Melbourne Water Darebin Flood Mapping Project

Flood Mapping Darebin LGA

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Melbourne Water



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Jacobs Group (Australia) Pty Limited
ABN 37 001 024 095
Level 11
452 Flinders Street
Melbourne
VIC 3000
+61 3 8668 3000
+61 3 8668 3001
www.jacobs.com

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Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
RevA	10/2022	Draft hydrology				
RevB	11/2022	Draft hydraulics				
Draft	3/11/2023	Flood Mapping Report				
Final	19/08/2024	Flood Mapping Report				

Executive Summary

Jacobs was appointed by Melbourne Water (MW) to update flood information for the City of Darebin Local Government Area (LGA). This project will include flood mapping and generation of planning scheme-ready flood extents to update the LGA's planning overlays. The study presents the modelling approach and results of investigations undertaken on the catchments within the LGA. Modelled MW main drains include Fairfield Main Drain, Preston Main Drain, Sumner Avenue Main Drain, Merrilands Drain, and Mont Park Drain.

The Yarra River, Darebin Creek, Merri Creek, Edgars Creek and Central Creek are waterways which interact with the study area. These waterways have been included as boundary conditions for the modelling but are not included in the flood maps generated by this study. Melbourne Water are undertaking separate studies for these waterways.

The objective of this study is to support future decisions regarding flood risk management, catchment planning, risk mitigation strategies, and emergency planning. The hydrological and hydraulic modelling has been undertaken in accordance with the Melbourne Water Flood Mapping Projects Specifications (AM STA 6200, 2020) and the Australian Rainfall and Runoff 2019 guidelines (ARR, 2019) Version 4.1. The climate change scenario assumed an 18.5% increase in rainfall intensities for 2100. The adopted hydrological modelling software was RORB (Version 6.45) and the hydraulic software was TUFLOW (Version: 2020-10-AB). Both models have undergone an independent peer review by an external consultant in line with the project requirements.

The combined catchment area for the modelling is approximately 56 km^2. The study area has been divided into four modelling areas. The land use within the study area is primarily a mix of residential, urban, and industrial areas. La Trobe University's Bundoora campus is also located within the study area.

TUFLOW HPC was adopted for the hydraulic modelling, utilising a quadtree mesh with varying cell sizes of 1m, 2m, and 4m across the study area. Modelled scenarios include the 1% Annual Exceedance Probability (AEP), the 1% AEP plus climate change scenario, and a range of frequent events, consistent with Melbourne Water's standard modelling approach..

GIS flood mapping deliverables have been derived in accordance with Melbourne Water's Flood Mapping Projects Specifications AM STA 6200 (July 2020).

The hydraulic model's performance for the Fairfield Main Drain catchment was evaluated by comparing simulated water levels to recorded flood marks from the December 2003 flood event. The model showed good agreement with the flood marks across the modelling domain.

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Abbreviations and definitions

1D Hydraulic Model	1-Dimensional hydraulic model where flood levels are determined by cross sections perpendicular to the flow path.
2D Hydraulic Model	2-Dimensional hydraulic model based on terrain/elevation data at a specified grid size. Capable of modelling floods across a floodplain where flow direction varies in space and time.
1D/2D Hydraulic Model	Coupled 1D/2D modelling, typically the floodplain would be represented in 2D and the main flow paths in 1D together with small scale hydraulic structures.
AEP	Annual Exceedance Probability. The probability that an event of a given size will be equalled or exceeded in a given year.
ARR 2019	2019 release of Australian Rainfall & Runoff Guidelines.
BoM	Bureau of Meteorology
DEECA	Victorian Department of Energy, Environment and Climate Action
DELWP	Victorian Department of Environment, Land, Water and Planning (now DEECA)
DEM	Digital Elevation Model
Design event	A theoretical flood event representing a specific likelihood of occurrence (for example the 1% AEP flood).
Flood depth	The height or elevation of floodwaters above ground level.
Flood level	The height or elevation of floodwaters relative to a datum (typically the Australian Height Datum).
FME	Feature Manipulation Engine
GIS	Geographic Information System
Hydraulics	The term given to the study of water flow in rivers, estuaries and coastal systems.
Hydrograph	A time series of flow which changes at each timestep and naturally captures the peak flood flow.
Hydrology	The term given to the study of the rainfall-runoff process in catchments.
LGA	Local Government Area
LiDAR	Light Detection and Ranging is a remote sensing method that uses light in the form of a pulsed laser to distance to the Earth.
m AHD	Meters Australian Height Datum.
m/s	Metres per second (a measure of speed / velocity).
m^3/s	Cubic metres per second (a measure of flow).
Manning's "n" value	A coefficient which represents the roughness of terrain on which water flows over.
MW	Melbourne Water Corporation.
Peak flood level, flow or velocity	The maximum flood level, flow or velocity occurring during a flood event at a particular location.
RORB	Runoff routing computer model for hydrologic analysis of catchment runoff.
SES	State Emergency Services
TUFLOW	Fully two-dimensional and one-dimensional unsteady flow hydraulic computer modelling software.
Velocity	The speed at which the floodwaters are moving. Typically, modelled velocities in a river or creek are quoted as the depth and width averaged velocity, i.e. the average velocity across the whole river or creek section if a one-dimensional solution is used; and depth average if a two-dimensional solution is used.

Water Surface Elevation	Water Surface Elevation, the surface of the water at a given point.

1. Introduction

Jacobs was appointed by Melbourne Water (MW) to update flood information for the City of Darebin Local Government Area (LGA). This project includes flood mapping and generation of planning scheme-ready flood extents to update the LGA's planning overlays.

This report outlines the methodology adopted to generate flood mapping products as per Melbourne Water AM STA 6200 Flood Mapping Projects Specification (July 2020) and the Australian Rainfall and Runoff 2019 guidelines (ARR, 2019 Version 4.1), including assumptions, limitations, and recommendations.

2. Background

2.1 Study Approach

The purpose of the study was to produce flood mapping products to support a variety of Melbourne Water business functions. The flood models underpin all the study outcomes. The flood models for the Darebin LGA combine an event-based hydrologic model (RORB) and a hydraulic model (TUFLOW).

RORB is a runoff and streamflow routing program that was used to calculate flood hydrographs from rainfall and catchment characteristics parameters. The model subtracts losses from rainfall to determine rainfall excess hydrographs across the modelling domain. RORB is a spatially distributed, non-linear model applicable to both urban and rural catchments. It accounts for both temporal and spatial distribution of rainfall depths and relies on catchment losses, catchment geometry, and routing data defined in a catchment file and the program. The event-based flood model was used to estimate flood flows for various probabilities of occurrence, enabling the assessment of flood risk.

The RORB outputs were then applied to the hydraulic model which calculates the extent, depth, velocity and other hydraulic properties. Four (4) 2-D TUFLOW hydraulic models with embedded 1-D elements were developed for the Darebin LGA. The mapping extent is illustrated in Figure 2.1. The flood mapping encompasses the entire Darebin LGA, excluding the waterways of Merri Creek, Darebin Creek, Edgars Creek, and Central Creek. These waterways are not included in the flood maps generated by this study. However, the modelling included the areas outside the Darebin LGA that interact with flooding within the LGA.

Although no streamflow gauge is available within the catchment, these modelling activities were compared against available flood marks from the December 2003 flood event.

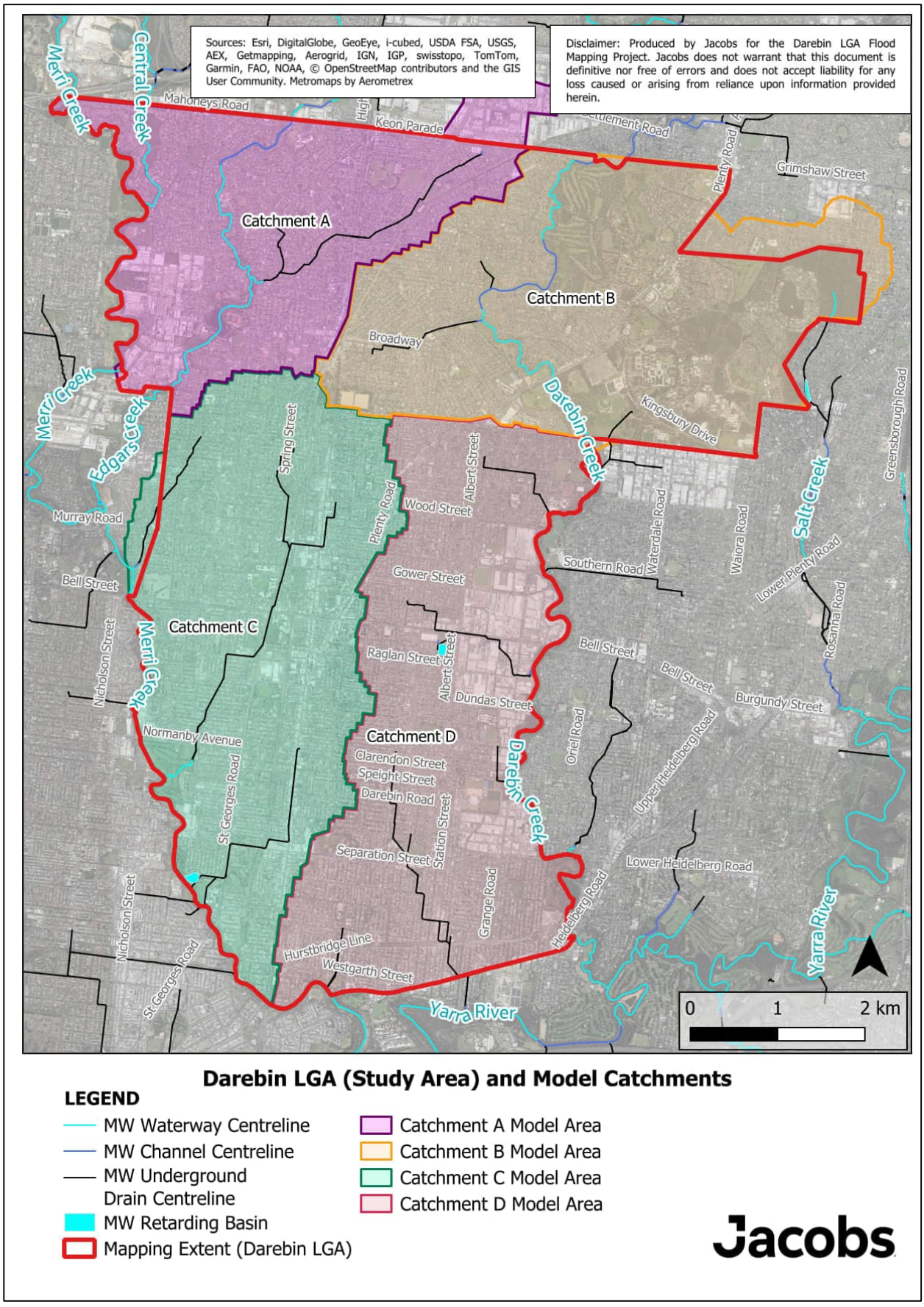


Figure 2-1: Darebin Local Government Area **(Study Area) and Melbourne Water Assets and Sub-Catchments**

2.2 Study Area Characteristics

The City of Darebin LGA sits within the downstream reaches of two major Melbourne Water catchments: Merri Creek (390km^2) and Darebin Creek (130km^2). Merri Creek flows along the western LGA boundary, while Darebin Creek enters from the north and then runs along the eastern boundary. Edgars Creek also flows through the LGA's northeast region, eventually discharging into Merri Creek. The southern boundary of the LGA is close to the confluences of Merri Creek and Darebin Creek with the Yarra River.

The study area is shown in relation to the Melbourne Water Major Catchments in Figure 2-2. Figure 2-3 depicts the study area with the Melbourne Water Drainage Sub-Catchments.

The Darebin LGA has been sub-divided into four (4) distinct drainage areas (Figure 2-1) named Catchment A, B, C and D. The Melbourne Water catchments within each model are summarised in Table 2-1. Land use throughout the LGA is mostly urban. Additional details for the four model areas are presented in Section 4.1.

Table 2-1: Darebin catchments and associated Melbourne Water catchments

Model Catchment	Area (km^2)	Location	Description	Melbourne Water Catchments/Assets Overlapping the Model Catchment
A	11	Merri Creek (North)	Encompasses the north-west region of the Darebin City Council, with its western border on Merri Creek and a portion of Edgars Creek running through its centre. The catchment is primarily urban.	4440 EDGARS CREEK 4441 MERRILANDS DRAIN 4446 CHAUVEL ST DRAIN 4470 MERRI CREEK (UPPER) 4472 CENTRAL CREEK 4473 THOMASTOWN WEST DRAIN
B	15	Darebin Creek (North)	Encompasses the north-east region of the Darebin City Council and includes a section of Darebin Creek. It is primarily urban; however, large pervious open spaces such as golf courses are present in the catchment.	4520 DAREBIN CREEK (MIDDLE) 4521 LILLIMUR AVENUE DRAIN 4522 BROADWAY DRAIN 4523 MONT PARK DRAIN 4525 BUNDOORA DRAIN 4533 PURINUAN ROAD DRAIN 4604 SALT CREEK
C	15	Merri Creek (South)	Encompasses the south-west corner of the Darebin City Council region with Merri Creek forming its western border. The catchment is primarily urban.	4420 MERRI CREEK (LOWER) 4424 SUMNER AVE M.D. 4430 MERRI CREEK (MIDDLE) 4431 PRESTON MAIN DRAIN 4432 SPRING ST M.D. 4433 ELIZABETH STREET MAIN DRAIN
D	15	Darebin Creek (South)	Encompasses the south-east corner of the Darebin City Council with Darebin Creek forming its eastern border. The catchment is primarily urban, with small portions of parkland on its eastern edge.	4422 GREEN ST M.D. 4500 YARRA RIVER MAINSTREAM 4501 FAIRFIELD MAIN DRAIN 4502 KELLETT ST M.D. 4510 DAREBIN CREEK (LOWER) 4512 BELL STREET MAIN DRAIN 4514 STEANE ST DRAIN 4515 POWER STREET DRAIN 4516 QUARRY STREET DRAIN

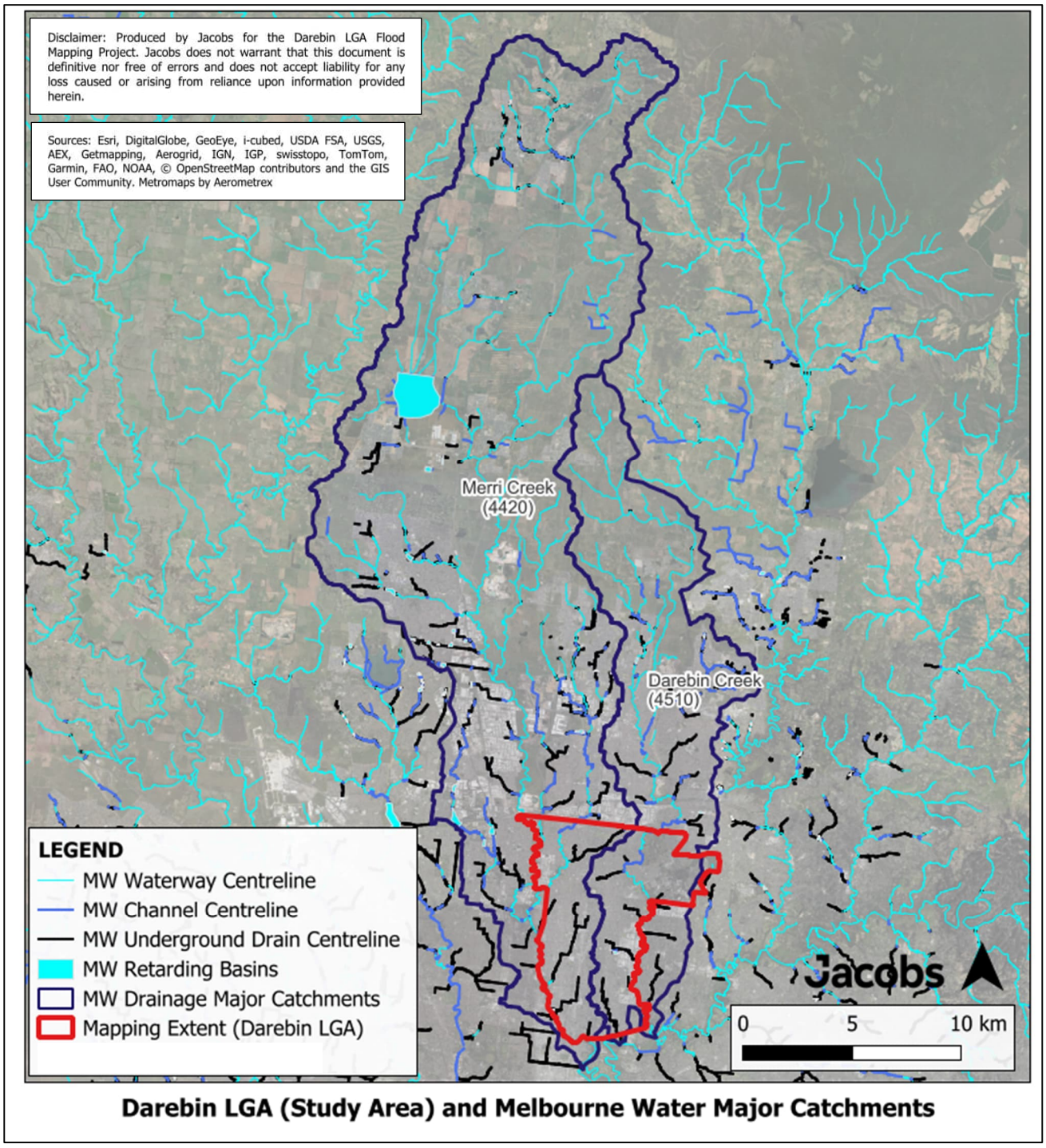


Figure 2-2: Darebin Local Government Area (Study Area) and Melbourne Water Assets and Major Catchments

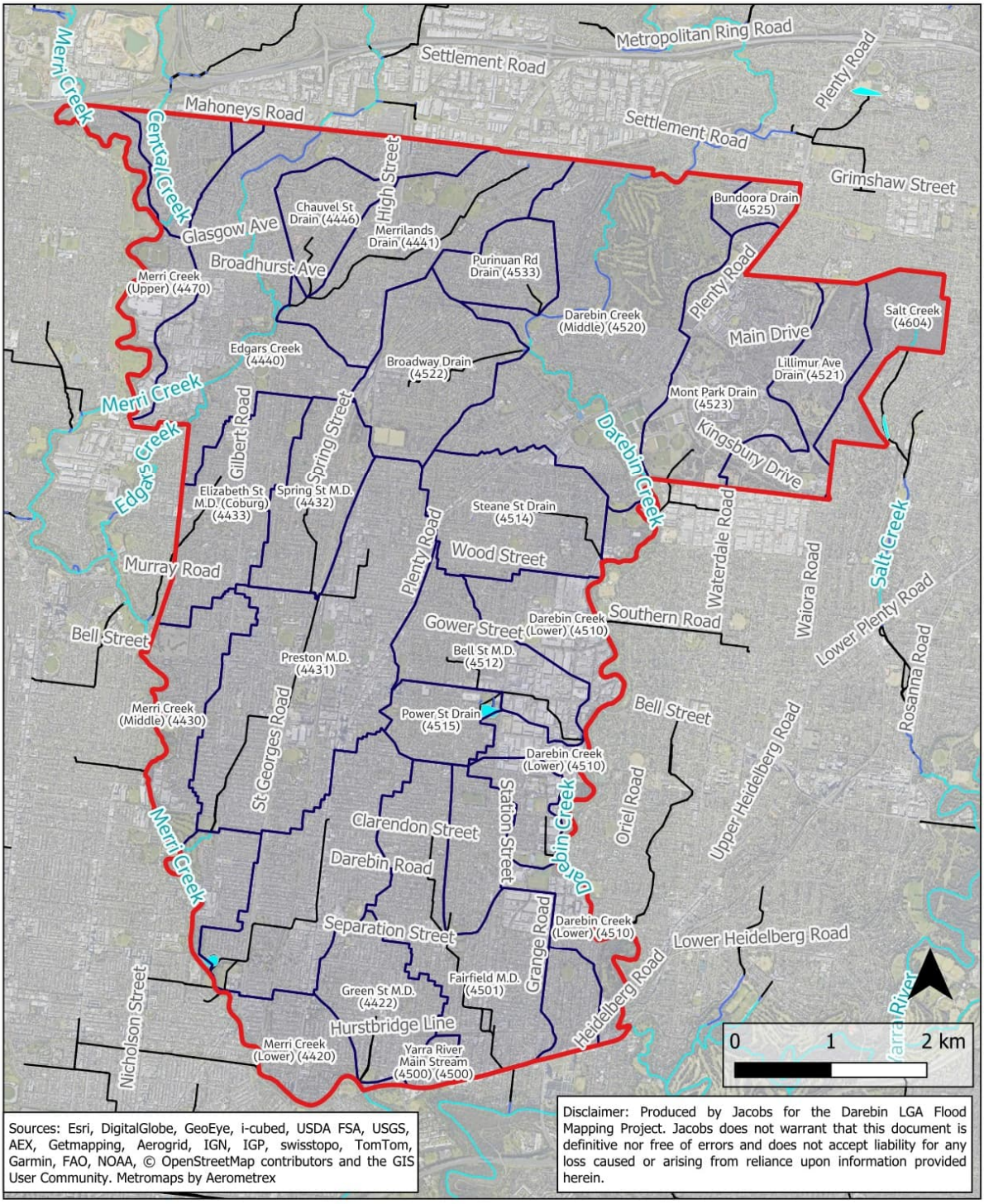


Figure 2-3: Darebin Local Government Area (Study Area) and Melbourne Water Assets and Sub-Catchments

2.3 Report Layout

This report summarises the data collection, and hydrologic and hydraulic modelling work undertaken to develop the four catchment models for the study area. The following sections detail the model development process and its final configuration:

- Data Collection and Review (Section 3): An overview of the review and identification of relevant information for the hydrologic and hydraulic model setup.
- Hydrology (Section 4): An outline of how the hydrologic model was developed, and the approach adopted for this study.
- Hydraulics (Section 5): An overview of the hydraulic model development and setup adopted for this study, including the selection of critical storms.
- Quality Assurance (Section 6)
- Results (Section 7): An overview of the storm events modelled, and details of GIS deliverables that have been provided as per Melbourne Water Flood Mapping Projects Specifications.
- Sensitivity Analysis and Model Checks (Section 8): A summary of the checks undertaken, including sensitivity analysis on boundary conditions, and model performance against the 2003 flood marks.
- Recommendations (Section 9): An outline of some of the key possible limitations, assumptions, and recommendations for future work.
- References (Section 10)

2.4 Limitations

The sole purpose of this report and the associated services performed by Jacobs is to undertake a local flood assessment for the Darebin LGA catchment area, in accordance with the scope of services set out in the contract between Jacobs and Melbourne Water (the Client). As described in this report, the scope of services was developed with the Client.

In preparing this report, Jacobs has relied upon and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, Jacobs has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate, or incomplete, then it is possible that our observations and conclusions, as expressed in this interim report, may change.

Jacobs derived the data in this report from information sourced from the Client, third parties, and/or available in the public domain at the time or times outlined in this interim report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations, and conclusions expressed in this report. Jacobs has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures, and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

This report should be read in full, and no excerpts are to be taken as representative of the final findings. Jacobs accepts no responsibility for using any part of this report in any other context.

Topographic data used in this study included that sourced from a LiDAR and ground survey that was carried out by third parties. Undertaking independent checks on the accuracy of the topographic data was outside Jacobs's scope of work for this study, except where otherwise stated in the report.

The sole purpose of the flood modelling undertaken for this report is to define flood behaviour in the vicinity of the project sites. Flood extents and flood behaviour around the boundary of the TUFLOW hydraulic model domain should be interpreted with caution.

This report has been prepared on behalf of, and for the exclusive use of, Melbourne Water, and is subject to, and issued in accordance with, the provisions of the contract between Jacobs and Melbourne Water. Jacobs accepts no liability or responsibility whatsoever for, or in respect of, any use of, or reliance upon, this report by any third party.

3. Data collection and review

3.1 Previous studies

Table 3-1 summarises previous studies relevant to this project. The previous studies focused on smaller catchments within the Darebin LGA and used different catchment names and numbering systems. Refer to the reports listed in Table 3-1 for details. In contrast, this study amalgamated the Melbourne Water drainage catchments (Table 2-1) into four larger modelling areas (A, B, C, and D) as shown in Figure 2-1. Naming conventions of previous studies can be determined by reviewing the associated reporting referenced in Table 3-1.

Table 3-1: Previous Flood Modelling Studies undertaken for Darebin LGA

Title	Company	Date	Method	Elements considered for this Study
Bell Street Level Crossing	NWPA	2022	RORB and TUFLOW	Level crossing design included in the model
Purinuan and Broadway Catchment – ARR 2019 Modelling Updates	Engeny	2020	TUFLOW	RORB and TUFLOW setup
Bell Street Main Drain Flood Mapping	Cardno	2013	RORB and TUFLOW	RORB and TUFLOW setup
Broadway Drain and Purinuan Road Drain Flood Mapping				
Catchment T, U, V, X, W – ARR 2019 Modelling Updates Note: This catchment naming convention has not been adopted by Jacobs.	Engeny	2020	TUFLOW	RORB and TUFLOW setup
Catchment Z – ARR 2019 Modelling Updates Note: This catchment naming convention has not been adopted by Jacobs				
Darebin Creek – Flood Modelling Report	Cardno	2020	RORB and TUFLOW	Boundary conditions
Darebin Flood Model Review – Bell Street Main Drain				RORB and TUFLOW setup
Darebin Flood Model Review – Fairfield and Green Street				RORB and TUFLOW setup
Darebin Flood Model Reviews for: • Bell Street Main Drain • Fairfield and Green Street • Catchment J, K, N, P and R • Elizabeth Main Drain • Preston Main Drain • Steane Street • Sumner Main Drain	Cardno	2020	RORB and TUFLOW	RORB and TUFLOW setup
Edgars Creek - Flood Modelling Report	Cardno	2020	RORB and TUFLOW	Boundary conditions

Title	Company	Date	Method	Elements considered for this Study
Elizabeth Street Main Drain Flood Mapping	Cardno	2013	RORB and TUFLOW	RORB and TUFLOW setup
Fairfield Main Drain and Green Street Main Drain Flood Mapping	Cardno	2013	RORB and TUFLOW	RORB and TUFLOW setup
Preston Main Drain Flood Mapping	Cardno	2013	RORB and TUFLOW	RORB and TUFLOW setup
Steane Street Drain Flood Mapping	Cardno	2013	RORB and TUFLOW	RORB and TUFLOW setup
Sumner Avenue Main Drain Flood Mapping (Cardno, 2013)	Cardno	2013	RORB and TUFLOW	RORB and TUFLOW setup
Fairfield Main Drain and Green Street Main Drain Flood Investigations (Cardno Lawson Treloar, 2005)	Cardno Lawson Treloar	2005	RORB + SOBEK	considered with relation to the 2003 event
Merri Creek HEC-RAS model	unknown	Unknown	HEC-RAS	Boundary condition
Conference Papers which focused on December 2003 flooding in Fairfield catchment: • Baker et al. (2005) A case study of the December 2003 Melbourne storm: the meteorology, rainfall intensity, and impacts of flash flooding. 29th Hydrology and Water Resources Symposium, 21-23 February 2005, Canberra. • Swan, R, Howells, L, Bonello, D, Watkinson, R, Robertson, J. (2005) Flood Studies and Extreme Events - Modelling, Mitigation and Assessment at Fairfield, Victoria, the 4th Victorian Floodplain Management Conference, October 2005 • Swan, R., and Thomson, R. (2011) Direct Rainfall - Verifying the technique across two States, Proceedings of the 34th IAHR World Congress and the 33rd National Hydrology and Water Resources Symposium and the 10th National Conference on Hydraulics in Water Engineering, June 2011 • Swan, R. (2010) Direct Rainfall - Loss Modelling Approaches, Presented at the 7th Victorian Floodplain Management Conference, October 2010	NA	2005-2011	NA	considered with relation to the 2003 event

3.2 Historical Flood Information

This section details the available flood information for the study area. Notably, a significant rainfall and flood event occurred on December 2-3, 2003. Information gathered relevant to this event is presented in this section.

3.2.1 Historical Rainfall Data

Historic daily and sub-daily rainfall data for the study area and its surroundings were obtained from several sources. These included data from Melbourne Water and the Bureau of Meteorology, encompassing both daily and sub-daily (pluviograph) records (refer to Table 3-2 and Figure 3-1). Rainfall was extracted for the December 2003 event. The rainfall totals for this event are also summarised in Table 3-2.

Table 3-2: Rainfall gauges within the Darebin LGA

Gauge ID	Station Name	Temporal Resolution Available During December 2003 Event	Period of Record	Total event rainfall (2-3 December 2003) (mm)
229403A	Darebin Creek at Bell St	Sub-daily (6min)	1999 – current	101.6
229143A	Yarra River at Chandler Highway – Fairfield	Sub-daily (6min)	1984 – current	101.8
229149A	Merri Creek at St Georges Rd	Sub-daily (6min)	1999 – current	89.8
086351	Bundoora Latrobe University	Daily	1979 – current	54.6
229645A	Merri Creek at Bell Street	Daily	1979 – current	115.2
586011	Preston	Daily	1991 – current	99.0

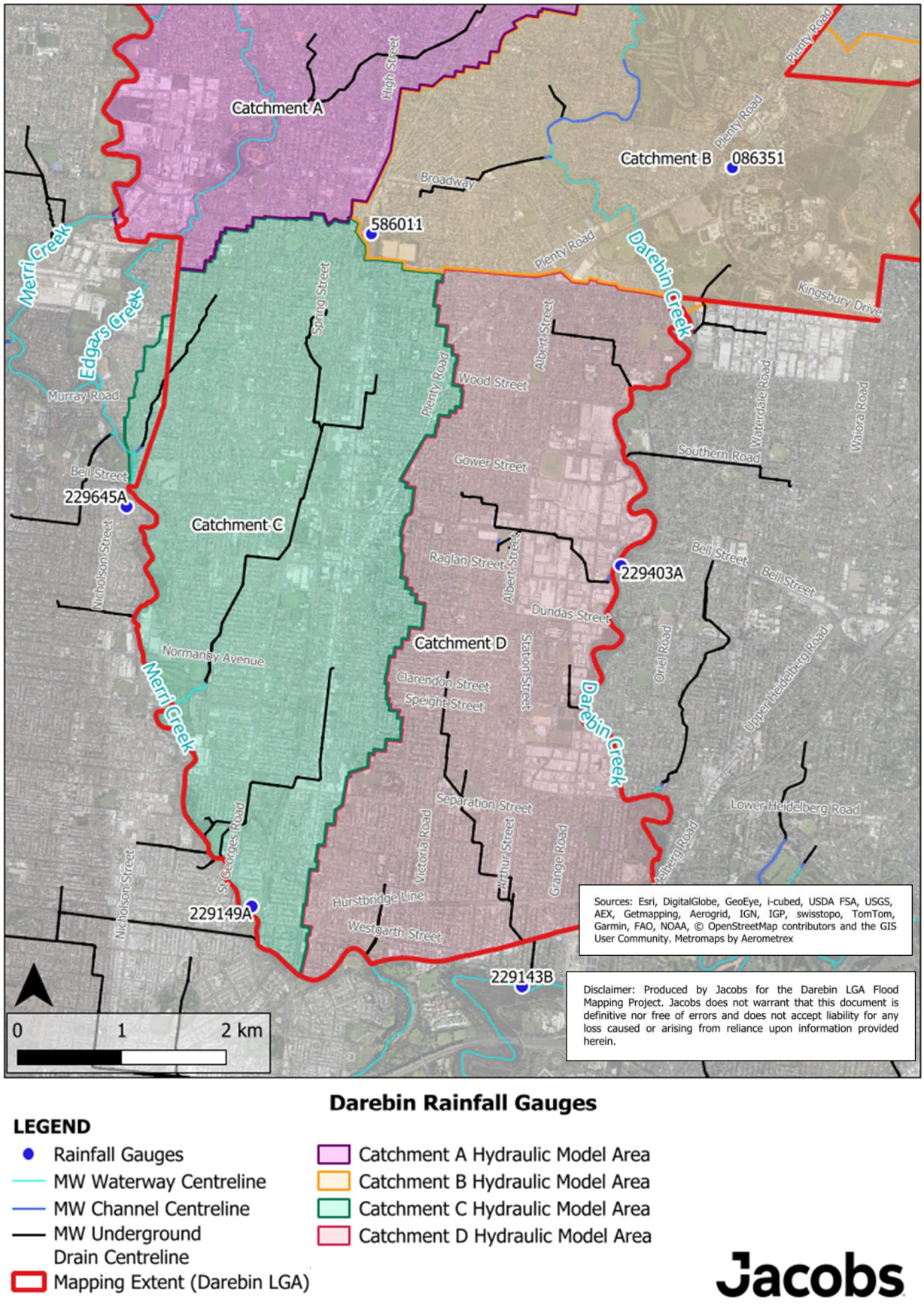


Figure 3-1: Rainfall Gauges relevant to Darebin LGA and the 2003 rainfall event

3.2.2 Historical River Level and Flow Data

There are no flow or water level gauges within the LGA. The project scope excluded explicit flood mapping for Merri Creek, Darebin Creek, Edgars Creek, and the Yarra River. Consequently, flow and water level gauges located on these waterways were not considered for this study.

3.2.3 Historical Flood Marks

Flood marks, collected by Melbourne Water during or after flood events, were available for the Darebin LGA (excluding Merri Creek, Darebin Creek, and Edgars Creek) from the 2-3 December 2003 event. A cluster of flood marks from this event is available in the south and east regions of the LGA within the Fairfield Main Drain Melbourne Water catchment. This overlaps with model area 'D' developed for this study. The flood marks from the 2003 event and how they have been adopted in this study are discussed in section 8.2.

No other flood marks in the Darebin LGA were suitable for use in this study.

3.3 Topographical Data

The 2017/2018 LiDAR DEM with a 1-metre grid resolution covering the Darebin LGA was made available by Melbourne Water for the Study. This dataset has stated vertical accuracy of 0.1 m (RMSE 68% Conf.). Details on the LiDAR dataset are available in the 2017-18 Greater Melbourne LiDAR Project Metadata Report (DELWP (Now DEECA), 2019). Based on Jacobs' experience in reviewing this dataset against survey the vertical accuracy of the 2017/2018 LiDAR dataset is typically observed to perform well against survey data.

The topographic data was not further scrutinised by Jacobs and deemed appropriate for use in the modelling and development of flood mapping.

3.4 Hydraulic Structures

Hydraulic structures across the study area are managed by several government agencies including the City of Darebin, the Department of Transport and Planning (VIC Roads), and Melbourne Water. The key Melbourne Water hydraulic structures are listed in Table 3-3.

Table 3-3: Key structures

Relevant Model Catchment	Assets	Available information (SE numbers are MW survey reference numbers)
A	Merrilands Drain (4441), Chauvel Street Drain (4446)	MW GIS (Underground Drains) and EPMS drawings (Electronic Plan Management System)
B	Purinuan Road Drain (4533), Broadway Drain (4522)	MW GIS (Underground Drains) and EPMS drawings
C	Elizabeth Street Main Drain (4433), Preston Main Drain (4431), Spring Street Main Drain (4432), Sumner Ave Main Drain (4424)	MW GIS (Underground Drains) and EPMS drawings
C	Edwardes Lake Spillway and Gauge Board Levels - Reservoir	Survey report specifying spillway levels

Relevant Model Catchment	Assets	Available information (SE numbers are MW survey reference numbers)
D	H.L.T Oulton Reserve Retarding Basin Steane Street Drain (4514), Power Street Drain (4515), Bell Street Main Drain (4512), Quarry Street Drain (4516), Green Street Main Drain (4422), Fairfield Main Drain (4501), Kellett Street Main Drain (4502) Wingrove Street Pedestrian underpass (survey data 041002.dwg)	MW GIS (Underground Drains) and EPMS drawings Wingrove Street Pedestrian underpass: survey data (AutoCAD files) 041002.dwg
All	Bridges along Merri Creek and Darebin Creek	Survey data (PDFs and AutoCAD files) Merri Creek: SE990123/SE040122/SE040007 Darebin: SE080002 (SES1303)/SE990049

3.5 Geospatial Data

Geospatial data was sourced from the Victorian Spatial Data online portal (https://datashare.maps.vic.gov.au) and Melbourne Water. This data is presented in Table 3-4.

Table 3-4: Geospatial data

Type	Format	Description/Application
Planning Scheme Zone (VMPLAN_PLAN_ZONE DELWP, 2021)	Shapefile (Polygon)	Used to define catchment land use for determination of fractions impervious and materials layers. Downloaded Nov 2011.
Property Parcels (Vicmap Property Parcel Polygon, PARCEL VIEW)	Shapefile (Polygon)	Used for application within the materials layer. Used for the generation of parcels flooded in the GIS deliverables. Downloaded Sep 2025
Buildings	Mapinfo File (polygon)	Used for the assessment of buildings flooded in the GIS deliverables phase. The dataset was provided by Melbourne Water.
Watercourse	Shapefile (Polyline)	Used to display on maps and identify major water sources within the Study area
Melbourne Water Assets	Shapefile (Polyline, Polygon)	pipes, pits, culverts, and retarding basins, used for implementation into the models
LGA Assets	Shapefile (Polyline, Polygon)	Council pit and pipe data
Flood levels 100yr,50yr 10yr	MapInfo (polyline)	MW GIS database for the Yarra River (Flood Contour Waterways)

3.6 Site Visit

Jacobs, accompanied by representatives from Melbourne Water and Darebin City Council, undertook site visits to inspect the study area in April 2021. These visits focused on key areas of interest, including hydraulic structures, land use types, and general catchment conditions. Sites with a history of flooding, such as Station Street and Wingrove Street, were also visited.

4. Hydrologic modelling

The purpose of hydrologic modelling is to convert rainfall to runoff for a given probability, that then provides a flow time series for input to the hydraulic model. For this study, the hydrologic modelling software RORB was used. Rainfall excess outputs from the RORB models were used as inflow boundary conditions into the TUFLOW models. No routed flows from the Darebin LGA catchment area were applied to the TUFLOW models.

This section details the development of the hydrologic models across the study area.

4.1 RORB model development

As stated earlier, four RORB models have been developed to cover the study area (Table 2-1). The four catchments are a combination of Melbourne Water catchments across the LGA.

It was noted the Darebin LGA interacts with the Merri Creek, Edgars Creek, Central Creek and Darebin Creek. Boundary conditions from these waterways are considered in the hydraulic modelling (section 5.4).

4.2 RORB Model Setup

The RORB model layouts are presented in Figure 4-1, Figure 4-2, Figure 4-3, and Figure 4-4 and are described in the following sub-sections.

4.2.1 Catchment and sub-catchment boundaries

Catchment boundaries were determined using the 2017/2018 LiDAR DEM supplied for the project. Initial boundaries were determined using CatchmentSim and were then refined using Melbourne Water and Council pit and pipe networks and aerial imagery to ensure all assets were captured. Existing RORB model boundaries for the Darebin catchments were also used to confirm the catchment boundaries.

4.2.2 Node-link network

The node-link network was determined using 2017/2018 LiDAR DEM (DELWP 2018), contours and major underground pipe networks. These were developed to align with what is considered the major flow path in the catchment.

Given that the RORB models were used in the Darebin LGA project to generate rainfall excess hydrographs for input to hydraulic models, and no routing was used, the choice of node-link network was not important. However, to provide flexibility for Melbourne Water's future needs, Jacobs incorporated routing parameters into the models.

4.2.3 Reach types

Reach types were based on what is considered the major land use and primary flow path in a large flood event. Reaches were based on the LiDAR, contours, aerial image, and pipe alignments and considered:

- Representation of the flow path from the centroid.
- The alignment of reaches to flow.
- Reach type to best reflect the actual flow path (mainly type 2 in urbanised catchments or for steep and/or well-defined natural waterways or creeks):
    - Type 1 – For Natural channels including Merri and Darebin Creeks
    - Type 2 - Excavated but unlined – primary reach used across the Darebin models

- Type 3 – Lined channel or pipe, including Edgars Creek
- Type 4 – Drowned, not used in this study
- Type 5 – Dummy, no routing properties,

Given that the RORB models were used in the Darebin LGA project to generate rainfall excess hydrographs for input to hydraulic models, and no routing was used, the choice of node-link network was not important for this study. However, to provide flexibility for Melbourne Water's future needs, Jacobs incorporated routing parameters into the models.

4.2.4 Storages

Storages were not modelled in RORB, as these were modelled within the TUFLOW models.

4.2.5 Printout locations

Print statements were added at the outlet of each of the models and key junctions. This enabled validation against regional flow calculation methods. Rainfall excess outputs were also selected at each printout location for application to the TUFLOW model.

4.2.6 RORB version

RORB version 6.45 was used for modelling.

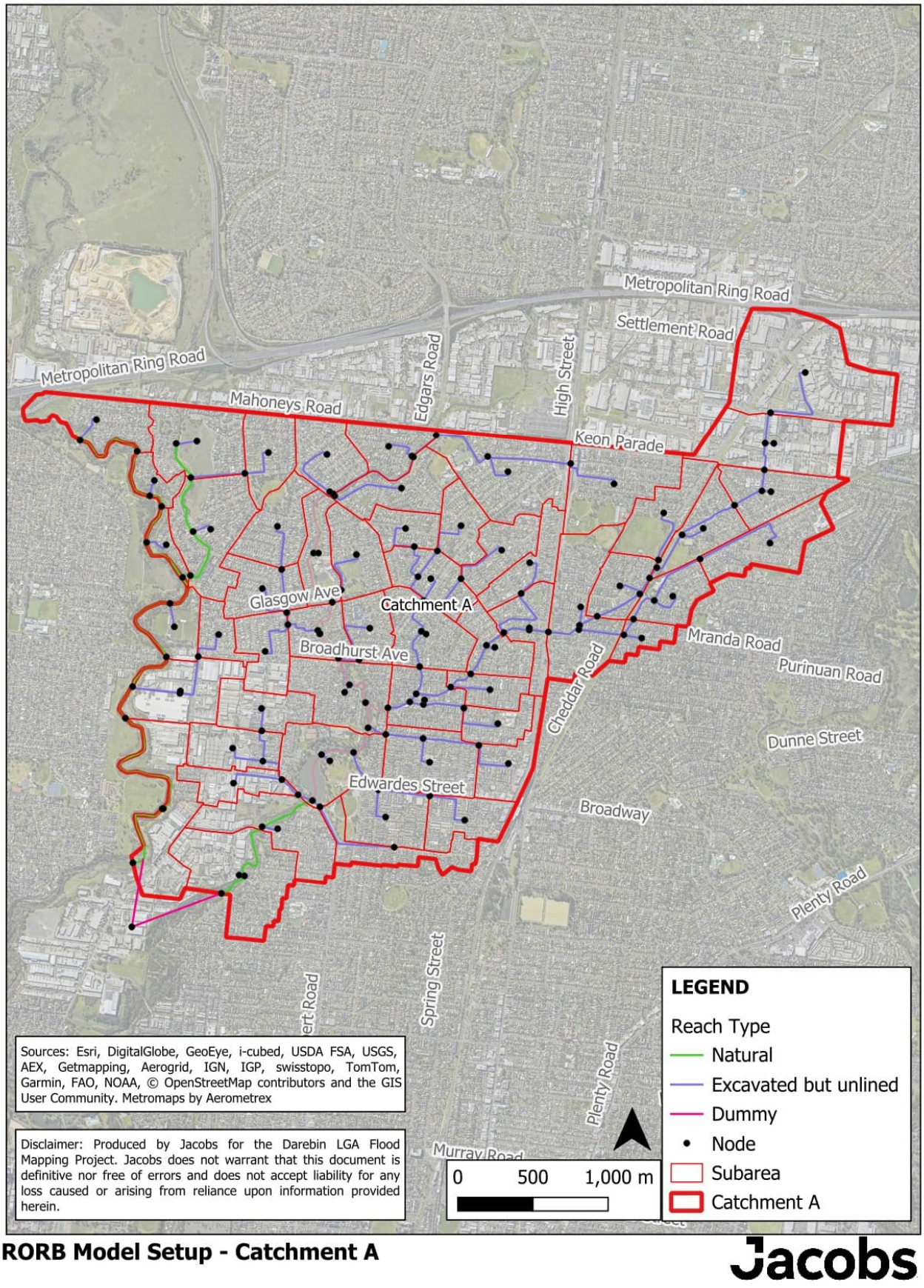


Figure 4-1: RORB setup Catchment A

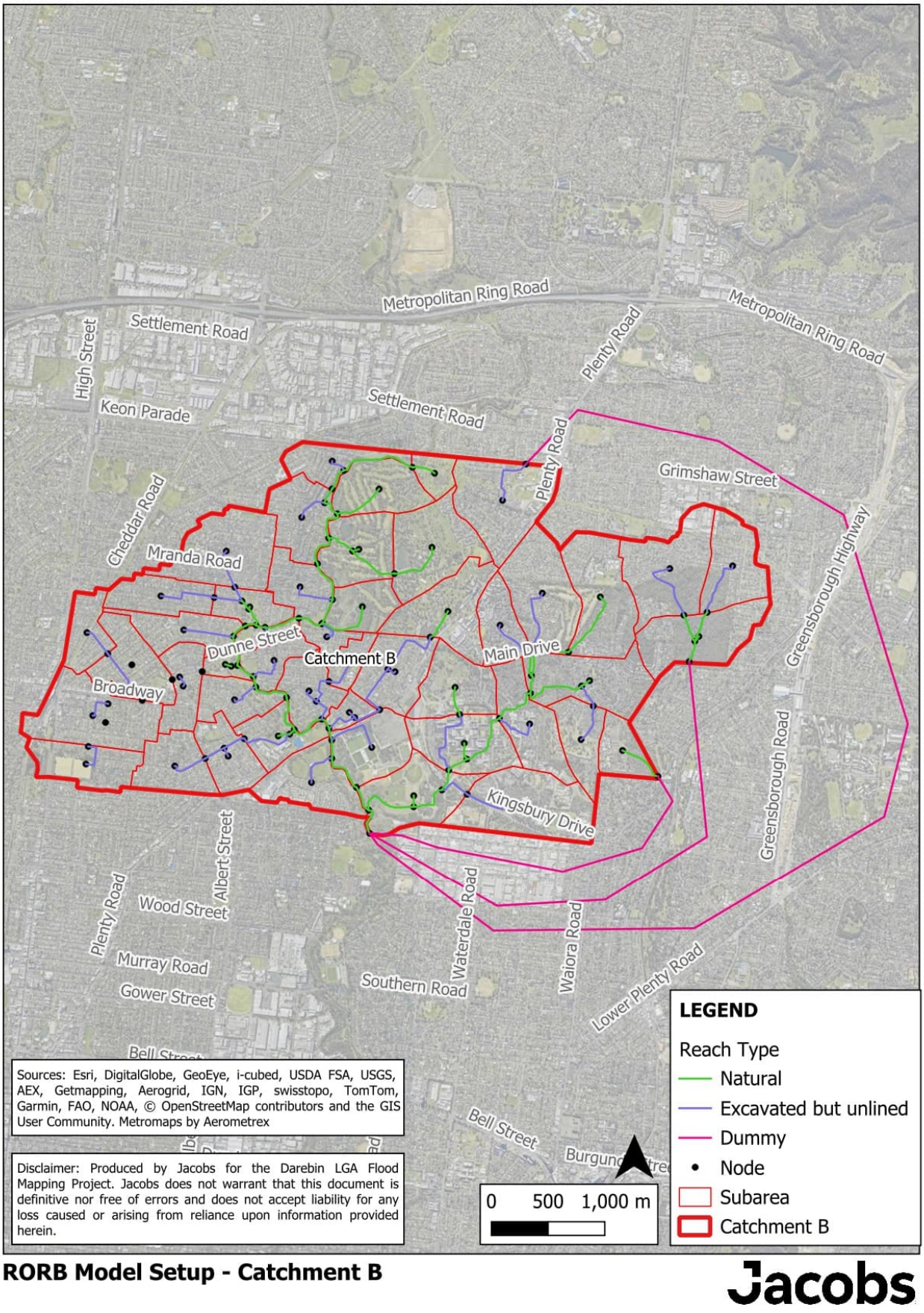


Figure 4-2: RORB setup Catchment B

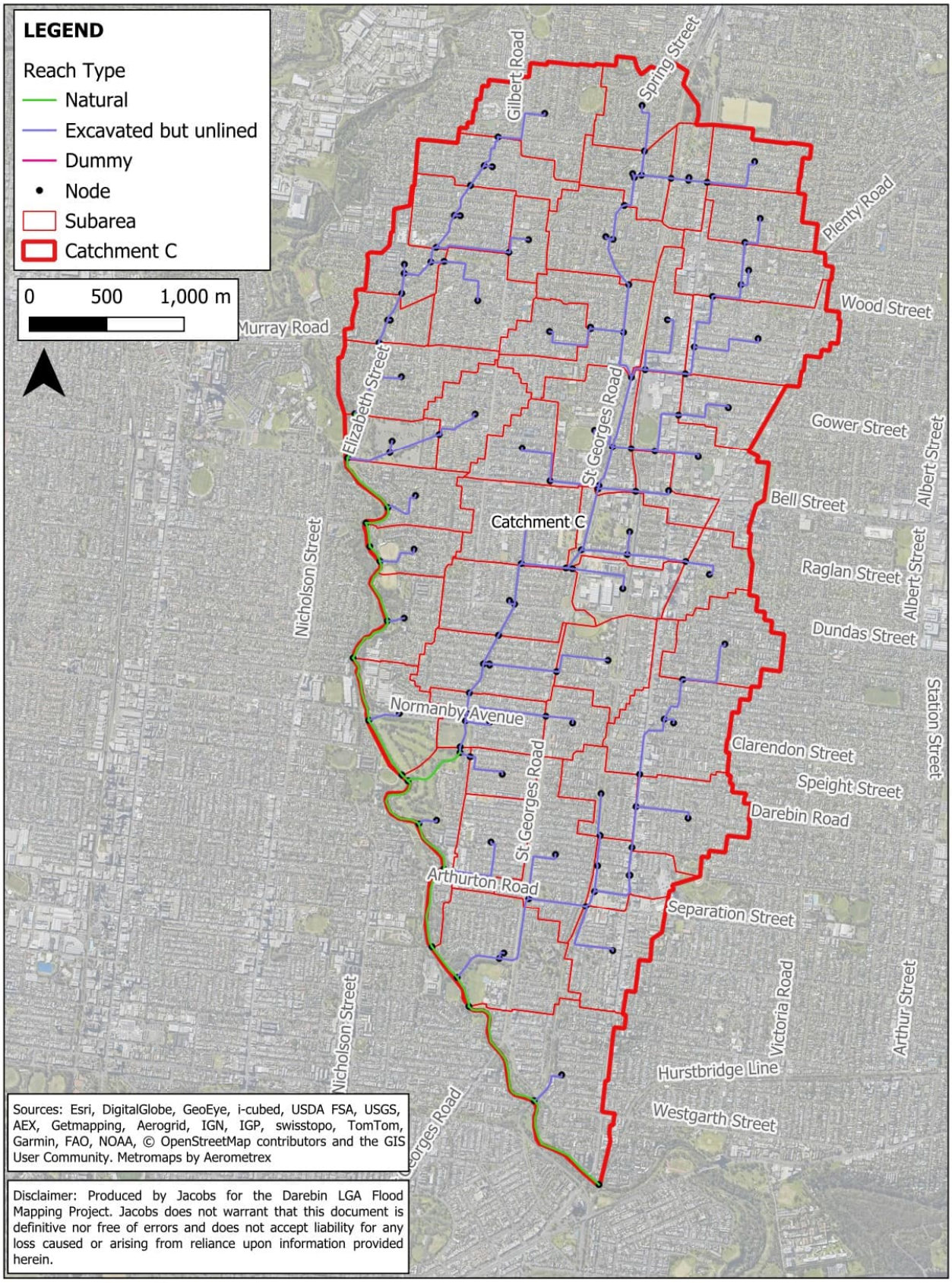


Figure 4-3: RORB setup Catchment C

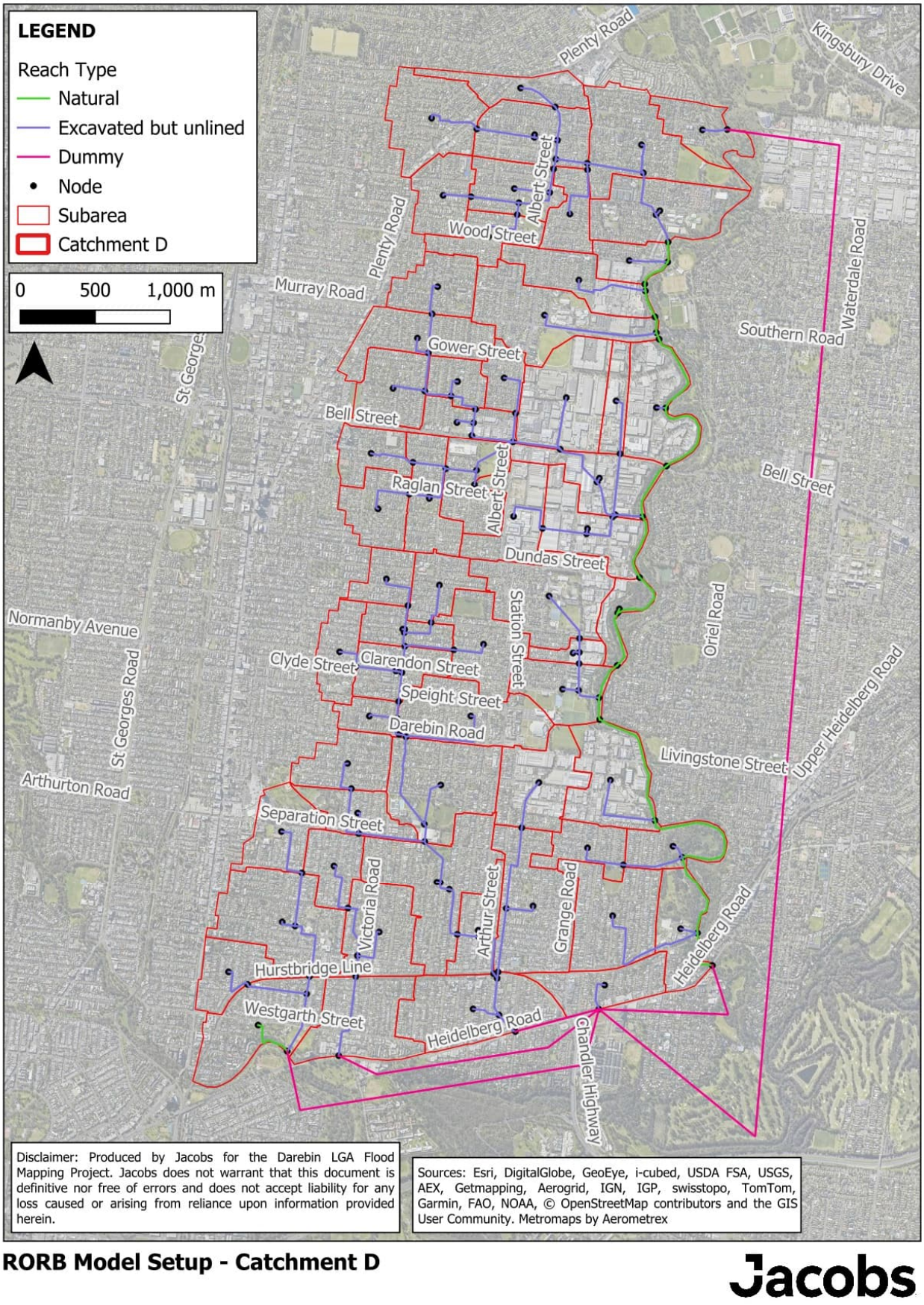


Figure 4-4: RORB setup Catchment D

4.2.7 Impervious Fractions

The ARR 2019 Version 4.1 guidelines and the Melbourne Water Flood Mapping Project Specifications identify three types of land use with respect to impervious areas; these are:

- **Effective Impervious Areas (EIA) or Directly Connected Areas (DCA)** – these are considered to be impervious areas that are directly connected to a drainage path. These areas have low losses; typically, 1 to 2mm for initial loss and 0mm/hr for continuing losses.
- **Indirectly connected area (ICA)** – these are considered to be a combination of impervious areas not connected directly to a drainage system, and pervious areas, such as gardens or nature strip, that can generate runoff which enters the drainage system. These areas have initial losses that are typically a proportion of 0.6 - 0.8 of pervious initial losses and continuing losses that are between 1 and 3 mm/hr.
- **Pervious areas (PA)** – these are considered to be large open spaces, rural or forest areas that do not interact with impervious areas or do not provide flow to drainage systems. These areas have losses that are the same as the rural areas.

The percentages of EIA, ICA and PA were determined for each sub-catchment across the RORB models. To determine the impervious fractions, the procedure outlined in the Melbourne Water Flood Mapping Project Specifications was followed. This means that planning layers were assigned a Total Impervious Area (TIA) value in line with those presented in the Melbourne Water Flood Mapping Project Specifications. Aerial imagery and photos from the site visits were used to assess and modify the catchment fractions required, and where no value was available, such as in special purpose zones. TIA values per land use (based on DELWP's VMPLAN_PLAN_ZONE layer) are documented in Table 4-1 and presented in Figure 4-5.

During the assignment of TIA values, each layer was assessed to determine if it was pervious or impervious. This assessment is crucial for identifying whether pervious areas need to be included in further calculations. T A list of planning scheme zones in the study area that were considered to have pervious fractions are listed below:

- Public Conservation and Resource
- Green Wedge A
- Farming
- Public Park and Recreation
- Rural Conservation
- Public Use
- Rural Living
- Urban Floodway

The EIA was then calculated by factoring the TIA using the relationship specified in the Melbourne Water Flood Mapping Project Specifications, in most cases, EIA = 0.6 x TIA, linearly increasing to 1 for TIAs above 80%.

The ICA and PA were determined based on the following logic:

- If a pervious area was identified: ICA = TIA - EIA
- If no pervious area was present: ICA = 1 - EIA

The Pervious Area (PA) was then determined as:

- PA = 1 - TIA (if pervious area was present)
- PA = 0 (if no pervious area was present)

This approach ensures the sum of EIA, ICA, and PA for each land type equals 1.

The weighted average EIA, ICA and PA values for each sub-catchment were determined for input to the RORB model using the directly and indirectly connected impervious areas functionality in the Graphical Editor. The adopted sub-catchment impervious fractions are documented in Appendix C.

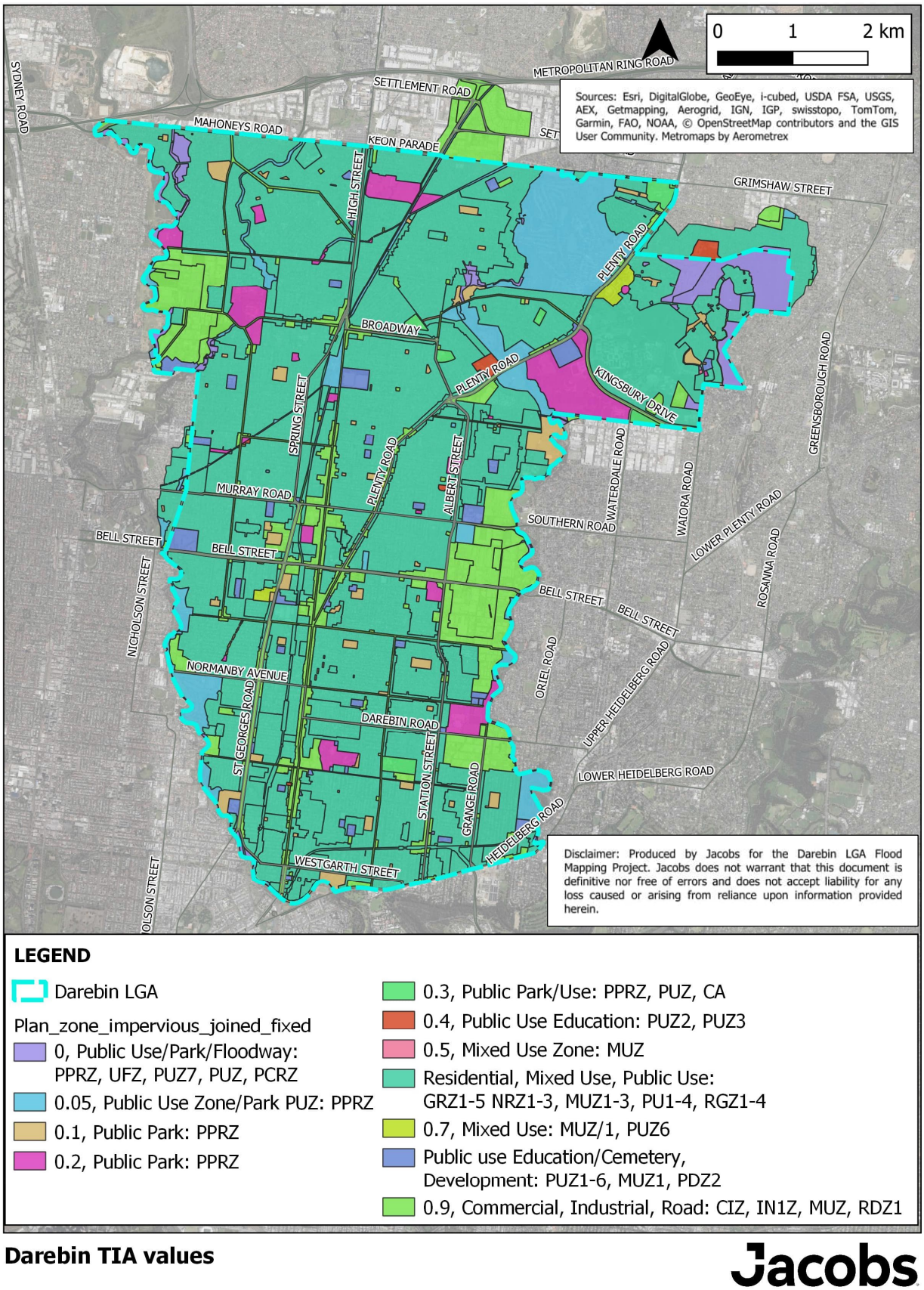


Figure 4-5: TIA values Darebin (Based on Plan_Zone layer extracted from Vic Planning, DELWP (2021))

Table 4-1 Total Impervious Area values (based on DELWP PLAN ZONE layer)

Land use	Relevant Zone Codes within the VMPLAN_PLAN_ZONE dataset (DELWP, 2021)	Total Impervious Area (TIA)
Commercial Zone 1	C1Z/C2Z	0.90
General Residential	GRZ1-5	0.60
Industrial Zone	IN1Z-IN3Z	0.90
Mixed Use Zone	MUZ-MUZ3	0.50 – 0.90
Neighbourhood Residential Zone	NRZ1-NRZ3	0.60
Priority Development Zone	PDZ1-PDZ2	0.90
Public Conservation and Resource Zone	PCRZ	0.00
Public Park and Recreation Zone	PPRZ	0.00 – 0.50
Public Use Zone - Cemetery	PUZ5	0.80
Public Use Zone - Education	PUZ2	0.20 – 0.80
Public Use Zone – Health and Community	PUZ3	0.40 – 0.90
Public Use Zone – Local Government	PUZ6	0.05 – 0.90
Public Use Zone – Other Public Use	PUZ7	0.00 – 0.90
Public Use Zone – Service and Utility	PUZ1	0.00 – 0.90
Public Use Zone - Transport	PUZ4	0.60
Residential Growth Zone	RGZ1-RGZ5	0.60
Road Zone	RDZ1-2	0.90
Urban Floodway Zone	UFZ	0.00

4.3 RORB Design Inputs

The following section details the RORB inputs for the hydrological modelling of design events. Rainfall inputs were sourced from the Bureau of Meteorology (see Appendix A) while hydrological inputs were sourced from the ARR Data Hub (see Appendix B).

4.3.1 Intensity-Frequency-Duration (IFD) data

Intensity-Frequency-Duration (IFD) data for the four catchment centroids was sourced from the Bureau of Meteorology. The coordinates adopted for each catchment are provided in Table 4-2. As per the Melbourne Water Flood Mapping Project Specifications rainfalls were increased by 18.5% to establish climate change rainfalls.

A sensitivity assessment was undertaken on the variance of rainfall throughout the catchments using the 1% AEP 60-minute gridded rainfall data. This assessment indicated that the variation in depths was less than 3% (on average less than 1 mm) and therefore point rainfalls from the centroids were considered appropriate for use. The data is presented in Table 4-3.

Table 4-2: Catchment centroid for rainfall data

Catchment	Latitude	Longitude
A	-37.704331	145.000497
B	-37.713945	145.041469
C	-37.747118	144.995575
D	-37.756896	145.019676

Table 4-3: 1% AEP 60min grid rainfall sensitivity

	Catchment A	Catchment B	Catchment C	Catchment D
Gridded rainfall max difference across the catchment (m)	0.6	0.4	1.2	1.2
Difference across the catchment (%)	1.2	0.8	2.4	2.4

4.3.2 Areal reduction factors (ARF)

Design rainfall information for flood estimation is made available in the form of rainfall Intensity Frequency Duration (IFD) data that relates to specific points in a catchment rather than to the whole catchment area. The Areal Reduction Factors (ARF) represent the ratio between the design value of the areal average rainfall and point rainfall, computed for the same duration and AEP (ARR, 2019).

As per the ARR 2019 Version 4.1 guidance, catchments that are less than 1 km^2 in area require no reduction in design rainfalls. Where the catchment area is greater than 1 km^2, the ARR 2019 Version 4.1 recommends the calculation of an ARF, to apply to design rainfalls, with the ARF value varying across catchment area, AEP, and storm duration. ARR 2019 Version 4.1, Book 2, Chapter 4 Table 2.4.1 provides guidance on the equations to adopt for the calculation of ARF.

Calculating ARF across a catchment can significantly increase the complexity of an assessment. For this study, a practical approach was adopted, which involved assessing the relationship between the catchment area, critical duration, and AEP. The details are as follows:

- To determine the relationship between catchment critical duration and ARF, the full suite of 10 temporal patterns across durations ranging from 10 minutes to 6 hours was run through coarse grid TUFLOW models (8 m) using a point ARF (no reduction) for the 1%, 10% and 20% AEP events. These three AEPs were selected because they represent frequent, intermediate, and rare storm events.
- For each AEP:
    - Median water level grids were determined for each duration (i.e., a median grid was generated from each of the 10 temporal pattern model simulations).
    - A maximum envelope grid, derived from the median grids representing the peak flood levels for all durations, was then generated.
    - Based on the critical duration grids and selected points within the catchment, a relationship between critical duration and contributing catchment area was established. The selected points, spatially distributed throughout the catchment, are presented in Figure 4-6 to Figure 4-9.

The adopted relationships between catchment areas and critical durations are presented in Table 4-4 to Table 4-6. For implementation into RORB, the catchment area was set as an input parameter for every storm duration. RORB determines the appropriate ARF to apply based on the guidance in ARR 2019 Version 4.1 (Book 2, Section 6.3.1).

Table 4-4: Adopted catchment area and durations for the generation of ARF (1% and 2% AEP event)

Catchment	Critical duration	ARF Area (km^2)	Comment
Catchment A (see Figure 4-6)	2 hour and less	1.0	Excluding external catchment flows most of the local contributing catchment areas are less than 1km^2.
	3 hours and above	2.0	Based on flooding upstream of the rail embankment at McCrae Street. The rail embankment is an overland flow constraint.
Catchment B (see Figure 4-7)	1 hour and below	1.0	Represents the urban areas, short durations, and small catchment areas.
	1.5 hours and above	3.0	The eastern catchment through Latrobe University is dominated by storage in the floodplain.
Catchment C (see Figure 4-8)	1 hour and below	1.0	Represents the urban areas, short durations, and small catchment areas.
	1.5 hours and above	3.0	Caters for the informal storages in the catchment resulting in the attenuation of peak flows.
Catchment D (see Figure 4-9)	1.5 hours and below	1.0	Represents the urban areas, short durations, and small catchment areas.
	2 hours and above	2.0	Caters for the informal storages in the catchment resulting in the attenuation of peak flows.

Table 4-5: Adopted catchment area and durations for the generation of ARF (10% and 5% AEP event)

Catchment	Critical duration	ARF Area (km^2)	Comment
Catchment A	45 min and less	1	Excluding external catchment flows most of the local contributing catchment areas are less than $1km^{2.}$
	1 hour and above	1.5	Based on flooding upstream of the rail embankment at McCrae Street. The rail embankment is an overland flow constraint.
Catchment B	30 min and below	1	Represents the urban areas, short durations, and small catchment areas.
	45 min and above	2	The eastern catchment through Latrobe University is dominated by storages in the floodplain.
Catchment C	30 min and below	1	Represents the urban areas, short durations, and small catchment areas.
	45 min	1.5	Caters for the informal storages in the catchment resulting in the attenuation of peak flows.
	1 hour and above	5	
Catchment D	1 hour and below	1	Represents the urban areas, short durations, and small catchment areas.
	1.5 hours and above	2	Caters for the informal storages in the catchment resulting in the attenuation of peak flows.

Table 4-6: Adopted catchment area and durations for the generation of ARF (20% AEP event)

Catchment	Critical duration	ARF Area (km^2)	Comment
Catchment A	30 min and below	1	Excluding external catchment flows most of the local contributing catchment areas are less than $1km^2$.
	45 min and above	1.5	Based on flooding upstream of the rail embankment at McCrae Street. The rail embankment is an overland flow constraint.
Catchment B	45 min and below	1	Represents the urban areas, short durations, and small catchment areas.
	1 hour and above	2	The eastern catchment through Latrobe University is dominated by storage in the floodplain.
Catchment C	30 min and below	1	Represents the urban areas; short durations, and small catchments.
	45 min and above	3	Caters for the informal storages in the catchment resulting in the attenuation of peak flows.
Catchment D	1 hour and below	1	Represents the urban areas, short durations, and small catchment areas.
	1.5 hours and above	2	Caters for the informal storages in the catchment resulting in the attenuation of peak flows.

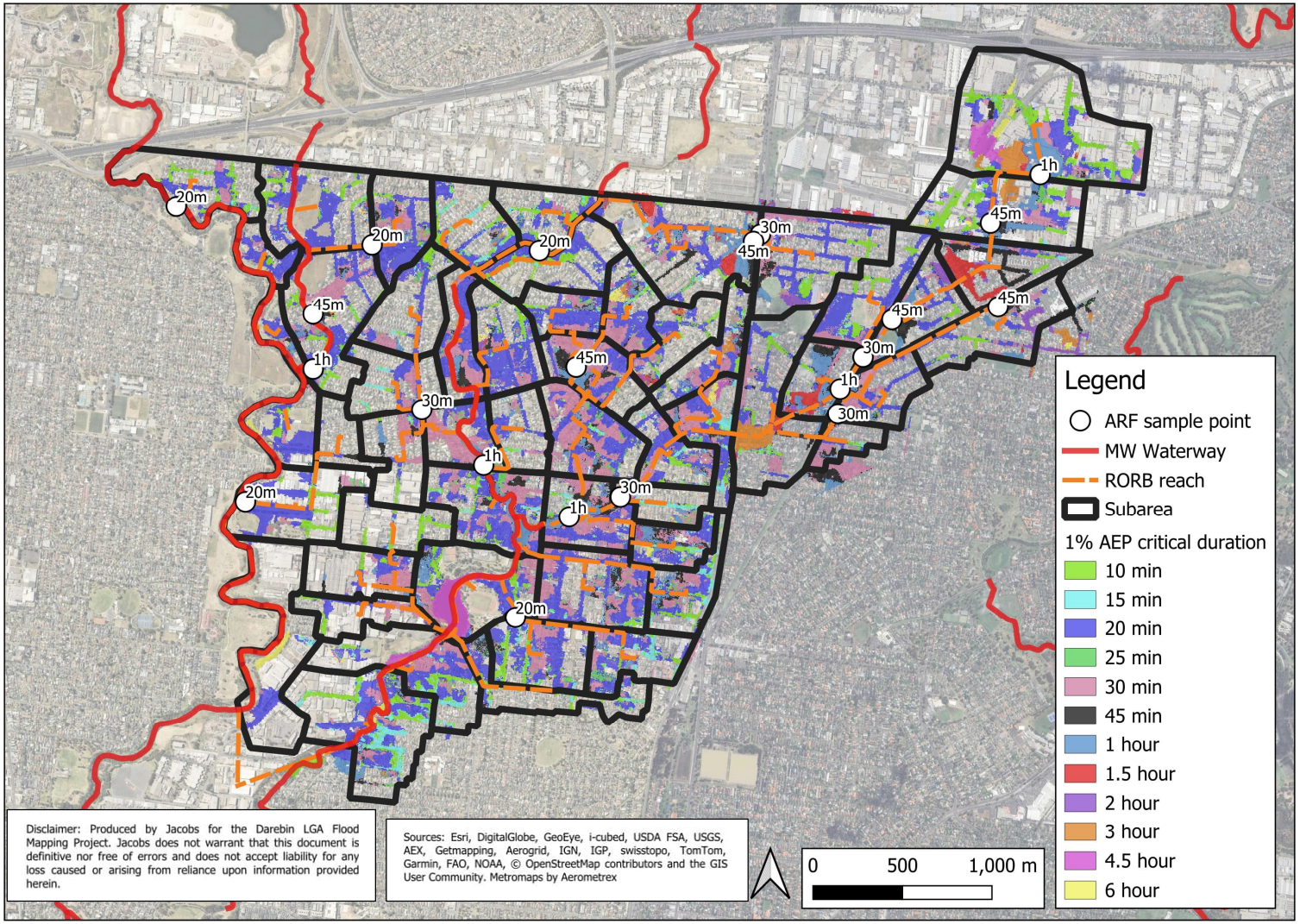


Figure 4-6: Catchment A 1% AEP critical duration (flood level) grid and sample points (critical duration noted)

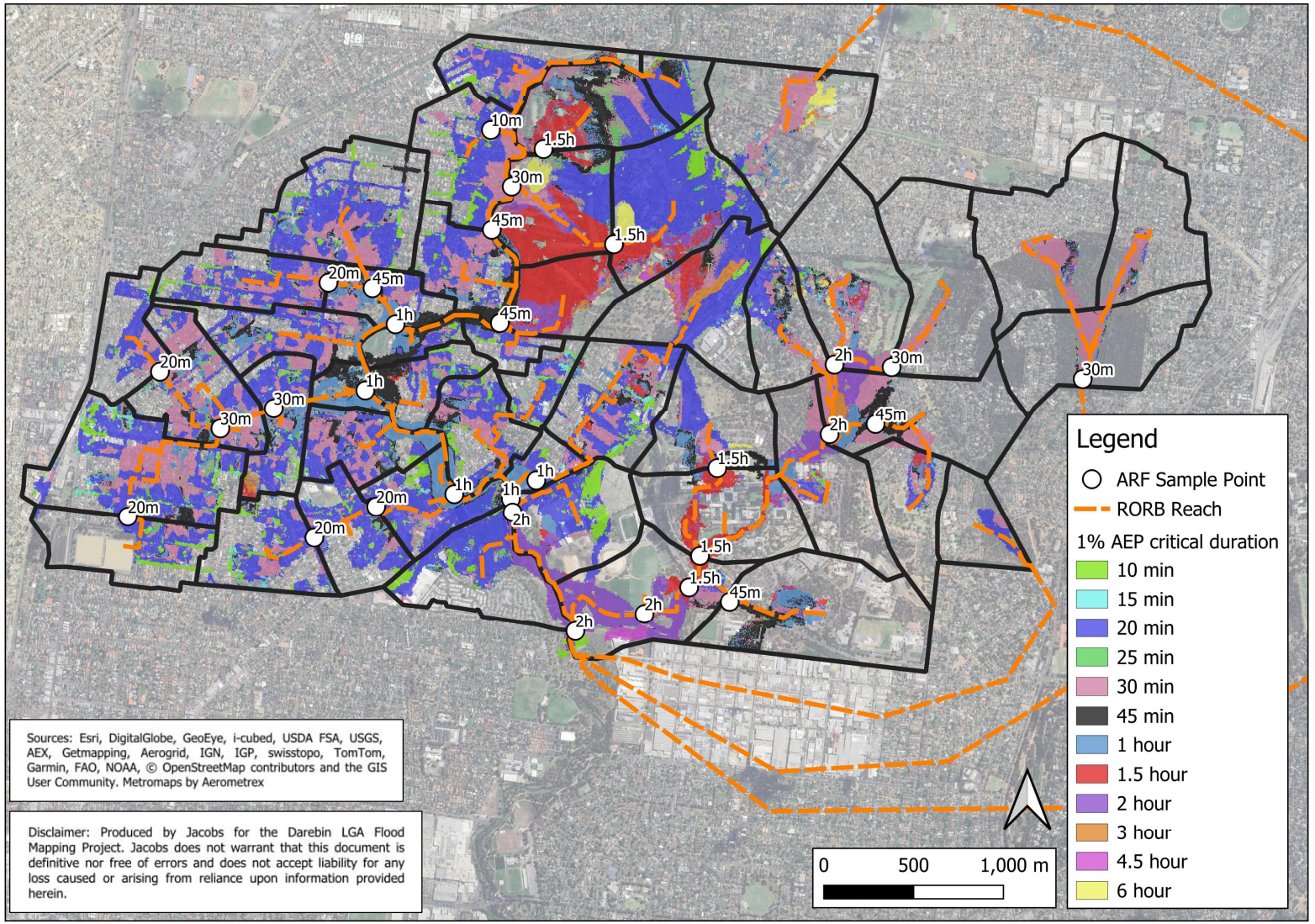


Figure 4-7: Catchment B 1% AEP critical duration (flood level) grid and sample points (critical duration noted)

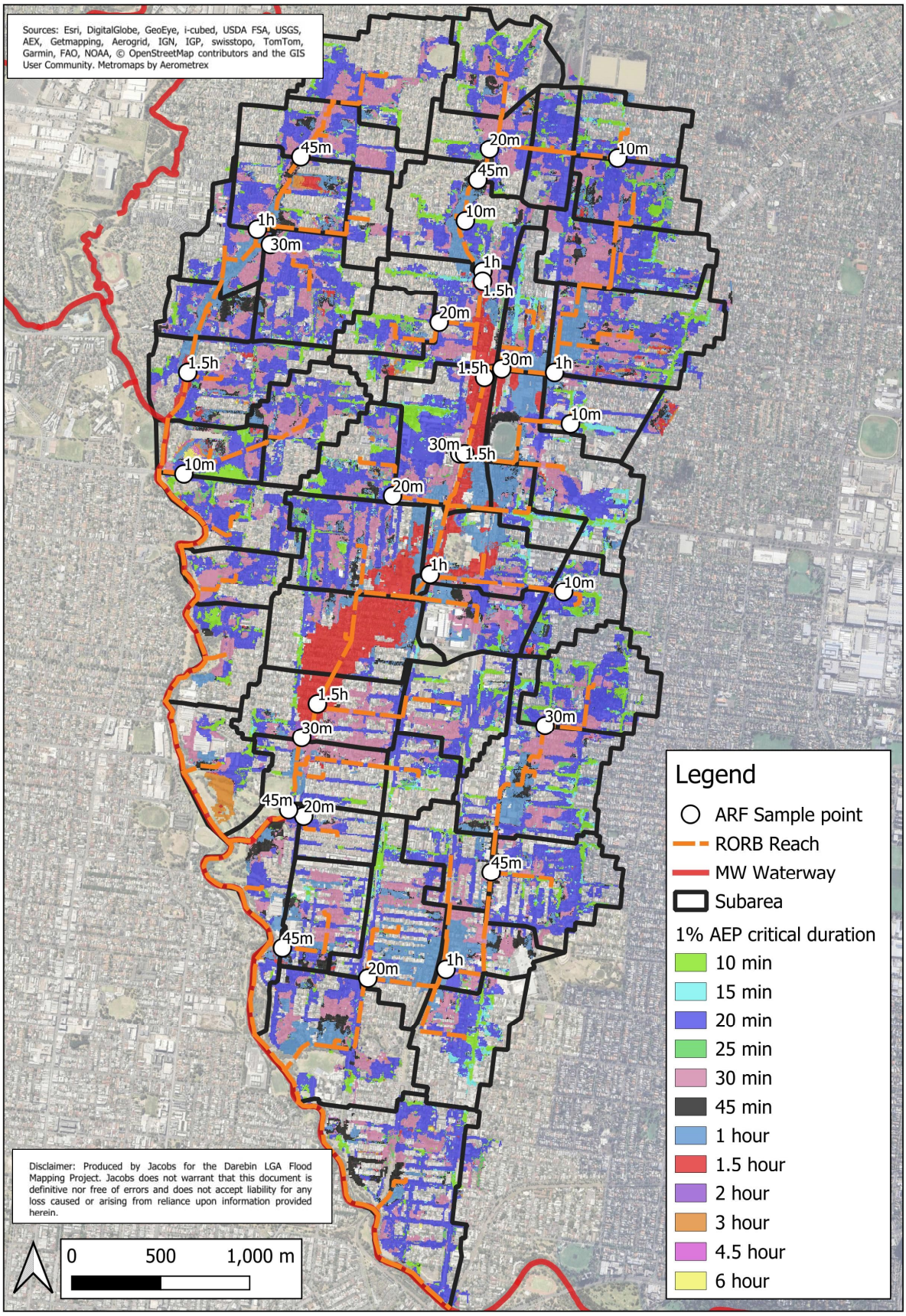


Figure 4-8: Catchment C 1% AEP critical duration (flood level) grid and sample points (critical duration noted)

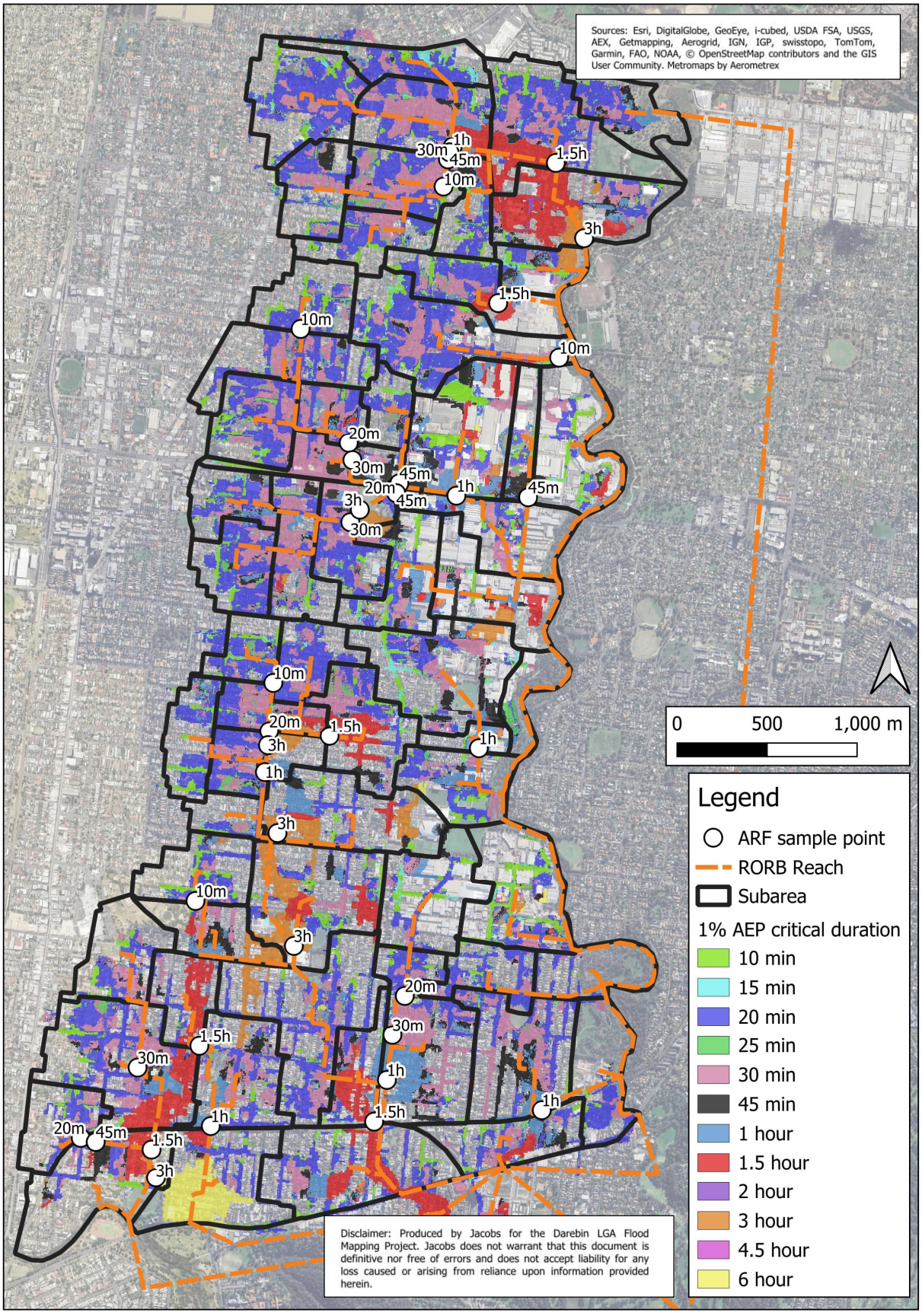


Figure 4-9: Catchment D 1% AEP critical duration (flood level) grid and sample points (critical duration noted)

4.3.3 Losses and pre-burst

Losses were adopted from the ARR 2019 Version 4.1 Data hub which is documented in Table 4-7. No variability was found across the LGA when the data hub losses were sampled. RORB's in-built land-use function was adopted for this study. The PA, EIA and ICA losses were added to the model. The Indirectly connected area initial loss was set at 70% of the pervious initial loss as recommended in ARR 2019 Version 4.1.

The provided storm losses on the Data Hub site are based on complete storms, while the IFD data uses a burst depth. To address this discrepancy, pre-burst depths are applied. Following the ARR Data Hub recommendations for loss region 3 (https://data.arr-software.org/vic_specific), the 75th percentile burst values are adopted. This is achieved by pre-pending the 75th percentile pre-burst depths (provided in Appendix B) to the beginning of the storm. The temporal patterns for applying the pre-burst depths are based on Jordan et al. (2005) and implemented in the RORB model.

For durations shorter than 1-hour the pre-burst ratios were assumed to be the same as the 1-hour storm. This is based on guidance in the Melbourne Water Flood Mapping Projects Specifications. Where depths for a particular duration were not available on the Datahub, the closest longer duration depth was used.

Table 4-7: Data Hub losses and adopted losses

Parameters	Initial Loss (mm)	Continuing Loss (mm/h)
Effective Impervious Area (EIA)	1.0	0.0
Indirectly Connected Area (ICA)	8.4	1.9
Pervious Area (PA)	12.0	1.9
Datahub	12.0	1.9

4.3.4 Temporal patterns

Since the catchment area is less than 75 km^2, point temporal patterns were sourced from the ARR Data Hub and applied in the analysis (30 for each of the durations using the rare, frequent and intermediate AEP range of event frequencies), as recommended by ARR 2019 Version 4.1. Temporal patterns were filtered for embedded bursts using the option in RORB.

4.3.5 Spatial Pattern

The catchment area for each RORB model area is less than 20km^2, as per the guidance in ARR 2019 Version 4.1 uniform spatial patterns have been adopted across the four RORB catchments.

4.4 RORB Model Performance Check

The routing calculation in RORB uses two parameters, k_c and m. The parameter m describes the degree of non-linearity of the catchment's response to rainfall excess, while the parameter k_c describes the delay in the catchment's response to rainfall excess. The m parameter was set at the default value of 0.8 as per the advice in the Melbourne Water Flood Mapping Project Specifications.

The inputs for the TUFLOW models for catchments A, B, C and D are based on rainfall-excess hydrographs without routing, which means that the flood modelling results are insensitive to the k_c routing parameter. Given that the RORB models were used in the Darebin LGA project to generate rainfall excess hydrographs for input to hydraulic models, and no routing was used, the choice of routing parameters does not influence the outcomes of this study. However, to provide flexibility for Melbourne Water's future needs, Jacobs incorporated routing parameters into the models. If future assessments adopt these RORB models for the generation of routed hydrographs additional checks are recommended.

An assessment was undertaken based on regional equations to validate peak flows generated from each of the four RORB models. This involved applying adopted loss parameters and assessing the peak flow from the catchment against two validation methods; the Melbourne Water 'Rule of Thumb' (urban) method (10 cumec per 100 ha), and the Nikolaou/von't Steen (urban) method (see Table 4-8). These 'Rule of Thumb' method checks are documented in the Melbourne Water Flood Mapping Project Specifications however are at best a guide and are not comprehensive.

The RORB model peak flows closely match the Nikolaou/von't Steen estimates but are lower than the Melbourne Water rule of thumb. This is likely because the Melbourne Water rule of thumb, for urban areas, tends to overestimate peak flows in catchments with significant green space.

Table 4-8: Peak Flow Values Catchment A, B, C and D

Catchment	k_c	RORB Q_{100} (m^3/s)	MW rule of thumb (urban) Q_{100} (m^3/s) (MW Flood Mapping Projects Specifications	Nikolaou/von't Steen (urban) Q_{100} (m^3/s)
A	RORB manual k_c =2.2 x $A^{0.5}$ =7.34	59.9	135.5	65.5
B	RORB manual k_c =2.2 x $A^{0.5}$ =8.61	51.1	153.0	71.4
C	RORB manual k_c =2.2 x $A^{0.5}$ =8.43	66.3	147.0	69.4
D	RORB manual k_c =2.2 x $A^{0.5}$ =8.53	80.3	150.2	70.5

5. Hydraulic Modelling

A coupled 1D-2D TUFLOW hydraulic model was adopted for this Study to simulate the behaviour of overland flows, major underground pit and pipe networks, and structures such as bridges and culverts for the selected flood events. TUFLOW version 2020-10-AB was adopted and utilised the HPC solver. Quadtree functionality was utilised across the road network to provide a higher level of resolution throughout the model domain. As agreed with Melbourne Water the model did not adopt the TUFLOW SGS (sub grid sampling) functionality.

Hydrographs derived from the developed RORB models were applied to the four (4) hydraulic respective TUFLOW models which covers each of the study areas.

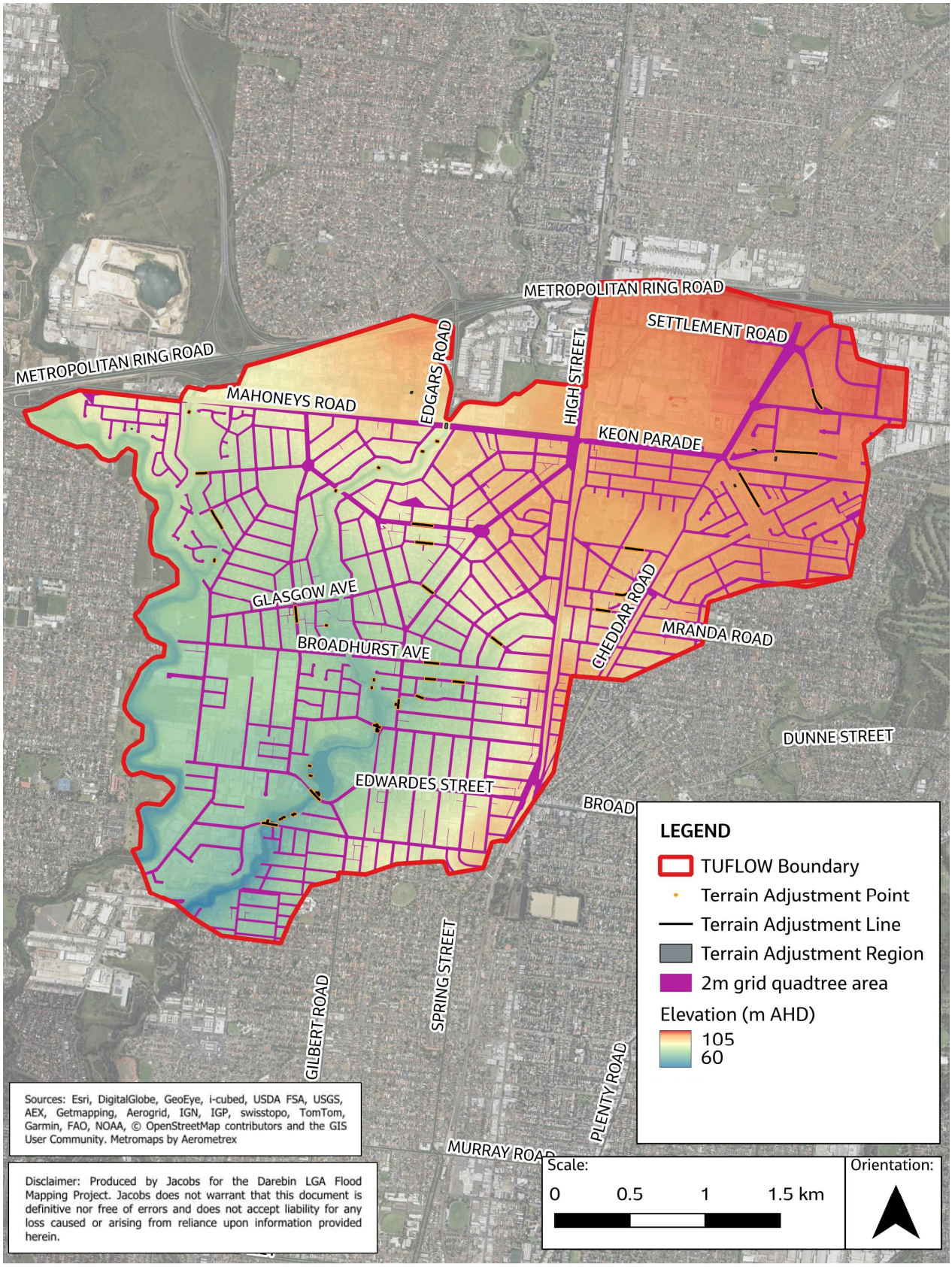
The following sections summarise the TUFLOW model development.

5.1 Model build

Quadtree was applied with a level 2 nest (4-meter and 2-meter grid resolution). The 2-meter grid resolution was adopted along the road network which captured the primary overland flow paths in the urban catchments. Catchment D adopts grid resolution of 1 meter in the region near the Wingrove Street pedestrian underpass which is further discussed in Section 8.2.

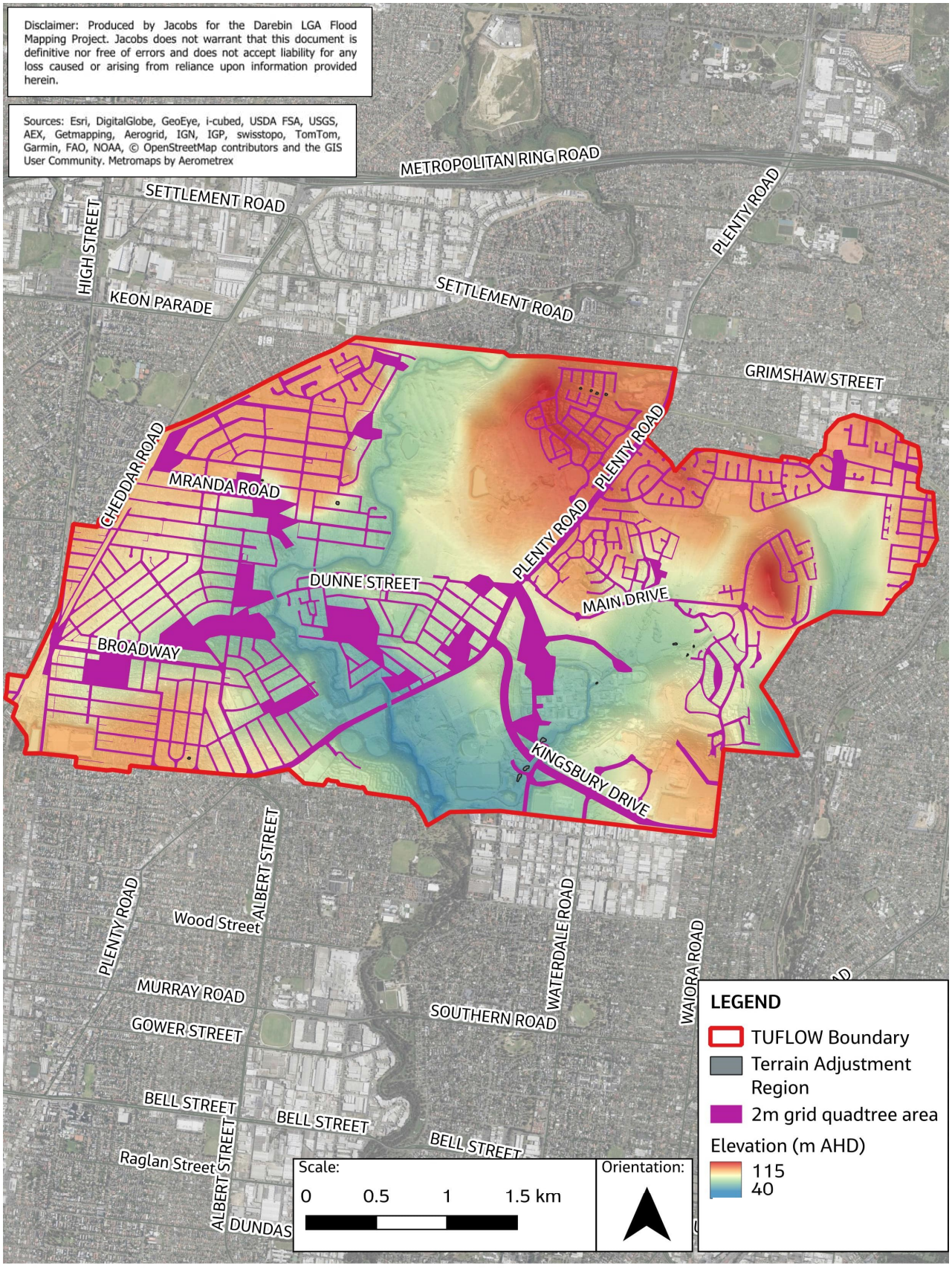
The models were oriented to align with major creeks (Darebin and Merri) and primary overland flow paths. The model setups are presented in Figure 5-1 to Figure 5-4.

In accordance with the Melbourne Water Flood Mapping Project Specifications Z-shapes were applied to ensure identified hydraulic controls including rail embankments and road crests were applied across the model domains. There are presented as 'terrain adjustment' regions, lines and points in Figure 5-1 to Figure 5-4.



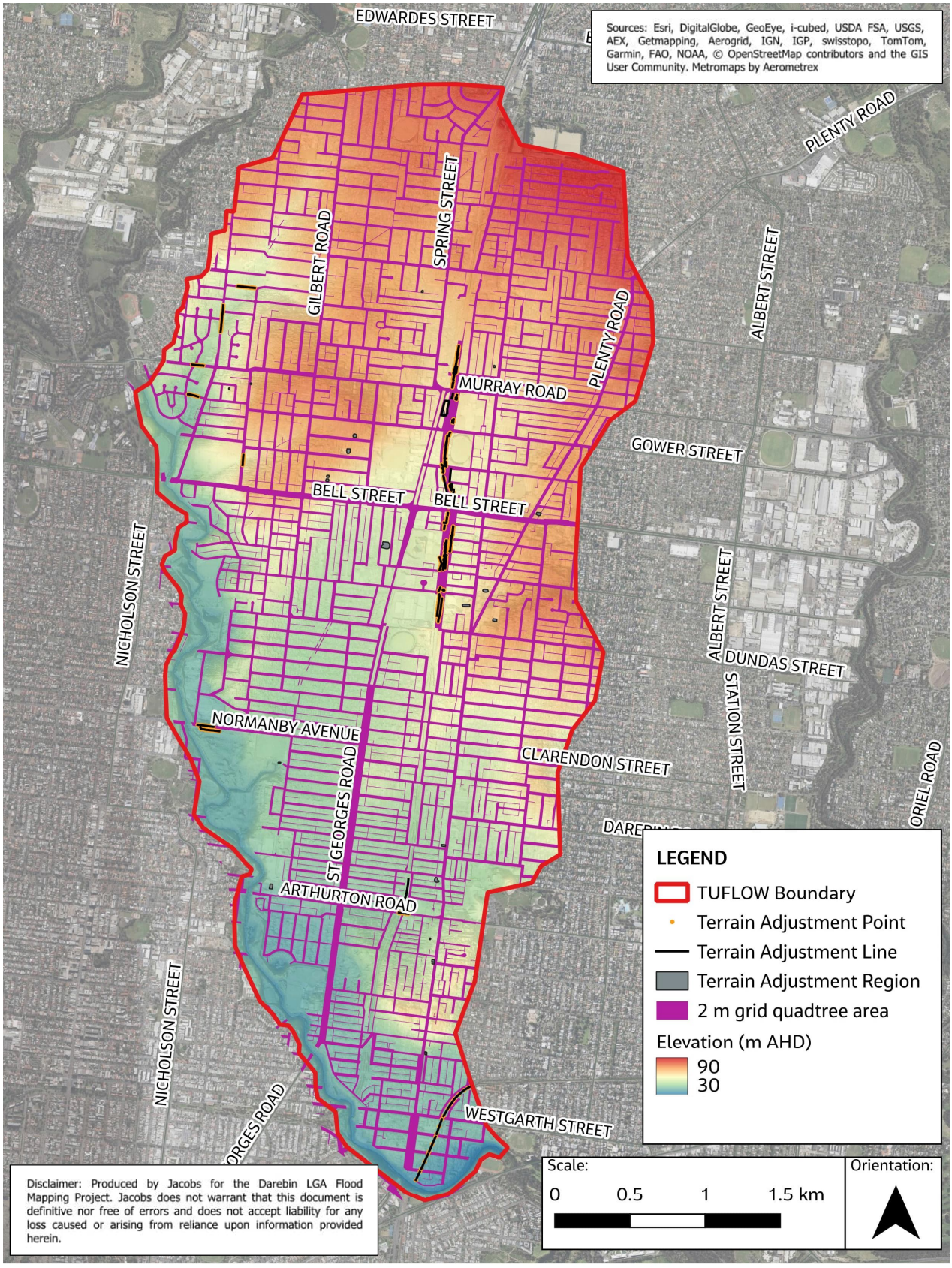
Topographic Setup Catchment A

Figure 5-1: Catchment A Topographic Setup



Topographic Setup Catchment B

Figure 5-2: Catchment B Topographic Setup



Topographic Setup Catchment C

Jacobs

Figure 5-3: Catchment C Topographic Setup

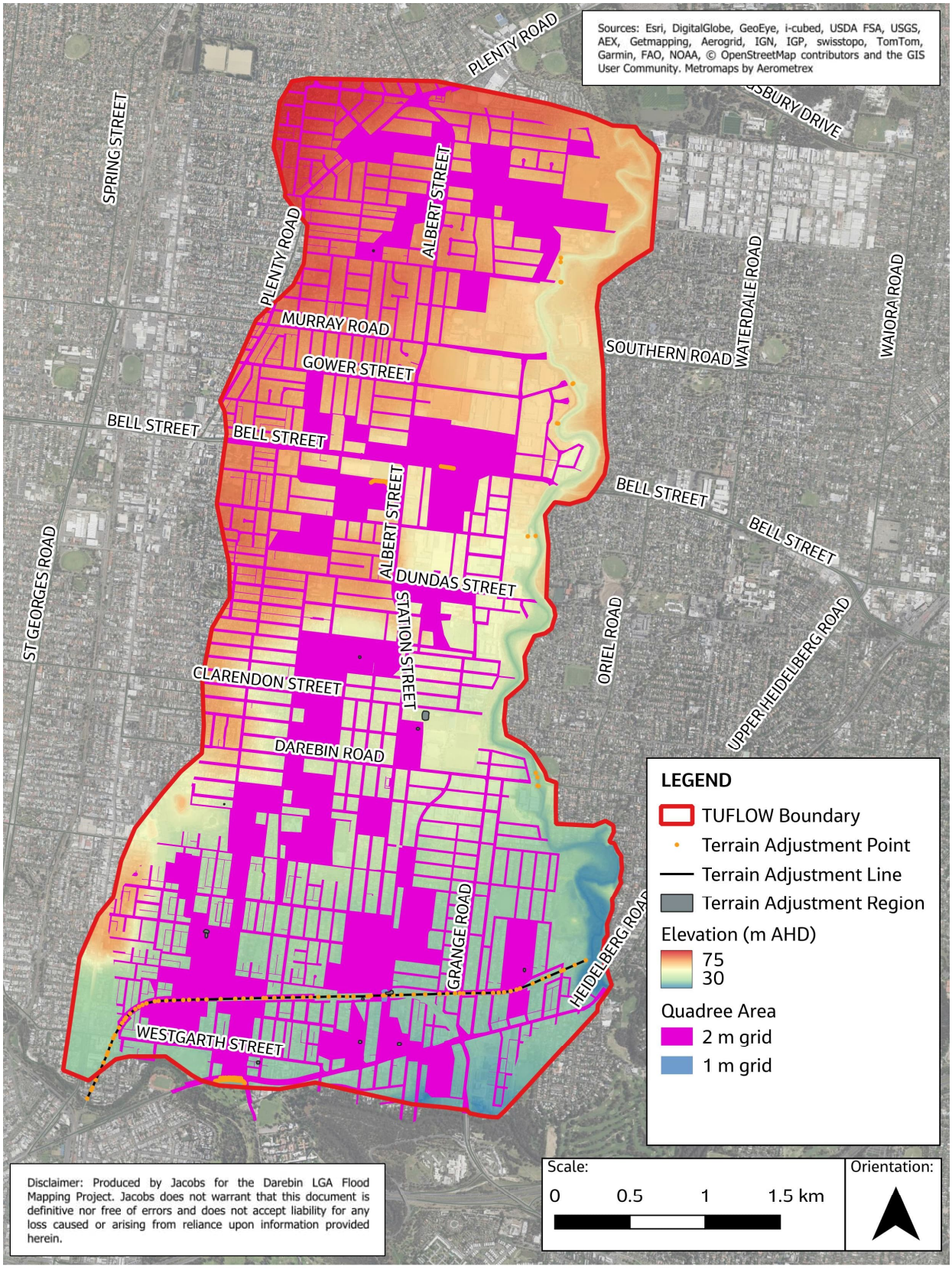


Figure 5-4: Catchment D Topographic Setup

5.1.1 Bridges

Bridges have been included into the TUFLOW models based on available survey information/drawings which is documented in Table 3-3. TUFLOW inputs for the bridges are summarised in Table 5-1. It is noted that the waterways and thus the bridges on Merri Creek, Darebin Creek and Edgars Creek form boundary conditions for the TUFLOW models. Waterway flood mapping is not captured in this project and the bridges have only been included for completeness. They do not influence the council and/or MW drain flood extents generated for this project. Any bridges outside of the Darebin LGA on the aforementioned waterways have not been included in the modelling as they are outside the project boundary. An example of this is Merri Creek which crosses into the Merri-Bek LGA.

The adopted form losses were calculated based on the empirical methods outlined in Hydraulics of Bridge Waterways (Bradley, 1978).

Table 5-1: Adopted Bridges in the TUFLOW models

Model	Location	Soffit Level (m AHD)	Pier Form Loss	Deck thickness (m)	Estimate Railing height (m)	Railing blockage (%)
Darebin Creek						
B	Chenies Street	72.67	0	1.37	1	10
B	Dunne Street	70.71	0	1.38	1	10
B	Plenty Road	65.5	0.21	1.27	1	10
B	Footbridge near Village Drive (Darebin)	60.74	0	0.5	1	10
D	Dougharty Road Footbridge	56.3	0	2.07	1	10
D	Murray Road	54.88	0.21	1.11	1	10
D	Bell Street	50.89	0.34	1.4	1	10
D	Dundas Street Footbridge	43.95	0	0.94	1	10
D	Livingstone Street	37.63	0.29	1.37	1	10
D	Abercorn Avenue	31.2	0.03	0.65	1	10
D	Rail over (Darebin)	29.73	0.18	2.26	1	10
D	Heidelberg Road	21.06	0	1.77	1	10
Mont Park Drain (La Trobe)						
B	Moat Bridge (La Trobe)	77.37	0	0.5	1	10
B	Carpark 8 Bridge 2 (La Trobe)	75.72	0	0.5	1	10
B	Fitzpatrick Bridge (La Trobe)	75.71	0	0.5	1	10
B	Carpark 8 Bridge 1 (La Trobe)	75.6	0	0.5	1	10
B	Trendall Walk (La Trobe)	72.65	0	0.5	1	10
B	Centre way (La Trobe)	72.54	0	0.5	1	10
B	Kingsbury Drive	71.69	0.12	1	1	10
B	La Trobe Academic Lawn Bridge	69.94	0	1	1	10
Edgars Creek						
A	Mahoneys Road	88.95	0	1.85	1	30
A	Hughes Parade	83.92	0	1.27	1	20
A	Hughes Parade	83.92	0	1.27	1	20

Model	Location	Soffit Level (m AHD)	Pier Form Loss	Deck thickness (m)	Estimate Railing height (m)	Railing blockage (%)
A	Glasgow Ave	75.5	0	1	1	20
A	Broadhurst Ave bridge	73.12	0	1.27	1	20
A	Pedestrian bridge (downstream of Leamington St)	70.72	0	0.5	1	40
Merri Creek						
A	Mountbatten Ct footbridge	79.82	0	0.4	1	10
A	Broadhurst Ave footbridge	67.83	0	0.4	1	10
A	Brex Ct footbridge	67.37	0	0.9	1	10
A	Northern Iron footbridge	66.33	0	0.4	1	10
C	De Chene Reserve Footbridge	40.5	0.02	0.5	1	10
C	Bell Steet Merri Creek Crossing	39.03	0	3.9	1	10
C	Koonda Lat Bridge	39	0.09	1	1	10
C	Kingfisher Gardens Footbridge	38.2	0	0.5	1	10
C	Harding Street Bridge	38.07	0	0.5	1	10
C	St Georges Road	34.96	0.5	1.38	1	10
C	Normanby Avenue	34.28	0.11	1.44	1	10
C	Blyth Street	34.08	0.19	1.6	1	10
C	Eltham Rail	32	0.2	1.2	1	10
C	Merri Park Footbridge	30.94	0	0.5	1	10
C	Green Reserve Footbridge	30.49	0.14	0.9	1	10
C	Rushall Station Footbridge	29.3	0.05	0.28	1	10
C	High Street	25.51	0.18	5.5	1	10
C	Creek Parade Footbridge	19.47	0	0.34	1	10

Other hydraulic controlling structures which have been represented in the models include:

- Model A: Edwardes Lake Crest
    - Weir crest 69.28 m AHD based on provided survey information.
- Model C: Merri Creek Retarding Basin – (4420). Outlet configuration based on provided drawings information.
- Model D: H.L.T Oulton Reserve Retarding Basin – Crest level hydraulically re-enforced. Pump station assumed to be offline during the design flood event simulations.

5.2 Model Roughness

Model roughness was based on the values in the Melbourne Water Flood Mapping Project Specifications. The adopted values are presented in Table 5-2 and presented in Figure 5-5 to Figure 5-8. To classify the roughness values various data sources were adopted including:

- Aerial imagery
- Planning Scheme Zone (VMPLAN_PLAN_ZONE DELWP, 2021)

Table 5-2: Adopted Manning's 'n' values

Land Use	Manning's 'n' Value
Natural Waterway (minimal vegetation)	0.04
Natural Waterway (vegetated)	0.06
Open pervious area (minimal vegetation)	0.035
Open pervious area (moderate vegetation)	0.06
Open pervious area (thick vegetation) Coburg Pine Ridge Cemetery (Model C)	0.08
Residential Land (modelled separately to buildings)	0.1
Building footprint	0.40
Industrial/Commercial parcels (modelled separately to buildings)	0.10
Industrial/ Commercial buildings and parcels modelled as a whole (Station Street)	0.5
Station Street Underpass	0.015
Roads	0.02
Rail	0.10
Wetlands/Lakes	0.05
Concrete lined channel	0.02
Gravel/pervious area	0.03

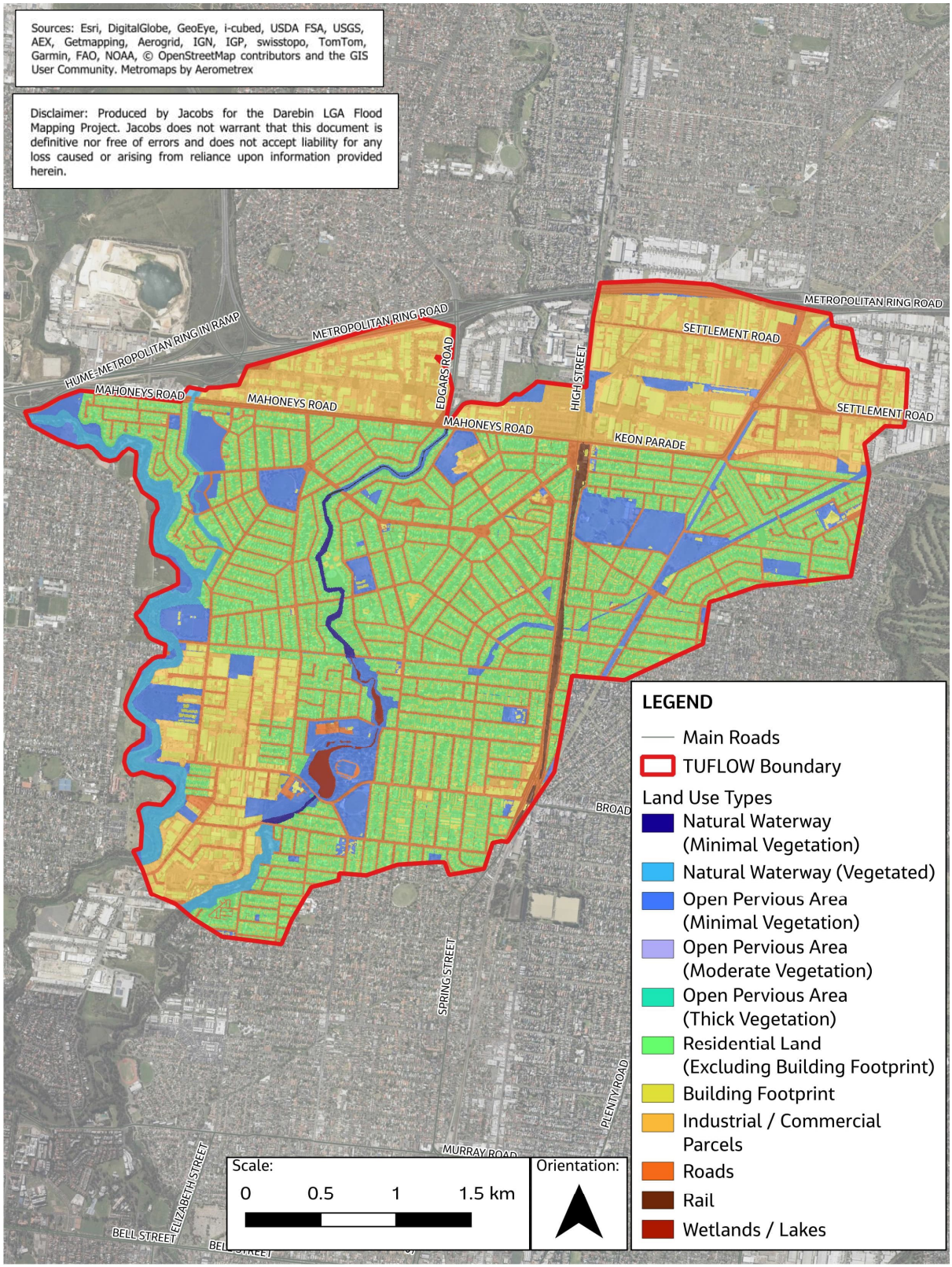


Figure 5-5: Catchment A Model roughness

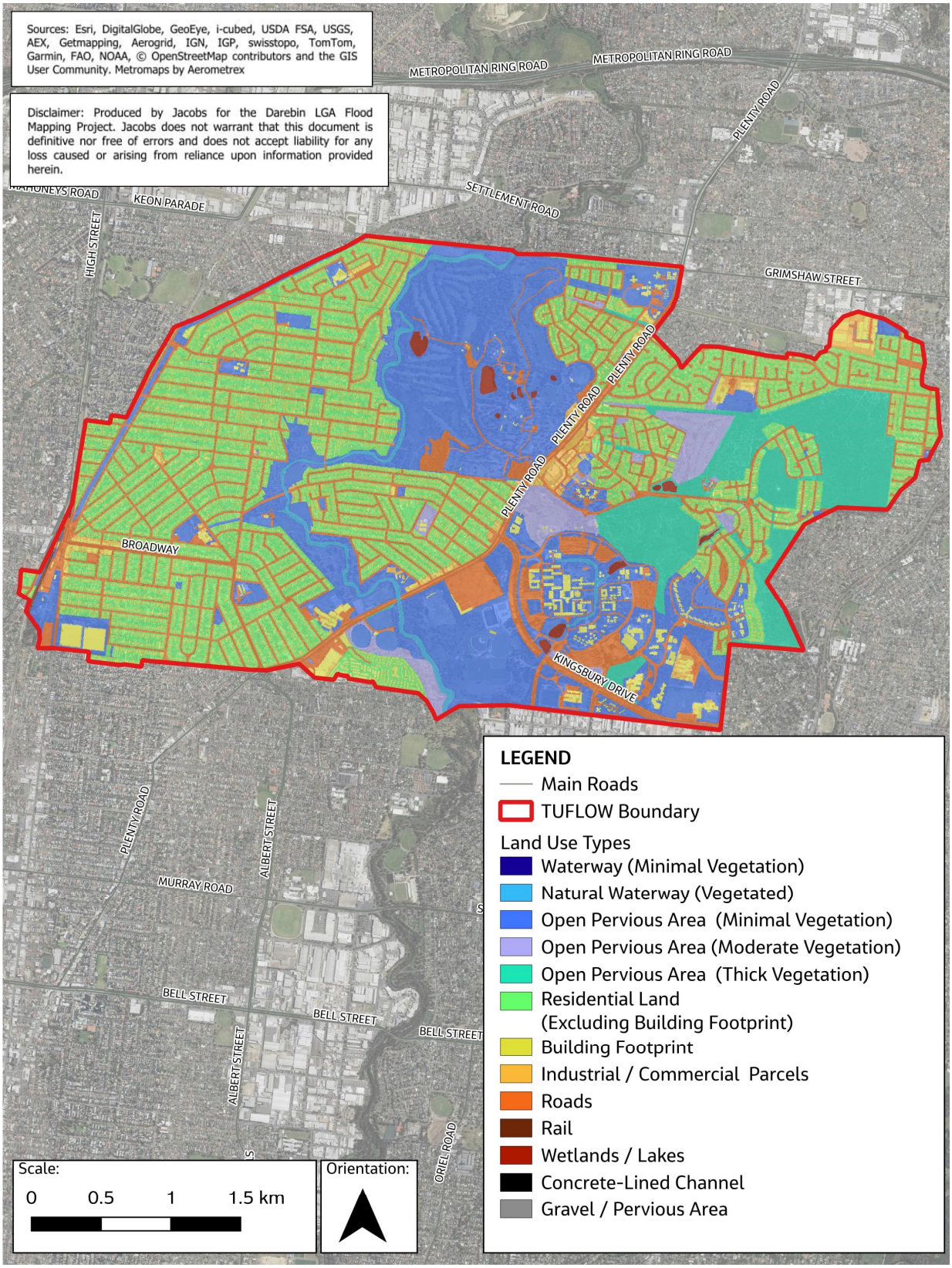
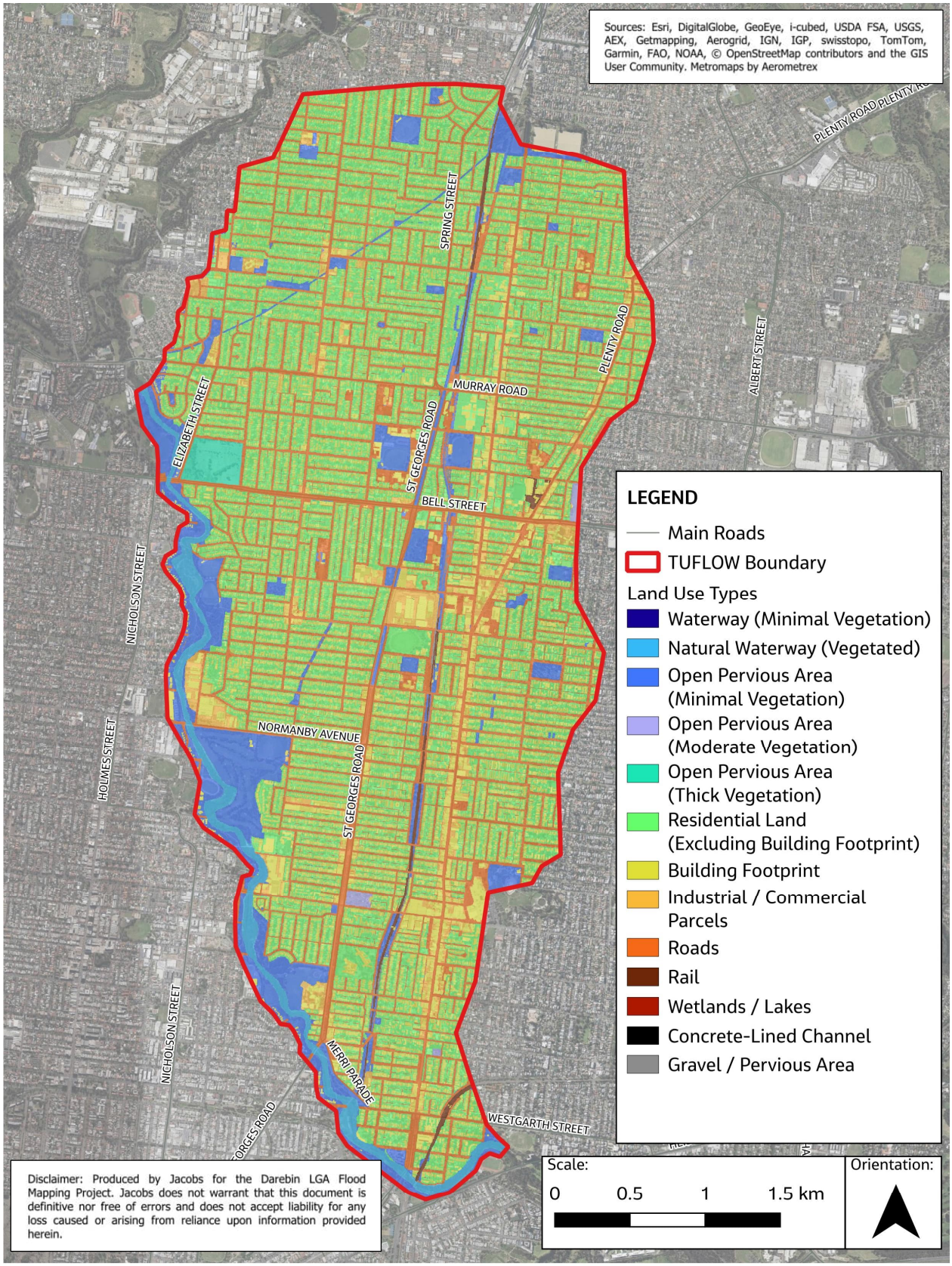
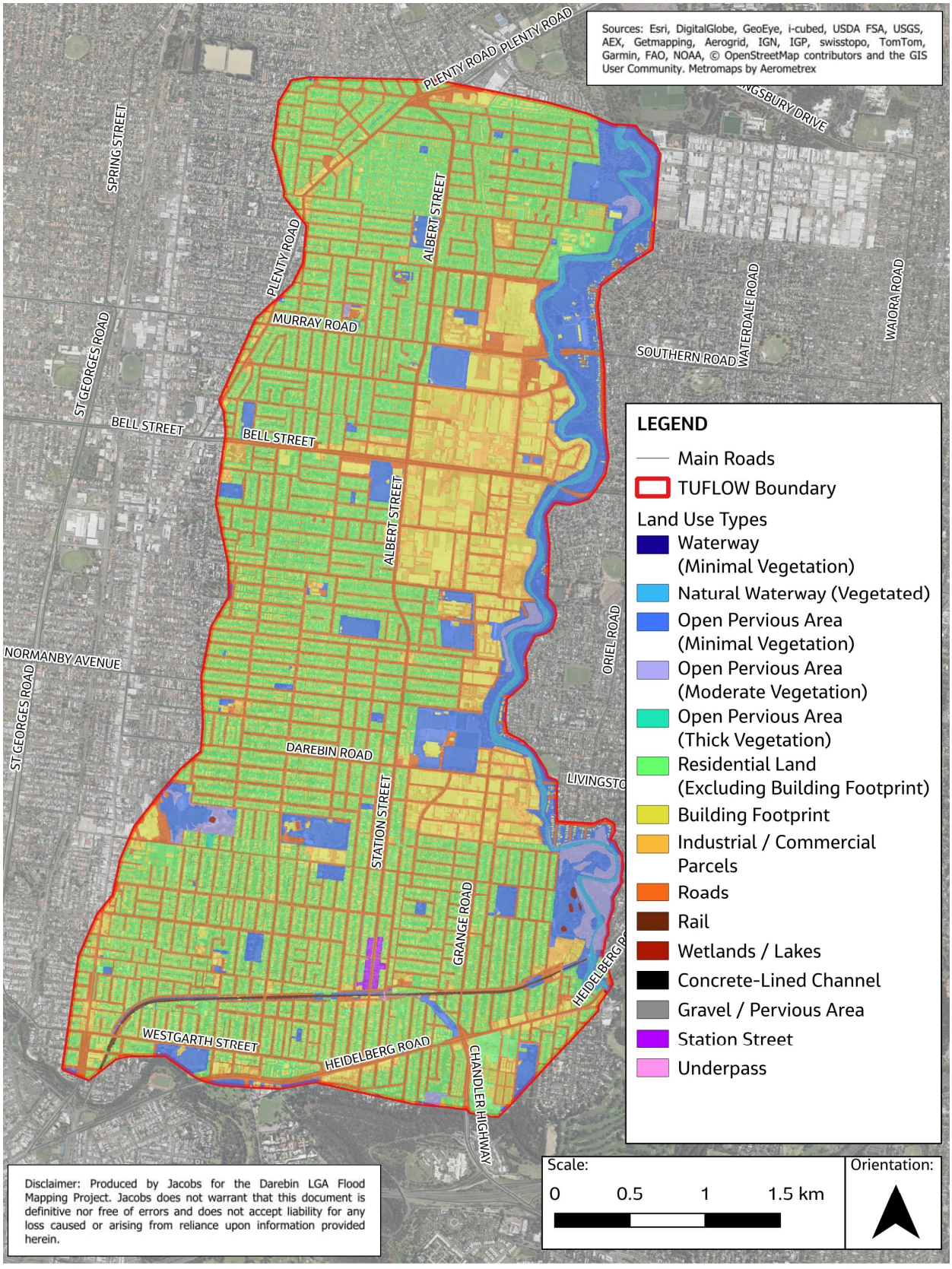


Figure 5-6: Catchment B Model roughness



Model Setup Catchment C

Figure 5-7: Catchment C Model roughness



Model Setup Catchment D

Figure 5-8: Catchment D model roughness

5.3 1-D Network

Underground pit and pipe networks and culverts were represented in 1-D within each model. As per the Melbourne Water Flood Mapping Project Specifications the pits were modelled as 'Q Type pits' with depth-discharge curves developed to allow flow to enter the underground pipe network. Pits were modelled as either: side-entry, grated side entry or grated pits while junction pits were modelled as nodes. The assignment of pit types was based on supplied council and Melbourne Water data. The pits were set to be 0.1 m below the DEM to emulate the concentration of flows at pit locations. The adopted pit types are quantified in Table 5-3.

'R type' pits have been used in areas outside of the Darebin LGA study area where data from previous studies (Table 3-1), specifically the Cardno (2020) study. R type pits are similar to Q type pits where there is a depth-discharge relationship however the relationship is more generic and less representative of the in-situ physical characteristics. The pits were sized to assume they had sufficient capacity to fill the pipes (height and width of 1 meter). The application of these pit types is common in TUFLOW. R type pits were only adopted in Model A and B. The pit types were not updated to Q types as they are located outside the study area where the production of flood mapping outputs was not required. This approach was agreed with Melbourne Water.

Where existing models were available, the pit and pipe networks were adopted. In order to develop robust stable models, the following adjustments and checks were made across the 1-D network:

- Pipes were modelled as either:
    - Circular with a diameter set
    - Rectangular with the dimensions set
    - Irregular, required the establishment of a height vs width relationship i.e. for an arch
    - Connector, connectors do not have any physical properties and only connect the ends of 1d networks to nodes
- The QGIS TUFLOW 1d-Integrity tool was adopted to improve the health of the 1-D network.
    - The QGIS TUFLOW 1d-Integrity tool is a plugin added to the spatial software QGIS. The 1d-Integrity tool enables modellers to find and fix issues with the 1D network in TUFLOW models.
- Pipes were snapped where there were disconnections.
- Pipe directions were corrected as necessary to ensure that all pipes were digitised in the correct direction (i.e., downstream towards outfall).
- If the provided pipe data included missing diameters and inverts, engineering judgement was applied to fill in data gaps where possible. Typically, diameters were set to 375 mm and assumed to be 600mm below the surface level at the upstream pit. Where pipe invert information was missing the geometry layer was manually updated to assign pipe inverts values based on ground elevations, 600mm of cover and upstream and downstream points.
- A cover check to determine if any pipes were located "above ground" using the DEM was completed. If pipes were found to be above ground inverts were adjusted accordingly.
- In instances where there were 1d stability issues a nodal area was added to pits to achieve stability.
- Adopted losses and contraction coefficients;
    - 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 = 0.5.
    - Exit loss coefficient = 1.0.

Figure 5-9 to Figure 5-12 present the 1d network setup for each model including the pit network ('Q', 'R' and 'nodes'), pipe network (circular, rectangular and irregular) plus the 'CN' and 'SX' connections between the 1d and 2d domain.

Table 5-3: Count of pit types across the TUFLOW models.

Pit Type	VicRoads standard pit type	Model A	Model B	Model C	Model D
Side Entry Pit	Standard Drawing 1301 - Side Entry Pit - B Type Curb - 1m Inlet	2,222	2,580	3,117	3,829
Grated Side Entry Pit	Standard Drawing 1322 - Grated Side Entry Pit - B Type Curb - 1m Inlet	93	117	657	552
Grated Pit	Standard Drawing 431 - Grated Pit - Flush Steel Grate - 1m x 1m Inlet - Grate Type B	189	273	1244	857

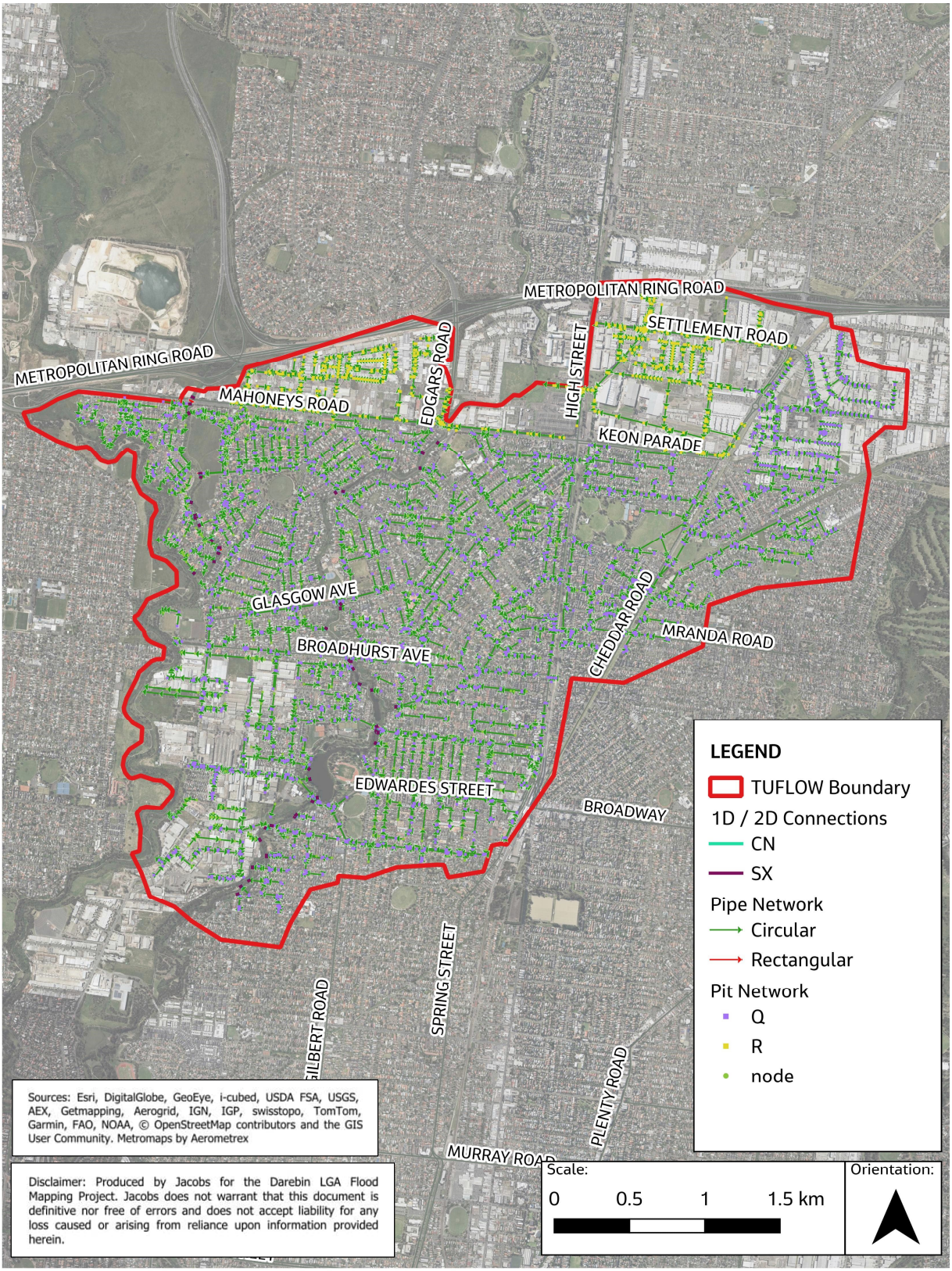
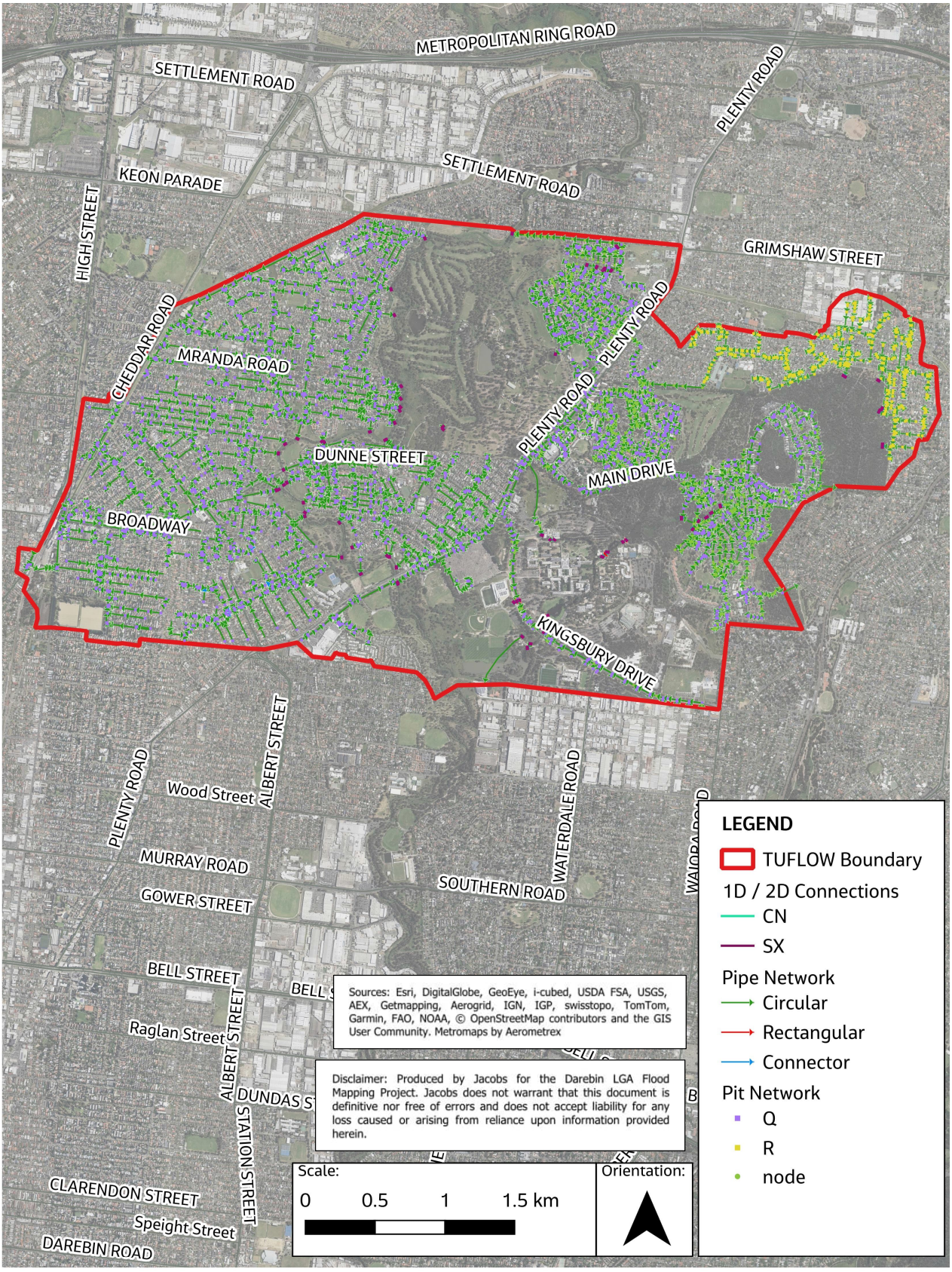
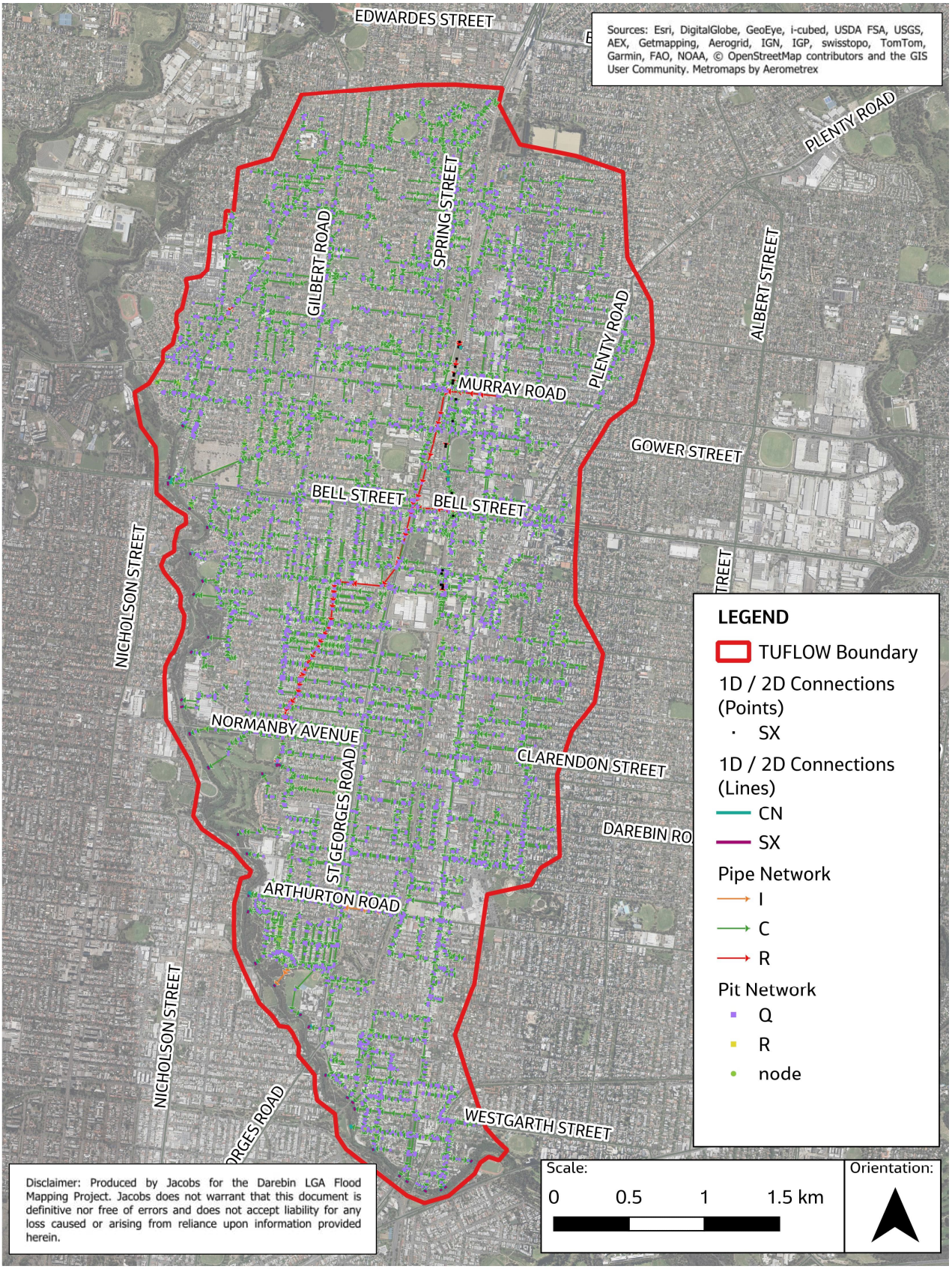


Figure 5-9: Catchment A Model Network



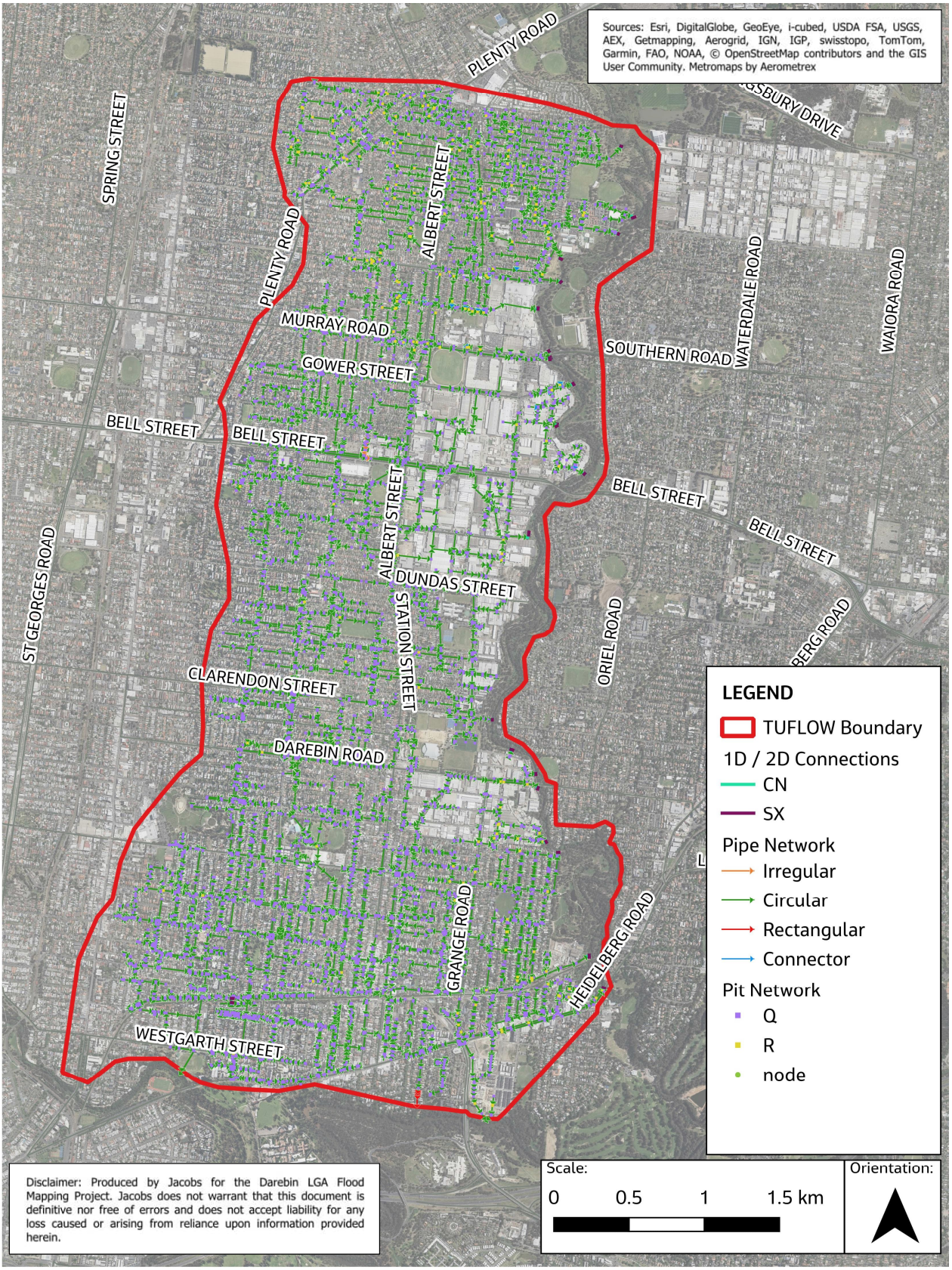
Model Setup Catchment B

Figure 5-10: Catchment B Model Network



Model Setup Catchment C

Figure 5-11: Catchment C Model Network



Model Setup Catchment D

Figure 5-12: Catchment D Model Network

5.4 Boundary Conditions

The model boundary conditions setups are presented in Figure 5-13 to Figure 5-16 and discussed in the sections below.

5.4.1 Internal Inflows

Across all four TUFLOW models rainfall-excess hydrographs from the respective RORB models were applied to the pit and pipe network that overlapped with the RORB sub catchments. The adopted method applied inflow to the top of the pits (2d_sa PITS option) which enables the 2d cell the pits are connected to and the 1-D pits (Q and R types) to be engaged. This method aligns with the recommendations in the Melbourne Water Flood Mapping Project Specifications.

For areas without pit information, streamlines were applied to concentrate rainfall excess information along overland flow paths. Pipes that outlet into the 2-D domain were connected either with 2d points or 2d CN/SX lines on culverts larger than the model grid size.

In Model A, flows in the area north of the Darebin LGA (in Hume LGA) between Mahoneys Road and the Western Ring Road have been based on the Cardno (2020) Edgars Creek RORB model (Figure 5-13). This area was incorporated to capture flood interactions across the LGA boundaries. This Cardno (2020) hydrological model was reviewed against the current Melbourne Water Flood Mapping Projects Specifications and considered suitable for use in this study. No updates were made to the RORB .catg files. To generate rainfall-excess hydrographs for input into the TUFLOW models the provided Cardno (2020) models were simulated with the following RORB parameters:

- IFD and pre-burst patterns (adopted as per Model A)
- Initial loss and continuous loss: 10 mm and 2.5 mm/h (from Cardno 2020).
- Is it noted the Cardno (2020) approach did not explicitly split the losses in PA/EIA/ICA. Instead Cardno adopted an approach of estimating the effective impervious area in accordance with ARR 2019 Version 4.1 to enable the application of one set of losses into TUFLOW. Jacobs concluded this approach to be reasonable.

5.4.2 Water retaining structures

An initial water level was applied across Model B as a shapefile to infill waterbodies (i.e. lakes, dams, etc) located with La Trobe University and the Bundoora Golf Course. The initial water levels were set to be at the full supply level (i.e., crest) of the storages.

5.4.3 Flood levels in receiving waterways

The Darebin LGA interacts with the following creeks/waterways:

- Merri Creek (Model A and C)
- Darebin Creek (Model B and D)
- Edgars Creek and Central Creek (Model A)
- Yarra River (Model D)

Each of these waterways originate outside of the Darebin LGA. To simplify the study steady state water levels were assumed in the receiving waterway, with the following relationship adopted in collaboration and agreement with Melbourne Water:

- 1% AEP with climate change storm event
    - 5% AEP flood level in the receiving waterway
- 1% AEP storm event
    - 10% AEP flood level in the receiving waterway
- 2% AEP storm event
    - 10% AEP flood level in the receiving waterway
- 5% AEP storm event
    - 10% AEP flood level in the receiving waterway
- 10% AEP with climate change storm event
    - 20% AEP flood level in the receiving waterway
- 10% AEP storm event
    - 20% AEP flood level in the receiving waterway
- 20% AEP with climate change
    - 20% AEP flood level in the receiving waterway
- 20% AEP storm event
    - 20% AEP flood level in the receiving waterway

Data for the 20% AEP, 10% AEP and 5% AEP design flood levels in the receiving waterways was not available at the commencement of this study. To generate this information outputs from previous studies were reviewed and upstream flows extracted, this is detailed in Table 5-4.

To generate an initial water level profile for the Merri Creek, Darebin Creek, Edgars Creek and Central Creek the respective catchment TUFLOW models were simulated with a steady state flow (Table 5-5) at the upstream boundary of each model. For these simulations it was assumed there was no catchment inflow from the Darebin LGA. This approach 'infilled' the receiving waterways based the flows in Table 5-5. The resulting flood extent along each waterway was converted into an initial water level grid for addition as a boundary condition in each of the TUFLOW models.

For pipes connected to waterways initial water levels (points) were applied to the pipe inverts that were below the generated waterway initial water levels. This was adopted to match the initial water levels in the waterway at pipe outlets to avoid the potential surge or backflow at the start of the design event simulations. The location of the initial water level points are provided in Figure 5-13 to Figure 5-16.

Sensitivity of the adopted boundary conditions is documented in Section 8.1.

Table 5-4: Derivation of boundary conditions (refer to section 3, Table 3-1)

	Darebin Creek	Edgars Creek/Central Creek	Central Creek	Yarra River	Merri Creek
Source of data	Cardno (2020) Darebin Creek Flood Mapping plus information from the Enengy (2022) Bundoora -Banyule outputs. Information extracted from the PO lines from the GIS deliverables	Cardno (2020) Edgars Creek Flood Mapping Information extracted from the PO lines from the GIS deliverables	Cardno (2020) Edgars Creek Flood Mapping Information extracted from the PO lines from the GIS deliverables	Melbourne Water database flood contours (MW GIS database)	Melbourne Water HEC-RAS model of Merri Creek (model supplied by MW)

Table 5-5: Adopted method for water levels in receiving waterways

Waterway	Relevant Model	Method to extract flows for the boundary AEP conditions: 20% AEP (10% climate change to 20% AEP design event) 10% AEP (5% to 1% AEP design events) 5% AEP (1% AEP Climate Change design events)
Darebin Creek	Model B Model D	For the 20%, 10%, 5% adopted a steady state upstream inflow into Model B of 55 m^3/s, 71 m^3/s and 92 m^3/s respectively (flows extracted from the Cardno 2020 Darebin Creek GIS Deliverables). This method was continued through to Model B, that is the outputs from B were applied to the upstream end of Model D. No increase in these flows was applied through the models with an increasing contributing catchment. The application of a steady state inflow likely results in a conservative boundary level.
Edgars Creek	Model A	For the 20%, 10% and 5% adopted a steady state upstream inflow into Model A of 22.7 m^3/s, 35.8 m^3/s and 43.9 m^3/s respectively (flows extracted from the Cardno 2020 Edgars Creek/Central Creek GIS Deliverables).
Central Creek	Model A	For the 20%, 10% and 5% adopted a static upstream inflow into Model A of 17.4m^3/s, 23.7 m^3/s and 28 m^3/s respectively.
Yarra River	Model D	Adopted a static level based on the contour information on Melbourne Water pipe outlets (Fairfield Main Drain) 10% AEP: 13.13 m AHD 20% AEP: 12.06 m AHD Note, overland flooding from the Yarra River does not interact with the Darebin LGA.
Merri Creek	Model A Model C	Convert the peak water level for the 20%, 10% and 5% events into a peak water level surface.

5.4.4 Boundaries along the model domain

Height versus time 'HT' boundaries were applied on waterways at the downstream end of each model. The HT levels were based on the generated water level surfaces in the receiving waterways.

Automatically generated Height vs Flow 'HQ' boundaries were applied to locations where water exits the 2D model domain to enable water to freely drain from the TUFLOW models. HQ boundaries enable the TUFLOW model to calculate the level based on the level, flow and slope at the boundary. The slope is a user input typically based upon the approaching water level profile grades.

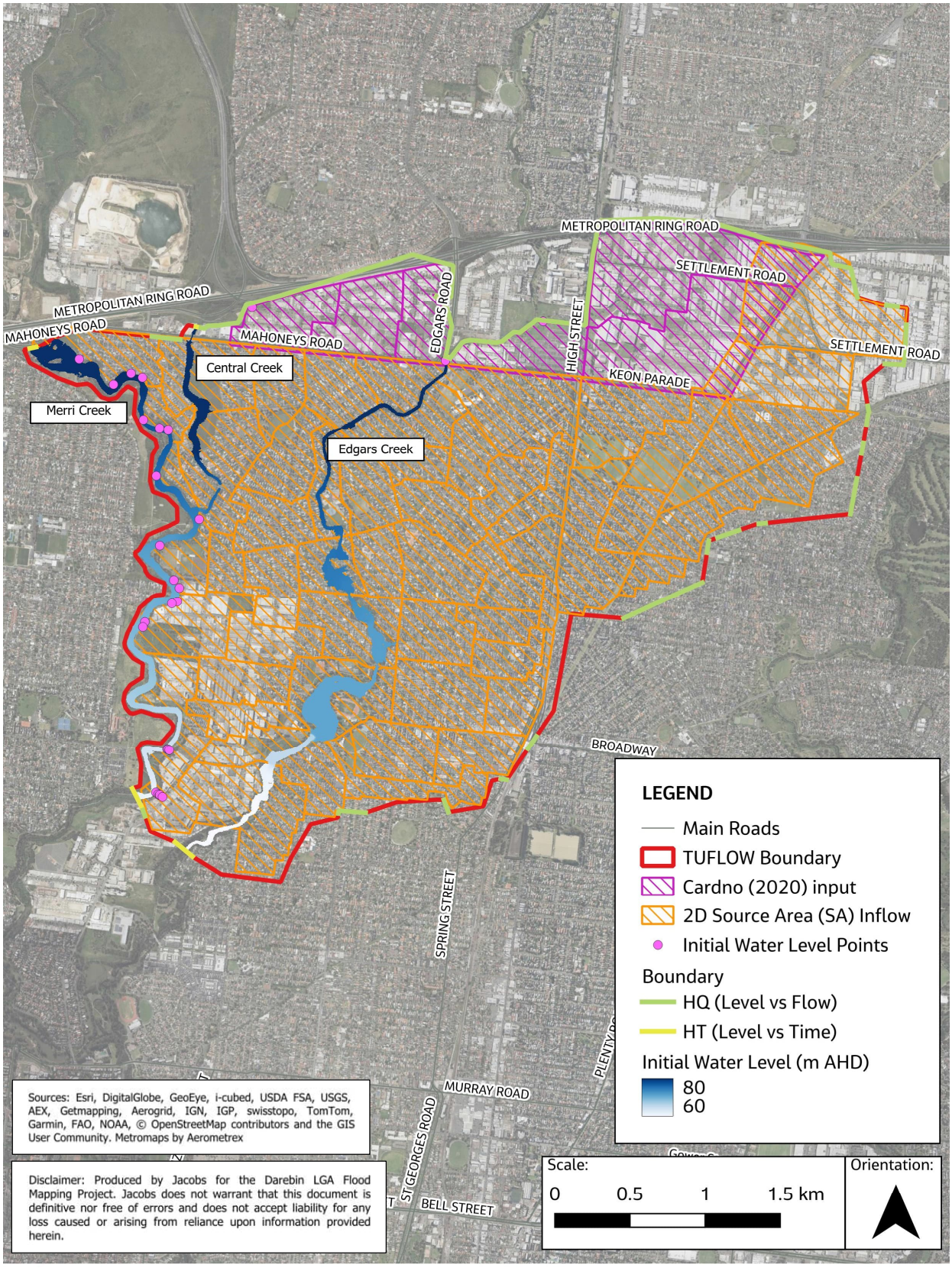
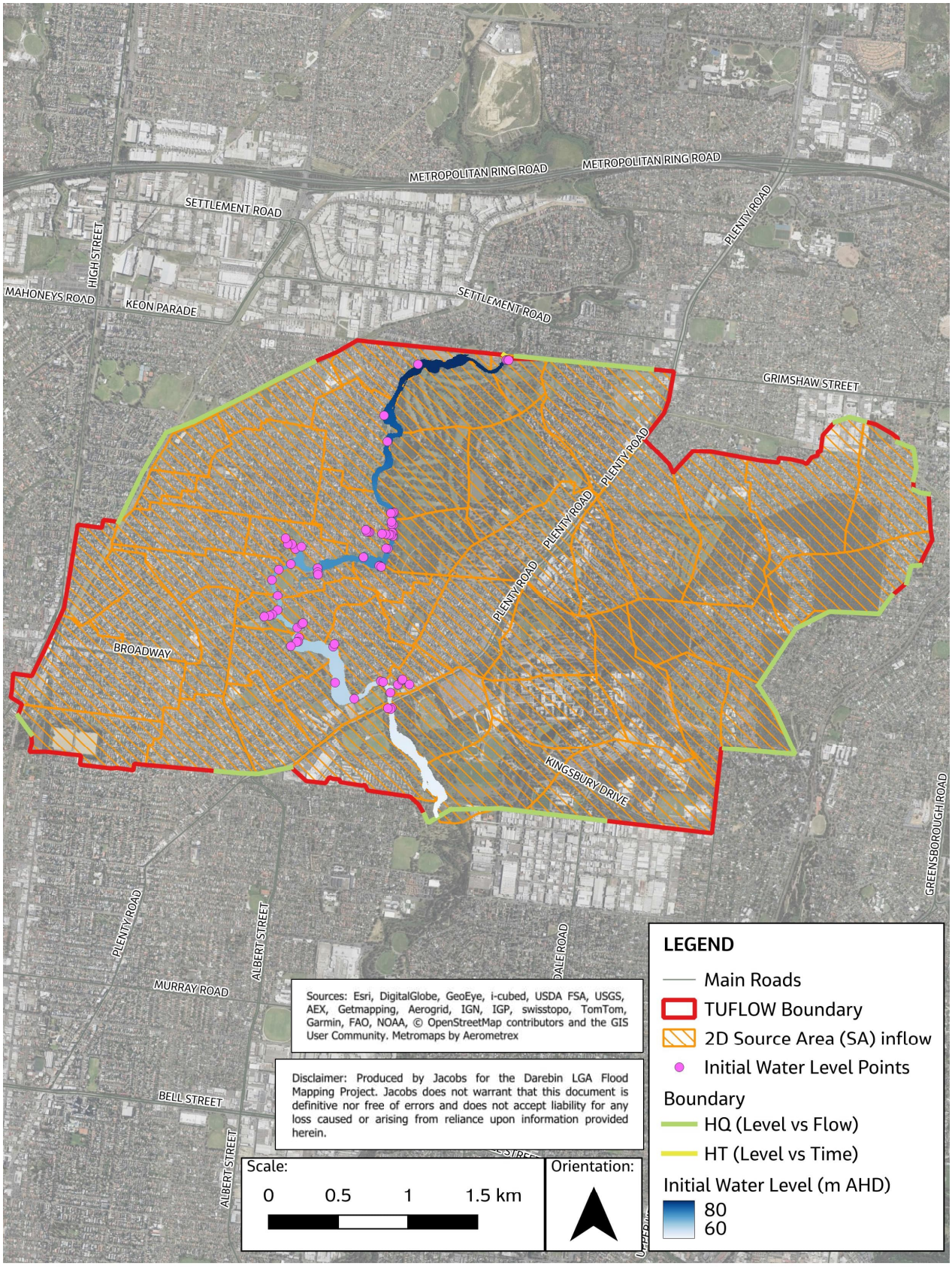
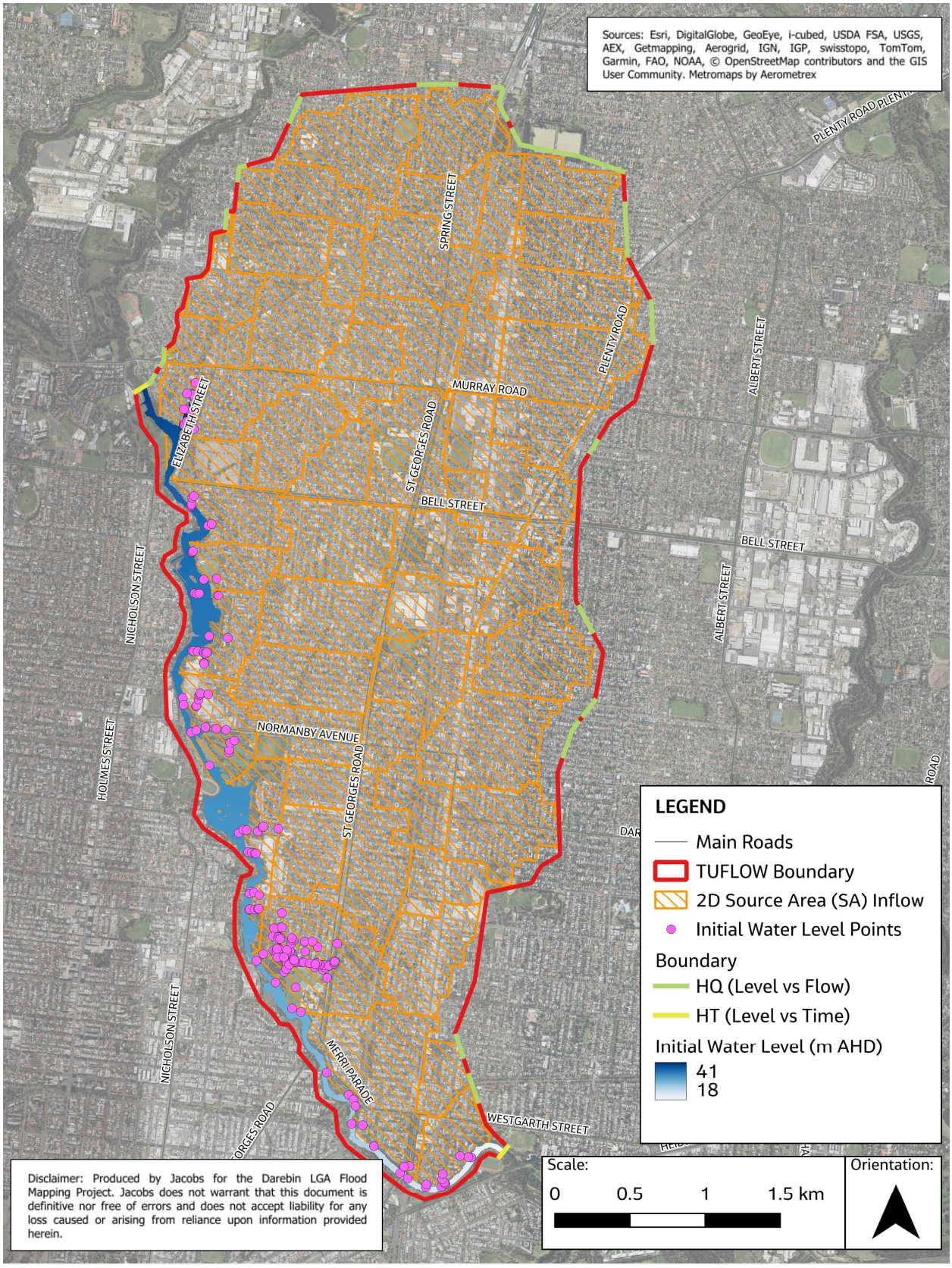


Figure 5-13: Catchment A Model boundaries and initial water levels



Model Setup Catchment B

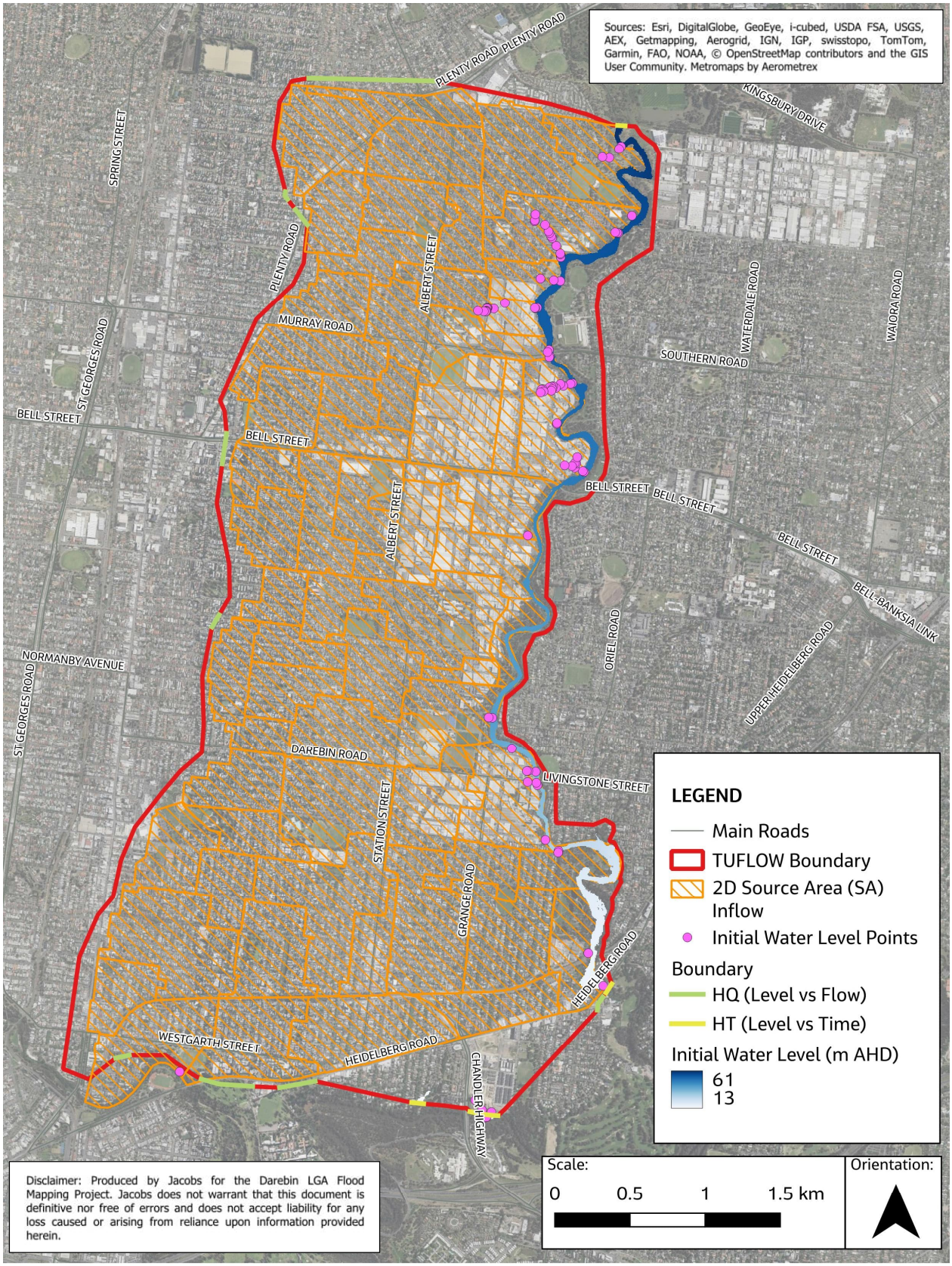
Figure 5-14: Catchment B Model boundaries and initial water levels



Model Setup Catchment C

Jacobs

Figure 5-15: Catchment C Model boundaries and initial water levels



Model Setup Catchment D

Figure 5-16: Catchment D Model boundaries and initial water levels

5.5 Critical Duration and Temporal Pattern Analysis

The selection of critical durations and temporal pattern selection across the study area was based on the following process:

1. Convert the quadtree TUFLOW models developed in Section 5 to an 8 m grid model. Sub grid sampling (SGS) was enabled to capture the terrain resolution within each 8 m grid. Minor adjustments were made to the connected of the 1-D pit and pipe network to the 2-D domain to cater for the adjusted grid size.

2. Simulate the ensemble of ten temporal patterns for each duration for the 1%, 10% and 20% AEP event across the four models. The RORB areal reduction factor was set to represent an area of 1km^2 (further discussed in 4.3.2).

3. Determine the median temporal pattern grid (based on flood level) for each duration listed in Table 5-6 to Table 5-8.

4. Determine the maximum flood level grid for the 1%, 10% and 20% AEP event across all the durations. The maximum grid represents a model's peak water level that envelops all of the simulated durations for each AEP.

5. Analyse the maximum flood level grid across each of the four models:

    - Convert the maximum flood level source grid to a vector (shapefile) to enable geo-processing of the outputs. The source grid is a file that is produce that spatially indicates which duration the flood level represents at each grid cell across the model domain.

    - Calculate the area of each critical duration and percent coverage of each duration across the flood extent. Review the analysis as well as a visual inspection of the maximum depth grids to select an appropriate range of critical durations for each model. This considered the percentage of each area and any floodplain storage within each model.

    - Based on the selected critical durations the median temporal pattern grids for each duration were reviewed to select a representative median temporal pattern.

The selected durations and temporal patterns are provided in Table 5-6 to Table 5-8. The temporal pattern naming convention has been adopted from the RORB outputs. Contributing areas for each duration are provided in Table 5-9.

Table 5-6: Critical durations and temporal patterns (1% and 2% AEP)

Duration	Catchment Model and Selected Temporal Pattern			
	A	B	C	D
10 min	26	26	26	26
15 min	Non critical	Non critical	Non critical	Non critical
20 min	27	25	25	25
25 min	Non critical	Non critical	Non critical	Non critical
30 min	22	25	22	22
45 min	26	26	26	26
1 hour	28	28	28	28
1.5 hour	Non critical	26	29	29
2 hour	Non critical	27	Non critical	Non critical
3 hour	27	Non critical	Non critical	28
4.5 hour	28	Non critical	Non critical	Non critical
6 hour	Non critical	Non critical	Non critical	Non critical

Table 5-7: Critical durations and temporal patterns (10% and 5% AEP)

Duration	Catchment Model and Selected Temporal Pattern			
	A	B	C	D
10 min	18	14	18	18
15 min	12	12	12	12
20 min	18	18	Non critical	Non critical
25 min	14	13	20	20
30 min	11	11	18	18
45 min	13	-	12	-
1 hour	19	19	16	19
1.5 hour	Non critical	Non critical	Non critical	Non critical
2 hour	19	17	15	19
3 hour	Non critical	Non critical	Non critical	18
4.5 hour	18	Non critical	Non critical	Non critical
6 hour	Non critical	15	Non critical	Non critical

Table 5-8: Critical durations and temporal patterns (20% AEP)

Duration	Catchment Model and Selected Temporal Pattern			
	A	B	C	D
10 min	5	5	10	10
15 min	6	6	5	6
20 min	7	7	2	6
25 min	6	6	6	6
30 min	-	-	-	3
45 min	3	3	1	1
1 hour	4	7	4	7
1.5 hour	Non critical	Non critical	3	2
2 hour	Non critical	Non critical	Non critical	2
3 hour	5	Non critical	Non critical	Non critical
4.5 hour	-	Non critical	Non critical	Non critical
6 hour	8	9	Non critical	Non critical

Table 5-9: Contributing area from each duration across each model (1% AEP)

Duration	Catchment Model and Contributing Area Percentage			
	A	B	C	D
10 min	12%	5%	9%	9%
15 min	5%	1%	3%	2%
20 min	40%	38%	43%	38%
25 min	2%	2%	2%	2%
30 min	20%	21%	20%	21%
45 min	6%	8%	5%	6%
1 hour	8%	8%	12%	7%
1.5 hour	2%	7%	6%	10%
2 hour	<1%	6%	<1%	<1%
3 hour	2%	1%	<1%	4%
4.5 hour	2%	1%	<1%	<1%
6 hour	<1%	<1%	<1%	1%

6. Quality Assurance

The TUFLOW model has been reviewed in accordance with Melbourne Water's Quality Assurance (QA) Framework spreadsheet to confirm the health of the models.

The model has undergone an independent peer review by an external consultant in line with the project requirements.

7. Results

7.1 Storm Events and Scenarios

Modelled scenarios include the 1% Annual Exceedance Probability (AEP), the 1% AEP plus climate change scenario, and a range of frequent events, consistent with Melbourne Water's standard modelling approach.

7.2 GIS Deliverables

In accordance with the Melbourne Water's requirements flood mapping outputs have been delivered to Melbourne Water. Data provided is summarised in Table 7-1.

Table 7-1: Deliverables

Deliverable	Comment
Hydrology model	The RORB model including the setup files and outputs have been provided to MW.
Hydraulic model	The TUFLOW model build files and results (zipped) have been provided to MW. Post processing grids of the results (i.e., the calculation of the max-max grid for each AEP) has also been provided)
GIS Deliverables	In accordance with the Melbourne Water Project Specifications (July, 2020), including flood extent, flood hazard and parcels flooded. Melbourne Water's filtering guidelines have been applied to the flood model results when developing the flood extents. Flood modelling can sometimes produce results that show very shallow water or isolated puddles that do not represent a genuine flood hazard. To ensure the flood maps are meaningful and relevant to the community safety, Melbourne Water applies filtering rules to remove these minor features. Specifically: • Water depths less than 5 cm are considered too shallow to pose a real hazard and are excluded from the flood extent. • Isolated areas of inundation smaller than 100 square metres are also excluded. These filters help remove technical "noise" so the maps focus on areas where flooding could cause problems during a major storm.
Flood Maps	Flood extents for the 1% AEP and 1% AEP with climate change events are provided Appendix D.

8. Sensitivity Analysis and Model Checks

8.1 Boundary Conditions

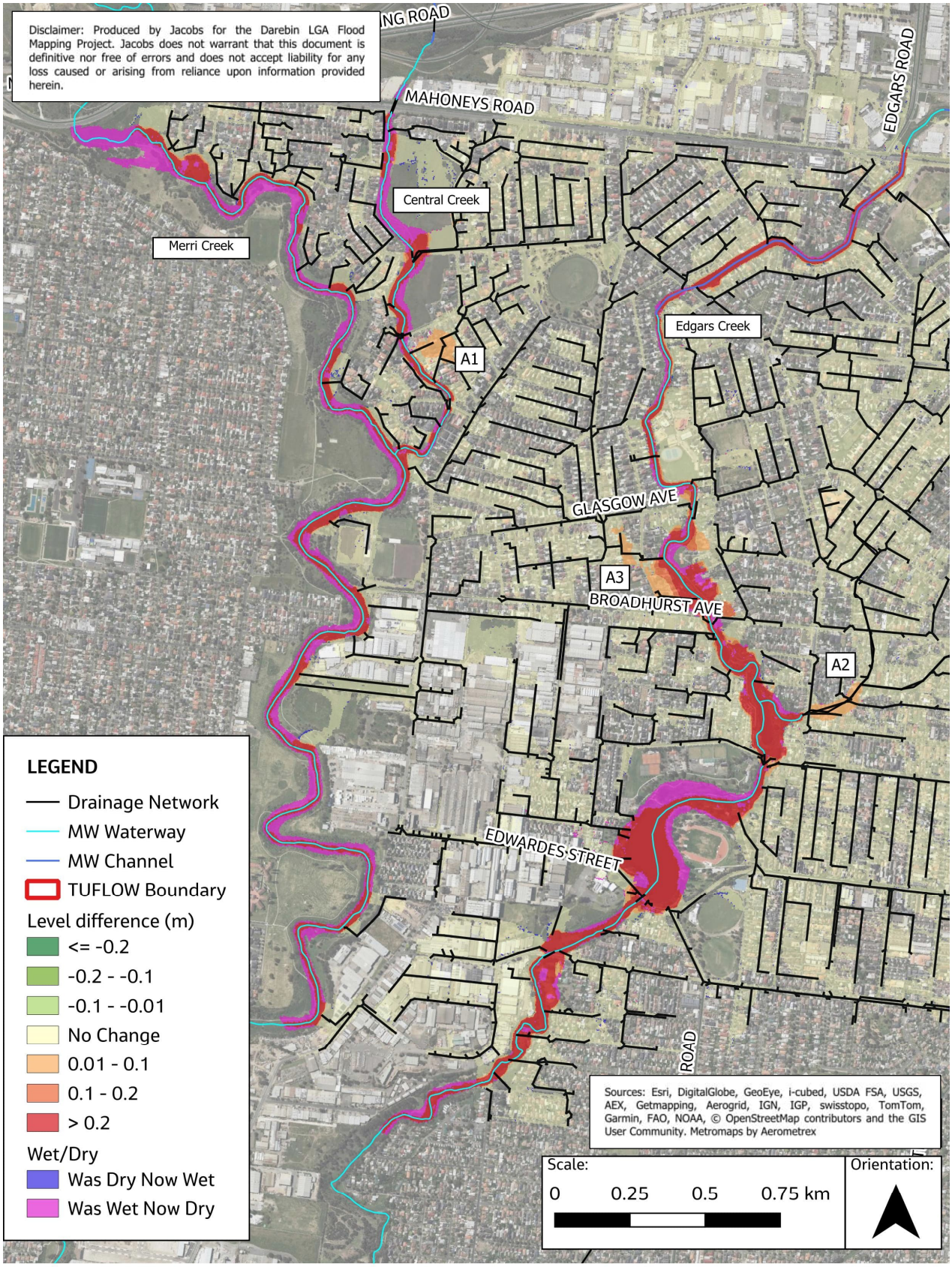
The application of the boundary conditions (refer section 5.4) assumes there is a flood event in the receiving waterways. Small, urbanised catchments like those in this study with high imperviousness can results in short duration peak flood events entering receiving waterways with relatively dry antecedent conditions. A sensitivity test on three of the four hydraulic models was completed which assumed free discharge conditions on all pipe outlets draining into waterways. Peak water level difference grids for a 1% with Climate Change AEP storm have been generated for models in catchments A, B and D model (see. Figure 8-1 to Figure 8-3). The figures present the difference in the adopted peak water surface elevation minus the free discharge scenario.

The colour scheme on the figures represents the change in water level. For example, red indicates there is over a 0.2 metre increase in the peak water level. The results of the analysis are discussed in Table 8-1.

Overall, the influence of the adopted boundary condition approach has minor to negligible influence on the flood extents and levels across the study area.

Table 8-1: Contributing area from each duration across each model

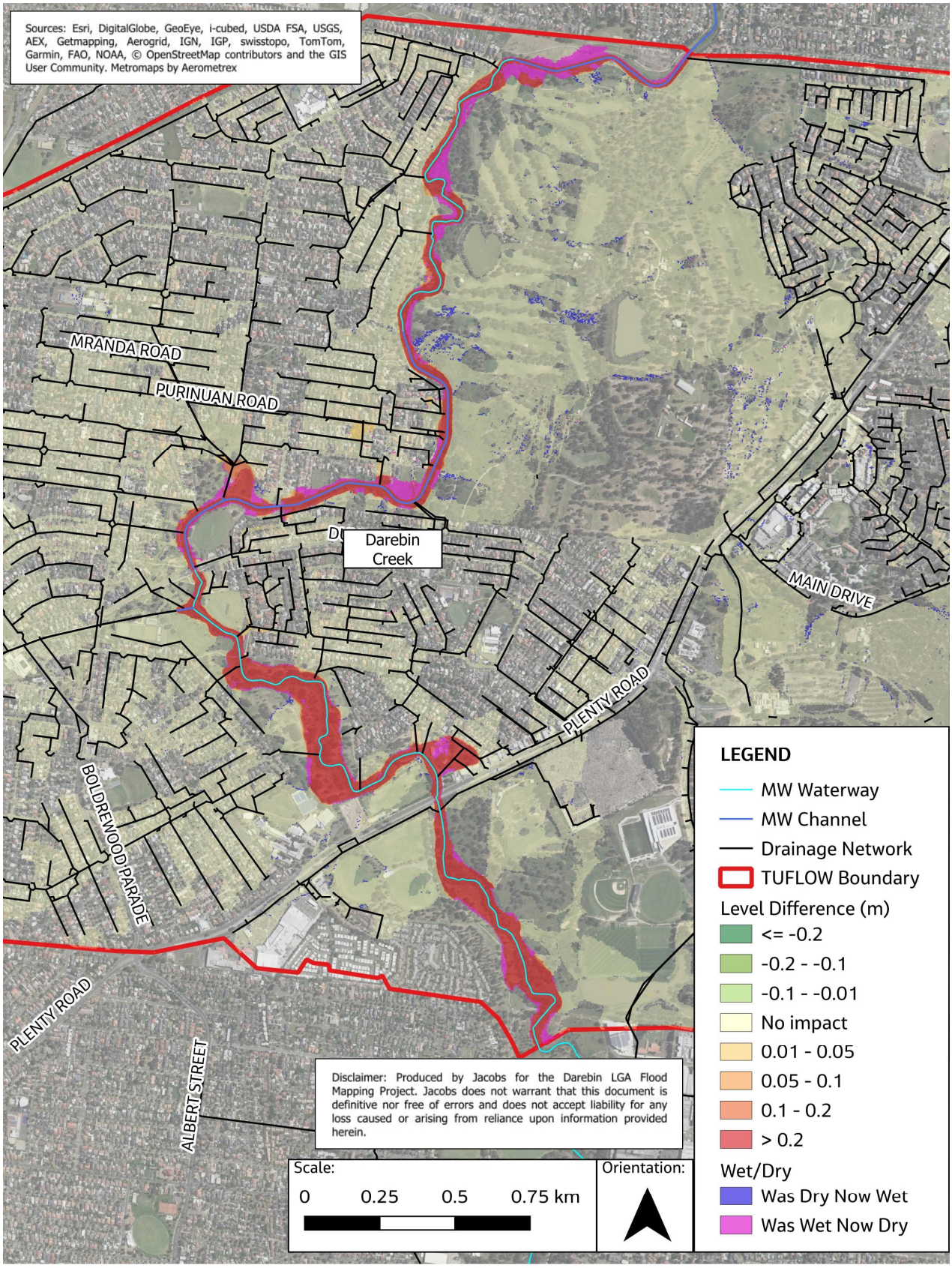
Catchment	**Results**
A (Figure 8-1)	• The influence of Merri Creek water levels is restricted to the waterway and regions adjacent to the waterway. • The influence of Central Creek is primarily restricted to the waterway. The area at Point A1 maybe impacted by up to 15 mm by a constricted drainage network due to high levels in Central Creek. • The influence of Edgars Creek is primarily restricted to the waterways. The area at Point A2 maybe impacted up to 20 mm by a constricted drainage network that outlets into Edgars Creek Wetlands. Upstream of Broadhurst Avenue (Point A3) maybe influenced by the restriction at this location by up to 15mm. • The locations identified above will likely be dominated by Edgars Creek flooding.
B (Figure 8-2)	• The influence of Darebin Creek water levels is primarily restricted to the waterway and regions adjacent to the waterway. • There is minor influence near the Purinuan Road Drain outlet however flooding in this area will likely be dominated by the Darebin Creek flooding. • Overall there is little influence and interaction between the modelled waterway levels and the urban drainage.
D (Figure 8-3)	• The influence of Darebin Creek water levels is restricted to the waterway and areas adjacent to the waterway. There is little influence and interaction between the modelled waterway levels and the urban drainage. • The water level changes on the figure in the south-west corner (Wingrove Street) were associated with some model discrepancies and not associated with the tailwater sensitivity assessment.



Sensitivity Catchment A Boundary Conditions

Jacobs

Figure 8-1: Peak water level difference Model A (Adopted boundary levels minus no boundary conditions)



Sensitivity Catchment B Boundary Conditions

Jacobs

Figure 8-2: Peak water level difference Model B (Adopted boundary levels minus no boundary conditions)

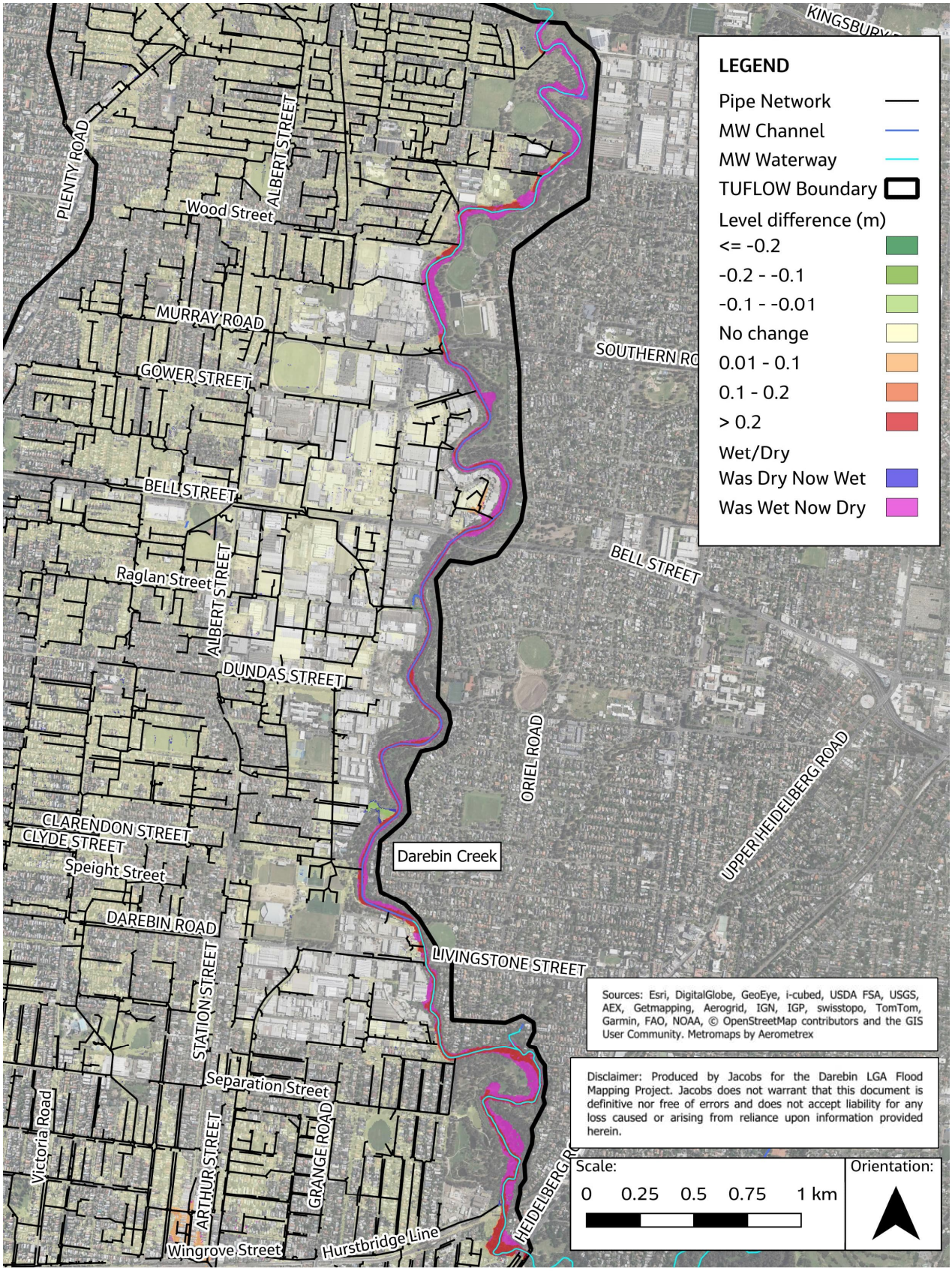


Figure 8-3: Peak water level difference Model D (Adopted boundary levels minus no boundary conditions)

8.2 Model performance against flood marks

A significant rainfall event occurred over the Darebin LGA on the 2-3 December 2003. Rainfall totals in excess of 90 mm were recorded within a space of 2 hours, and flash flooding was recorded through the suburb of Fairfield (catchment D) and the surrounding area. Based on the IFD dataset adopted for this study this event was equivalent to a 0.1% to 0.05% AEP rainfall event (between a 1 in 1000 to 1 in 2000).

Following the event Melbourne Water conducted a field survey to document physical evidence of flooding, such as debris lines on structures and visible water marks. The flood marks captured by the surveyors are provide in the Appendix E.

An analysis was completed by Cardno Lawson Treloar (2005) which documented the event and simulated the event in a hydrological and hydraulic model. The conclusion at the time was the model results adequately captured the behaviour of the 2003 event. Various papers were also written about the event which are documented in Table 3-1.

Jacobs has assessed the 2003 event with this flood model and compared survey data with model outputs, details of this assessment are provided in Appendix E. This assessment was carried out for Catchment D and sought to review the performance of the model against the historical 2003 event (in excess of 20 years ago). Furthermore, it considered the model adjustments required to improve the model performance to the 2003 event. This assisted in identifying the most appropriate set of parameters to adopt for the design flood modelling.

The assessment was not a calibration/validation investigation. To calibrate the model more than one event would be required (ideally 2-3 flood events) to ensure the model can be validated against independent data. The flood mark survey data is useful but has limitations to its accuracy as it provides an approximation of the peak water surface elevations at a specific point in time with specific conditions within the catchment that may vary over time. Various influencing factors such as aleatory and epistemic uncertainty will affect this data and as a result these survey marks are an approximation of the peak water surface elevation. These marks can, and are, affected by factors such as vehicle placement, blockages in drainage networks, temporary and construction works, vegetation, etc.

Generally, there is a good fit across the model domain and the hydraulic model is able to match the hydraulic behaviour of the December 2003 flood event. The performance of the TUFLOW model near Wingrove Street and upstream of the pedestrian underpass was found to plot higher than the flood marks from the 2003 event. The assessment concluded that the flood levels immediately upstream of the pedestrian underpass on Wingrove Street are sensitive to:

- The incoming overland flow (i.e. storm volume).
- The assumed hydraulic capacity of the pedestrian underpass.

The outcomes of the assessment and an understanding of the sensitivities resulted in adjustments to the initial setup of the Catchment D TUFLOW model, including:

- Roughness representation of the commercial zone along Station Street set to 0.5. This increased the water levels along Station Street and marginally reduced the levels on Wingrove Street for the 2003 event.

- Representation of the arched pedestrian underpass at Wingrove Street within the 2-D domain using a reduced TUFLOW model grid size (1 m). This approach enabled a hydraulic representation of the pedestrian underpass that aligned with independent checks.

In completing the assessment, the following was also concluded:

- The RORB model cannot be calibrated to the event due to insufficient data. As a result, there is uncertainty associated with RORB's representation of the 2003 event. No adjustments were made to the RORB models to reflect the model sensitivity at Wingrove Street.
- There are two flow paths to the Wingrove Street pedestrian underpass, one to the north-east along Station Street and the other from the north along Arthur Street. A difference in timing of these two flow paths reaching the underpass would influence the levels upstream.
- The model performs well to the flood marks downstream of the Wingrove Street pedestrian underpass.

9. Recommendations

The flood models have been developed in accordance with the Melbourne Water Flood Mapping Projects Specifications, ARR 2019 Version 4.1 guidelines and in consultation with Melbourne Water. Riverine flooding was not assessed as part of this flood study. The flood models and the associated datasets should be used to update and inform planning overlays, emergency response, climate change adaptation and floodplain management activities that typically follow a flood mapping study.

9.1 Data recommendations

- It is recommended that a procedure be developed for capturing flood data immediately following flood events. It is envisaged that this would include capturing social media feeds, newspaper articles, SES call out records, road closures, information collected by Council as well as data collection such as flood marks, aerial photography (oblique and plan), drone survey etc.

- Updated LiDAR dataset and aerial photography should inform any future study revisions.

9.2 Stakeholder communication

- It is recommended that the results of this study are communicated to stakeholders and the wider community. It is envisaged that when these results are communicated there will be feedback from the community. This feedback could provide valuable information to enhance the confidence in the results or highlight areas for improvement. It would also be beneficial to provide these results in an online platform to allow rapid dissemination of this information.

9.3 Hydrology recommendations

- Losses have been adopted from the ARR Data Hub as this was the most reliable loss estimate at the time of the study. In future modelling, it is recommended that losses adopted in nearby gauged catchments such as Merri-Creek and Darebin Creek are considered for application into future modelling of the LGA.

- It is recommended that the hydrology rainfall inputs and loss parameters be revised in the next round of modelling to incorporate future updates to design rainfall guidelines. The Climate Change Considerations chapter in Australian Rainfall and Runoff (DCCEEW, 2023) is expected to be adopted in late 2024.

9.4 Floodplain management

- The findings from this study may support future decisions regarding flood risk management, catchment planning, risk mitigation strategies, and emergency planning.

9.5 Future flood mapping studies

- It is recommended that modelling be revised every 5 years, or sooner if a major flood event occurs. Revisions to modelling should also adhere to new guidance on climate change, flood hydrology and flood hydraulics.

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- Bell Street Main Drain Flood Mapping
- Broadway Drain and Purinuan Road Drain Flood Mapping
- Elizabeth Street Main Drain Flood Mapping
- Fairfield Main Drain and Green Street Main Drain Flood Mapping
- Preston Main Drain Flood Mapping
- Steane Street Drain Flood Mapping
- Sumner Avenue Main Drain Flood Mapping

Cardno 2020

- Darebin Flood Model Review – Bell Street Main Drain
- Darebin Flood Model Review – Fairfield and Green Street
- Darebin Flood Model Review – Catchment J
- Darebin Flood Model Review – Catchment K
- Darebin Flood Model Review – Catchment N
- Darebin Flood Model Review – Catchment P
- Darebin Flood Model Review – Catchment R
- Darebin Flood Model Review – Elizabeth Main Drain Catchment
- Darebin Flood Model Review – Preston Main Drain
- Darebin Flood Model Review – Steane Street
- Darebin Flood Model Review – Sumner Main Drain Catchment

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- Catchment T – ARR 2019 Modelling Updates

- Catchment U and V – ARR 2019 Modelling Updates
- Catchment X – ARR 2019 Modelling Updates
- Catchment W – ARR 2019 Modelling Updates
- Catchment Z – ARR 2019 Modelling Updates (model results only)

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Appendix A: BoM IFD Data

A.1 Catchment A

A- 1: Catchment A IFD

									Climate change (CC)		
Duration	Duration in min	63%	50%	20%	10%	5%	2%	1%	20%CC	10% CC	1% CC
10 min	10	7.11	8.06	11.4	14.1	17	21.5	25.5	13.5	16.7	30.2
15 min	15	8.66	9.82	13.9	17.2	20.9	26.4	31.2	16.5	20.4	37.0
20 min	20	9.82	11.1	15.8	19.5	23.6	29.9	35.4	18.7	23.1	41.9
25 min	25	10.8	12.2	17.2	21.3	25.8	32.6	38.6	20.4	25.2	45.7
30 min	30	11.6	13.1	18.4	22.7	27.5	34.8	41.2	21.8	26.9	48.8
45 min	45	13.4	15.1	21.2	26	31.5	39.7	47.1	25.1	30.8	55.8
1 hour	60	14.8	16.7	23.2	28.5	34.3	43.3	51.3	27.5	33.8	60.8
1.5 hour	90	17.1	19.1	26.4	32.2	38.7	48.7	57.6	31.3	38.2	68.3
2 hour	120	18.8	21	28.9	35.2	42.2	53	62.6	34.2	41.7	74.2
3 hour	180	21.7	24.1	33	40	47.8	59.8	70.4	39.1	47.4	83.4
4.5 hour	270	25.1	27.9	37.9	45.8	54.7	68.1	79.8	44.9	54.3	94.6
6 hour	360	27.8	30.9	42	50.8	60.4	75	87.6	49.8	60.2	103.8
9 hour	540	32.2	35.9	48.9	59.1	70.1	86.5	101	57.9	70.0	119.7
12 hour	720	35.7	39.9	54.7	66	78.2	96	111	64.8	78.2	131.5
18 hour	1080	41	46.2	63.8	77.2	91.2	111	128	75.6	91.5	151.7

A.2 Catchment B

A- 2: Catchment B IFD

									Climate Change (CC)		
Duration	Duration in min	63%	50%	20%	10%	5%	2%	1%	20%CC	10% CC	1% CC
10 min	10	7.16	8.09	11.4	14.1	17.1	21.7	25.7	13.5	16.7	30.5
15 min	15	8.72	9.86	14	17.3	20.9	26.5	31.5	16.6	20.5	37.3
20 min	20	9.89	11.2	15.8	19.5	23.7	30.1	35.7	18.7	23.1	42.3
25 min	25	10.8	12.2	17.3	21.3	25.8	32.8	38.9	20.5	25.2	46.1
30 min	30	11.6	13.1	18.5	22.8	27.6	35	41.5	21.9	27.0	49.2
45 min	45	13.5	15.2	21.2	26.1	31.5	39.9	47.3	25.1	30.9	56.1
1 hour	60	14.9	16.7	23.3	28.5	34.4	43.4	51.5	27.6	33.8	61.0
1.5 hour	90	17.2	19.2	26.4	32.2	38.7	48.7	57.6	31.3	38.2	68.3
2 hour	120	19	21.1	28.8	35.1	42.1	52.8	62.4	34.1	41.6	73.9
3 hour	180	21.8	24.2	32.9	39.8	47.6	59.5	70	39.0	47.2	83.0
4.5 hour	270	25.1	27.9	37.7	45.6	54.2	67.5	79.1	44.7	54.0	93.7
6 hour	360	27.9	30.9	41.8	50.4	59.9	74.2	86.7	49.5	59.7	102.7
9 hour	540	32.2	35.8	48.6	58.5	69.3	85.4	99.2	57.6	69.3	117.6
12 hour	720	35.6	39.8	54.2	65.3	77.2	94.7	109	64.2	77.4	129.2
18 hour	1080	40.9	46	63.2	76.2	89.9	110	126	74.9	90.3	149.3

A.3 Catchment C

A- 3: Catchment C IFD

Duration	Duration in min	63%	50%	20%	10%	5%	2%	1%	Climate Change (CC) 20% CC	10% CC	1% CC
10 min	10	7.18	8.13	11.5	14.1	16.9	21.3	25	13.6	16.7	29.6
15 min	15	8.74	9.9	14	17.2	20.8	26.1	30.8	16.6	20.4	36.5
20 min	20	9.92	11.2	15.9	19.5	23.5	29.6	34.9	18.8	23.1	41.4
25 min	25	10.9	12.3	17.3	21.3	25.7	32.3	38	20.5	25.2	45.0
30 min	30	11.7	13.2	18.5	22.8	27.4	34.4	40.6	21.9	27.0	48.1
45 min	45	13.6	15.3	21.3	26.1	31.3	39.3	46.2	25.2	30.9	54.7
1 hour	60	15	16.9	23.4	28.5	34.2	42.8	50.2	27.7	33.8	59.5
1.5 hour	90	17.3	19.3	26.5	32.2	38.5	47.9	56.2	31.4	38.2	66.6
2 hour	120	19.1	21.3	29	35.1	41.9	52	60.8	34.4	41.6	72.0
3 hour	180	22	24.4	33.1	39.8	47.3	58.5	68.2	39.2	47.2	80.8
4.5 hour	270	25.3	28.1	37.9	45.6	53.9	66.3	77.1	44.9	54.0	91.4
6 hour	360	28	31.2	42	50.4	59.4	72.9	84.6	49.8	59.7	100.3
9 hour	540	32.4	36	48.7	58.4	68.7	84	97	57.7	69.2	114.9
12 hour	720	35.8	40	54.3	65.1	76.5	93.3	107	64.3	77.1	126.8
18 hour	1080	40.9	46.1	63.2	75.9	89.1	108	124	74.9	89.9	146.9

A.4 Catchment D

A- 4: Catchment D IFD

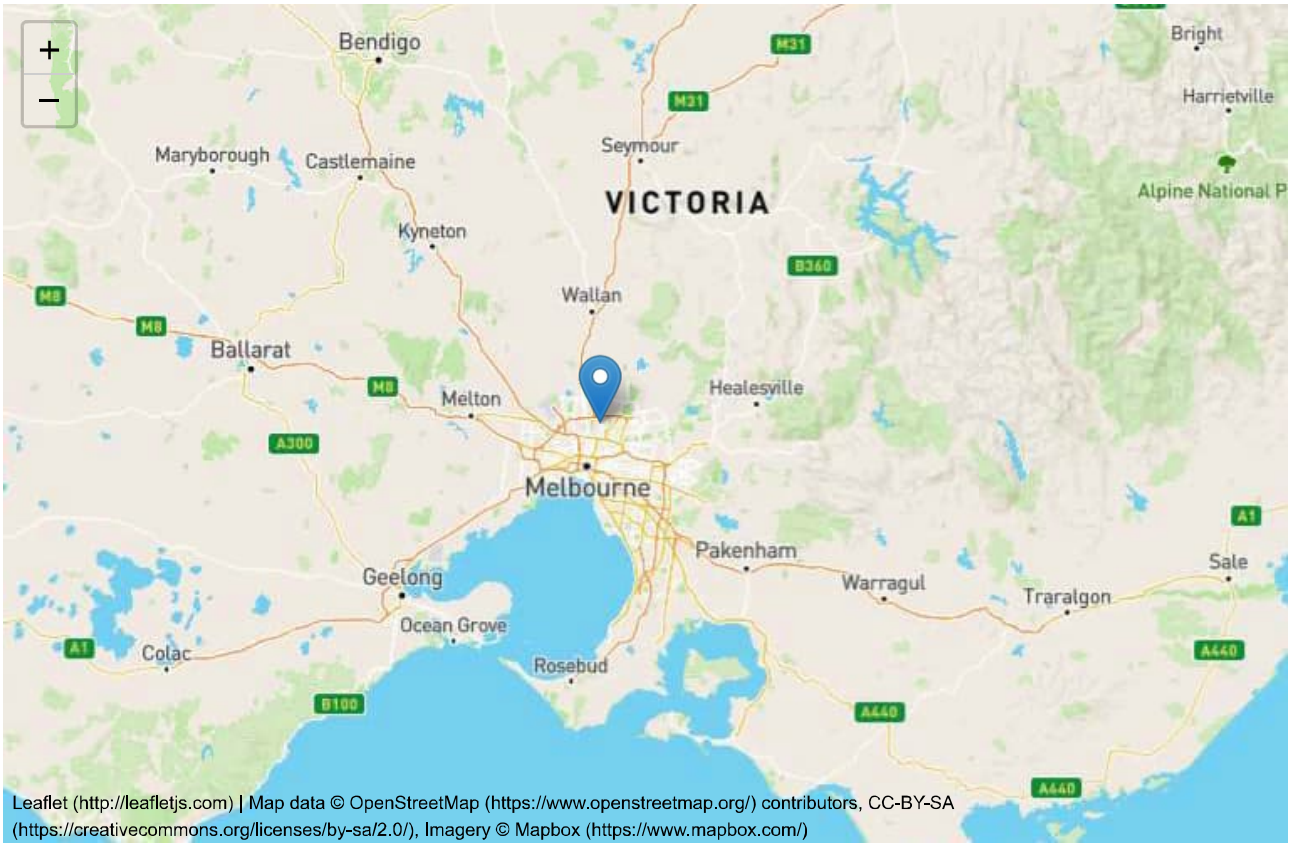
									Climate change (CC)		
Duration	Duration in min	63%	50%	20%	10%	5%	2%	1%	20% CC	10% CC	1% CC
10 min	10	7.3	8.2	11.5	14.1	17.0	21.3	25.1	13.6	16.7	29.7
15 min	15	8.9	10.0	14.1	17.3	20.8	26.2	30.9	16.7	20.5	36.6
20 min	20	10.1	11.4	15.9	19.6	23.6	29.7	35.0	18.8	23.2	41.5
25 min	25	11.1	12.5	17.4	21.4	25.7	32.3	38.1	20.6	25.4	45.1
30 min	30	11.9	13.4	18.6	22.8	27.4	34.5	40.6	22.0	27.0	48.1
45 min	45	13.8	15.5	21.4	26.1	31.3	39.2	46.1	25.4	30.9	54.6
1 hour	60	15.3	17.1	23.5	28.5	34.1	42.5	49.8	27.8	33.8	59.0
1.5 hour	90	17.7	19.7	26.7	32.2	38.3	47.4	55.4	31.6	38.2	65.6
2 hour	120	19.5	21.6	29.2	35.0	41.5	51.2	59.6	34.6	41.5	70.6
3 hour	180	22.5	24.8	33.2	39.7	46.8	57.4	66.5	39.3	47.0	78.8
4.5 hour	270	25.9	28.6	38.0	45.2	53.1	64.8	74.8	45.0	53.6	88.6
6 hour	360	28.6	31.6	42.0	49.9	58.5	71.1	81.9	49.8	59.1	97.1
9 hour	540	32.9	36.5	48.6	57.8	67.5	81.8	94.0	57.6	68.5	111.4
12 hour	720	36.3	40.4	54.1	64.4	75.1	90.9	104.0	64.1	76.3	123.2
18 hour	1080	41.5	46.5	63.0	75.1	87.5	106.0	121.0	74.7	89.0	143.4

Appendix B: ARR Data Hub Information

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	145.0
Latitude	-37.704
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Baseflow Factors	show



Data

River Region

Division	South East Coast (Victoria)
River Number	6
River Name	Yarra River

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\text{ x }10^{-3}\text{ x }Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\text{ x }Area^{0.213}\text{ x }10^{-0.021\frac{(Duration\ \ 180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

ID	6491.0
Storm Initial Losses (mm)	12.0
Storm Continuing Losses (mm/h)	1.9

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.70433123&longitude=145.00049673&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	21 May 2021 12:25PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.2 (0.073)	1.6 (0.069)	1.8 (0.065)	2.1 (0.061)	1.5 (0.035)	1.1 (0.021)
90 (1.5)	3.1 (0.161)	2.8 (0.106)	2.6 (0.081)	2.4 (0.063)	1.3 (0.026)	0.4 (0.007)
120 (2.0)	3.4 (0.162)	3.0 (0.103)	2.7 (0.076)	2.4 (0.057)	1.5 (0.028)	0.8 (0.013)
180 (3.0)	1.9 (0.078)	2.4 (0.072)	2.7 (0.067)	3.0 (0.062)	5.3 (0.089)	7.0 (0.100)
360 (6.0)	1.1 (0.035)	1.5 (0.035)	1.7 (0.034)	2.0 (0.033)	5.6 (0.074)	8.3 (0.094)
720 (12.0)	0.2 (0.005)	2.1 (0.038)	3.4 (0.051)	4.6 (0.059)	7.2 (0.075)	9.2 (0.083)
1080 (18.0)	0.0 (0.000)	0.9 (0.015)	1.6 (0.020)	2.2 (0.024)	3.3 (0.030)	4.2 (0.033)
1440 (24.0)	0.0 (0.000)	0.2 (0.003)	0.4 (0.005)	0.5 (0.005)	2.7 (0.022)	4.3 (0.030)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.4 (0.003)	0.6 (0.004)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.002)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	8.0 (0.479)	11.0 (0.474)	13.0 (0.458)	15.0 (0.436)	12.2 (0.281)	10.1 (0.196)
90 (1.5)	10.4 (0.546)	12.4 (0.469)	13.7 (0.424)	14.9 (0.384)	14.3 (0.293)	13.8 (0.240)
120 (2.0)	12.5 (0.595)	13.4 (0.465)	14.0 (0.399)	14.6 (0.346)	16.3 (0.308)	17.6 (0.281)
180 (3.0)	11.9 (0.493)	13.1 (0.398)	13.9 (0.349)	14.7 (0.308)	19.1 (0.320)	22.5 (0.319)
360 (6.0)	6.7 (0.218)	12.3 (0.292)	15.9 (0.313)	19.4 (0.321)	24.7 (0.330)	28.7 (0.328)
720 (12.0)	4.3 (0.109)	10.6 (0.194)	14.7 (0.223)	18.7 (0.239)	23.9 (0.249)	27.9 (0.251)
1080 (18.0)	3.3 (0.070)	7.4 (0.116)	10.2 (0.132)	12.8 (0.141)	19.3 (0.173)	24.1 (0.189)
1440 (24.0)	1.7 (0.033)	4.8 (0.068)	6.9 (0.081)	9.0 (0.088)	13.6 (0.111)	17.1 (0.122)
2160 (36.0)	0.1 (0.002)	0.9 (0.011)	1.3 (0.014)	1.8 (0.016)	7.5 (0.053)	11.7 (0.074)
2880 (48.0)	0.0 (0.000)	0.5 (0.006)	0.9 (0.008)	1.2 (0.010)	3.3 (0.021)	4.8 (0.028)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.5 (0.003)	0.8 (0.004)

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	20.3 (1.220)	25.2 (1.084)	28.4 (0.998)	31.5 (0.917)	30.7 (0.709)	30.2 (0.588)
90 (1.5)	21.4 (1.122)	23.3 (0.882)	24.5 (0.761)	25.7 (0.663)	28.7 (0.588)	30.9 (0.536)
120 (2.0)	25.4 (1.207)	29.2 (1.012)	31.8 (0.904)	34.2 (0.812)	40.1 (0.758)	44.6 (0.712)
180 (3.0)	20.7 (0.859)	26.0 (0.790)	29.5 (0.738)	32.9 (0.687)	44.5 (0.744)	53.2 (0.756)
360 (6.0)	15.8 (0.511)	27.1 (0.645)	34.6 (0.680)	41.7 (0.690)	52.2 (0.696)	60.1 (0.686)
720 (12.0)	20.9 (0.524)	28.6 (0.524)	33.7 (0.511)	38.6 (0.494)	51.5 (0.537)	61.1 (0.551)
1080 (18.0)	16.0 (0.345)	20.5 (0.321)	23.4 (0.304)	26.3 (0.288)	33.4 (0.300)	38.7 (0.303)
1440 (24.0)	15.4 (0.302)	20.4 (0.287)	23.7 (0.276)	26.9 (0.265)	30.9 (0.251)	33.9 (0.241)
2160 (36.0)	5.7 (0.098)	9.3 (0.114)	11.7 (0.118)	14.0 (0.120)	26.1 (0.186)	35.2 (0.222)
2880 (48.0)	3.2 (0.051)	6.9 (0.078)	9.4 (0.087)	11.8 (0.093)	17.9 (0.118)	22.6 (0.132)
4320 (72.0)	0.8 (0.012)	2.5 (0.026)	3.7 (0.031)	4.8 (0.034)	16.6 (0.100)	25.5 (0.137)

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	11203
Area (km2)	6192.737856
Catchment Number	11147
Volume Factor	0.309605
Peak Factor	0.058074

Layer Info

Time Accessed	21 May 2021 12:25PM
Version	2016_v1

Download TXT (downloads/e73d5a4a-ba40-47d4-9a4a-faa810a7b481.txt)

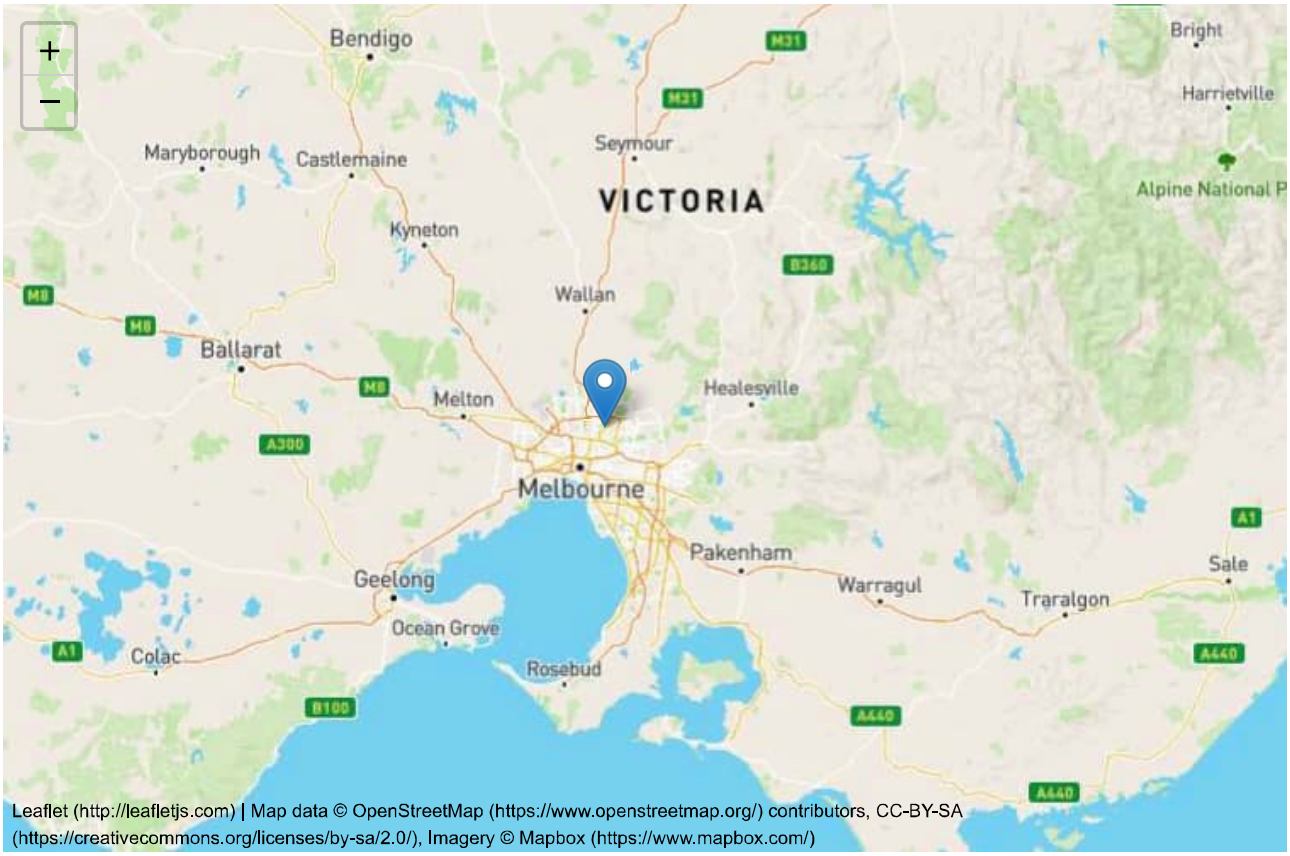
Download JSON (downloads/78a2c5f5-9790-4985-a460-6c0e91b183be.json)

Generating PDF... (downloads/39051847-10d5-451b-8bfe-dd4752dbc299.pdf)

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	145.041
Latitude	-37.714
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Baseflow Factors	show



Data

River Region

Division	South East Coast (Victoria)
River Number	6
River Name	Yarra River

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

ID	6491.0
Storm Initial Losses (mm)	12.0
Storm Continuing Losses (mm/h)	1.9

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.71394532&longitude=145.0414685&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	21 May 2021 12:30PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	1.2 (0.073)	1.6 (0.068)	1.8 (0.065)	2.1 (0.061)	1.5 (0.035)	1.1 (0.021)
90 (1.5)	3.1 (0.160)	2.8 (0.106)	2.6 (0.081)	2.4 (0.063)	1.3 (0.026)	0.4 (0.007)
120 (2.0)	3.4 (0.162)	3.0 (0.103)	2.7 (0.076)	2.4 (0.057)	1.5 (0.028)	0.8 (0.013)
180 (3.0)	1.9 (0.078)	2.4 (0.072)	2.7 (0.067)	3.0 (0.062)	5.3 (0.089)	7.0 (0.101)
360 (6.0)	1.1 (0.035)	1.5 (0.035)	1.7 (0.034)	2.0 (0.033)	5.6 (0.075)	8.3 (0.095)
720 (12.0)	0.2 (0.005)	2.1 (0.039)	3.4 (0.052)	4.6 (0.059)	7.2 (0.076)	9.2 (0.084)
1080 (18.0)	0.0 (0.000)	0.9 (0.015)	1.6 (0.021)	2.2 (0.024)	3.3 (0.030)	4.2 (0.033)
1440 (24.0)	0.0 (0.000)	0.2 (0.003)	0.4 (0.005)	0.5 (0.005)	2.7 (0.022)	4.3 (0.031)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.4 (0.003)	0.6 (0.004)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.002)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	8.0 (0.477)	11.0 (0.474)	13.0 (0.458)	15.0 (0.436)	12.2 (0.280)	10.1 (0.195)
90 (1.5)	10.4 (0.544)	12.4 (0.469)	13.7 (0.425)	14.9 (0.385)	14.3 (0.293)	13.8 (0.240)
120 (2.0)	12.5 (0.592)	13.4 (0.465)	14.0 (0.400)	14.6 (0.347)	16.3 (0.309)	17.6 (0.282)
180 (3.0)	11.9 (0.491)	13.1 (0.399)	13.9 (0.350)	14.7 (0.309)	19.1 (0.322)	22.5 (0.321)
360 (6.0)	6.7 (0.218)	12.3 (0.293)	15.9 (0.316)	19.4 (0.324)	24.7 (0.333)	28.7 (0.331)
720 (12.0)	4.3 (0.109)	10.6 (0.195)	14.7 (0.226)	18.7 (0.242)	23.9 (0.253)	27.9 (0.254)
1080 (18.0)	3.3 (0.071)	7.4 (0.117)	10.2 (0.134)	12.8 (0.143)	19.3 (0.176)	24.1 (0.192)
1440 (24.0)	1.7 (0.033)	4.8 (0.069)	6.9 (0.082)	9.0 (0.090)	13.6 (0.112)	17.1 (0.124)
2160 (36.0)	0.1 (0.002)	0.9 (0.011)	1.3 (0.014)	1.8 (0.016)	7.5 (0.054)	11.7 (0.075)
2880 (48.0)	0.0 (0.000)	0.5 (0.006)	0.9 (0.008)	1.2 (0.010)	3.3 (0.022)	4.8 (0.028)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.5 (0.003)	0.8 (0.004)

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	20.3 (1.214)	25.2 (1.083)	28.4 (0.998)	31.5 (0.917)	30.7 (0.708)	30.2 (0.586)
90 (1.5)	21.4 (1.117)	23.3 (0.882)	24.5 (0.762)	25.7 (0.664)	28.7 (0.588)	30.9 (0.536)
120 (2.0)	25.4 (1.203)	29.2 (1.013)	31.8 (0.907)	34.2 (0.814)	40.1 (0.760)	44.6 (0.714)
180 (3.0)	20.7 (0.857)	26.0 (0.792)	29.5 (0.741)	32.9 (0.691)	44.5 (0.748)	53.2 (0.760)
360 (6.0)	15.8 (0.511)	27.1 (0.648)	34.6 (0.685)	41.7 (0.697)	52.2 (0.704)	60.1 (0.693)
720 (12.0)	20.9 (0.526)	28.6 (0.529)	33.7 (0.517)	38.6 (0.501)	51.5 (0.544)	61.1 (0.558)
1080 (18.0)	16.0 (0.347)	20.5 (0.324)	23.4 (0.308)	26.3 (0.293)	33.4 (0.305)	38.7 (0.307)
1440 (24.0)	15.4 (0.304)	20.4 (0.290)	23.7 (0.280)	26.9 (0.269)	30.9 (0.255)	33.9 (0.245)
2160 (36.0)	5.7 (0.098)	9.3 (0.115)	11.7 (0.120)	14.0 (0.122)	26.1 (0.189)	35.2 (0.225)
2880 (48.0)	3.2 (0.051)	6.9 (0.079)	9.4 (0.088)	11.8 (0.094)	17.9 (0.120)	22.6 (0.133)
4320 (72.0)	0.8 (0.012)	2.5 (0.026)	3.7 (0.031)	4.8 (0.034)	16.6 (0.101)	25.5 (0.138)

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	11203
Area (km2)	6192.737856
Catchment Number	11147
Volume Factor	0.309605
Peak Factor	0.058074

Layer Info

Time Accessed	21 May 2021 12:30PM
Version	2016_v1

Download TXT (downloads/e5b64778-e363-40e8-9ce0-f87e7f263f49.txt)

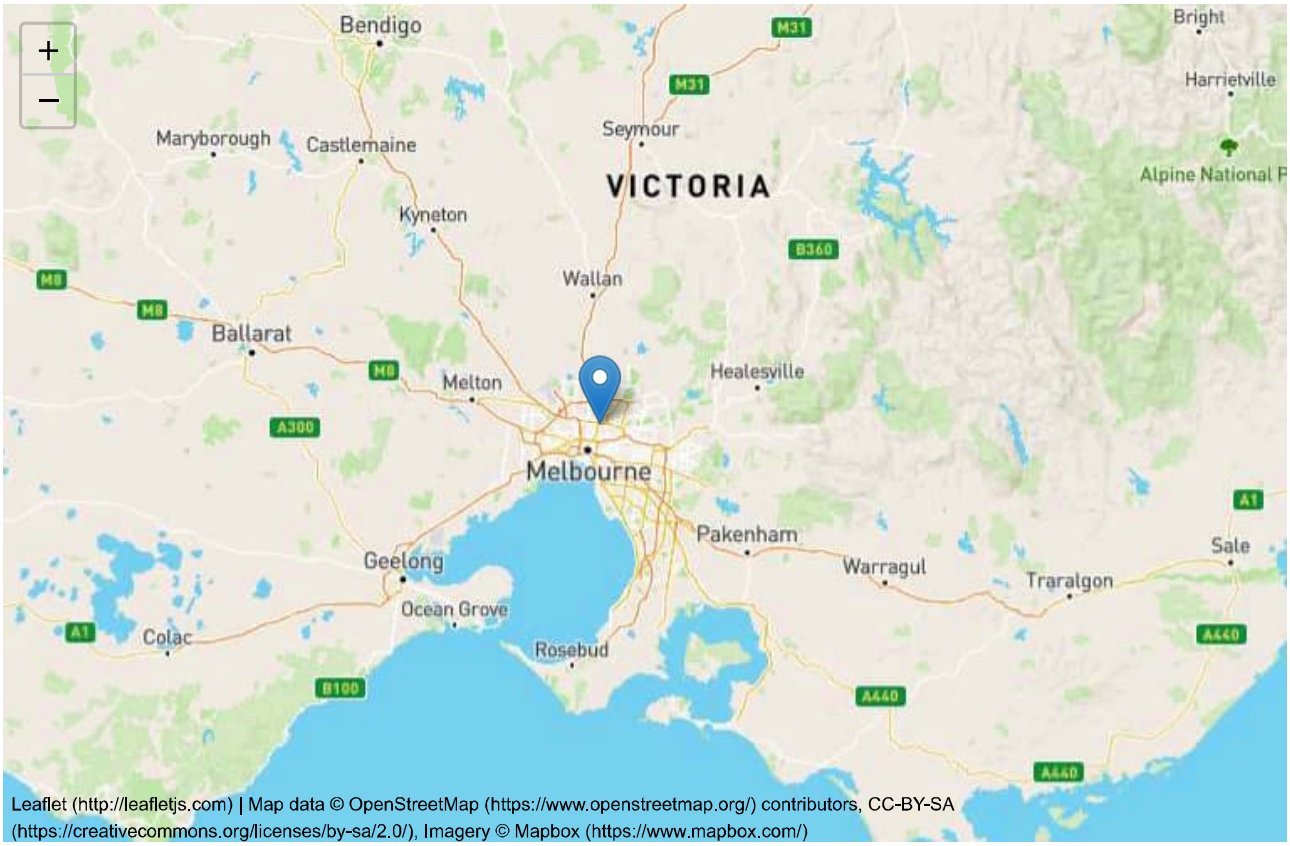
Download JSON (downloads/e286a535-bc33-471e-90a5-9b6a4811d6d1.json)

Generating PDF... (downloads/33ce393a-ba76-41b3-ba5d-f90b85c345cc.pdf)

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	144.996
Latitude	-37.747
Selected Regions (clear)	
River Region	show
ARF Parameters	show
Storm Losses	show
Temporal Patterns	show
Areal Temporal Patterns	show
BOM IFDs	show
Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Baseflow Factors	show



Data

River Region

Division	South East Coast (Victoria)
River Number	6
River Name	Yarra River

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \mathrm{x}\ 10^{-3}\ \mathrm{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \mathrm{x}\ Area^{0.213}\ \mathrm{x}\ 10^{-0.021\frac{(Duration-180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

ID	6491.0
Storm Initial Losses (mm)	12.0
Storm Continuing Losses (mm/h)	1.9

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.74711751&longitude=144.99557464&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	21 May 2021 12:33PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	3.5 (0.207)	2.9 (0.123)	2.5 (0.087)	2.1 (0.061)	1.5 (0.035)	1.0 (0.021)
90 (1.5)	3.7 (0.193)	3.0 (0.112)	2.5 (0.076)	2.0 (0.051)	1.4 (0.029)	1.0 (0.018)
120 (2.0)	2.4 (0.112)	2.6 (0.088)	2.7 (0.076)	2.8 (0.066)	1.9 (0.036)	1.2 (0.020)
180 (3.0)	2.7 (0.110)	2.7 (0.082)	2.7 (0.068)	2.7 (0.058)	5.5 (0.093)	7.5 (0.110)
360 (6.0)	1.1 (0.034)	1.7 (0.042)	2.2 (0.044)	2.6 (0.044)	4.6 (0.063)	6.0 (0.071)
720 (12.0)	0.3 (0.008)	0.8 (0.016)	1.2 (0.018)	1.5 (0.020)	5.1 (0.055)	7.9 (0.073)
1080 (18.0)	0.0 (0.000)	0.3 (0.005)	0.5 (0.007)	0.7 (0.008)	2.2 (0.020)	3.2 (0.026)
1440 (24.0)	0.0 (0.000)	0.1 (0.002)	0.2 (0.003)	0.3 (0.003)	0.5 (0.004)	0.6 (0.005)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.1 (0.007)	0.1 (0.003)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.4 (0.021)	0.2 (0.008)	0.1 (0.003)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.001)	0.0 (0.001)	0.1 (0.001)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.1 (0.003)	0.0 (0.001)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.1 (0.002)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	10.5 (0.621)	12.3 (0.525)	13.5 (0.472)	14.6 (0.427)	11.4 (0.267)	9.0 (0.179)
90 (1.5)	13.1 (0.680)	13.6 (0.511)	13.9 (0.430)	14.1 (0.367)	14.6 (0.305)	15.0 (0.267)
120 (2.0)	9.8 (0.463)	13.0 (0.448)	15.1 (0.429)	17.1 (0.408)	15.4 (0.297)	14.2 (0.234)
180 (3.0)	9.8 (0.403)	11.8 (0.357)	13.1 (0.329)	14.3 (0.303)	19.4 (0.332)	23.2 (0.340)
360 (6.0)	8.5 (0.273)	12.7 (0.302)	15.5 (0.307)	18.1 (0.305)	20.0 (0.274)	21.4 (0.253)
720 (12.0)	6.0 (0.151)	9.7 (0.178)	12.0 (0.185)	14.3 (0.188)	20.3 (0.218)	24.8 (0.231)
1080 (18.0)	2.8 (0.060)	6.1 (0.096)	8.2 (0.108)	10.3 (0.116)	14.5 (0.134)	17.7 (0.143)
1440 (24.0)	2.8 (0.054)	4.5 (0.064)	5.7 (0.067)	6.8 (0.068)	10.2 (0.085)	12.7 (0.093)
2160 (36.0)	0.5 (0.008)	1.5 (0.018)	2.1 (0.022)	2.8 (0.024)	6.8 (0.050)	9.9 (0.064)
2880 (48.0)	0.0 (0.000)	0.5 (0.005)	0.8 (0.007)	1.1 (0.009)	2.3 (0.016)	3.2 (0.019)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.5 (0.003)	0.9 (0.005)

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	21.6 (1.284)	25.9 (1.108)	28.7 (1.007)	31.4 (0.919)	28.7 (0.671)	26.7 (0.531)
90 (1.5)	24.3 (1.257)	25.1 (0.945)	25.6 (0.795)	26.1 (0.678)	27.6 (0.576)	28.7 (0.511)
120 (2.0)	27.4 (1.289)	30.1 (1.037)	31.9 (0.908)	33.6 (0.803)	39.9 (0.767)	44.6 (0.733)
180 (3.0)	24.4 (0.997)	28.5 (0.861)	31.2 (0.782)	33.8 (0.714)	43.5 (0.743)	50.7 (0.744)
360 (6.0)	27.8 (0.893)	30.3 (0.721)	31.9 (0.634)	33.5 (0.564)	45.2 (0.620)	54.0 (0.639)
720 (12.0)	22.1 (0.554)	26.8 (0.494)	29.9 (0.459)	32.9 (0.430)	40.0 (0.429)	45.4 (0.423)
1080 (18.0)	16.0 (0.347)	18.9 (0.299)	20.8 (0.274)	22.6 (0.254)	28.0 (0.259)	32.0 (0.259)
1440 (24.0)	15.3 (0.302)	21.5 (0.307)	25.6 (0.304)	29.6 (0.299)	29.9 (0.249)	30.1 (0.221)
2160 (36.0)	8.8 (0.154)	11.7 (0.145)	13.6 (0.140)	15.4 (0.135)	25.1 (0.183)	32.3 (0.208)
2880 (48.0)	1.8 (0.029)	5.0 (0.057)	7.1 (0.067)	9.2 (0.073)	11.8 (0.079)	13.8 (0.082)
4320 (72.0)	0.9 (0.013)	2.1 (0.022)	3.0 (0.025)	3.7 (0.027)	15.6 (0.095)	24.5 (0.133)

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	11203
Area (km2)	6192.737856
Catchment Number	11147
Volume Factor	0.309605
Peak Factor	0.058074

Layer Info

Time Accessed	21 May 2021 12:33PM
Version	2016_v1

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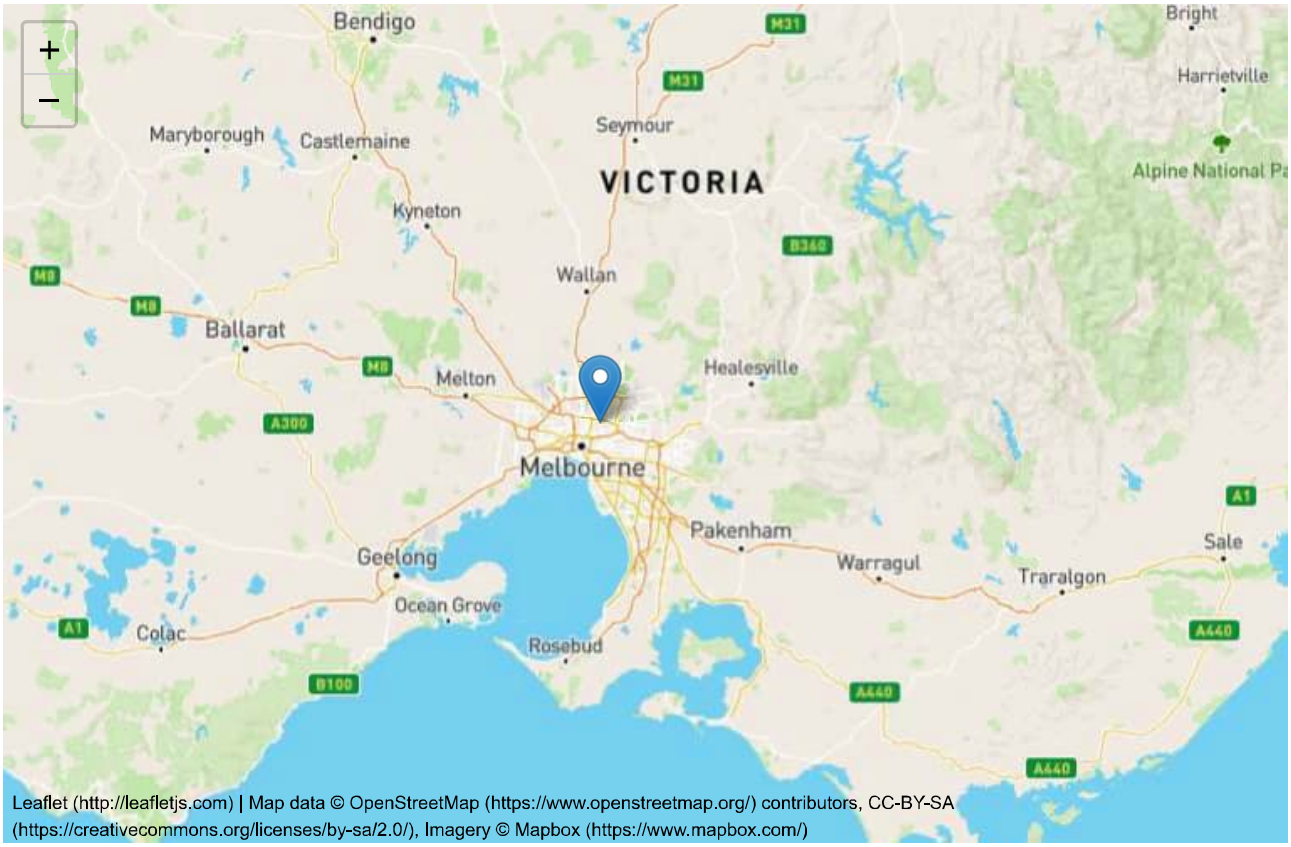
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Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	145.02
Latitude	-37.757
Selected Regions (clear)	
River Region	show
ARF Parameters	show
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Temporal Patterns	show
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Median Preburst Depths and Ratios	show
10% Preburst Depths	show
25% Preburst Depths	show
75% Preburst Depths	show
90% Preburst Depths	show
Interim Climate Change Factors	show
Baseflow Factors	show



Data

River Region

Division	South East Coast (Victoria)
River Number	6
River Name	Yarra River

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2016_v1

ARF Parameters

$$ARF = Min\left\{1, \left[1 - a\left(Area^{b} - c\log_{10}Duration\right)Duration^{-d} + eArea^{f}Duration^{g}\left(0.3 + \log_{10}AEP\right) + h10^{iArea\frac{Duration}{1440}}\left(0.3 + \log_{10}AEP\right)\right]\right\}$$

Zone	a	b	c	d	e	f	g	h	i
Southern Temperate	0.158	0.276	0.372	0.315	0.000141	0.41	0.15	0.01	-0.0027

Short Duration ARF

$$ARF = Min\left[1, 1 - 0.287\left(Area^{0.265} - 0.439\log_{10}(Duration)\right).Duration^{-0.36} + 2.26\ \text{x}\ 10^{-3}\ \text{x}\ Area^{0.226}.Duration^{0.125}\left(0.3 + \log_{10}(AEP)\right) + 0.0141\ \text{x}\ Area^{0.213}\ \text{x}\ 10^{-0.021\frac{(Duration\ \ 180)^2}{1440}}\left(0.3 + \log_{10}(AEP)\right)\right]$$

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

Note: These losses are only for rural use and are **NOT FOR DIRECT USE** in urban areas

ID	6491.0
Storm Initial Losses (mm)	12.0
Storm Continuing Losses (mm/h)	1.9

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2016_v1

Temporal Patterns | Download (.zip) (static/temporal_patterns/TP/SSmainland.zip)

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2016_v2

Areal Temporal Patterns | Download (.zip) (./static/temporal_patterns/Areal/Areal_SSmainland.zip)

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-37.75689601&longitude=145.01967627&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	21 May 2021 02:34PM

Median Preburst Depths and Ratios

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	3.5 (0.204)	2.9 (0.122)	2.5 (0.086)	2.1 (0.061)	1.5 (0.035)	1.0 (0.021)
90 (1.5)	3.7 (0.190)	3.0 (0.111)	2.5 (0.076)	2.0 (0.051)	1.4 (0.030)	1.0 (0.018)
120 (2.0)	2.4 (0.110)	2.6 (0.088)	2.7 (0.076)	2.8 (0.067)	1.9 (0.037)	1.2 (0.020)
180 (3.0)	2.7 (0.108)	2.7 (0.082)	2.7 (0.068)	2.7 (0.058)	5.5 (0.095)	7.5 (0.113)
360 (6.0)	1.1 (0.034)	1.7 (0.042)	2.2 (0.044)	2.6 (0.045)	4.6 (0.064)	6.0 (0.073)
720 (12.0)	0.3 (0.008)	0.8 (0.016)	1.2 (0.019)	1.5 (0.020)	5.1 (0.057)	7.9 (0.076)
1080 (18.0)	0.0 (0.000)	0.3 (0.005)	0.5 (0.007)	0.7 (0.008)	2.2 (0.021)	3.2 (0.027)
1440 (24.0)	0.0 (0.000)	0.1 (0.002)	0.2 (0.003)	0.3 (0.003)	0.5 (0.004)	0.6 (0.005)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

10% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

25% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	0.1 (0.007)	0.1 (0.003)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
90 (1.5)	0.4 (0.020)	0.2 (0.008)	0.1 (0.003)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
120 (2.0)	0.0 (0.000)	0.0 (0.001)	0.0 (0.001)	0.1 (0.001)	0.0 (0.000)	0.0 (0.000)
180 (3.0)	0.1 (0.003)	0.0 (0.001)	0.0 (0.001)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
360 (6.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.1 (0.002)
720 (12.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1080 (18.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
1440 (24.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

75% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	10.5 (0.611)	12.3 (0.522)	13.5 (0.471)	14.6 (0.428)	11.4 (0.268)	9.0 (0.180)
90 (1.5)	13.1 (0.668)	13.6 (0.508)	13.9 (0.430)	14.1 (0.369)	14.6 (0.308)	15.0 (0.271)
120 (2.0)	9.8 (0.455)	13.0 (0.446)	15.1 (0.430)	17.1 (0.411)	15.4 (0.301)	14.2 (0.238)
180 (3.0)	9.8 (0.396)	11.8 (0.356)	13.1 (0.330)	14.3 (0.307)	19.4 (0.338)	23.2 (0.349)
360 (6.0)	8.5 (0.269)	12.7 (0.302)	15.5 (0.310)	18.1 (0.310)	20.0 (0.281)	21.4 (0.261)
720 (12.0)	6.0 (0.150)	9.7 (0.178)	12.0 (0.187)	14.3 (0.191)	20.3 (0.224)	24.8 (0.239)
1080 (18.0)	2.8 (0.059)	6.1 (0.096)	8.2 (0.110)	10.3 (0.118)	14.5 (0.138)	17.7 (0.147)
1440 (24.0)	2.8 (0.054)	4.5 (0.064)	5.7 (0.068)	6.8 (0.070)	10.2 (0.087)	12.7 (0.095)
2160 (36.0)	0.5 (0.008)	1.5 (0.018)	2.1 (0.022)	2.8 (0.025)	6.8 (0.051)	9.9 (0.065)
2880 (48.0)	0.0 (0.000)	0.5 (0.005)	0.8 (0.008)	1.1 (0.009)	2.3 (0.016)	3.2 (0.019)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.5 (0.003)	0.9 (0.005)

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

90% Preburst Depths

Values are of the format depth (ratio) with depth in mm

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	21.6 (1.263)	25.9 (1.101)	28.7 (1.006)	31.4 (0.921)	28.7 (0.675)	26.7 (0.535)
90 (1.5)	24.3 (1.235)	25.1 (0.940)	25.6 (0.795)	26.1 (0.681)	27.6 (0.582)	28.7 (0.519)
120 (2.0)	27.4 (1.267)	30.1 (1.033)	31.9 (0.910)	33.6 (0.809)	39.9 (0.778)	44.6 (0.747)
180 (3.0)	24.4 (0.981)	28.5 (0.858)	31.2 (0.786)	33.8 (0.722)	43.5 (0.758)	50.7 (0.763)
360 (6.0)	27.8 (0.880)	30.3 (0.722)	31.9 (0.639)	33.5 (0.573)	45.2 (0.636)	54.0 (0.659)
720 (12.0)	22.1 (0.548)	26.8 (0.495)	29.9 (0.464)	32.9 (0.438)	40.0 (0.441)	45.4 (0.436)
1080 (18.0)	16.0 (0.344)	18.9 (0.300)	20.8 (0.277)	22.6 (0.259)	28.0 (0.265)	32.0 (0.266)
1440 (24.0)	15.3 (0.300)	21.5 (0.308)	25.6 (0.307)	29.6 (0.304)	29.9 (0.255)	30.1 (0.225)
2160 (36.0)	8.8 (0.152)	11.7 (0.145)	13.6 (0.141)	15.4 (0.137)	25.1 (0.185)	32.3 (0.211)
2880 (48.0)	1.8 (0.029)	5.0 (0.057)	7.1 (0.067)	9.2 (0.074)	11.8 (0.080)	13.8 (0.083)
4320 (72.0)	0.9 (0.013)	2.1 (0.022)	3.0 (0.025)	3.7 (0.027)	15.6 (0.095)	24.5 (0.133)

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

	RCP 4.5	RCP6	**RCP 8.5**
2030	**0.648 (3.2%)**	0.687 (3.4%)	**0.811 (4.0%)**
2040	**0.878 (4.4%)**	0.827 (4.1%)	**1.084 (5.4%)**
2050	**1.081 (5.4%)**	1.013 (5.1%)	**1.446 (7.3%)**
2060	**1.251 (6.3%)**	1.229 (6.2%)	**1.862 (9.5%)**
2070	**1.381 (7.0%)**	1.460 (7.4%)	**2.298 (11.9%)**
2080	**1.465 (7.4%)**	1.691 (8.6%)	**2.719 (14.2%)**
2090	**1.496 (7.6%)**	1.906 (9.7%)	**3.090 (16.3%)**

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	11203
Area (km2)	6192.737856
Catchment Number	11147
Volume Factor	0.309605
Peak Factor	0.058074

Layer Info

Time Accessed	21 May 2021 02:34PM
Version	2016_v1

Download TXT (downloads/522dc7ac-ddac-47c5-860c-c99394e58db8.txt)

Download JSON (downloads/7d3d2f51-ea11-4a0a-a66b-c61850b911f3.json)

Generating PDF... (downloads/985a6d28-5594-402f-9c4d-cd37af9cb076.pdf)

Appendix C: Impervious Fractions

Catchment A Impervious Fractions

Subarea	Effective Impervious Area (EIA)	Indirectly Connected Area (ICA)	Pervious Area (PA)
A	0.70	0.30	0.00
AA	0.37	0.63	0.00
AB	0.41	0.59	0.00
AC	0.33	0.60	0.07
AD	0.37	0.57	0.07
AE	0.40	0.58	0.02
AF	0.34	0.66	0.00
AG	0.31	0.54	0.16
AH	0.33	0.67	0.00
AI	0.37	0.63	0.00
AJ	0.34	0.55	0.11
AK	0.30	0.70	0.00
AL	0.20	0.80	0.00
AM	0.52	0.45	0.04
AN	0.46	0.44	0.10
AO	0.68	0.31	0.01
AP	0.61	0.39	0.00
AQ	0.62	0.38	0.00
AR	0.52	0.48	0.00
AS	0.37	0.63	0.00
AT	0.31	0.69	0.00
AU	0.26	0.44	0.31
AV	0.35	0.49	0.16
AW	0.22	0.39	0.39
AX	0.30	0.52	0.18
AY	0.14	0.25	0.61
AZ	0.39	0.61	0.00
B	0.70	0.30	0.00
BA	0.20	0.14	0.66
BB	0.63	0.25	0.12
BC	0.53	0.27	0.20
C	0.35	0.61	0.04
D	0.34	0.60	0.05
E	0.27	0.67	0.06
F	0.27	0.73	0.00
G	0.33	0.60	0.07
H	0.37	0.62	0.01
I	0.35	0.61	0.04
J	0.33	0.66	0.01
K	0.35	0.65	0.00
L	0.39	0.59	0.02

Subarea	Effective Impervious Area (EIA)	Indirectly Connected Area (ICA)	Pervious Area (PA)
M	0.40	0.60	0.00
N	0.37	0.63	0.00
O	0.40	0.60	0.00
P	0.38	0.62	0.00
Q	0.36	0.64	0.00
R	0.36	0.64	0.00
S	0.35	0.65	0.00
T	0.38	0.62	0.00
U	0.50	0.50	0.00
V	0.42	0.58	0.00
W	0.36	0.64	0.00
X	0.36	0.64	0.00
Y	0.37	0.63	0.00
Z	0.37	0.63	0.00

Catchment B Impervious Fractions

Subarea	Effective Impervious Area (EIA)	Indirectly Connected Area (ICA)	Pervious Area (PA)
A	0.35	0.65	0.00
AA	0.07	0.09	0.85
AB	0.08	0.11	0.81
AC	0.03	0.02	0.95
AD	0.33	0.58	0.09
AE	0.03	0.02	0.95
AF	0.30	0.45	0.25
AG	0.20	0.21	0.59
AH	0.39	0.57	0.04
AI	0.36	0.64	0.00
AI2	0.36	0.64	0.00
AJ	0.39	0.57	0.04
AK	0.37	0.63	0.00
AL	0.33	0.67	0.01
AM	0.19	0.37	0.44
AN	0.28	0.57	0.14
AO	0.35	0.64	0.01
AP	0.33	0.63	0.05
AQ	0.26	0.45	0.29
AR	0.18	0.37	0.45
AS	0.28	0.38	0.34
AT	0.28	0.50	0.22
AU	0.15	0.28	0.57
AV	0.33	0.64	0.03
B	0.41	0.59	0.00
C	0.34	0.66	0.00
D	0.34	0.66	0.00
E	0.38	0.62	0.00
F	0.37	0.63	0.00
G	0.36	0.64	0.00
H	0.28	0.29	0.43
I	0.21	0.43	0.36
J	0.28	0.47	0.25
K	0.12	0.11	0.76
L	0.35	0.57	0.08
M	0.35	0.65	0.00
N	0.35	0.65	0.00
Q	0.25	0.45	0.30
R	0.25	0.35	0.40
S	0.30	0.51	0.19
T	0.30	0.52	0.18

Subarea	Effective Impervious Area (EIA)	Indirectly Connected Area (ICA)	Pervious Area (PA)
U	0.39	0.46	0.16
V	0.23	0.75	0.02
W	0.17	0.73	0.10
X	0.30	0.53	0.17
Y	0.30	0.47	0.23
Z	0.03	0.02	0.95

Catchment C Impervious Fractions

Subarea	Effective Impervious Area (EIA)	Indirectly Connected Area (ICA)	Pervious Area (PA)
A	0.35	0.65	0.00
AA	0.41	0.59	0.00
AB	0.47	0.53	0.00
AC	0.49	0.51	0.00
AD	0.47	0.53	0.00
AE	0.53	0.47	0.00
AF	0.39	0.61	0.00
AG	0.44	0.56	0.00
AH	0.42	0.58	0.00
AI	0.51	0.49	0.00
AJ	0.39	0.61	0.00
AK	0.37	0.63	0.00
AL	0.39	0.61	0.00
AM	0.43	0.57	0.00
AN	0.36	0.64	0.00
AO	0.45	0.55	0.00
AP	0.34	0.52	0.14
AQ	0.38	0.62	0.00
AR	0.41	0.59	0.00
AS	0.39	0.61	0.00
AT	0.40	0.60	0.00
AU	0.42	0.58	0.00
AV	0.51	0.49	0.00
AW	0.52	0.48	0.00
AX	0.34	0.50	0.16
AY	0.38	0.53	0.09
B	0.37	0.63	0.00
C	0.39	0.61	0.00
D	0.39	0.61	0.00
E	0.37	0.63	0.00
F	0.38	0.62	0.00
G	0.34	0.66	0.00
H	0.38	0.59	0.03
I	0.37	0.63	0.00
J	0.43	0.49	0.08
K	0.36	0.56	0.07
L	0.29	0.50	0.19
M	0.28	0.42	0.30
N	0.30	0.22	0.48
O	0.20	0.24	0.56
P	0.34	0.66	0.00

Subarea	Effective Impervious Area (EIA)	Indirectly Connected Area (ICA)	Pervious Area (PA)
Q	0.37	0.63	0.00
R	0.37	0.63	0.00
S	0.34	0.66	0.00
T	0.37	0.63	0.00
U	0.36	0.64	0.00
V	0.45	0.55	0.00
W	0.41	0.59	0.00
X	0.50	0.50	0.00
Y	0.39	0.61	0.00
Z	0.37	0.63	0.00

Catchment D Impervious Fractions

Subarea	Effective Impervious Area (EIA)	Indirectly Connected Area (ICA)	Pervious Area (PA)
A	0.40	0.60	0.00
AA	0.62	0.38	0.00
AB	0.66	0.26	0.09
AC	0.68	0.27	0.05
AD	0.30	0.26	0.43
AE	0.48	0.52	0.00
AF	0.37	0.63	0.00
AG	0.39	0.61	0.00
AH	0.39	0.61	0.00
AI	0.37	0.63	0.00
AJ	0.40	0.60	0.00
AK	0.36	0.64	0.00
AL	0.59	0.41	0.00
AM	0.28	0.71	0.02
AN	0.35	0.65	0.00
AO	0.41	0.59	0.00
AP	0.36	0.64	0.00
AQ	0.36	0.64	0.00
AR	0.56	0.44	0.00
AS	0.62	0.31	0.06
AT	0.16	0.27	0.57
AU	0.36	0.64	0.00
AV	0.37	0.63	0.00
AW	0.37	0.63	0.00
AX	0.32	0.68	0.00
AY	0.32	0.68	0.00
AZ	0.36	0.64	0.00
B	0.45	0.55	0.00
BA	0.37	0.63	0.00
BB	0.36	0.64	0.00
BC	0.47	0.53	0.00
BD	0.36	0.64	0.00
BE	0.23	0.27	0.50
BF	0.42	0.58	0.00

Subarea	Effective Impervious Area (EIA)	Indirectly Connected Area (ICA)	Pervious Area (PA)
BG	0.40	0.60	0.00
BH	0.41	0.59	0.00
BI	0.38	0.62	0.00
BJ	0.33	0.67	0.00
C	0.31	0.52	0.16
D	0.21	0.32	0.47
E	0.38	0.62	0.00
F	0.38	0.62	0.00
G	0.35	0.65	0.00
H	0.37	0.63	0.00
I	0.33	0.57	0.10
J	0.52	0.43	0.05
K	0.50	0.49	0.01
L	0.35	0.65	0.00
M	0.38	0.62	0.00
N	0.44	0.56	0.00
O	0.62	0.24	0.13
P	0.72	0.28	0.00
Q	0.68	0.32	0.00
R	0.40	0.60	0.00
S	0.38	0.62	0.00
T	0.35	0.65	0.00
U	0.36	0.64	0.00
V	0.57	0.43	0.00
W	0.37	0.63	0.00
X	0.37	0.63	0.00
Y	0.38	0.62	0.00
Z	0.39	0.61	0.00

Appendix D: Flood Extent Maps

METROPOLITAN RING IN-HUME RAMP
HUME-METROPOLITAN RING IN RAMP
METROPOLITAN RING ROAD
SETTLEMENT ROAD
HIGH STREET
EDGARS ROAD
MAHONEYS ROAD
KEON PARADE KEON PARADE
DALTON ROAD
WOOD STREET
SETTLEMENT ROAD
GLASGOW AVE
BROADHURST AVE
CHEDDAR ROAD
MRANDA ROAD
PURINUAN ROAD
DUNNE STREET
EDWARDES STREET
HIGH STREET
SPRING STREET
BROADWAY
BOLDREWOOD PARADE
PLENTY ROAD
GILBERT ROAD
SPRING STREET
PLENTY ROAD
ALBERT STREET
Wood Street
MURRAY ROAD

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, TomTom, Garmin, FAO, NOAA, © OpenStreetMap contributors and the GIS User Community. Metromaps by Aerometrex

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Extents include 50mm cut of depth as per Melbourne Water requirements

Legend

- Drainage Network
- Parcels
- Darebin LGA Boundary
- Hydraulic Model Boundary
- 1% AEP Council Flood Extent
- 1% AEP MW UG Drains Flood Extent

0 200 400 600 800 m

Jacobs

Melbourne Water

Original Size:	A3	Scale:	1:23000
Coordinate System:	MGA 55	Modeller:	
Height Datum:	AHD	Reviewer:	BM

Darebin LGA Flood Mapping Catchment A

1% AEP Base Case Flood Extents

30/03/2023

IA5000CY

METROPOLITAN RING ROAD
METROPOLITAN RING ROAD
SETTLEMENT ROAD
EDGARS ROAD
HIGH STREET
WOOD STREET
MAHONEYS ROAD
KEON PARADE
SETTLEMENT ROAD
PLENTY ROAD
GRIMSHAW STREET
CHEDDAR ROAD
MRANDA ROAD
PURINUAN ROAD
BROADHURST AVE
HIGH STREET
DUNNE STREET
PLENTY ROAD
MAIN DRIVE
SPRING STREET
BROADWAY
BOLDREWOOD PARADE
KINGSBURY DRIVE
GREENSBOROUGH ROAD
SPRING STREET
PLENTY ROAD
ALBERT STREET
Wood Street
MURRAY ROAD
GOWER STREET
WATERDALE ROAD
WAIORA ROAD
SOUTHERN ROAD
LOWER PLENTY ROAD
ROSANNA ROAD
BELL STREET
BELL STREET
ORIEL ROAD
SUNDAS STREET

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, TomTom, Garmin, FAO, NOAA, © OpenStreetMap contributors and the GIS User Community. Metromaps by Aerometrex

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Extents include 50mm cut of depth as per Melbourne Water requirements

Legend

- Drainage Network
- Parcels
- Darebin LGA Boundary
- Hydraulic Model Boundary
- 1% AEP Council Flood Extent
- 1% AEP MW UG Drains Flood Extent

0 200 400 600 800 m

Jacobs

Melbourne Water

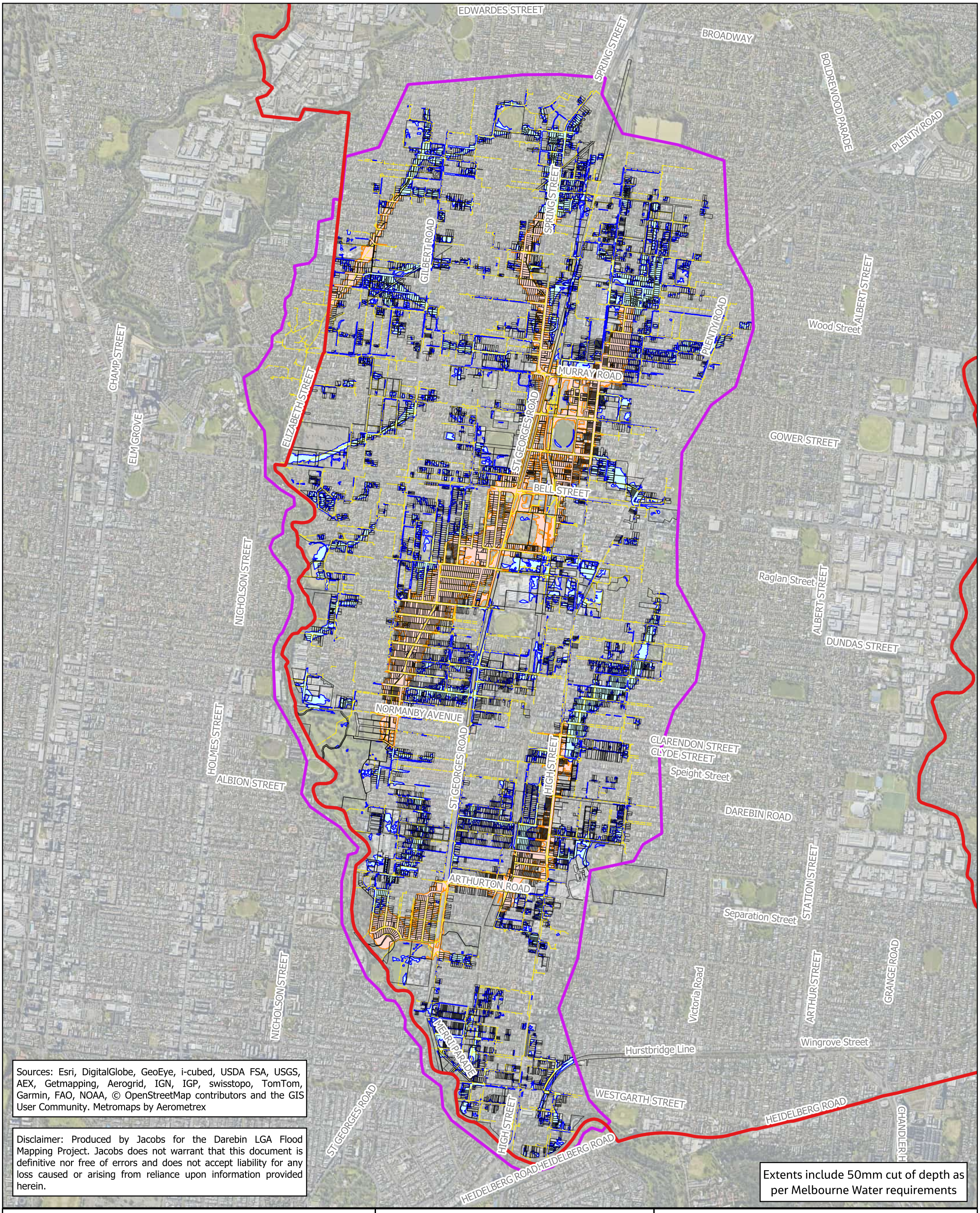
Darebin LGA Flood Mapping Catchment B

1% AEP Base Case Flood Extents

Original Size:	A3	Scale:	1:26000
Coordinate System:	MGA 55	Modeller:	
Height Datum:	AHD	Reviewer:	BM

30/03/2023

IA5000CY



Legend

- Drainage Network
- Parcels
- Darebin LGA Boundary
- Hydraulic Model Boundary
- 1% AEP Council Flood Extent
- 1% AEP MW UG Drains Flood Extent

0 200 400 600 800 m

Jacobs

Melbourne Water

Darebin LGA Flood Mapping Catchment C

1% AEP Base Case Flood Extents

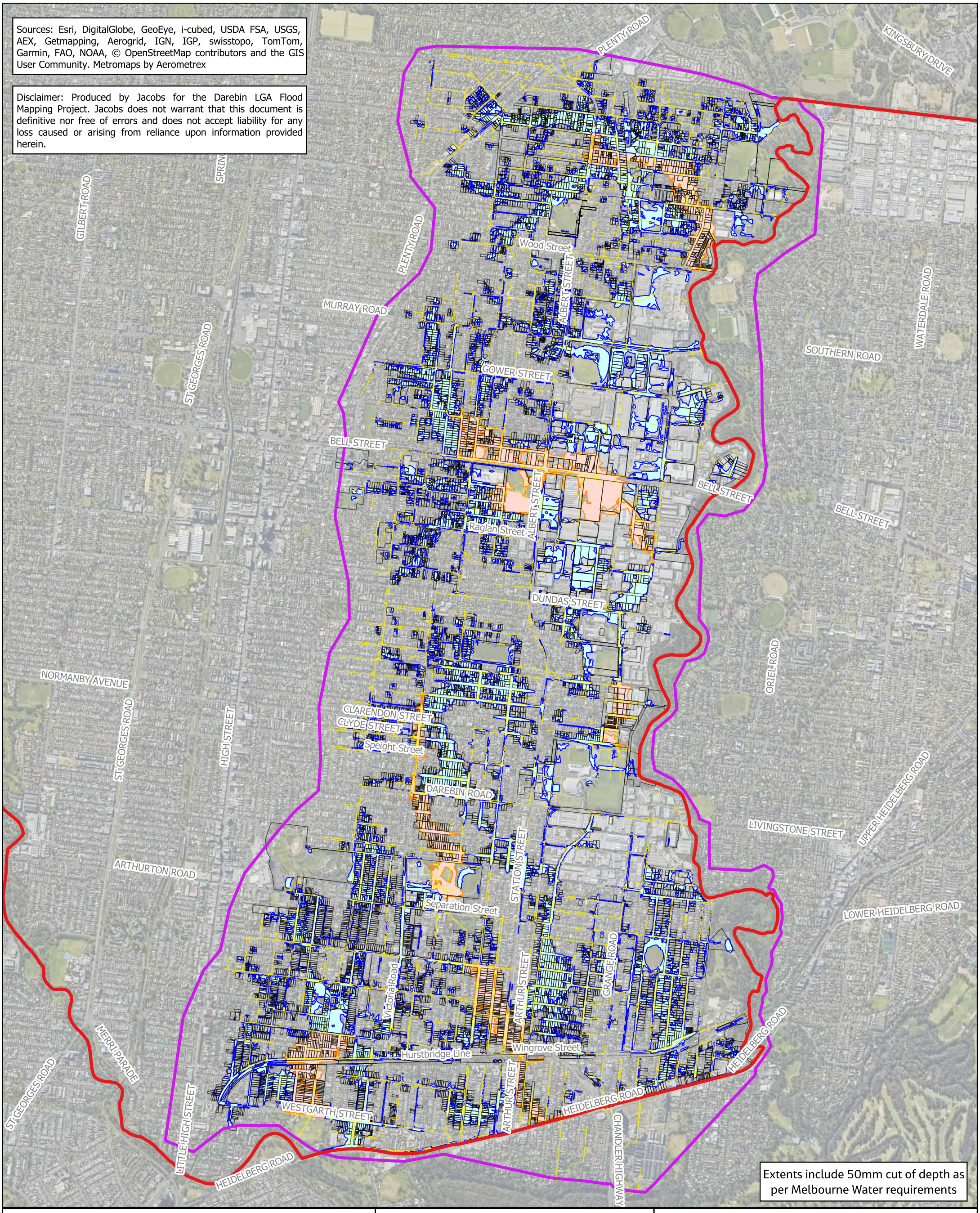
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Coordinate System:	MGA 55	Modeller:	
Height Datum:	AHD	Reviewer:	BM

30/03/2023

IA5000CY

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, TomTom, Garmin, FAO, NOAA, © OpenStreetMap contributors and the GIS User Community. Metromaps by Aerometrex

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Legend

- Drainage Network
- Parcels
- Darebin LGA Boundary
- Hydraulic Model Boundary
- 1% AEP Council Flood Extent
- 1% AEP MW UG Drains Flood Extent

0 200 400 600 800 m

Jacobs

Melbourne Water

Darebin LGA Flood Mapping Catchment D

1% AEP Base Case Flood Extents

Original Size:	A3	Scale:	1:20500
Coordinate System:	MGA 55	Modeller:	
Height Datum:	AHD	Reviewer:	BM

30/03/2023

IA5000CY

METROPOLITAN RING IN-HUME RAMP
HUME-METROPOLITAN RING IN RAMP
METROPOLITAN RING ROAD
SETTLEMENT ROAD
HIGH STREET
EDGARS ROAD
MAHONEYS ROAD
WOOD STREET
DALTON ROAD
KEON PARADE
KEON PARADE
GLASGOW AVE
CHEDDAR ROAD
MRANDA ROAD
BROADHURST AVE
PURINUAN ROAD
DUNNE STREET
EDWARDES STREET
HIGH STREET
SPRING STREET
BROADWAY
BOLDREWOOD PARADE
PLENTY ROAD
GILBERT ROAD
SPRING STREET
PLENTY ROAD
ALBERT STREET
Wood Street
MURRAY ROAD

Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, TomTom, Garmin, FAO, NOAA, © OpenStreetMap contributors and the GIS User Community. Metromaps by Aerometrex

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Extents include 50mm cut of depth as per Melbourne Water requirements

Legend

- Drainage Network
- Parcels
- Darebin LGA Boundary
- Hydraulic Model Boundary
- 1% AEP CC Council Flood Extent
- 1% AEP CC MW UG Drains Flood Extent

0 200 400 600 800 m

Jacobs

Melbourne Water

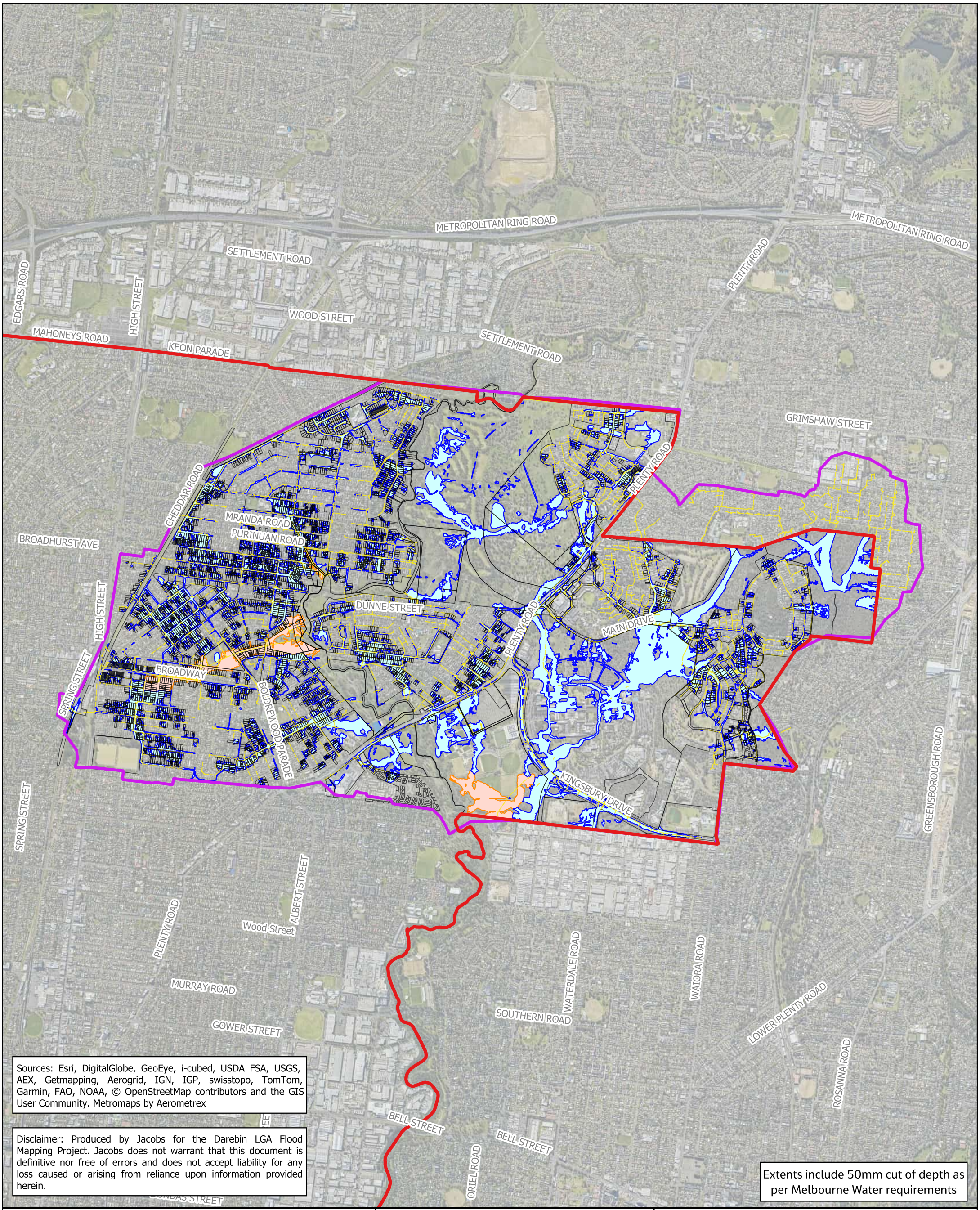
Original Size:	A3	Scale:	1:23000
Coordinate System:	MGA 55	Modeller:	
Height Datum:	AHD	Reviewer:	BM

Darebin LGA Flood Mapping Catchment A

1% AEP with Climate Change Flood Extents

30/03/2023

IA5000CY



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Extents include 50mm cut of depth as per Melbourne Water requirements

Legend

- Drainage Network
- Parcels
- Darebin LGA Boundary
- Hydraulic Model Boundary
- 1% AEP CC Council Flood Extent
- 1% AEP CC MW UG Drains Flood Extent

0 200 400 600 800 m

Jacobs

Melbourne Water

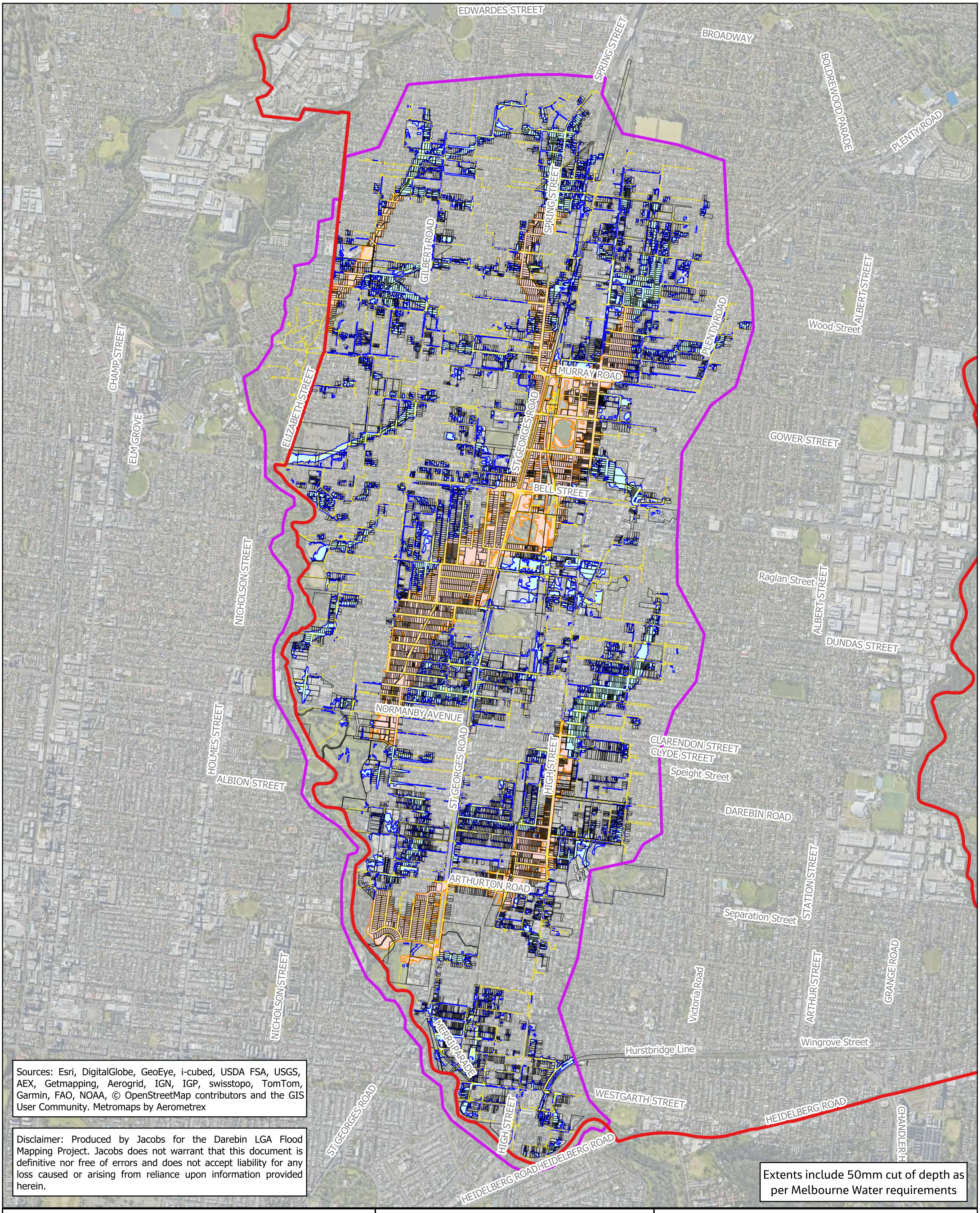
Darebin LGA Flood Mapping Catchment B

1% AEP with Climate Change Flood Extents

Original Size:	A3	Scale:	1:26000
Coordinate System:	MGA 55	Modeller:	
Height Datum:	AHD	Reviewer:	BM

30/03/2023

IA5000CY



Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, TomTom, Garmin, FAO, NOAA, © OpenStreetMap contributors and the GIS User Community. Metromaps by Aerometrex

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Extents include 50mm cut of depth as per Melbourne Water requirements

Legend

- Drainage Network
- Parcels
- Darebin LGA Boundary
- Hydraulic Model Boundary
- 1% AEP CC Council Flood Extent
- 1% AEP CC MW UG Drains Flood Extent

0 200 400 600 800 m

Jacobs

Melbourne Water

Darebin LGA Flood Mapping Catchment C

1% AEP with Climate Change Flood Extents

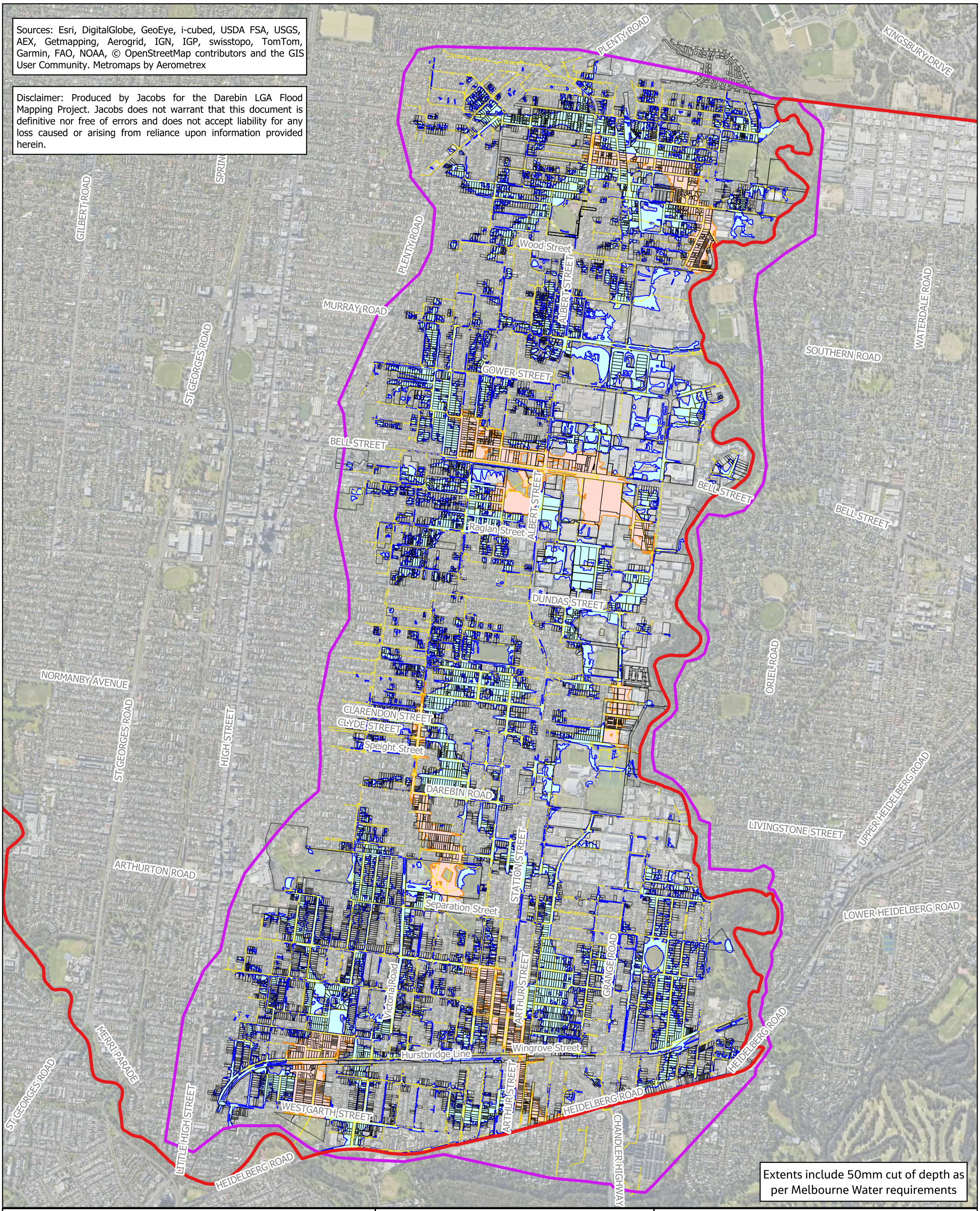
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Coordinate System:	MGA 55	Modeller:	
Height Datum:	AHD	Reviewer:	BM

30/03/2023

IA5000CY

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Extents include 50mm cut of depth as per Melbourne Water requirements

Legend

- Drainage Network
- Parcels
- Darebin LGA Boundary
- Hydraulic Model Boundary
- 1% AEP CC Council Flood Extent
- 1% AEP CC MW UG Drains Flood Extent

0 200 400 600 800 m

Jacobs Melbourne Water

Original Size:	A3	Scale:	1:20500
Coordinate System:	MGA 55	Modeller:	
Height Datum:	AHD	Reviewer:	BM

Darebin LGA Flood Mapping Catchment D

1% AEP with Climate Change Flood Extents

30/03/2023

IA5000CY

Appendix E: Assessment against the 2003 flood level survey

2003 flood event

Between 2 and 3 December 2003 a significant rainfall event occurred for approximately 2 hours. Up to 90 mm of rain fell over the suburbs of Preston, Fairfield and Kew. Based on the current IFD data for the area this equates to approximately a 1 in 1,000 to 1 in 2,000 rainfall event. The available rainfall gauge data is summarised in section 3.2.1. Significant urban flooding occurred through the area.

Flood Survey and captured data

Post the event field survey was undertaken by Melbourne Water which captured flood marks across the Darebin LGA with a concentration of the flood marks within the Fairfield Main Drain Catchment (located with Catchment D for this study). It is assumed the flood levels are based on the residual sediment left as flood lines (i.e. debris lines) from the flood event. The surveyed data is also summarised in Table E1. An additional commentary column has been added which highlights some discrepancies with the dataset. The natural surface level recorded against the flood marks compared to the 2017/2018 LiDAR dataset across each parcel is presented in Table E2. The mean difference is 0.12 m (the 2017/2018 LiDAR is higher) however the data indicates there is a reasonable level of terrain variability across each parcel.

Although a sufficient dataset was captured post the event the flood marks are based on debris marks and therefore there is an element of uncertainty and limitations associated with the dataset, specifically:

- A set of coordinates of the exact points for the dataset is not available. It is noted that the water level can vary across a parcel.
- Aleatory Uncertainty: It's unclear if the measured level captures the peak flood level from the event or a peak level resulting from transient conditions in the catchment such as obstructions of overland flow paths, blockage of drainage networks, temporary or permanent construction works, waves, etc.
- The flood lines may not represent the maximum level during the flood but the level at which the water was at for enough time to leave a sediment deposit.
- Unlike gauge data the flood marks do not capture the time or duration the level was at the debris line, limiting the understanding of how the flood wave travelled through the catchment.

The following sections detail an assessment of the 2003 event in the hydrological and hydraulic models developed for this study.

Table E1: Surveyed flood marks from the December 2003 event.

ID	Comment	Melway Ref.	Flood Level (m AHD)	Floor Level (m AHD)	Natural Surface Level (m AHD)
East Side of Station Street, Fairfield					
FM23	Flood level appears to be an error, footpath (32.43) + the 1170 mm detailed in the surveyors comments equals 33.47 m AHD not 33.6 m AHD	30 K 10	33.6	32.43	32.3
FM24		30 K 10	33.37	32.3	32.15
FM25		30 K 10	33.35	32.41	32.26
FM26		30 K 10	33.35	32.41	32.26
FM32					
FM27	Flood level appears to be an error, footpath (33.02) + 490 mm detailed in the surveyors comments equals 33.51 m AHD, not 33.77 m AHD	30 K 10	33.77	33.28	33.02
FM28		30 K 10	33.4	33.27	33.21
West Side of Station Street, Fairfield					
FM20	Odd results – the parcel is downstream of FM21 but the flood level is approx. 300 mm higher	30 K 10	33.67	33.33	33.29
FM22		30 K 10	33.32	32.99	32.62
FM21		30 K 10	33.38	32.42	32.27
FM33		30 K 10	33.46	-	32.66
FM34					
East Side of Arthur Street, Fairfield					
FM1	Flood level appears to be an error, floor level (31.16) + 50mm detailed in the surveyors comments equals 31.21, not 31.66 m AHD	30 K 11	31.66	31.16	30.85
FM3		30 K 11	31.29	31.11	30.79
FM4		30 K 11	31.36	31.01	30.85
FM5		30 K 11	31.37	31.4	30.94
FM6	Directly downstream of the Wingrove St pedestrian underpass	30 K 11	31.65	31.57	31.21
FM35		30 K 10	32.73	32.56	32.26
West Side of Arthur Street, Fairfield					
FM29	Upstream of the Wingrove St pedestrian underpass	30 K 10	32.72	32.17	31.86
FM30	Upstream of the Wingrove St pedestrian underpass	30 K 10	32.73	31.84	31.82
FM36		30 K 10	32.4	31.75	31.75
FM2	Upstream of the Wingrove St pedestrian underpass	30 K 10	32.72	32.54	32.08
Other Locations					
FM37		31A 8	39.23	39.47	38.92
FM17		31 A 9	39.06	38.93	38.54
FM16		31 A 9	38.08	38.07	37.66

ID	Comment	Melway Ref.	Flood Level (m AHD)	Floor Level (m AHD)	Natural Surface Level (m AHD)
FM13		30 J 7	43.46	43.58	43.04
FM9		30 J 7	43.24	43.52	42.86
FM12		30 J 7	45.23	45.63	44.91
FM11		30 J 6	46.14	46.6	45.74
FM19		30 J 6	46.5	46.73	46.15
FM10		30 J 6	47.18	47.09	46.86
FM8		30 J 6	47.88	48.63	47.79

Table E2: Surveyed natural surface level compared to the 2017/18 LiDAR dataset

ID	2003 Natural Surface (m AHD)	LiDAR max (m AHD)	LiDAR min (m AHD)	LiDAR mean (m AHD)	Maximum difference (m)	Minimum difference (m)	Mean difference (m)
FM1	30.85	30.99	29.85	30.44	0.14	-1.00	-0.41
FM2	32.08	32.25	31.71	32.00	0.17	-0.37	-0.08
FM3	30.79	30.84	30.22	30.63	0.05	-0.57	-0.16
FM4	30.85	31.01	30.59	30.77	0.16	-0.26	-0.08
FM5	30.94	31.32	30.82	30.92	0.38	-0.12	-0.02
FM6	31.21	31.89	31.12	31.47	0.68	-0.09	0.26
FM7	32.26	32.88	32.21	32.58	0.62	-0.05	0.32
FM8	47.79	48.22	47.77	47.97	0.43	-0.02	0.18
FM9	42.86	43.51	42.82	43.24	0.65	-0.04	0.38
FM10	46.86	47.02	46.38	46.76	0.16	-0.48	-0.10
FM11	45.74	46.24	45.74	46.00	0.50	0.00	0.26
FM12	44.91	45.29	44.87	45.16	0.38	-0.04	0.25
FM13	43.04	43.53	42.95	43.26	0.49	-0.09	0.22
FM14	48.44	48.78	48.39	48.67	0.34	-0.05	0.23
FM15	52.92	53.48	52.65	53.19	0.56	-0.27	0.27
FM16	37.66	37.87	37.36	37.63	0.21	-0.30	-0.03
FM17	38.92	39.06	38.70	38.90	0.14	-0.22	-0.02
FM18	38.54	38.71	38.36	38.51	0.17	-0.18	-0.03
FM19	46.15	46.40	45.95	46.14	0.25	-0.20	-0.01
FM20	32.3	32.24	31.99	32.11	-0.06	-0.31	-0.19
FM21	32.15	32.46	32.13	32.27	0.31	-0.02	0.12
FM22	32.26	33.15	32.32	32.61	0.89	0.06	0.35
FM23	32.66	33.11	32.53	32.88	0.45	-0.13	0.22
FM24	33.02	33.59	32.76	33.13	0.57	-0.26	0.11
FM25	33.21	33.24	33.02	33.13	0.03	-0.19	-0.08
FM26	33.29	34.09	33.11	33.68	0.80	-0.18	0.39
FM27	32.62	33.66	32.61	33.26	1.04	-0.01	0.64
FM28	32.27	33.14	32.25	32.65	0.87	-0.02	0.38
FM29	31.86	32.17	31.50	31.95	0.31	-0.36	0.09

ID	2003 Natural Surface (m AHD)	LiDAR max (m AHD)	LiDAR min (m AHD)	LiDAR mean (m AHD)	Maximum difference (m)	Minimum difference (m)	Mean difference (m)
FM30	31.82	32.26	31.64	31.93	0.44	-0.18	0.11
				Average (m)	**0.40**	**-0.29**	**0.12**

Previous Assessments - Cardno Lawson Treloar (2005)

At the time of the December 2003 event Cardno Lawson Treloar were undertaking a flood investigation for the Fairfield Main Drain and Green Street Main Drain catchments for Melbourne Water. The investigation was adjusted to include an analysis of the 2003 rainfall event and a report was published in 2005.

The Cardno Lawson Treloar 2005 investigation was completed in two software packages adopted by the industry at the time, the hydrological modelling software RORB and the hydraulic modelling software SOBEK. The RORB model was available to Jacobs for this study however it does not align with the current RORB model setup requirements in the Melbourne Water Project Specifications. The hydrological inputs for the investigation were based on the guidelines in ARR 1987 and routed flows from the RORB model were applied to major pipes in the hydraulic model. The hydraulic modelling software SOBEK is no longer accepted for Melbourne Water flood studies, and it was not made available to Jacobs during this study. Cardno Lawson Treloar concluded that the SOBEK model adequately captured the flood event with the mean values of the maximum, minimum and average flood level difference between the surveyed flood mark levels and modelled levels of 0.081, -0.026 and 0.025 m respectively.

Catchment understanding

Terrain information

Through reviewing the flood extents produced by this study and previous studies (Cardno Lawson Treloar 2005, Cardno 2020) for the Fairfield Main Drain catchment it was observed flood waters are constricted by the Hurstbridge Rail Line embankment, specifically the constriction at the Wingrove Street pedestrian underpass. How this occurs is presented in Figure E1 which presents the terrain profile upstream of the pedestrian underpass at Wingrove Street. This profile is like that of a dam or retarding basin where flood levels upstream of the embankment of the Hurstbridge Line are influenced by the:

- Underground drainage network (i.e. ability to drain low flows)
- The hydraulic capacity of the outlet (in this case the underpass)
- The incoming flood volume.

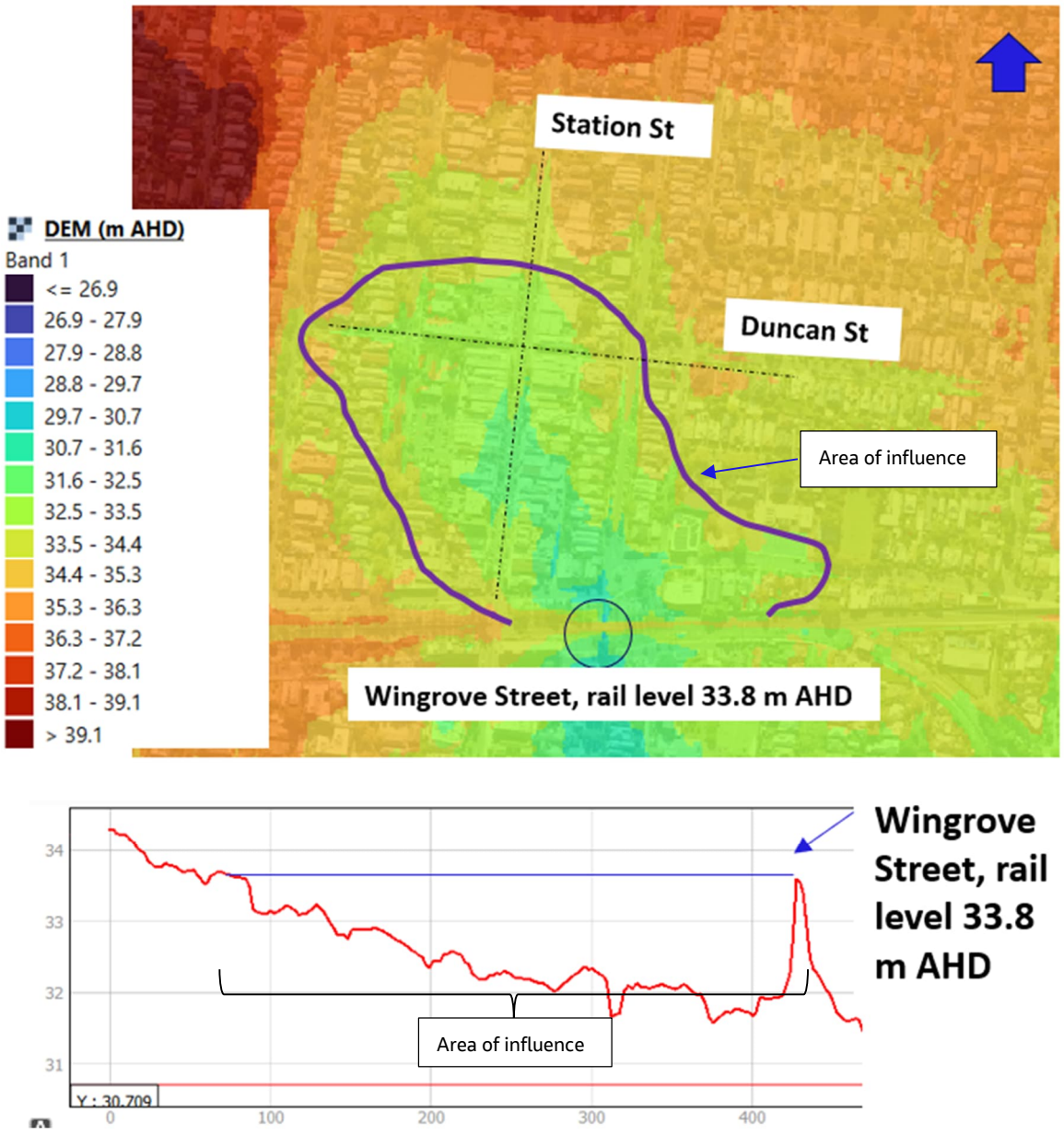


Figure E1: Terrain profile upstream of the Wingrove Street underpass (Hurstbridge rail line)

Wingrove Street Pedestrian Underpass

The Wingrove Street pedestrian underpass consists of an arched structure with an approach slope of 8% and exit ramp slope of 3% (levels increasing upstream). The underpass is located in a depression with the northern entry point sloping down into the underpass off Wingrove street and the southern entrance sloping up to the Railway Place/Arthur Street intersection and provides pedestrian access between Arthur Street to the north and south of the rail line. Based on survey data provided by Melbourne Water the underpass has the following dimensions:

- Width of the arch is 2.45 m
- Height to the apex is between 2.2 m to 2.4 m (32.81 m AHD).
- Invert at the northern entrance (from Wingrove Street) slopes from the east (30.64 m AHD) to west (30.41 m AHD).
- Invert at the southern entrance sloping east to west (30.67 m AHD to 30.55 m AHD).
- Vertical height until the curvature of the arch begins is 1.12 m.

Wingwalls are located at the northern and southern face of the underpass. The underpass as of 2024 is presented in Figure E2 and a cross section of the underpass is presented in Figure E3.

Based on the surveyed flood marks along Wingrove street (i.e. upstream) the flood level peak was 32.72 m AHD during the 2003 event. Assuming the flood level was similar at the northern face of the underpass entrance it is likely the water level was near to the apex of the underpass, and it was either flowing full or just below full during the event (apex of 32.8 m AHD). To estimate the likely flow passing through the underpass two independent checks were completed outside of TUFLOW; a nomograph check and a 1d culvert capacity check in HY-8.



Figure E2: Northern face of the underpass (left), southern face of the underpass (right)

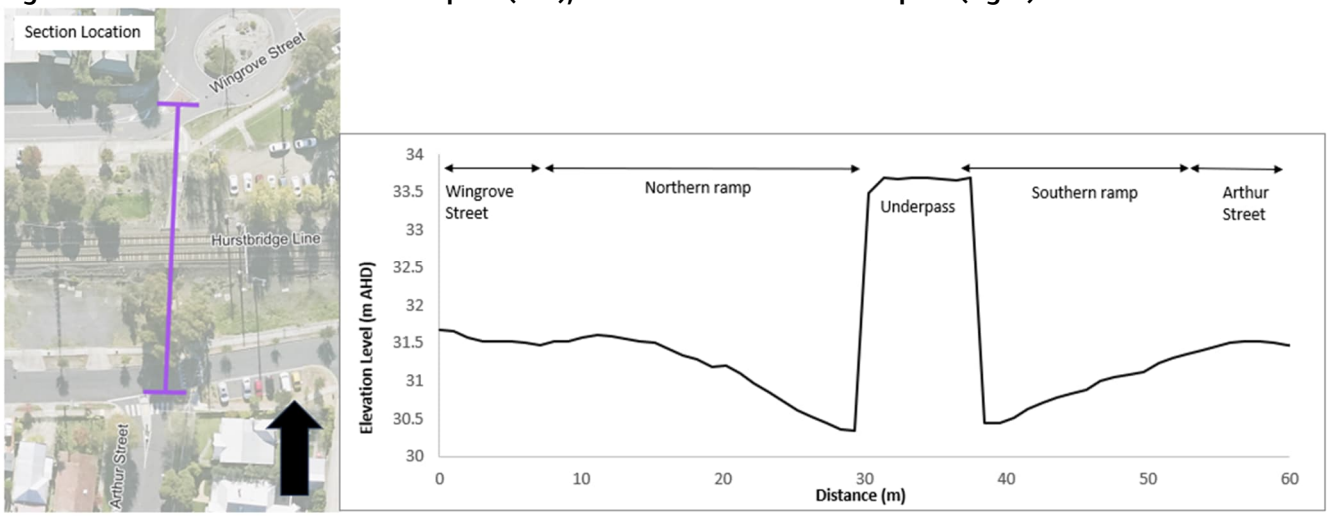


Figure E3: Cross Section of the underpass based on LiDAR (2017/18)

Nomograph

An inlet controlled nomograph for a box culvert was adopted for this assessment. Nomographs are freely available online, for this assessment the nomograph was sourced from Austroads Guidelines 2023 *(Guide to Road Design Part 5B: Drainage-Open Channels, Culverts and Floodway Crossings*). Although the structure is an arch the geometry of the arch is similar to that of a box culvert specifically from the base to mid-height. Inlet controlled was assumed because the downstream levels on Arthur Street were below the apex of the underpass. Assuming the peak level upstream of the underpass was approximately at the apex level or just below the peak flow through underpass was likely to be between 12-15 m^3/s varying based on the upstream peak head level.

HY-8

HY-8 is a 1d culvert design software developed by the U.S Department of Transportation Federal Highway Administration. The software allows the user to input data into the model including the cross-sectional area of the underpass, the upstream and downstream levels (30.5 m AHD and 30.6 m AHD), the road profile above the culvert (rail crest 33.6 m AHD based on LiDAR), roughness values (0.013), tailwater conditions and culvert configuration characteristics. The outputs of the software are a headwater level elevation vs total discharge table. This table is presented in Table E3. For an upstream level between 32.7 and 32.8 m AHD HY-8 estimates the flow to be between 12 m^3/s and 13 m^3/s.

Table E3: HY-8 estimate of the underpass level discharge relationship

Headwater Elevation (m)	Total Discharge (m^3/s)
32.49	10
32.62	11
32.75	12
32.88 (approx. apex)	13
33.00	14
33.13	15
33.26	16
33.39	17

In undertaking the independent checks, it is noted assumptions have been inferred with respect to the peak upstream levels and that the flow through the underpass can be appropriately represented by the analysis methods. It is possible the crossing was blocked during the event altering the flood marks. There is likely to be some simplification applied in the analysis however for the purposes of this study which is a catchment wide flood study the applied checks are representative of the rigor typically applied. More detailed investigations such as CFD modelling was outside the scope of works.

Hydrological and Hydraulic model assessment

An assessment of the hydrological model (RORB) and hydraulic (TUFLOW) models developed for this study against the December2003 event was completed. The assessment was focused on the ability of the models to mimic the behaviour (i.e. flood levels) of the 2003 event. Specific focus was applied to understanding the behaviour along Wingrove Street, Station Street and Arthur Street. The assessment considered and checked various input parameters which influence the model performance, including:

- RORB model (hydrology)
    - Check of rainfall inputs for the 2003 event
    - Check of the RORB model setup
    - Testing of the application of losses (initial loss and continuous loss) and the influence on the hydraulic model results.
- TUFLOW model (hydraulics)
    - Representation of the Wingrove Street underpass (including survey)
    - Manning's representation
    - Terrain modifications
    - Inflow application
    - Tailwater levels

Hydrology model

The development of the RORB model for this study is detailed in Section 4. The RORB model has been developed in accordance with the Melbourne Water Flood Mapping Projects Specifications, ARR 2019 Version 4.1 and in consultation with Melbourne Water. The RORB model was developed based on land use data and aerial imagery from recent years. The catchment land use types were likely to be very similar during the 2003 event as the catchment is well established and the location of residential and commercial/urban areas across the Fairfield Main Drain have not significantly altered.

To simulate the 2003 event in the RORB model the following process was adopted:

- Pluvio rainfall data was extracted from the nearby gauges for the 2003 event, this includes gauges 229403, 229149 and 229143.
- The pluviograph (6min) data was converted into a RORB storm file format to represent the 2003 event.
- A spatial pattern was developed based on a Thiessen polygon calculation of the gauge totals. The spatial pattern was converted to a format that was added to the RORB storm file. The spatial pattern applies rainfall to the RORB subareas based on the Thiessen polygon distribution of the three gauges.
- The RORB model was simulated with the developed storm file using the adopted ARR 2019 Version 4.1 datahub values presented in Section 4.3.3 and in Table E4.

The challenge of replicating a storm event in RORB without flow gauge data (i.e. a hydrograph) is the uncertainty associated with the losses to adopt. Typically, when a RORB model is checked against a storm event the losses and routing parameter k_c for a specific storm would be adjusted to match the hydrograph from a flow gauge.

Losses outside of typical values may be required to match the storm hydrograph. For this model there is no hydrograph to match, and the flows can only be assessed in the TUFLOW model. To limit over complicating this assessment and simulating combinations of loss inputs in the hydraulic model reference was made to the Cardno Lawson Treloar (2005) RORB model. This was completed as the Cardno Lawson Treloar (2005) assessment was documented as adequately matching the 2003 event. The Cardno Lawson Treloar RORB model was reviewed, and the following was concluded:

- The 2005 RORB model adopted a different loss model approach (Runoff Coefficient = 0.6) compared to the Initial Loss/Continuous Loss RORB model setup adopted for this study.
- The 2005 RORB model adopted an initial loss of 10 mm. This was standard at the time.
- The influence of the Runoff Coefficient model on the 2003 event is the 2005 RORB removes approximately 20% of the runoff at each timestep from the model outputs.
- Compared to the Initial Loss/Continuous Loss model for this study and the d design losses in Table E4, only 2% of the runoff is removed every timestep.

Based on the above conclusion it was considered the RORB model for this study would be tested with a higher continuous loss to determine the influence on the hydraulic model performance. The adopted losses for this sensitivity test are presented in Table F4.

Table E4: RORB losses adopted for the assessment

	Design losses		Sensitivity test - Higher Continuous loss	
Parameters	Initial Loss (mm)	Continuing Loss (mm/h)	Initial Loss (mm)	Continuous Loss (mm/h)
Effective Impervious Area (EIA)	1.0	0.0	1	0
Indirectly Connected Area (ICA)	8.4	1.9	12	21.25
Pervious Area (PA)	12.0	1.9	12	21.25

Hydraulic model

The previous section discussed the influence of the RORB model parameters on the model outputs. When a hydraulic model is developed the decisions regarding the model setup and assumption associated with the input parameters can significantly influence the outcome of the model. The development of the hydraulic (TUFLOW) model for this study has been in accordance with the Melbourne Water Flood Mapping Projects Specifications. Despite this there are several parameters within each model which can be altered within the guidelines of the Melbourne Water Flood Mapping Projects Specifications which may produce different model outcomes, such parameters include:

- Model roughness values.
- Application of the RORB inputs into the model.
- Representation of hydraulic structures including the assumed losses, for this assessment the focus was placed on the Wingrove Street.
- Terrain modifications including the representation of building.

- Tailwater level influences.
- Specific to this model the application of the TUFLOW functionality, quadtree.

As stated, the purpose of this assessment was not to calibrate the model to the 2003 event but to develop the best set of model parameter for the application in the design modelling. In total, 40 TUFLOW simulations were completed of the 2003 event where either the hydraulic parameters such as those listed above were adjusted or the hydrological input volumes were adjusted. This enabled an understanding of the model behaviour to be established with respect to 2003 event. The majority of the 40 simulations have various parameters adjusted and as the assessment progressed, favorable parameters were identified and adopted. To determine the influence of the parameters at each flood mark the difference between the modelled mean, maximum and minimum peak water levels from each simulation and the surveyed flood mark was calculated. This was tabulated for each property and the differences assessed across the flood marks. A summary of the tests completed is presented in Table E5.

Table E5: Summary of the tested hydraulic model options

Hydraulic input tested	Options Tested (separate paragraphs are separate options)	Outcomes
Manning's roughness	Remove all buildings from the model, set residential parcel roughness to 0.2 and commercial parcels to 0.5. Represent the station street commercial area with a roughness value of 0.5 (buildings removed) Represent the Station Street commercial area with a roughness value of 0.7 (outside the Flood Mapping Projects Specifications range) (buildings removed)	Removing the roughness representation of the buildings across the whole model domain did not have a significant improvement on the model performance to the 2003 event. Increasing roughness values along Station Street improved the performance to the 2003 flood marks. The representation of the roughness values for the commercial properties along Station Street has been set to 0.5. Higher values above 0.5 such as 0.7 slightly improved the results, however this value has not been adopted as it is not a standard value in accordance with the MW Project Specifications. A higher roughness on Station Street was also found to slightly reduce levels on Wingrove Street
Blockage of buildings	This option was not tested. There is insufficient information across the catchment to justify the removal of buildings from the floodplain for this study. There is insufficient data available across the catchment to stamp in building floor levels.	N/A
Application of RORB inputs	Apply the RORB inflows to the base of the pits in the 1d network	No tangible change to the flood levels for the 2003 event
RORB input volumes for the 2003 event	Lower volumes tested by reducing the incoming storm volume by 5%, 10%, 15%	Reducing the incoming volume globally reduced the flood levels, however levels upstream of the pedestrian underpass were the most sensitive to the volume change.

Hydraulic input tested	Options Tested (separate paragraphs are separate options)	Outcomes
	Adjustment of the continuous loss (Table E4)	Typically, with a 5% reduction in storm volume the average modelled flood levels upstream of the pedestrian underpass reduced by 10 mm. Other locations the change was averaging 5 mm or less for a 5% storm volume reduction. Downstream of the pedestrian underpass the level reduction was only 2 mm.
Tailwater assumptions	Adjust the tailwater levels (reduce) in the Yarra River.	The flood levels near the flood marks were not sensitive to tailwater levels in the Yarra River
Representation of the Wingrove Street Underpass	Refer to Table E6	Refer to Table E6
Terrain adjustments	Adjust terrain upstream and downstream of the Wingrove street pedestrian underpass	No terrain adjustments that could be justified as defensible for application in the design modelling were identified.

Table E6: Summary of the tested hydraulic model options (representation of the pedestrian underpass)

Underpass Representation	Option Test	Discuss/Outcomes
1d hydraulic structure	Adjustments to the entry and exit losses	In the early iterations of the modelling the underpass was represented in 1d, i.e., as a structure in the 1d domain. It was represented as an irregular culvert with a height and width relationship (to define the shape). Early iterations of the model did not apply height, width contraction values and exit/entry losses to the structure and the hydrograph through the structure was unstable on the rising limb and falling limb. Flows passing through the structure were up to 20-25 m^3/s for the 2003 event. Focus was placed on stablising the underpass hydrograph and various options were tested. The stability of the hydrograph was resolved by applying the exit/entry losses and the height and width contraction values. Various iterations of values were tested to understand the influence on the shape of the hydrograph through the structure. All options reduced the flows to approximately 14-16 m^3/s for the 2003 event, however, as anticipated this increased the modelled flood levels upstream of the pedestrian underpass on Wingrove Street. Testing of the exit, entry, width and contraction values concluded lower exit and entry losses provided a favorable outcome with respect to the flood levels upstream of the pedestrian underpass. The loss values required on the structure were likely to be outside the standard TUFLOW recommended range (suggested exist loss
	Adjustment to the 1d height and width contraction/expansion values.	
	Adjustment to the 1d/2d SX/CN connections Added storage factors on the connections Add initial water levels to the underpass to stabilise flow.	

Underpass Representation	Option Test	Discuss/Outcomes
		and entry loss were 0.1 compared to the standard of 0.5 to 0.9). With limited data available to calibrate the exit and entry losses appropriately at this point in the assessment it was decided to test the ability of the TUFLOW model to simulate the underpass in the 2d domain. Modelling the underpass in the 2d domain would also allow for momentum transfer which can be reduced in TUFLOW when structures are modelled in 1d and the connection to the 2d is with TUFLOW SX links.
2d representation	Remove the underpass from 1d and represent the culvert in 2d. Reduce the grid size around the underpass to 1 m x 1 m (from 2 m x 2m) to improve resolution.	As the model had been setup with quadtree the capabilities of this TUFLOW functionality were utilised for the representation of the underpass. To stamp in the underpass the terrain was modified to the remove the 2d blockage to enable the free flow of water. The manning's values was also change to 0.013 (concrete) through this area. Initially the quadtree configuration across the model was 4m/2m. As the width of the underpass is approximately 2.45 m the initial terrain modifications were found to enable the passage of too much flow through the underpass. The quadtree functionality was used to implement a 1 m grid resolution around and through the structure and was adopted. This enabled a finer resolution through the underpass and a refinement to the terrain modifications. The final representation of the underpass was found to convey approximately 13-16 m^3/s depending on the incoming volumes (discussed below). This was deemed to be a suitable representation of the structure based on the independent checks completed (estimated flow range of 12-15 m^3/s for this event). The hydrograph also did not show any signs of instability. The pedestrian underpass roof and track formation were represented as a layered flow constriction in TUFLOW with the following setup: • Deck obvert: 32.8 m AHD. • Deck thickness: 0.9 m. • Deck blockage 100%. • Flow constriction 1.56.

Performance of the flood marks and conclusion

The performance of the hydraulic model to the 2003 flood marks has been assessed for hydrological scenarios as detailed in Table F4:

- Scenario 1: The adopted RORB design losses
- Scenario 2: RORB with a higher continuous loss

Table E7 provides a summary of the performance of the hydraulic model to the 2003 flood event flood marks. The data in the table represents the maximum, minimum and mean water level across each parcel as defined by the survey data set. Commentary is provided with respect to the how the model performs relatively to the flood marks. Adopting the design losses (Scenario 1) the mean flood level difference across all the parcels is 0.06 m.

The commentary provided generally indicates either the minimum or maximum flood level are a good fit across the parcels. The main area where there is a discrepancy is upstream of rail underpass on Wingrove Street where the levels are higher due to the constriction of the underpass. In this scenario the peak flow passing through the underpass is up to 16 m^3/s. For Scenario 2 the levels upstream of the underpass have reduced compared to Scenario 1 and the flow is approximately 13 m^3/s.

Long plots of the hydraulic profile were provided in section 8.2 The figures indicate the peak water surface elevation generally follow the hydraulic profile of the flood marks across the model domain and there is an acceptable fit to the dataset.

The discrepancies associated with the flood levels on Wingrove Street are attributed to:

- The incoming volume – the hydraulic model maybe overestimating the volume received at the underpass either due to:
    - An overestimation of the volume of the storm.
    - The timing of flows from Station Street and Arthur Street may not have coincident during the 2003 event.

As there is insufficient data to confirm the hydraulic performance to another model event the items above have not been investigated further.

Across the model domain the adopted hydraulic model setup is considered to provide a reasonably good fit to the flood marks from 2003. The hydraulic performance of the underpass is within an acceptable flow range based on the assumed hydraulic characteristics of the event.

Table E7: Performance of the hydraulic model for the two hydrology scenarios. Scale: Green (+/- 0.1 m), Yellow <-0.1 m, Orange > 0.1 m

		Scenario 1: Design losses							Scenario 2: Sensitivity test - Higher initial loss					
ID	Flood mark (m AHD)	Mean water level (m AHD)	Mean diff (m)	Min water level for the parcel (m AHD)	Min diff (m)	Max water level (m AHD)	Max diff (m)	Comment	Mean water level (m AHD)	Mean diff (m)	Min water level (m AHD)	Min diff (m)	Max water level (m AHD)	Max diff (m)
FM14	49.08	49.02	-0.06	49.02	-0.06	49.02	-0.06	good fit	48.94	-0.14	48.94	-0.14	48.9	-0.14
FM38	48.46	48.50	0.04	48.14	-0.32	49.74	1.28	good fit with the mean	48.43	-0.03	48.09	-0.37	49.7	1.28
FM8	47.88	48.03	0.15	47.94	0.06	48.0	0.20	plots higher off Clarendon St	47.99	0.11	47.92	0.04	48.0	0.16
FM9	43.24	43.54	`0.30	43.52	0.28	43.5	0.32	Min is the closest to the road.	43.46	0.22	43.45	0.21	43.5	0.23
FM10	47.18	47.15	-0.03	46.95	-0.23	47.30	0.12	mean is a good, significant variation across the parcel	47.10	-0.08	46.90	-0.28	47.3	0.07
FM11	46.14	46.36	0.22	46.36	0.22	46.36	0.22	generally higher	46.29	0.15	46.29	0.15	46.3	0.15
FM12	45.23	45.50	0.27	45.30	0.07	45.63	0.40	min good fit (significant drop across the parcel)	45.43	0.20	45.23	0.00	45.5	0.31
FM13	43.46	43.56	0.10	43.55	0.09	43.57	0.11	good fit	43.48	0.02	43.47	0.01	43.5	0.02
FM19	46.5	46.54	0.04	46.44	-0.06	46.66	0.16	mean and min good fit	46.50	0.00	46.39	-0.11	46.6	0.11
FM15	53.04	53.23	0.19	53.07	0.03	53.37	0.33	min good fit	53.15	0.11	52.98	-0.06	53.4	0.31
FM16	38.08	37.94	-0.14	37.69	-0.39	38.22	0.14	max level a good fit to the flood marks. Reasonable grade along this profile and max levels are nearest to the road.	37.92	-0.16	37.67	-0.41	38.2	0.12
FM18	39.23	39.15	-0.08	39.11	-0.12	39.27	0.04		39.13	-0.10	39.09	-0.14	39.3	0.03
FM17	39.06	38.97	-0.09	38.87	-0.19	39.05	-0.01		38.96	-0.10	38.85	-0.21	39.0	-0.03
FM23	33.47	33.31	-0.16	33.47	0.00	33.34	-0.13	max level is a good fit which is nearest to the road where flooding is coming from, FM20 is an outlier (located downstream all of the other points but has a higher level, flood marker doesn't follow the trend)	33.15	-0.32	33.08	-0.39	33.2	-0.25
FM24	33.37	33.31	-0.06	33.27	-0.10	33.35	-0.02		33.17	-0.20	33.09	-0.28	33.2	-0.15
FM25	33.35	33.32	-0.03	33.27	-0.08	33.35	0.00		33.18	-0.17	33.09	-0.26	33.2	-0.13
FM26	33.46	33.40	-0.06	33.36	-0.10	33.49	0.03		33.30	-0.16	33.23	-0.23	33.4	-0.04
FM27	33.51	33.44	-0.07	33.41	-0.10	33.55	0.04		33.34	-0.17	33.30	-0.21	33.6	0.04
FM28	33.4	33.45	0.05	33.42	0.02	33.50	0.10		33.37	-0.03	33.31	-0.09	33.4	0.04
FM20	33.67	33.35	-0.32	33.35	-0.32	33.35	-0.32		33.22	-0.45	33.22	-0.45	33.2	-0.45
FM21	33.32	33.35	0.03	33.35	0.03	33.36	0.04		33.23	-0.09	33.22	-0.10	33.2	-0.09

			Scenario 1: Design losses						Scenario 2: Sensitivity test - Higher initial loss					
FM22	33.32	33.35	0.03	33.35	0.0	33.36	0.04		33.23	-0.09	33.22	-0.10	33.2	-0.09
FM2	32.72	3.22	0.50	33.21	0.49	33.23	0.51		32.97	0.25	32.95	0.23	33.0	0.26
FM7	32.73	33.21	0.48	33.21	0.48	33.22	0.49	Underpass location - as discussed likely an issue with the incoming volume.	32.95	0.22	32.95	0.22	33.0	0.22
FM29	32.72	33.21	0.49	33.21	0.49	33.22	0.50		32.95	0.23	32.95	0.23	33.0	0.24
FM30	32.73	33.22	0.49	33.21	0.48	33.23	0.50		32.96	0.23	32.95	0.22	33.0	0.25
FM1	31.21	31.00	-0.2	30.9	-0.28	31.16	-0.05		30.91	-0.30	30.85	-0.36	31.1	-0.09
FM3	31.29	31.16	-0.1	31.06	-0.23	31.29	0.00	max level is a good fit which is nearest to the road where flooding is coming from	31.10	-0.19	30.97	-0.32	31.2	-0.05
FM4	31.36	31.19	-0.17	31.07	-0.29	31.32	-0.04		31.14	-0.22	30.99	-0.37	31.3	-0.09
FM5	31.37	31.25	-0.12	31.13	-0.24	31.37	0.00		31.22	-0.15	31.08	-0.29	31.3	-0.04
FM6	31.65	31.75	0.10	31.7	0.05	31.86	0.21	approx. 31.7 m AHD at the road, reasonable fit	31.72	0.07	31.65	0.00	31.9	0.21
Average (m)			**0.06**		**-0.01**		**-0.17**			**-0.04**		**-0.12**		**0.08**