary

Utilising the updated design flood model results, the following study area focussed flood maps have been provided for this flood planning review:

- Flood extents for the 1% AEP, PMF events and FPA incorporating a 0.5m freeboard (**Figure 5-2**);
- Flood function for the 1% AEP showing floodway, flood storage and flood fringe (**Figure 5-3**);
- Provision flood hazard for the 1% AEP showing high hazard areas and potential mitigations (**Figure 5-4**);
- H1-H6 Hazard categories for the PMF event showing hazard areas for different occupant types in the extreme flood event, relevant to flood emergency response planning (**Figure 5-5 to Figure 5-8**).

In support of these planning related flood maps, a more comprehensive set of flood result maps for the study area is provided in **Appendix A** including peak flood depth, velocity, provisional hazard, H1-H6 hazard categories, and flood function (floodway, flood storage and flood fringe) all for the 1% AEP and PMF design flood events, as well as 1% AEP climate change impact flood maps.

The key flood behaviour for the study area can best be described as follows:

- There is flooding from Cooks River mainstream in some parts of the study area along the Cooks River foreshore area.
- Five flowpaths (shown in **Figure 5-2**) carry flows from southwest towards northeast, including:
  1. A formal channel, which intersects Bruce Avenue when it reaches the study area, passes adjacent Rudd Park and pours into Cooks River at some point between Third Avenue and Fourth Avenue.
  2. An overland flowpath, which intersects corner of Alma Avenue and Campsie Street when it reaches the study area, passes through Harcourt Public School and Harcourt Reserve and pours into Cooks River at some point between Third Avenue and Fourth Avenue.
  3. An overland flowpath which originates around Orisa Street and Fletcher Street intersection, passes through western side of Campsie Shopping Centre, reaches the railway around Lilian Street and continues its pass through Fifth Avenue and pours into Cooks River.
  4. An overland flowpath which originates around Perry Street towards Wairoa Street and covers Phillips Avenue and Tasker Park adjacent Cook River where the flowpath reaches the river. While the railway has disconnected this overland flowpath, the flowpath exists downstream the railway and pours into Cook River through Frederick Street.
  5. A short overland flowpath which is formed around Cressy Street and Northcote Street intersection outside the study area, reaches the study area at Canterbury Road and joins the fourth overland flow path Tasker Park adjacent Cook River where the flowpath reaches the river.

5.2 Land Use Zoning Changes

Ministerial Direction 4.1 under Section 2 notes 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. These land use changes represent an intensification in zoning from a non-developable use which could potentially increase flood risk.

The FPA extents and the proposed land use zoning of the Precinct are shown in Figure 1 of **Appendix A**. As can be seen in Figure 1, the FPA extent covers several of the proposed areas of land use change.

A summary of the land use change areas proposed in the Proposal with location numbering is shown in **Figure 5-1**. The land use changes for the numbered areas, and whether or not they are flood affected and therefore not in accordance with this provision of the Policy is summarised in **Table 5-1**. All land use changes are not in the categories listed in the NSW Flood Prone Land 2021 package, therefore are eligible changes even if they are flood affected.

Table 5-1 Review of Proposed Land Use Change Areas

Location	Existing Land Use	Proposed Land Use	Flood Affectation	Consistent with Direction Provision
1	Medium Density Residential	High Density Residential	Yes	Yes – Eligible Change
2	Medium Density Residential	High Density Residential	Yes	Yes – Eligible Change
3	Medium Density Residential	High Density Residential	No	Yes – Eligible Change
4	Medium Density Residential	Low Density Residential	No	Yes – Eligible Change
5	Mixed Use	Mixed Use	Yes	Yes – Eligible Change
6	Medium Density Residential	High Density Residential	Yes	Yes – Eligible Change
7	Medium Density Residential	Low Density Residential	No	Yes – Eligible Change
8	Mixed Use	High Density Residential	Yes	Yes – Eligible Change
9	Medium Density Residential	High Density Residential	No	Yes – Eligible Change
10	Medium Density Residential	Local Centre	No	Yes – Eligible Change
11	Medium Density Residential	Mixed Use	No	Yes – Eligible Change

5.2.1 Outcome

Any of the land use changes are not in the categories listed in the Ministerial Direction 4.1, not proposing a change from non-developable to developable use, therefore are eligible changes even if they are flood affected.

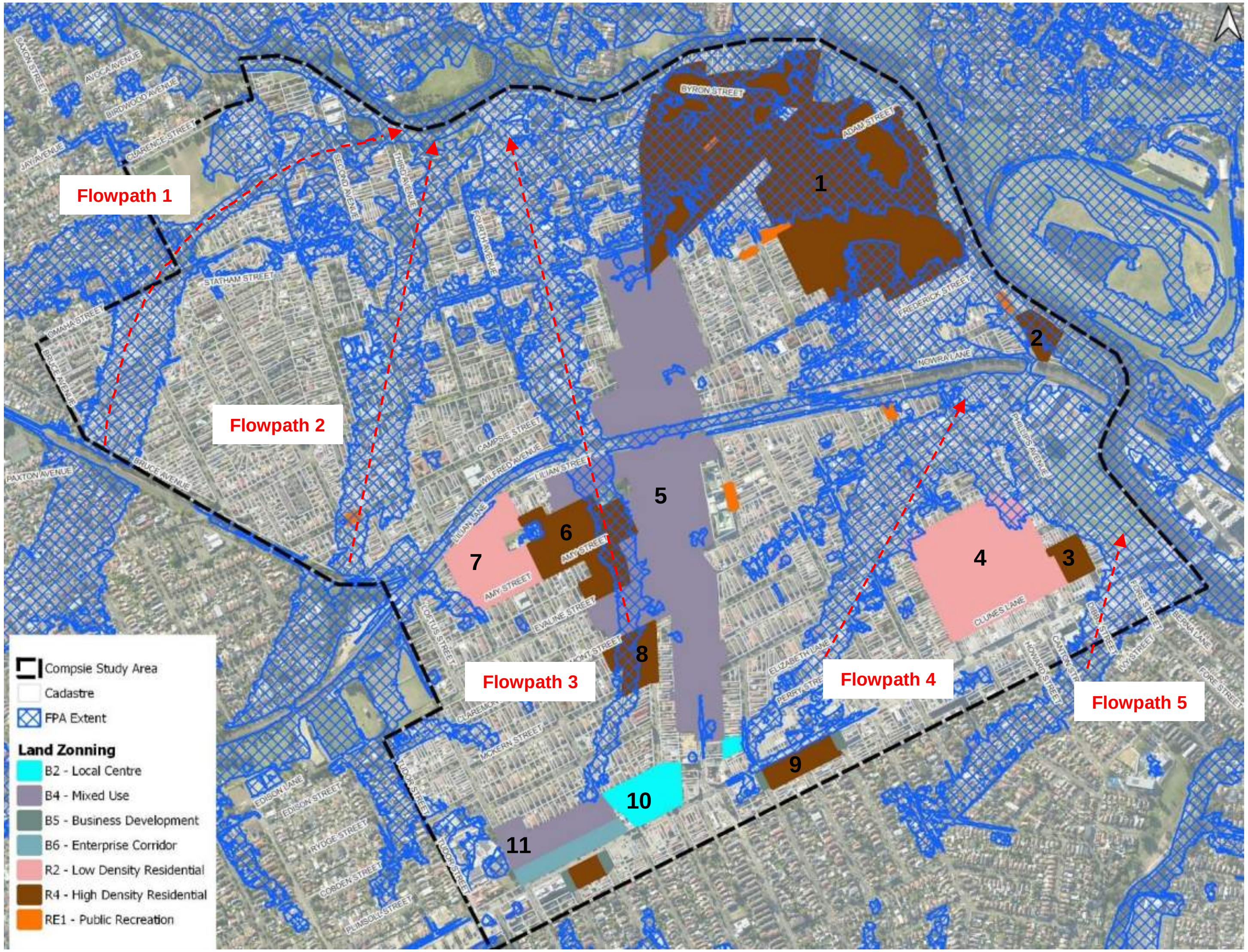


Figure 5-1 Numbered Locations of Developable Land Use Changes from the Planning Proposal

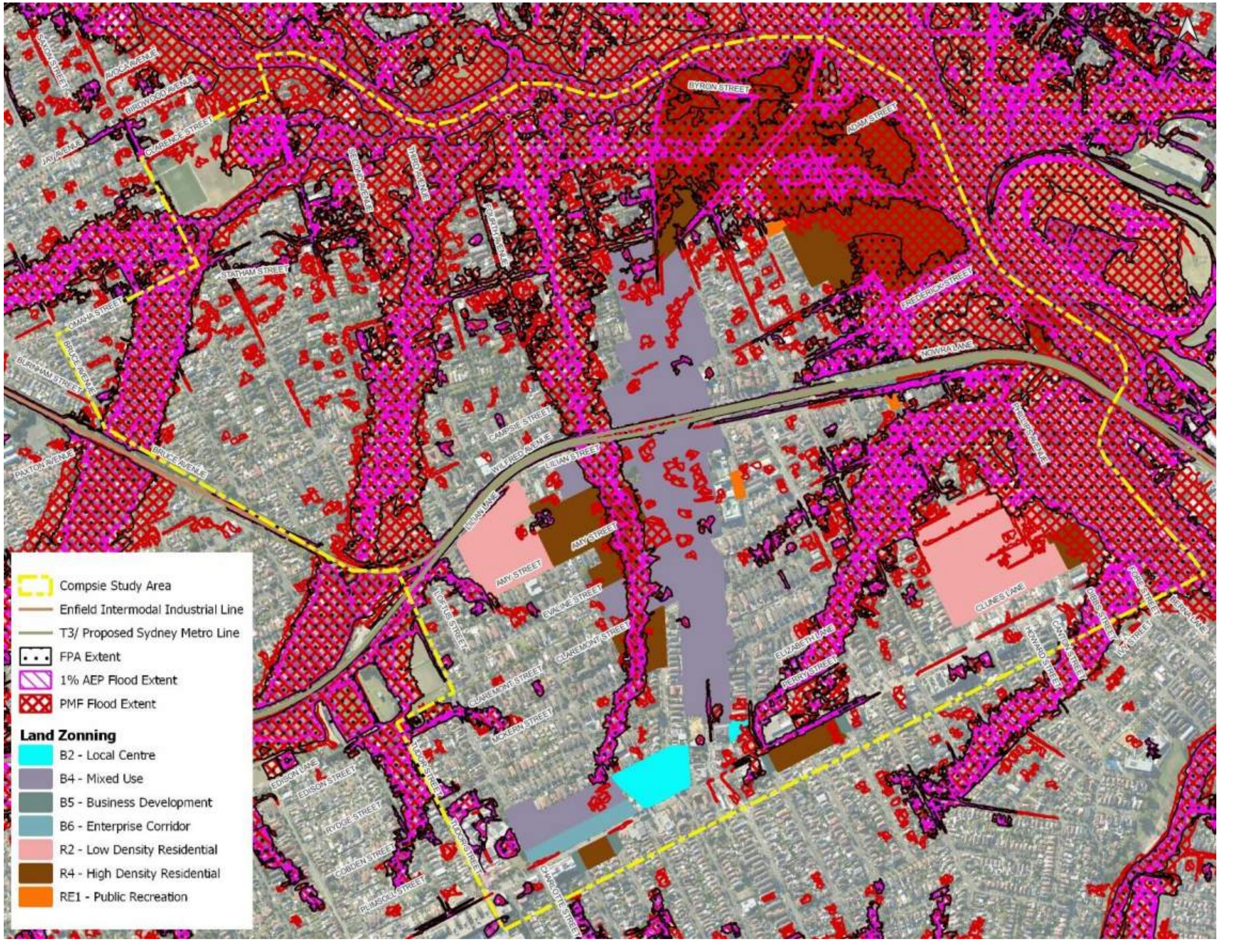


Figure 5-2 1% AEP and PMF Flood Extents – Campsie Precinct

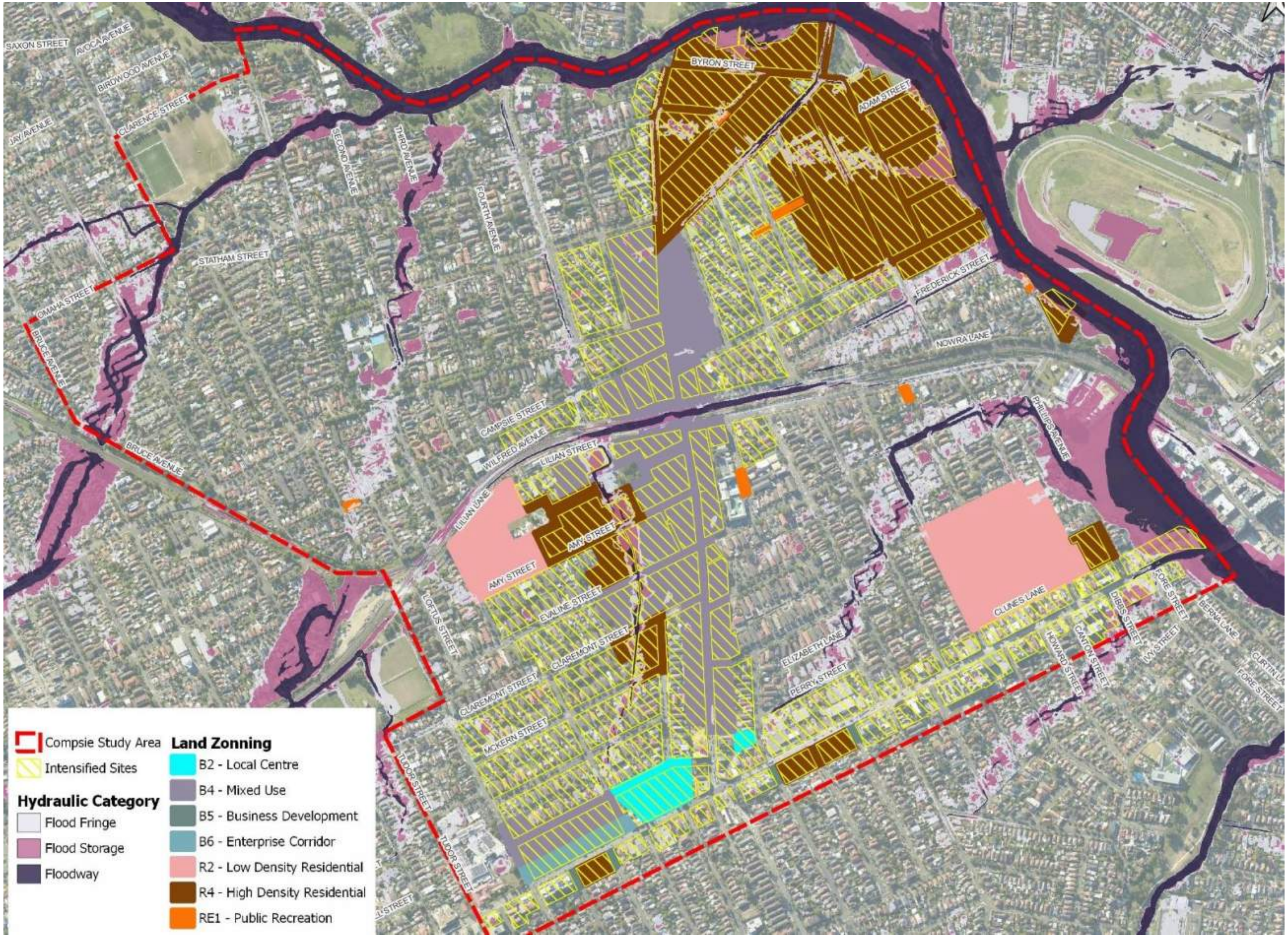


Figure 5-3 1% AEP Flood Function (Floodway, Flood Storage and Flood Fringe) – Campsie Precinct

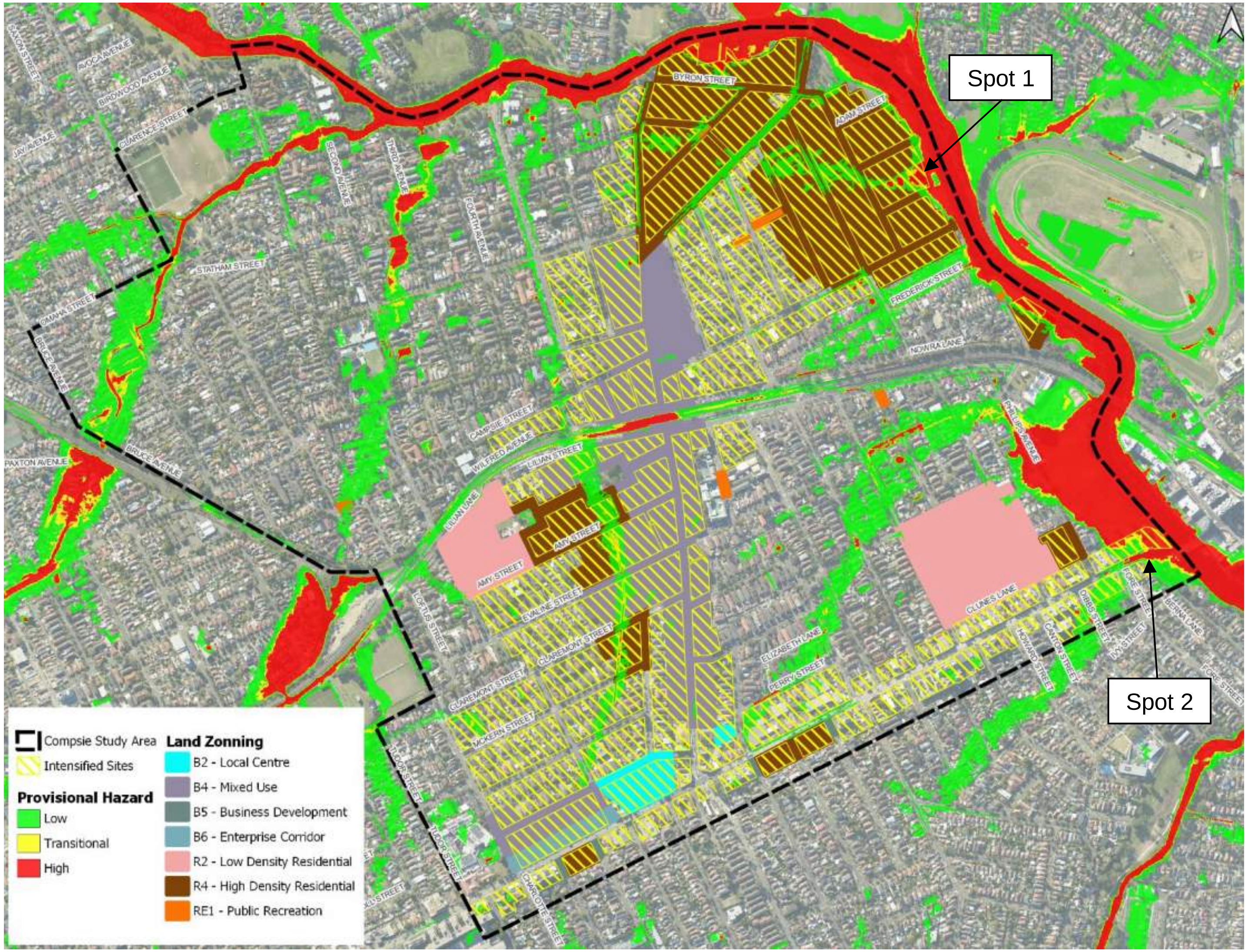


Figure 5-4 1% AEP Provisional Flood Hazard (High, Transitional and Low Hazard) – Campsie Precinct

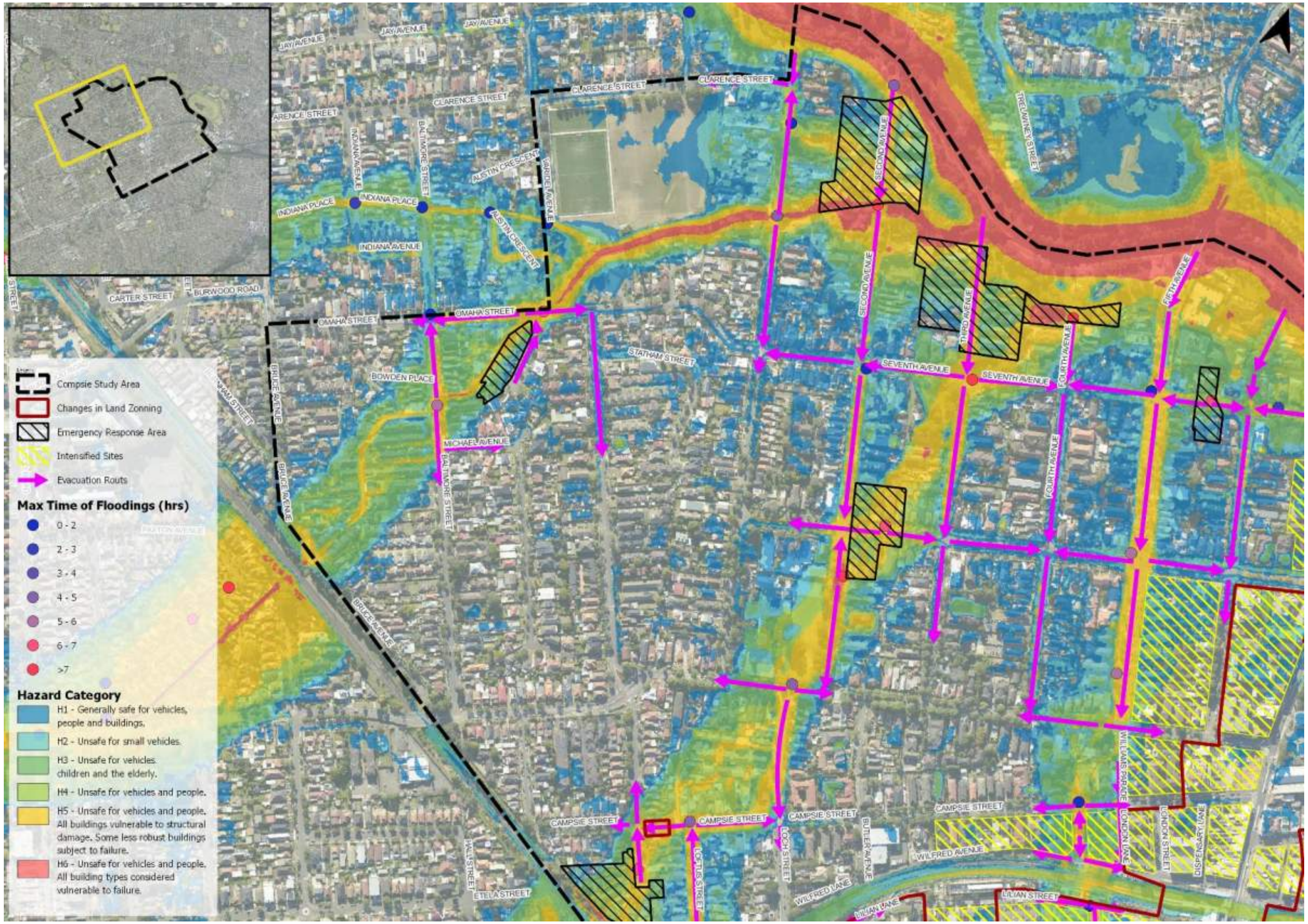


Figure 5-5 PMF H1-H6 Hazard Categories with Evacuation Route Mapping, Flood Duration Inspection Points and Potential Flood Emergency Response Areas – Campsie Precinct (Northwest Part)

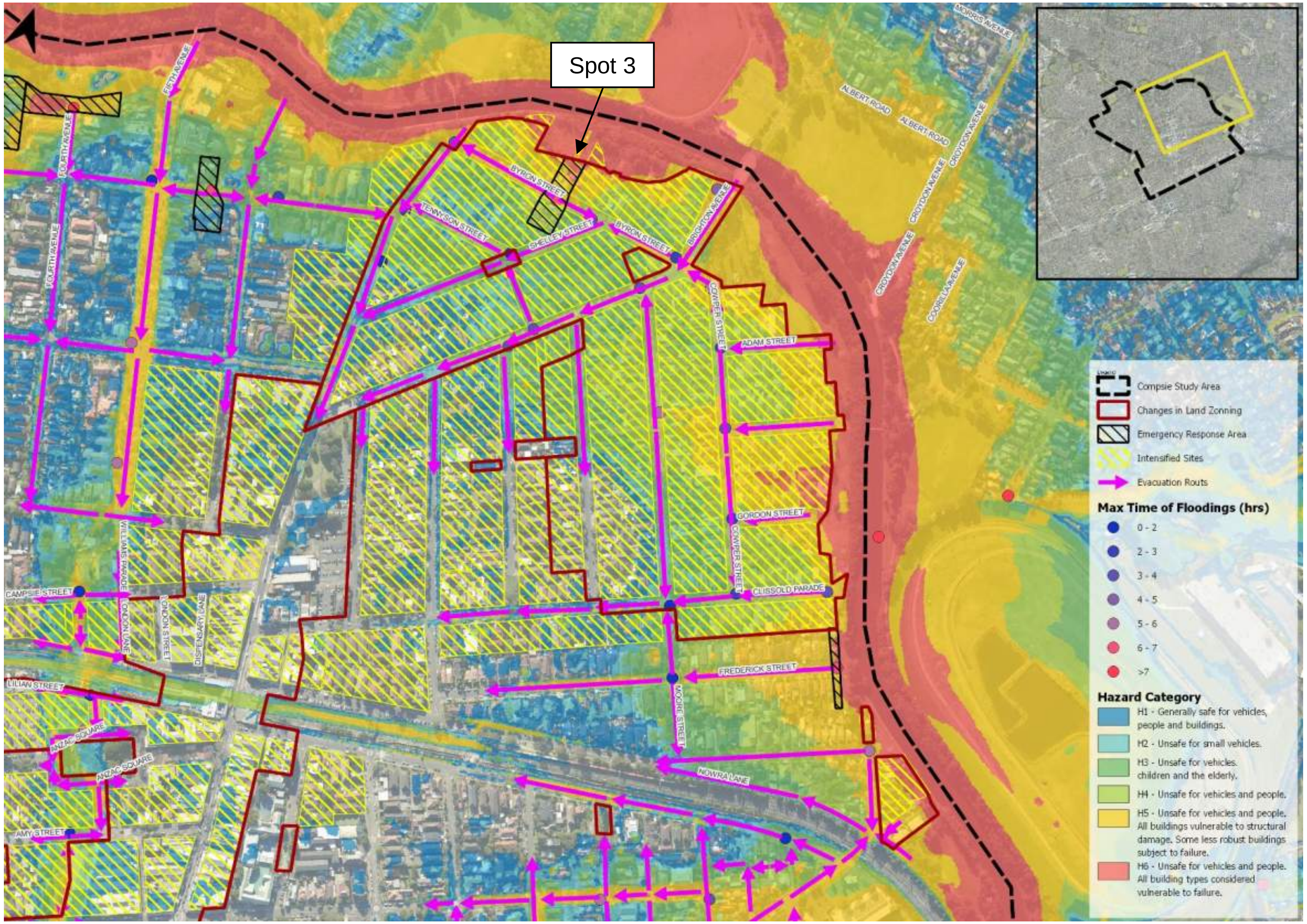


Figure 5-6 PMF H1-H6 Hazard Categories with Evacuation Route Mapping, Flood Duration Inspection Points and Potential Flood Emergency Response Areas – Campsie Precinct (Northeast Part)

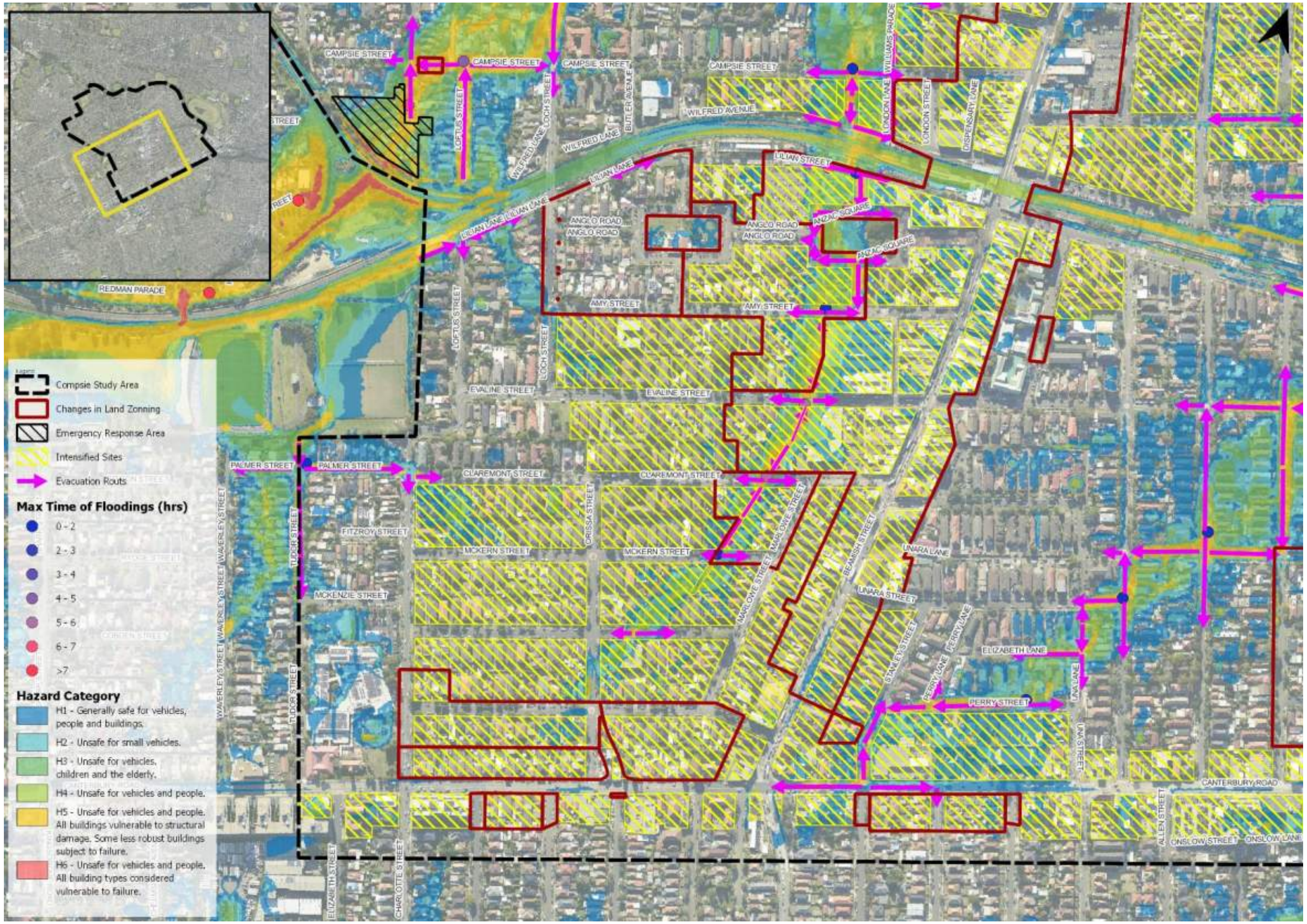


Figure 5-7 PMF H1-H6 Hazard Categories with Evacuation Route Mapping, Flood Duration Inspection Points and Potential Flood Emergency Response Areas – Campsie Precinct (Southwest Part)

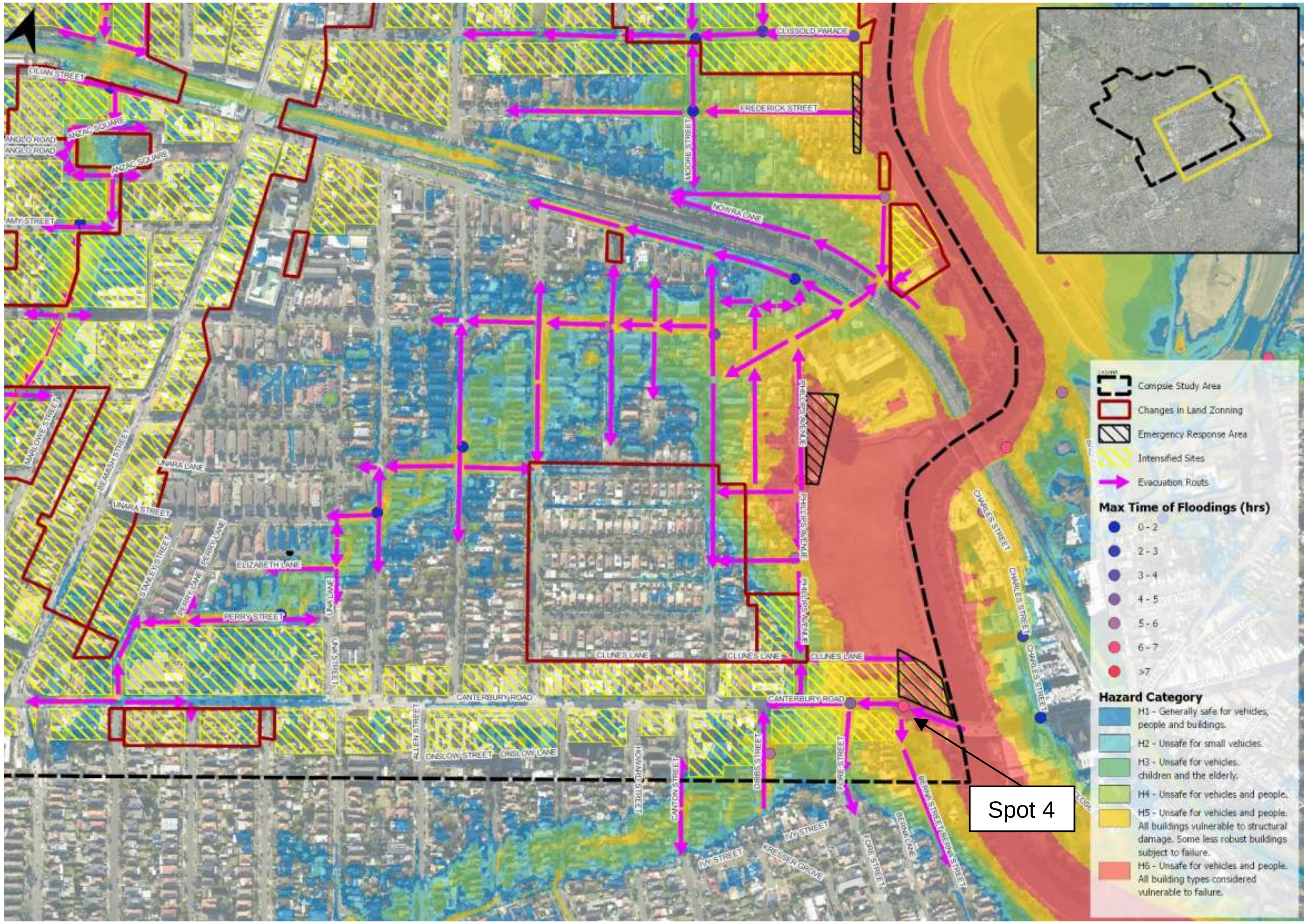


Figure 5-8 PMF H1-H6 Hazard Categories with Evacuation Route Mapping, Flood Duration Inspection Points and Potential Flood Emergency Response Areas – Campsie Precinct (Southeast Part)

5.3 Development in High Flood Risk Areas

5.3.1 Floodway and Impacts

The NSW Flood Prone Land 2021 package notes planning proposals should not propose development in floodway areas, interpreted to mean the floodway areas in a 1% AEP flood. The second requirement is that development not result in significant flood impacts on other properties. The second point cannot be assessed at a Planning Proposal Pre-Gateway level as it would rely on site-specific detailed flood modelling to assess flood impacts of development proposals.

The 1% AEP floodway is mapped against the land use zoning of the study area in **Figure 5-3** (also Figure 11 of **Appendix A**). It shows that the floodway is generally confined to Cooks River channel and in very isolated locations in overland flow areas. It has negligible overlay on developable land, essentially only for the flowpath on the west side of the study area. Critically of all areas proposed for intensification (shown by yellow hatching in **Figure 5-3**) there is no floodway interaction with development sites.

- In accordance with these provisions, **Figure 5-3** shows that these floodway areas have not been considered as part of the Planning Proposal.

5.3.2 High Hazard

The NSW Flood Prone Land 2021 package notes planning proposals should not propose development for the purposes of residential accommodation in high hazard areas, which is interpreted as high hazards in a 1% AEP flood. This would likely relate to flood risk to buildings and occupants.

The 1% AEP high hazard is mapped against the land use zoning of the Planning Proposal in **Figure 5-4** (Figure 12 of **Appendix A**). It shows that the high hazard is generally confined to Cooks River channel and public road reserves in most locations. However it marginally covers some portions of areas proposed for intensification without any proposed changes to existing land use on the Cooks River foreshore , including a small area between Linday Street and Gordon Street and another area on the southern part of Tasker Park. These two small areas have been shown as **Spot 1** and **Spot 2**, respectively, in **Figure 5-4**.

In accordance with these provisions, these high hazard areas should not be developed for residential uses.

Consideration could be given to re-aligning the high hazard flowpaths to consolidate the developable portion of a site or consideration could be given to elevating structures one level above the high hazard flowpath to maintain the flood conveyance up to the PMF and to allow for maintenance.

5.3.3 Outcome

The NSW Flood Prone Land 2021 package notes planning proposals should not propose any development within floodway areas, or residential developments for high hazard areas (which is interpreted as under 1% AEP flooding). The maps in **Appendix A** show that the Planning Proposal is mostly not affected by these high risk areas, however in two limited location does propose developable land uses within high hazard areas in Cooks River foreshore areas (refer to **Figure 5-4** where shows **Spot 1** and **Spot 2**). However due to the isolated and narrow extents of these flood areas and through potential site-specific design opportunities, there may be development potential for these affected sites. Therefore the proposed zoning of the Planning Proposal may need to be qualified in the two areas to align with these provisions of the NSW Flood Prone Land 2021 package. This would normally be addressed through filling of these high hazard sites to reduce the flood risk, however modelling is required for these fill designs to ensure no adverse flood impacts. The fill design and modelling are commonly assessed prior to public exhibition of the planning proposal.

5.4 Intensification of Development and Cumulative Development

The NSW Flood Prone Land 2021 package notes a planning proposal must not permit a significant increase in the development and/or dwelling density within the FPA. Similarly, the standard LEP clause notes that Councils should consider the impacts of cumulative development on the floodplain.

This is particularly relevant for the Planning Proposal as can be seen in **Figure 5-3** and **Figure 5-4**, a large portion of the study area is proposed for intensified development (the yellow hatched areas in the figures).

In most instances, the proposed intensification will be in the form of vertical development with HOB and FSR increases to accommodate the growing population. As discussed in the previous section, for the proposed change of land use areas, most involve an intensification of land use as well (for example locations -1-3, 6 and 9 all involve change from medium to high density residential zones).

Using the Flood Planning Area (FPA) for the study area shown in **Figure 5-1** (and Figure 1 of **Appendix A)**, there are sites that are within the FPA in the existing scenario for the study area and proposed for intensification in the Planning Proposal. A large portion of these sites have marginal affectation in the 1% AEP event, with low existing hazards categories either H1 or H2.

To assess the potential intensification of occupation of these sites, three potential occupation scenarios should be considered:

- Existing site – Estimated occupation of the existing site with current use
- Existing capacity – The maximum potential occupation of the site under current LEP zoning, FSR and HOB not considering other site constraints;
- Proposed capacity – The maximum potential occupation of the site under proposed rezoning, FSR and HOB, not considering other site constraints.

As this assessment is for the planning proposal, the emphasis is on the comparison of existing capacity (with current zoning) and proposed capacity. The sites have existing development potential under the current zoning, therefore the impacts of the incremental increase in intensification from existing to proposed capacity is the focus of this review.

It is assumed that the developable portions of these sites will be flood-free in the post-development condition. This assumption is based on adherence to CBC current Flood Planning Level (FPL) requirements for all proposed residential buildings to have all habitable floor levels suspended above the 1% AEP plus 0.5m freeboard (FPL).

In greenfield development precincts, flood affected areas are made flood free through proposed filling of the land above the FPL, at which point intensification from undeveloped use to residential is permissible.

Similarly for infill developments as is proposed for the study area, the developable portions of the sites are proposed to be elevated above the FPL through fill and elevated building footprints, in turn taking the developable portions of the site out of the Flood Planning Area (FPA). Through appropriate site design, and adherence to Council's flood-related development controls it is therefore assumed the relevant areas of the development sites will be elevated above the FPL and therefore intensification would be suitable in accordance with Ministerial Direction 4.1. No alterations to the Planning Proposal are recommended in response to this Policy provision, however it is recommended that this interpretation and conclusion be confirmed by Council in discussions with DCCEEW.

5.4.1 Flood Risk Implications of Intensification

Considering the flood risk implications of intensification and the associated filling or raising of portions of these sites to facilitate the development:

- The potential filling or raising of development sites would involve consideration of potential flood impacts.
- Based on the proposed FSR and HOB, much of the intensification in the Planning Proposal will occur vertically in multi-storey residential buildings compared to existing capacity for current zoning which in most cases has significant redevelopment opportunity when compared to existing use. This would mean that any additional occupants as a result of the rezoning would reside above the PMF level as well as the FPL, essentially residing elevated above the entire floodplain.
- It is expected that new multi-storey buildings could be designed to be stable during flooding up to the PMF and that all non-ground floor residents in multi-storey residential development would be only exposed to an indirect flood risk in all events. PMF hazard mapping of the study area shows several sites are affected by up to H5 hazard which would require structural design for flood forces, however no sites are affected by H6 hazard where structural stability may be vulnerable.
- Implementation of flood emergency response plans for new multi-storey development could potentially reduce the flood risk faced directly and indirectly by future residents in contrast to the flood risks faced by existing residents or potential residents under the existing capacity of development sites.

5.5 Flood Emergency Response

5.5.1 Flood Evacuation Potential

Unlike consideration of development in floodway and high hazard areas as discussed in the above sections which focus on the 1% AEP event, emergency response needs to consider provisions for all flood conditions, therefore the design event for this consideration is up to the PMF event. H1-H6 Hazard category mapping for the PMF event in the study area is shown in **Figure 5-5** to **Figure 5-8**. Review of the flood behaviour shows that most of the flood affected portions of the study area should have rising road access or overland escape route to flood free land in the near vicinity. This suggests that suitable flood evacuation provisions may be possible for future developments in these areas.

As part of this study, flood evacuation routes were investigated and proposed for any sites that have hazard areas greater than H1 across the study area. Proposed evacuation routes are shown with Pink arrows in **Figure 5-5** to **Figure 5-8**. Any evacuation route should be rising along all the way and should not pass through areas with hazard greater than H2. The results of the investigations show that most of the study area has suitable rising road evacuation routes to flood free land.

5.5.2 Flood Shelter-in-Place Potential

A review of duration of flooding in hours has been conducted for the PMF-90min, 2hr, 3hr and 6hr events, with the maximum duration of flooding adopted from these events. The analysis has been conducted at all key road crossing and junctions in the study area as shown in **Figure 5-5** to **Figure 5-8**. The results show that throughout most of the study area the maximum duration of flooding is less than 6 hours at most locations. As it can be seen to **Figure 5-5** to **Figure 5-8**, there is no location with duration of flooding greater than 6 hours within the area proposed for change to land use. Based on guidance within the Draft SiP guidelines this is considered ‘short duration’ flooding and should be suitable for shelter-in-place.

There is only one location with duration of flooding greater than 6 hours within the area proposed for intensification (not within the area proposed for change to land use) that has been shown as **Spot 4** in **Figure 5-8**. This location is at the south-western corner of the proposed Precinct and still may allow residents on both side of this location (**Spot 4**) to use an evacuation route defined through Canterbury Road. This location has flooding of roads in excess of 6 hours suggesting they are not suitable for shelter-in-place unless alternative evacuation routes could be considered, potentially through site amalgamation.

As noted in **Section 3.3.3**, the limitation of the current modelling is that mainstream model boundaries have applied 2-hour duration results. Therefore this duration of flooding analysis should be updated in future stages of the planning proposal process.

The results in **Figure 5-5** to **Figure 5-8** show that aside from **Spot 4** shown in (**Figure 5-8**), the majority of the proposed Precinct, including either areas of changes to land use or proposed for intensification, has hazard areas mostly lower than H5 meaning low risk of potential structural instability. The results in **Figure 5-5** to **Figure 5-8** show that the exceptions are in narrow areas around the third and fourth flowpaths’ centrelines where areas are classed as H5 with instability concerns under normal construction without any H6 areas with instability concerns even under special design.

5.5.3 Flood Emergency Response Key Areas

Flood emergency response key issue areas have been shown as black hatched in **Figure 5-5** to **Figure 5-8**. The criteria for these key emergency response areas is one or all of the following issues:

- If evacuation routes are flood affected on both sides of several areas they can be classed as a flood island under the provisions of the Flood Emergency Response Classification of Communities. This means that evacuation would likely be difficult.
- If the PMF duration of flooding for the road location needed for evacuation exceeds 6-hours, or significant parts of the site are H6 hazard in the PMF, then these sites have been noted as potentially not suitable for shelter-in-place

As shown in **Figure 5-5** to **Figure 5-8**, the majority of the Emergency Response Key Areas are not located in parts of the study area near any form of changes to land use or intensification. Examples of these key areas that are located outside of the proposed intensification areas include:

- areas mostly located in narrow areas around the third flowpath and the fourth flowpath centrelines (**Section 5.1**); and
- areas adjacent to Cooks River where the PMF hazard is high and the duration of flooding is relatively long.

Among the Flood Emergency Response Key Areas, there is only one site that has overlap with areas proposed for change to land use along with intensification. This area is shown as **Spot 3** in **Figure 5-6**. This is a higher risk category as it means that evacuation may not be possible in rare events. In light of the higher risk, this area may be considered to have less development potential, particularly for vulnerable developments (as discussed further below) than other parts of the study area unless effective shelter-in-place provisions could be developed for these sites, though with H5-H6 hazard in the PMF, shelter-in-place may be difficult to justify as a suitable emergency response. Further investigation of shelter-in-place potential of this site, or potential filling to provide greater flood immunity should be considered in future planning proposal stages.

5.5.4 Flood Emergency Response in Land Use Planning

Section D4 of the FRM Guide EM01 outlines two decision-making frameworks for proposed development:

1. Future community growth directions – This includes identifying areas where new development does not adversely impact on existing development and where flood risks to the new development and its users can be effectively managed. This may inform the making of an LEP by rezoning areas to support greenfield development or redevelopment and the inclusion of development controls required to manage the flood and EM risk to development within these zonings in a DCP. This forms the basis of Figure 20 of the Guide.
2. Development consistent with current zonings – This relates to the strategic application of development controls in the DCP in existing zoned and developed areas. For example, controls may be tailored to minimise risk to infill development and ‘one off’ single dwelling redevelopment and their occupants within an area. This forms the basis of Figure 21 of the Guide.

The decision-making framework for type 1 (Figure 20 of the Guide), notes that for any greenfield site or strategic rezoning, shelter-in-place is not viable and evacuation is the only form of emergency response, otherwise ‘reconsider development in this area’. However, the framework for type 2 (Figure 21 of the Guide), notes that any infill development ‘consistent with current zoning’ shelter-in-place may be suitable if ‘consider restricting development types and apply controls’.

Based on this framework, and given that due to the flash flooding nature of the study area meaning that evacuation may not be relied upon exclusively, this would mean that any development sites without flood free access from the floodplain would not be eligible for rezoning.

However, development type whether that be within current zoning or rezoned infill development, is not a considered determinant of the flood risk associated with shelter-in-place. Therefore for infill rezoning similar to that proposed for Campsie, a broader consideration of flood risk is recommended. This approach is consistent with flood risk based assessment is recommended within Planning Circular

PS24-001 and other relevant guidance. This approach is currently being discussed between Stantec and DCCEEW for other projects of a similar nature.

To confirm potential impacts on the proposal of assessing the suitability of shelter-in-place, a review of development sites with direct access to PMF flood free land has been conducted. Conservatively, if evacuation is not possible in flash flooding areas, and shelter-in-place were not considered feasible based on EM01, then any development site without direct access out of the PMF extent would not be eligible for rezoning. The development sites this would apply to are shown as Brown hatched in **Figure 5-9** across the entire study area noting that not all of them are included in the area of intensification for this Planning Proposal. In **Figure 5-10**, only affected sites within intensification areas of the planning proposal are shown:

- yellow hatched for those proposed for both land use change and intensification;
- red hatched for those proposed only for land use change; and
- pink hatched for those proposed only for intensification.

As shown, given the number of sites potentially affected, this would have an impact on the proposal. As a result, if shelter-in-place is not deemed possible and these affected sites would not be able to rely on evacuation, then a conservative interpretation of the flood risk may limit the development potential of the sites shown in **Figure 5-10**. This is considered a conservative assessment of the flood risk, and is not supported by Stantec at this time, however this review is included as a potential worst-case assessment of the potential limitations flooding may place on the proposed development.

5.6 Special Flood Consideration and Vulnerable Developments

Ministerial Direction 4.1 under 4 notes planning proposals should contain provisions that apply to areas between the flood planning area and PMF extent to which Special Flood Considerations apply. These SFCs are also outlined within the optional LEP clause that Council has not adopted.

In accordance with the package, planning proposals should not 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.

With respect to proposed vulnerable developments, the only specified vulnerable / critical development in the proposal is the medical precinct proposed near Canterbury Hospital. This area is one of the highest elevated areas of the study area, and would generally be considered suitable based on the flood risk in this area.

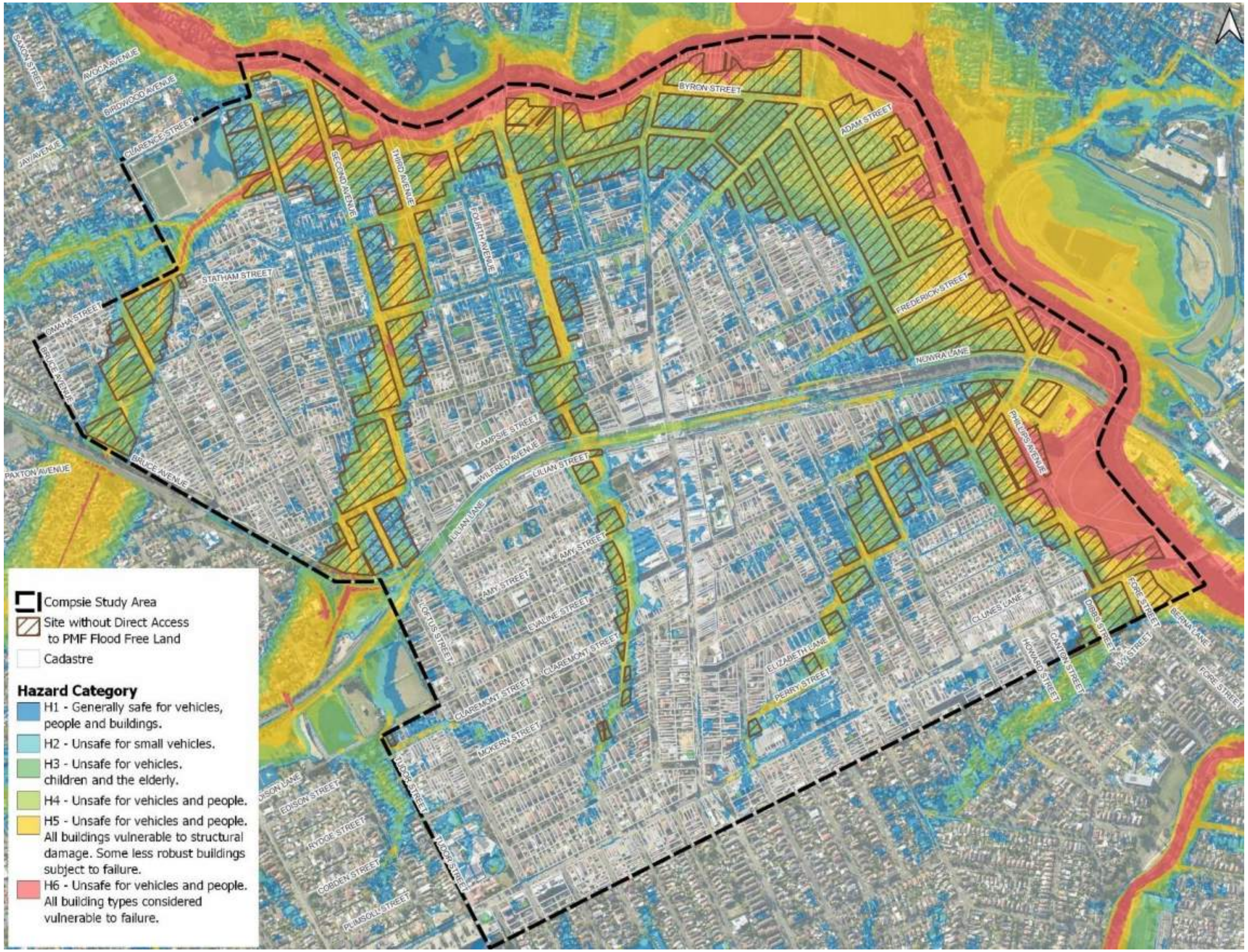


Figure 5-9 Sites Without Direct Access to PMF Flood Free Land – with PMF H1-H6 Hazard

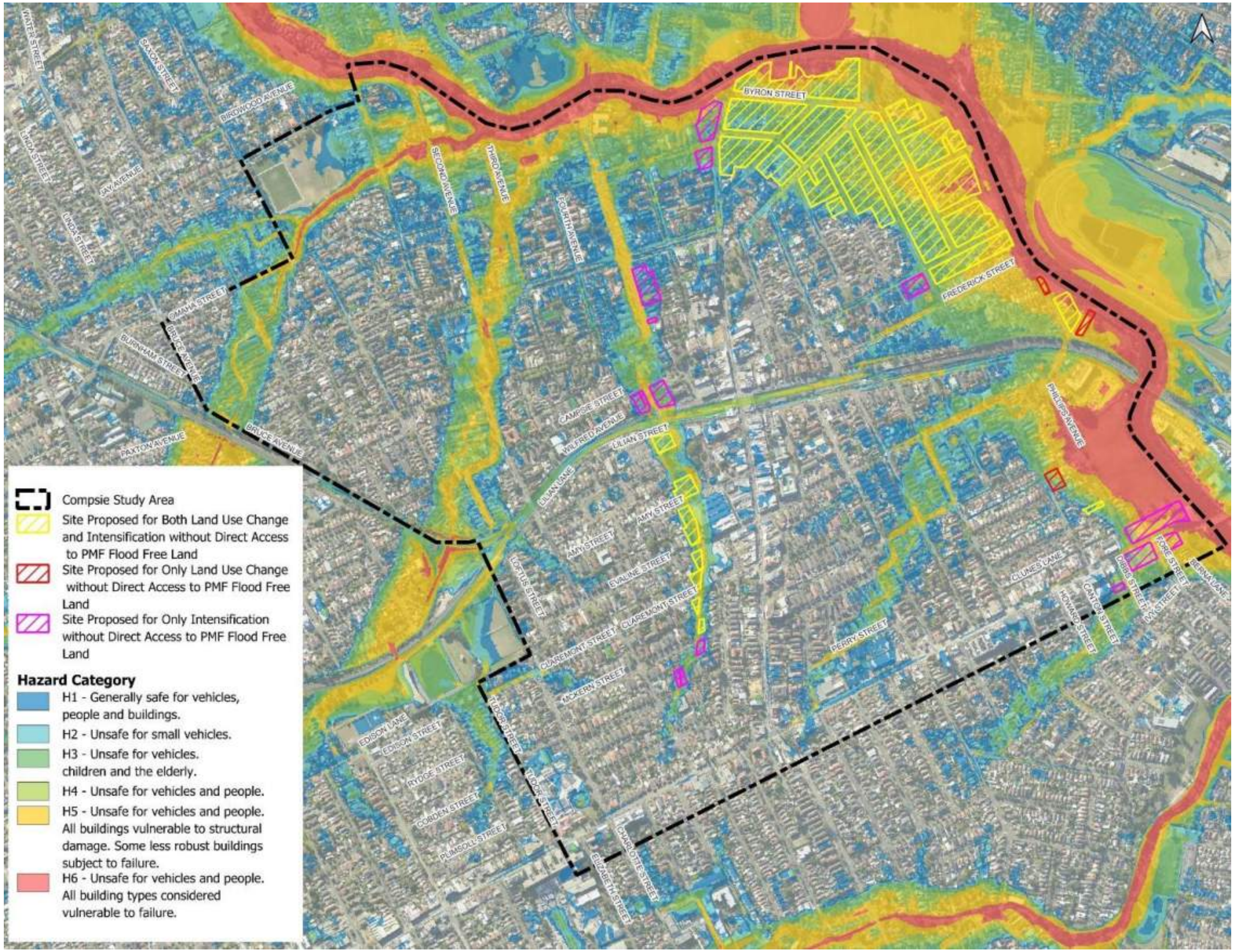


Figure 5-10 Sites Proposed for Changes to Land Use or Intensification Without Direct Access to PMF Flood Free Land – with PMF H1-H6 Hazard

6 Conclusion

6.1 Potential Flood Constraint Areas

Through this assessment, a number of areas were identified to be reviewed further in the next step of the Planning Proposal when getting developed for gateway stage assessment. These four flood constraint areas have been considered potentially limited by flood hazard (Spots 1 and 2 shown in Figure 5-4), or flood emergency response key areas (Spot 3 in Figure 5-6 and Spot 4 in Figure 5-8). Further consideration of their development potential should be conducted in the next stages of the planning proposal, potentially through a regional fill design, site amalgamation to improve evacuation routes, or other potential means to address their flood risk.

Furthermore, a more conservative assessment of development potential as it relates to flood risk has been conducted in response to provisions of Figure 20 of Section D4 of the FRM Guide EM01. Under this guidance, rezoning proposals should not consider flood shelter-in-place a viable form of emergency response. Combined with the flash flooding nature of the floodplain providing potential limitations on any flood evacuation, any sites without direct access to PMF flood free land may need to reconsider development. As shown in **Figure 5-10**, given the number of sites potentially affected, this would have an impact on the proposal. As a result, if shelter-in-place is not deemed possible and these affected sites would not be able to rely on evacuation, then a conservative interpretation of the flood risk may limit the development potential of the sites shown in **Figure 5-10**. This is considered a conservative assessment of the flood risk, and is not supported by Stantec at this time, however this review is included as a potential worst-case assessment of the potential limitations flooding may place on the proposed development.

6.2 Summary of Flood Review Outcomes

The Campsie Precinct Rezoning Proposal has been reviewed against the Ministerial Directions 4.1 as discussed in **Section 5**. A summary of each of the planning proposal requirements is included in **Table 6-1** below.

Table 6-1 Review of Study Area Flood Affectation Compared to Ministerial Direction Planning Proposal Requirements

Direction Provision	Comment
A planning proposal must include provisions that give effect to and are consistent with the NSW Flood Prone Land Policy, the principles of the Floodplain Development Manual 2005, the Considering flooding in land use planning guideline 2021, and any adopted flood study and/or floodplain risk management plan adopted by the relevant council	Yes, upon review it appears that the Planning Proposal adheres to the principles of all of these documents.

Direction Provision	Comment
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	Yes, all proposed rezoning does not fit within these categories and therefore are eligible changes.
A planning proposal must not contain provisions that apply to the flood planning area which: a) permit development in floodway areas, b) permit development that will result in significant flood impacts to other properties, c) permit development for the purposes of residential accommodation in high hazard areas, d) permit a significant increase in the development and/or dwelling density of that land, e) 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,	All of these conditions may reasonably be satisfied as follows: a) Floodway is generally confined to Cooks River channel and in very isolated locations in overland flow areas. It has very limited overlay on developable land, with negligible interaction with proposed intensification areas of the planning proposal. In accordance with these provisions, **Figure 5-3** shows that these floodway areas have not been considered as part of the Planning Proposal, b) It is not possible to assess flood impacts at this early pre-gateway Planning Proposal stage. There is no evidence that any site could be developed without ensuring no offsite flood impacts. This can be assessed in the next stage when design-related information about the proposed buildings is available, however this would still be a high-level impact assessment commensurate with the planning proposal stage of the development process. c) The 1% AEP high hazard is mapped against the land use zoning of the Planning Proposal in **Figure 5-4**. It shows that the high hazard is generally confined to Cooks River channel and public road reserves in most locations. However it marginally covers some portions of areas proposed for intensification without any proposed changes to existing land use on the Cooks River foreshore, including a small area between Linday Street and Gordon Street and another area on the southern part of Tasker Park. These two small areas have been shown as **Spot 1** and **Spot 2**, respectively, in **Figure 5-4.** In accordance with these provisions, these high hazard areas should be reconsidered for residential uses. However, as the high hazard extents are mostly quite narrow it is assumed that most sites will be only partially affected by high hazard floodwaters. Consideration could be given to re-aligning the high hazard flowpaths to consolidate the developable portion of a site or consideration could be given to elevating structures one level above the high hazard flowpath to maintain the flood conveyance up to the PMF and to allow for maintenance. d) It is assumed that the developable portions of these sites will be flood-free in the post-development condition. This assumption is based on adherence to CBC current Flood Planning Level (FPL) requirements for all proposed residential buildings to have all habitable floor levels suspended above the 1% AEP plus 0.5m freeboard (FPL). Through appropriate site design, and adherence to Council's flood-related development controls it is therefore assumed the relevant areas of the development sites will be elevated above the FPL and therefore intensification would be suitable in accordance with this provision. e) A high-level review of flood emergency response suggests that evacuation may be feasible for most of the Planning Proposal study area as most areas have rising road access to flood free land in the PMF event. Also within the Proposed Rezoning, there is no vulnerable development has been proposed.

Direction Provision	Comment
f) permit development to be carried out without development consent except for the purposes of exempt development or agriculture. Dams, drainage canals, levees, still require consent, g) 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 h) permit hazardous industries or hazardous storage establishments where hazardous materials cannot be effectively contained during the occurrence of a flood event.	f) It is not possible to assess this at this pre-gateway Planning Proposal stage. g) A high-level review of flood emergency response suggests that evacuation may be feasible for most of the Planning Proposal study area as most areas have rising road access to flood free land in the PMF event. This should be possible through site specific emergency response plans that do not increase the burden on emergency services or require significant road upgrades to enable evacuation. Flood emergency response key issue areas have been shown as black hatched areas in **Figure 5-5** to **Figure 5-8**. Among the flood emergency response areas there is only one site that has overlap with areas proposed for change to land use along with intensification. This area is shown as **Spot 3** in **Figure 5-6**. Further investigation of shelter-in-place potential of this site, or potential filling to provide greater flood immunity should be considered in future planning proposal stages. h) It is not possible to assess this at this pre-gateway Planning Proposal stage, the current DCP has specific requirements that do not permit hazardous material storage below a certain level which should address this concern for future development associated with the Master Plan. Appropriate DCP controls can be developed to address storage. Also, within the Proposed Rezoning, there is no hazardous material storage has been proposed.
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 a), b), d), e), f) from item 3 above. An additional requirement for this area is if a planning proposal is likely to affect the safe occupation of and efficient evacuation of the lot	The same responses as noted in the relevant items above apply to Special Flood Considerations. The medical precinct proposed near Canterbury Hospital. This area is one of the highest elevated areas of the study area, and would generally be considered suitable based on the flood risk in this area.
For the purposes of preparing a planning proposal, the flood planning area must be consistent with the principles of the Floodplain Development Manual 2005 or as otherwise determined by a Floodplain Risk Management Study or Plan adopted by the relevant council	In accordance with this provision, the 1% AEP plus 500mm freeboard should be used when assessing the planning proposal associated with the Master Plan. This requirement is also in accordance with Part 2.2 of the draft Consolidated Canterbury-Bankstown DCP.

Overall, this flood planning review concludes that generally the proposed intensification of development and changes in zoning in the floodplain in this Planning Proposal are in accordance with the provisions of the NSW Flood Prone Land 2021 as discussed above. However, constraint areas as discussed in **Section 6.1** are to be considered further in the next stage of the Planning Proposal.

It is noted that this is a high-level review of the flood conditions of the study area. These requirements should be reviewed in further detail and more formally during the development stage. Included within this may be further identification and development of potential flood mitigation measures to facilitate any potential development. Appropriate DCP controls can be developed to address key flooding matters within the study area.

7 References

Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), 2019, *Australian Rainfall and Runoff: A Guide to Flood Estimation*, Commonwealth of Australia

Canterbury-Bankstown Council (2021) *Campsie Town Centre Master Plan Draft for Exhibition*, March

MWH+PB (2009) *Cooks River Flood Study*, February

NSW Government (2005) *Floodplain Development Manual*

NSW Government (2021) *Considering flooding in land use planning: Guideline*, July 2021

NSW Government (2021) *Environmental Planning and Assessment Amendment (Flood Planning) Regulation 2021*

NSW Government (2021) *Local Planning Direction - Section 9.1(2) of the Environmental Planning and Assessment Act 1979 - Flooding*

NSW Government (2021) *Planning Circular - Considering flooding in land use planning: guidance and statutory requirements*

NSW Government (2021) *Standard Instrument (Local Environmental Plans) Amendment (Flood Planning) Order 2021*

NSW Government (2021) *State Environmental Planning Policy Amendment (Flood Planning) 2021*

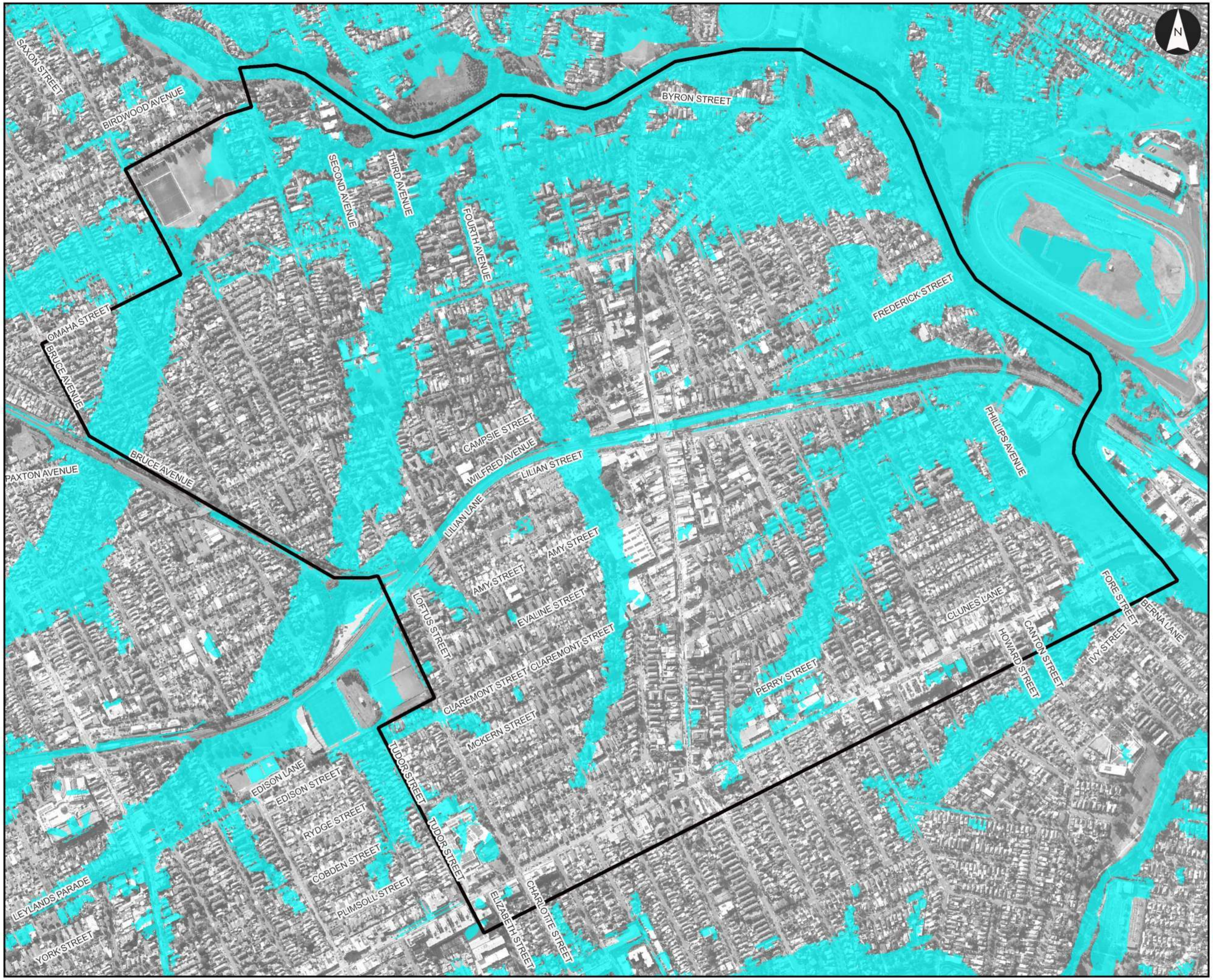
Smith, G and Cox, R. (2019) *Book 6: Flood Hydraulics* in Australian Rainfall and Runoff - A Guide to Flood Estimation, Commonwealth of Australia

Stantec formerly Cardno (2016) *Cooks River Final Overland Flow Study*

Stantec (2024) *Flood Planning Assessment for Belmore, Lakemba and Canterbury Local Centre Master Plans and Belfield Small Village Centre Master Plan*

Appendices

Appendix A Flood Mapping Figures



1% AEP Updated Existing Flood Model
Flood Planning Area

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 1

Legend

- Campsie Study Area
- Flood Planning Area

Notes:
1. Map displayed in EPSG:28356

References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000

Key Map

1% AEP Updated Existing Flood Model Flood Depth

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 2

Legend

Compsie Study Area
0.5m Flood Level Contours

Flood Depth (m)

0.00 to 0.10
0.10 to 0.50
0.50 to 0.70
0.70 to 1.00
1.00 to 1.50
1.50 to 3.00
> 3.00

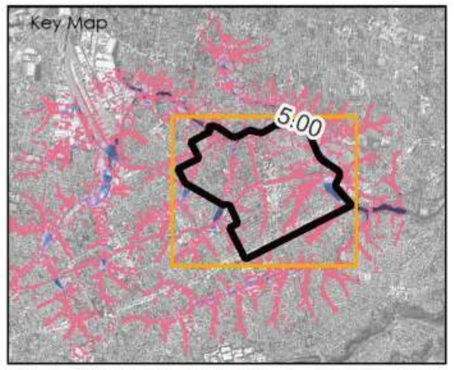
Notes:
1. Map displayed in EPSG:28356

References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000



1% AEP + Climate Change Updated Existing Flood Model Flood Depth

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 3

Legend

- Campsie Study Area
- 0.5m Flood Level Contours

Flood Depth (m)

- 0.00 to 0.10
- 0.10 to 0.50
- 0.50 to 0.70
- 0.70 to 1.00
- 1.00 to 1.50
- 1.50 to 3.00
- > 3.00

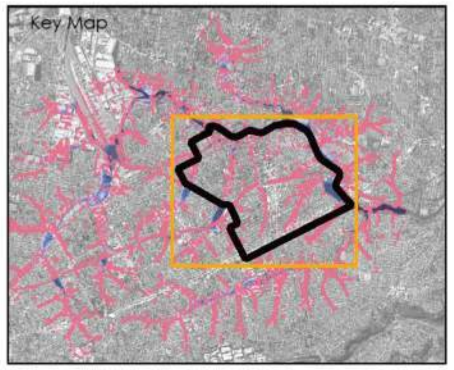
Notes:
1. Map displayed in EPSG:28356

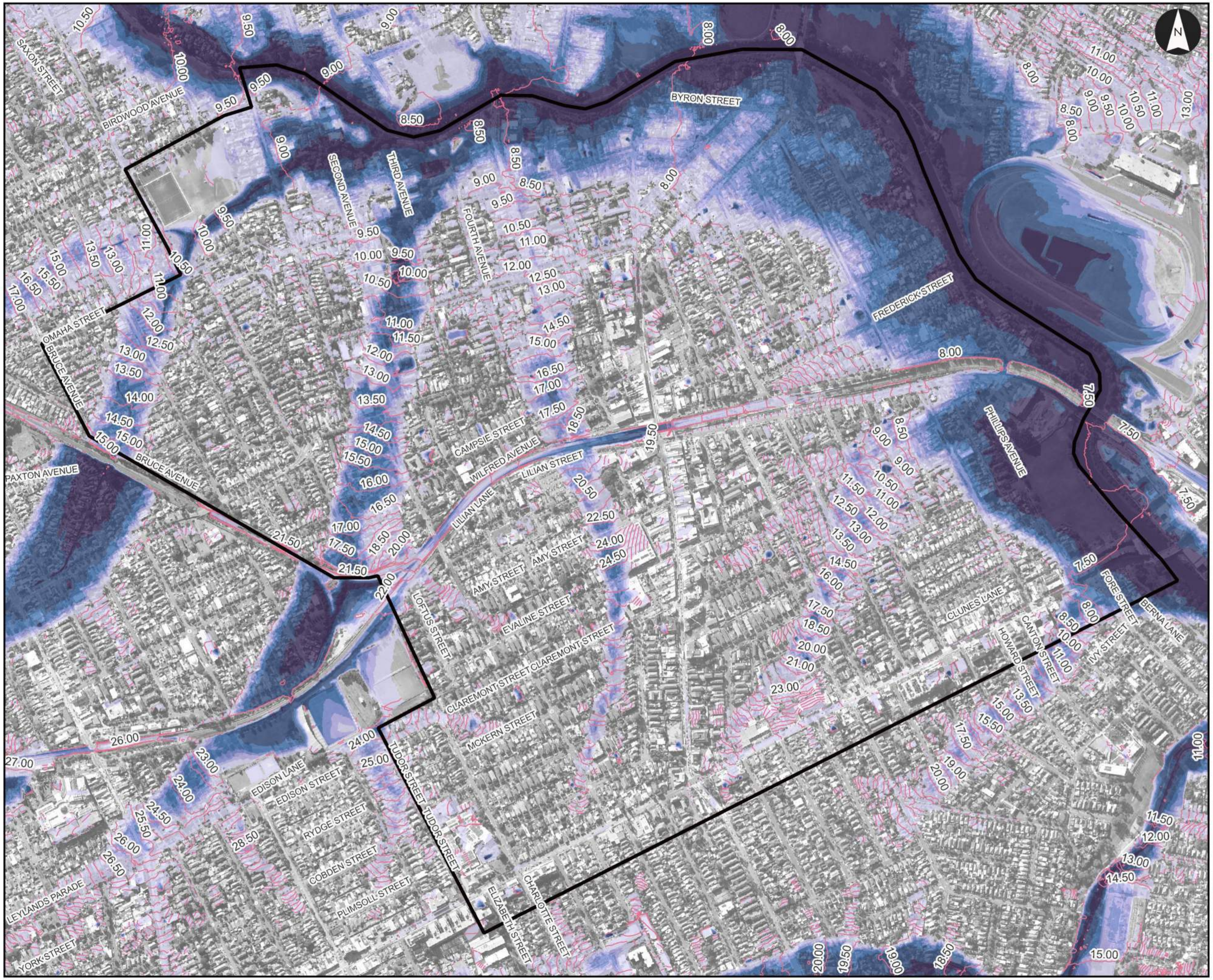
References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000





PMF Updated Existing Flood Model Flood Depth

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 4

Legend

- Campsie Study Area
- 0.5m Flood Level Contours

Flood Depth (m)

- 0.00 to 0.10
- 0.10 to 0.50
- 0.50 to 0.70
- 0.70 to 1.00
- 1.00 to 1.50
- 1.50 to 3.00
- > 3.00

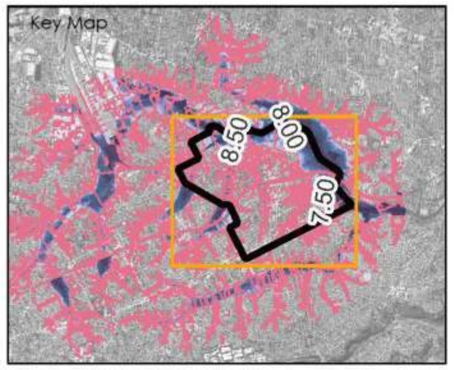
Notes:
1. Map displayed in EPSG:28356

References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000



1% AEP Updated Existing Flood Model Flood Velocity

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 5

Legend

Compsie Study Area

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

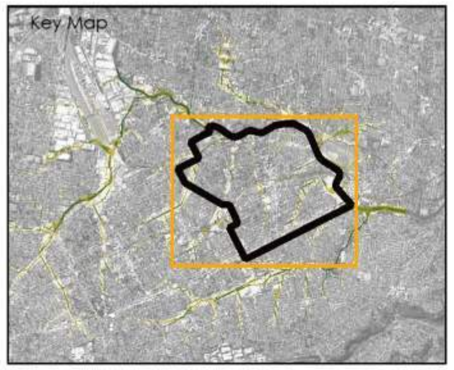
Notes:
1. Map displayed in EPSG:28356

References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000



PMF Updated Existing Flood Model Flood Velocity

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 6

Legend

Campsie Study Area

Flood Velocity (m/s)

- 0.00 to 0.50
- 0.50 to 1.00
- 1.00 to 1.50
- 1.50 to 2.00
- 2.00 to 3.00
- > 3.00

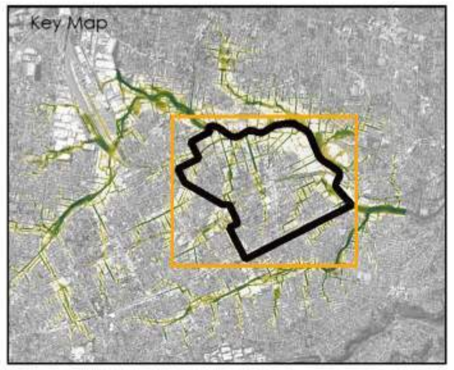
Notes:
1. Map displayed in EPSG:28356

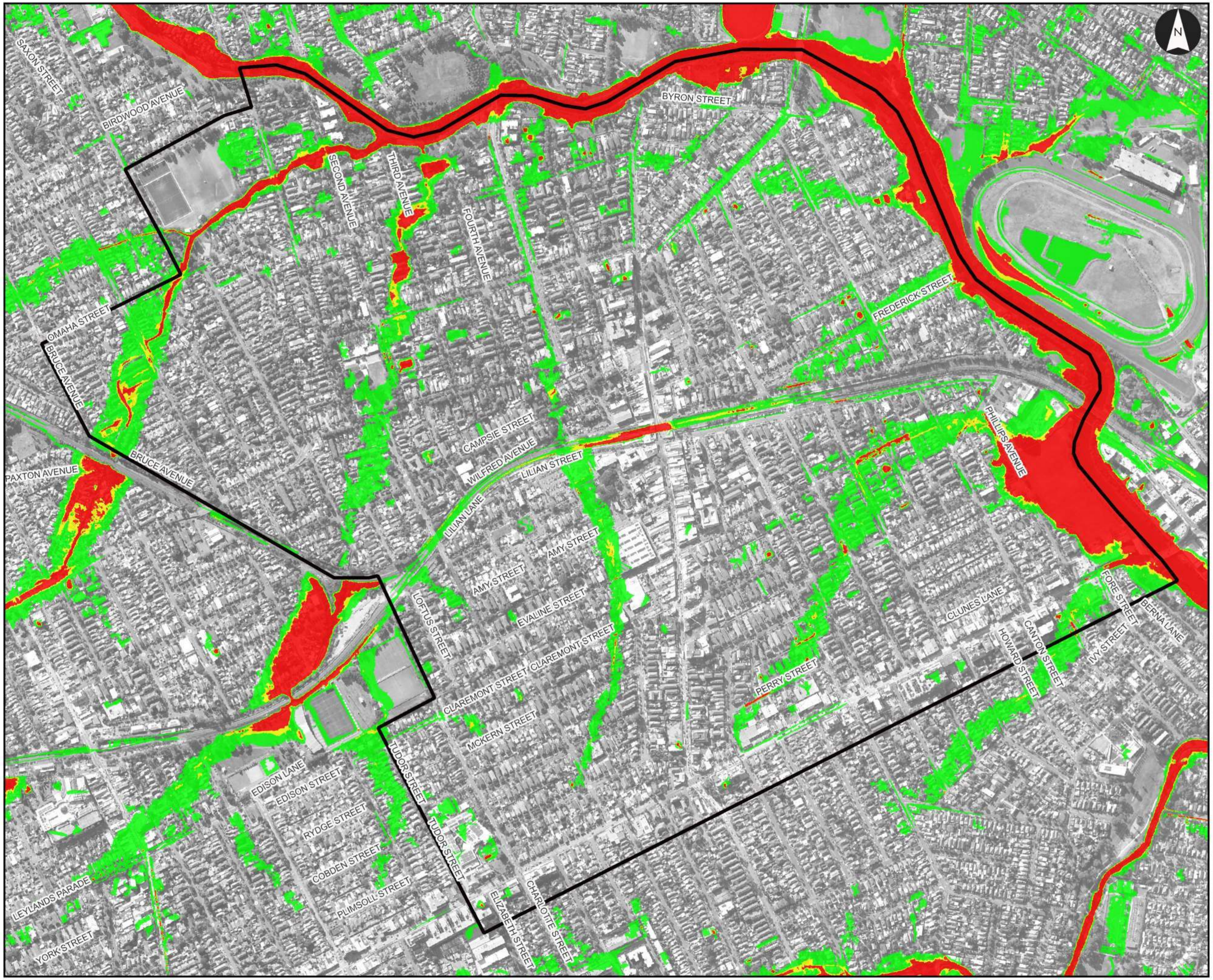
References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000





1% AEP Updated Existing Flood Model Provisional Hazard

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 7

Legend

Compsie Study Area

Provisional Hazard

- Low
- Transitional
- High

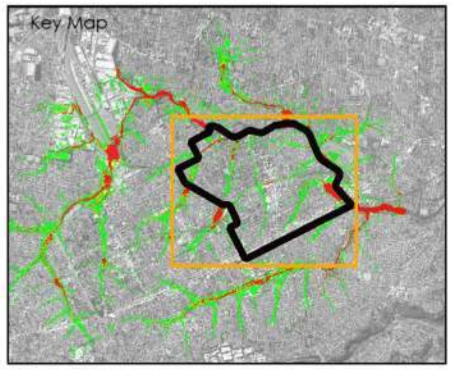
Notes:
1. Map displayed in EPSG:28356

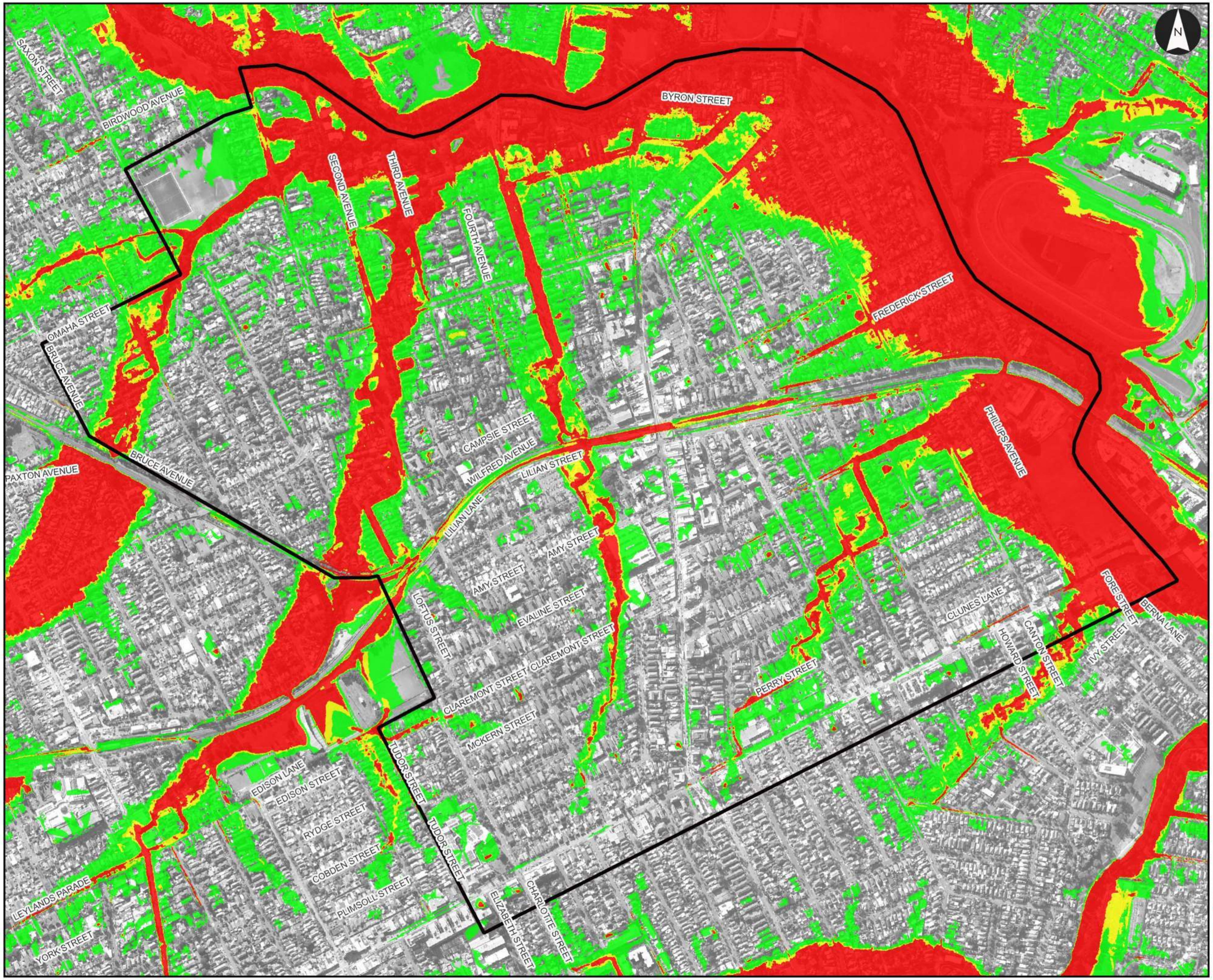
References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000





PMF Updated Existing Flood Model Provisional Hazard

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 8

Legend

Compsie Study Area

Provisional Hazard

- Low
- Transitional
- High

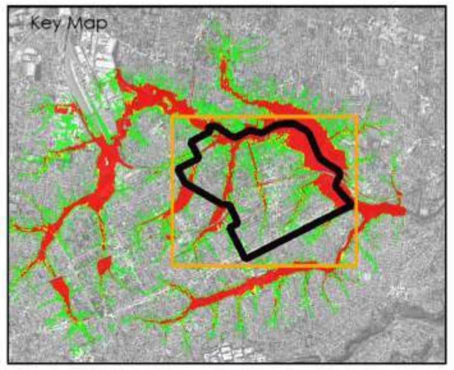
Notes:
1. Map displayed in EPSG:28356

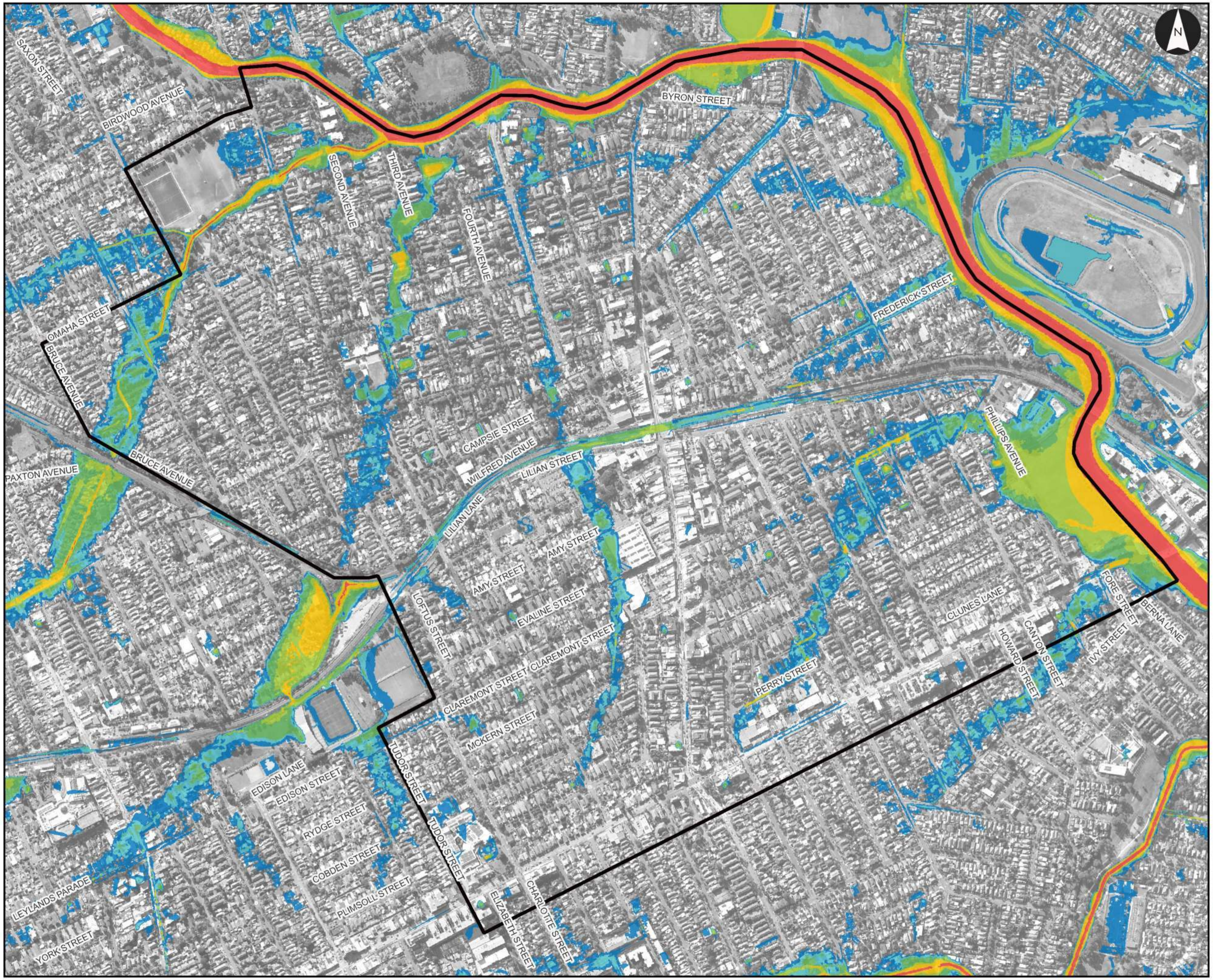
References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000





1% AEP Updated Existing Flood Model Hazard Category

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 9

Legend

- Campsie Study Area

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles, children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

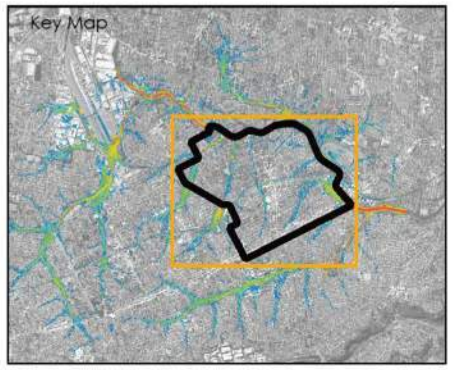
Notes:
1. Map displayed in EPSG:28356

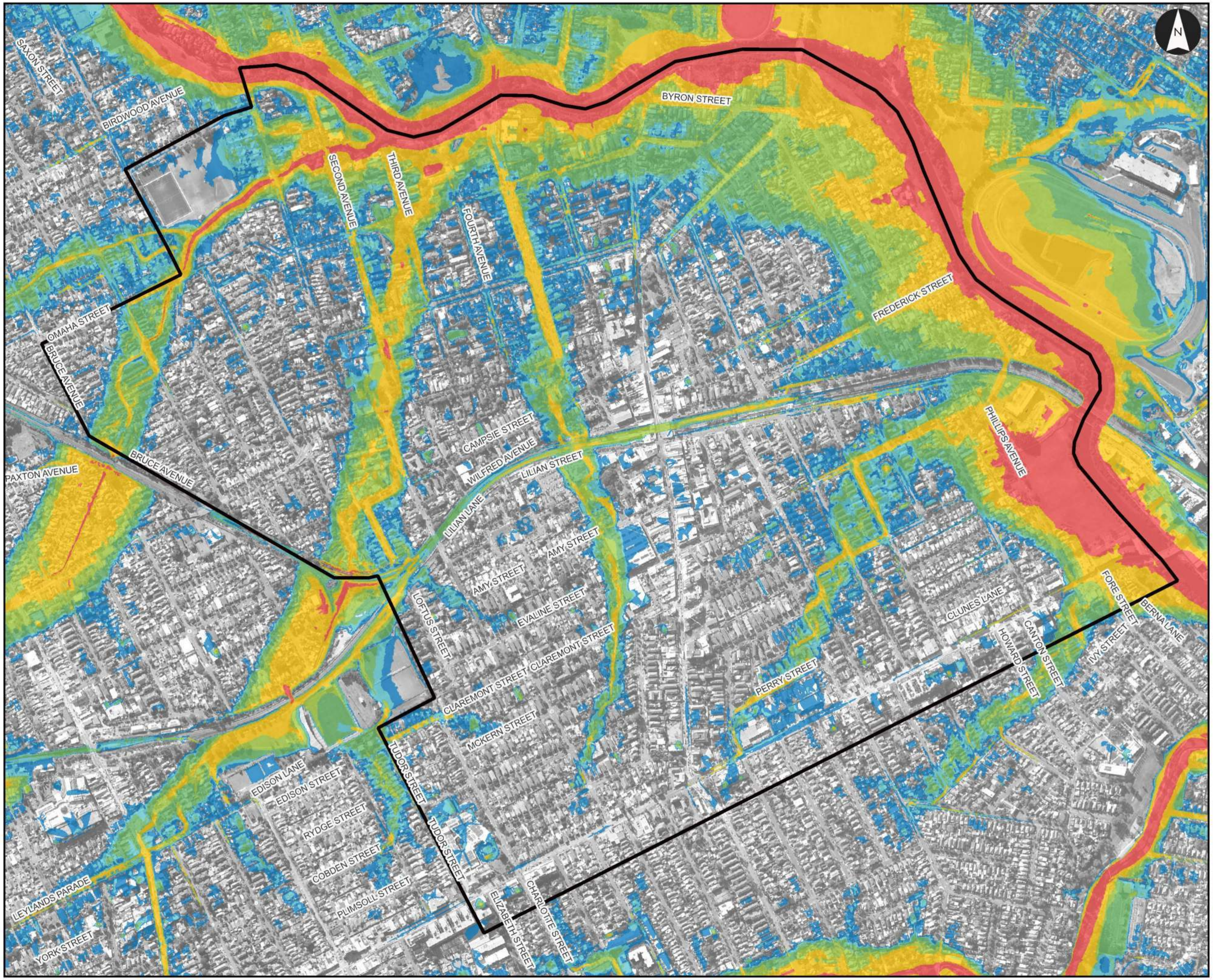
References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000





PMF Updated Existing Flood Model Hazard Category

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 10

Legend

Campsie Study Area

Hazard Category

- H1 - Generally safe for vehicles, people and buildings.
- H2 - Unsafe for small vehicles.
- H3 - Unsafe for vehicles, children and the elderly.
- H4 - Unsafe for vehicles and people.
- H5 - Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust buildings subject to failure.
- H6 - Unsafe for vehicles and people. All building types considered vulnerable to failure.

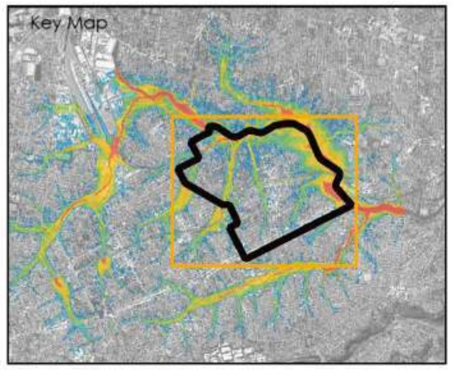
Notes:
1. Map displayed in EPSG:28356

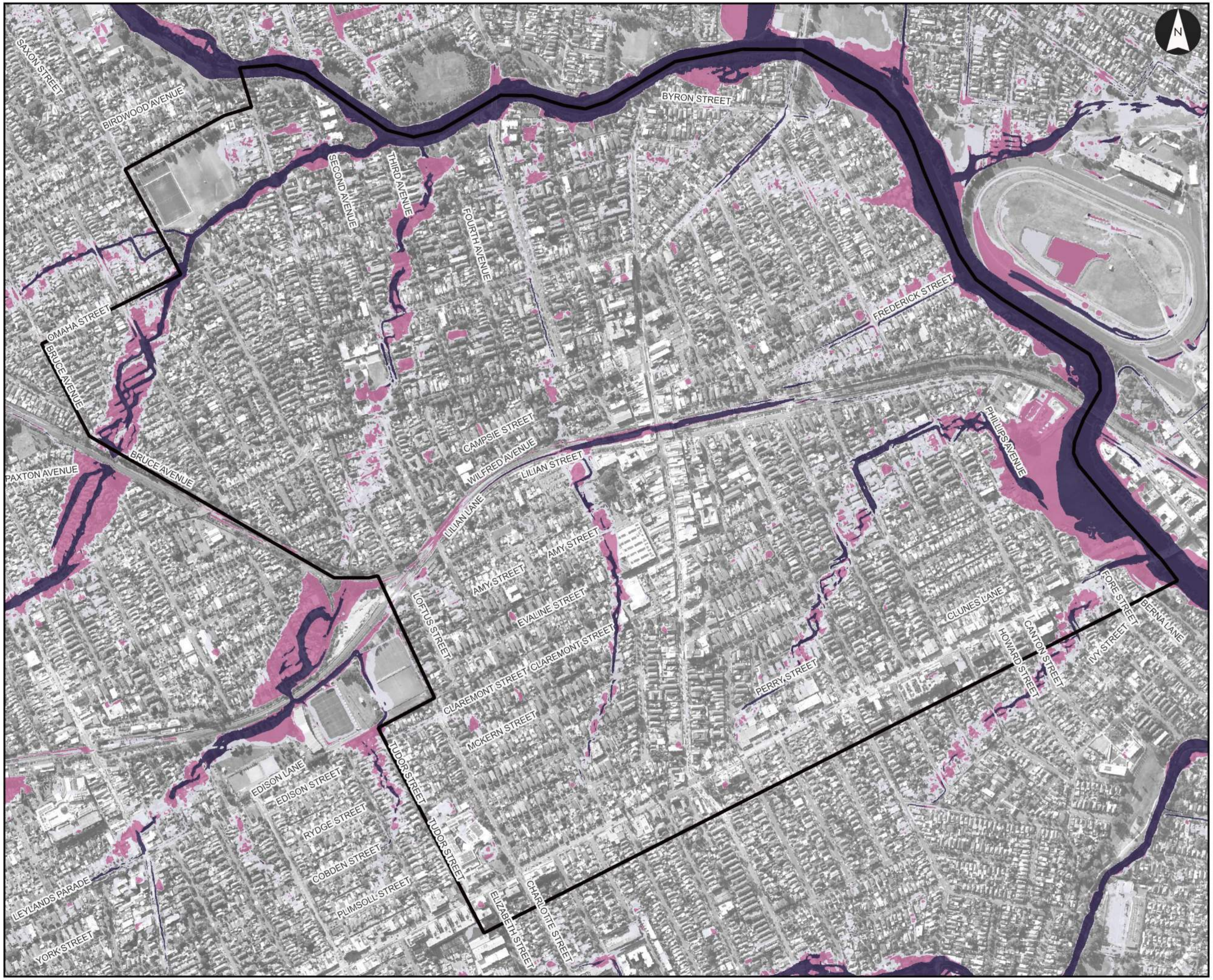
References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000





1% AEP Updated Existing Flood Model
Hydraulic Category

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 11

Legend

- Campsie Study Area

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

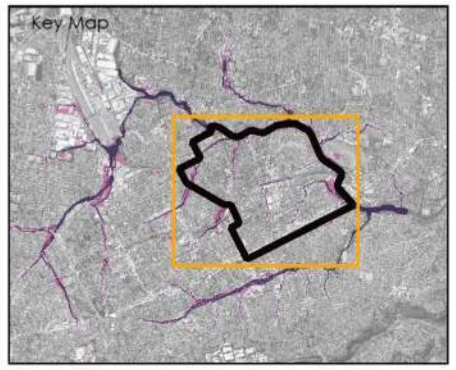
Notes:
1. Map displayed in EPSG:28356

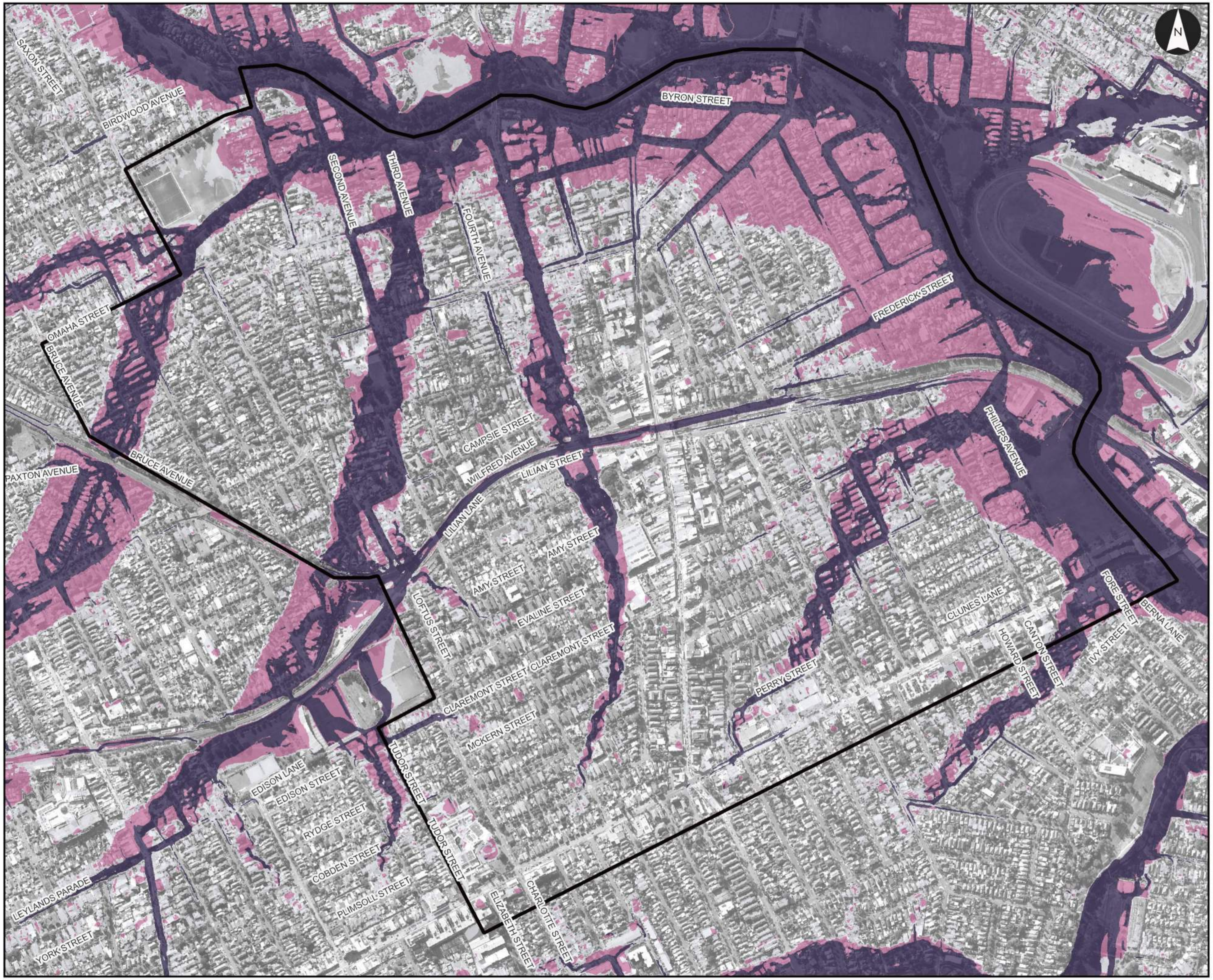
References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000





PMF Updated Existing Flood Model Hydraulic Category

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 12

Legend

- Compsie Study Area

Hydraulic Category

- Flood Fringe
- Flood Storage
- Floodway

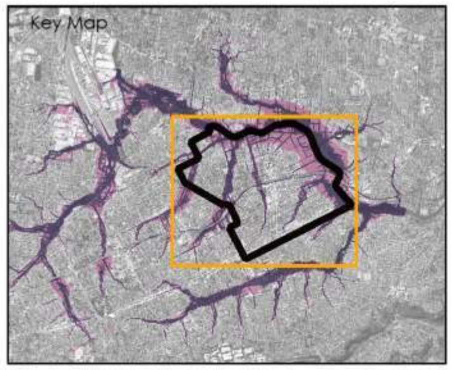
Notes:
1. Map displayed in EPSG:28356

References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000



1% AEP + Climage Change Less 1% AEP Updated Existing Flood Model Water Level Difference

Project: Campsie Flood Risk Assesment

Client: Canterbury-Bankstown Council
Project Code: 300204096
Drawn By: HR, Checked By: AP
Date: (2024-08-22)
Figure No: 13

Legend

Compsie Study Area

Wet/Dry Analysis

- Was Wet, Now Dry
- Was Dry, Now Wet

Water Level Difference (m)

- < -0.50
- -0.50 to -0.20
- -0.20 to -0.10
- -0.10 to -0.05
- -0.05 to -0.01
- -0.01 to 0.01
- 0.01 to 0.05
- 0.05 to 0.10
- 0.10 to 0.20
- 0.20 to 0.50
- > 0.50

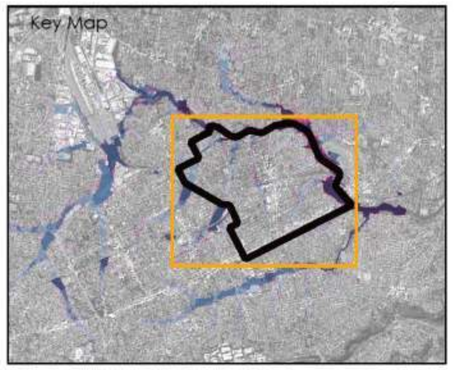
Notes:
1. Map displayed in EPSG:28356

References:
1. Metro Map
2. Road NSW

Stantec

90 0 90 180 270 360 m

Scale at A3: 1:9000



Stantec

Stantec is a global leader in sustainable architecture, engineering, and environmental consulting. The diverse perspectives of our partners and interested parties drive us to think beyond what's previously been done on critical issues like climate change, digital transformation, and future-proofing our cities and infrastructure. We innovate at the intersection of community, creativity, and client relationships to advance communities everywhere, so that together we can redefine what's possible.