ENGENY

MELBOURNE WATER AND MOONEE VALLEY CITY COUNCIL

Moonee Valley Municipal Flood Mapping

Final Report

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8 MAY 2026

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EXECUTIVE SUMMARY

Most established suburbs in metropolitan Melbourne have areas affected by stormwater overland flows. These flows come from intense rainfall when major storms affect urban areas. Moonee Valley City Council (Council) is the local drainage authority for 4,300 hectares of urbanised catchments north-west of Melbourne's city centre. Council has a role to manage stormwater risk in these catchments. This includes having a stormwater map, which is imbedded into statutory mechanisms. Then, risks can be managed when land development is proposed.

In recent years Council has completed a range of tasks to identify and manage risks for stormwater overland flows. Collectively, these represent a robust approach to informing a Stormwater Map. A chronological summary of these studies and associated events, is given below.

2019-2020 – Initial Modelling and Stormwater Map

Initial stormwater overland flow modelling and mapping was completed across the entirety of the City of Moonee Valley with a focus on defining stormwater overland flow paths where Council is the relevant drainage authority. This study was completed to the Australian Rainfall Runoff 2019 version 4.1 (ARR v4.1) guidelines.

2019-2020 - Mitigation Assessment

Several locations were identified as a priority for investigation because of stormwater flows impacting private properties in recent years, as reported by the local community. Assessing these locations has provided Council with an understanding of priority and future risk areas by testing and assessing the effectiveness of available options to reduce risk at each site.

2022 - Community Consultation

In 2022, Council consulted with residents across the City of Moonee Valley via Council's 'your say' website.

Under the heading of "Better Flood Planning", Council sought local knowledge of historical stormwater overland flows within the municipality with the intent of using that information to help Council plan, mitigate risk and prepare response initiatives alongside Melbourne Water.

The information captured via this activity was used to validate the modelling results created from Council's overland flow models.

2021-2024 – Melbourne Water Involvement

Melbourne Water collaborated with Council to pursue a 'whole-of-catchments' approach for both the smaller (local) and larger (main) drainage catchments. This included an independent peer review of the models developed for the initial stormwater map in 2019-2020.

2024 – Building Act Designation and PSA Ready Overlays

All work completed was then used to prepare updated Stormwater Maps for the city's local drainage catchments, where Council is the relevant drainage authority. This resulted in reviewed stormwater modelling mapping for the 1% Annual Exceedance Probability (AEP) event (or 1 in 100-year event). Predictions of climate change was factored into this work.

A Planning Scheme Amendment (PSA) process will be required to adopt the proposed Special Building Overlay that has also been developed as part of this work.

A 'Building Regulations 153' Overlay (BR153 Overlay) was developed to accompany, or precede, any existing or future planning zones/overlays to assist Council in assessing future development proposal in accordance with Buildings Regulations (2018).

2025 – Special Building Overlay and GIS Deliverables Update

In 2025, the May 2024 Council Special Building Overlay was updated to a revised flood depth filtering criterion. Subsequently, the demarcation between the Council and Melbourne flood extents was also updated. After approval of both Council and Melbourne Water flood overlays, a new set of GIS deliverables were produced.

The 'Building Regulations 153' Overlay (BR153 Overlay) has not been affected.

LIST OF TERMS & ABBREVIATIONS

The following terms and abbreviations are used in this report.

Term (Abbreviation)	Explanation
Annual Exceedance Probability (AEP)	Refers to the probability or risk of a rainfall event of a given magnitude (intensity and duration) occurring or being exceeded in any given year. A 90 % AEP event has a high probability of occurring or being exceeded; it would occur quite often and would be a relatively minor rainfall event. A 1 % AEP event has a low probability of occurrence or being exceeded; but is likely to cause extensive damage. A 1 % AEP event has the same probability as a 1 in 100-year ARI.
AEP bin	According to ARR v4.1, AEP bins are groupings of standard rainfall temporal patterns based on the AEP of a storm event. Each AEP bin contains 10 temporal patterns that provide realistic storm shapes for flood modelling and take into consideration storm location and duration.
Areal Reduction Factor (ARF)	The ratio between the design values of areal average rainfall and point rainfall (measured at a single location), computed for the same duration and Annual Exceedance Probability (AEP), is called the Areal Reduction Factor (ARF). This coefficient is used to convert point rainfall data to an average rainfall value over a larger area. The ARF accounts for the fact that larger catchments are less likely than smaller catchments to experience high intensity storms simultaneously over the whole of the catchment area.
Australian Height Datum (AHD)	A common national surface level datum approximately corresponding to mean sea level. Introduced in 1971 to eventually supersede all earlier datums.
Australian Rainfall and Runoff 2019 version 4.1 (ARR v4.1)	Australian Rainfall and Runoff (ARR v4.1) is the national guideline for flood estimation in Australia, providing updated, evidence-based methods and data for assessing rainfall, runoff, and flood risk across diverse catchments.
Average Recurrence Interval (ARI)	Refers to the average time interval between a given storm event magnitude occurring or being exceeded. For instance, a 100-year ARI event is expected to be exceeded on average once every 100 years. The AEP is the ARI expressed as a percentage.
Bureau of Meteorology (BoM)	Australia's national agency responsible for providing weather forecasts, warnings, monitoring, and climate information. Since 2008, the Bureau of Meteorology (BoM) has been responsible for delivering water data throughout Australia.
Flood Modelling Decision Change Note (DCN)	DCNs are formal updates to the current Melbourne Water AM ST 6200 Flood Mapping Project Specifications documentation (latest release is 2025). In the case of live/in progress studies, not all DCNs need to be implemented – typically just those applicable to future stages of work, but all are considered.
Department of Energy, Environment and Climate Action (DEECA)	Formerly known as DELWP (pre-January 2023), DEECA is a Victorian Government department responsible for managing energy policy, environmental protection, climate action, biodiversity, water resources, and land management.

Term (Abbreviation)	Explanation
Digital Elevation Model (DEM)	A digital representation of the Earth's surface topography, showing elevation data in a grid format. Each cell in the model contains a value representing ground height above a reference level.
Effective Impervious Area (EIA) or Directly Connected Area (DCA)	Impervious areas which are directly connected to underground drains or concrete lined channels. Examples include roofs with downpipes connecting to drains, road pavement and large carparks.
Freeboard	A factor of safety above the relevant design standard (e.g., 1 in 100 year) stormwater level. Is typically used for setting of floor levels or crest heights of levees. It is usually expressed as a height above the level of the design storm event.
Feature Manipulation Engine (FME)	A spatial data integration platform that enables the translation and conversion of geospatial data across different formats and systems. FME supports spatial and non-spatial data types, allowing users to create repeatable workflows for data cleaning, validation, and translation without extensive coding.
Fraction Impervious (FI)	The ratio of area covered by impervious surfaces to the total land area in each site or catchment. It is a dimensionless value between 0 and 1 that indicates how much of the land does not allow water to infiltrate, impacting runoff and drainage characteristics.
Geographic Information System (GIS)	A computer-based system used to create, manage, analyse, and display spatial or geographic data. GIS connects data to a map. Two of the most used GIS platforms are: QGIS - an open-source GIS platform and ArcGIS - a commercial GIS platform
Hydraulics	The term given to the study of water flow in a river, channel, or pipe. In particular, for the evaluation of flow parameters - such as depth and velocity.
Hydrograph	A graphical representation of water flow (discharge – m^3s^{-1}) versus time at a specific location in a watercourse, drainage system, or catchment outlet.
Hydrology	Terms given to the study of the rainfall and runoff. Determining how much rain is likely to fall in each event and how much of that rain will become runoff.
Hyetograph	A graphical representation of rainfall depth or intensity (in mm or mm/hr) versus time for a specific storm event or design rainfall scenario.
Impervious	A ground covering or surface which water cannot pass though. Examples include roofs, concrete and asphalt. The opposite of impervious is pervious.
Indirectly Connected Area (ICA)	Includes all small pervious areas within a catchment (gardens, nature strips, pocket parks, lawns) and impervious areas which are not directly connected to an underground drain or concrete channel (runoff flows onto a pervious surface). Examples of impervious areas which are not directly connected include footpaths next to a nature strip, concrete or gravel paths through parks, roof of a garden shed where water falls onto the garden, most residential driveways and landscaped paving.
Intensity Frequency Duration (IFD)	Statistical analysis of rainfall, describing the rainfall intensity (mm/hr), frequency (probability measured by the AEP), duration (hrs). This analysis is used to generate design rainfall estimates.

Term (Abbreviation)	Explanation
Land Subject to Inundation Overlay (LSIO)	A land subject to inundation overlay is used to designate areas that are subject to overland flow from waterways.
Light Detection and Ranging (LiDAR)	Airborne surveying technology that provides a regularly spaced grid (one-metre horizontal interval in this case) of ground levels. The data allows for the representation of elevations along waterways and other key topographical features across the project area.
Melbourne Water AM ST 6200 Flood Mapping Project Specifications (Melbourne Water Project Specification [20xx])	This document provides key project specifications and requirements to this Project. In this report, this document will be referred to as the 'Melbourne Water Project Specifications [YEAR OF RELEASE]'. As each of the Melbourne Water Project Specifications 2019, 2021 ,2023 and 2025 documents were used during this project, the shorthand will specify which release is being referenced for each instance.
Pervious Area (PA)	A ground covering or surface which water can pass though. Examples include gardens, grass (lawns, nature strips, ovals) and other green landscaped areas. The opposite of pervious is impervious.
Planning Scheme Amendment (PSA)	A formal change or update to a local government's planning scheme, which sets out land use policies, zoning, and development controls. Amendments are made to respond to new planning needs, policy changes, or environmental considerations. Planning schemes may be modified to reflect updated flood data or risk assessments.
RORB (RunOff Routing Burroughs)	Hydrological modelling software used in this study to calculate the runoff (or excess rainfall) generated for rainfall events.
Special Building Overlay (SBO)	Special Building Overlays designate areas at risk of flooding when the capacity of Melbourne Water and council infrastructure is exceeded.
Sub-Grid Sampling (SGS)	Sub-grid sampling (SGS) enables TUFLOW to incorporate high-resolution Digital Terrain Models (DTMs) or Triangulated Irregular Networks (TINs) by sampling terrain at sub-cell resolution, improving the representation of topography within each computational cell.
Total Impervious Area (TIA)	The sum of all impervious surfaces within a defined land area or catchment.
TUFLOW	Hydraulic modelling software used in this study to simulate the flow of stormwater through the project area. The model uses numerical equations to describe the water movement.
Victoria State Emergency Service (VICSES)	A volunteer-based emergency service which plays a pivotal role in emergency management, focusing on preparedness, response, and recovery. VICSES provides information on flood 'hotspot' locations.

1. INTRODUCTION

1.1 Study Overview

The Moonee Valley Flood Mapping Project commenced in 2019, when Moonee Valley City Council commissioned flood mapping for the City of Moonee Valley. In 2021, Melbourne Water joined the project as a key stakeholder and expanded the scope to include Melbourne Water assets and flow paths which involved updates to the 2020 flood models. Additionally, in 2024, Engeny was provided with updated requirements for the final flood mapping deliverables which led to the production of a new set of deliverables in accordance with the Melbourne Water Flood Mapping Project Specification (2025). As outlined in the glossary, in the case of live / in progress studies, not all DCNs need to be implemented – typically just those applicable to future stages of work, but all are considered.

The Moonee Valley Flood Mapping project consisted of the complete flood mapping of a four drainage catchments within the City of Moonee Valley including:

- Maribyrnong Lower (ML),
- Moonee Ponds Creek Lower (MPCL),
- Moonee Ponds Creek Upper (MPCU), and
- Steele Creek (SCrk).

Four flood models were developed for each of the catchments listed above to comprehensively flood map the Council and Melbourne Water drainage assets. The Steele Creek catchment model extends beyond the City of Moonee Valley into the municipalities of Hume and Brimbank, enabling comprehensive flood mapping of Melbourne Water drainage assets across the full catchment. Explicit modelling and mapping of Maribyrnong River and Moonee Ponds Creek was not included in the scope. Please refer to Figure 1.1 for a study overview and locations of the four catchment models.

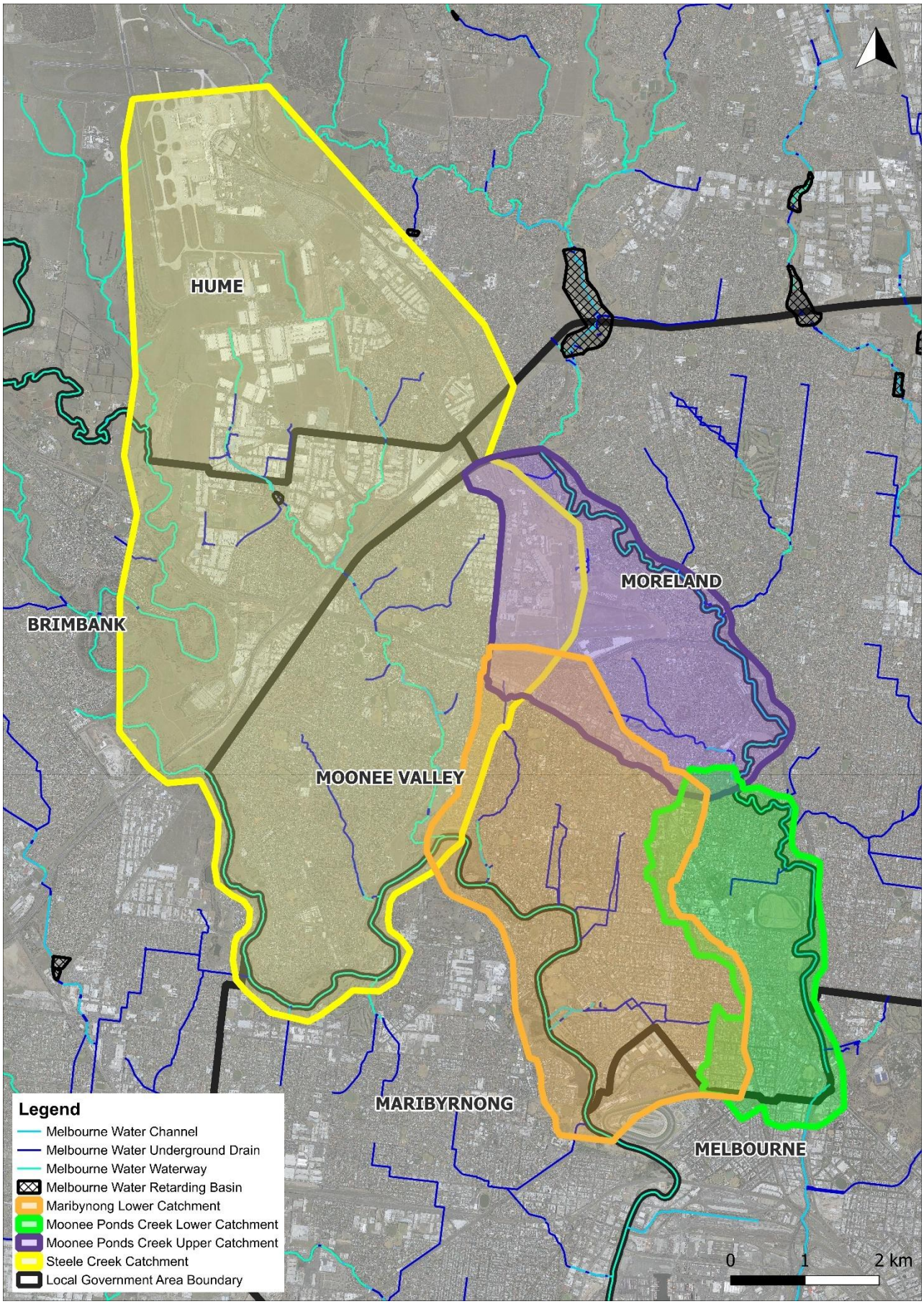


FIGURE 1.1: STUDY AREA AND CATCHMENT LAYOUT PLAN

1.1.1 Planning and Jurisdiction Information

The study area comprises an area of approximately 60 square kilometres (km^2), covering portions of the Hume (~11 km^2), Brimbank (~6 km^2) and Moonee Valley (~43 km^2) municipalities. Land use is predominately medium to high density residential, with exception of vast areas of two airports (Melbourne and Essendon Airports) zoned as Commonwealth Land, and some commercial and industrial areas located along the major roads and near to the two airports. There are also several reserves scattered across the study area and stretching along the waterway reserve corridors.

The drainage system within the study area includes both Melbourne Water and Council drainage assets. Table 1.1 summarises the key Melbourne Water drains within the Moonee Valley municipality.

TABLE 1.1: MELBOURNE WATER DRAINS IN STUDY AREA

Catchment	Drain ID	Asset Name	Start Location	End Location
Moonee Ponds Creek Upper	4330	Five Mile Creek	Bulla Road	Moonee Ponds Creek (Lower)
	4331	Magdala Avenue Main Drain	Alf Pearce Reserve	Five Mile Creek
	4344	Mascoma Street Drain	Mascoma Street	Moonee Ponds Creek (Upper)
	4350	Moonee Ponds Creek (Upper)	Albion-Broadmeadows Rail Bridge	Moonee Ponds Creek (Lower)
	R006	Essendon North Reservoir	Essendon North Reservoir	Quintus Avenue
Moonee Ponds Creek Lower	4314	Bent Street Main Drain	Pascoe Vale Road	Moonee Ponds Creek (Lower)
	4310	Moonee Ponds Creek (Lower)	Moreland Road	Racecourse Road
Maribyrnong Lower	4223	Ascot Vale Main Drain	Ascot Vale Road	Maribyrnong River (Lower)
	4224	Clarinda Rd Diversion Drain	Clarinda Park	Maribyrnong River (Lower)
	4225	Holmes Rd Main Drain	Washington Street	Maribyrnong River (Lower)
	4226	Aberfeldie Main Drain	Forrester Street	Maribyrnong River (Lower)
	4227	Hoffmans Rd Main Drain	Keilor Road	Maribyrnong River (Lower)
Steele Creek	4230	Steele Creek	Annadale Road	Maribyrnong River
	4231	Hutchison Street Drain	Hutchison Street	Steele Creek
	4232	Clydesdale Road Drain	Halsey Road	Steele Creek
	4233	Airport West Drain	Glenys Avenue	Steele Creek
	4234	Steele Creek North	North of Dawson Street	Steele Creek
	4235	Theresa Street Drain	Melrose Drive	Steele Creek North
	4236	Keilor Park Drain	South Centre Road	Steele Creek
	4238	Niddrie West Drain	Rachelle Road	Steele Creek
	4241	Mileara Road Drain	Regent Street	Maribyrnong River

1.2 Key Objectives

The objective of this study is to support future decisions regarding flood risk management, catchment planning, risk mitigation strategies, and emergency planning.

1.3 Scope

The following tasks have been completed for the project:

- Data collection and analysis.
- Calibration of hydrological model losses to gauged water levels for the March 2001 and January 2021 storm events in the hydraulic model.
- Hydrological and hydraulic modelling for the 1 %, 2 %, 5 %, 10 %, and 20 % AEP storm events (Base Case Climate Scenario).
- Hydrological and hydraulic modelling for the 1 %, 10 %, and 20 % AEP storm events under the conditions of increased rainfall intensity (Climate Change Scenario).
- TUFLOW Classic versus TUFLOW HPC comparison of the 1 % and 10 % AEP storm events (Base Case Scenario) as based on the pre-existing Council flood model.
- Production of GIS based deliverables.

Please note that comprehensive flood mapping of the Essendon Airport was not part of the scope, thus deliverables in this area have been excluded. Additionally, explicit flood modelling and mapping of the Maribyrnong River and Moonee Ponds Creek waterways was not included in the scope of this study, they are tailwater representations for the local municipal catchments only. These areas are being explicitly mapped as part of other studies.

As this project was completed over several years due to various factors, the applicable Melbourne Water Flood Mapping Project Specifications have evolved and been updated over this time. There are references to different versions of the specifications, and in general, the following applies:

- RORB hydrological and TUFLOW hydraulic models were originally developed in accordance with the specification available at the time of project initiation, being the version released in 2019. As the models were built and finalised, they adhered to the version released in 2021.
- The GIS deliverables generated by using the TUFLOW hydraulic model outputs were originally created in accordance with the specification available at the time when the modelling phase was completed, being the version released in 2021. The GIS deliverables were then updated iteratively over the past few years, adhering to the versions released in 2023 and then ultimately 2025.

2. DATA REVIEW AND COLLECTION

2.1 Summary of Data Provided

Data for the flood study has been obtained from Melbourne Water, Moonee Valley City Council, Hume City Council, Brimbank City Council, the Department of Energy, Environment and Climate Action (DEECA), Bureau of Meteorology (BoM), and the Data VIC website. Table 2.1 summarises the data obtained for this study, its purpose and the source.

TABLE 2.1: SUMMARY OF DATA USED

Data	Purpose	Source
Existing hydrologic and hydraulic models	Existing hydrologic and hydraulic models developed for Melbourne Water as part of older flood modelling studies.	Melbourne Water
Council pit and pipe data GIS data and design plans	Pit and pipe data (along with the standard drawings) were used to represent Council assets in the TUFLOW hydraulic model. Drainage alignments were also used to inform the delineation of sub-catchment boundaries.	Moonee Valley City Council Hume City Council Brimbank City Council Merri-bek City Council
Melbourne Water drainage asset data (underground drains, channels and waterways) and GIS data and plans	Pit and pipe data were used to represent Melbourne Water assets in TUFLOW hydraulic model. Drainage alignments were also used to inform the delineation of sub-catchment boundaries.	Melbourne Water
Melbourne Water GIS data (catchment boundaries, building footprints, existing flood extents and flood contours)	Catchment boundaries used to inform the delineation of sub-catchment boundaries. Building footprints used in the hydraulic TUFLOW model (materials layers).	Melbourne Water
Aerial Photography (March – October 2018)	Used to verify the adopted fraction impervious values (an input to the hydrological RORB model). Used to verify the adopted Manning's roughness values (an input to the hydraulic TUFLOW model).	DEECA
Light Detection and Ranging (LiDAR) Data (2017-2018)	Used as the 2D terrain surface input to the hydraulic TUFLOW model to represent the overland flow paths.	DEECA
Mapbase information (including, but not limited to parcels, road, easements)	Used to assign the Manning's roughness values (an input to the hydraulic TUFLOW model) and confirm drainage alignments.	Data VIC
Planning scheme information	Used to estimate the impervious fraction for hydrological model input. Used to estimate the Manning's roughness values for hydraulic model input.	Data VIC
Rainfall Gauge Data	Used to developed rainfall files for the March 2001 and January 2021 storm events for use in the RORB hydrological model for model calibration	BoM
Streamflow Gauge Data	Used to extract streamflow levels and flows for the Steele Creek at Rosehill Road Gauge for model calibration	Melbourne Water
Steele Creek Survey Data	Cross sectional data along Steele Creek to assess accuracy of the LiDAR data captured in 2018. Used to verify accuracy of LiDAR in producing the Digital Elevation Model (DEM) for the hydraulic model	Surfcoast Survey & Drafting Services (engaged by Engeny)

2.2 Drainage Data

Drainage data was obtained from the following organisations:

- Melbourne Water
- VicRoads
- Spiire (Melbourne Airport Stormwater Harvesting Asset)
- Brimbank City Council
- Hume City Council
- Moonee Valley City Council

An initial review of the provided drainage asset information identified drainage asset data gaps requiring resolution. These gaps were addressed by obtaining available detailed design or as-constructed drawings from the relevant drainage authority where possible, and through targeted on-site inspection where documentation was unavailable.

2.3 Site Inspections

Engeny, Council and Melbourne Water conducted several site inspections of the study area with a focus to:

- Gain an understanding of site conditions including flow paths and low-lying areas
- Verify the existence of drainage assets.
- Obtain measurements of drainage assets and bridge structures.
- Fill gaps in Council, Melbourne Water, and VicRoads drainage data around / within Melbourne Airport (north of Western Ring Road)

Appendix A includes a selection of photographs of assets taken during the site visits.

3. CATCHMENT DESCRIPTIONS

3.1 Maribyrnong Lower (ML)

The ML catchment area covers approximately 12 km^2. The catchment is bounded by the Maribyrnong River to the west. Land use is predominately medium to high density residential, with a small number of commercial and industrial precincts located along the major roads. There are also large open space areas along the river and several small parks and reserves scattered throughout the catchment. Figure 3.1 shows the catchment layout.

The catchment drainage system involves both Melbourne Water and Council drainage assets. Melbourne Water assets include waterways, channels and underground drains which outlet into Maribyrnong River. Table 3.1 shows the key Melbourne Water drains within the ML catchment. There are no formal Melbourne Water retarding basins in this catchment.

TABLE 3.1: MELBOURNE WATER DRAINS WITHIN THE MARIBYRNONG LOWER CATCHMENT

Drain ID	Asset Name	Start Location	End Location
4223	Ascot Vale Main Drain	Ascot Vale Road	Maribyrnong River (Lower)
4224	Clarinda Rd Diversion Drain	Clarinda Park	Maribyrnong River (Lower)
4225	Holmes Rd Main Drain	Washington Street	Maribyrnong River (Lower)
4226	Aberfeldie Main Drain	Forrester Street	Maribyrnong River (Lower)
4227	Hoffmans Rd Main Drain	Keilor Road	Maribyrnong River (Lower)

3.2 Moonee Ponds Creek Lower (MPCL)

The MPCL catchment area covers approximately 5.6 km^2. The catchment is bounded by Moonee Ponds Creek to the east. Land use is predominately medium to high density residential, with one activity centre zone in the central part of the catchment close to Moonee Valley Racecourse and a few commercial and industrial zones along Mt Alexander Road and Racecourse Road. Green areas are located predominantly along the Moonee Ponds Creek. Figure 3.2 shows the catchment layout.

The catchment drainage system involves both Melbourne Water and Council drainage assets. Table 3.2 summarises the key Melbourne Water drains within the catchment. There are no formal Melbourne Water retarding basins.

TABLE 3.2: MELBOURNE WATER DRAINS WITHIN THE MOONEE PONDS CREEK LOWER CATCHMENT

Drain ID	Asset Name	Start Location	End Location
4314	Bent Street Main Drain	Pascoe Vale Road	Moonee Ponds Creek (Lower)
4310	Moonee Ponds Creek (Lower)	Moreland Road	Racecourse Road

3.3 Moonee Ponds Creek Upper (MPCU)

The MPCU catchment area covers approximately 8.7 km^2, with a small portion extending northward into the Merri-bek municipality. The catchment is bounded by Moonee Ponds Creek to the east. Land use is predominately medium to high density residential, with exception of the area occupied by the Essendon Fields Airport, which is Commonwealth Land (and not flood mapped as part of this study). There are also commercial and industrial zones located along Keilor Road and Broadmeadows Railway Line. Green areas are represented by parks and reserves in the catchment and stretched along the main overland flow paths and waterways (Five Miles Creek and Moonee Ponds Creek). Figure 3.3 shows the catchment layout.

The catchment drainage system involves both Melbourne Water and Council drainage assets (alongside a small number of Merri-bek City Council drainage assets to the north). Melbourne Water assets include waterways, channels and underground drains which outlet into Moonee Ponds Creek, except for Essendon North Reservoir drainage system, which connects to the Council drainage network at Quintus Avenue. Table 3.3 summarises the Melbourne Water drains within the catchment. There are no formal Melbourne Water retarding basins in this catchment.

TABLE 3.3: MELBOURNE WATER DRAINS WITHIN THE MOONEE PONDS CREEK UPPER CATCHMENT

Drain ID	Asset Name	Start Location	End Location
4330	Five Mile Creek	Bulla Road	Moonee Ponds Creek (Lower)
4331	Magdala Avenue Main Drain	Alf Pearce Reserve	Five Mile Creek
4344	Mascoma Street Drain	Mascoma Street	Moonee Ponds Creek (Upper)
4350	Moonee Ponds Creek (Upper)	Albion-Broadmeadows Rail Bridge	Moonee Ponds Creek (Lower)
R006	Essendon North Reservoir	Essendon North Reservoir	Quintus Avenue

3.4 Steele Creek (SCrk)

The SCrk catchment comprises an area of approximately 35 km^2, covering portions of the Hume and Brimbank municipalities. Land use is predominately medium to high density residential, with exception of two airports (Melbourne and Essendon Airports) zoned as Commonwealth Land, and some commercial and industrial areas located along the major roads and near the two airports. There are also reserves across the catchment, stretching along the Maribyrnong River and Steele Creek. Figure 3.4 shows the catchment layout.

The drainage system within the catchment includes both Melbourne Water and Council drainage assets. Table 3.4 summarises the key Melbourne Water drains within the Steele Creek catchment. There is also one Melbourne Water retarding basin (Steele Creek Retarding Basin).

TABLE 3.4: MELBOURNE WATER DRAINS WITHIN THE STEELE CREEK CATCHMENT

Drain ID	Asset Name	Start Location	End Location
4230	Steele Creek	Annandale Road	Maribyrnong River
4231	Hutchison Street Drain	Hutchison Street	Steele Creek
4232	Clydesdale Road Drain	Halsey Road	Steele Creek
4233	Airport West Drain	Glenys Avenue	Steele Creek
4234	Steele Creek North	North of Dawson Street	Steele Creek
4235	Theresa Street Drain	Melrose Drive	Steele Creek North
4236	Keilor Park Drain	South Centre Road	Steele Creek
4238	Niddrie West Drain	Rachelle Road	Steele Creek
4241	Milleara Road Drain	Regent Street	Maribyrnong River

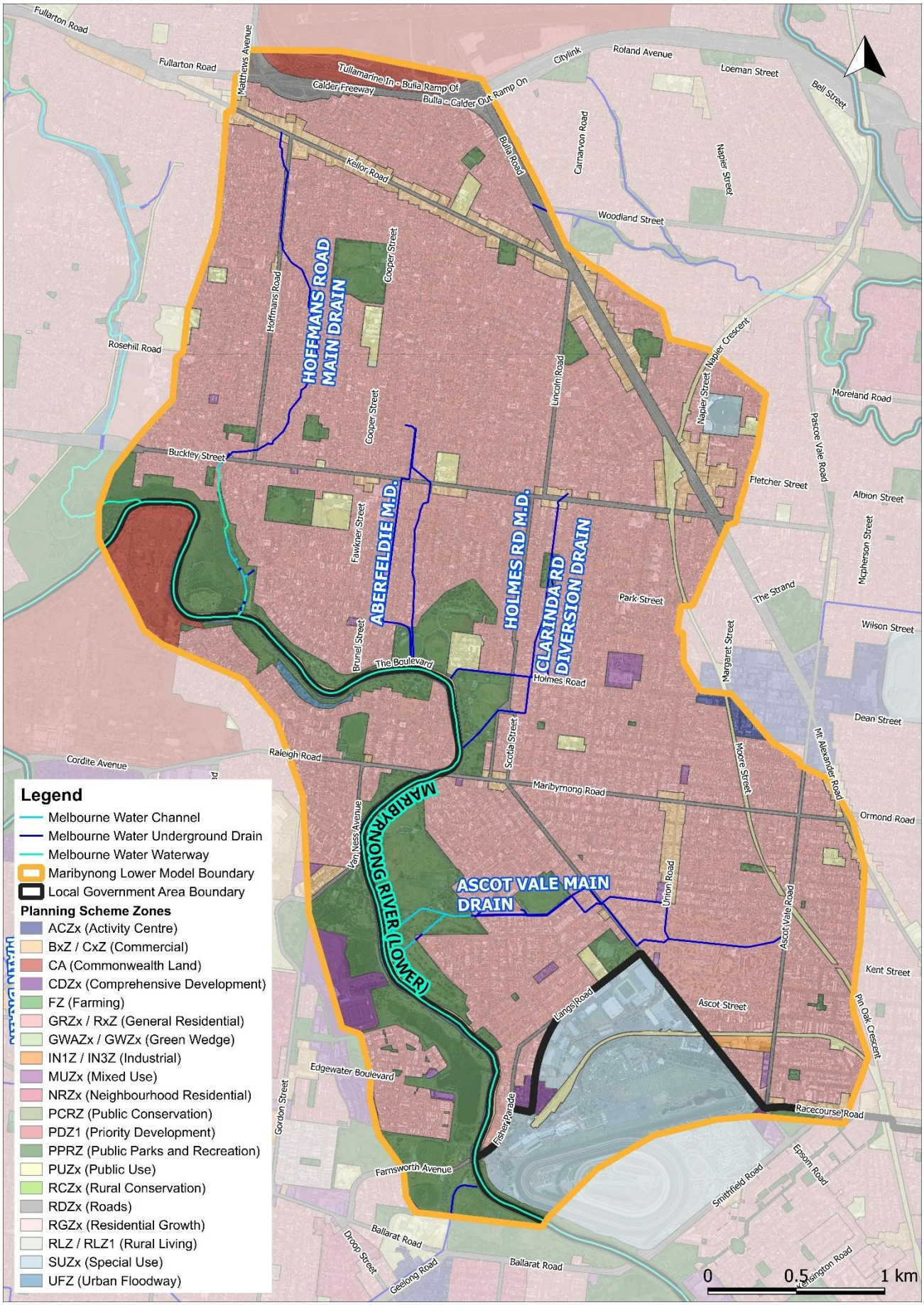


FIGURE 3.1: MARIBYRNONG LOWER CATCHMENT LAYOUT PLAN

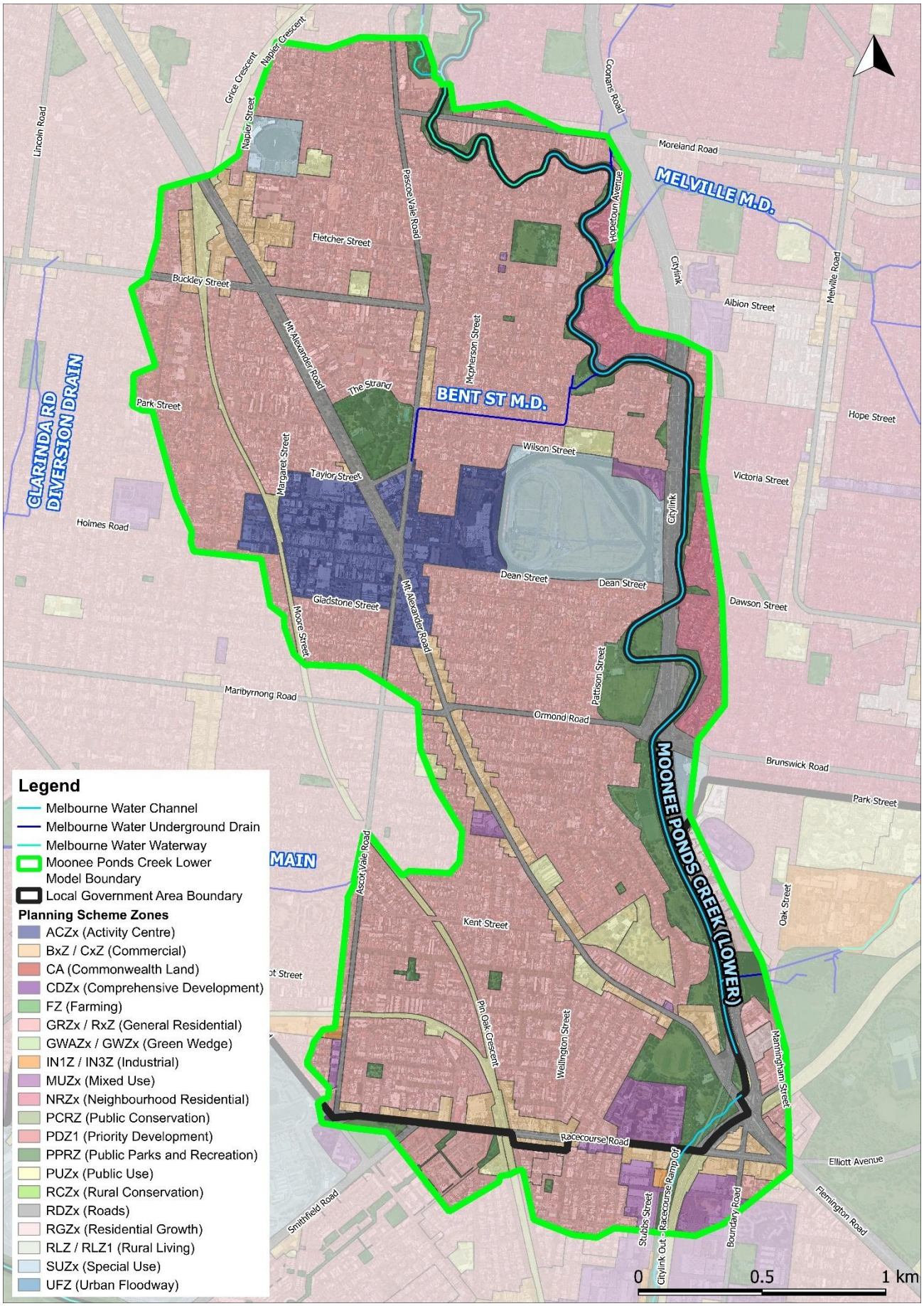


FIGURE 3.2: MOONEE PONDS CREEK LOWER CATCHMENT LAYOUT PLAN

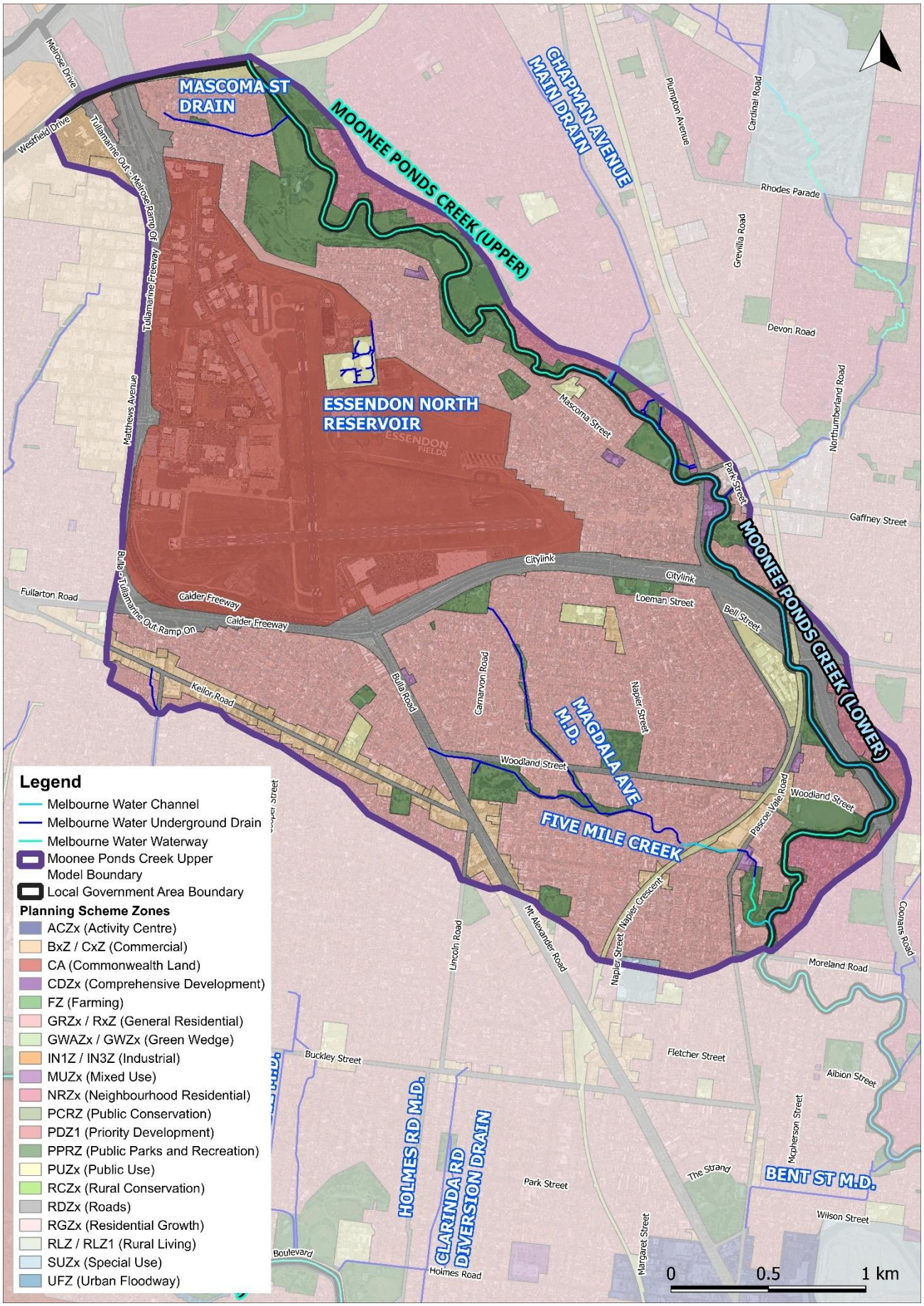


FIGURE 3.3: MOONEE PONDS CREEK UPPER CATCHMENT LAYOUT PLAN

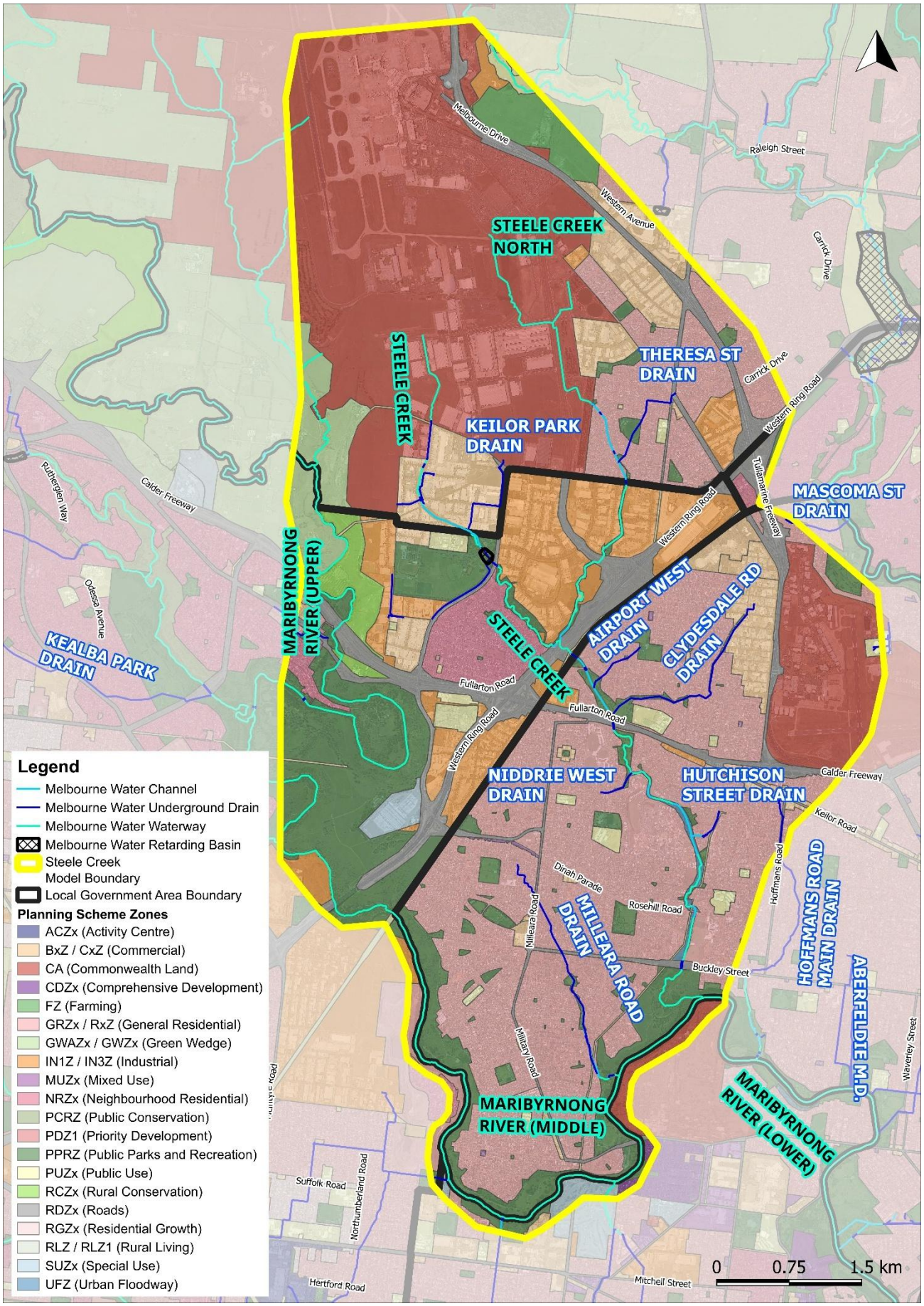


FIGURE 3.4: STEELE CREEK CATCHMENT LAYOUT PLAN

4. OVERVIEW OF MODELLING APPROACH

The modelling approach adopted for this study involves both hydrologic and hydraulic modelling. The objective of the hydrological modelling is to produce rainfall excess hydrographs for each sub-catchment delineated within the study area. These are then used as inputs into the TUFLOW hydraulic model to undertake flow routing and estimate flood dynamics within the catchment.

As part of this study, hydrologic and hydraulic models were developed that include Council and Melbourne Water drainage assets within the four catchments, including the portion of the Steele Creek catchment outside of the Moonee Valley municipality (covering parts of the Brimbank and Hume municipalities). Explicit flood modelling and mapping of the Maribyrnong River and Moonee Ponds Creek waterways was not included in the scope of this study.

The hydrologic models were built in RORB in accordance with ARR v4.1 and Melbourne Water's Flood Mapping Projects Specification (2021). The rainfall-excess hydrographs were produced for all sub-catchments within the study area for both base case and climate change scenarios for all required AEP events, storm durations and a full ensemble set of ten temporal patterns. Section 5 contains an overview of the hydrologic modelling process and **Appendix B** provides a detailed description of hydrological model development.

The hydraulic models were developed in accordance with Melbourne Water's Flood Mapping Projects Specification (2021) using the most up-to-date version of TUFLOW HPC available at the time of modelling (2020-10-AB). Section 6 contains an overview of the hydraulic modelling process and **Appendix C** provides a detailed description of hydraulic model development, including model calibration and validation, TUFLOW HPC vs. TUFLOW Classic comparison and a blockage risk analysis.

A Quality Assurance (QA) assessment is undertaken prior to each project submission. The QA assessments are designed to provide confidence that the flood modelling results are as accurate and robust as reasonably practicable. Melbourne Water has provided documentation outlining a comprehensive set of technical checks to be applied at each stage of the project. These checks are completed by the modeller, after which the model is subject to an internal review by a qualified senior or principal engineer. Once all internal review comments have been addressed, the model and supporting QA documentation are submitted to Melbourne Water for external review by an independent peer reviewer engaged by Melbourne Water. Review comments from the peer reviewer are addressed through iterative updates until the model configuration is finalised and approved by Melbourne Water.

5. HYDROLOGICAL MODELLING

RORB is an interactive runoff and streamflow routing program that calculates catchment losses and streamflow hydrographs resulting from rainfall events. A RORB hydrologic model has been developed to produce inflow hydrographs for the one-dimensional (1D) / two-dimensional (2D) TUFLOW hydraulic model that was created to estimate flood patterns within the study catchment.

RORB calculates a rainfall excess hyetograph from each sub-catchment by applying the catchment pervious area losses and impervious area losses to each sub-catchment using an initial loss / continuing loss model specified by the user. The user is also able to define the land use in each sub-catchment by adjusting the proportion of pervious and impervious area. After deducting losses, it converts the hyetograph to 'hydrographs' of rainfall-excess on the sub-areas.

The hydrological modelling was performed using the latest version of RORB software available (version 6.45) in accordance with ARR v4.1 and Melbourne Water's Flood Mapping Projects Specification (2021). **Appendix B** provides a detailed summary of the RORB hydrologic model development.

All RORB models were subject to the QA process outlined in Section 5 and the RORB models, accompanied by the completed QA spreadsheet and hydrology report, were submitted to Melbourne Water for review in 2022 prior to commencement of hydraulic model development and final model simulations.

5.1 General Methodology

The following steps outline the overall process in developing a RORB model for each catchment and to create outputs which were utilised in the subsequent hydraulic modelling:

- Assign fraction impervious values (Total Impervious Area – TIA) for each sub-catchment
- Create RORB nodes and reaches connecting the delineated sub-catchments to a single outfall
- Develop MapInfo tables of the key RORB inputs (catchment boundary, sub-catchment boundaries, nodes and reaches) using MiRORB
- Export MiRORB MapInfo tables to create the baseline graphical catchment file (.catg) for use in RORB
- Calculate the loss values for each land surface type (Effective Impervious Area – EIA and Indirectly Connected Area – ICA, pervious areas within the catchment were considered to comprise ICA, given the highly urbanised nature of the catchment)
- Calculate the area component of each delineated sub-catchment for each land surface type (EIA / ICA)
- Create a graphical catchment file for each land surface type (EIA / ICA) with each sub-catchment comprising the associated area component only (this step was undertaken to correctly apply calculated losses for each surface type)
- Obtain design rainfall data (IFD data) from the Bureau of Meteorology (BoM)
- Calculate the storm pre-burst losses for each event / duration
- Assess requirements (if any) with regards to Areal Reduction Factor (ARF), temporal rainfall patterns and spatial rainfall patterns as based on catchment area (and other factors as required)
- Obtain historical recorded rainfall data from Melbourne Water and BoM gauges to produce storm files for the March 2001 & January 2021 events
- Utilise the Steele Creek RORB model to simulate the March 2001 and January 2021 storm event and extract the rainfall excess hydrographs from RORB for calibration to gauged water levels in the TUFLOW hydraulic model.
- Iteratively adjust the RORB model hydrology losses to provide a close match to the gauged water levels in the TUFLOW hydraulic model
- Run RORB models for the base case scenario – 1 %, 2 %, 5 %, 10 % and 20 % AEP storm events (design events)
- Run RORB models for the climate change (increased rainfall intensity) scenario – 1 %, 10 % and 20 % AEP events

In 2021 when Melbourne Water became a stakeholder of the project, it was agreed with Melbourne Water and Council to represent flows in the Maribyrnong River and Moonee Ponds Creek by extracting hydrographs from an existing Melbourne Water RORB hydrological model, based on ARR 1987, without update to ARR v4.1.This decision was based on a joint probability investigation of Maribyrnong River Catchment compared to the local municipal catchment. The adopted approach was considered conservative in terms of tailwater representation and locations experiencing tailwater influence is expected to be superseded by the current Melbourne Water Riverine Flood Mapping studies.

6. HYDRAULIC MODELLING

A combined 1D/2D dynamic hydraulic model of the study area was developed using TUFLOW to estimate flood water levels, extents, flows and other hydraulic variables for a range of scenarios and design events. The model was developed in accordance with Melbourne Water's Flood Mapping Projects Specification (2021) and was run using the latest version of TUFLOW HPC with Sub-grid Sampling (2020-10-AB) at the commencement of the modelling.

All hydraulic models underwent the QA process outlined in Section 5. The flood models were constructed and tested for stability using both TUFLOW's Classic and HPC solution schemes. The hydraulic-modelling QA process comprises guided model health and stability checks of the final model, followed by internal and external technical reviews.

Some checks undertaken as part of this review process include:

- Review and fixing of TUFLOW Warnings, Checks, and Errors produced during TUFLOW model simulations.
- HPC model stability checks to ensure the TUFLOW hydraulic model is stable and functioning as expected.
- A Control Number Sensitivity (CNS) analysis which acts as a stress test for the TUFLOW hydraulic models. The CNS analysis lowers the tolerance of TUFLOW so that it can verify that the model can function under stricter conditions.
- Checking the model setup against a Melbourne Water developed checklist that verifies setup is structurally sound.

The TUFLOW hydraulic models were finalised through this review process and were approved by Melbourne Water following an independent, external peer review.

6.1 General Methodology

The following steps outline the tasks undertaken to develop a TUFLOW model for each catchment and to obtain results and outputs which were used for flood mapping:

- Generate DEM based on latest available LiDAR survey
- Compile hydrographs for the March 2001 and January 2021 storm events using RORB
- Compile hydrographs for the range of storm durations for the 20 %, 10 %, 5 %, 2 %, 1 % AEP events for existing conditions (base case scenario) using RORB model
- Compile rainfall excess hydrographs for one climate change scenario comprising increase in rainfall intensity extrapolated to year 2100 levels for the 1 %, 10 % and 20 % AEP events (increased rainfall intensity by 18.5 %, in accordance with ARR v4.1)
- Review and update surface roughness (materials layer)
- Input, review and verify data for the 1D network
- Apply z-shapes to the waterways / channels as required to allow a continuous path of flow to the outfall
- Set 1D and 2D boundary conditions
- Calibrate the Steele Creek flood model to determine appropriate hydrological loss parameters:
  - Run the model in TUFLOW HPC with Sub-grid Sampling (SGS) for the March 2001 and January 2021 storm events and calibrate the hydraulic model by adjusting the Initial Loss (IL) and Continuing Loss (CL) values in the hydrological model until a match in water levels is achieved between the Steele Creek hydraulic model and Rosehill Road Gauge.
  - Run the calibrated model in TUFLOW HPC with SGS for the standard storm durations for all the 1 %, 10 % and 20 % AEP events, for the ensemble suite of temporal patterns for existing conditions
  - Identify the critical durations and temporal patterns associated with each of the temporal pattern 'bins' per AEP event run.
  - Run the calibrated hydraulic model in TUFLOW HPC with SGS for the identified critical durations and temporal patterns (as based on the full ensemble of durations and temporal patterns run for the 1 %, 10 % and 20 % AEP flood events) for the remaining 2 % and 5 % AEP events for base case and 1 %, 10 % and 20 % AEP events for the climate change scenario.
- Simulate the TUFLOW hydraulic models for all standard storm durations and full ensemble temporal patterns for the storm events presented in Table 6.1, to produce the flood results used to generate the flood mapping GIS deliverables from this study.
- Prepare flood maps and GIS deliverables from the TUFLOW HPC with Sub-grid Sampling runs, in line with Melbourne Water's Flood Mapping Projects Specification (2025) and relevant DCNs.

Table 6.1 provides a summary of the AEP events run for each modelling scenario.

TABLE 6.1: TUFLOW MODELLING SCENARIOS

Scenario	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP
A: Base Case Climate	✓	✓	✓	✓	✓
D: Climate Change 3 – Increased Rainfall Intensity	✓	✓			✓

Appendix C provides details of the hydraulic modelling, including key assumptions and analyses including a TUFLOW HPC vs. TUFLOW Classic comparison and a blockage assessment of key structures.

Appendix D contains flood depth maps for each of the AEP storm event scenarios simulated as part of this study.

7. FLOOD MAPPING RESULTS AND GIS DELIVERABLES

Gridded flood mapping outputs for peak water depth, water surface elevation, velocity and hazards have been delivered to Melbourne Water and Council for all AEP events modelled. This data has been delivered ASCII format in GDA2020, Zone 55 MGA projection=. GIS deliverables files are named and provided as per Melbourne Water's Flood Mapping Projects Guidelines and Project Specifications (2025).

The following appendices contain flood maps which have been produced with the outputs of the final TUFLOW HPC with Sub-grid Sampling runs:

- **Appendix D** contains maps showing the maximum flood depth for each of the AEP events run for both base case and climate change scenarios.
- **Appendix E** contains the flood extents for all AEP events run for both base case and climate change scenarios.

All GIS deliverables produced as part of this study have been independently peer reviewed by a third-party selected by Melbourne Water, as agreed by Council and have undergone the QA process.

The results from this study have been used to inform an update of Council's Flood and Storm Emergency Plan (A Sub-Plan of the Municipal Emergency Plan) during 2024.

As noted previously, production of GIS deliverables for this model has excluded the Essendon Airport area, as comprehensive flood mapping of this area has been excluded from this study.

7.1 Filtering of Flood Model Results to Produce Flood Extents

For each AEP event and modelled scenario, TUFLOW results from the full range of storm durations were combined to determine the maximum value at each model cell. Melbourne Water's flood extent filtering guidelines have been applied to these results to develop flood extents in accordance with the Melbourne Water Project Specifications (2025) and associated DCNs.

To ensure the quality and consistency of the final flood maps, Melbourne Water and Council apply a set of filtering criteria to the derived flood extents. Locations satisfying the following criteria for the 1% AEP event inclusive of climate change were included within the final flood extent and are proposed for application as a future Special Building Overlay (SBO):

- Water depths less than or equal to 0.05 m in Council areas (to be demarcated as SBO2) and Melbourne Water areas (to be demarcated as SBO1) are considered too shallow to pose a real hazard and so are excluded from the flood extent.
- Isolated areas of flooding less than 100 m^2 are excluded from the flood extent
- Surrounded dry islands (or high points) less than or equal to 100 m^2 are considered to be flooded and are included in the flood extent
- Area of flooding covers 2 % or greater of the total parcel area OR
- Area of flooding covers a minimum of 25 % of the road frontage.

As per the Melbourne Water Project Specifications (2025) and associated DCNs, the flood extents are generated and filtered using the program FME. Manual checks are done on the produced which include:

- Connecting the discontinuous areas of the flood extent, where the model results identify disconnected areas are connected by wet cells
- Removing areas where the section of the flood extent was due to the modelling approach of applying flows directly to the 2D domain (i.e. 2d source areas).

Flood extents for each AEP and scenario have been delineated between 'Council' and 'Melbourne Water' flood extents to identify the responsible drainage authority. Melbourne Water flood extents are generally also delineated into the categories of flooding from 'underground drains' and 'waterways' in accordance with the requirements of Melbourne Water's Projects Technical Specifications (2025).

In 2023, Engeny met with Melbourne Water and Council to discuss demarcation and confirm the assignment of flooding referral authorities to flood affected areas. The objective of this discussion was to ensure a one parcel, and one referral authority outcome was applied where possible and flood ownership was accepted by either Melbourne Water or Council. During the 2025 flood extent updates, the original demarcation was revised, and the new proposed demarcation locations were approved by Melbourne Water and Council.

Appendix E provides flood extent plans of the municipality, presenting the proposed Council and Melbourne Water SBO layers.

Additionally, Engeny developed a secondary flood extent layer for Council to be used to identify / designate land liable to flooding outside of proposed flood overlays (e.g., SBO and LSIO). The 'Buildings Regulation 153 Overlay' will be used internally by Council to assist with review of future development proposals in accordance with the Building Regulations (2018), typically used to manage minor flooding concerns. The BR153 overlay was developed adopting a similar approach to that of Council's SBO described above; however, the SBO overlay undergoes a more rigorous review to qualify under the Planning Scheme.

7.2 Parcel Cadastre GIS Update

After submission of the initial draft and final deliverables for this study in early 2023, there was an update to the spatial VicMap parcel cadastre made by the Department of Transport and Planning (DTP) and published to the public in October 2023, as part of the Digital Cadastre Modernisation Project (DCMP). Review of the updated VicMap parcel cadastre layer identified a spatial shift between 0 m and 1.5 m in the positioning of parcel boundaries compared to the previous parcel cadastre layer that was originally used to inform the generation of deliverable outputs from the flood study. Engeny has updated Council and Melbourne Water flood overlays and associated flood mapping GIS deliverables to ensure all GIS outputs align with the latest parcel cadastre layer in GDA 94, Zone 55 MGA projection (dated October 24th, 2023).

7.3 Council and Melbourne Water GIS Deliverables Update

In 2025, the May 2024 Council GIS deliverables were revised to reflect an updated flood-depth filtering criterion. Following this update, the demarcation between the Council and Melbourne flood extents was also amended. After approval from both Council and Melbourne Water, new GIS deliverables were produced in accordance with the Melbourne Water Flood Mapping Project Specification (2025) and associated DCNs.

8. FLOOD MITIGATION ASSESSMENT

A key component of the project scope delivered for Council involved undertaking flood mitigation assessments at the following locations within the municipality:

(1) El Reno Crescent, Airport West

(2) Mt Alexander Road, Moonee Ponds

(3) Houston Ave, Strathmore

(4) Warrick Ct / Riviera Road, Avondale Heights

(5) Laluma St, Essendon

The locations listed above have a history of reported flooding by residents. At the time of preparing this report, physical drainage improvement works have been completed at Location 1, 4, and 5. Location 2 is under further consideration and the opportunity for flood reduction at Location 3 has been considered by Council in partnership with Melbourne Water given that drainage in this location involves assets owned by both authorities.

The modelling completed as part of this study provides Council and Melbourne Water with a basis to identify priority locations across the municipality for future flood risk reduction works. Importantly, the modelling also enables the testing and assessment of the effectiveness of potential flood mitigation options in reducing flood risk.

9. CONCLUSION

Melbourne Water and Moonee Valley City Council engaged Engeny to complete flood mapping of the City of Moonee Valley in accordance with ARR v4.1 methodologies. Engeny has provided Melbourne Water and Council with final GIS deliverables for the four model areas that spanned the entire municipality. In line with the study objective, the findings from this study may support future decisions regarding flood risk management, catchment planning, risk mitigation strategies, and emergency planning.

Following the conclusion of this study, Engeny recommends that Council:

- Engages with and informs the community of the risks of flooding which Council is now aware of.
- Considers the practicality of structural and non-structural mitigation measures to reduce the risk of flooding to the community.
- Considers undertaking a prioritisation of flooding hotspots based on the information produced by the flood modelling to help to ensure that Council's drainage renewal / upgrade investment is targeted in areas where benefit to cost ratios is most favourable.
- Considers implementing or modifying planning scheme overlays (a non-structural mitigation measure) based on the flood modelling results.

10. REFERENCES

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Melbourne Water Corporation, 2023, *AM STA Flood Mapping Project Specifications –Version 13, August 2023.*

Melbourne Water Corporation, 2025, *AM STA Flood Mapping Project Specifications – Version 14, December 2025*

11. QUALIFICATIONS

(1) In preparing this document, including all relevant calculation and modelling, Engeny Australia Pty Ltd (Engeny) has exercised the degree of skill, care and diligence normally exercised by members of the engineering profession and has acted in accordance with accepted practices of engineering principles.

(2) Engeny has used reasonable endeavours to inform itself of the parameters and requirements of the project and has taken reasonable steps to ensure that the works and document is as accurate and comprehensive as possible given the information upon which it has been based including information that may have been provided or obtained by any third party or external sources which has not been independently verified.

(3) Engeny reserves the right to review and amend any aspect of the works performed including any opinions and recommendations from the works included or referred to in the works if:

   (a) Additional sources of information not presently available (for whatever reason) are provided or become known to Engeny; or

   (b) Engeny considers it prudent to revise any aspect of the works in light of any information which becomes known to it after the date of submission.

(4) Engeny does not give any warranty nor accept any liability in relation to the completeness or accuracy of the works, which may be inherently reliant upon the completeness and accuracy of the input data and the agreed scope of works. All limitations of liability shall apply for the benefit of the employees, agents and representatives of Engeny to the same extent that they apply for the benefit of Engeny.

(5) This document is for the use of the party to whom it is addressed and for no other persons. No responsibility is accepted to any third party for the whole or part of the contents of this Report.

(6) If any claim or demand is made by any person against Engeny on the basis of detriment sustained or alleged to have been sustained as a result of reliance upon the Report or information therein, Engeny will rely upon this provision as a defence to any such claim or demand.

(7) This Report does not provide legal advice.

APPENDIX A: SITE VISIT PHOTOS



FIGURE A.1: WEIR STRUCTURE ON MELBOURNE WATER ASSET, WALTER STREET, ASCOT VALE 3032



FIGURE A.2: CHANNEL DOWNSTREAM OF STANFORD STREET, ASCOT VALE 3032



FIGURE A.3: CROSS-RAIL CULVERT ON QUEENS AVENUE, ASCOT VALE 3032



FIGURE A.4: DRAINAGE HEADWALL / ENDWALL IMMEDIATELY DOWNSTREAM OF CROSS-RAIL CULVERT ON QUEENS AVENUE, ASCOT VALE 3032

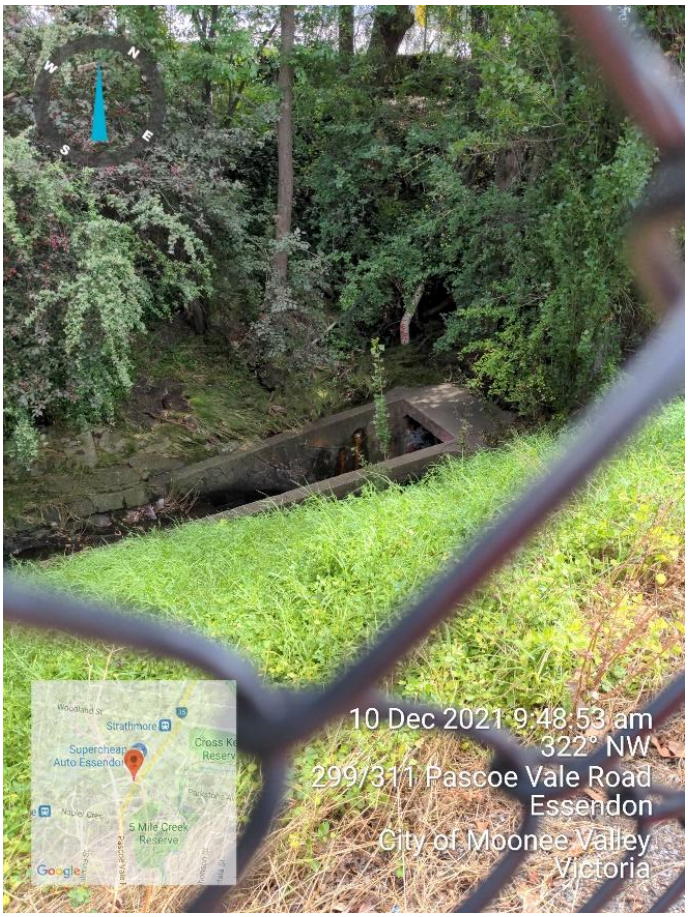


FIGURE A.5: CULVERT HEADWALL TO FIVE MILE CREEK (UPSTREAM OF PASCOE VALE ROAD), ESSENDON 3040



FIGURE A.6: WOODLANDS PARK WETLAND, ESSENDON 3040

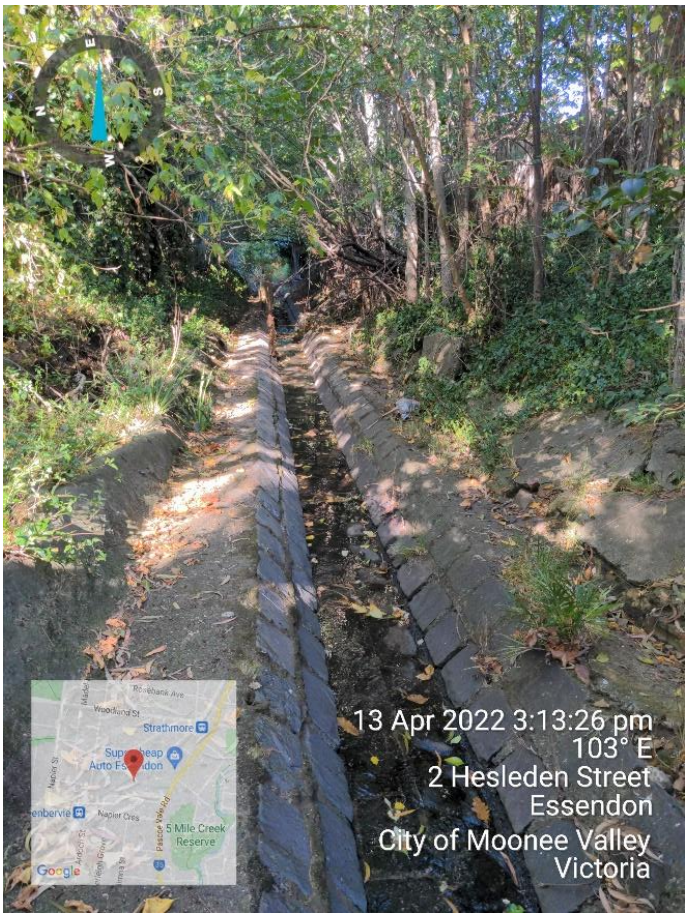


FIGURE A.7: SECTION OF FIVE MILE CREEK (EAST OF HESLEDEN STREET, ESSENDON 3040)

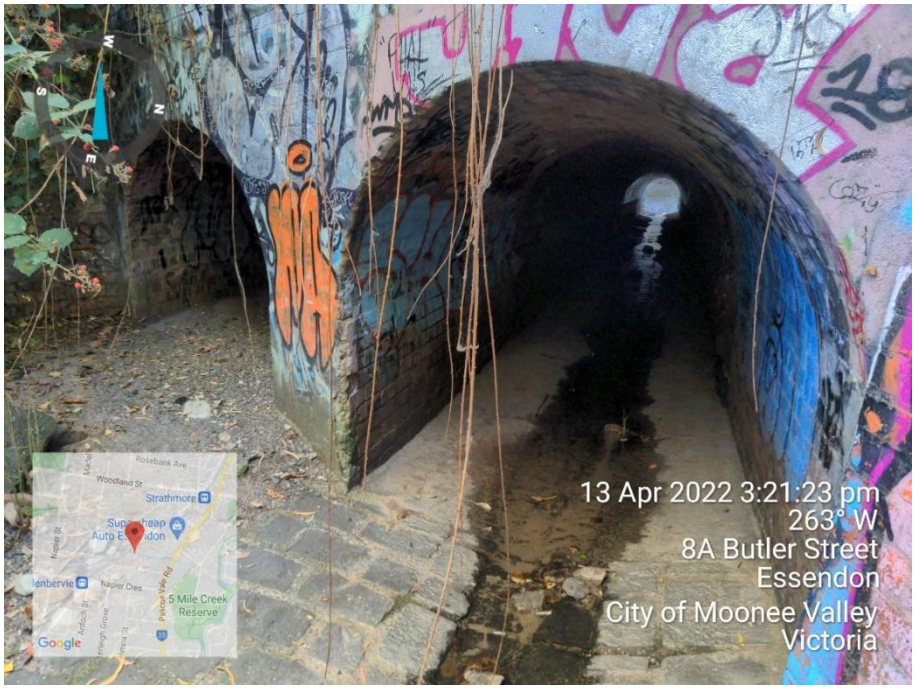


FIGURE A.8: RAIL CULVERTS ON FIVE MILE CREEK (BETWEEN HESLEDEN STREET AND PASCOE VALE ROAD) ESSENDON 3040



FIGURE A.9: CROSS-RAIL CULVERT ON QUEENS AVENUE, ASCOT VALE 3032



FIGURE A.10: DRAINAGE HEADWALL / ENDWALL IMMEDIATELY DOWNSTREAM OF CROSS-RAIL CULVERT ON QUEENS AVENUE, ASCOT VALE 3032

APPENDIX B: RORB HYDROLOGICAL MODEL DEVELOPMENT

B.1 RORB Model Development

B.1.1 Catchment Delineation

The catchment and sub-catchments (sub-catchments) were delineated considering the following information:

- The DEM generated from the available LiDAR data and terrain contours created from the DEM (for consideration of predicted 1 % AEP overland flow paths)
- drainage asset locations and alignment (for consideration of piped flows)
- land use identified in the Victorian Planning Scheme
- property boundaries
- aerial photography

Sub-catchments were delineated to represent both pipe flow and overland flow pathways. Where practicable, predicted 1% AEP overland flow paths were incorporated into the model layout. Greater priority was, however, given to representing the piped drainage catchment and maintaining consistent land use characteristics within each sub-catchment.

This approach was adopted to improve the accuracy of the subsequent flood hydraulic modelling, where rainfall excess runoff hydrographs generated by RORB were applied as inflows. Where possible, each sub-catchment was delineated to include a single land use type, thereby avoiding the need to average losses across differing land uses within a sub-catchment in RORB. Separating urban residential impervious areas and rural pervious areas to account for the different loss factors attached to each surface type reduces the effect of averaging runoff volumes across a sub-catchment.

Refer to Figure B.1, Figure B.2, Figure B.3 and Figure B.4 for the hydrologic model layouts of ML, MPCL, MPCU, and SCrk, respectively.

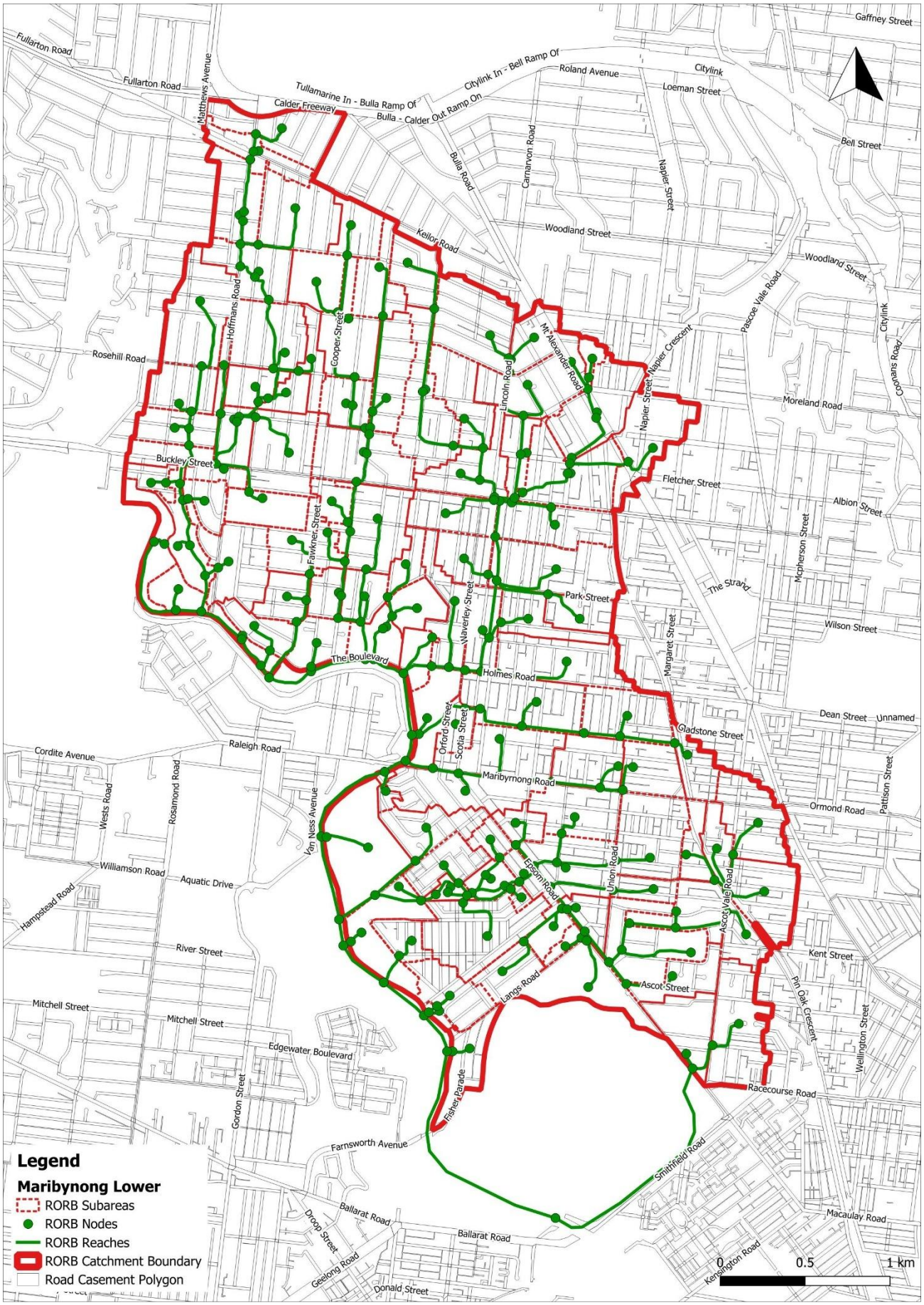


FIGURE B.1: MARIBYRNONG LOWER RORB LAYOUT PLAN



FIGURE B.2: MOONEE PONDS CREEK LOWER RORB LAYOUT PLAN



FIGURE B.3: MOONEE PONDS CREEK UPPER RORB LAYOUT PLAN

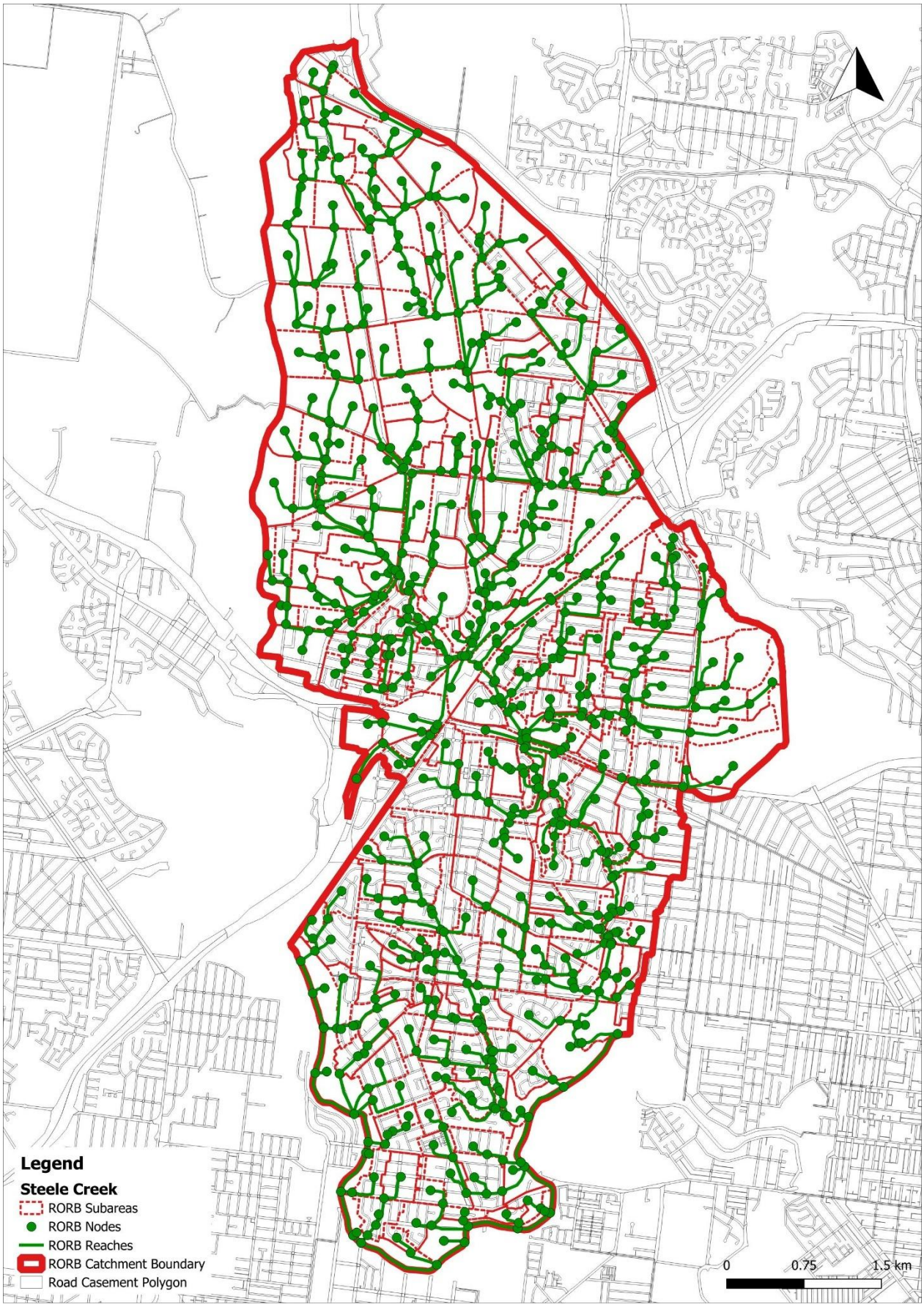


FIGURE B.4: STEELE CREEK RORB LAYOUT PLAN

B.1.2 Fraction Impervious

The initial impervious fraction (FI) values were assigned at a parcel scale based on the recommended values for different planning zones (Appendix M of Melbourne Water's Flood Mapping Projects Specification 2021). The FI applied at parcel scale was then further reviewed and refined based on aerial photography with consideration of both zoned land use and current development levels. Sub-catchment FI (Total Impervious Area – TIA) was then calculated as a weighted average of imperviousness of the different land parcels comprising the sub-catchment. Figure B.5, Figure B.6, Figure B.7 and Figure B.8 show the assigned fraction imperviousness for ML, MPCL, MPCU, and SCrk, respectively.

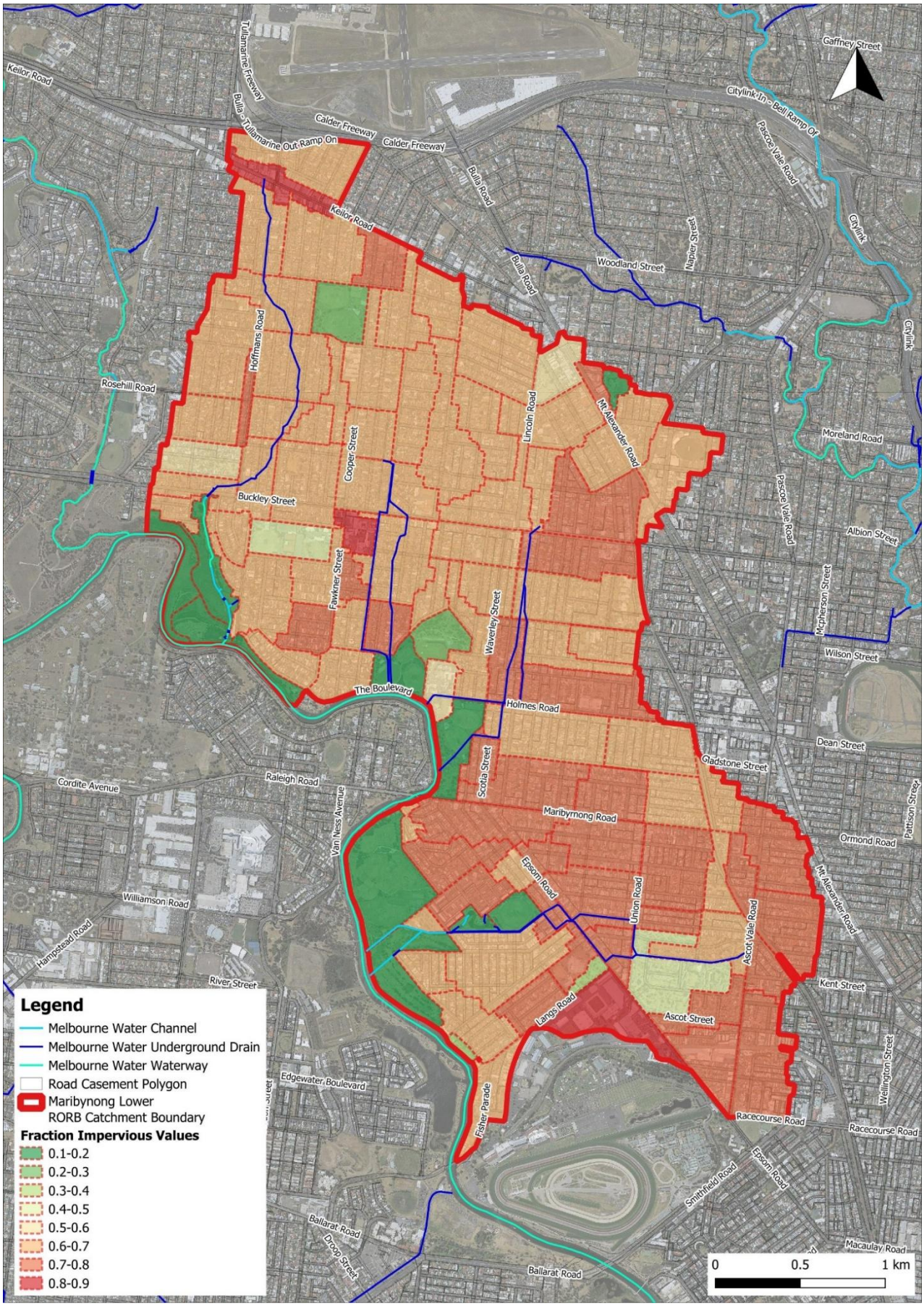


FIGURE B.5: MARIBYRNONG LOWER RORB IMPERVIOUS FRACTIONS PLAN

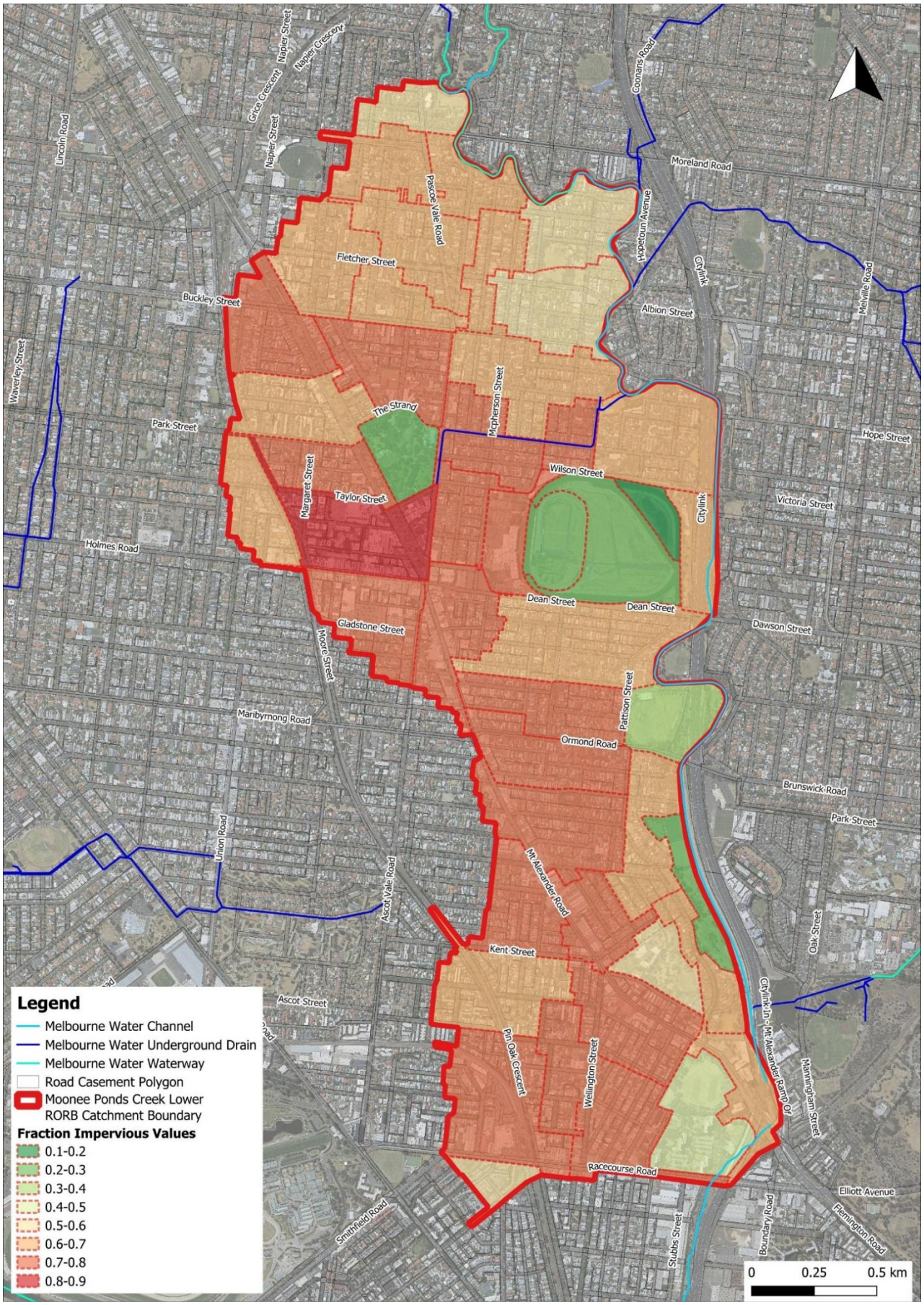


FIGURE B.6: MOONEE PONDS CREEK LOWER RORB IMPERVIOUS FRACTIONS PLAN

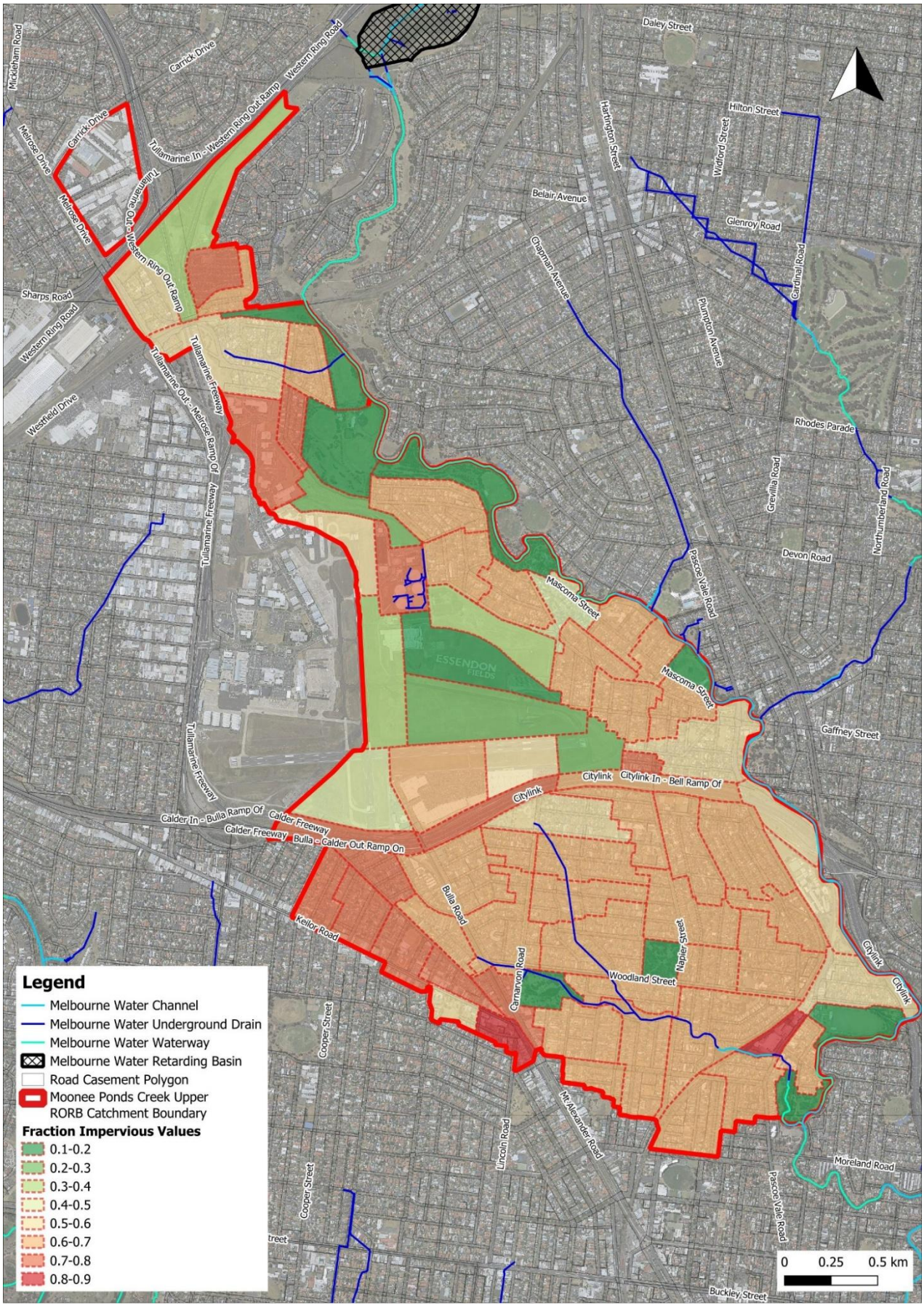


FIGURE B.7: MOONEE PONDS CREEK UPPER RORB IMPERVIOUS FRACTIONS PLAN

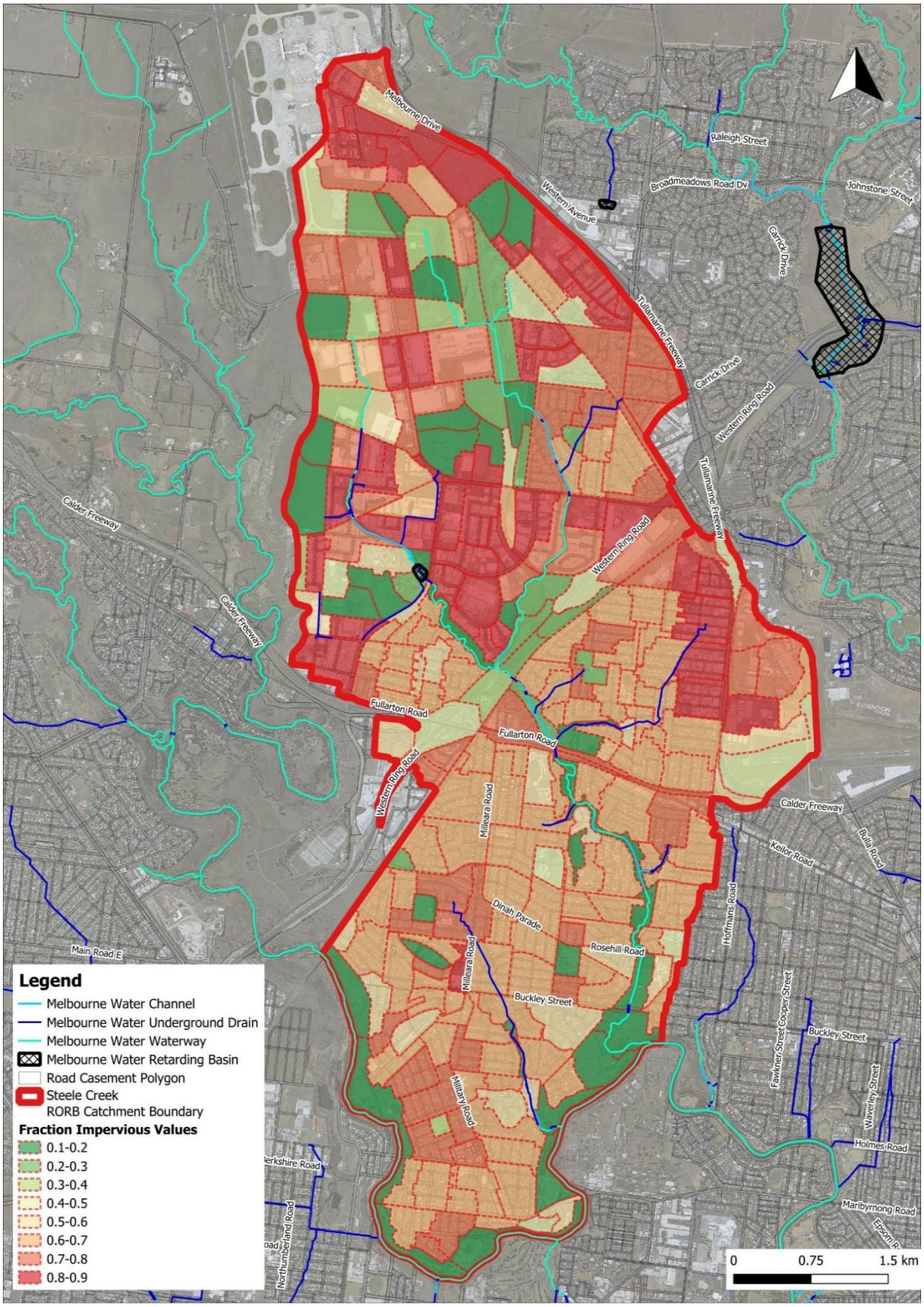


FIGURE B.8: STEELE CREEK RORB IMPERVIOUS FRACTIONS PLAN

B.2 Design Event Rainfall

B.2.1 Burst Rainfall

B.2.1.1. Base Case

The IFD information was sourced from the BoM using the online IFD request tool in 2020. The coordinates used for the tool were based on the geographic centroids of the sub-catchments modelled. The IFDs used for design event RORB modelling are presented in the following tables.

TABLE B.1: DESIGN RAINFALL DEPTHS IN MILIMETERS (MM) FOR THE BASE CASE SCENARIO – ML

Storm Duration	Annual Exceedance Probability (AEP)				
	20 %	10 %	5 %	2 %	1 %
10 minutes	11.4	14	16.7	20.6	23.9
15 minutes	14	17.1	20.4	25.3	29.4
30 minutes	18.5	22.7	27.1	33.5	39
1 hour	23.5	28.5	34	42.1	49
2 hours	29.2	35.3	42	51.9	60.3
3 hours	33.2	40.1	47.6	58.7	68.2
6 hours	42.1	50.7	59.9	73.6	85.3
12 hours	54	65.2	76.8	93.8	108
24 hours	69.3	83.7	98.5	119	136
48 hours	85.7	104	122	147	165
72 hours	94.1	114	135	160	180

TABLE B.2: DESIGN RAINFALL DEPTHS IN MILIMETERS (MM) FOR THE BASE CASE SCENARIO – MPCL

Storm Duration	Annual Exceedance Probability (AEP)				
	20 %	10 %	5 %	2 %	1 %
10 minutes	11.5	14	16.8	20.8	24.2
15 minutes	14	17.2	20.5	25.5	29.7
30 minutes	18.6	22.7	27.2	33.8	39.4
1 hour	23.5	28.6	34.1	42.2	49.2
2 hours	29.2	35.3	41.9	51.7	60.1
3 hours	33.2	40	47.4	58.3	67.7
6 hours	42	50.4	59.4	72.8	84.2
12 hours	54	64.8	76.1	92.7	107
24 hours	69.3	83.3	97.8	118	135
48 hours	86	104	122	146	165
72 hours	94.6	115	135	161	180

TABLE B.3: DESIGN RAINFALL DEPTHS IN MILIMETERS (MM) FOR THE BASE CASE SCENARIO – MPCU

Storm Duration	Annual Exceedance Probability (AEP)				
	20 %	10 %	5 %	2 %	1 %
10 minutes	11.4	14	16.7	20.7	24
15 minutes	13.9	17.1	20.4	25.3	29.4
30 minutes	18.5	22.6	27	33.5	39
1 hour	23.3	28.4	33.9	42.1	49
2 hours	29	35.3	42	52	60.7
3 hours	33.2	40.2	47.8	59.2	69
6 hours	42.3	51.2	60.8	75	87.1
12 hours	54.9	66.4	78.7	96.5	111
24 hours	70.8	86	102	123	141
48 hours	88	107	127	152	171
72 hours	96.5	118	139	165	185

TABLE B.4: DESIGN RAINFALL DEPTHS IN MILIMETERS (MM) FOR THE BASE CASE SCENARIO – SCRK

Storm Duration	Annual Exceedance Probability (AEP)				
	20 %	10 %	5 %	2 %	1 %
10 minutes	11.3	13.9	16.5	20.4	23.5
15 minutes	13.8	16.9	20.2	24.9	28.7
30 minutes	18.3	22.4	26.7	32.9	38.1
1 hour	23.1	28.2	33.6	41.6	48.2
2 hours	28.8	35.1	41.9	51.8	60.3
3 hours	33	40.2	47.9	59.3	69.1
6 hours	42.2	51.4	61.2	75.7	88.1
12 hours	54.8	66.8	79.5	98	113.5
24 hours	70.6	86.2	102.6	125	143.2
48 hours	87.1	106.6	126.9	152.1	171.7
72 hours	95.2	116.4	138.7	164.6	184.5

B.2.1.2. Climate Change

The influence of climate change was modelled as an increase in rainfall intensity, with the climate change scenario modelled for the 1 %, 10 % and 20 % AEP events. The IFD values for the base case were increased by a factor that scales rainfall intensity to be appropriate for the 2100 RCP 8.5 scenario. Based on Melbourne Water's Flood Mapping Projects Specifications (2021) and ARR v4.1, a factor of 18.5 % was adopted. The resultant Climate Change IFDs are in the following tables.

TABLE B.5: DESIGN RAINFALL DEPTHS IN MILIMETERS (MM) FOR THE CLIMATE CHANGE SCENARIO – MPCL

Duration	Annual Exceedance Probability (AEP)		
	20 %	10 %	1 %
10 min	13.6	16.6	28.7
15 min	16.6	20.4	35.2
30 min	22	26.9	46.7
1 hour	27.8	33.9	58.3
2 hours	34.6	41.8	71.2
3 hours	39.3	47.4	80.2
6 hours	49.8	59.7	99.8
12 hours	64	76.8	126.8
24 hours	82.1	98.7	160
48 hours	101.9	123.2	195.5
72 hours	112.1	136.3	213.3

TABLE B.6: DESIGN RAINFALL DEPTHS IN MILIMETERS (MM) FOR THE CLIMATE CHANGE SCENARIO – MPCU

Duration	Annual Exceedance Probability (AEP)		
	20 %	10 %	1 %
10 min	13.5	16.6	28.4
15 min	16.5	20.3	34.8
30 min	21.9	26.8	46.2
1 hour	27.6	33.7	58.1
2 hours	34.4	41.8	71.9
3 hours	39.3	47.6	81.8
6 hours	50.1	60.7	103.2
12 hours	65.1	78.7	131.5
24 hours	83.9	101.9	167.1
48 hours	104.3	126.8	202.6
72 hours	114.4	139.8	219.2

TABLE B.7: DESIGN RAINFALL DEPTHS IN MILIMETERS (MM) FOR THE CLIMATE CHANGE SCENARIO – SCRK

Duration	Annual Exceedance Probability (AEP)		
	20 %	10 %	1 %
10 min	13.4	16.5	27.9
15 min	16.4	20.1	34.1
30 min	21.7	26.5	45.2
1 hour	27.4	33.5	57.2
2 hours	34.2	41.7	71.6
3 hours	39.2	47.6	81.9
6 hours	50.1	60.9	104.5
12 hours	65	79.2	134.7
24 hours	83.7	102.3	169.9
48 hours	103.3	126.4	203.6
72 hours	112.9	138	218.8

B.2.2 Areal Reduction Factors

The IFD data provided by the BoM is applicable for rainfall in small catchments. As catchment size increases the chance of that average intensity of rainfall occurring over the entire catchment decreases. To address this issue an Areal Reduction Factor (ARF) can be applied to the IFD data to account for the larger catchment area based on the process described in ARR v4.1.

Different ARFs values have been determined and adopted to best represent rainfall volumes at both local sub-catchments (less than 1 km^2) and major waterways (contributing catchment areas between 3 - 35 km^2). The different catchment areas adopted are discussed in the subsequent sub-sections. The process of selecting the temporal patterns and critical durations for the different ARFs used to produce Council and Melbourne Water deliverables was undertaken in the hydraulic model and is discussed further in Section C.3.

B.2.2.1. ML, MPCL, MPCU

Within the ML, MPCL, and MPCU catchments, either the catchment area to the Melbourne Water Drain is less than 1 km^2 or the total catchment area is less than 10 km^2, so in accordance with ARR v4.1 recommendations an ARF of 1.0 was adopted.

B.2.2.2. SCrk

The total catchment size of the SCrk model is 35.2 km^2. The average sub-catchment size within the hydraulic model extent is less than 1 km^2 (approximately 15 ha). Since water (rainfall excess) is applied to the hydraulic model on a sub-catchment basis, using an ARF representative of the total catchment area (35 km^2) will underrepresent the volume of water applied to the model. Equally adopting an ARF of 1 km^2 will overrepresent the volume of water applied to the major waterways within the catchment (i.e., Steele Creek).

The RORB model was run using the following ARFs to generate rainfall excess inflows for the different hydrologic modelling catchments and hydraulic modelling areas of interest. This approach was reviewed and approved by Melbourne Water.

- ARF = 1 km^2 was used for hydraulic modelling of local (Council) sub-catchments and Melbourne Water Underground Drains.
- ARF = 5 km^2 was used for hydraulic modelling of the northern reaches of Steele Creek, north of Western Ring Road. The upstream catchment area along the Steele Creek North reaches ranges from 3 km^2 to 7 km^2 so an average ARF was adopted using a catchment of 5 km^2.
- ARF = 22 km^2 was used for hydraulic modelling along the southern reaches of Steele Creek, between Western Ring Road and the point of discharge to the Maribyrnong River. The catchment area of 22 km^2 represents the average catchment area along Steele Creek between Western Ring Road and the Maribyrnong River.
- ARF = 35 km^2 was used to generate hydrographs along the Maribyrnong River at the downstream end of the hydraulic model extent. These hydrographs have been used as inflows to the Maribyrnong Lower hydraulic model.

B.2.3 Pre-Burst Rainfall

The burst rainfall depths provided by the BoM are associated with rainfall bursts only. The RORB model losses were calibrated to complete storm events (refer to Section 6). To calculate the initial loss for the design rainfalls (IL_B), the initial loss value for the complete storms (IL_S) was reduced by the 75th percentile pre-burst depth, in accordance with the latest Victoria-specific ARR v4.1 guidelines (with the catchment being located within loss region 3). As pre-burst depths are not provided for storm durations of less than 60 minutes, the pre-burst rainfall is assumed to be the same for durations of 60 minutes and less in accordance with Appendix H of Melbourne Water's Flood Mapping Projects Specifications (2021). The pre-burst duration factors adopted for each catchment are summarised in the tables below.

TABLE B.8: PRE-BURST DURATION FACTORS - ML

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.07	0.00	0.00	0.09	0.33
15 minutes	0.07	0.00	0.00	0.09	0.33
30 minutes	0.07	0.00	0.00	0.09	0.33
1 hour	0.07	0.00	0.00	0.09	0.33
2 hours	0.00	0.00	0.00	0.00	0.00
3 hours	0.00	0.00	0.00	0.00	0.00
6 hours	0.00	0.00	0.00	0.00	0.00
12 hours	0.20	0.00	0.00	0.00	0.00
24 hours	0.64	0.54	0.46	0.22	0.03
48 hours	0.97	0.95	0.93	0.82	0.73
72 hours	1.00	1.00	1.00	0.98	0.95

TABLE B.9: PRE-BURST DURATION FACTORS - MPCL

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.68	0.63	0.58	0.69	0.77
15 minutes	0.68	0.63	0.58	0.69	0.77
30 minutes	0.68	0.63	0.58	0.69	0.77
1 hour	0.68	0.63	0.58	0.69	0.77
2 hours	0.56	0.53	0.51	0.52	0.53
3 hours	0.62	0.61	0.61	0.44	0.31
6 hours	0.65	0.59	0.53	0.43	0.36
12 hours	0.73	0.66	0.59	0.40	0.27
24 hours	0.88	0.84	0.81	0.73	0.67
48 hours	0.99	0.98	0.97	0.94	0.91
72 hours	1.00	1.00	1.00	0.99	0.98

TABLE B.10: PRE-BURST DURATION FACTORS - MPCU

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.63	0.60	0.57	0.66	0.73
15 minutes	0.63	0.60	0.57	0.66	0.73
30 minutes	0.63	0.60	0.57	0.66	0.73
1 hour	0.63	0.60	0.57	0.66	0.73
2 hours	0.59	0.55	0.52	0.54	0.56
3 hours	0.61	0.61	0.60	0.47	0.37
6 hours	0.65	0.53	0.42	0.28	0.17
12 hours	0.70	0.58	0.47	0.31	0.18
24 hours	0.86	0.77	0.69	0.58	0.49
48 hours	0.98	0.97	0.95	0.92	0.90
72 hours	1.00	1.00	1.00	0.98	0.97

TABLE B.11: PRE-BURST DURATION FACTORS - SCRK

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.63	0.60	0.57	0.66	0.73
15 minutes	0.63	0.60	0.57	0.66	0.73
30 minutes	0.63	0.60	0.57	0.66	0.73
1 hour	0.63	0.60	0.57	0.66	0.73
2 hours	0.59	0.55	0.52	0.54	0.56
3 hours	0.61	0.61	0.60	0.47	0.37
6 hours	0.65	0.53	0.42	0.28	0.17
12 hours	0.70	0.58	0.47	0.31	0.18
24 hours	0.86	0.77	0.69	0.58	0.49
48 hours	0.98	0.97	0.95	0.92	0.90
72 hours	1.00	1.00	1.00	0.98	0.97

B.2.4 Temporal Patterns

ARR v4.1 temporal patterns, downloaded from the ARR Data Hub in 2020, were adopted for all RORB models. ARR v4.1 states that point temporal patterns should be used for catchments less than 75 km^2. All catchment sizes were less than 75 km^2 and so point temporal patterns were adopted. The full set of ten temporal patterns was used for hydrological modelling in RORB.

B.2.5 Spatial Variation

B.2.5.1. ML, MPCL, and MPCU Catchments

Each of these catchments are less than 20 km^2, therefore uniform spatial patterns were applied to the modelled design storm events.

B.2.5.2. SCrk Catchment

The modelled catchment area exceeds 20 km^2, and as such a single non-uniform spatial pattern was applied to all modelled design storm events for each of the given storm durations. The single non-uniform spatial pattern was derived from the 1 % AEP base case IFD data and using the process provided in ARR v4.1.

B.3 Historical Event Calibration

Calibration of the Steele Creek hydrological model losses to gauged water levels at the Rosehill Road gauge was undertaken for the two highest events on record (March 2001 and January 2021). Pluviographic rainfall data sets (6 min) were reviewed for several BoM gauge stations to understand the spatial variability across the study area and surrounding catchments during the historic storm events. Figure B.9 presents the locations of each of these pluviograph stations in relation to the Steele Creek streamflow gauge at Rosehill Road. Table B.12 provides a summary of recorded depths for the rainfall gauges within the catchment. No data was available for the Avondale Heights Rain Gauge (230106A) prior to 2014, and as a result it was not included in the March 2001 event-based calibration.

The following sections provide additional information on the spatial variation and temporal patterns defined by the observed rainfall data during each storm. This information was used to create the storm files in RORB which was then run to produce rainfall excess hydrographs for input into the hydraulic model. The hydraulic model was run iteratively by adjusting the Initial Loss (IL) and Continuing Loss (CL) values in the RORB model until a match in water levels was achieved between the hydraulic model and gauged levels at Rosehill Road.

TABLE B.12: DAILY RAINFALL DEPTHS

Rainfall Station Gauge Name	Gauge ID	Recorded Rainfall Depth (mm)	
		22 March 2001	29 January 2021
Footscray Rain Gauge	587024	74.2	45.2
Essendon North Rain Gauge	586182	75.8	46.8
Avondale Heights Rain Gauge	230806A	-	48.2
Maribyrnong River at Chifley Drive, Maribyrnong	230106A	77.3	46.4
Maribyrnong River at Keilor	230105A	121.1	43
Moonee Ponds Creek at Jacana Retarding Basin, Jacana	229665A	64.2	45
Moonee Ponds Creek, Flemington	229643A	59.6	44.8

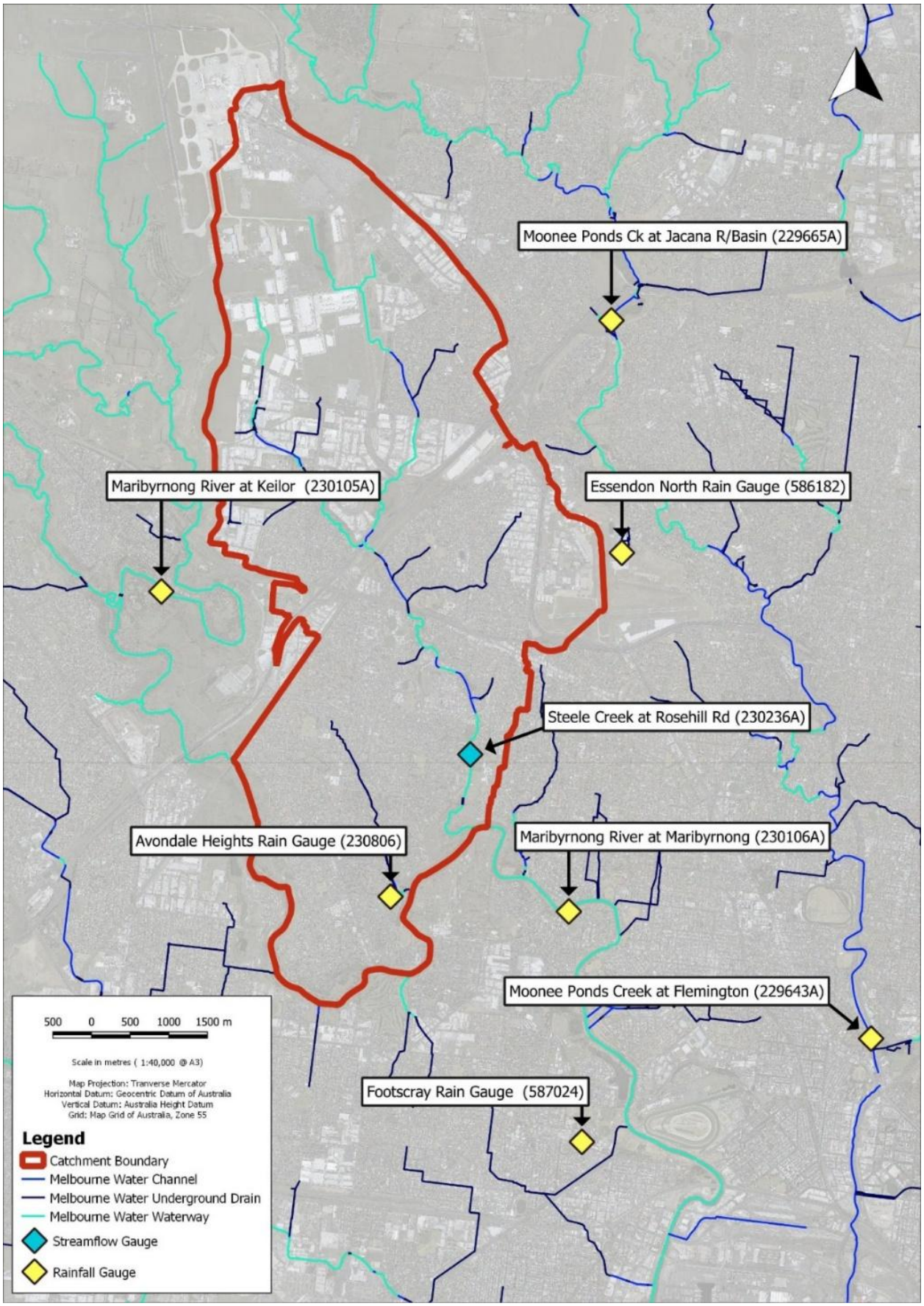


FIGURE B.9: LOCATION OF RAINFALL AND STREAMFLOW GAUGES

B.3.1 Spatial Variation

Rainfall totals recorded at each of the gauging stations were used to produce interpolated 50 m resolution rainfall grids for each storm event. These grids were produced using the Inverse Distance Weighting (IDW) method per ARR v4.1 and are presented in Figure B.10 and Figure B.11 for the March 2001 and January 2021, respectively. The rainfall applied to each sub-catchment during model calibration was calculated as the average of the IDW gridded rainfall depths within each sub-catchment boundary.

For the January 2021 event the rainfall distribution was found to be relatively uniform with each of the sub-catchment rainfall depths falling within +/- 5 mm of the catchment mean. For the March 2001 event, the rainfall distribution is influenced by the larger rainfall volumes recorded at the Maribyrnong River at Keilor Gauge, resulting in a variance of +/- 40 mm across the catchment. However, the larger volumes of rainfall recorded for the March 2001 event predominantly fell within the sub-catchments draining to the Maribyrnong River and therefore have minimal influence on the calibration of flood levels at the Rosehill Road Gauge along Steele Creek.

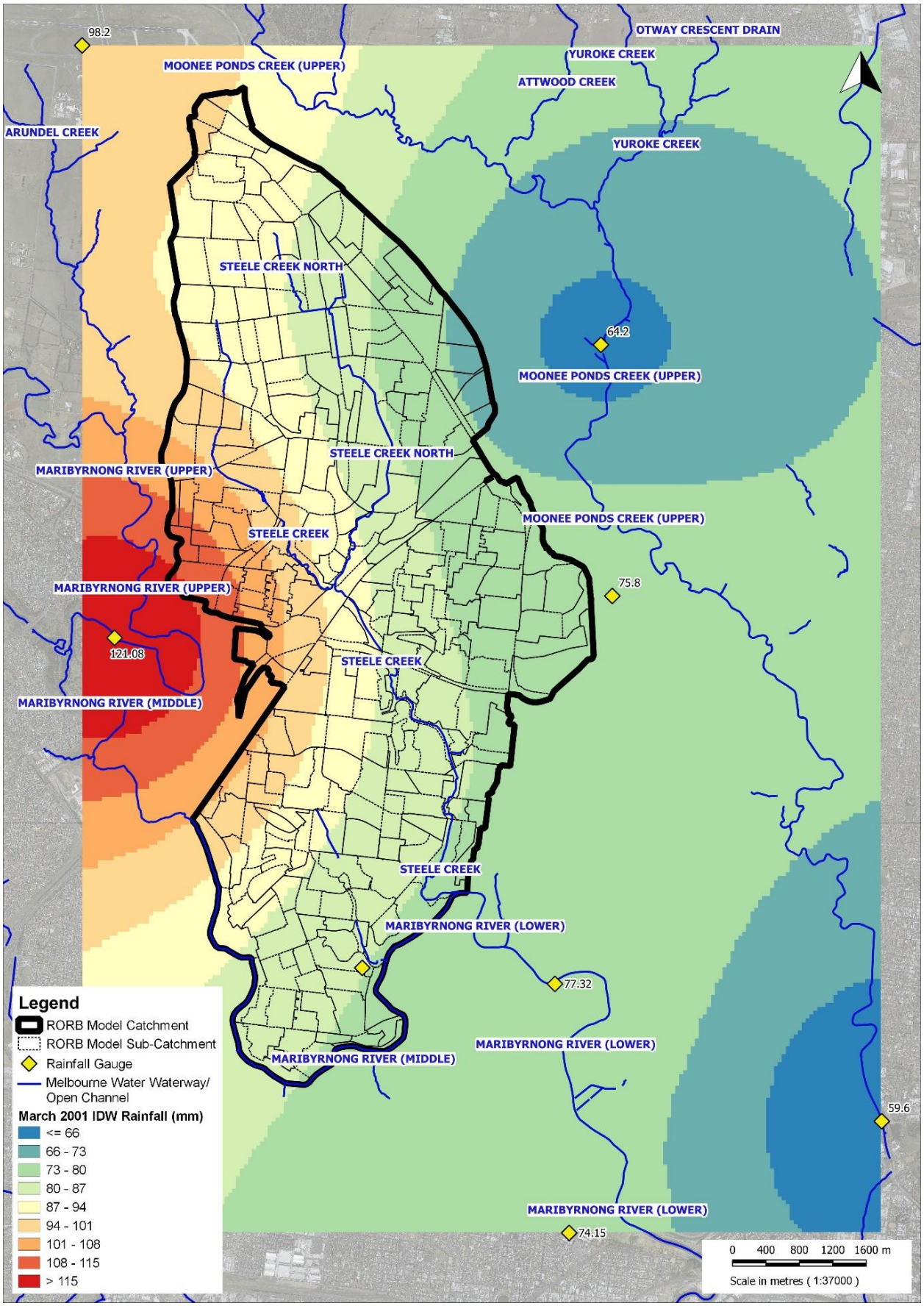


FIGURE B.10: INTERPOLATION OF RAINFALL USING IDW METHOD FOR MARCH 2001 EVENT

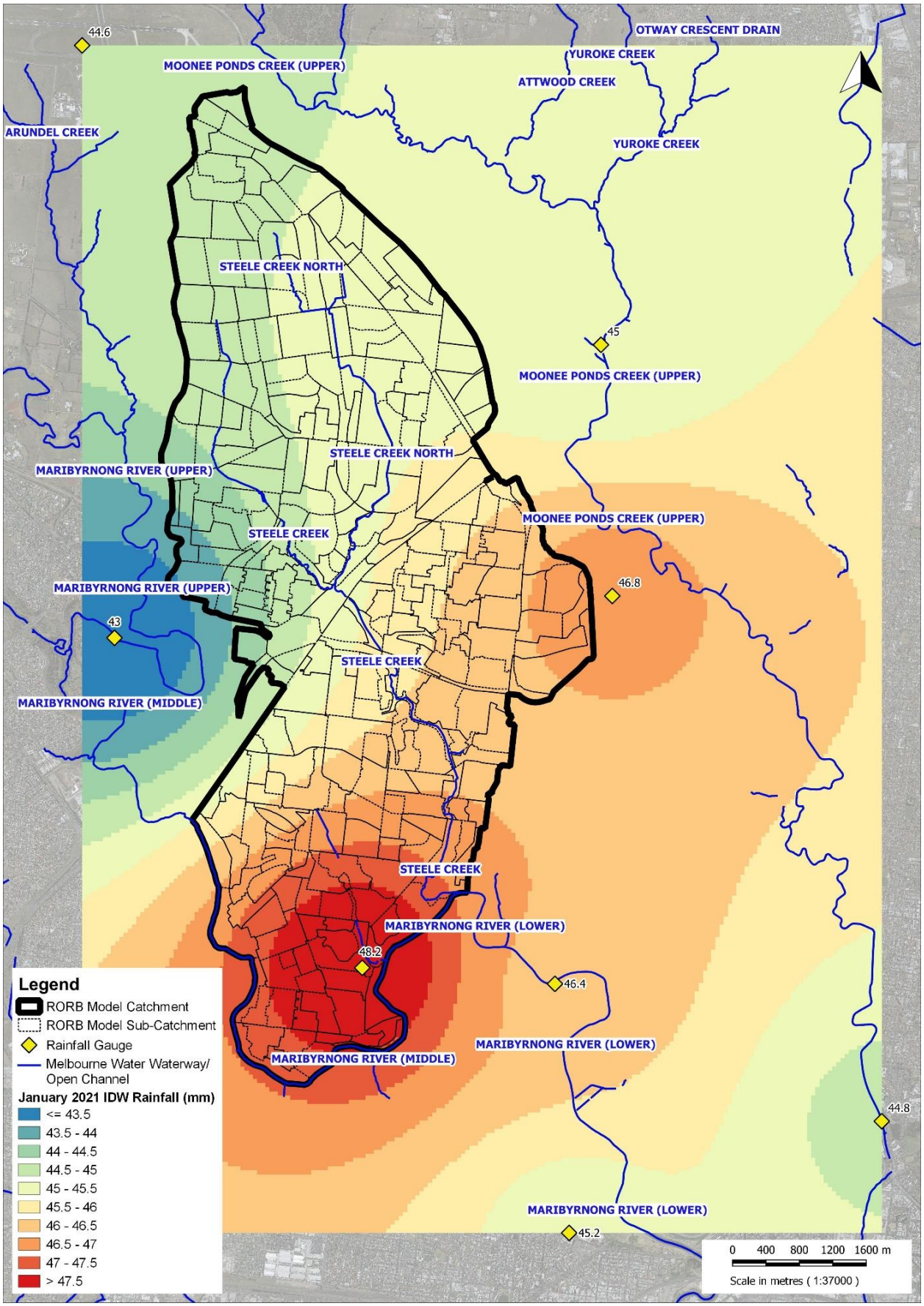


FIGURE B.11: INTERPOLATION OF RAINFALL USING IDW METHOD FOR JANUARY 2021 EVENT

B.3.2 Temporal Patterns

Rainfall data recorded at the Maribyrnong River at Chifley Drive (230106A) gauging station was used to derive temporal rainfall patterns for each design event. This gauge was selected as it is the closest rainfall station to the Rosehill Road streamflow gauge (approximately 3.5 km downstream) and contains complete records for both the March 2001 and January 2021 events. In addition, the rainfall depths recorded at this gauge were found to be closest to the mean spatially weighted rainfall depths derived in the previous section.

March 2001 Rainfall Distribution

Figure B.12displays the rainfall distribution from 4:00 am to 6:00 pm on 22 March 2001 at the Maribyrnong River at Chifley Drive station. Figure B.13 shows the temporal pattern derived for the March 2001 model event which represents the 12-hour duration storm over 24 increments. The rainfall distribution presented in Figure B.13 was utilised to create the storm file read into RORB and is inclusive of pre-burst rainfall.

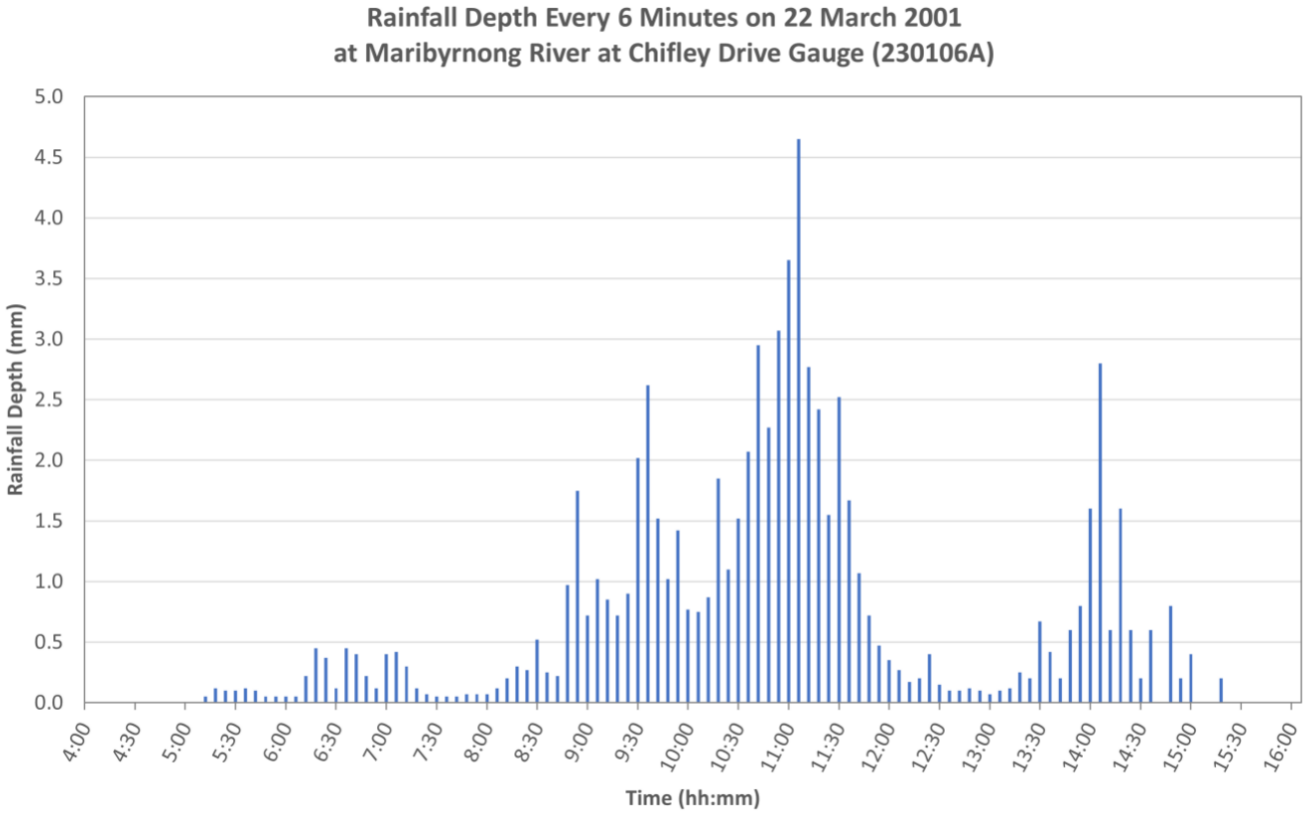


FIGURE B.12: 22 MARCH 2001 6-MINUTE PLUVIOGRAPHIC RAINFALL DATA

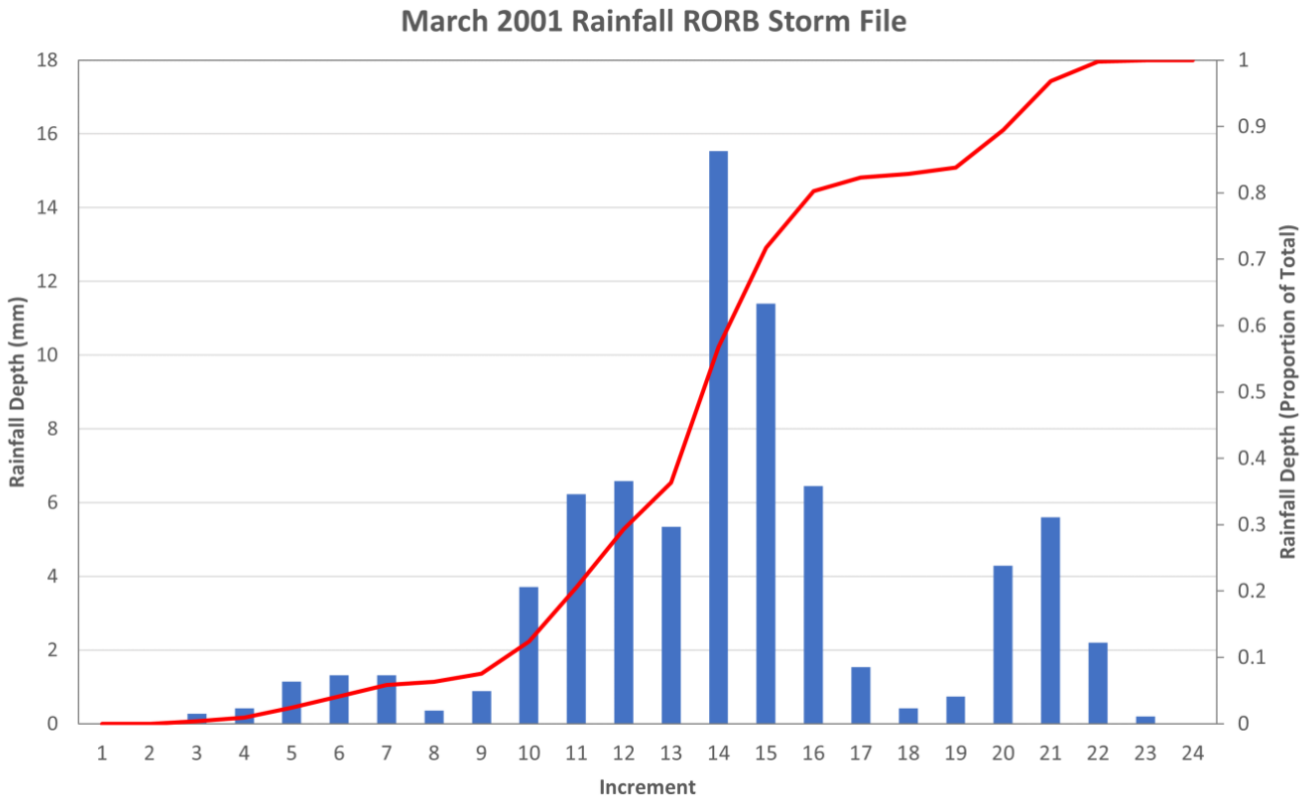


FIGURE B.13: MARCH 2001 EVENT RAINFALL DISTRIBUTION

January 2021 Rainfall Distribution

Figure B.14 displays the rainfall distribution from 5:00 am to 3:00 pm on 29 January 2021 at the Maribyrnong River at Chifley Drive station. Figure B.15 shows the temporal pattern derived for the January 2021 model event which represents the 10-hour duration storm over 20 increments. The rainfall distribution presented in Figure B.15 was utilised to create the storm file read into RORB and is inclusive of pre-burst rainfall.

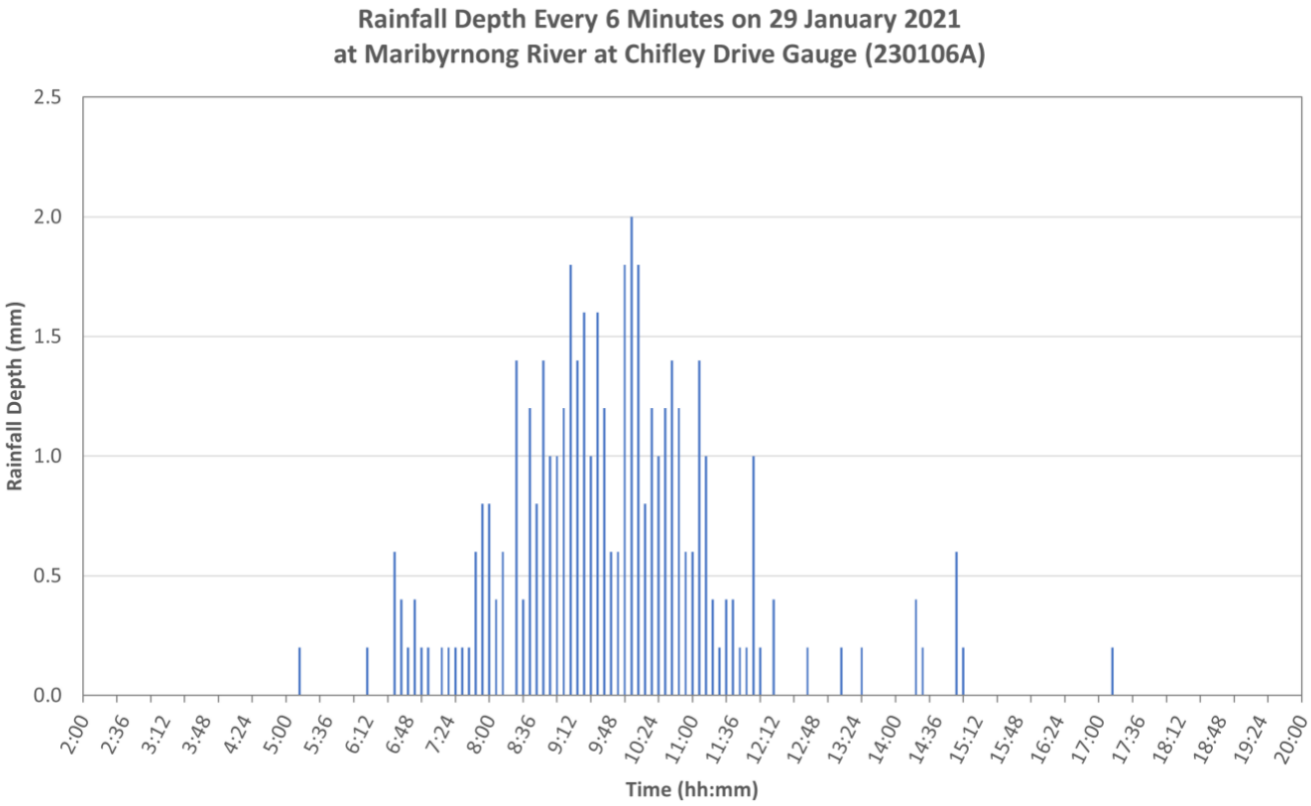


FIGURE B.14: 29 JANUARY 2021 6-MINUTE PLUVIOGRAPHIC RAINFALL DATA

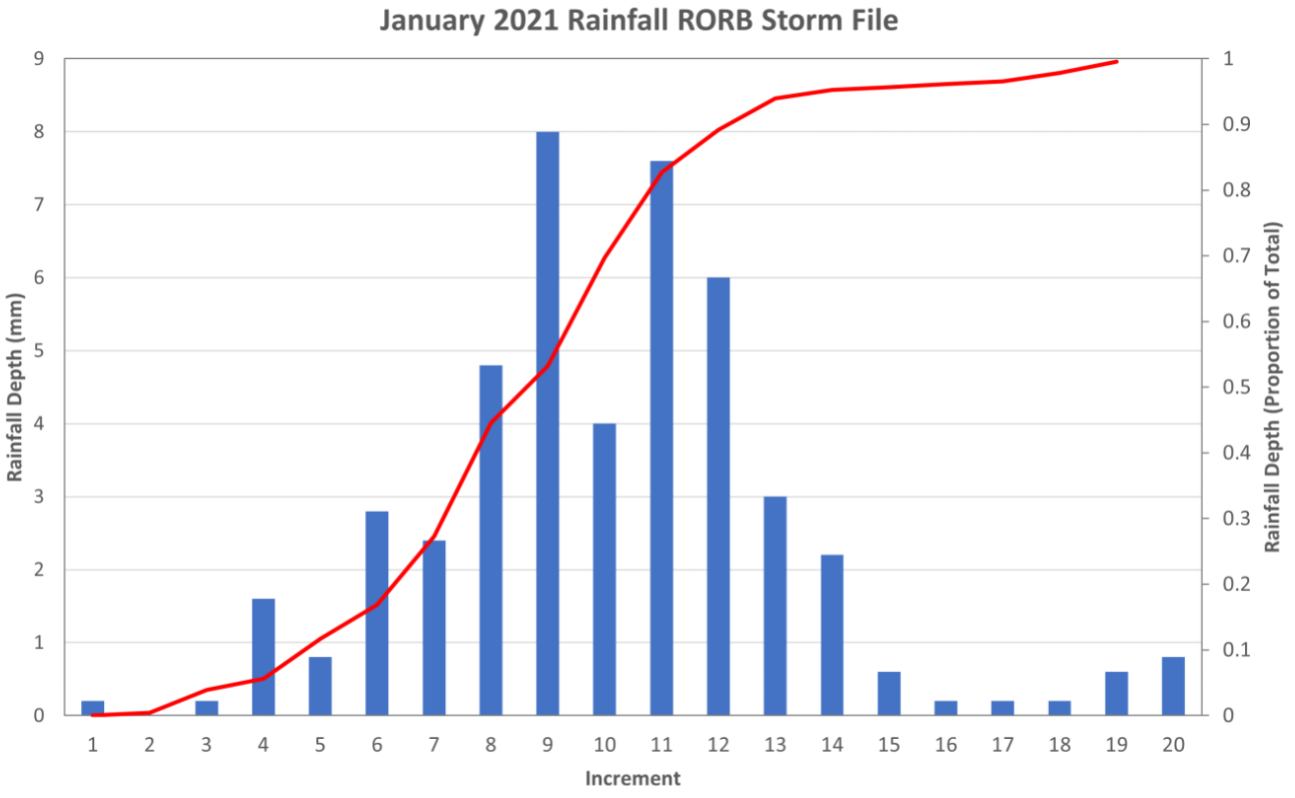


FIGURE B.15: JANUARY 2021 EVENT RAINFALL DISTRIBUTION

B.4 RORB Model Parameters.

B.4.1 Rainfall Losses

The RORB models utilise an initial loss (IL) /continuing loss (CL) model approach, in accordance with the recommendations of ARR v4.1. Losses in RORB were assigned based on three surface types:

- Effective Impervious Area (EIA) – comprising areas which are effectively impervious and are connected to the drainage system
- Indirectly Connected Area (ICA) – comprising impervious areas which are not directed to the drainage system (e.g. a paved patio or footpath) and pervious areas that interact with impervious areas which are not directly connected (e.g. nature strips and garden areas)
- Pervious Area – comprising parklands and bushlands

Of the surface types noted above, the RORB model has been split into EIA and ICA areas only, with pervious areas classified as ICA areas. Based on the highly urbanised nature of the catchment, it was considered that pervious and ICA areas were likely to have near identical losses and as such only two of the three surface types listed above were modelled.

The Total Impervious Area (TIA) of each sub-catchment was calculated as per the fraction impervious methodology described in Appendix Section B.1.2. The split between EIA and ICA was calculated based on the ratio of EIA / TIA as follows:

- Residential / educational / schools / mixed-use – EIA / TIA ratio: 60 % (ARR v4.1 suggests 50 to 70 %)
- Industrial / commercial – EIA / TIA ratio of 90 % (ARR v4.1 provides limited data, with EIA / TIA ratios ranging from 77 % to 94 % in one study and 74 % to 98 % in another. Given that a review of the aerial imagery indicates the majority of commercial and industrial parcels in the catchment to comprise large buildings and asphalt carparks, a ratio of 90 % was considered reasonable).
- For each of the sub-catchments, the remaining portion of area was determined to comprise ICA.

Table B.13 summarises the final loss values adopted for the design event modelling. These values are based on the results of model calibration, as completed via TUFLOW model runs and discussed in Table C.4.

TABLE B.13: SUMMARY OF ADOPTED LOSS VALUES BY SURFACE TYPE

Surface Type	Initial Loss (IL)	Continuing Loss (CL)
Effective Impervious Area (EIA)	2.0 mm (ARR v4.1 recommends an IL of 1-2 mm)	0 mm/h (ARR v4.1 states that CL for EIA can be assumed to be zero)
Indirectly Connected Area (ICA)	24.5 mm (ARR v4.1 recommends an IL 60-80 % of the rural IL)	3.0 mm/h (ARR v4.1 recommends a CL of 2.5 mm/h for south-east Australia, with a range of 1-3 mm/h.

B.4.2 Routing Parameters

The RORB model developed has been used to produce rainfall excess hydrographs only, rainfall – runoff flow routing and calibration of the IL and CL has been undertaken in the hydraulic (TUFLOW) model. As such the RORB model routing parameters (k_c and *m*) do not have any influence on the flood mapping results presented in this study.

A k_c value of 4.97 has been adopted when running the RORB model. This value is based on the regional relationship developed by Morris (1982) and Hansen et al. (1986) for regions with a mean annual rainfall less than 800 mm has been adopted. The lag routing parameter, *m*, in RORB was set at 0.8 for each interstation area as per the recommendations in the RORB manual and ARR v4.1.

APPENDIX C: TUFLOW HYDRAULIC MODEL DEVELOPMENT

C.1 TUFLOW Model Development

C.1.1 Digital Elevation Model (DEM)

The LiDAR used for this study is from the 2017-18 Greater Melbourne LiDAR Project, representing the most recent LiDAR data available at the commencement of the project. The LiDAR data has been used to generate a DEM with 1-metre resolution for the study area (Figure C.1)The red areas indicate the areas of higher elevation, whilst the blue areas designate the areas of lower elevation.

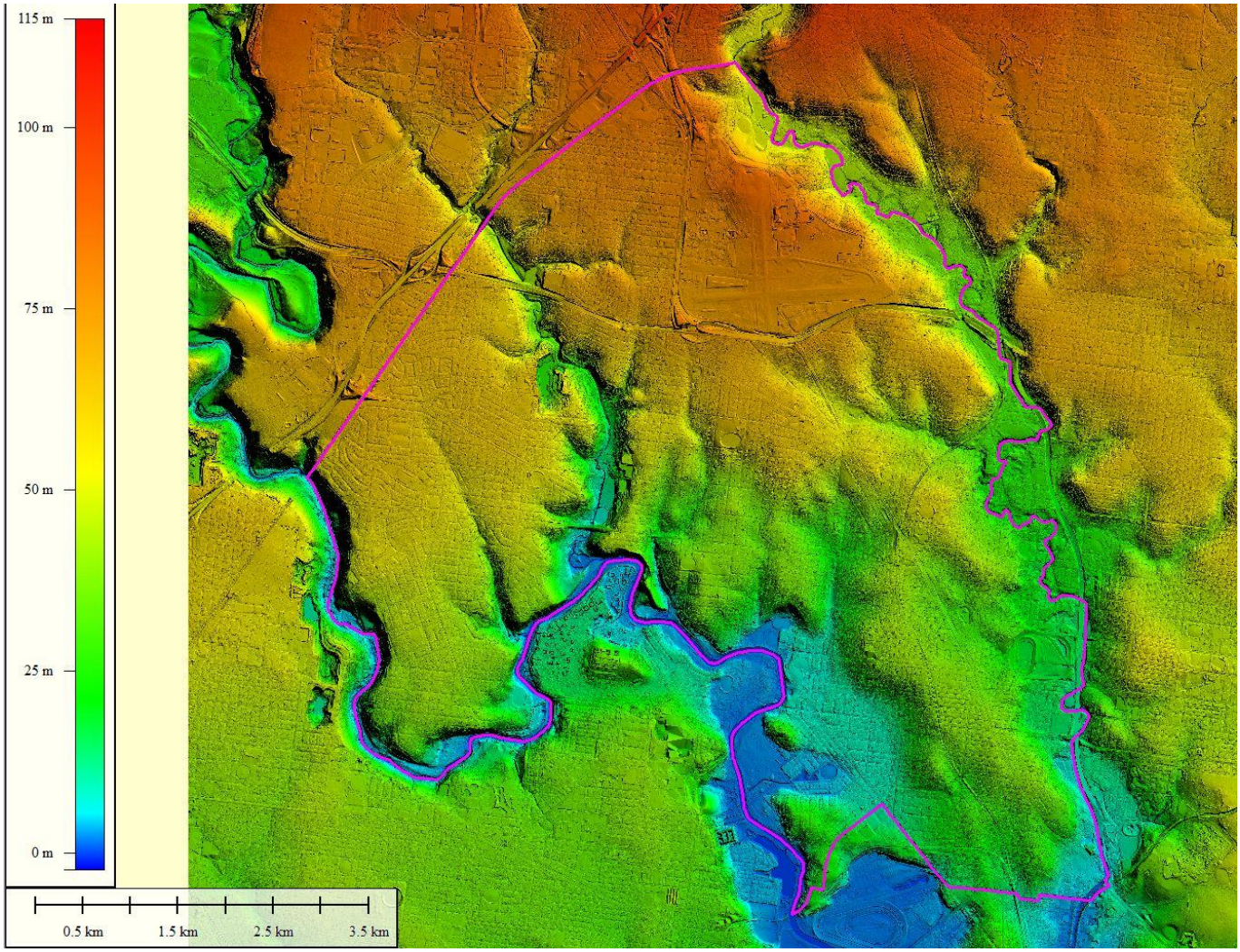


FIGURE C.1: DEM GENERATED FROM LIDAR DATA

C.1.1.1. Steele Creek Survey

January 2022 Survey data was provided at several cross-sections along Steele Creek between Western Ring Road and Buckley Street. This data was used to validate the 2017-2018 LiDAR elevation data along Steele Creek to ensure it was represented accurately in the hydraulic model. Z-lines were used in TUFLOW to reinstate the waterway invert levels for the extent of the survey data.

C.1.2 2D Grid Size

A TUFLOW model grid size of 3 metres with 1-metre sub-grid sampling (SGS) was used to hydraulically model catchment flows. The 3 m grid size alone is considered sufficiently high resolution to represent major catchment drainage features and is in accordance with the range of spatial resolutions recommended in Melbourne Water's Flood Mapping Projects Specification (2021). The 3 m cell size is also sufficiently small enough to enable the effects of raised roadside verges and medians to be modelled while at the same time providing reasonable model simulation times. The use of SGS enhances TUFLOW's ability to represent fine topographical features.

C.1.3 Model Time Steps

The 2020 Council TUFLOW models run in TUFLOW Classic used the following timesteps:

- Maribyrnong Lower – 0.75 s 1D timestep, 0.125 s 2D timestep
- Moonee Ponds Creek Lower – 0.75 s 1D timestep, 0.25 s 2D timestep
- Moonee Ponds Creek Upper – 0.75 s 1D timestep, 0.25 s 2D timestep
- Steele Creek – 0.75 s 1D timestep, 0.5 s 2D timestep

The 2D time steps are consistent with recommendations in Melbourne Water's Flood Mapping Projects Specification (2021) and the TUFLOW Manual which states that "*For the majority of flood models, the 2D timestep in seconds should be somewhere between 1/2 to 1/5 of the 2D cell size*," (3 meters for all models).

The updated 2021 flood modelling was completed using TUFLOW HPC which uses an adaptative timestep. QA checks and reviews were conducted on the final model including the time steps.

C.1.4 Surface Roughness

The initial Manning's roughness values were assigned to land parcels based on land use zonings following the recommendations from Melbourne Water's Flood Mapping Projects Guidelines and Technical Specifications (2021). The roughness values were then further refined based on the aerial photographs and observations made onsite to ensure that adopted roughness values are appropriate and correspond to actual surface type. Buildings were represented using a high roughness value in order to simulate limited conveyance in urban areas while preserving the amount of available storage. The roughness values adopted for different surface types are listed in Table C.1.

TABLE C.1: MANNING'S N ROUGHNESS VALUES

Material Number	Type of Zone	Manning's Roughness
1	High density residential	0.35
2	Low density residential	0.2
3	Open paddock	0.035
4	Open paddock with moderate trees	0.06
5	Commercial & residential building footprints	0.5
6	Car park / road	0.03
7	Paddock with high density trees	0.09
8	Remainder of parcel (residential high density)	0.1
9	Railway line	0.12
10	Open concrete channel	0.013
11	Open water with reedy vegetation	0.065
12	Open water with submerged vegetation	0.0225 to 0.04

C.1.5 1D Network Data

C.1.5.1. Melbourne Water Drainage Assets

Engeny obtained GIS data of the existing Melbourne Water stormwater network as well as available flood models, design drawings and as-constructed plans. This data was used to input Melbourne Water's drainage system into the hydraulic models.

There was uncertainty in the data in several areas, in some cases due to conflicting information between the GIS and design plans. To resolve this, Engeny undertook site visits to many of Melbourne Water's drainage assets in the study area to ensure the model setup best represented reality.

A small number of instances of missing pipe invert data were identified where the relevant design drawings or as-constructed plans could not be located. These data gaps were filled using engineering judgement, for example matching upstream inverts with the downstream invert of the adjacent upstream pipe and interpolating between known inverts, with assumed inverts verified against the generated DEM.

C.1.5.2. Council Drainage Pipes

Information regarding the upstream and downstream invert levels of each pipe was not available for a large portion of the drainage network within Council's GIS database. Therefore, it was necessary to artificially generate invert levels where they were missing or inaccurate (e.g. where the suggested invert of the pipe was above the ground level). Engeny estimated inverts by adopting the following formula:

- Invert level = Ground level RL (from LiDAR) – 600 mm (pipe cover) – pipe diameter / culvert height

The data was processed to grade the drainage network such that there are no pipes within the network with negative grade.

There were a number of areas where there were gaps in the drainage pipe data in either connectivity or pipe diameters. Council's GIS pipe layer covering all modelled areas contained a total of 20,603 pipes, of which, more than 4,031 pipes had missing pipe sizes. In addition to this, a large number of drainage pipe sizes were found to be incorrect. Design plans provided by Council were used to fill in gaps where possible, however for some pipes / pits this was not the case so field inspections were commissioned by Council to provide the necessary data to resolve the data gap or inaccuracy.

- Engineering judgement has been used to fill in the majority of these data gaps. The assumptions used to estimate the pipe sizes were:
  - Where the pipe diameter was missing for a single pipe but the upstream and downstream diameters were available, the pipe in the middle was assumed to be the same size.
  - If the pipe was within a road reserve and had no other upstream pipes a diameter of 300 mm was applied.
  - If the pipe was within a private property easement and had no other upstream pipes a diameter of 225 mm was applied.
- A Manning's roughness value of 0.013 was adopted for the concrete underground drainage pipes and culverts.
- The Engelund method of automatically created manholes has been used for determining pit losses. This method recalculates losses at each time step using the angle of the entry and exit culverts, water levels and flow distributions. Where manholes are not created the following losses apply to the drainage network:
  - Height contraction coefficient = 0 for circular pipes and 0.6 for rectangular pipes
  - Width contraction coefficient = 1.0 for circular pipes and 0.9 for rectangular pipes
  - Entry loss coefficient for culverts = 0.5
  - Entry loss coefficients for underground pipes = 1.5 (where pipe is connected to a upstream pit)
  - Exit loss coefficient for culverts = 1.0
  - Exit loss coefficients for underground pipes = 1.5 (where pipe is connected to a downstream pit)
- Instances where there is a drop in height between two pipes that are connected via a pit, i.e. the upstream pipe enters above the outfall pipe, is an example where TUFLOW does not create a manhole for loss calculation purposes. A check message, "CHECK 1402 - More than one culvert connected but could not create manhole at Node "XXX" is usually shown in these cases. The pressure head loss coefficients for pits (denoted Ku) are usually assumed proportional to the velocity head at the entrance of the downstream pipe. Empirical studies have estimated these losses and produced various loss coefficients for a range of pit and pipe layouts that account for lateral flow, through flow, and/or both. Engeny has adopted a K value of 3 for losses from drops in pits or other locations where manholes cannot be created. A K value of 3 was deemed to provide a conservative loss value that is applicable to a range of drainage junction layouts. This has been applied to the pipes into TUFLOW through the entry and exit loss, with each parameter given a value of 1.5 (i.e. K/2).
- Pipe directions were corrected as necessary to ensure that all pipes were digitised in the correct direction (i.e. flowing downhill).
- Pipes were snapped together where they were found to be graphically disconnected.

C.1.5.3. VicRoads Underground Drainage

Pit and pipe asset details, in the form of design drawings (where available) was sourced from VicRoads for roads managed by VicRoads across the City of Moonee Valley including but not limited to CityLink.

C.1.5.4. Open Waterways

The study area (comprising all four TUFLOW models) includes the following Melbourne Water managed waterways:

- Moonee Ponds Creek
- Maribyrnong River
- Steele Creek
- Five Mile Creek

Upstream inflows have been input for the following waterways which originate outside of the City of Moonee Valley:

- Moonee Ponds Creek
- Maribyrnong River

Moonee Ponds Creek and the Maribyrnong River were included in the models for the purpose of representing their interaction with Council and Melbourne Water stormwater drainage infrastructure. Waterway flood levels within these systems have not been refined for detailed assessment, as the modelling focus was on facilitating accurate representation of the stormwater drainage network. Inflows from upstream of the Moonee Valley area were incorporated only where waterway flows directly influence the hydraulic capacity or performance of the stormwater drainage system. Waterways that are deeply incised or have significant vertical separation from the stormwater network were therefore not modelled in detail, as they do not materially affect stormwater conveyance within the study area.

All waterways have been modelled in the 2-D domain as a result of being sufficiently defined by the LiDAR data as well as the following requirement outlined in the Melbourne Water Project Specifications (2021) being met:

If a river or watercourse is to be modelled exclusively in 2D, the grid size should be small enough that the smallest river / watercourse cross-section is defined by at least 5 grid cells if using TUFLOW Classic and HPC 2nd Order spatial solvers.

C.1.5.5. Drainage Pits

Interrogation of Council's pit drainage data identified 23,512 pits within Council's GIS database. Table C.2 provides a summary of the different pit types as derived from Council's GIS drainage database, standard drawings, and from the site inspection. These dimensions were represented in the TUFLOW model by modelling the pits as "Q-type pits". The inlet capacity of the Q pit is governed by a stage-storage curve. This allows for a better representation of the actual capacity of the particular type of pit within the model. Table C.2: Summary of Council pits modelled in TUFLOW.

TABLE C.2: SUMMARY OF COUNCIL PITS MODELLED IN TUFLOW

Pit Type	Description
Grated Pit	GP_900x600 (assumed standard dimension as per Council standard drawing for pits up to 1.2m deep) GP_600x450 (identified on site) GP_900x750 (identified on site) GP_900x900 (identified on site)
Double Grated Pit	GP_1800x600 GP_1800x750 (identified on site)
Grated Side Entry Pit	GSEP_900x750 (assumed standard dimension as per Council standard drawing for pits up to 1.2m deep) GSEP_900x900 (identified on site)
Double Grated Side Entry Pit	GSEP_1800x750
Side Entry Pit	SEP_900 (900mm wide kerb entry)
Double Side Entry Pit	SEP_1800 (1800mm wide kerb entry)
Other	Junction Pits Inspection Pits (dimensions were not available)

Junction pits and inspection pits have been modelled with and inlet dimension of 0.9 meters by 0.1 m. These junction pits were connected to the surface and allowed to surcharge to simulate the potential of pit lids being dislodged during heavy rainfall events.

Pits have typically not been modelled on Melbourne Water's system in accordance with the Melbourne Water Project Specifications (2021), however there were some instances where large, grated pits owned by Melbourne Water were identified and these were added to the model to reflect on-the-ground existing conditions.

C.1.6 Boundary Conditions and Initial Water Levels

Several types of boundary conditions were specified in the model in order to apply the rainfall excess hyetographs produced in RORB to the TUFLOW model, to connect 1D and 2D domains in certain locations, and to allow water to leave the model without ponding against the model boundaries.

C.1.6.1. 1D Boundary Conditions

The 1D boundary condition layer (1d_bc) has been used to read in RORB inflow hydrographs for the individual sub-catchments. The sub-catchment polygons created for the hydrological model were input into this layer. This allows for the total hydrograph for the RORB sub-catchment to be distributed equally across the pits.

Within some locations where the pit distribution was not even across the sub-catchment polygon, these sub-catchments were further delineated into smaller sub-catchments, with an area-weighted multiplier applied to each of the further delineated sub-catchments to redistribute flows.

Some sub-catchments do not contain any pits and therefore flow cannot be applied to the model using 1D boundary conditions. In these instances, 2D source areas (2d_sa) were utilized with TUFLOW.

Head versus time (HT) 1D boundary conditions were applied at the downstream end of the Council drainage network at locations where flow is discharging out of the study area. This includes a number of locations around the study area boundary where pipe flows are conveyed to an adjacent catchment, but any overflow from these pipes can contribute to flows within the study area. At each location, the tailwater levels at the 1-D boundary have been applied based on the obvert of the downstream pipe. Tailwater levels have been assigned at locations sufficiently far enough downstream such that they do not impact results within the area of interest.

Cross catchment flows have also been considered in the application of 1D boundary conditions. For example, application of sub-catchment flows to the drainage network within the Maribyrnong Lower catchment for rare AEP events results in overland flows being directed into the Moonee Ponds Creek Upper catchment near the boundary of the two catchments. As a result, the Moonee Ponds Creek Upper catchment model allows for this via inclusion of the relevant 1D boundary conditions from the Maribyrnong Lower model.

C.1.6.2. 2D Boundary Conditions

As part of the 1D network, 2D SX (source of flow from a 1D model) boundaries were assigned to the pits to allow surcharge of water from the pipe network to the 2D surface.

2-D head versus flow (HQ) boundary conditions have been adopted where overland flows leave the models, including at the downstream ends of the modelled waterways and where minor flow paths breakaway from the study area.

Some RORB sub-catchments used to define the hydrological models do not have any inlet pits. Alternatively, some RORB sub-catchments include few pits that are not well distributed through the sub-catchment. These include areas such as large parks and open spaces. In these instances, TUFLOW's 2-D source area (2d_sa) layer was used to apply flow directly to the 2-D domain of the hydraulic model. Application of flows via this method allows TUFLOW to complete flow routing through the 2-D domain.

C.1.6.3. Initial Water Levels

1-D initial water levels were specified upstream of fixed water level boundary conditions (HT boundaries). The initial water level was set to the same level as the boundary condition.

Applying the initial water level to the 1-D domain helps to prevent any "backflow wave" from the boundary conditions filling up pipes that are below the elevation specified at the boundary.

2-D initial water levels were specified where ponds, dams, lakes and wetlands were located throughout the study area to fill these storages throughout the models, providing a conservative flood modelling result. Where plans were available for wetlands, the initial water level was set to the normal water level within the feature. LiDAR data was alternatively used to set the 2-D initial water level where no plans were available.

C.1.6.4. Bridge Structures

Bridge structures have been included in the models layered flow constrictions in the 2-D domain (2d_lfcsh) to model the impacts of piers, decks, and handrails on overland flow paths. Table C.3 provides a summary of the bridge dimensions included in the 2-D layered flow constrictions, additional bridge structures are located within the hydraulic model extents but were not found to be impacting overland flow. Bridge loss factors within the hydraulic model are based on values from the *Hydraulics of Bridge Waterways* study undertaken by Bradley (1978).

TABLE C.3: SUMMARY OF BRIDGE STRUCTURE DIMENSIONS

Location	Data Source	Pier Blockage (%)	Deck Height (m)	Railing Height (m)
Steele Creek at Airport Drive	Vic Roads As-Constructed Plans	5.3 %	2.5	0.5
Steele Creek at M80	Vic Roads As-Constructed Plans	3 %	2	1.5
Steele Creek Pedestrian Foot Bridge at Rosehill Road Gauge	Melbourne Water As-Constructed Plans	0 %	2.2 [1]	1.2
Steele Creek at Rosehill Road	Site Visit	0 %	1.5	1.2

C.2 Model Calibration

The Steele Creek catchment hydraulic model was calibrated by adjusting the IL and CL values in the RORB model until a close match in water levels was achieved between the Steele Creek hydraulic model and the Rosehill Road stream flow gauge. The RORB and TUFLOW models were run several times until the losses presented within Table C.4 were determined.

Table C.4 shows a comparison of modelled and gauged water levels for the March 2001 and 2021 events. The final loss parameters achieve a difference of approximately 3% for each of the historical storm events, with the hydraulic model producing water levels 320 mm and 260 mm above those recorded for March 2001 and January 2021 events. This match was considered appropriate given the depths of the historical events (3.0 and 1.73 meters) and the loss recommendations presented in ARR v4.1. Raising the ICA CL or EIA IL to achieve an even closer match to the gauged water levels would push the loss parameters outside the range of those recommended in ARR v4.1 for south-east Australia.

TABLE C.4: EVENT BASED CALIBRATION RESULTS

Event	Rosehill Road Gauge			TUFLOW Level (m AHD)	TUFLOW – Gauge Difference (m)	TUFLOW – Gauge Difference (%)
	Zero level (m AHD)	Depth (m)	Level (m AHD)			
March 2001	7.25	3	10.25	10.57	0.32	3.1%
January 2021	7.25	1.73	8.98	9.24	0.26	3.0%

C.3 Model Validation

Council provided Engeny with photographs collected from residents documenting flooding associated with past flood events. These photographs were used to support model validation, with modelling results confirming that the locations identified in the photographs are subject to flooding under simulated conditions.

As part of the study, Council engaged with the community through its *Your Say* website, which communicated that the flood study was being undertaken and sought to identify appropriate flood management responses. Community members were invited to submit anecdotal evidence of flooding across the municipality, including written comments and, where available, photographs and videos, to further inform and validate the modelling undertaken as part of the study. A total of 30 community submissions were received. Engeny reviewed these submissions and identified alignment between reported flooding experiences and the modelled flood extents and depths.

C.4 Critical Storm Events

C.4.1 ML, MPCL, and MPCU

All ten temporal patterns were simulated for all standard storm durations up to the 360-minute storm duration.

C.4.2 SCrk Catchment

As discussed in Appendix Section B.2.2.2 for the Steele Creek catchment separate ARFs were run to accurately model rainfall volumes across the hydraulic model extent. An ARF representative of a catchment area of 1 km^2 has been used to produce Council and Melbourne Water Underground Drains deliverables. ARFs representative of catchment areas of 5 and 22 km^2 have been used to produce Melbourne Water Waterway (Steele Creek) deliverables. The following sections summarise how these different hydraulic model simulations have been processed to identify the temporal patterns and critical durations.

C.4.2.1. Critical Durations

For each AEP, Engeny has run a single, middle-loaded temporal pattern design storm through the hydraulic model using ARFs for catchments of 1 km^2 and 22 km^2. This was completed to determine the critical durations throughout the catchment. As the same volumetric runoff is applied for each duration, doing this allows for a reasonable estimation of critical durations within the catchment whilst reducing the overall runs required to develop the envelope of flood results. Table C.5 presents the selected critical durations for each of the nominated AEP events.

Four to five critical durations were selected based on the above approach, for which then all ten temporal patterns were run through the hydraulic model for each of those critical durations and AEP events to produce the ultimate outputs used to produce the flood mapping GIS deliverables.

TABLE C.5: CRITICAL DURATIONS

Duration	20 % AEP Base Case	20% AEP Climate Change	10 % AEP Base Case	10% AEP Climate Change	5 % AEP Base Case	2 % AEP Base Case	1 % AEP Base Case	1 % CC AEP Climate Change
10 minute						X	X	X
15 minute	X	X	X	X	X	X	X	X
30 minute	X	X	X	X	X	X	X	X
1 hour	X	X	X	X	X	X	X	X
2 hour	X	X	X	X	X	X	X	X
3 hour	X	X						

C.4.2.2. Temporal Patterns

C.4.2.2.1 Council and Melbourne Water Underground Drains (Steele Creek Catchment)

All ten temporal patterns were run through the hydraulic model for each of the critical durations and AEP events identified in B.2.2.2. For each grid cell within the Council and Melbourne Water Underground Drains extents the flood height derived from the median temporal pattern was calculated for each duration. The maximum for all durations was then calculated to provide the design flood height for each AEP event. This was repeated for the other gridded outputs (e.g., Flood Velocity and Hazard etc.) as part of this study.

C.4.2.2.2 Melbourne Water Waterways (Steele Creek Catchment)

For the climate change event runs (1 %, 10 % and 20 % AEP events), all ten temporal patterns were run per identified critical duration. Regarding ARFs, the ensemble of TUFLOW runs were completed twice, using hydrological inputs of ARF for catchment areas of 5 km^2 and 22 km^2 to represent flood levels along Steele Creek (the basis for these catchment areas is discussed in Appendix Section B.2.2.2).

Due to the different ARFs being applicable across different sections of the waterway (for example an ARF value for a catchment area of 5 km^2 being applicable north of the Western Ring Road, whilst an ARF value for a catchment area of 22 km^2 being relevant for the downstream sections of Steele Creek), there would be inaccuracies in the flood model outputs if the overall flood height was simply calculated from the median temporal patterns of all runs. Engeny developed an ARF tool in Python to iteratively process results to produce a combined flood level grid per AEP event which would best represent flood levels at key locations across the catchment. The following summarises the steps undertaken in this tool which has been used to identify the critical events (duration and temporal patterns) along the waterway extents (as based on the climate change event runs).

(1) Identify Areas of Interest (AoI) within the hydraulic model extent. Seven (7) AoIs were identified along Steele Creek, see Figure C.2. These areas represent sections along Steele Creek with the largest flood depths, just upstream of major hydraulic constraints (culverts or constricted bridge / pedestrian crossings), as these areas were found to be the most sensitive to different ARF values and temporal patterns.

(2) Run the hydraulic model for the ensemble of temporal patterns for 1 % AEP Climate Change event and the critical durations identified in Table C.6.

(3) Calculate the median temporal pattern and critical duration at each AoI using the appropriate ARF

(4) Produce a maximum grid of all the median events identified in Step 3, referred to as “enveloped grid”

(5) Calculate the difference between the flood levels in the enveloped grid against the critical event flood level at each AoI

(6) Identify and remove the event (duration / temporal pattern) producing the largest level difference in Step 5 from the enveloped grid

(7) Repeat Step 5, using the new enveloped grid from Step 6.

(8) Repeat Steps 5-7 until the level difference cannot be reduced any further or one temporal remains for each identified critical duration.

(9) Repeat Steps 2 – 8 for the 20 % and 10 % AEP Climate Change events.

The critical durations and temporal patterns identified for the different ARFs using the above methodology are presented in Table C.6 each of the Climate Change events. For each AEP event, the outputs of the selected critical durations and temporal patterns were combined to calculate the maximum value at each grid cell, which was then adopted for the final hydraulic modelling results and deliverables.

For the existing (base case) climate model, the suite of events (durations and temporal patterns) run were limited to those identified in Table C.6 for the corresponding AEP event. For AEP events not modelled using climate change rainfall parameters (i.e. the 2 % and 5 % AEP events) it is noted that these AEP events share the same “temporal pattern bins” as other AEP events (i.e. the 1 % AEP and 2 % AEP have the same set of 10 temporal patterns, as does the 5 % and 10 % AEP events). Accordingly, the critical events run for the 2 % and 5 % AEP events were based on the corresponding AEP event which shared the same temporal pattern bin.

TABLE C.6: IDENTIFIED EVENTS AND TEMPORAL PATTERNS FOR MELBOURNE WATER WATERWAYS

AEP Event	ARF	Critical Durations and Temporal Patterns Selected
20% Climate Change	ARF = 5 km^2	1 hour tp4 1 hour tp9
	ARF = 22 km^2	1 hour tp8 3 hour tp4
10% Climate Change	ARF = 5 km^2	1 hour tp15 1 hour tp18 1 hour tp19 2 hour tp15
	ARF =22 km^2	2 hour tp14 2 hour tp15 2 hour tp16 2 hour tp17
1 % Climate Change	ARF = 5 km^2	1 hour tp28
	ARF =22 km^2	2 hour tp21

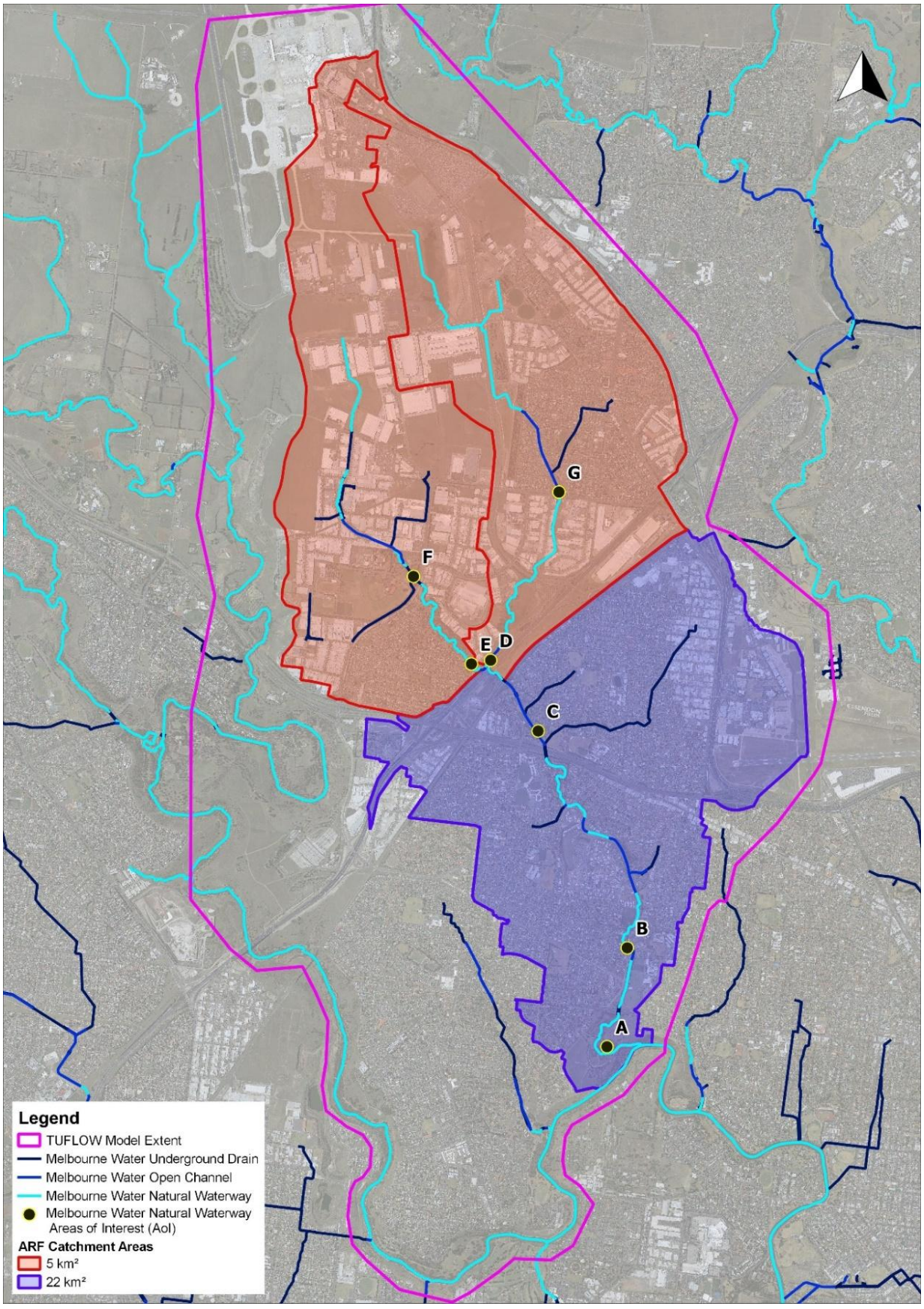


FIGURE C.2: STEELE CREEK AREAS OF INTEREST FOR CRITICAL EVENT AND TEMPORAL PATTERNS

C.5 TUFLOW HPC Versus TUFLOW Classic Comparison

TUFLOW HPC (and TUFLOW HPC with Sub-grid sampling) feature as TUFLOW's latest releases in modelling software, seeking to replace the previous TUFLOW Classic modelling solver used in previous iterations of flood modelling.

Noting that a Council flood model for each of the four Moonee Valley catchments has been previously developed by Engeny for the Council flood mapping study, it was discussed and agreed with Melbourne Water that a TUFLOW HPC versus TUFLOW Classic comparison would be undertaken on the existing Council models. This would allow Melbourne Water to review and approve the use of TUFLOW HPC (with Sub-grid Sampling) for subsequent model runs, particularly the proposed iterative model runs for the Steele Creek catchment for model calibration / selection of appropriate loss parameters for all four Moonee Valley flood models.

As such, the existing Council flood models for each of the four catchments have been run using both TUFLOW Classic and TUFLOW HPC (using TUFLOW build 2020-10-AA) for the 1 % and 10 % AEP flood events. These maps and associated modelling results were submitted to Melbourne Water for review in September 2021.

Subsequent discussion with Melbourne Water, with regards to the above findings, concluded "*the risk of adopting TUFLOW HPC is relatively low given that the 'original' model has been set up in TUFLOW Classic, and differences appear to be primarily in areas which aren't within the scope of the mapping outputs. Review of the model against the latest Melbourne Water QA framework and Tech Specs will be required to mitigate the risk of any model health or setup issues in TUFLOW HPC, and some adjustment of the model may be necessary when implementing SGS.*" (*pers. comm*., Melbourne Water 2021). Based on this, all subsequent modelling has been undertaken using TUFLOW HPC with Sub-grid Sampling, with the appropriate quality assurance checks undertaken (as further discussed in Section C.1).

C.6 Blockage Risk Assessment

Chapter 6 (Blockage of Hydraulic Structures) of ARR v4.1's Book 6: Flood Hydraulics provides a discussion of the impact of blockage on flood behaviour for various types of structures and drainage elements. Key groupings of structures and drainage elements as defined within Chapter 6, Book 6, ARR v4.1 are listed as follows:

- Bridges and culverts
- Drainage system inlets and pipes
- Open channels and waterways
- Overland flow paths
- Weirs and dams

Based on the above list, the key ARR v4.1 groupings of structures and drainage elements within the study area are drainage system inlets and pipes and overland flow paths. A methodology and framework for assessing the risk of blockage is provided within Chapter 6, Book 6 of ARR v4.1 however, focuses on blockage of bridges and culverts only. Table C.7 summarises the outcomes of the blockage assessment.

An analysis of ML and MPCL has identified no culvert and/or bridge crossing locations therefore, a blockage risk assessment of Melbourne Water assets was not undertaken.

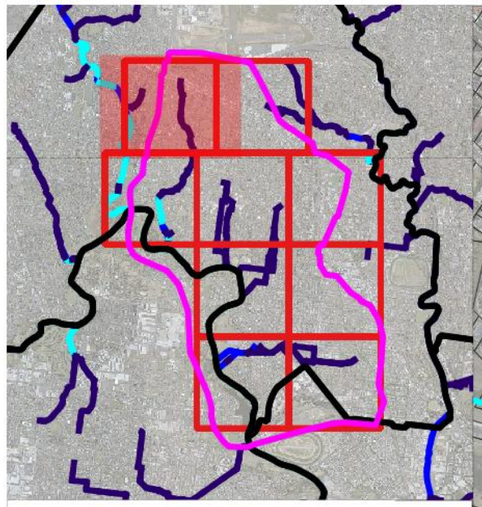
MPCU contained two locations that required a blockage risk assessment. Both sites presented medium to high-risk of debris blockage, driven by the availability of the material and dense forestry that are within the waterways.

SCrk contained 11 locations that required a blockage risk assessment. All the sites presented a medium risk of debris blockage with the exception of Willowtree Crescent Culverts, which was identified as a high risk. The high risk of blockage at the Willowtree Crescent Culverts is driven by the steep upstream catchment increasing the transportability of loose debris, and larger cobbles found directly upstream of the culverts, increasing the chance of the assets being fully blocked during a flood event.

TABLE C.7: OUTCOMES OF THE LOCATIONS INVESTIGATED AS PART OF THE BLOCKAGE ASSESSMENT

Catchment	Location and Description	Inlet (Debris) Blockage Risk	Barrel (Sediment) Blockage Risk
MPCU	Heslden Street Culverts (under railway)	Medium	Medium
MPCU	Pascoe Vale Road Culverts	High	Medium
SCrk	Willowtree Crescent Culverts	High	Medium
SCrk	Milleara Road Culvert	Medium	Low
SCrk	Steele Creek Buckley Street Culverts	Medium	Low
SCrk	Rosehill Road Pedestrian Bridge	Medium	Low
SCrk	Steele Creek at Airport Drive Bridge	Medium	Low
SCrk	Steele Creek Roberts Road Culverts	Medium	Low
SCrk	Steele Creek Calder Freeway Culverts	Medium	Low
SCrk	Steele Creek North Dawson Street Culvert	Medium	Low
SCrk	Steele Creek North Mclaren Street Culvert	Medium	Low
SCrk	Steele Creek North Sharps Road Culvert	Medium	Low
SCrk	Steele Creek Keilor Park Culverts	Medium	Low

APPENDIX D: PEAK FLOOD DEPTH MAPS



Legend

- Property Boundary
- Moonee Valley Municipality
- TUFLOW Model Boundary
- Railway
- Melbourne Water Underground Drain
- Melbourne Water Channel
- Melbourne Water Natural Waterway

Flood Depth

- 0.05 m to 0.1 m
- 0.1 m to 0.2 m
- 0.2 m to 0.3 m
- 0.3 m to 0.4 m
- 0.4 m to 0.5 m
- Above 0.5 m

CALDER FREEWAY
KEILOR ROAD
CALDER IN-BULLA RAMP OF
CALDER FREEWAY
BULLA-CALDER OUT RAMP ON
BULLA-TULLAMARINE OUT RAMP ON
TULLAMARINE FREEWAY
TULLAMARINE FREEWAY
TULLAMARINE IN-BULLA RAMP OF
CITYLINK IN-BELL RAMP OF
STEELE CREEK
KEILOR ROAD
HOFFMANS ROAD
STEELIE CREEK
ROSEHILL ROAD

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Melbourne Water

City of Moonee Valley

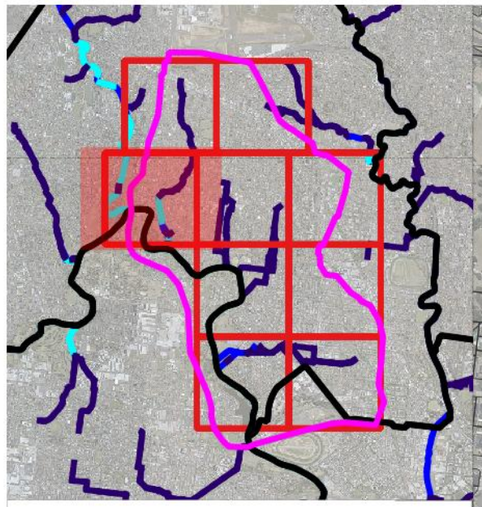
0 100 200 300 400 m

Scale in metres (1:7,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Moonee Valley Flood Mapping Project

Maribyrnong Lower
1% AEP Peak Flood Depth Base Case



Legend

- Property Boundary
- Moonee Valley Municipality
- TUFLOW Model Boundary
- Railway
- Melbourne Water Underground Drain
- Melbourne Water Channel
- Melbourne Water Natural Waterway

Flood Depth

- 0.05 m to 0.1 m
- 0.1 m to 0.2 m
- 0.2 m to 0.3 m
- 0.3 m to 0.4 m
- 0.4 m to 0.5 m
- Above 0.5 m

ROSEHILL ROAD
STEELE CREEK
HOFFMANS ROAD
BUCKLEY STREET
HOFFMANS ROAD MAIN DRAIN
STEELE CREEK
MARIBYRNONG RIVER (MIDDLE)
MARIBYRNONG RIVER (LOWER)

Level 43, Tenancy 2, 360 Elizabeth St,
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E: melb@engeny.com.au

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Melbourne Water

City of Moonee Valley

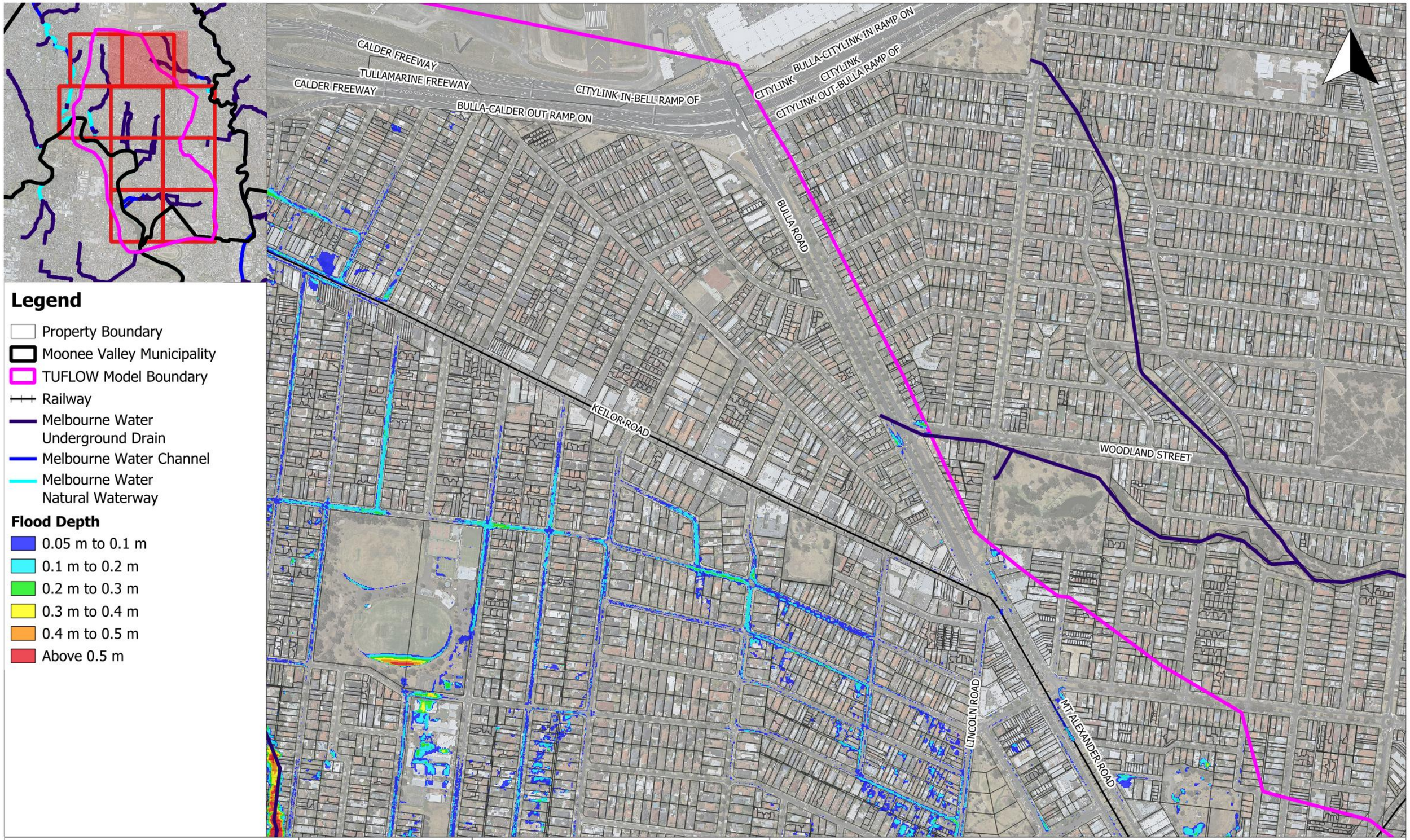
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Scale in metres (1:7,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Moonee Valley Flood Mapping Project

Maribyrnong Lower
1% AEP Peak Flood Depth Base Case



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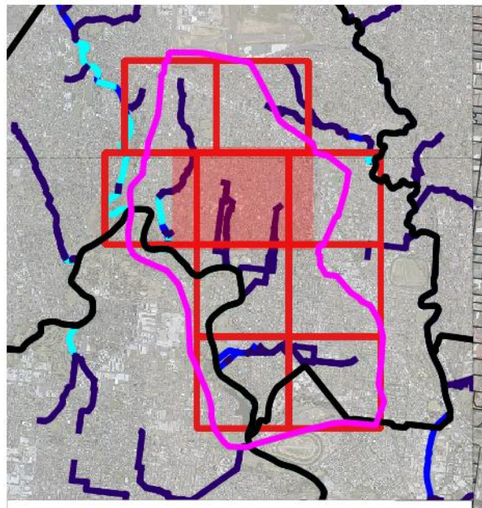
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Moonee Valley Flood Mapping Project

Maribyrnong Lower
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Legend

- Property Boundary
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- Railway
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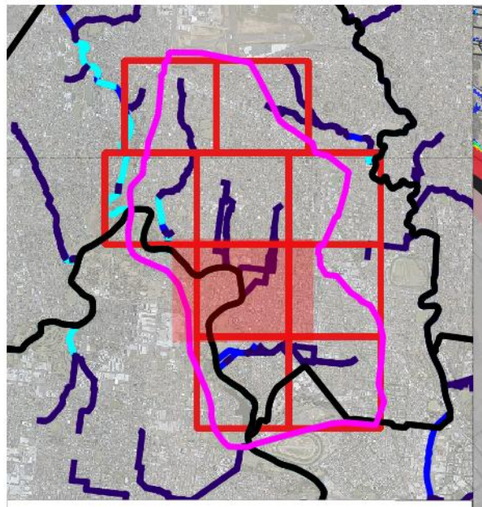
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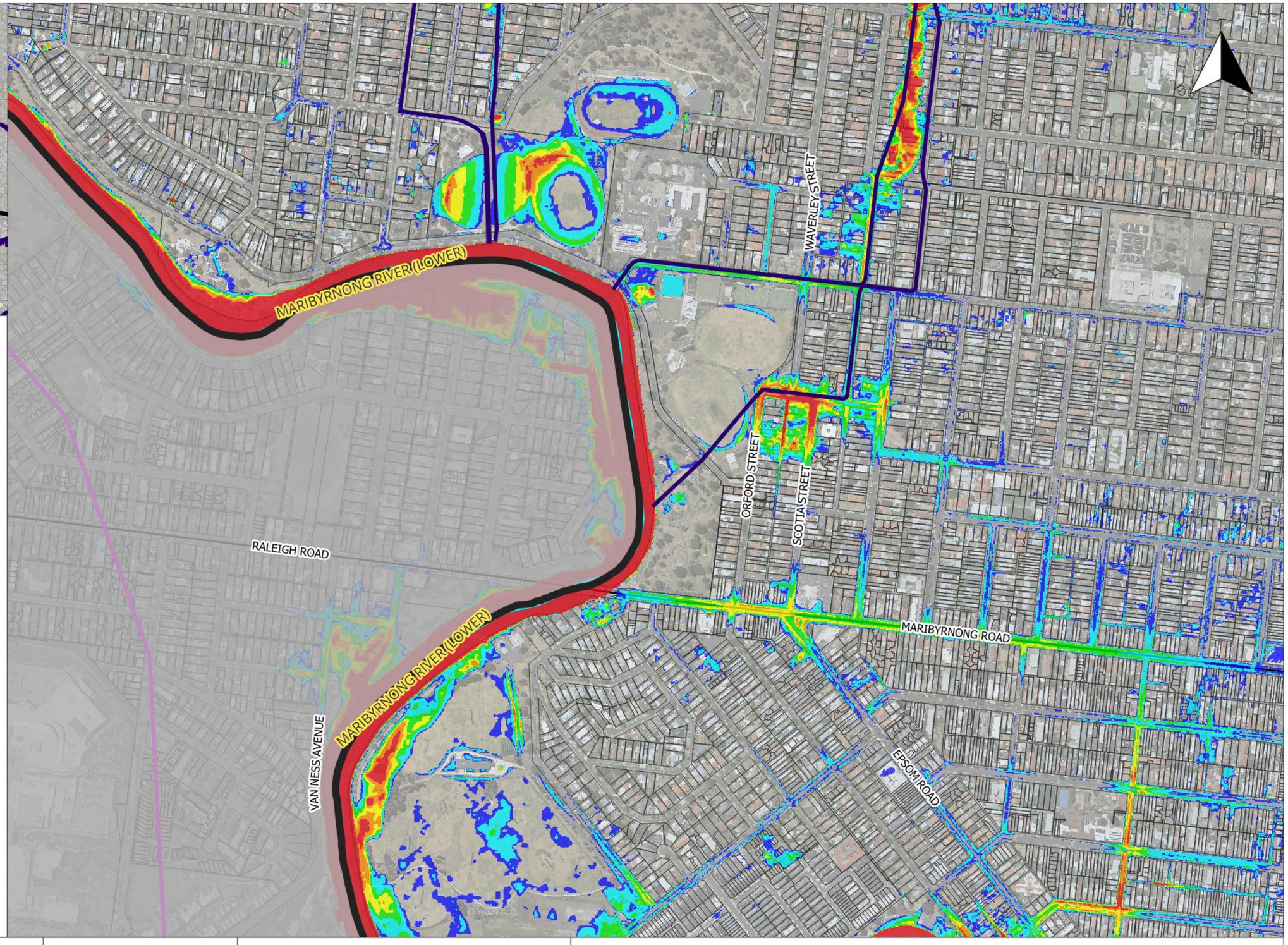


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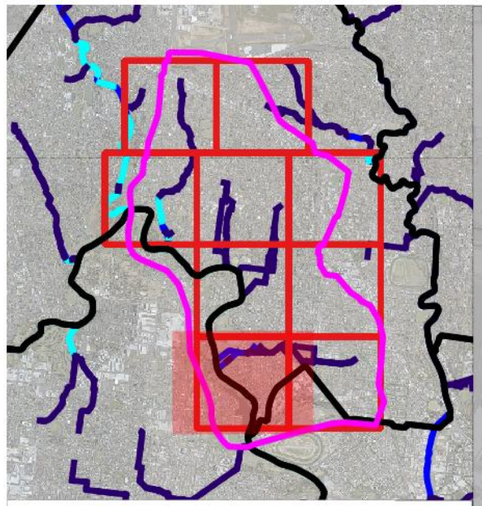
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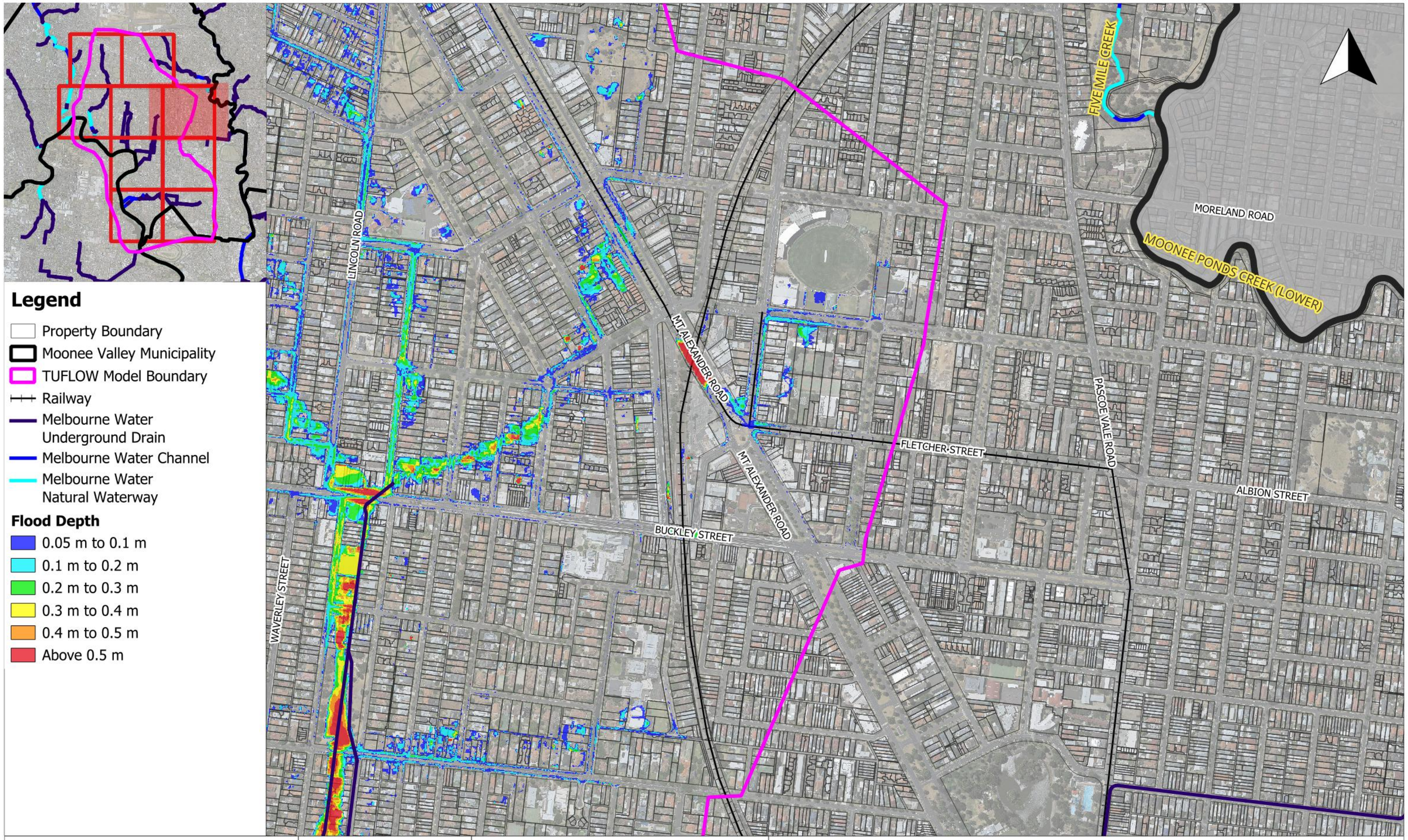
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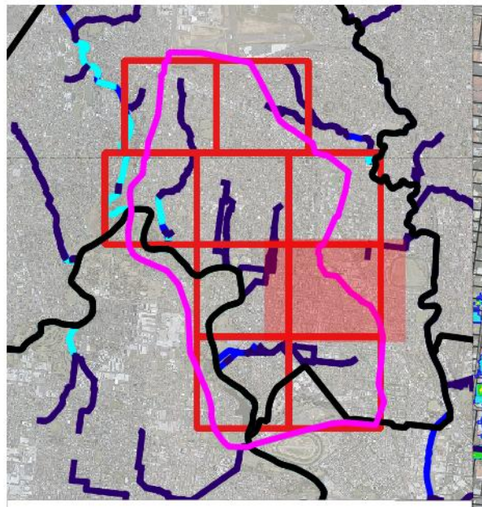
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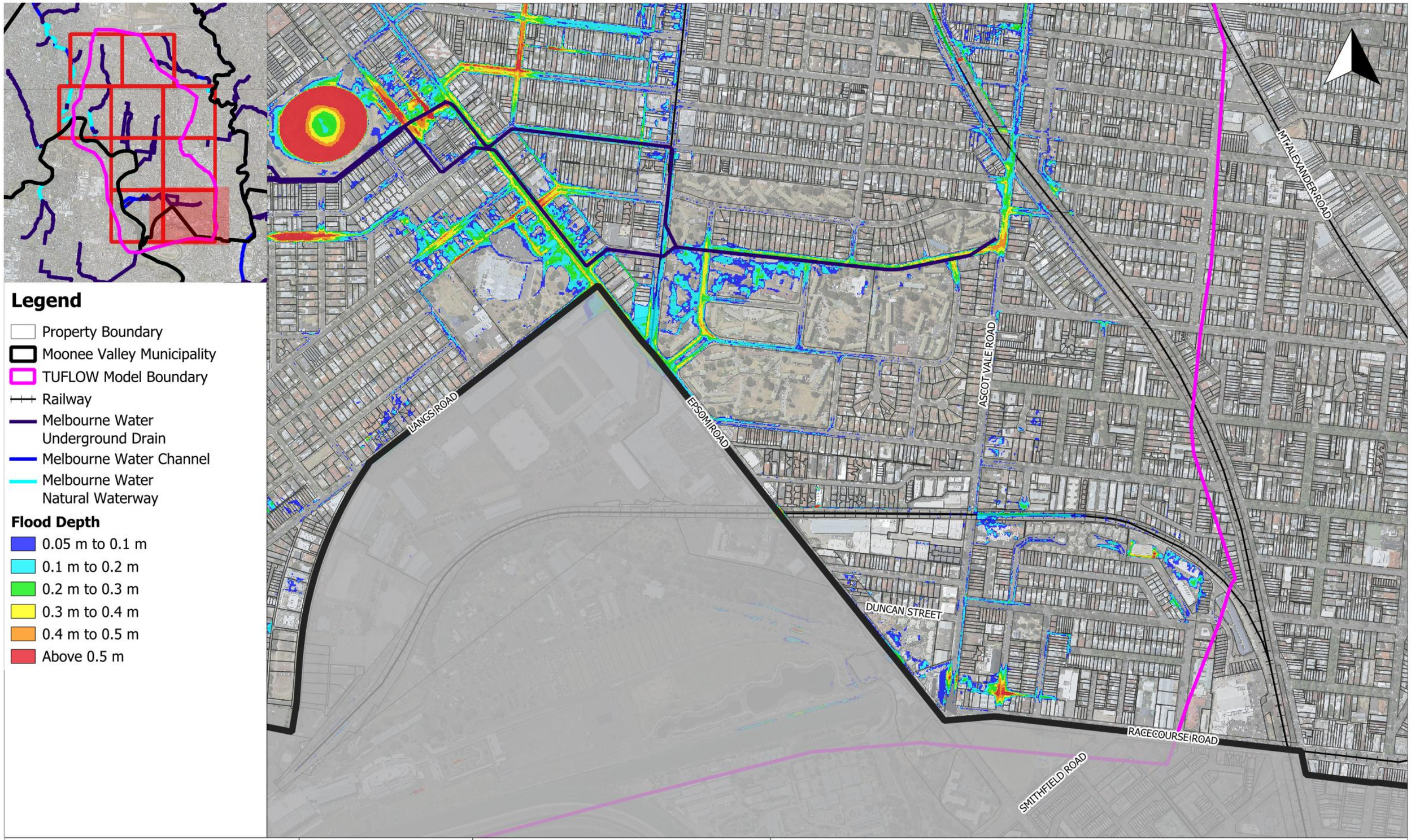
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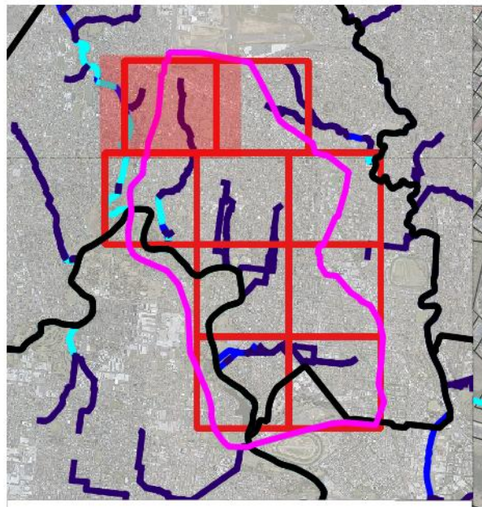
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CALDER FREEWAY
KEILOR ROAD
CALDER IN-BULLA RAMP OF
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TULLAMARINE IN-BULLA RAMP OF
CITYLINK IN-BELL RAMP OF
STEELE CREEK
KEILOR ROAD
HOFFMANS ROAD
STEELIE CREEK
ROSEHILL ROAD

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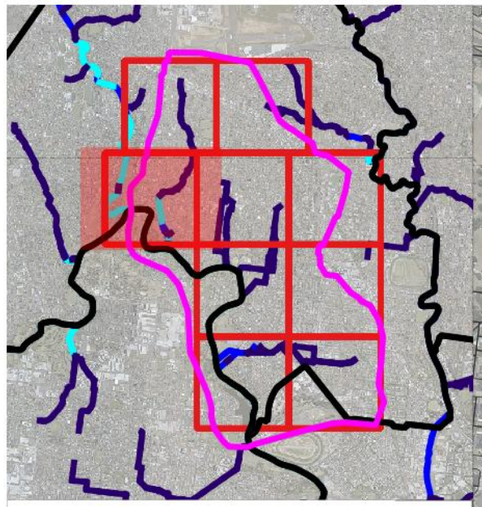
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Moonee Valley Flood Mapping Project

Maribyrnong Lower
1% AEP Peak Flood Depth Climate Change (Scenario D)



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ROSEHILL ROAD
STEELE CREEK
HOFFMANS ROAD
BUCKLEY STREET
HOFFMANS ROAD MAIN DRAIN
STEELE CREEK
MARIBYRNONG RIVER (MIDDLE)
MARIBYRNONG RIVER (LOWER)

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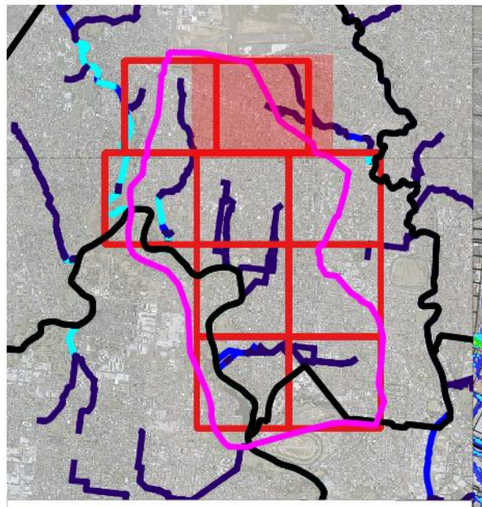
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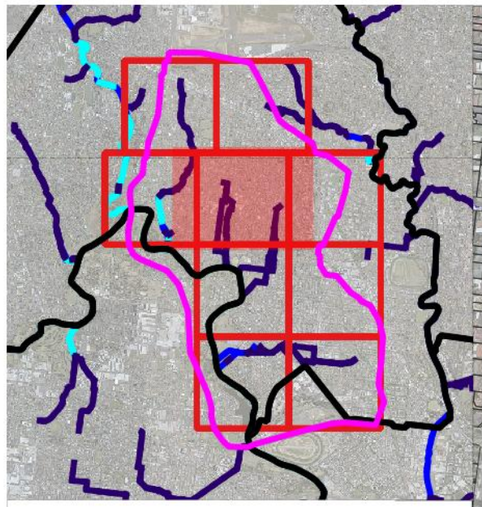
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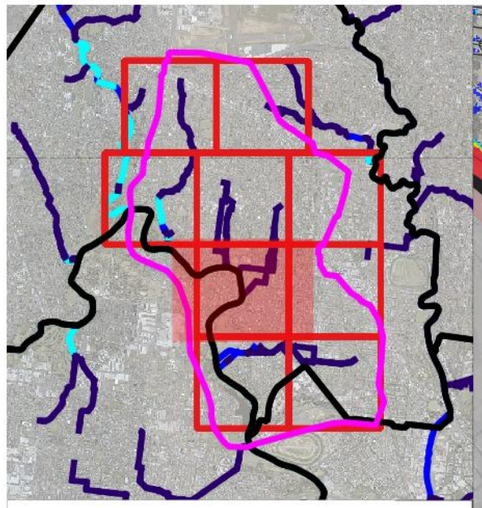
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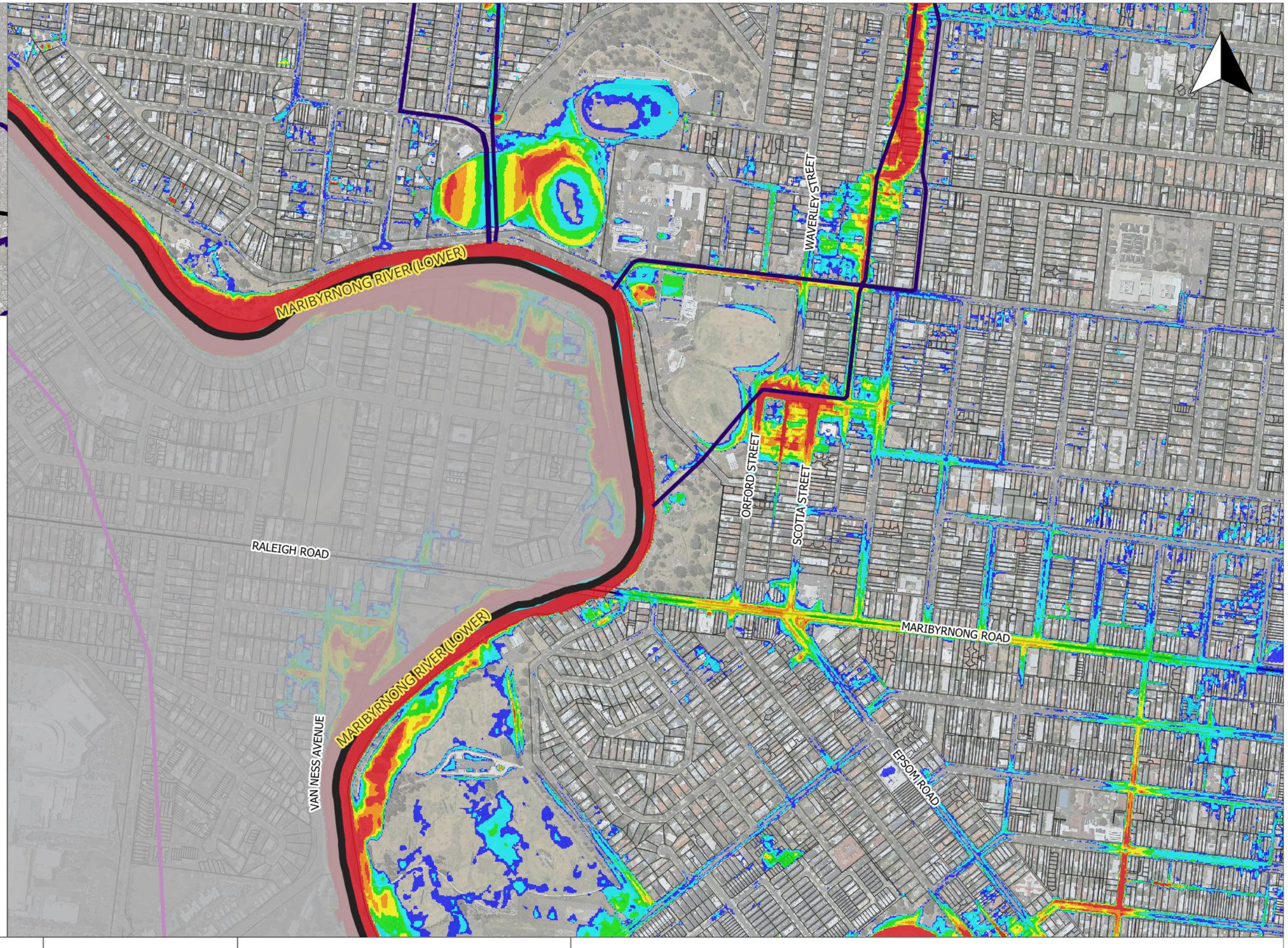


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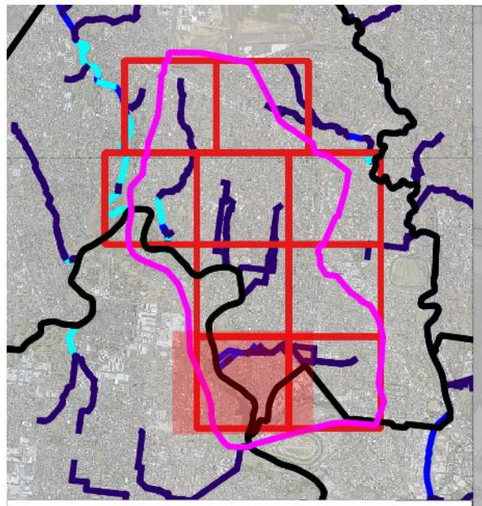
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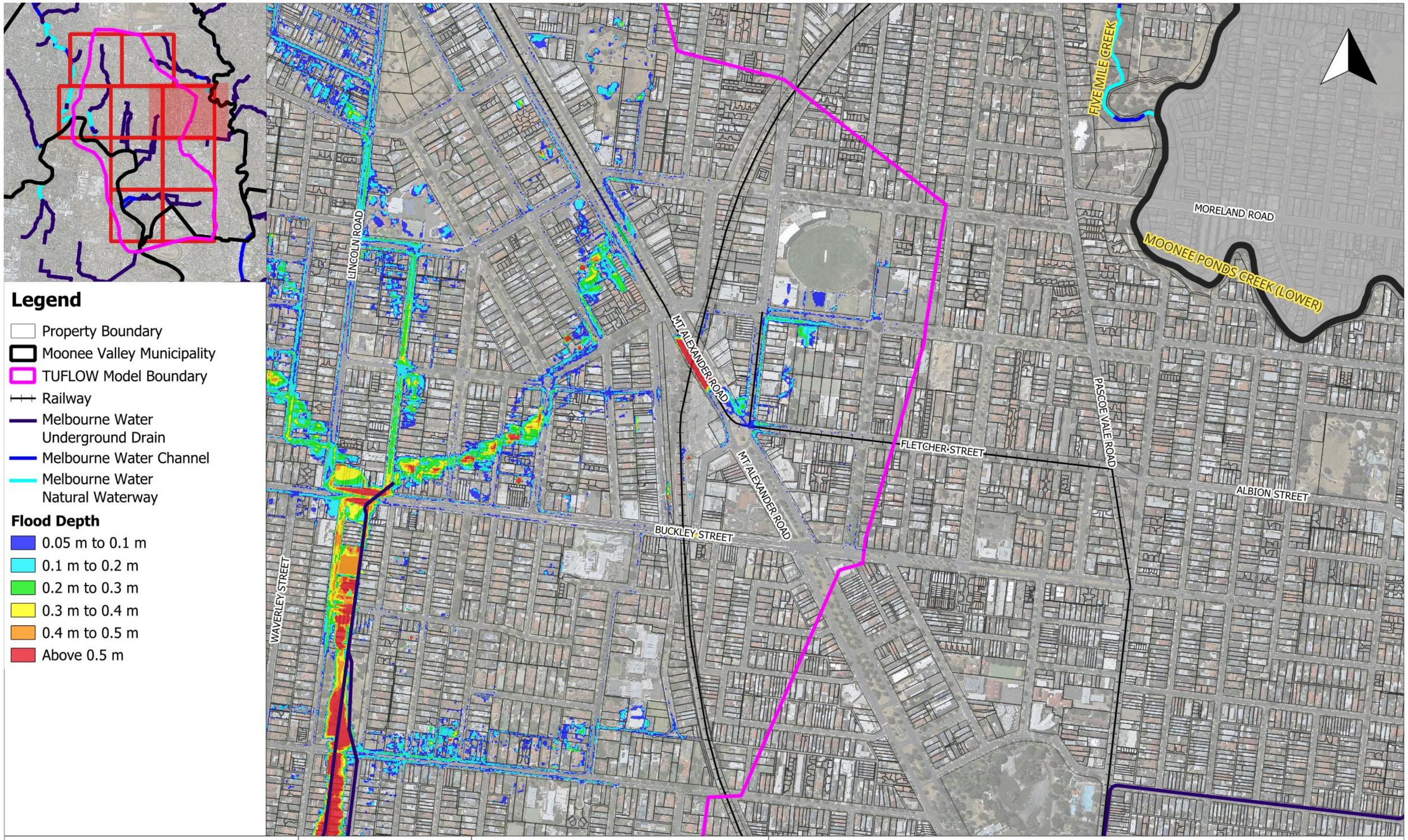
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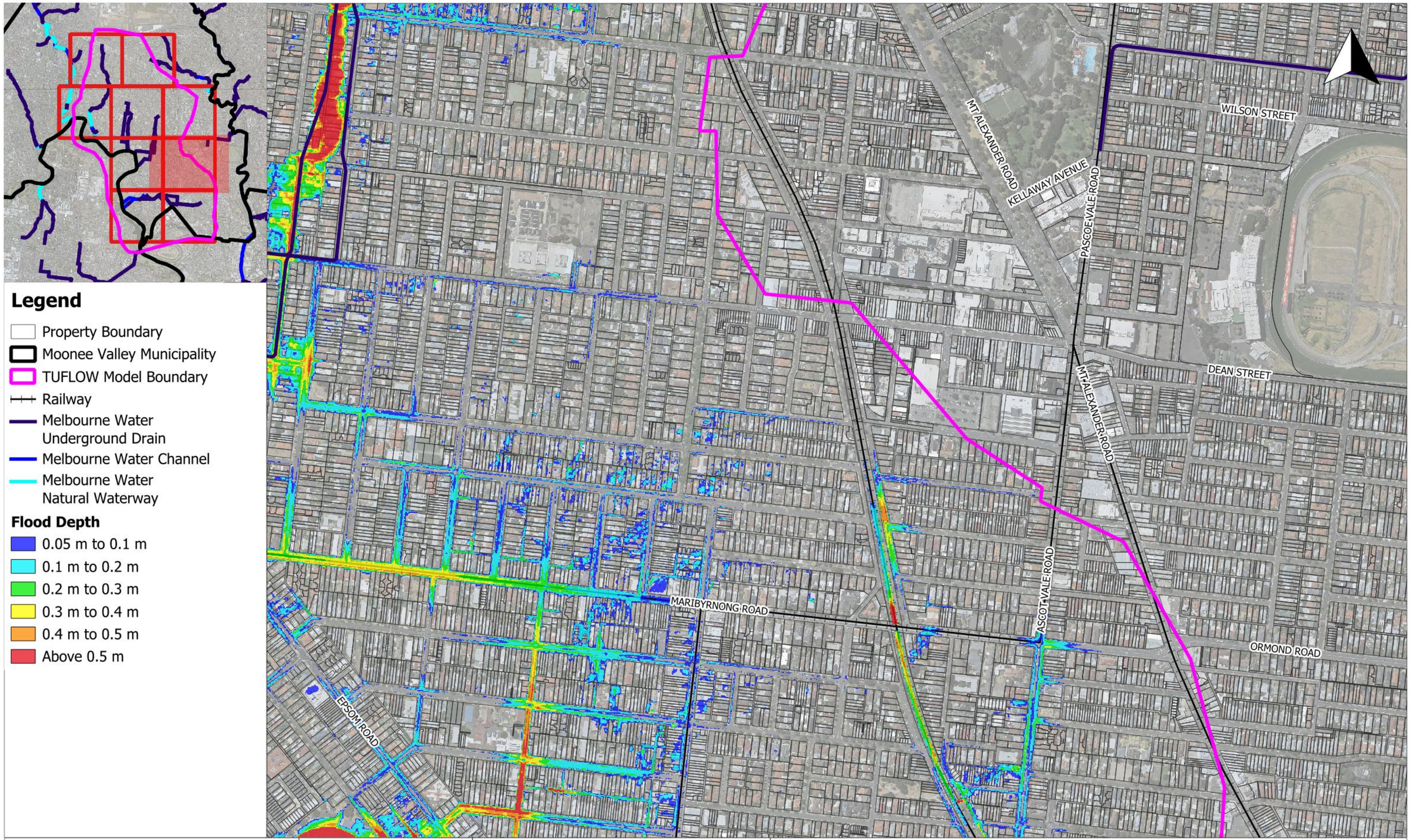
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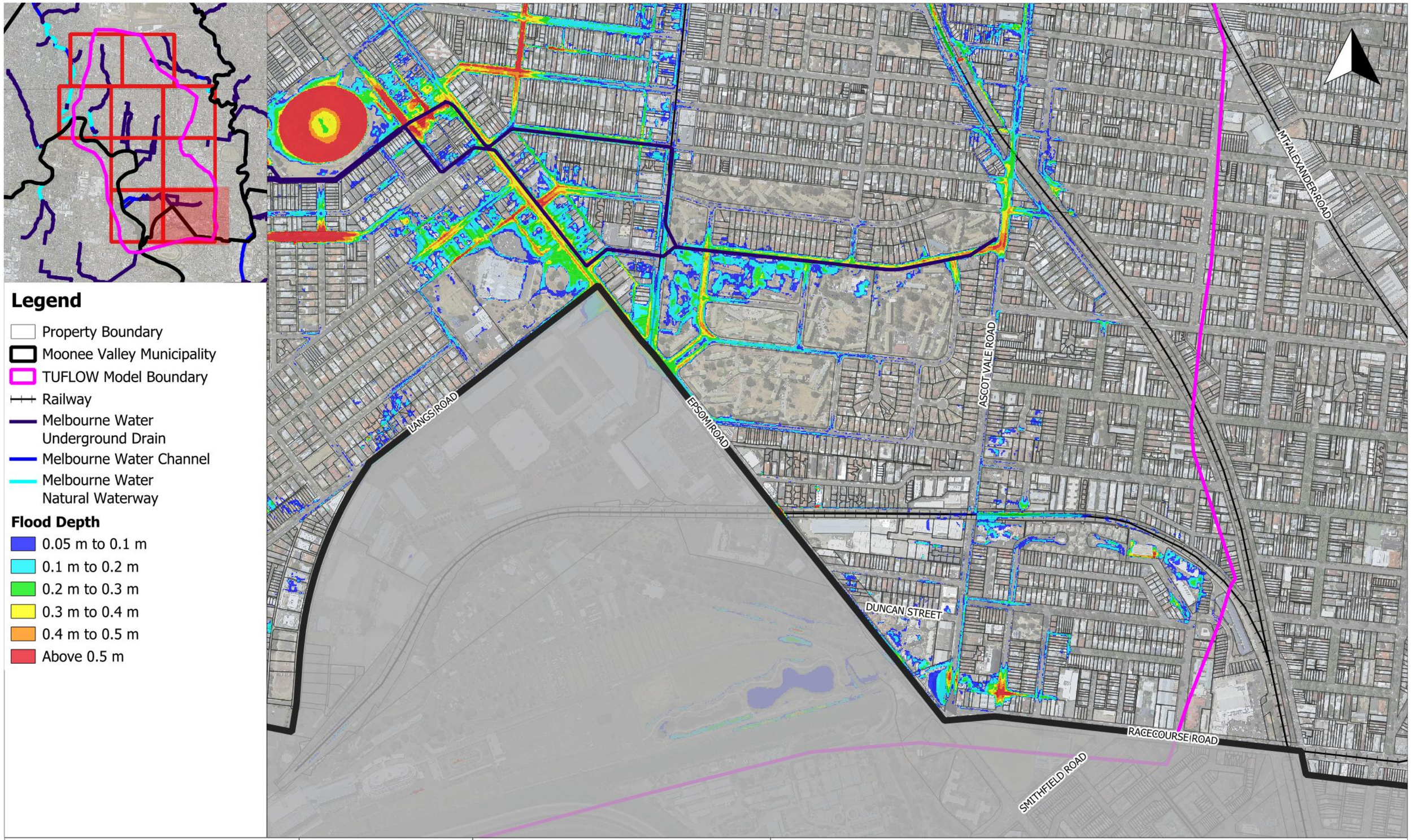
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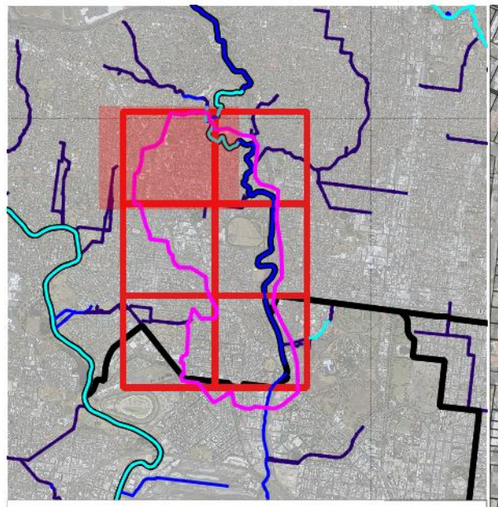
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Melbourne Water

City of Moonee Valley

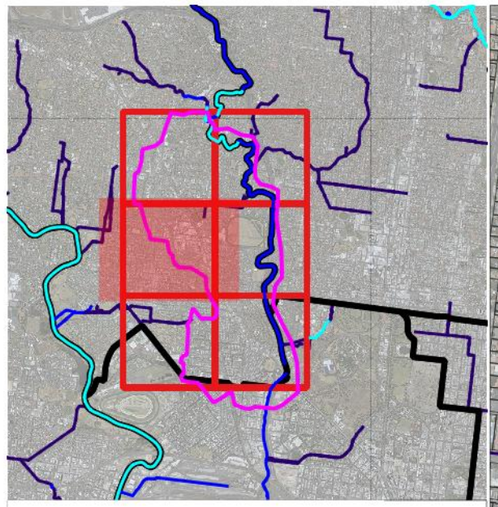
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Scale in metres (1:7,000 @ A3)

Map Projection: Transverse Mercator
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Lower
1% AEP Peak Flood Depth Base Case



Legend

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- Municipal Boundary
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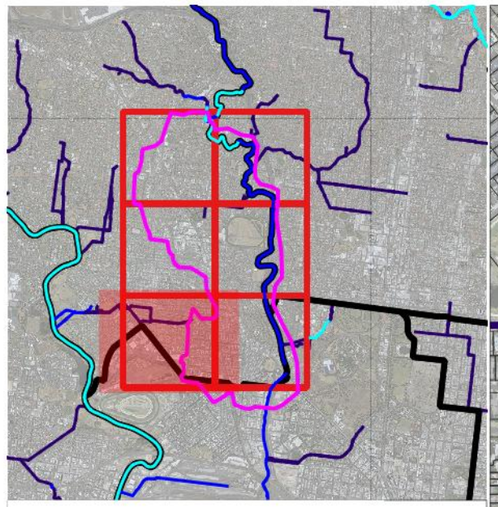
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Ascot Street

Epsom Road

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Ascot Vale Road

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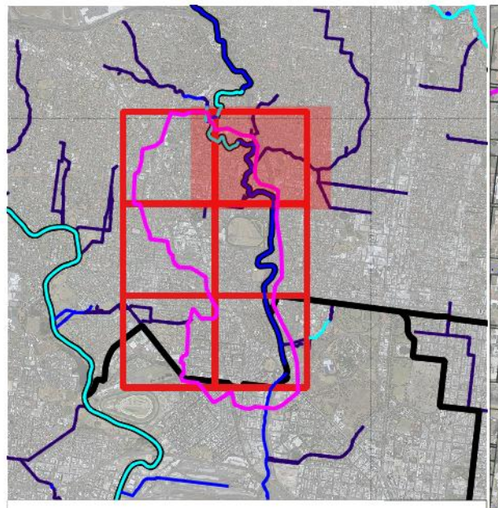
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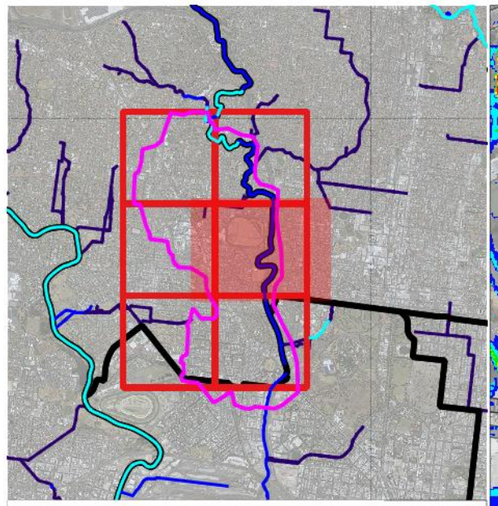
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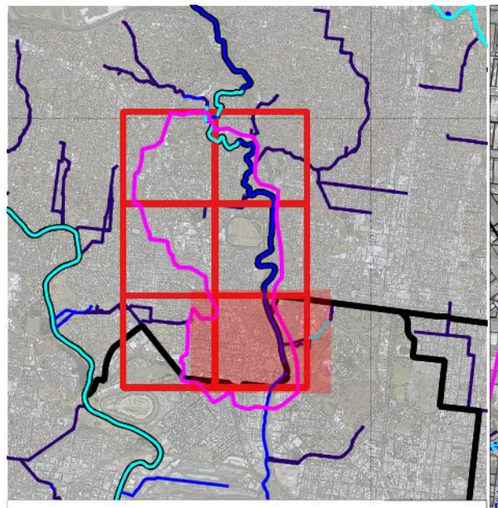
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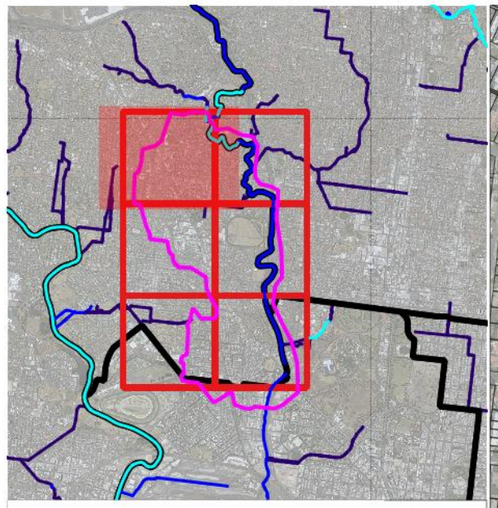
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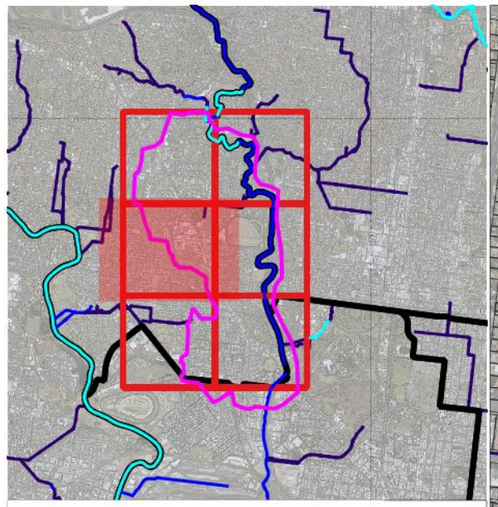
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Lower
1% AEP Peak Flood Depth Climate Change (Scenario D)



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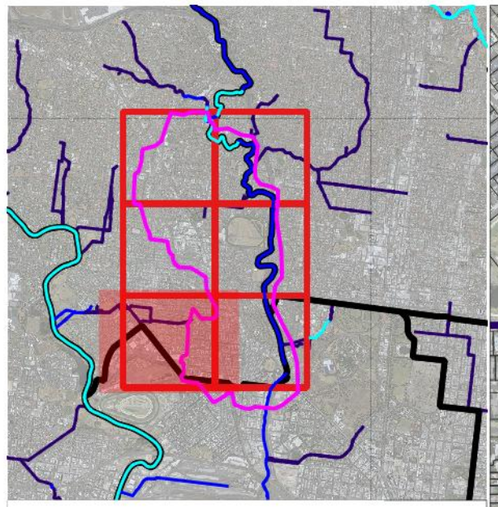
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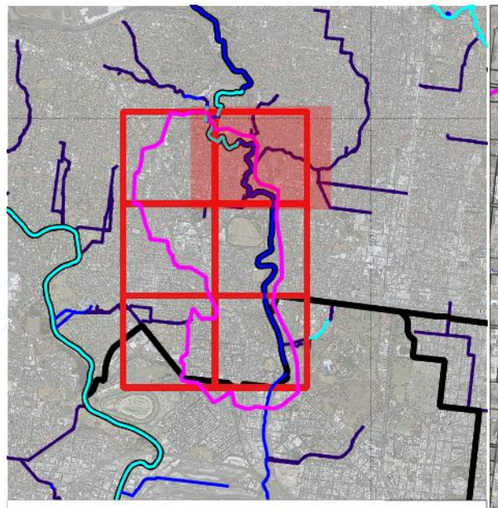
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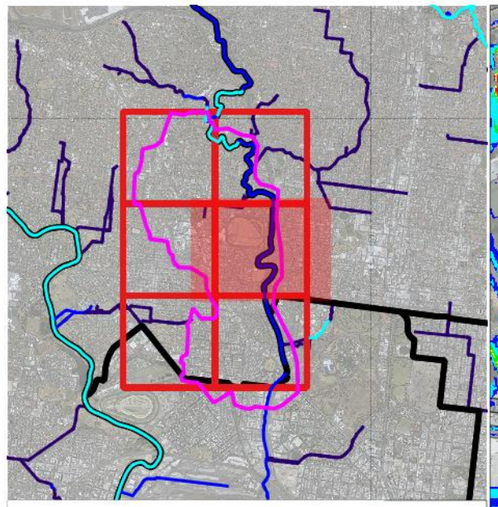
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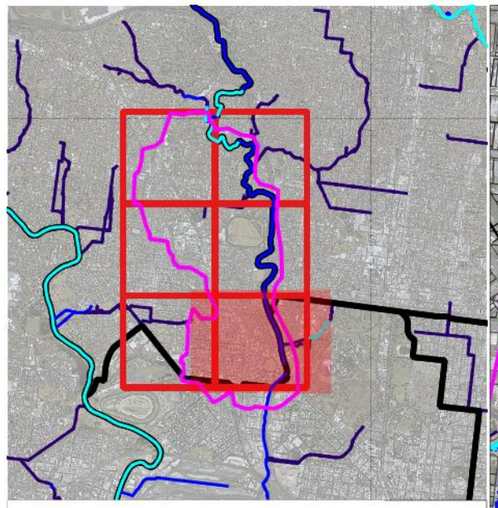
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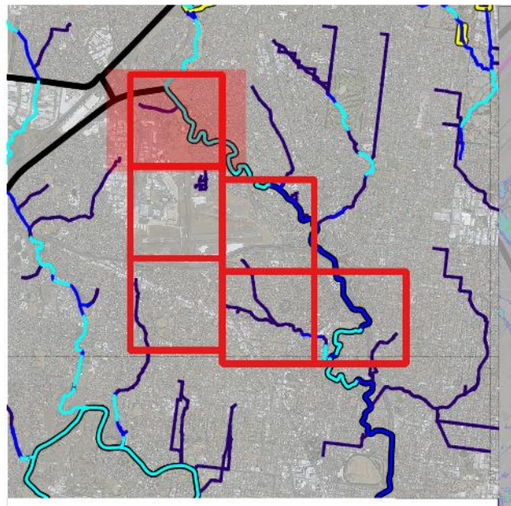
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MOONEE PONDS CREEK (UPPER)

Tullamarine Out - Melrose Ramp Of

Tullamarine Freeway

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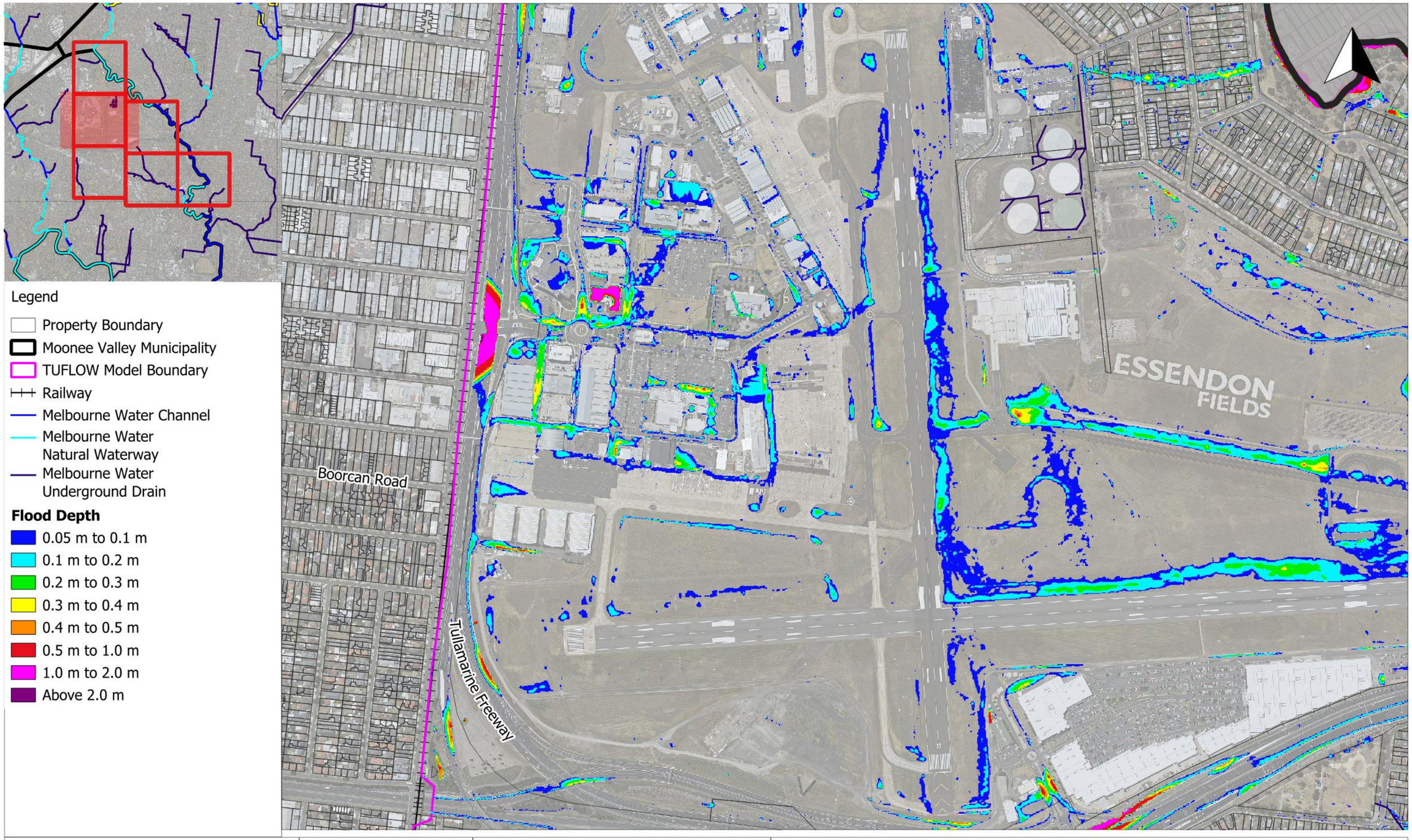
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1% AEP Peak Flood Depth Base Case



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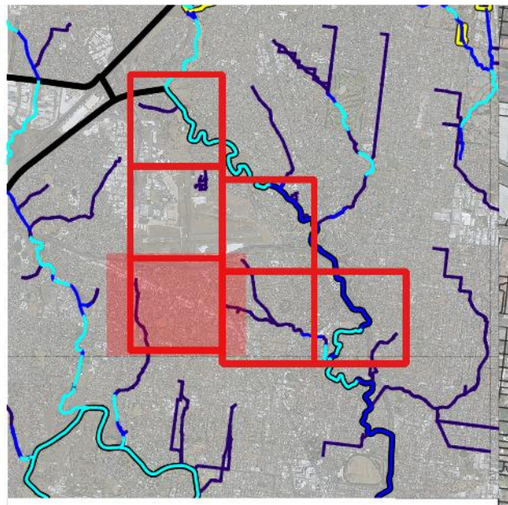
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Bulla Road
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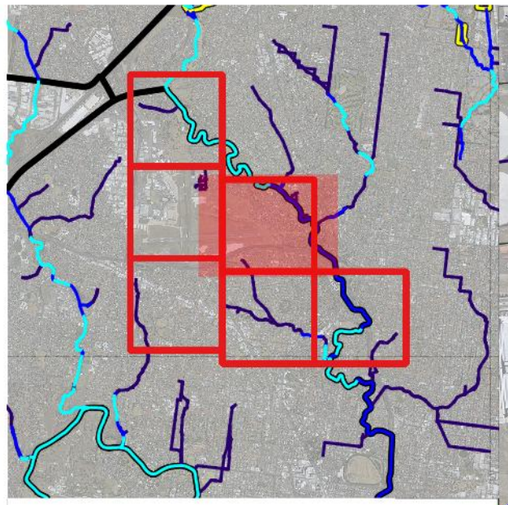
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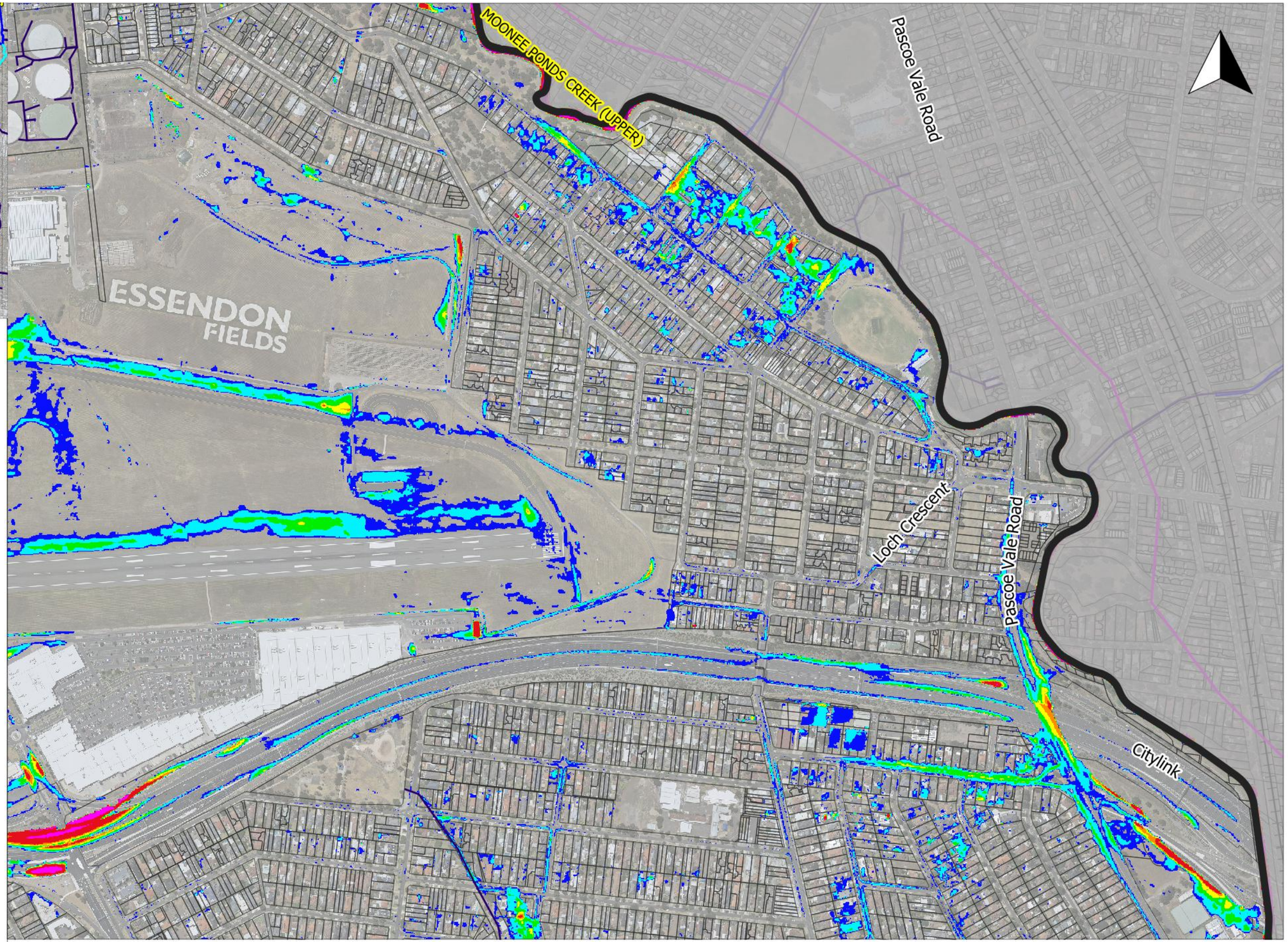


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Melbourne Water

City of Moonee Valley

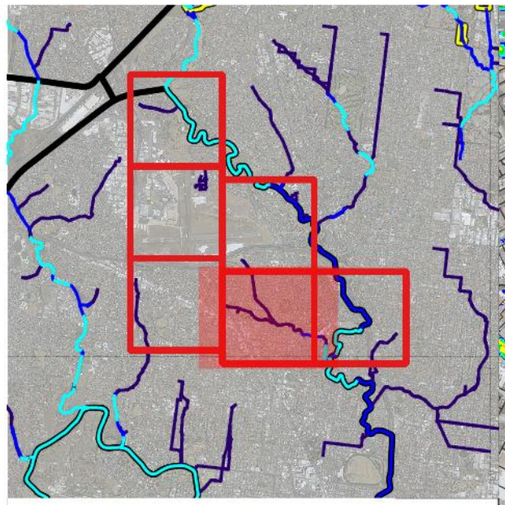
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Scale in metres (1:7,000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1% AEP Peak Flood Depth Base Case

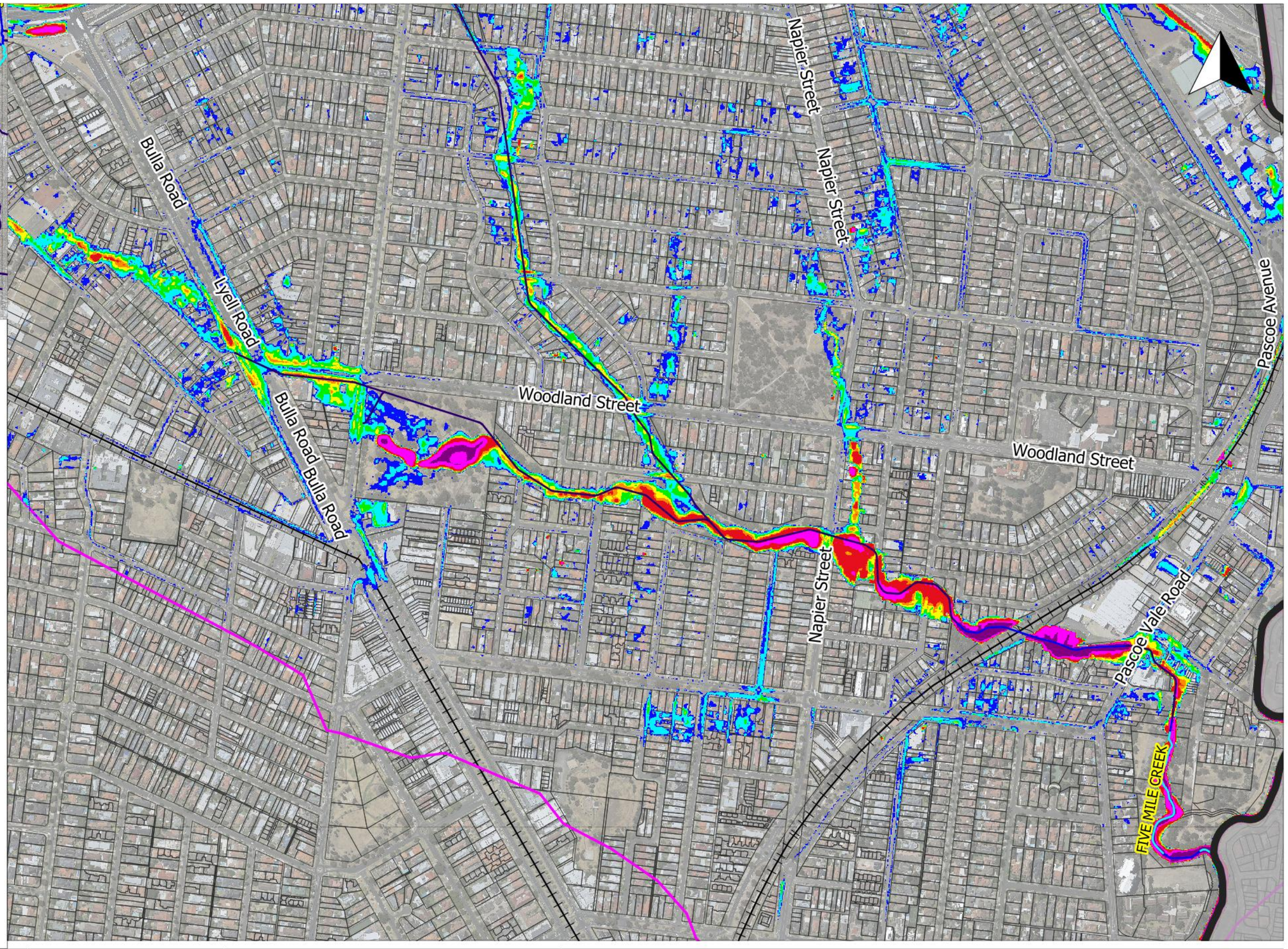


Legend

- Property Boundary
- Moonee Valley Municipality
- TUFLOW Model Boundary
- Railway
- Melbourne Water Channel
- Melbourne Water Natural Waterway
- Melbourne Water Underground Drain

Flood Depth

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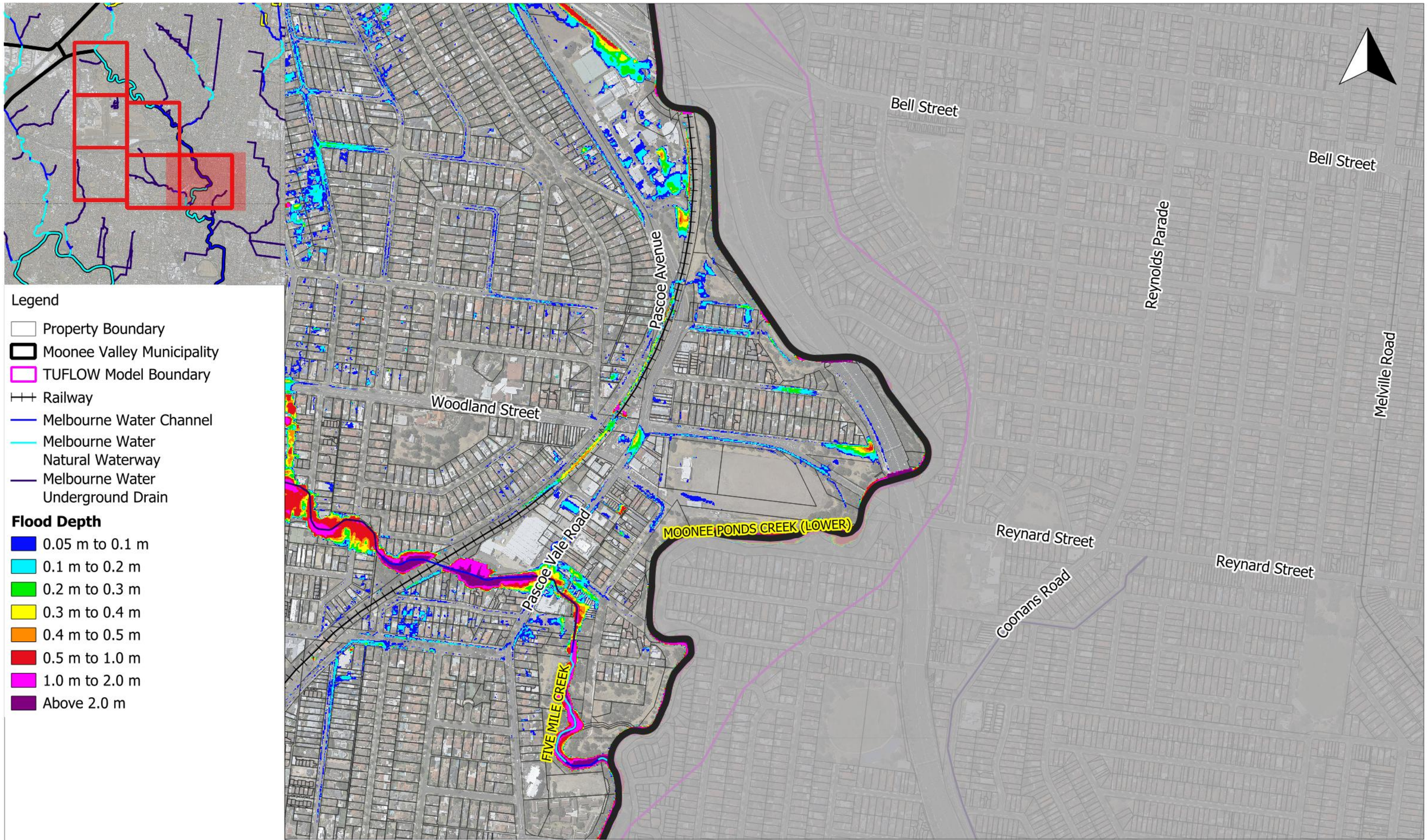
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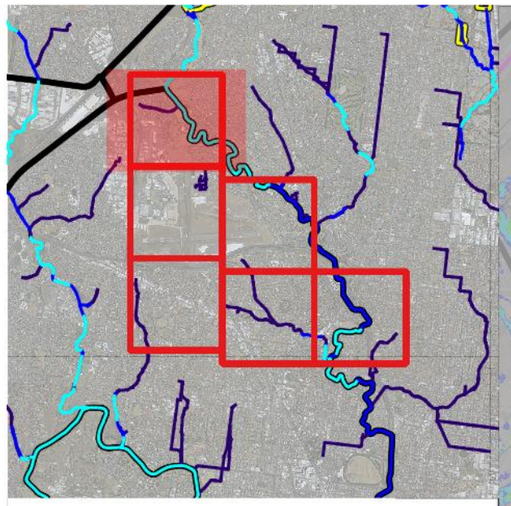
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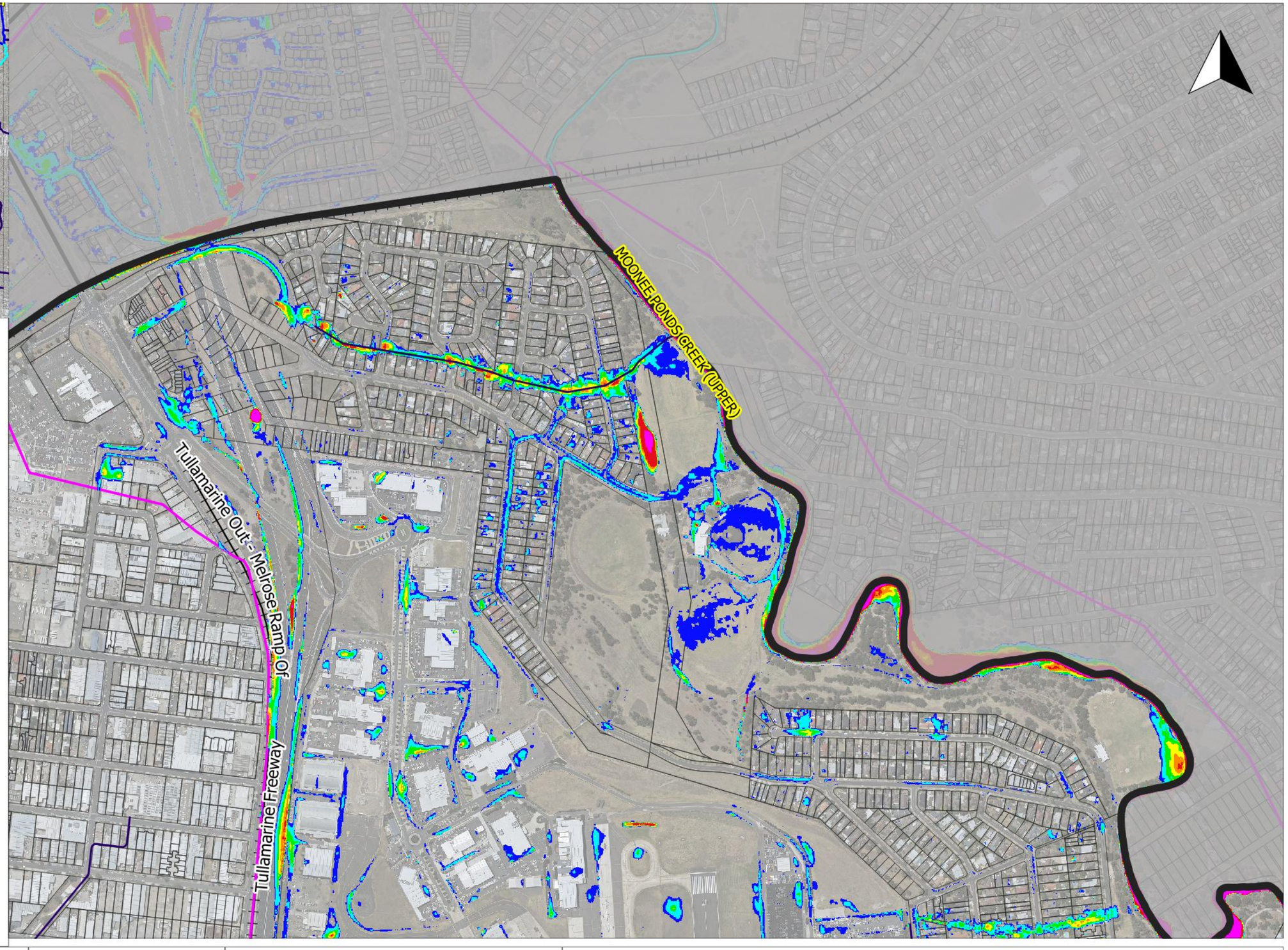
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Moonee Valley Flood Mapping Project

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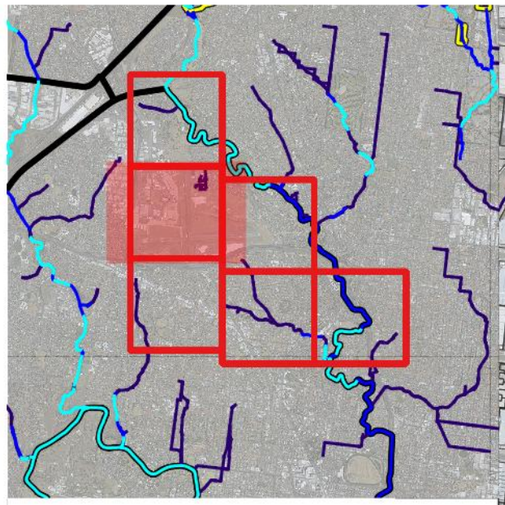
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1% AEP Peak Flood Depth Climate Change (Scenario D)

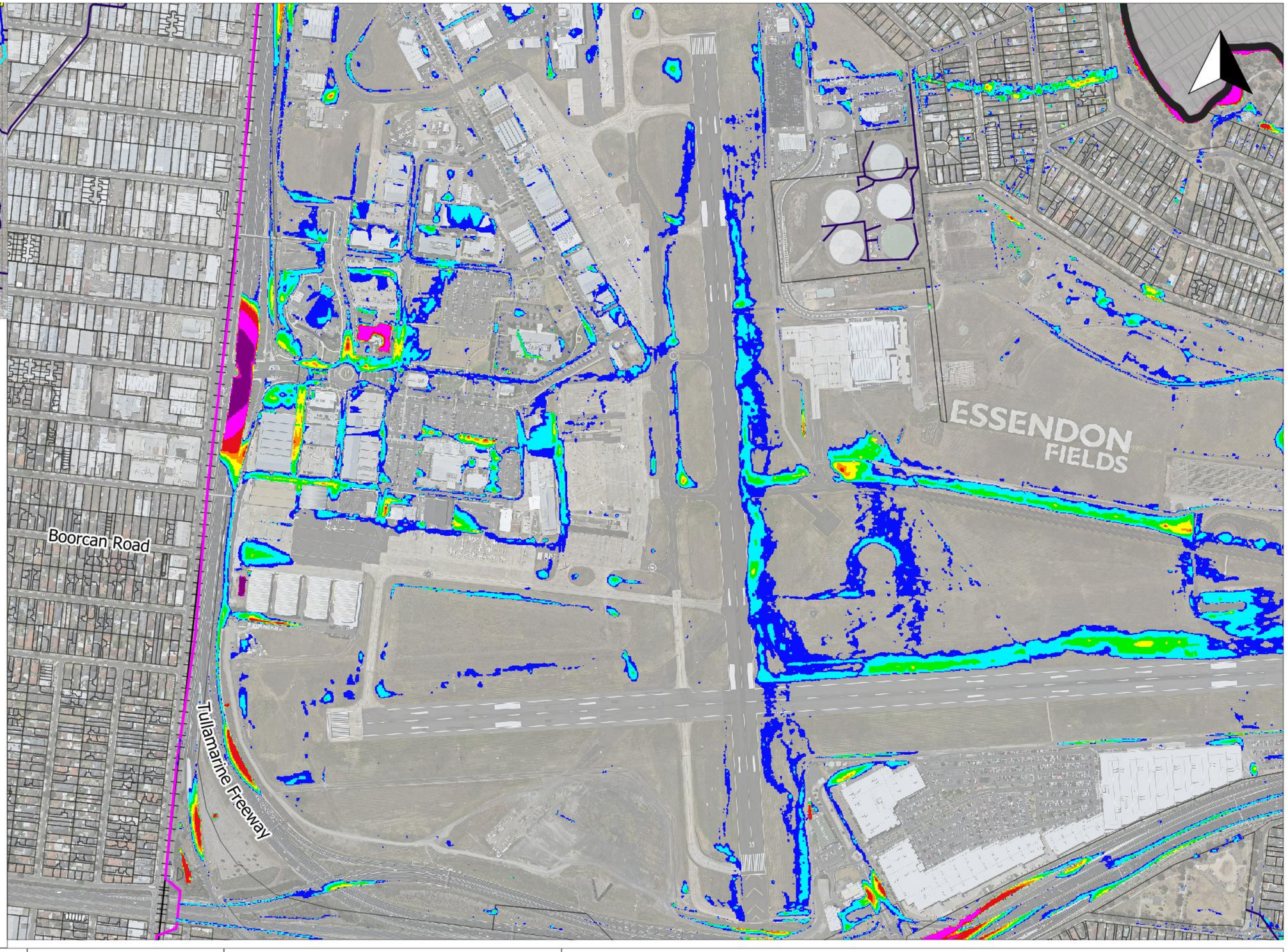


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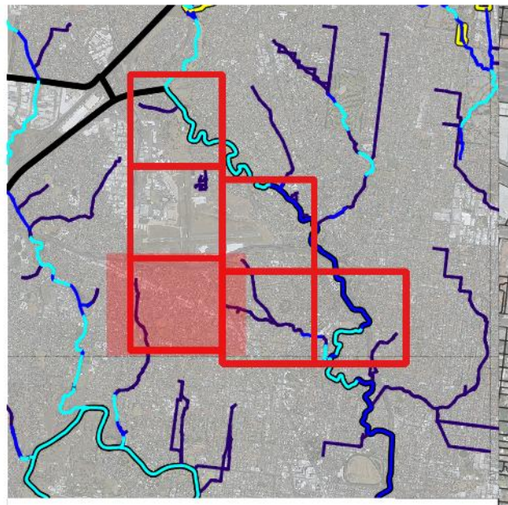
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Kilmoc Road
Keilor Road
Keilor Road
Keilor Road
Keilor Road
Bulla Road
Lyell Road
Woodland Street
Bulla Road
Bulla Road
Hoffmans Road
Little Chapel Street
Hoffmans Road
Cooper Street

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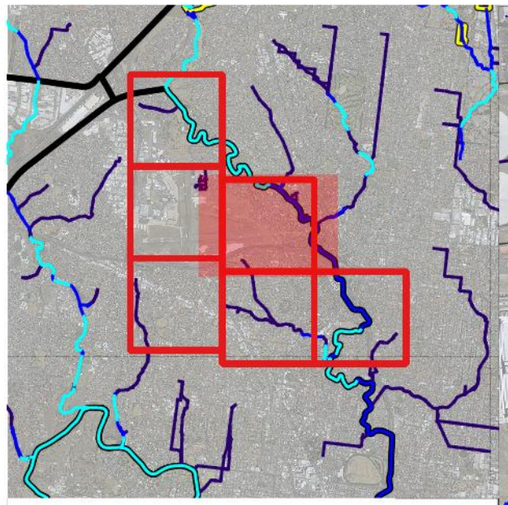
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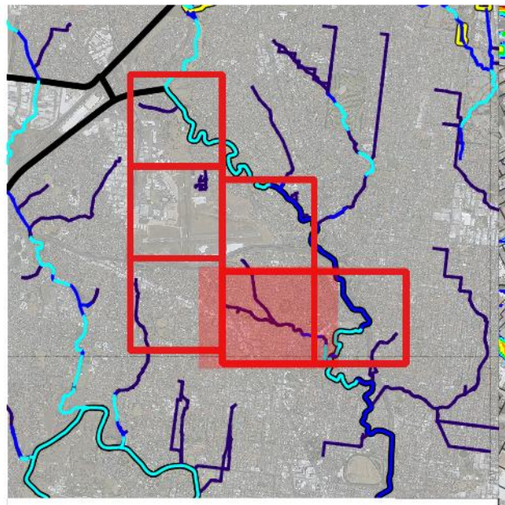
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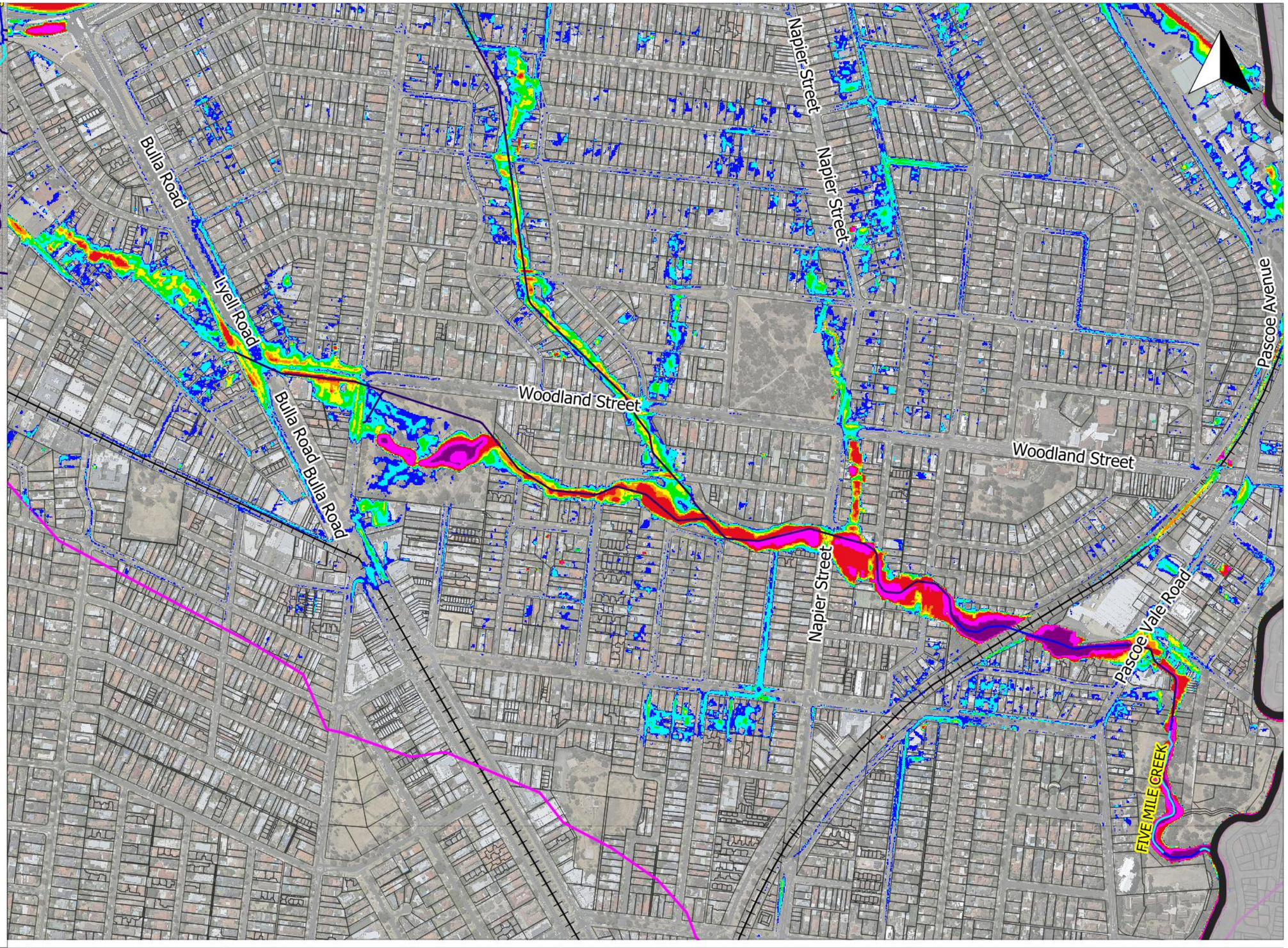


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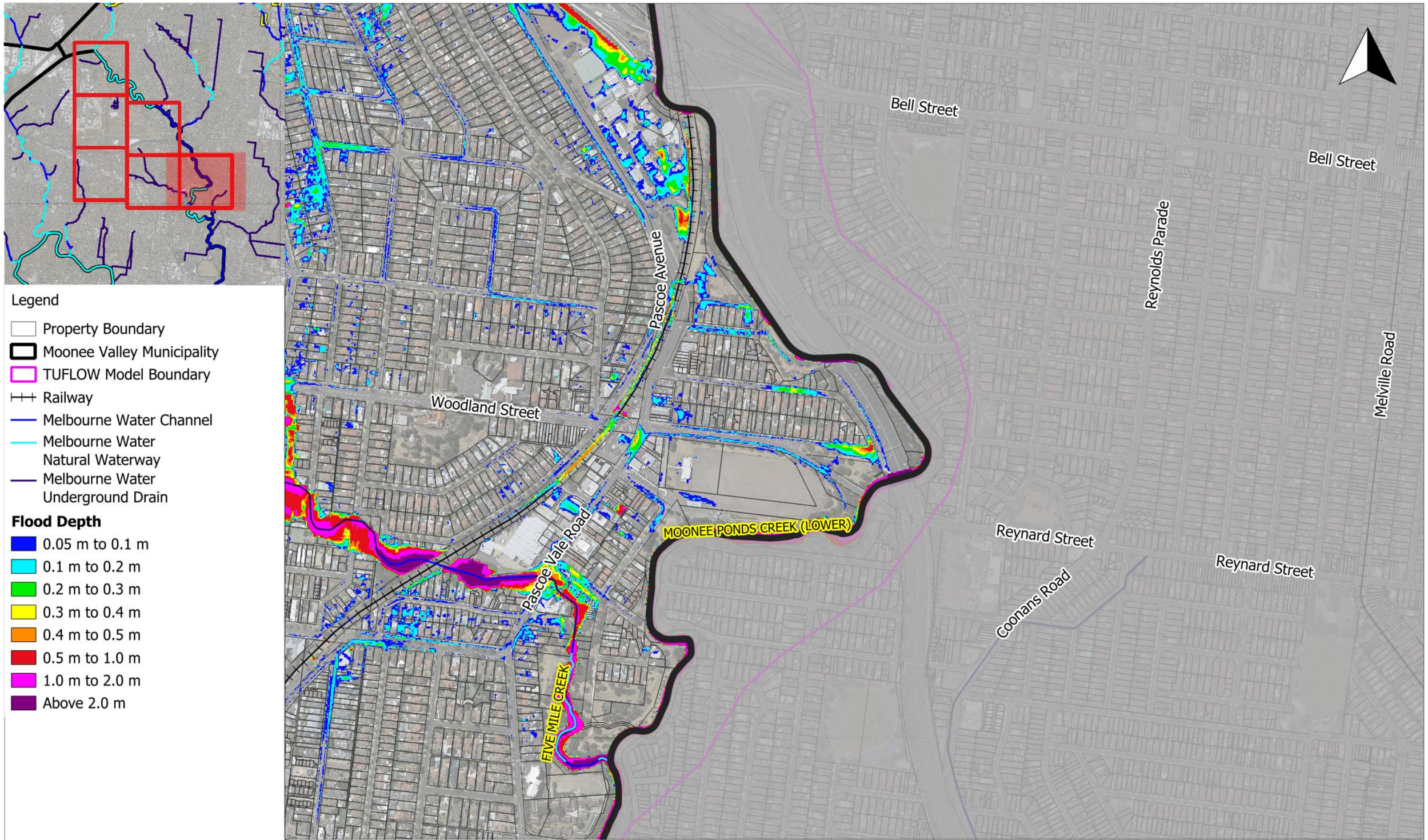
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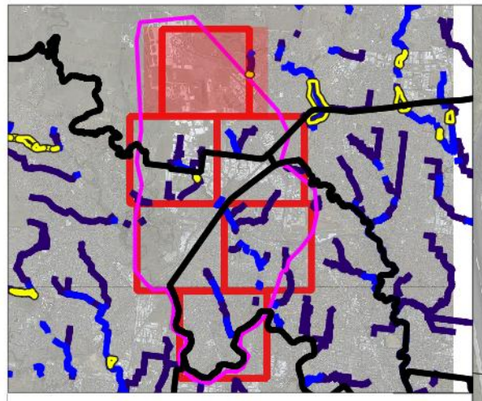
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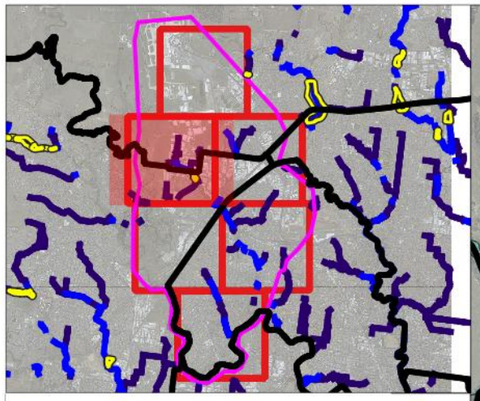
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Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Peak Flood Depth Base Case



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Calder Freeway Calder Freeway

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City of Moonee Valley

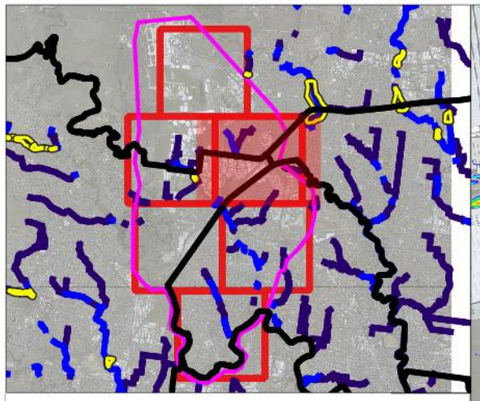
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Carrick Drive

Carrick Drive

Western Ring Road

Tullamarine Freeway

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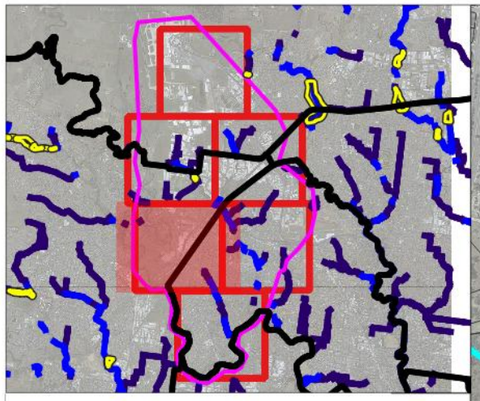
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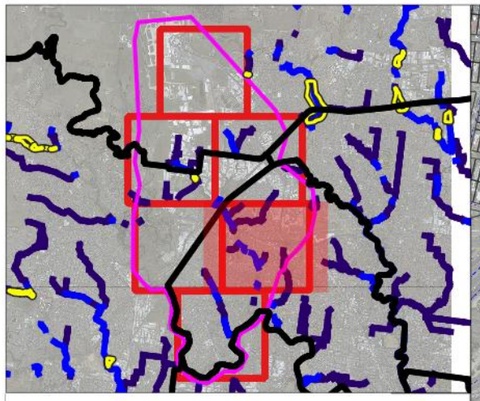
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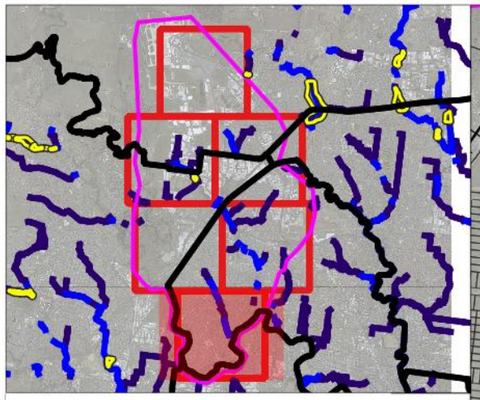
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Buckley Street

Military Road

Duke Street

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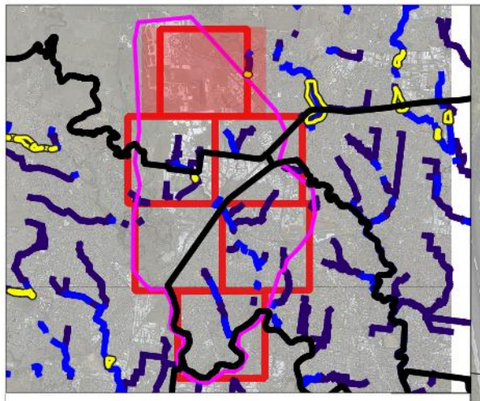
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Barry Way

Melrose Drive

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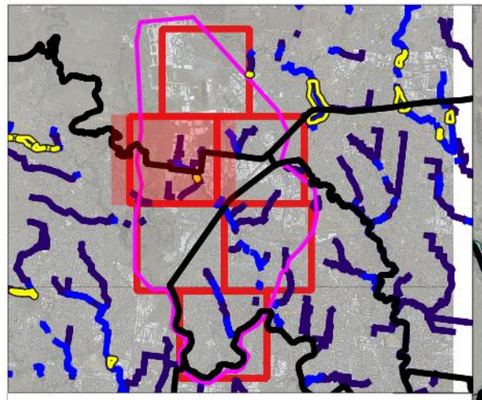
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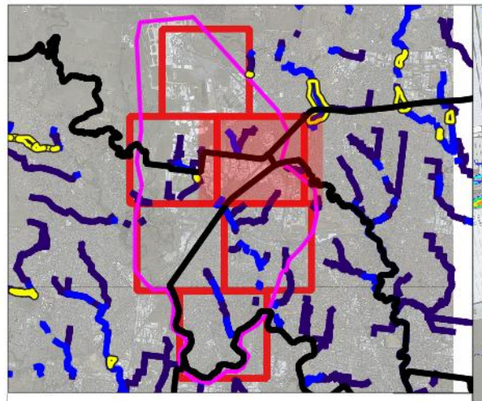
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Flood Depth

- 0.05 m to 0.1 m
- 0.1 m to 0.2 m
- 0.2 m to 0.3 m
- 0.3 m to 0.4 m
- 0.4 m to 0.5 m
- Above 0.5 m

Carrick Drive

Carrick Drive

Western Ring Road

Tullamarine Freeway

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City of Moonee Valley

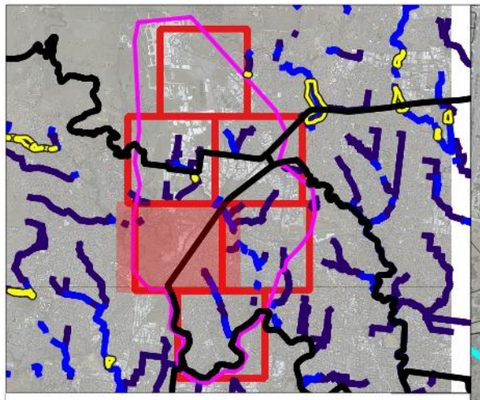
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Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Peak Flood Depth Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- TUFLOW Model Boundary
- Railway
- Melbourne Water Underground Drain
- Melbourne Water Channel
- Melbourne Water Natural Waterway

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- 0.2 m to 0.3 m
- 0.3 m to 0.4 m
- 0.4 m to 0.5 m
- Above 0.5 m

Western Ring Road

Milleara Road

Western Ring Road

Milleara Road

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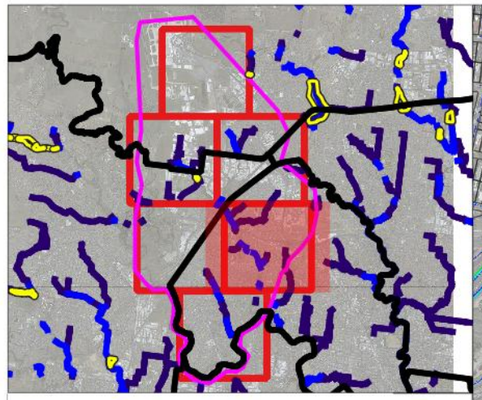
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Moonee Valley Flood Mapping Project

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- 0.4 m to 0.5 m
- Above 0.5 m

Boorcan Road
Milleara Road
Kilmoc Road
Keilor Road
Hoffmans Road
Bulla Road
ESSENDON FIELDS
Milleara Road
Rosehill Road
Cooper Street

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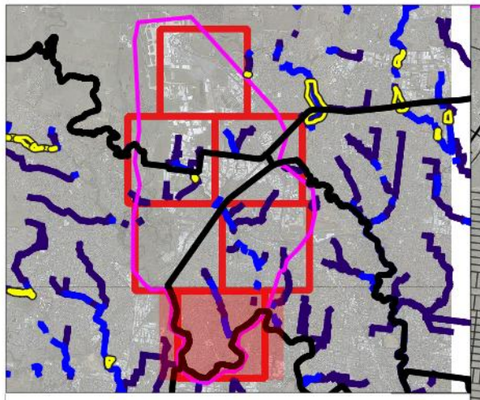
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Moonee Valley Flood Mapping Project

Steele Creek
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Buckley Street

Military Road

Duke Street

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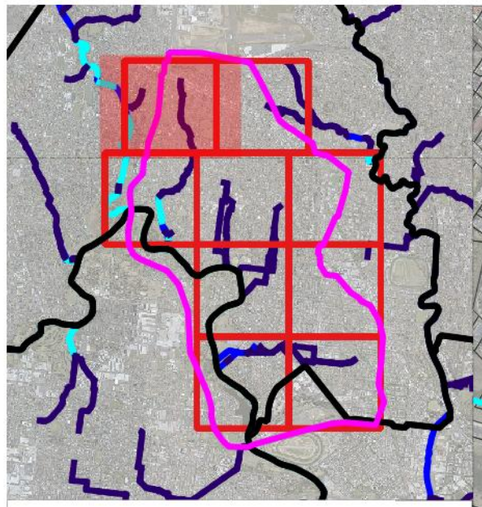
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Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Peak Flood Depth Climate Change (Scenario D)

APPENDIX E: FLOOD EXTENT MAPS



Legend

- Property Boundary
- Moonee Valley Municipality
- TUFLOW Model Boundary
- Railway
- Melbourne Water Underground Drain
- Melbourne Water Channel
- Melbourne Water Natural Waterway
- Flood Extent Council
- Flood Extent UG Drains
- Flood Extent Waterways

CALDER FREEWAY
KEILOR ROAD
CALDER IN-BULLA RAMP OF
CALDER FREEWAY
BULLA-CALDER OUT RAMP ON
BULLA-TULLAMARINE OUT RAMP ON
TULLAMARINE FREEWAY
TULLAMARINE FREEWAY
TULLAMARINE IN-BULLA RAMP OF
CITYLINK IN-BELL RAMP OF
STEELE CREEK
KEILOR ROAD
HOFFMANS ROAD
STEELE CREEK
ROSEHILL ROAD

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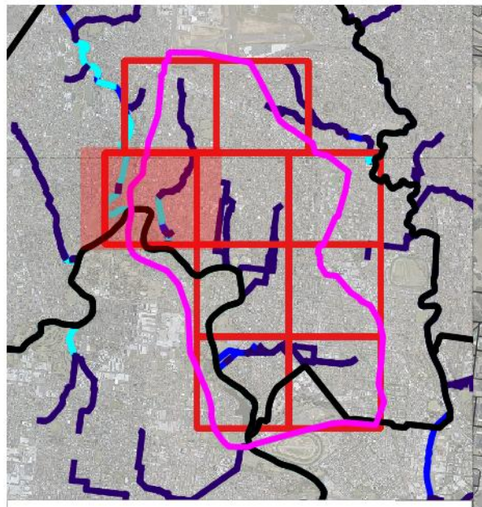
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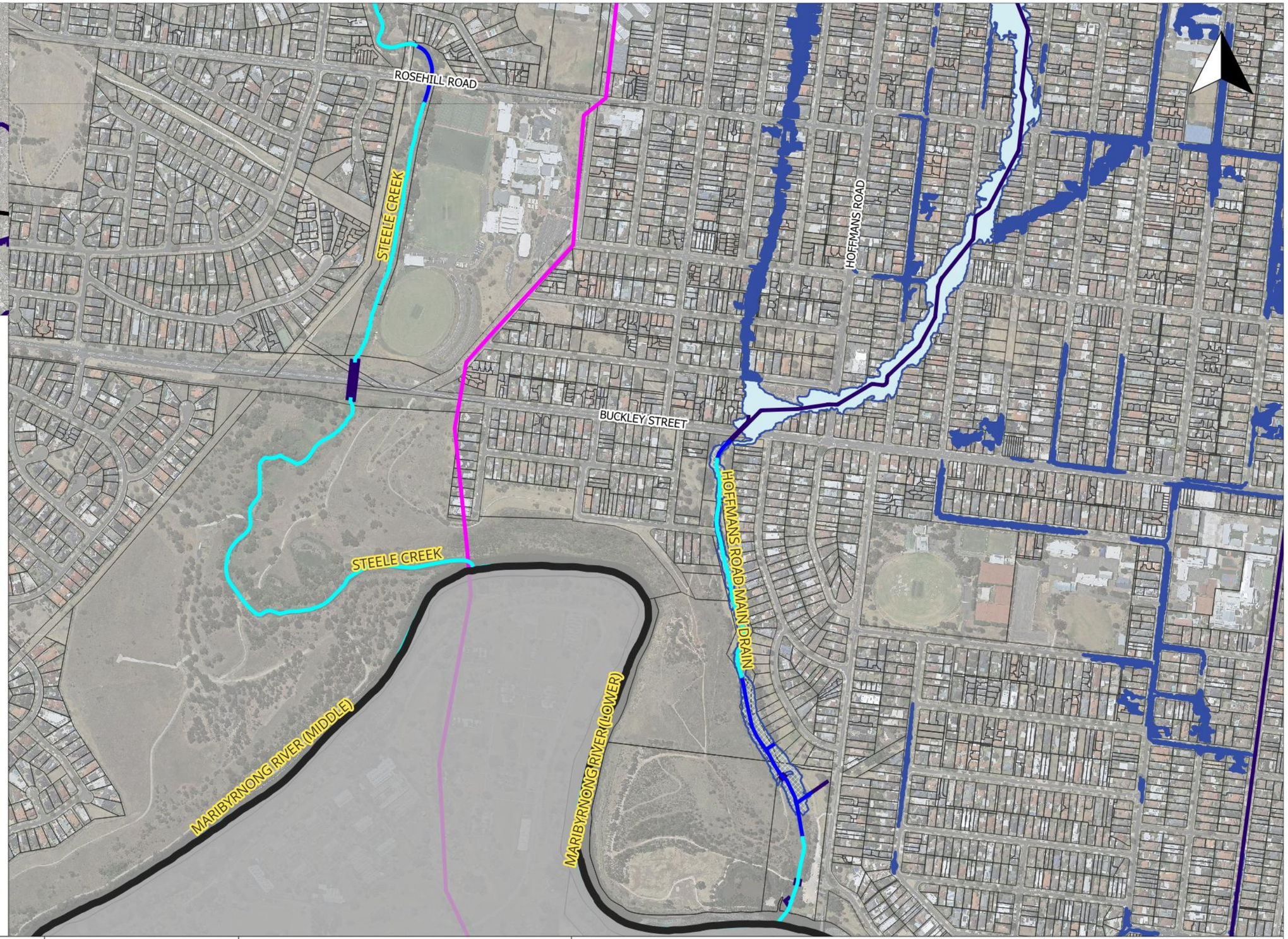
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Moonee Valley Flood Mapping Project

Maribyrnong Lower
1 % AEP Flood Extent Base Case





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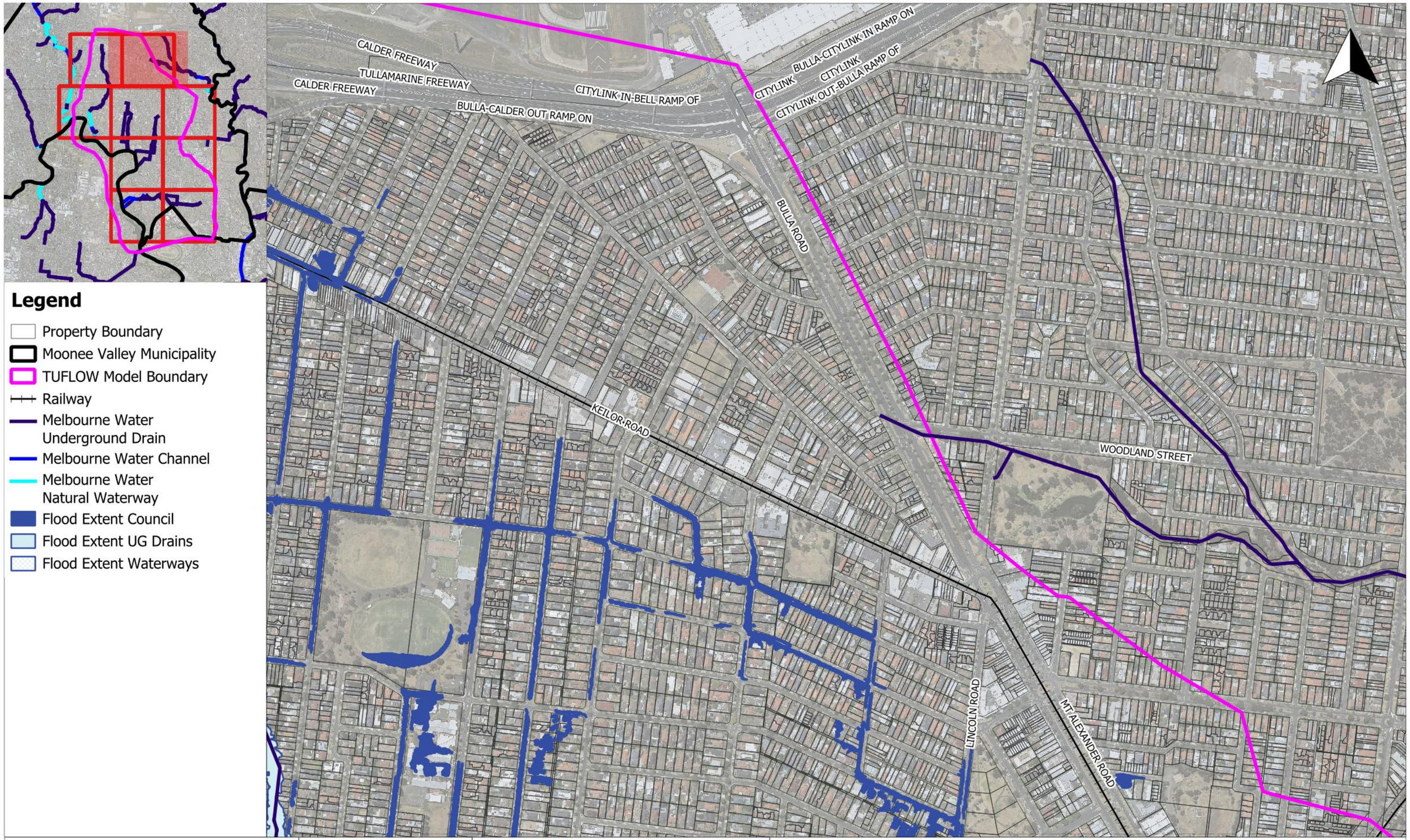
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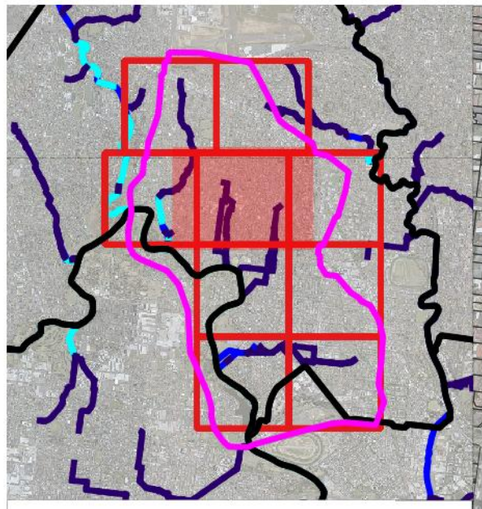
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Moonee Valley Flood Mapping Project

Maribyrnong Lower
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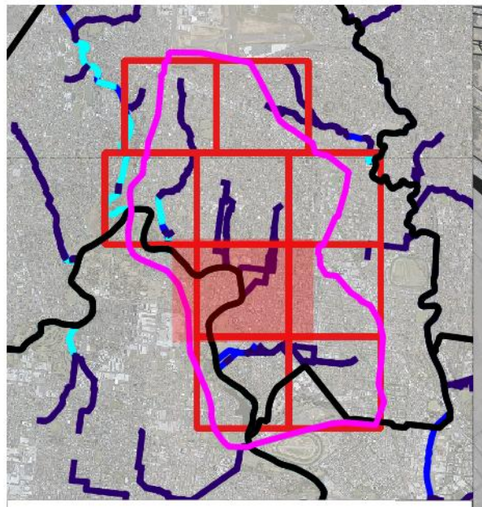
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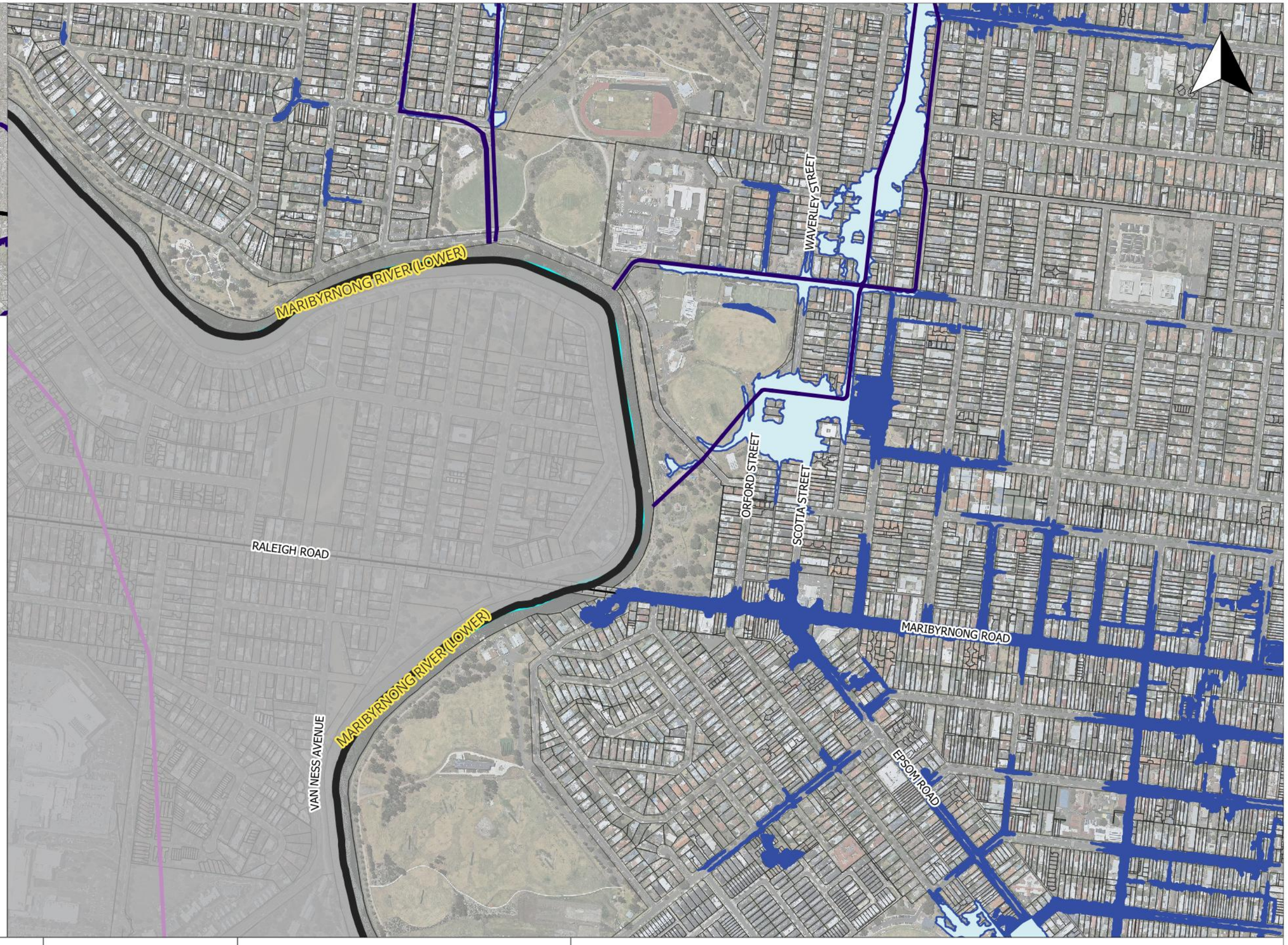
Moonee Valley Flood Mapping Project

Maribyrnong Lower
1 % AEP Flood Extent Base Case



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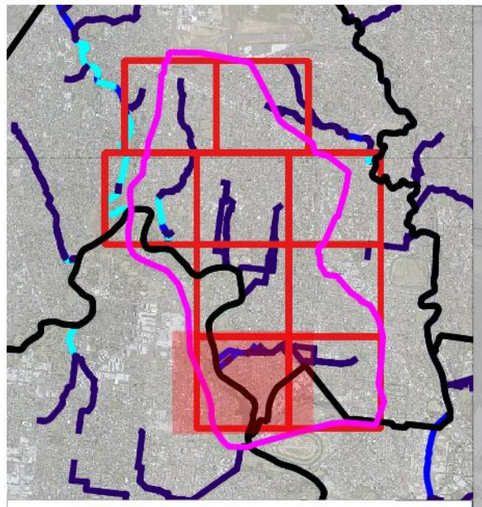
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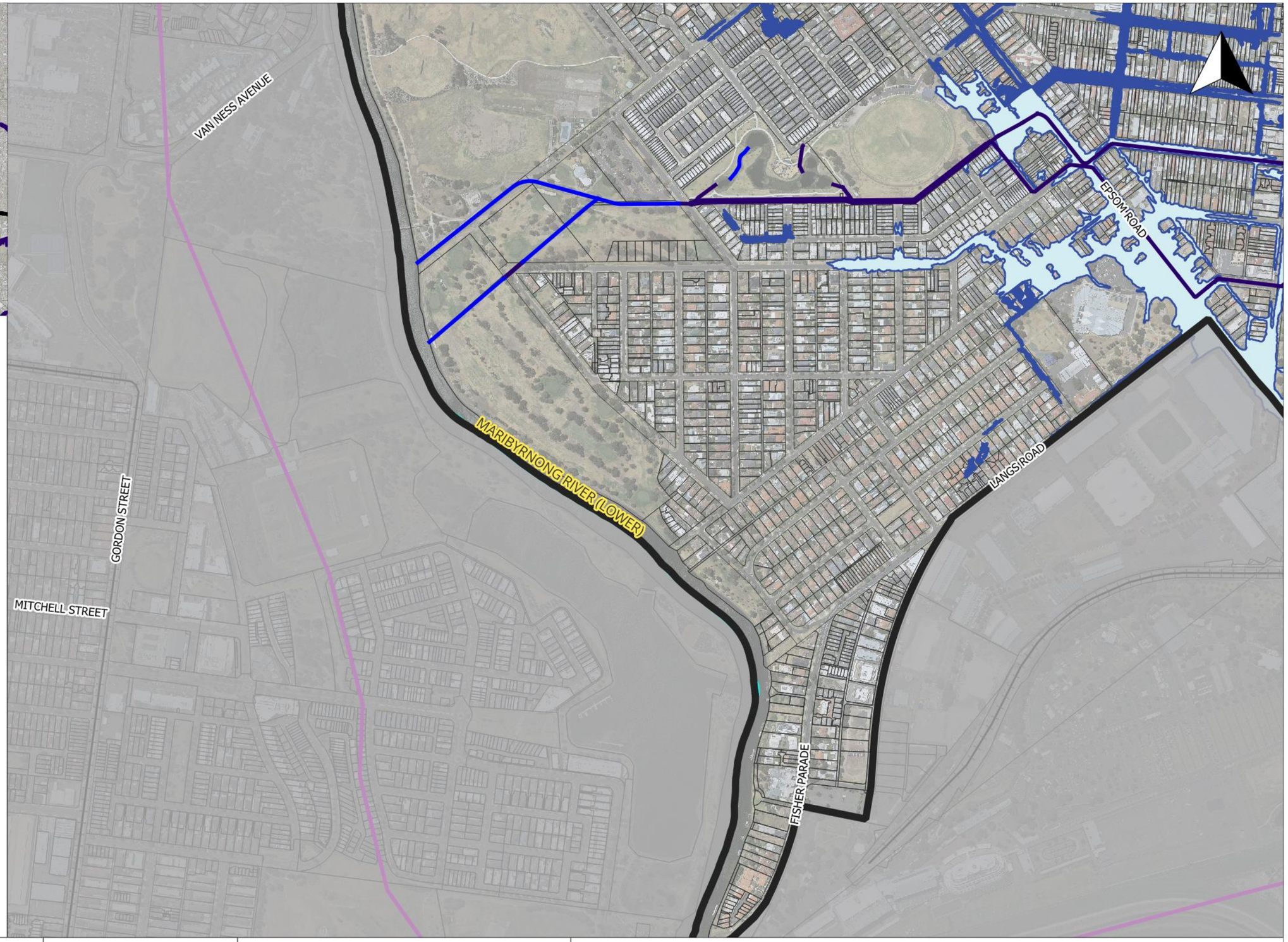
Moonee Valley Flood Mapping Project

Maribyrnong Lower
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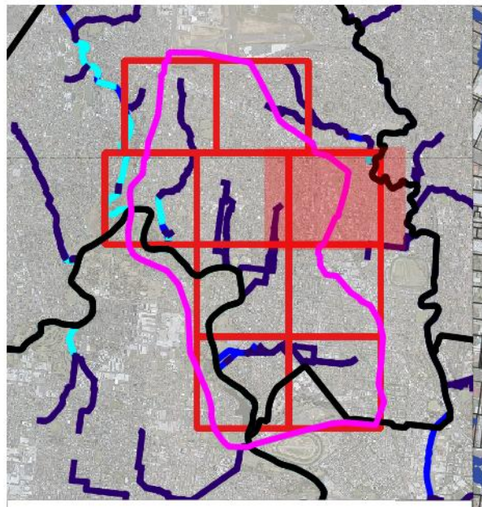
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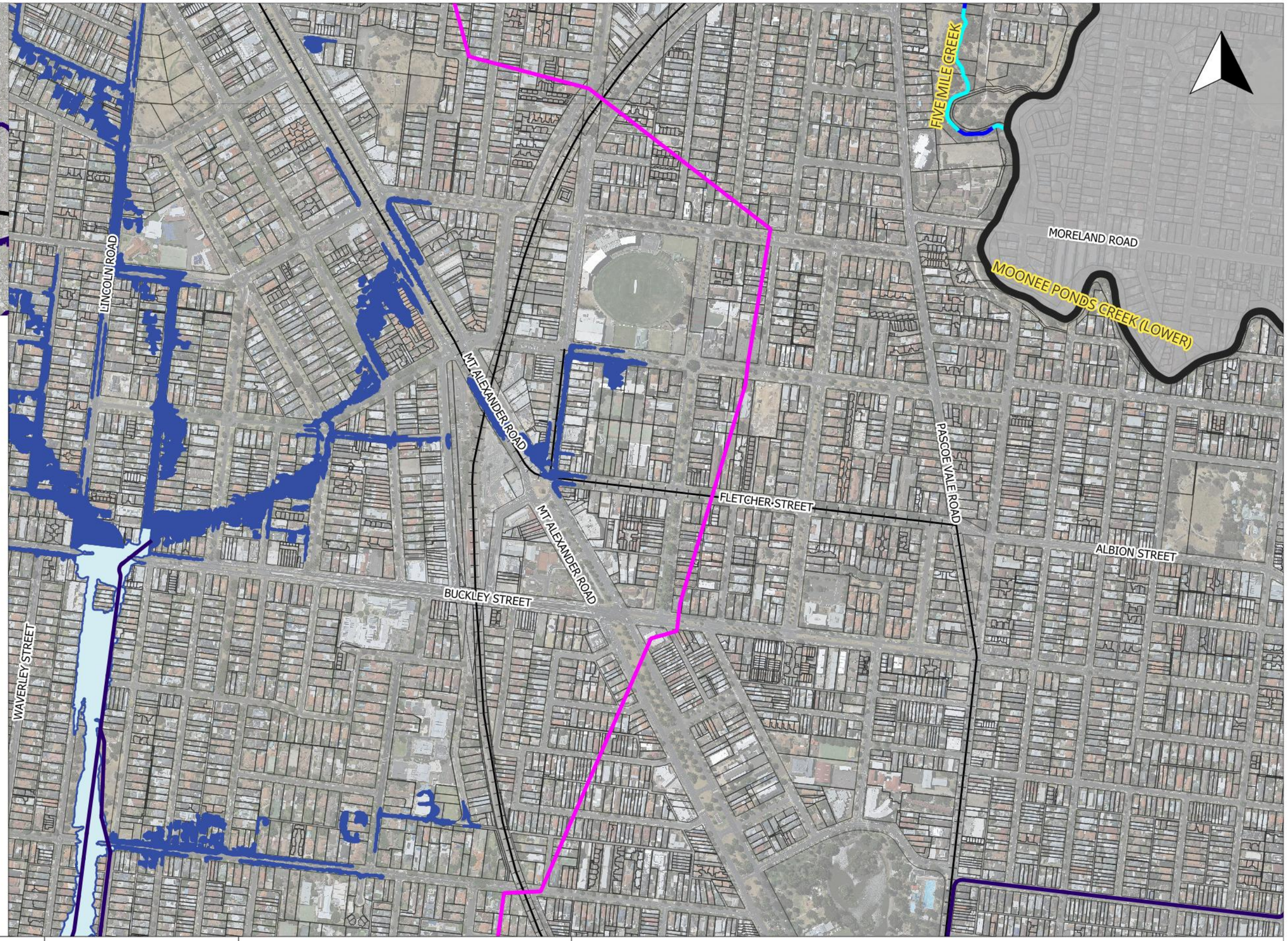
Moonee Valley Flood Mapping Project

Maribyrnong Lower
1 % AEP Flood Extent Base Case



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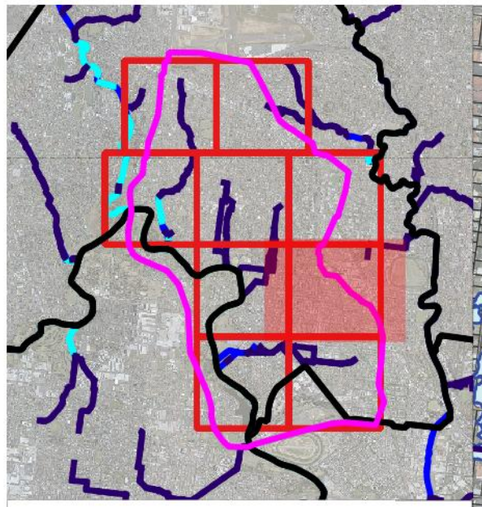
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MT ALEXANDER ROAD
KELLAWAY AVENUE
PASCOE VALE ROAD
WILSON STREET
DEAN STREET
MT ALEXANDER ROAD
ASCOT VALE ROAD
MARIBYRNONG ROAD
ORMOND ROAD
EPSOM ROAD

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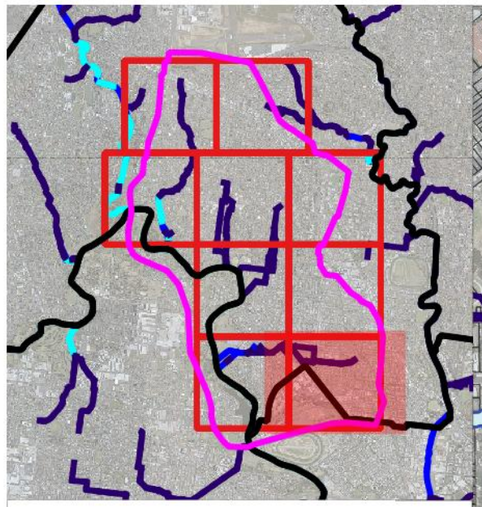
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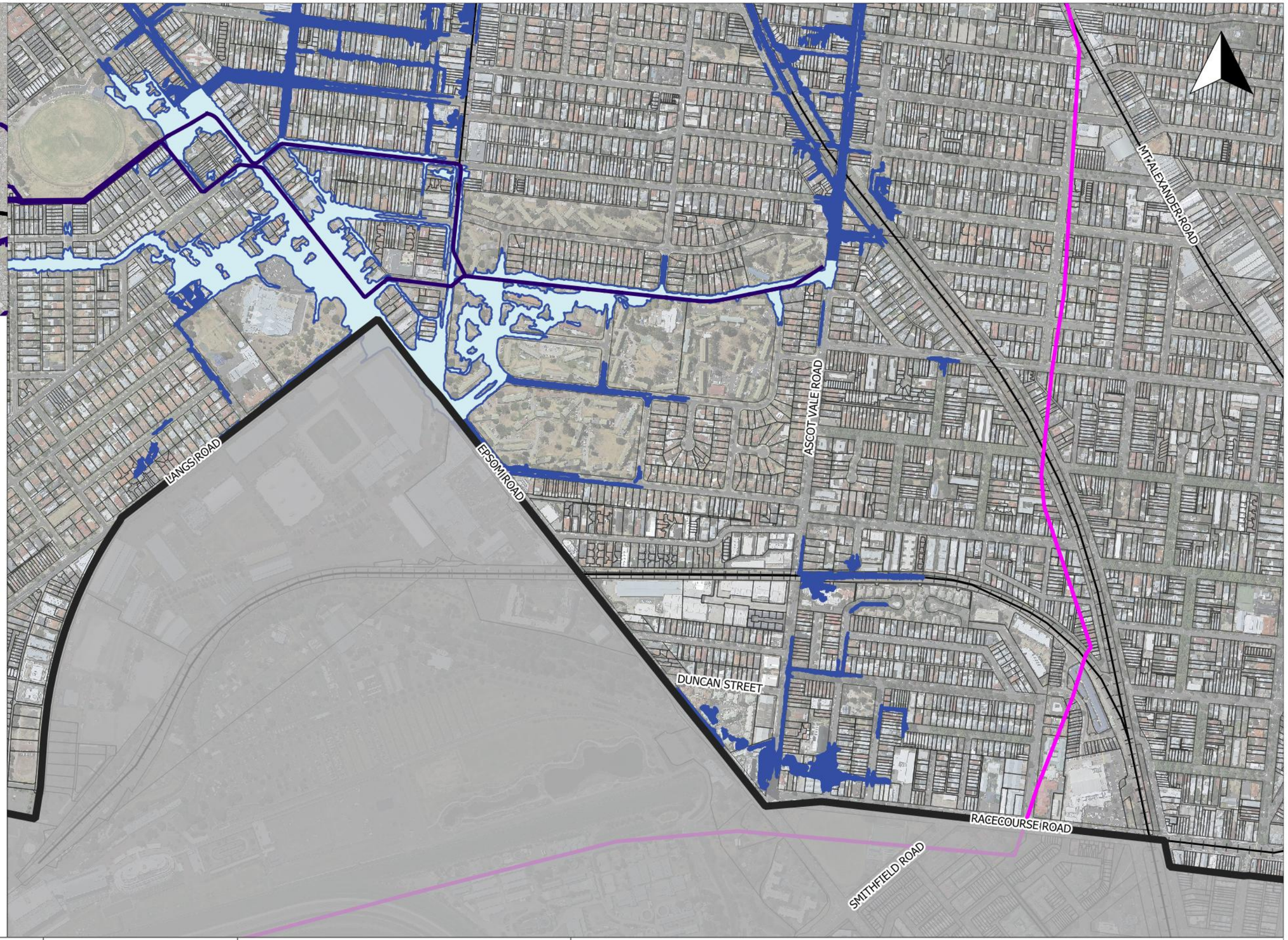
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Maribyrnong Lower
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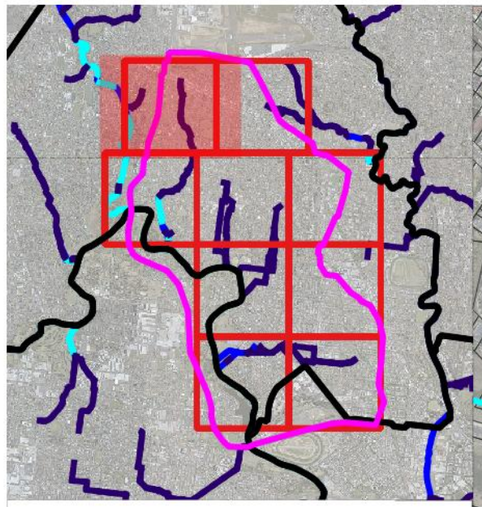
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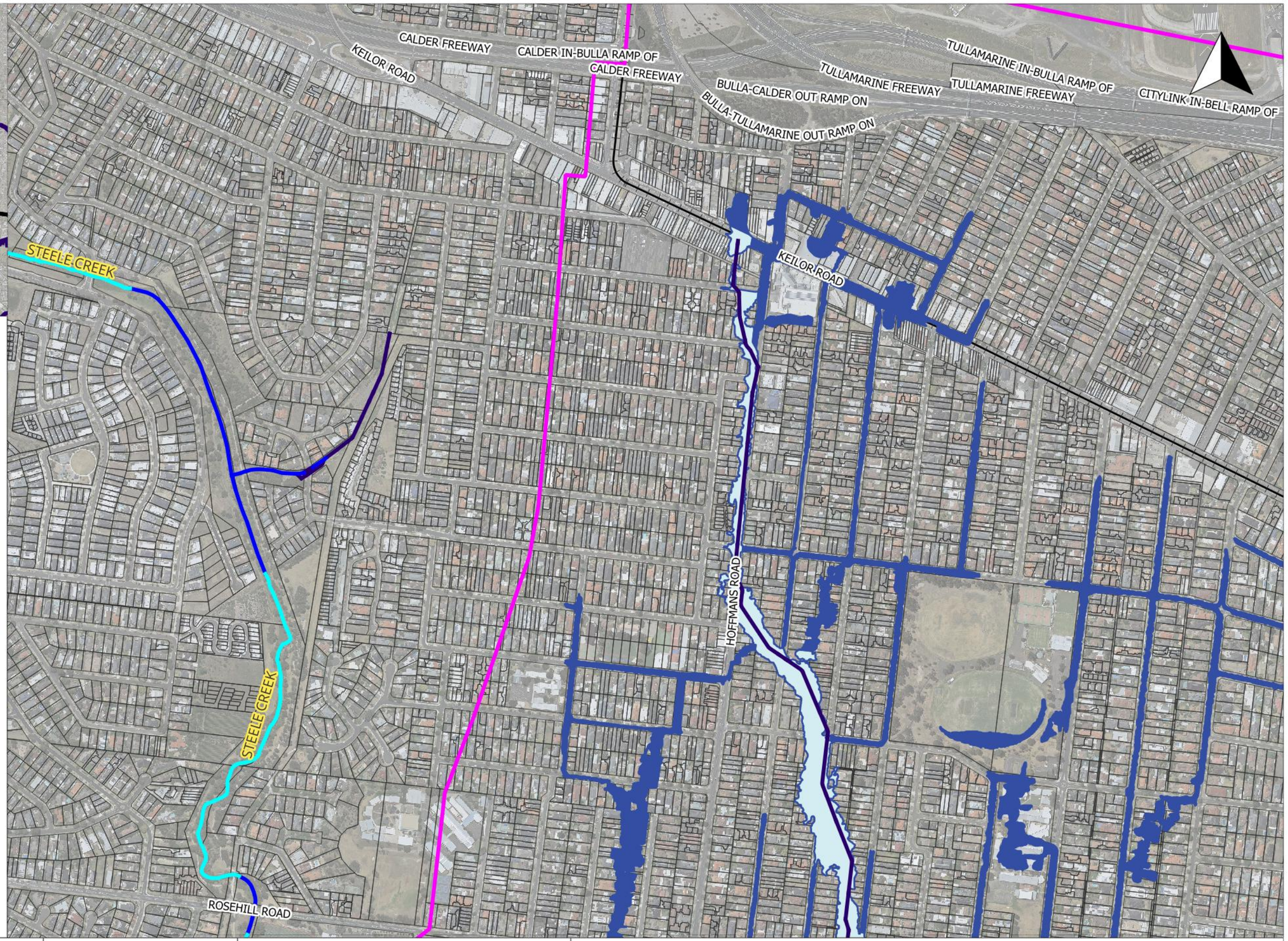
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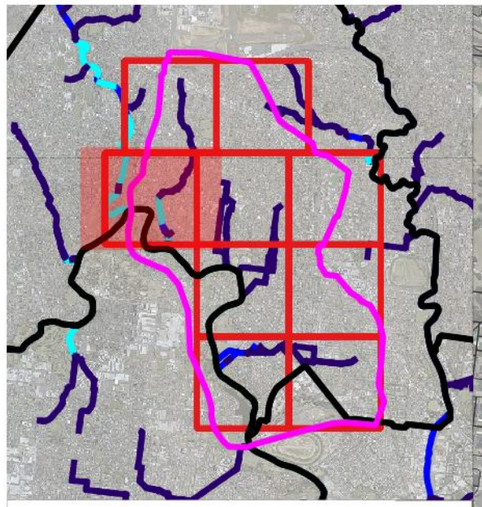
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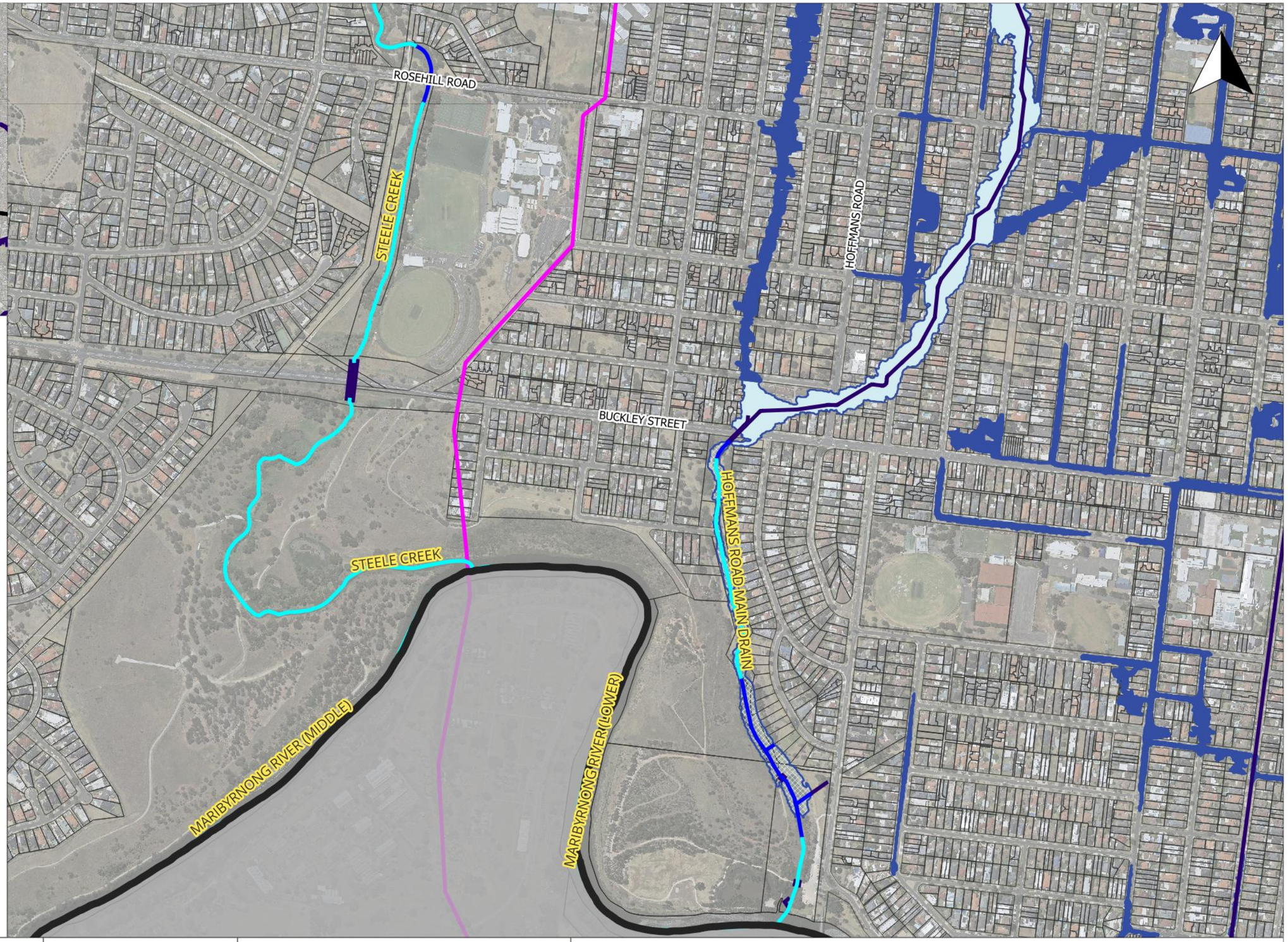
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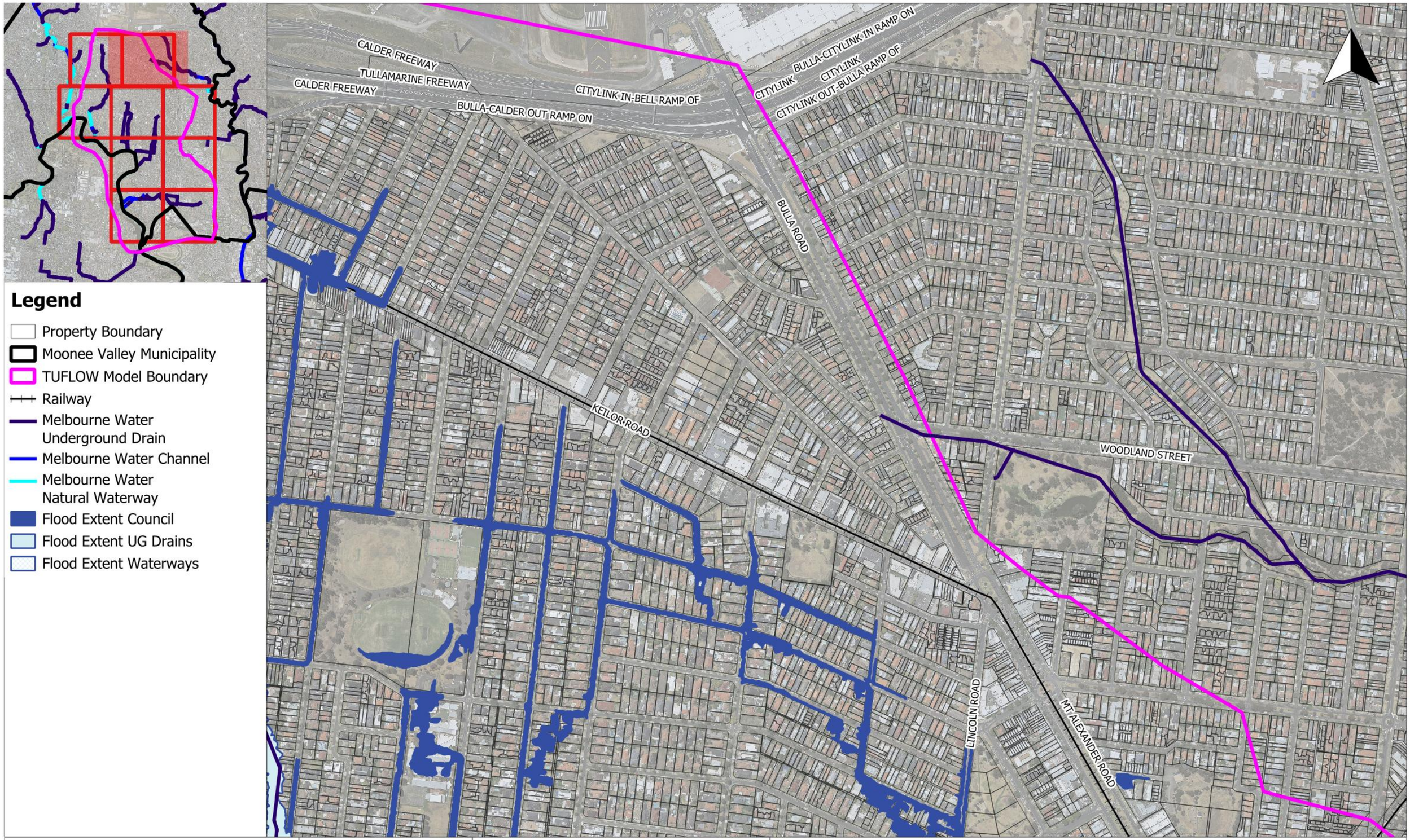
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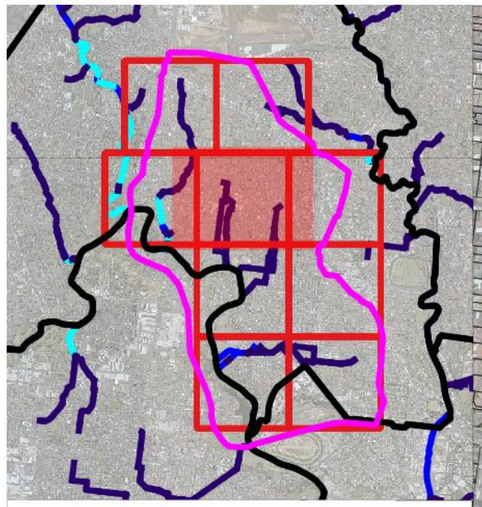
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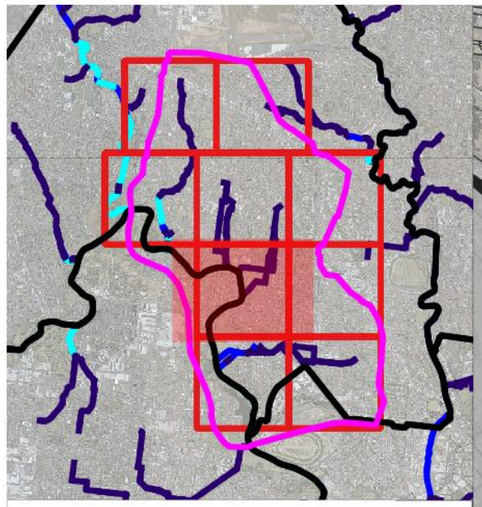
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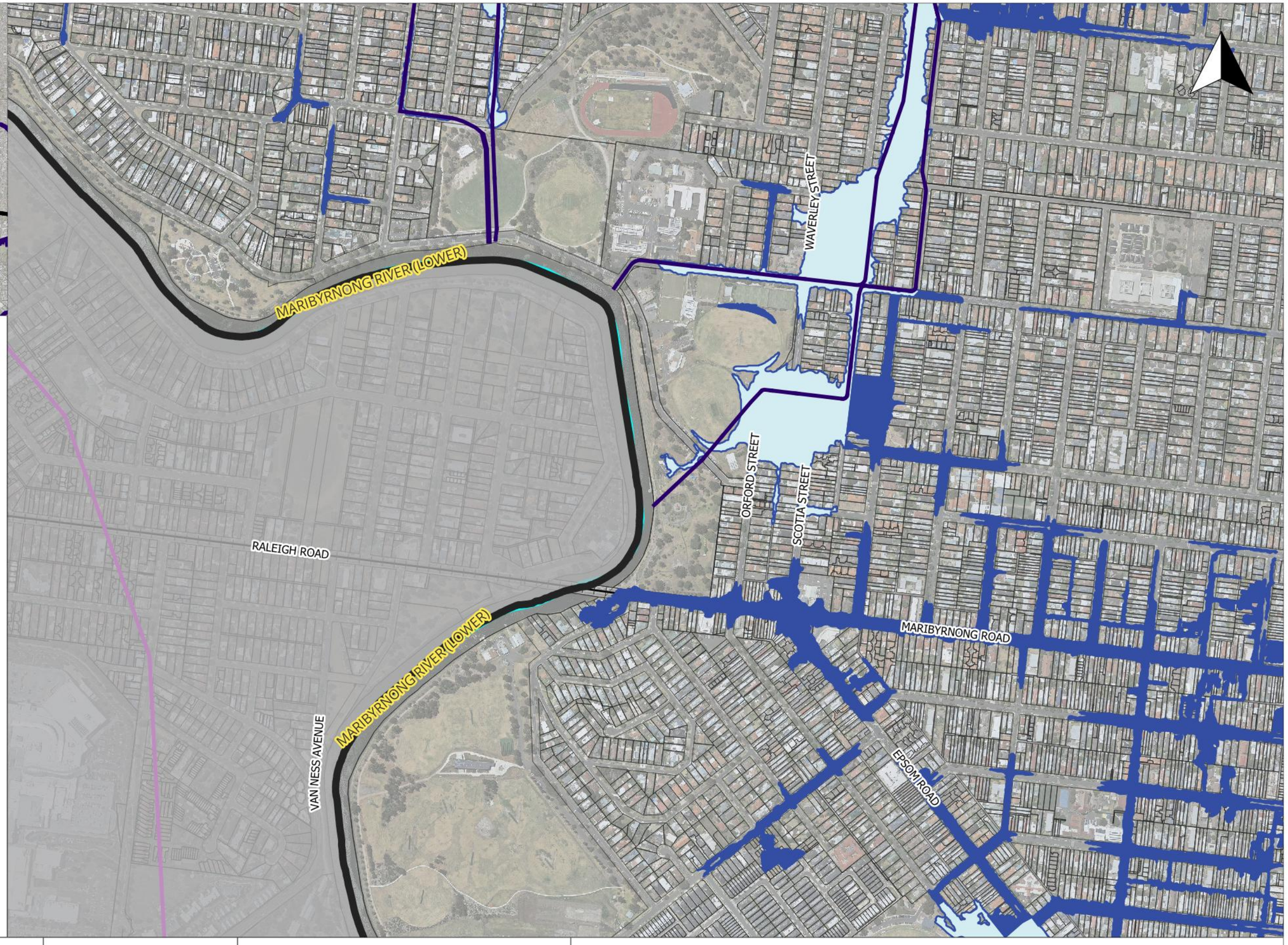
Moonee Valley Flood Mapping Project

Maribyrnong Lower
1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
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- TUFLOW Model Boundary
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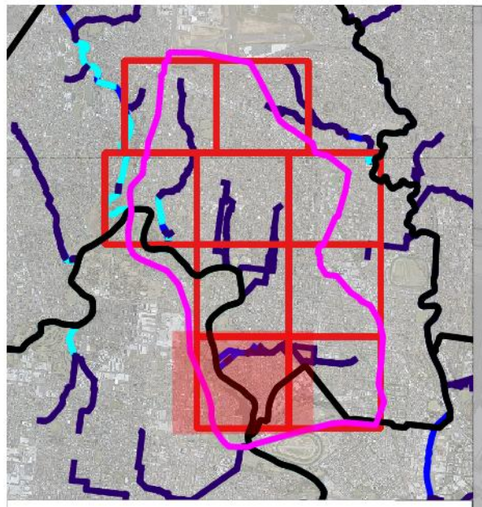
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VAN NESS AVENUE
GORDON STREET
MITCHELL STREET
MARIBYRNONG RIVER (LOWER)
EPSOM ROAD
LANGS ROAD
FISHER PARADE

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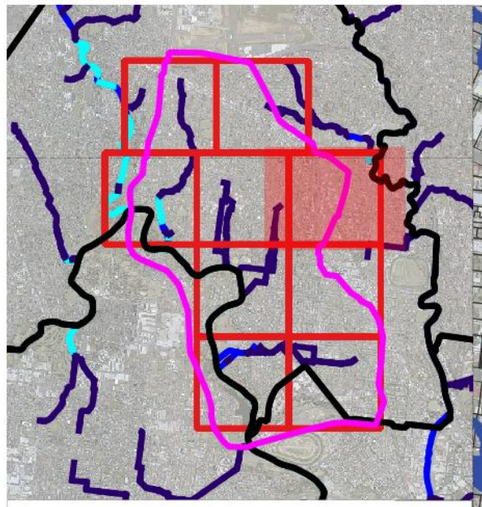
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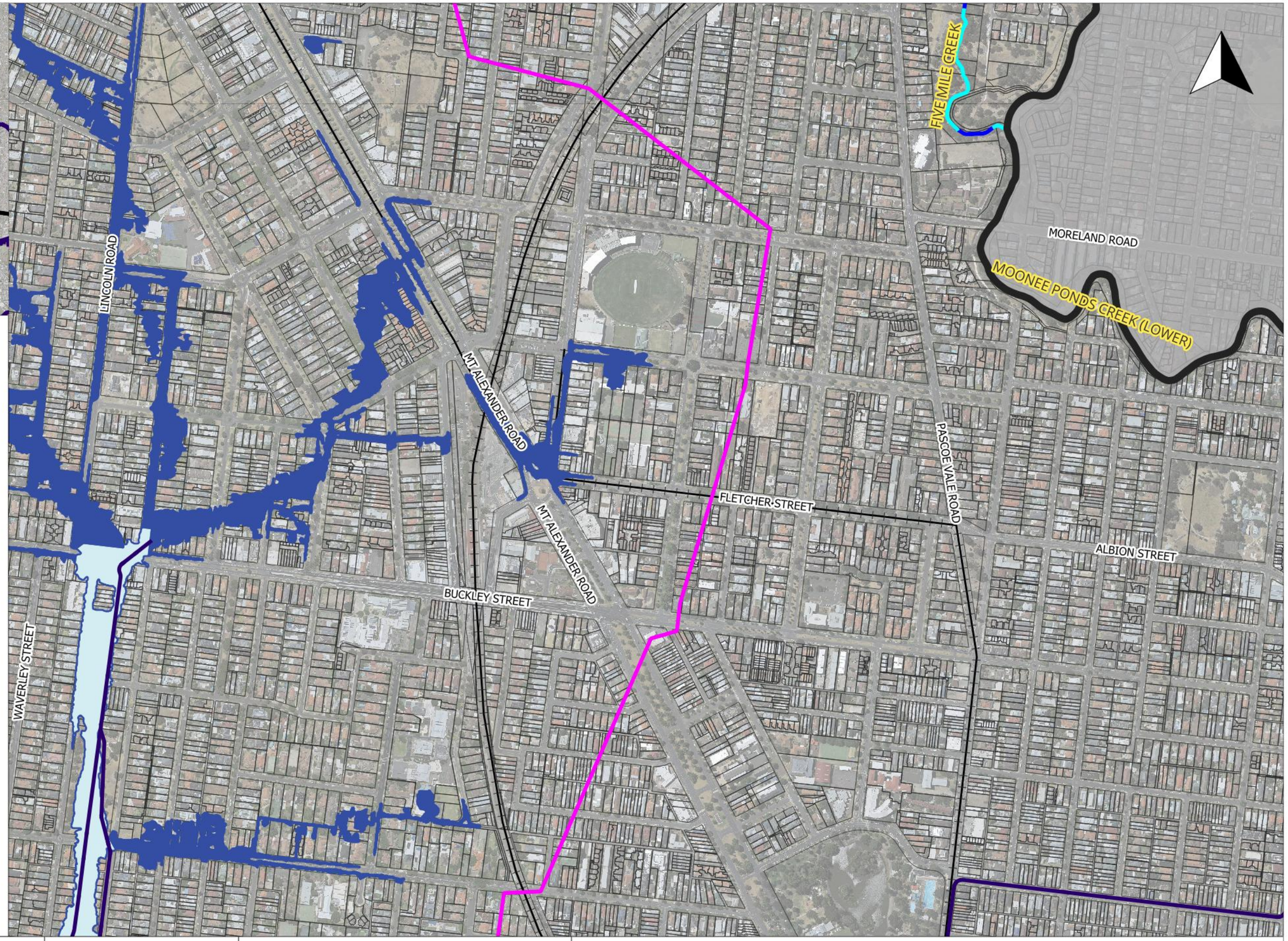
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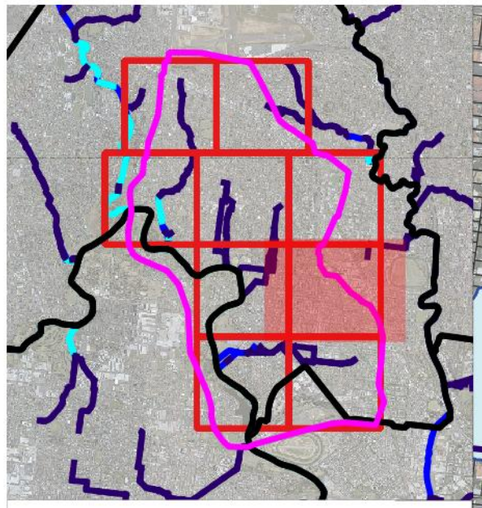
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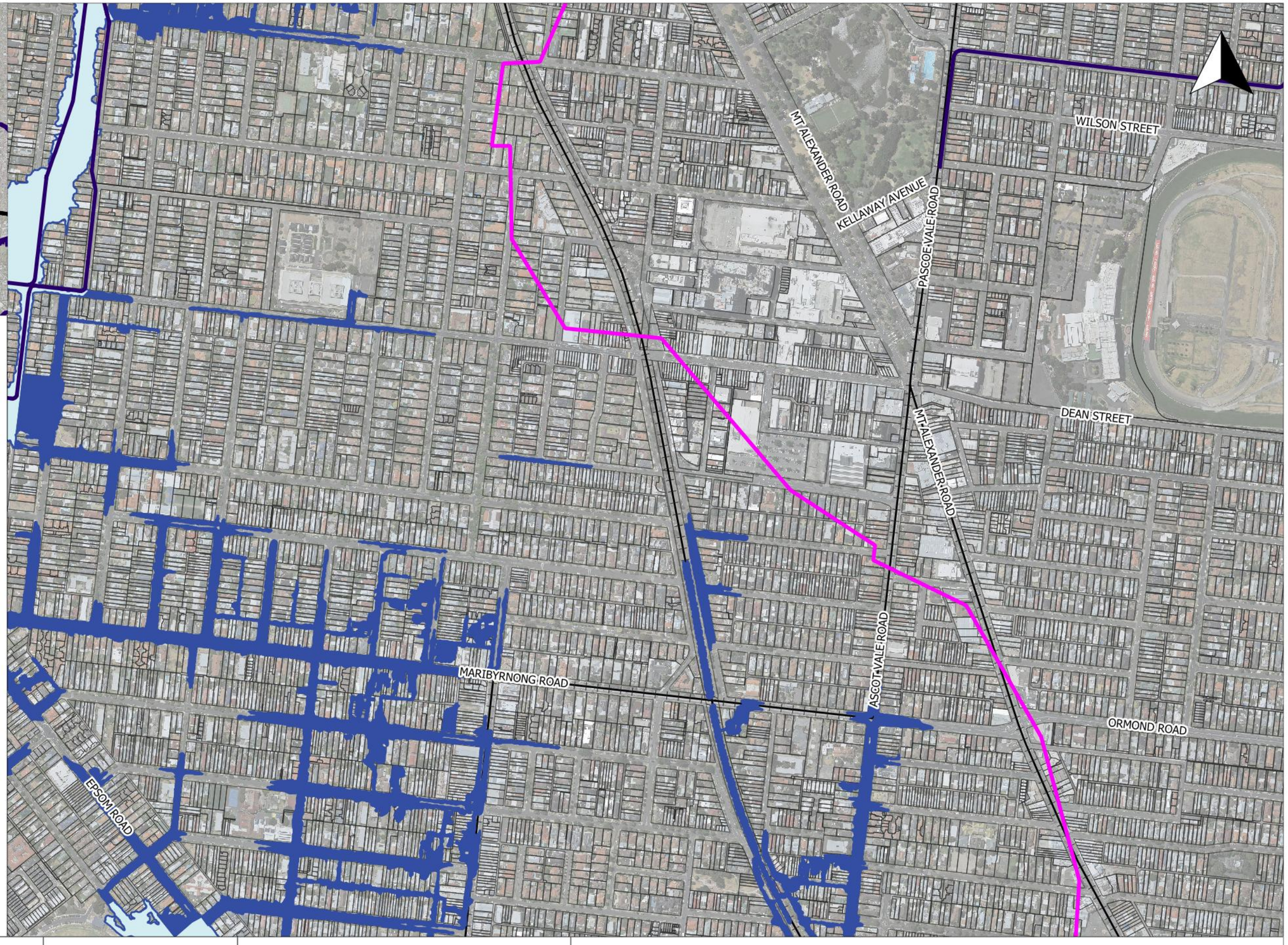
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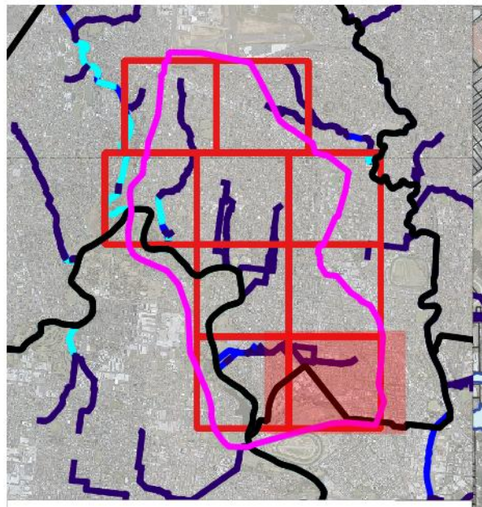
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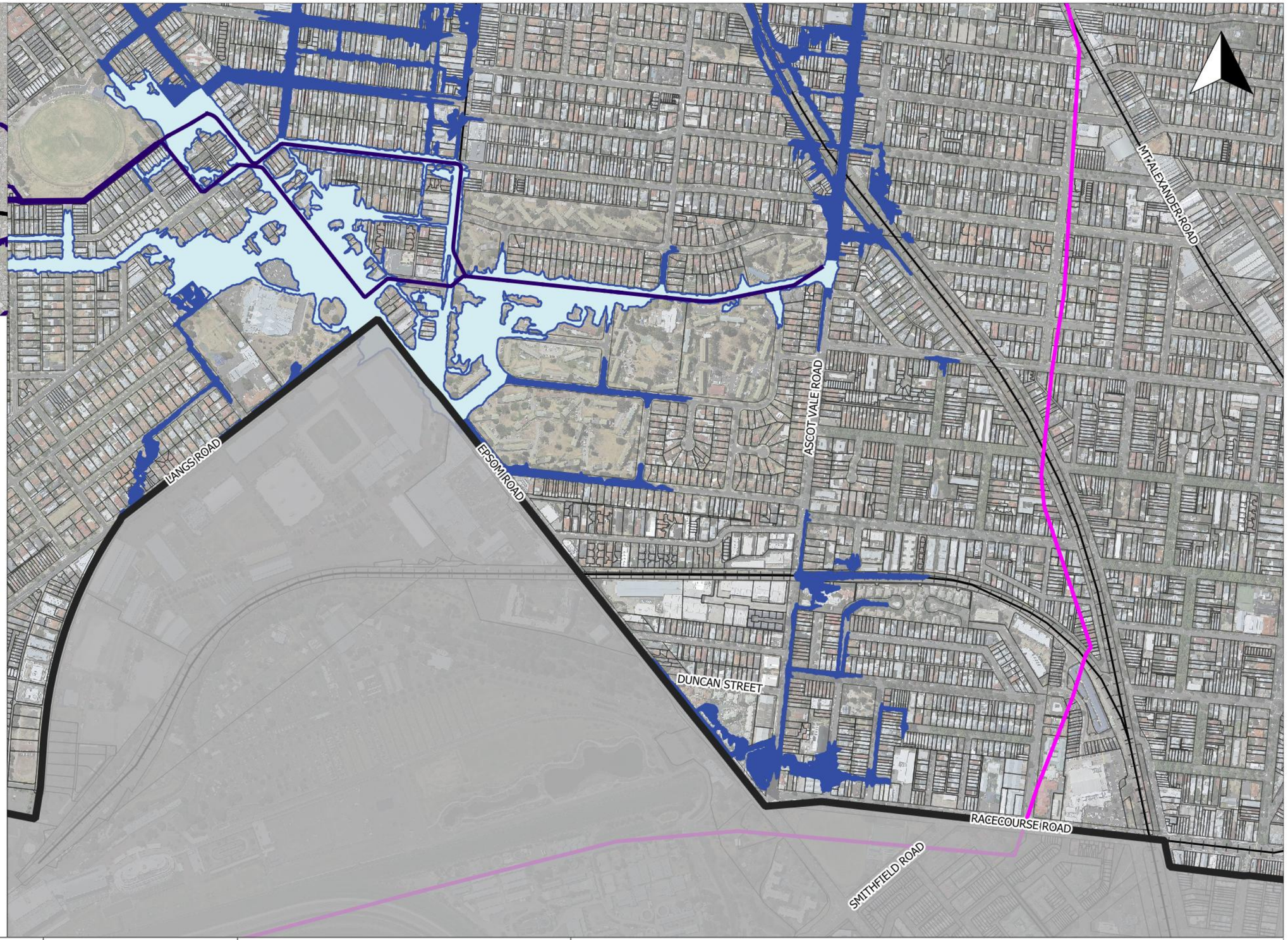
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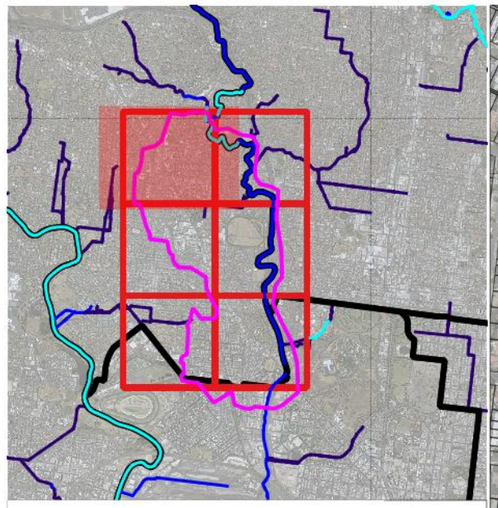
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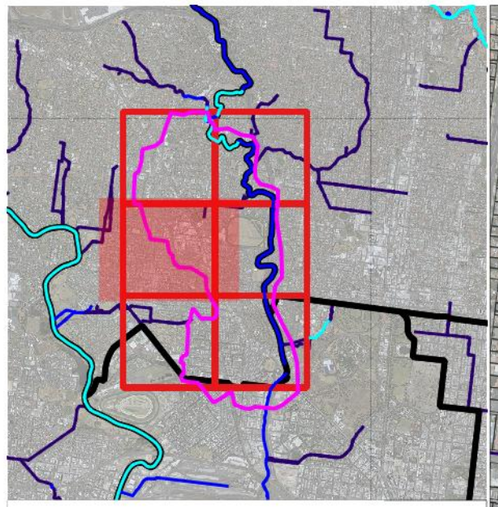
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Moonee Ponds Creek Lower
1 % AEP Flood Extent Base Case



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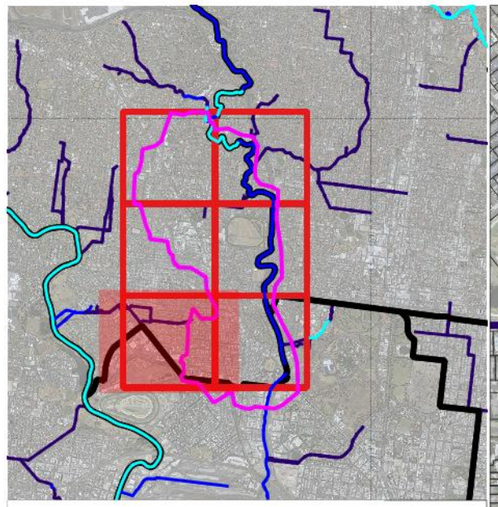
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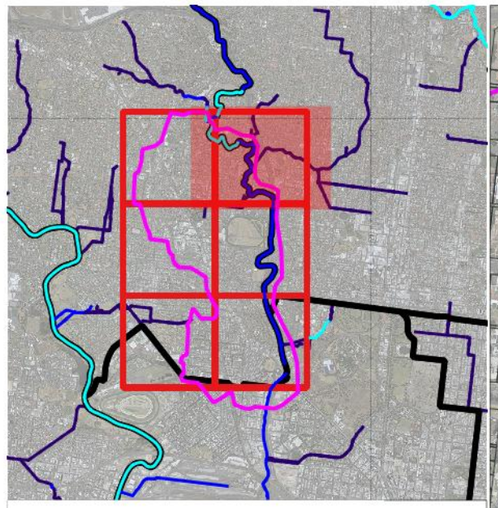
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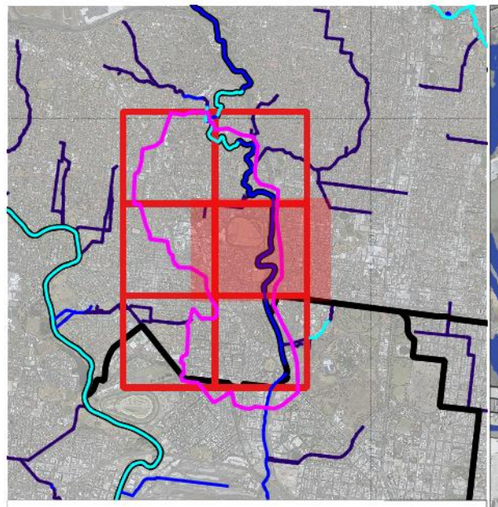
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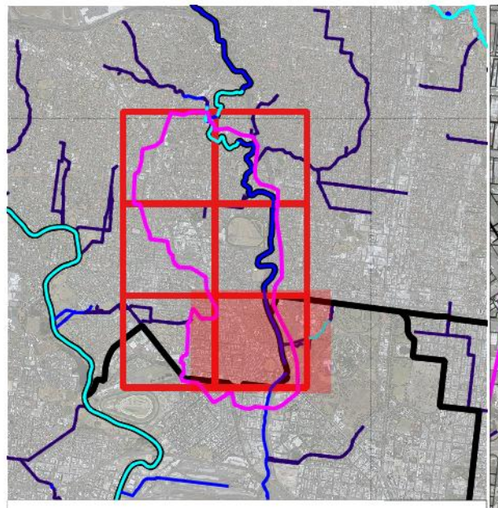
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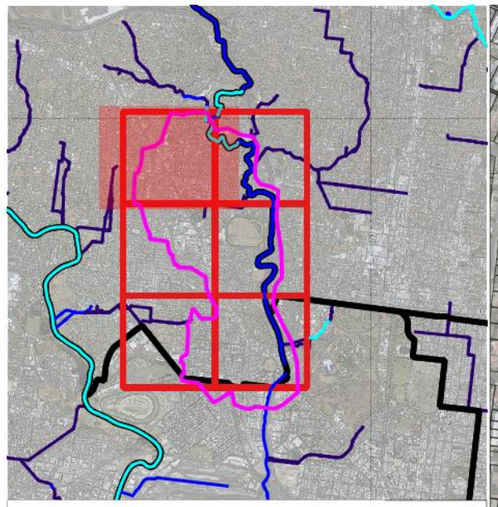
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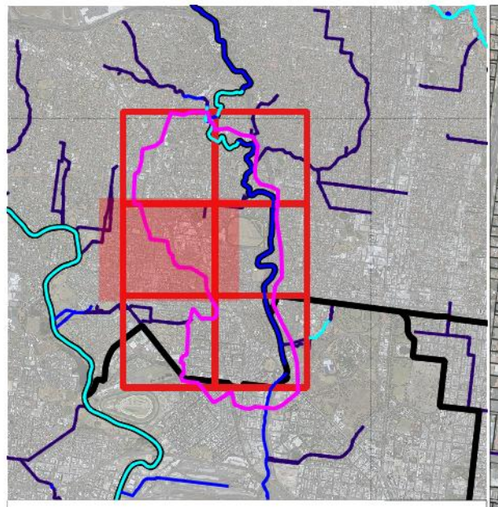
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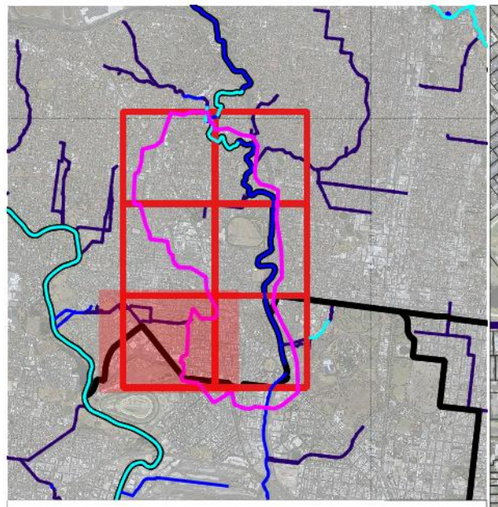
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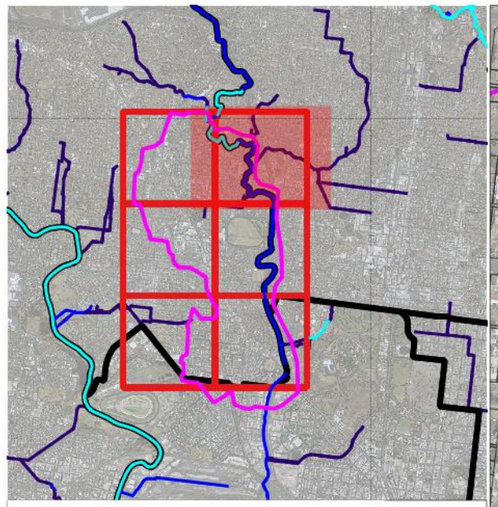
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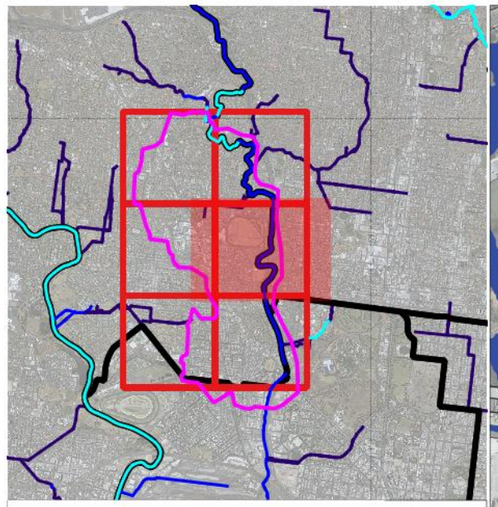
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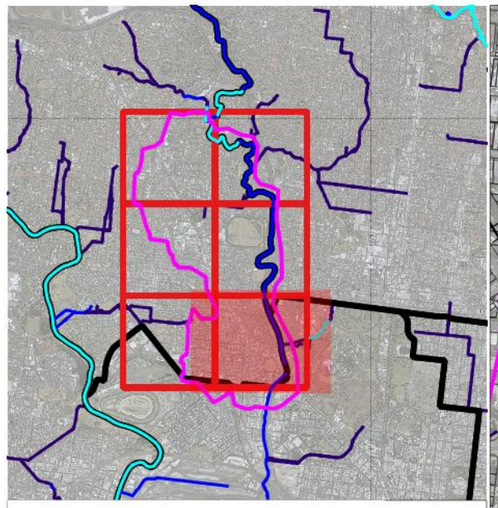
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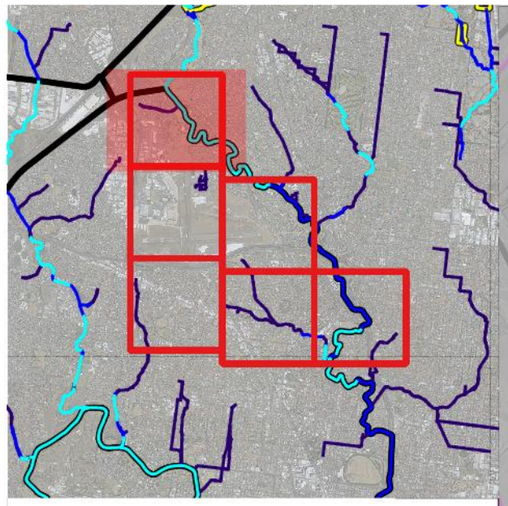
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- TUFLOW Model Boundary
- Railway
- Melbourne Water Channel
- Melbourne Water Natural Waterway
- Melbourne Water Underground Drain
- Flood Extent Council
- Flood Extent UG Drains
- Flood Extent Waterways

MOONEE PONDS CREEK (UPPER)

Tullamarine Out - Melrose Ramp Of

Tullamarine Freeway

Level 43, Tenancy 2, 360 Elizabeth St,
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Melbourne Water

City of Moonee Valley

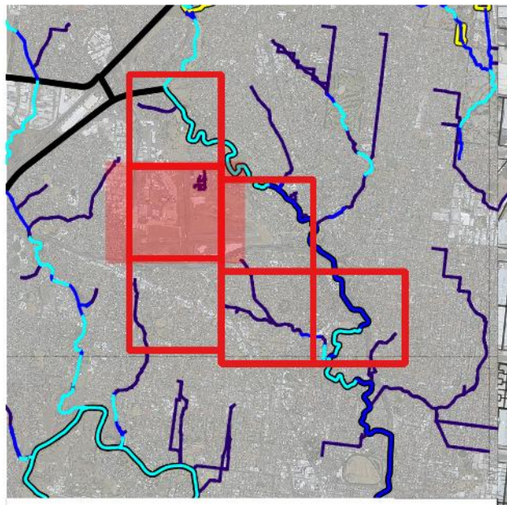
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Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1 % AEP Flood Extent Base Case



Legend

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Boorcan Road

Tullamarine Freeway

ESSENDON FIELDS

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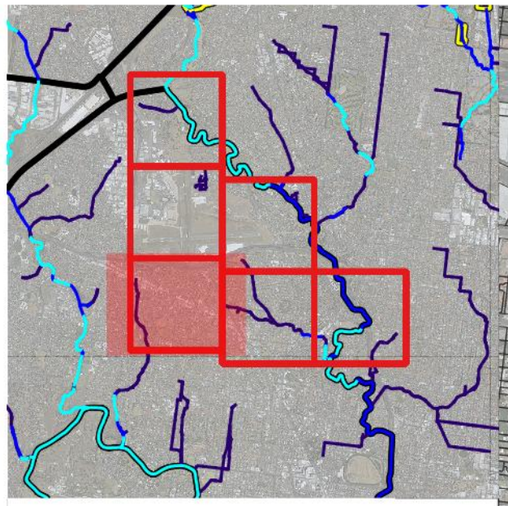
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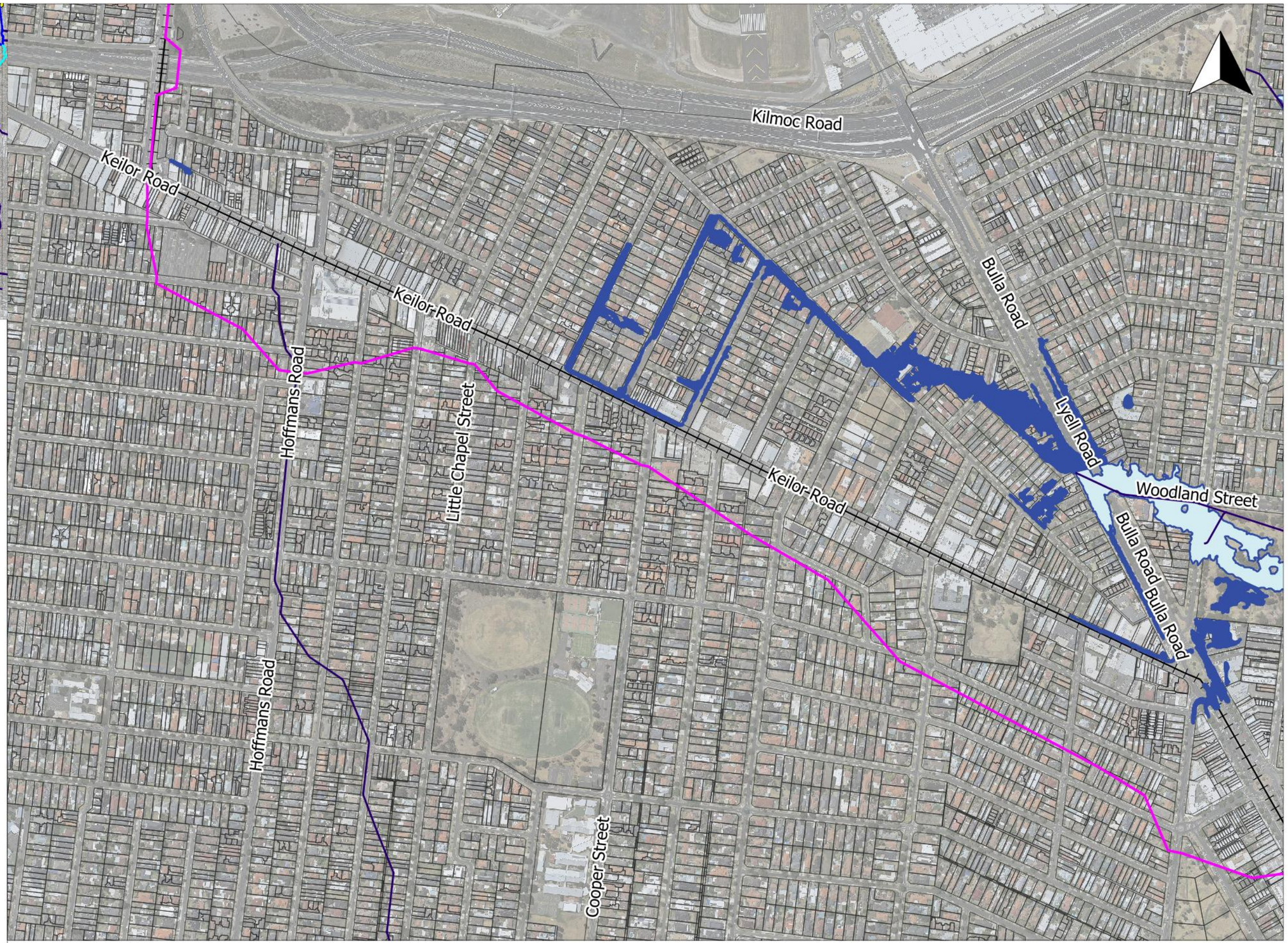
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Moonee Ponds Creek Upper
1 % AEP Flood Extent Base Case



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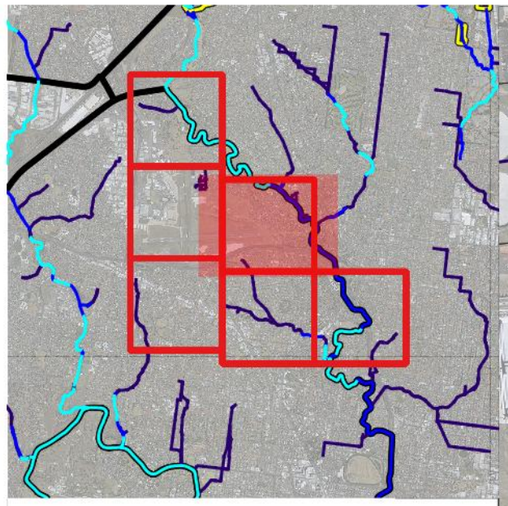
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1 % AEP Flood Extent Base Case



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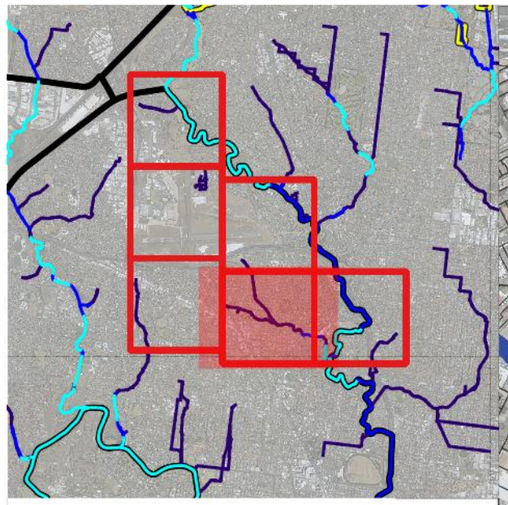
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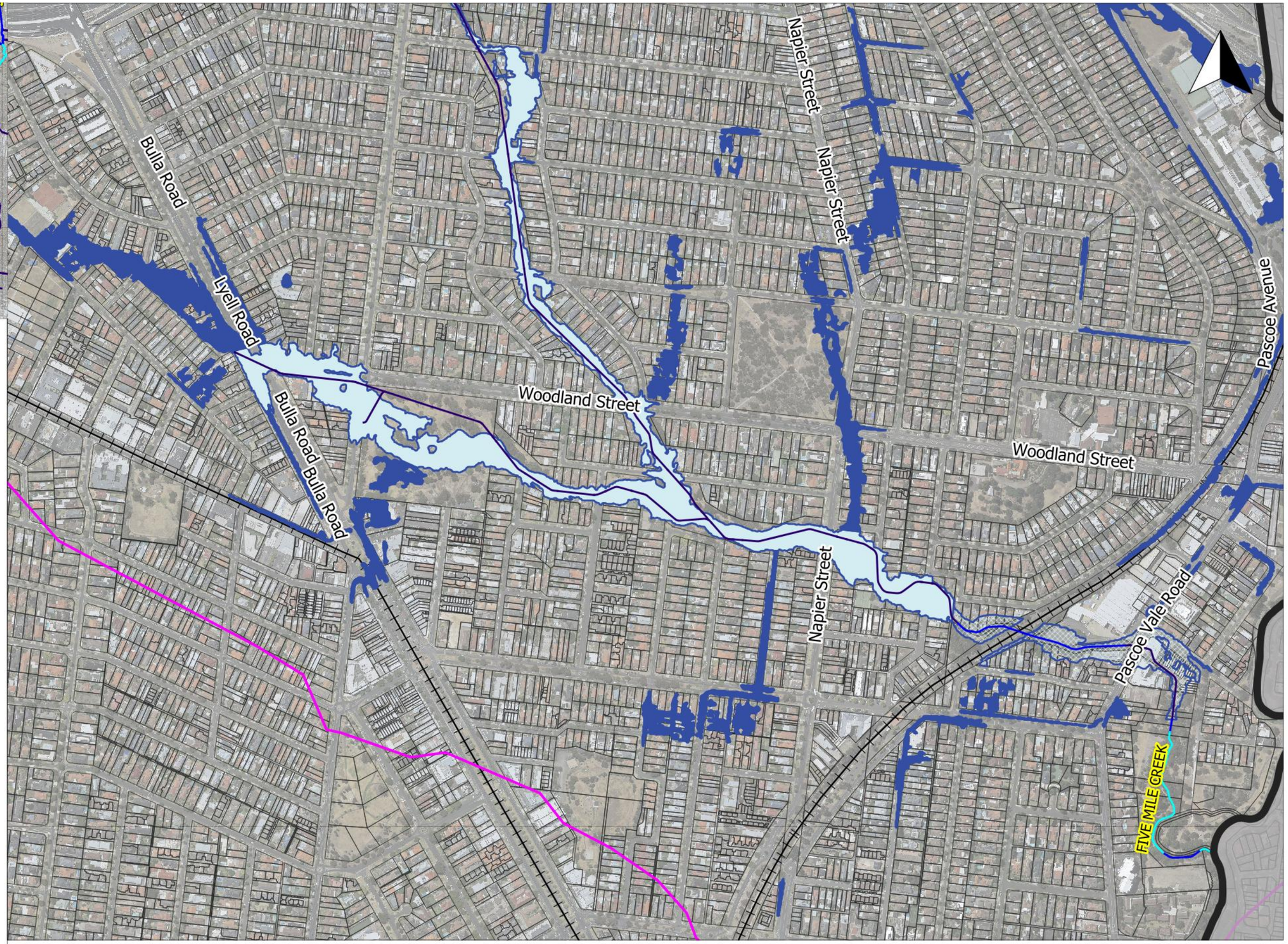
Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1 % AEP Flood Extent Base Case



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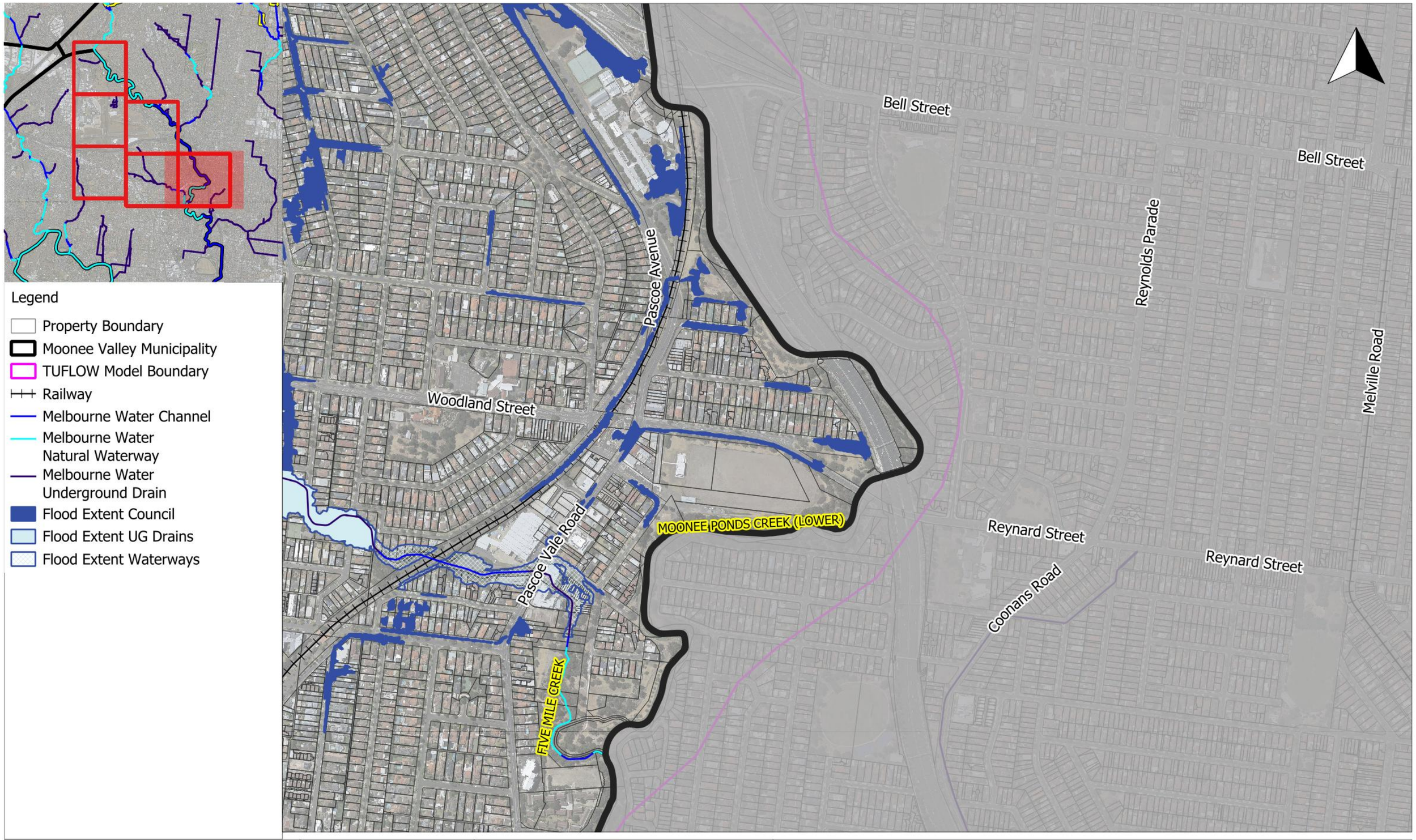
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1 % AEP Flood Extent Base Case



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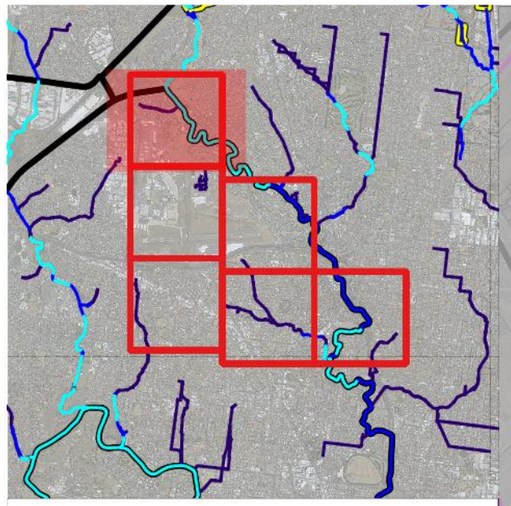
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1 % AEP Flood Extent Base Case



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MOONEE PONDS CREEK (UPPER)

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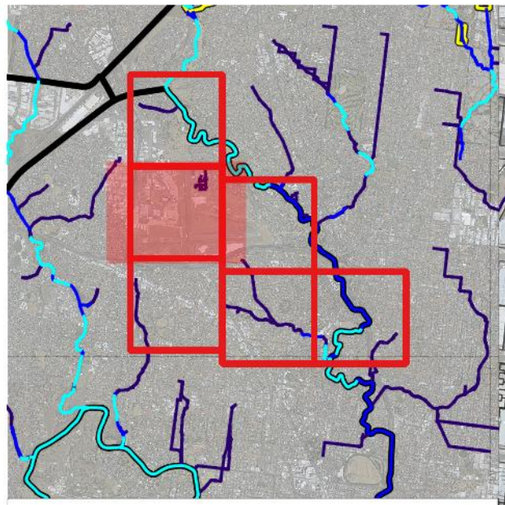
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1 % AEP Flood Extent Climate Change (Scenario D)



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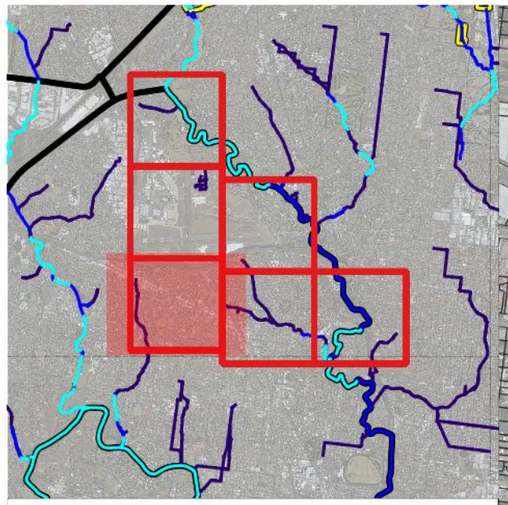
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
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Kilmoc Road
Keilor Road
Keilor Road
Keilor Road
Hoffmans Road
Little Chapel Street
Bulla Road
Lyell Road
Woodland Street
Bulla Road
Bulla Road
Hoffmans Road
Cooper Street

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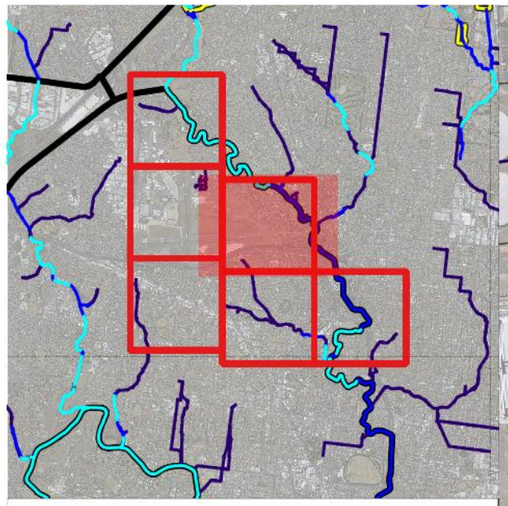
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
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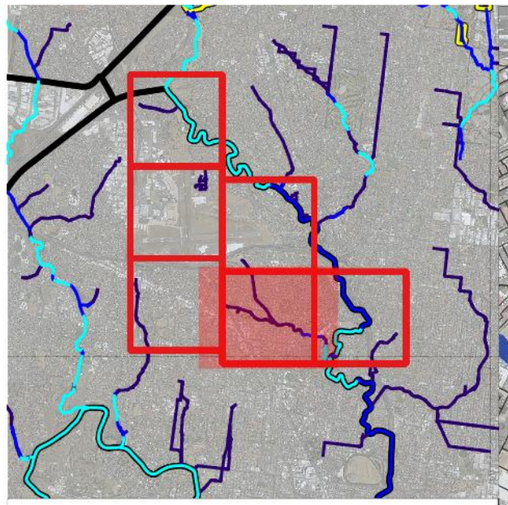
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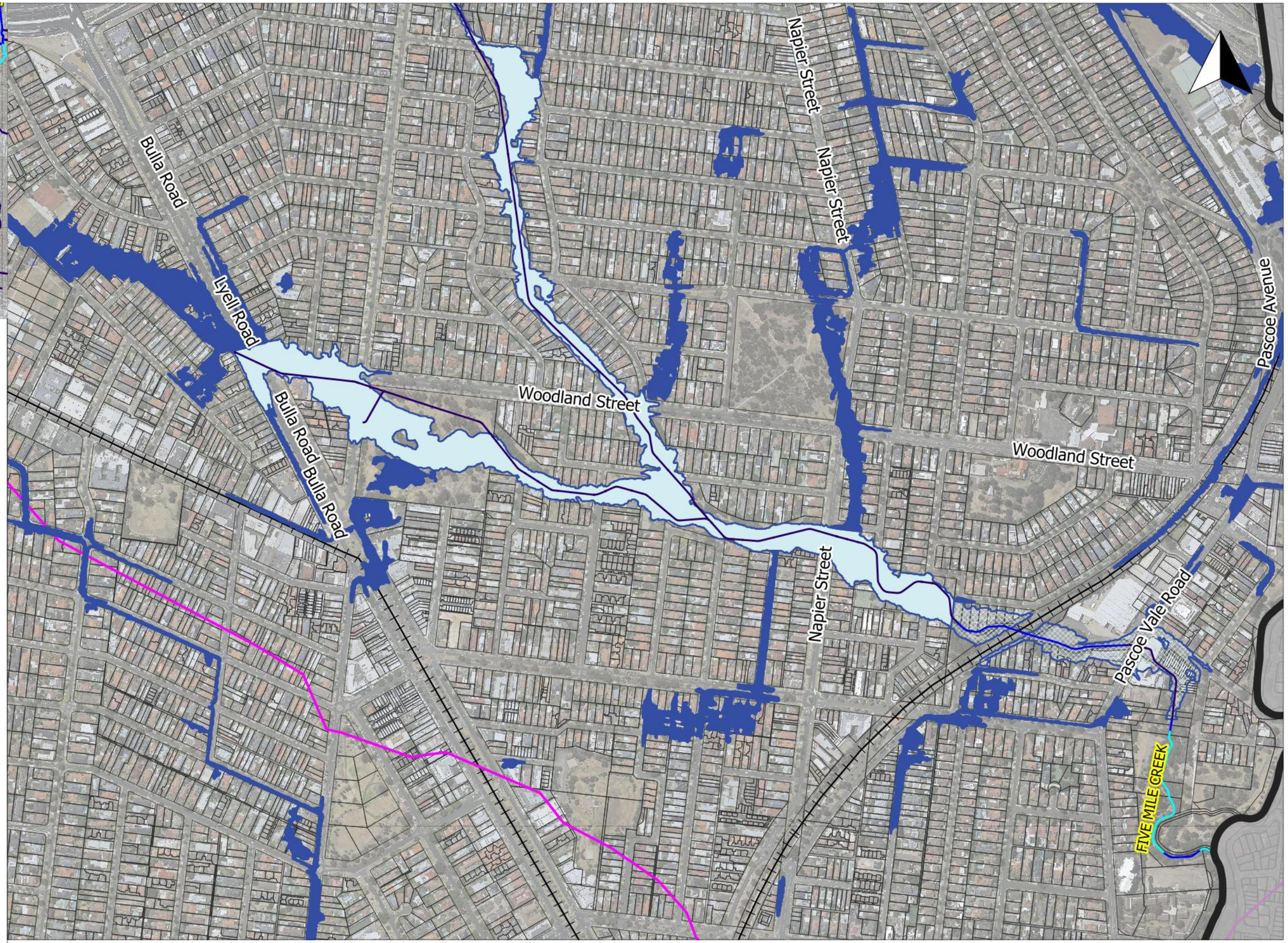
Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1 % AEP Flood Extent Climate Change (Scenario D)



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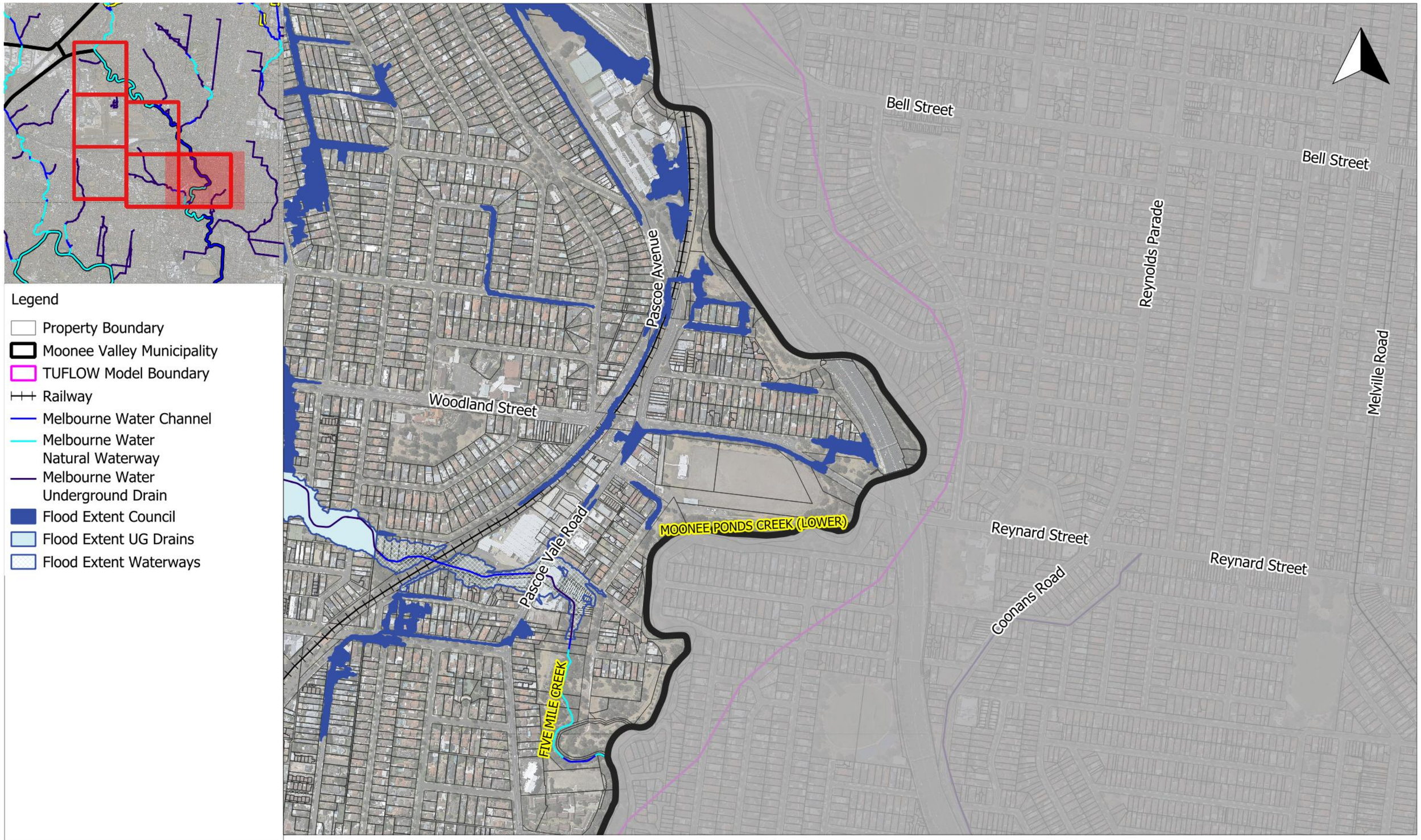
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Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1 % AEP Flood Extent Climate Change (Scenario D)



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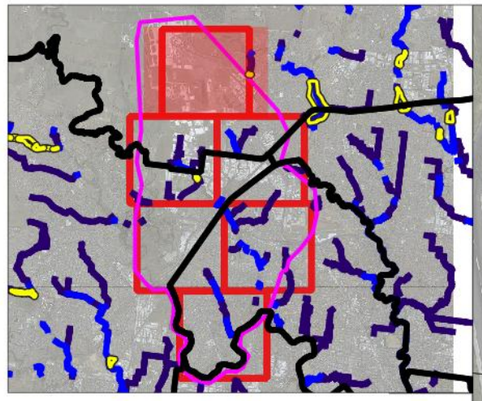
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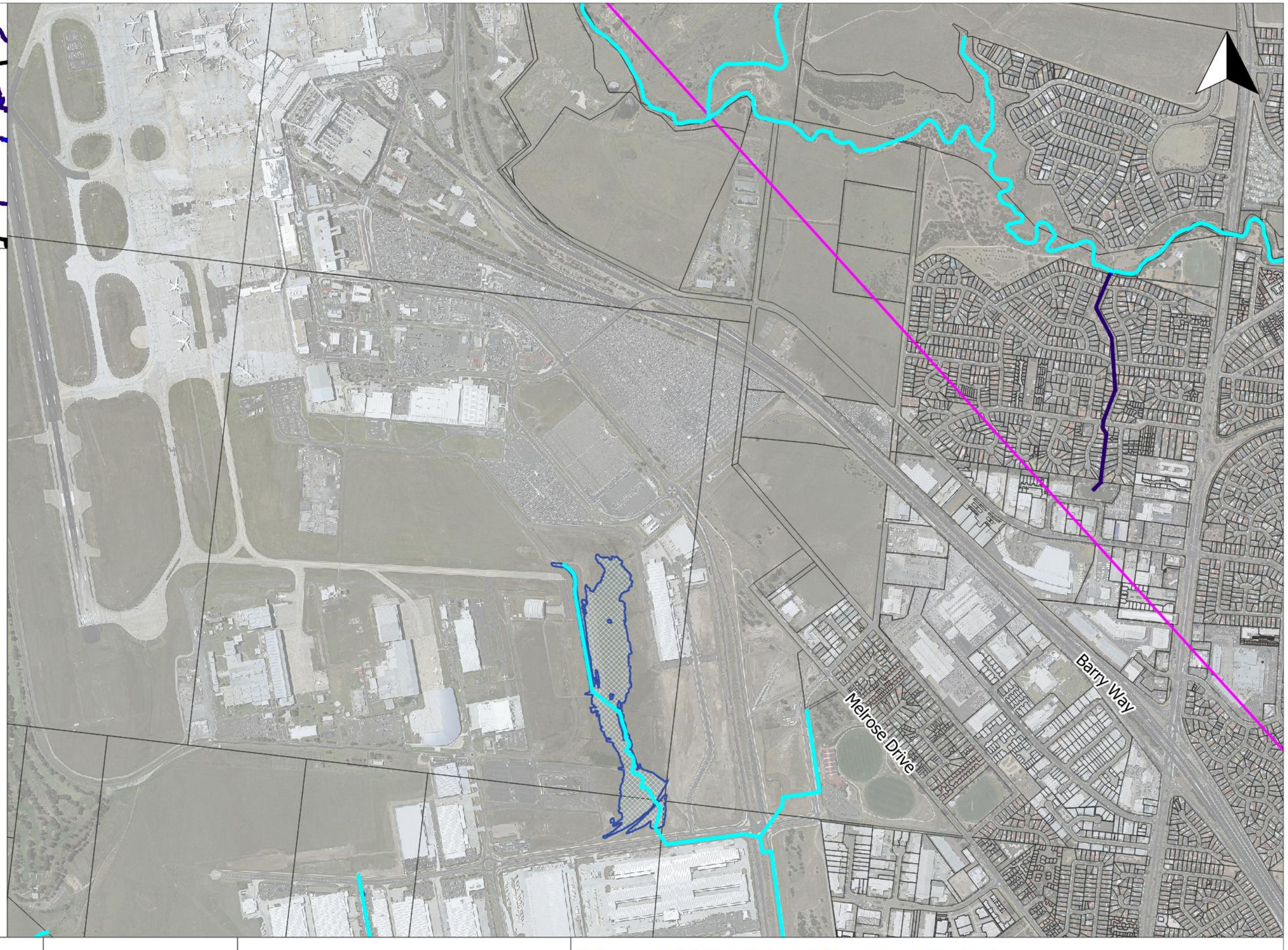
Moonee Valley Flood Mapping Project

Moonee Ponds Creek Upper
1 % AEP Flood Extent Climate Change (Scenario D)



Legend

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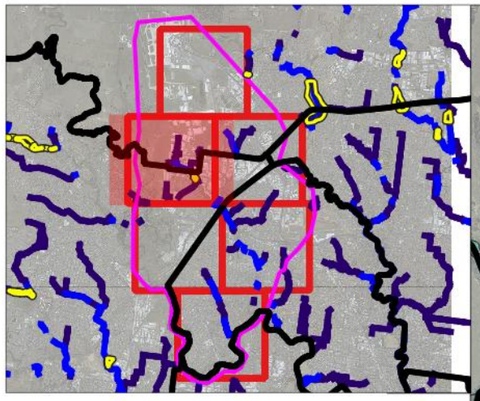
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Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Flood Extent Base Case



Legend

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- Flood Extent UG Drains
- Flood Extent Waterways

Calder Freeway Calder Freeway

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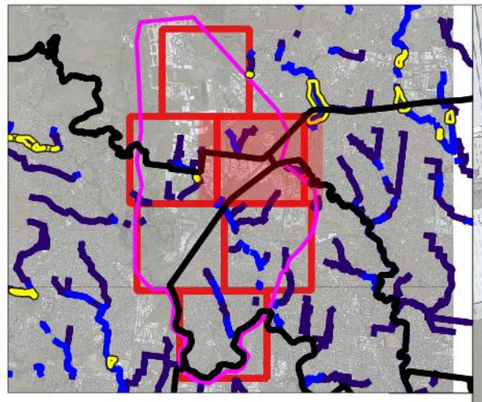
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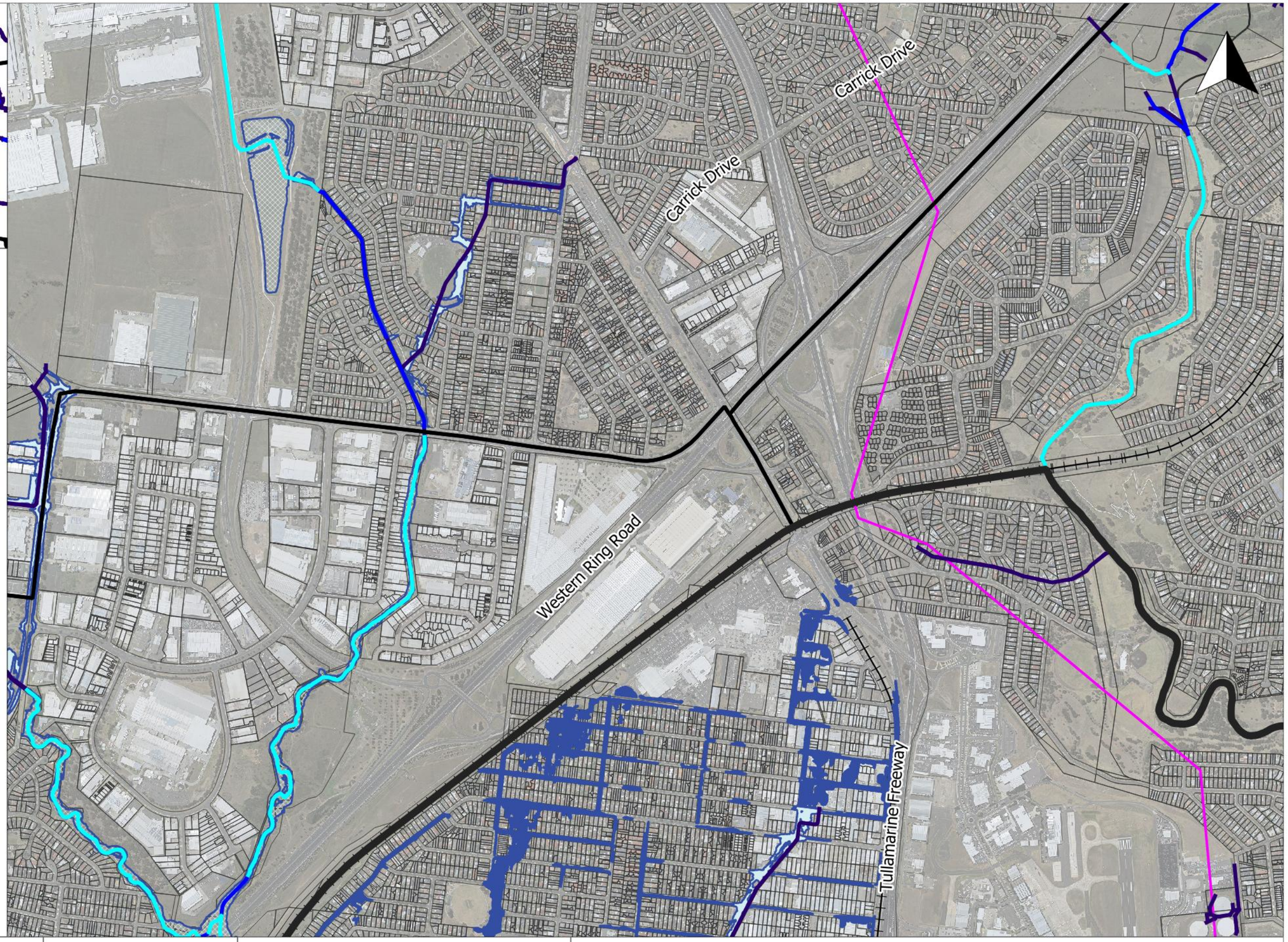
Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Flood Extent Base Case



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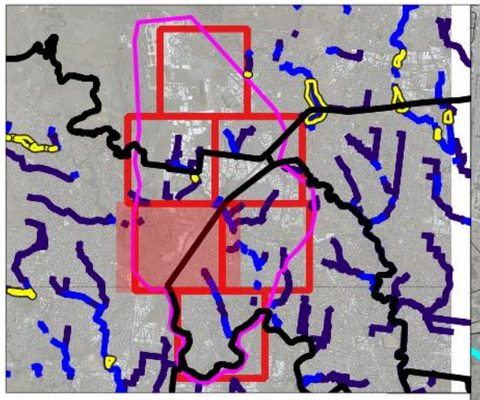
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Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Flood Extent Base Case

Job Number: VC2016_004
Revision: 0
Drawn: NB
Checked: DH
Date: 15/1/2026



Legend

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Western Ring Road

Milleara Road

Western Ring Road

Milleara Road

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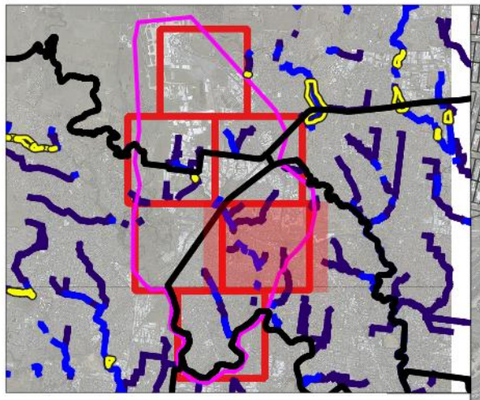
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Boorcan Road
Milleara Road
Kilmoc Road
Keilor Road
Hoffmans Road
Bulla Road
Rosehill Road
Cooper Street
ESSENDON FIELDS

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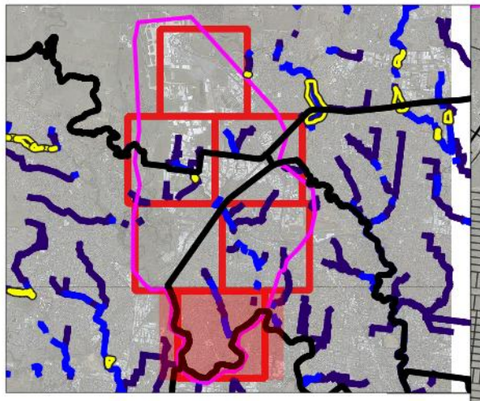
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Steele Creek
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Buckley Street

Military Road

Duke Street

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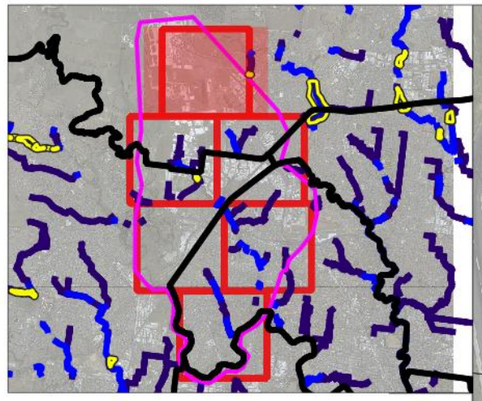
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Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Flood Extent Base Case



Legend

- Property Boundary
- Municipal Boundary
- TUFLOW Model Boundary
- Railway
- Melbourne Water Underground Drain
- Melbourne Water Channel
- Melbourne Water Natural Waterway
- Flood Extent Council
- Flood Extent UG Drains
- Flood Extent Waterways

Level 34, Tenancy 5, 360 Elizabeth St,
Melbourne VIC 3000
PO Box 12192, A'Beckett St
VIC 8006
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F: 03 9830 2601
E: melb@engeny.com.au

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Melbourne Water

City of Moonee Valley

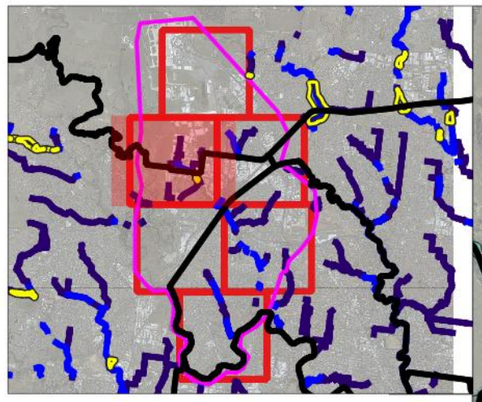
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Scale in metres (1:13,000 @ A3)

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Vertical Datum: Australia Height Datum
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Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- TUFLOW Model Boundary
- Railway
- Melbourne Water Underground Drain
- Melbourne Water Channel
- Melbourne Water Natural Waterway
- Flood Extent Council
- Flood Extent UG Drains
- Flood Extent Waterways

Calder Freeway Calder Freeway

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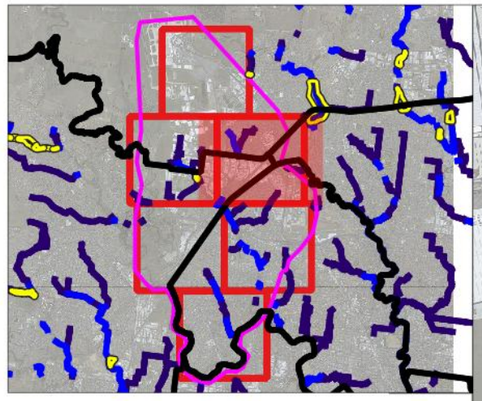
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Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
- Municipal Boundary
- TUFLOW Model Boundary
- Railway
- Melbourne Water Underground Drain
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- Flood Extent Waterways

Carrick Drive

Carrick Drive

Western Ring Road

Tullamarine Freeway

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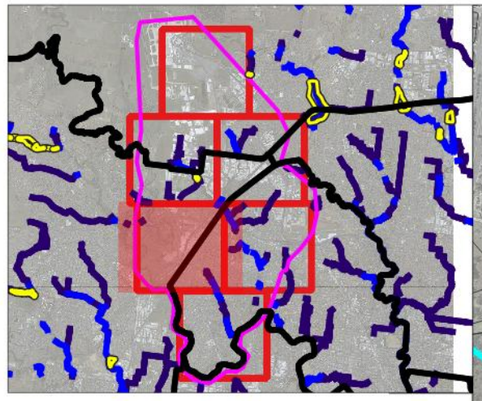
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Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Flood Extent Climate Change (Scenario D)



Legend

- Property Boundary
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- Railway
- Melbourne Water Underground Drain
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- Melbourne Water Natural Waterway
- Flood Extent Council
- Flood Extent UG Drains
- Flood Extent Waterways

Western Ring Road

Western Ring Road

Milleara Road

Milleara Road

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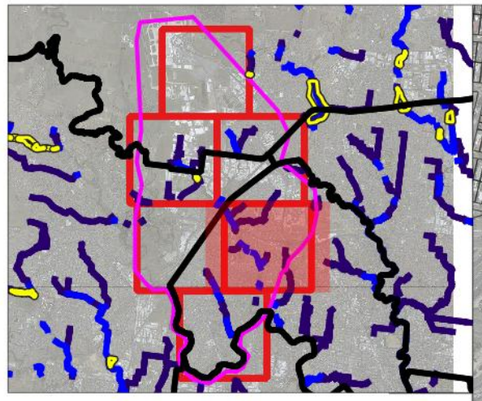
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Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Flood Extent Climate Change (Scenario D)



Legend

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- Flood Extent Waterways

Boorcan Road
Milleara Road
Kilmoc Road
Keilor Road
Hoffmans Road
Bulla Road
Rosehill Road
Cooper Street
ESSENDON FIELDS

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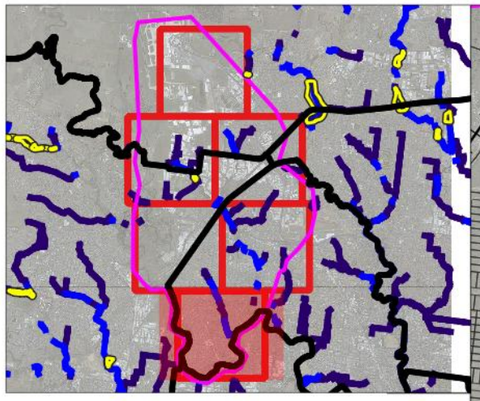
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Moonee Valley Flood Mapping Project

Steele Creek
1 % AEP Flood Extent Climate Change (Scenario D)



Legend

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- Railway
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- Melbourne Water Channel
- Melbourne Water Natural Waterway
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- Flood Extent UG Drains
- Flood Extent Waterways

Buckley Street

Military Road

Duke Street

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City of Moonee Valley

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Moonee Valley Flood Mapping Project

Steele Creek
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