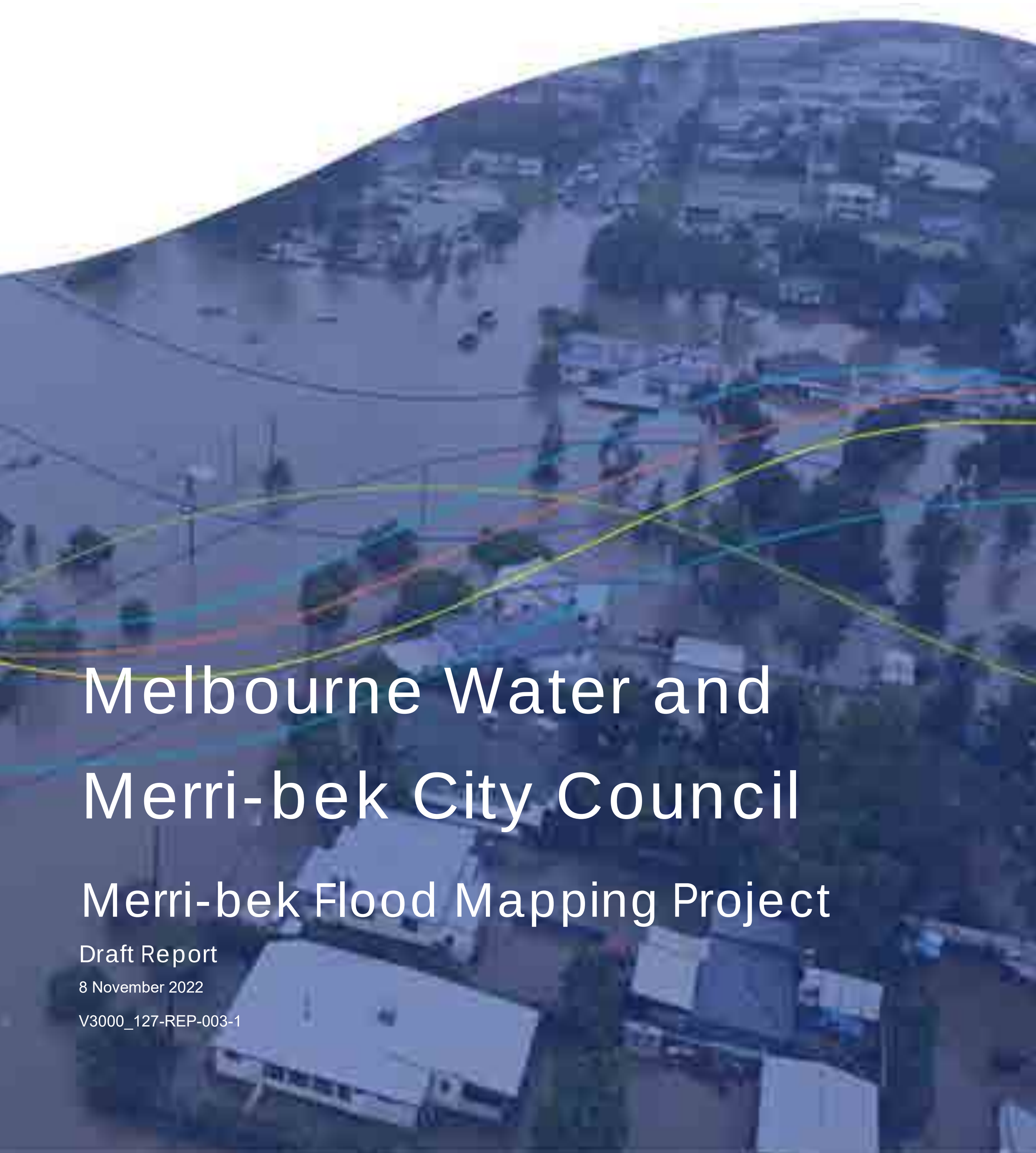
APPENDIX B: MELBOURNE WATER AND MERRI-BEK CITY COUNCIL MAPPING PROJECT REPORT (NOVEMBER 2022)



Melbourne Water and Merri-bek City Council

Merri-bek Flood Mapping Project

Draft Report

8 November 2022

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1 EXECUTIVE SUMMARY

The Merri-bek Flood Mapping Project has consisted of the hydrologic and hydraulic modelling of seven (7) catchments within the municipality of Merri-bek/Darebin. This study report presents the modelling approaches and results of the investigations undertaken for the seven catchments:

- Chapman Avenue Drain,
- Westbreen Creek Drain,
- Merlynston Drain,
- Melville Drain,
- Elizabeth Street Drain
- South East catchments and;
- Harding Street Drain.

The key objectives of this study were to:

- Identify flooding hotspots and associated risks.
- Improve flooding awareness including the identification of key overland flow paths and the expected depth and duration of flooding for major events.
- Confirm that the modelled flood affected areas corresponds to the expected / known historical flooding hotspots within the catchment.

The combined catchments cover approximately 54.15 km². The overall catchment is largely zoned a mixture of predominantly residential, commercial and industrial areas due to being almost fully developed.

The hydrologic modelling was undertaken utilising RORB generally in accordance with Melbourne Water's Flood Mapping Projects Guidelines and Technical Specifications (2020) and the Australian Rainfall and Runoff (ARR 2019) guidelines. In addition to the RORB models developed for the seven catchments the flows from two large external catchments on Merlynston Creek and Campbellfield Creek were applied to the North East Catchments TUFLOW model as routed flows from external catchment RORB models.

The hydraulic modelling was undertaken in accordance with Melbourne Water's Flood Mapping Projects Guidelines and Technical Specifications (2020) utilising a 3 metre grid cell size and TUFLOW Classic (Build: 2020-01-AB-iDP-w64). The modelling includes all Merri-bek City Council and Melbourne Water drainage assets. Modelling was undertaken for the base case 1 %, 2 %, 5 %, 10 % and 20 % Annual Exceedance Probability (AEP) storm events in addition to the climate change 1%, 20% and 10% AEP storm events.

Median temporal patterns were chosen for each critical duration to establish the flood mapping outputs.

The raw food mapping results were used to produce the GIS flood mapping deliverables including the relevant flood extents in accordance with Melbourne Water's Technical Specifications 2020. This data will be used to update Melbourne Water's flood mapping information and inform future flood risk assessments. These outputs were also delivered to Council and will improve their understanding of flooding hotspots in addition to informing future flood advice for new developments within the Catchment.

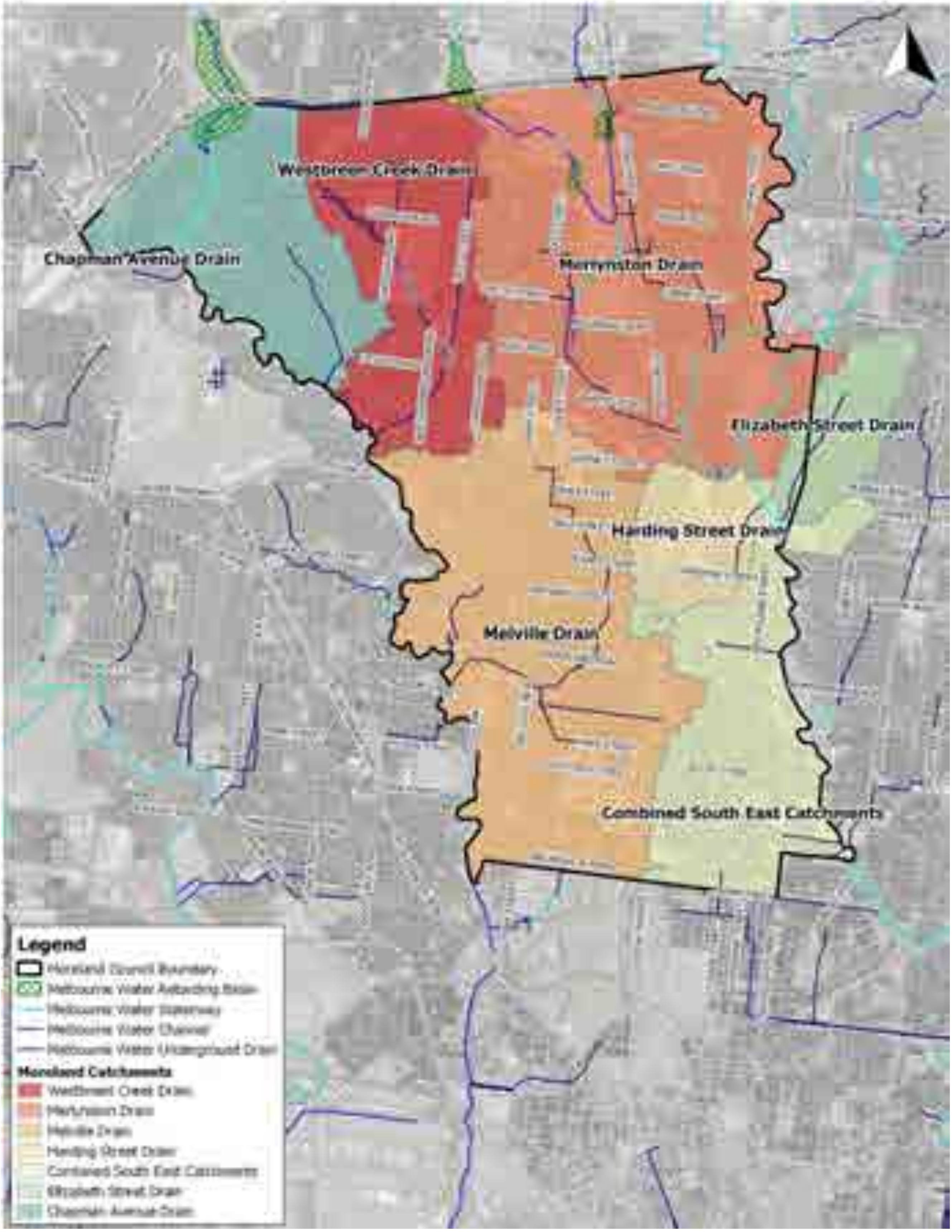
2 INTRODUCTION

2.1 STUDY OVERVIEW

Engeny Water Management (Engeny) was engaged by Melbourne Water to update the five existing flood models developed by Engeny for the City of Merri-bek (Council) in 2018, covering the municipality of Merri-bek to include all of Melbourne Water's drainage infrastructure. The catchments to be updated as part of this study are shown in Figure 2.1 and include:

- Combined North East Catchments (Including Westbreen Creek Drain, and Merlynston Drain)
- Chapman Avenue Drain.
- Melville Drain.
- Elizabeth Street Drain which partly sits in neighbouring municipality Darebin.
- South East catchments.
- Harding Street Drain.

Figure 2.1: Merri-bek Council Catchment Extents



2.2 KEY OBJECTIVES

The flood models developed in 2018 utilised Australian Rainfall and Runoff 2016 (ARR 2016) methodologies with a primary focus on mapping Council assets and catchments. The key drivers of this study are to:

- Update the 2018 flood models to be fully compliant with Australian Rainfall and Runoff 2019 (ARR 2019), Melbourne Water's current Flood Mapping Projects Guidelines and Technical Specifications (September 2020) and utilise updated LiDAR data captured in 2017-18
- Create planning scheme overlays relevant to Melbourne Water's and Council's drainage system (Council overlay to be completed with consideration of climate change)
- Give flood and development advice on parcels (formerly identified as 'properties') affected by overland flow and/or riverine flooding along Melbourne Water and Council drains and waterways.
- Enable Melbourne Water and Council to set their capital works program by identifying and quantifying flood risk.
- Resolve land development issues which may result in flood data being questioned at a Victorian Civil and Administrative Tribunal (VCAT) panel hearing.
- Allow VicSES to plan their emergency response strategies.

2.3 SCOPE

The following tasks have been completed for this stage of the project:

- Data collection and review of Melbourne Water's existing drainage assets.
- Updating the model's hydrology to be in accordance with ARR 2019, as per Melbourne Water's requirements.
- Hydrological modelling for the 1 %, 2 %, 5 %, 10 % and 20 % Annual Exceedance Probability (AEP) storm events.
- Hydrological modelling for the 1 %, 10 % and 20 % AEP storm events under climate change scenario.
- Hydraulic modelling for the 1 % and 20 % AEP storm events.
- Preparation of a flood modelling report (this document) for submission to Melbourne Water together with RORB and TUFLOW models for review.

As stated in the proposal, mapping of Moonee Ponds Creek, Edgars Creek, Merri Creek and Gladstone Park Drain is outside the scope of the current study. Deliverables for this study exclude areas impacted by flooding from these waterways and assets.

3 DATA COLLATION AND REVIEW

Data for this study was previously obtained from Melbourne Water, Merri-bek City Council, VicRoads, the Department of Environment, Land, Water and Planning (DELWP) and the Data VIC website and was incorporated into the Merri-bek Municipal Flood Mapping Study (2018). As part of the model updates undertaken for this study, Engeny was provided Melbourne Water and VicRoads drainage data for the municipality. Table 3.1 summarises the data obtained for this study, its purpose, and the source.

3.1 SUMMARY OF DATA

Table 3.1: Summary of Data Used

Data	Purpose	Source
VicRoads Survey	Determine if any major VicRoads drainage impacts Melbourne Water drainage and add in any drainage alignments that haven't been accurately represented.	VicRoads
Council pit and pipe data GIS data and civil plans	Pit and pipe data were used to represent Council assets in the TUFLOW hydraulic model. Drainage alignments were also used to inform the delineation of sub-catchment boundaries.	Merri-bek City Council
Melbourne Water drainage asset data (underground drains, channels and waterways) GIS data and plans	Pit and pipe data were used to represent Melbourne Water assets in TUFLOW hydraulic model. Drainage alignments were also used to inform the delineation of sub-catchment boundaries.	Melbourne Water
Melbourne Water GIS data (catchment boundaries, building footprints, existing flood extents and flood contours)	Catchment boundaries used to inform the delineation of sub-catchment boundaries. Building footprints used in the hydraulic TUFLOW model (materials layers).	Melbourne Water
RORB Model for Moonee Ponds Creek (MPC)	RORB model was used to obtain inflows for CHAP model to provide tailwater levels	Melbourne Water
Aerial Photography (December 2018)	Used to verify the adopted fraction impervious values (an input to the hydrological RORB model). Used to verify the adopted Manning's roughness values (an input to the hydraulic TUFLOW model).	DELWP
Light Detection and Ranging (LiDAR) Data (2017-2018)	Used as the 2D terrain surface input to the hydraulic TUFLOW model to represent the overland flow paths.	DELWP
Mapbase information (including, but not limited to parcels, road, easements)	Used to assign the Manning's roughness values (an input to the hydraulic TUFLOW model) and confirm drainage alignments.	Data VIC
Planning scheme information	Used to estimate the impervious fraction for hydrological model input. Used to estimate the Manning's roughness values for hydraulic model input.	Data VIC
Northern Cemetery Park drainage and surface information	Used to update terrain surfaces and culvert drainage assets in the NEC flood model.	Melbourne Water and Merri-bek City Council

Engeny were unable to obtain the information regarding topography and drainage system changes due to Level Crossing Removal Project to adequately represent them in the models. As agreed with Melbourne Water and Council during the inception meeting, Level Removal Project locations are left as represented by 2017/18 LiDAR and drainage systems assuming that any works undertaken at these locations are expected to provide no change in afflux and no adverse impacts to adjacent areas.

It should be noted that data provided by VicRoads regarding the Citylink drainage assets are very limited and modelling results for Citylink may not be accurate.

While calibration to gauge data is outside the scope of the current project, Engeny have reviewed available gauge data for waterways being modelled. It was estimated that the data range for Merlynston Creek at Fawkner (MW gauge number: 229402) is insufficient to achieve a confident estimate of the 1 % AEP event due to the data record only being from 1998 (~23 years long).

3.2 SITE INSPECTION

Engeny completed site inspections of the Merri-bek municipality in the past as part of the 2018 Council flood mapping study however, this focussed on Council drainage assets. A site visit with a focus on Melbourne Water drainage assets was conducted on the 6 December 2021 to inspect some of the key hydraulic control structures to verify existing information and / or resolve gaps in the supplied drainage data such as missing pipe diameters, unknown inlet sizes and measurement of the key dimensions of structures that could impact flows within the catchment. The list of data queries addressed on the day are summarised in Table 3.2, accompanied by key photos taken.

Table 3.2: Summary of Drainage Queries

ID	Model	Location	Query / Action Items	Resolution	Reference Photos
1	CHAP	Railway embankment between Strachan Street and Jessie Street, Oak Park	Using Google StreetView, the downstream side shows open concrete channel and pedestrian crossing, upstream side of railway difficult to see but may be a headwall. Need to inspect upstream side (Jessie St) on site.	There is a 900 mm diameter culvert under the railway and the outlet structure of a 750 mm diameter pipe aligned parallel to Waterloo Rd.	
2	NEC	Railway embankment between Elliot Street and Renown Street, Coburg North	Significant ponding on western side of embankment in flood model. Google Streetview shows 4 large culverts which are not in the flood model currently. VicTrack only shows MW underground drain, not the culverts. Need to inspect and measure culverts onsite if access is safe and the end of the culvert is in publicly accessible areas.	4 x 1300 mm diameter culverts.	

ID	Model	Location	Query / Action Items	Resolution	Reference Photos
3	NEC	Culvert crossing on Sydney Road, Coburg North south of Fame Street	Directly downstream of location 2, it is suspected that there are culverts underneath Sydney Road given there is an open channel visible, can't see culverts from Google StreetView. Can get access to channel on eastern side of Sydney Road (downstream end of likely culverts). Need to inspect and measure culverts onsite if access is safe and the end of the culvert is in publicly accessible areas.	Arch bridge with dimensions of 4.2m x 2.4 m, two culverts at the downstream end of the bridge with a 200 mm pier between them	
4	NEC	Railway embankment in south-east corner of Fawkner Cemetery	Significant ponding on eastern side of railway embankment. Suspect there may be a culvert here as well as MW u/g drain. VicTrack shows MW u/g drain only. Need to inspect and measure on site if access is safe and the end of the culvert is in publicly accessible areas.	Fenced off, no access. Review of NearMap Aerial imagery identified a large grated pit located on top of the underground drain shown to cross the railway line. As agreed with Melbourne Water, a 1200mm X 1200mm grated pit to the TUFLOW model, which will allow the flooded area to drain as per reality.	
5	NEC	Northern Memorial Park	Several road crossing culverts missing from flood model in cemetery. Need to inspect and measure on site if in publicly accessible areas.	Several road crossing culverts were found and measured on site. It was also noted that the existing LiDAR does not reflect recently constructed wetlands. Engeny has requested plans for the wetlands from MW. Council provided some valuable plans and terrain data which was used to update the flood model in this area.	

ID	Model	Location	Query / Action Items	Resolution	Reference Photos
6	NEC	Railway embankment between Devon Road and Railway Parade	Significant ponding in model east of railway embankment. model only has JPs here, likely to be an inlet pit or missing culvert. Want to see if this can be viewed onsite from publicly accessible areas, may be difficult to access.	1050 mm diameter round grated pit with the elevated entry (~ 500 mm above the ground surface elevation)	
7	MEL	McLean Street and Johns Reserve Playground, Pascoe Vale South	Two overland flow paths are intercepted by raised Citylink roadway. Want to inspect onsite to see if flow can pass under the roadway or if there are missing drainage assets in flood model. Site inspection would not involve accessing the freeway or onramps in any way, rather site inspection would be in publicly accessible open space or minor roads adjacent to the freeway.	Noise walls represent a complete blockage. 900 mm x 900 mm grated pit is located in the low point.	

4 CATCHMENT DESCRIPTIONS

The City of Merri-bek is a local government area in metropolitan Melbourne. It comprises the inner northern suburbs between 4 and 11 kilometres from the Melbourne Central Business District (CBD). The municipality is bordered by the Western Ring Road at the north, Merri Creek to its east (mostly), and Moonee Ponds Creek / CityLink to its west. The southern boundary is located at Brunswick Road. The entire municipality is 51 km² in size and sits at an elevation of between 30 and 115 m AHD (Figure 4.1). The municipality comprises a mixture of predominantly residential, commercial and industrial areas as shown in Figure 4.2. Several waterways run through the various catchments of Merri-bek including Moonee Ponds Creek, Westbreen Creek, Merlynston Creek, Campbellfield Creek, and Merri Creek.

Figure 4.1: Merri-bek Terrain Map

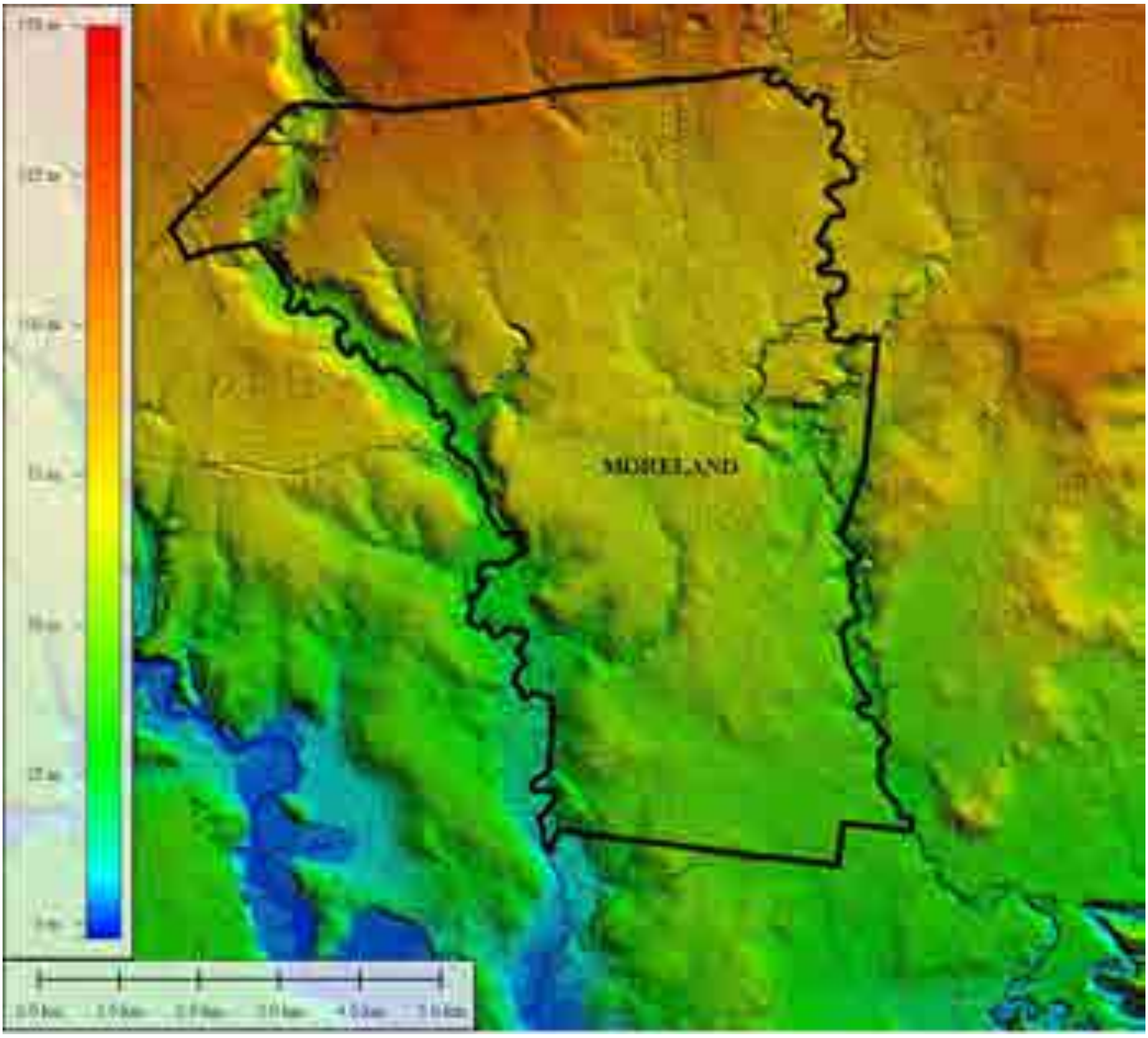
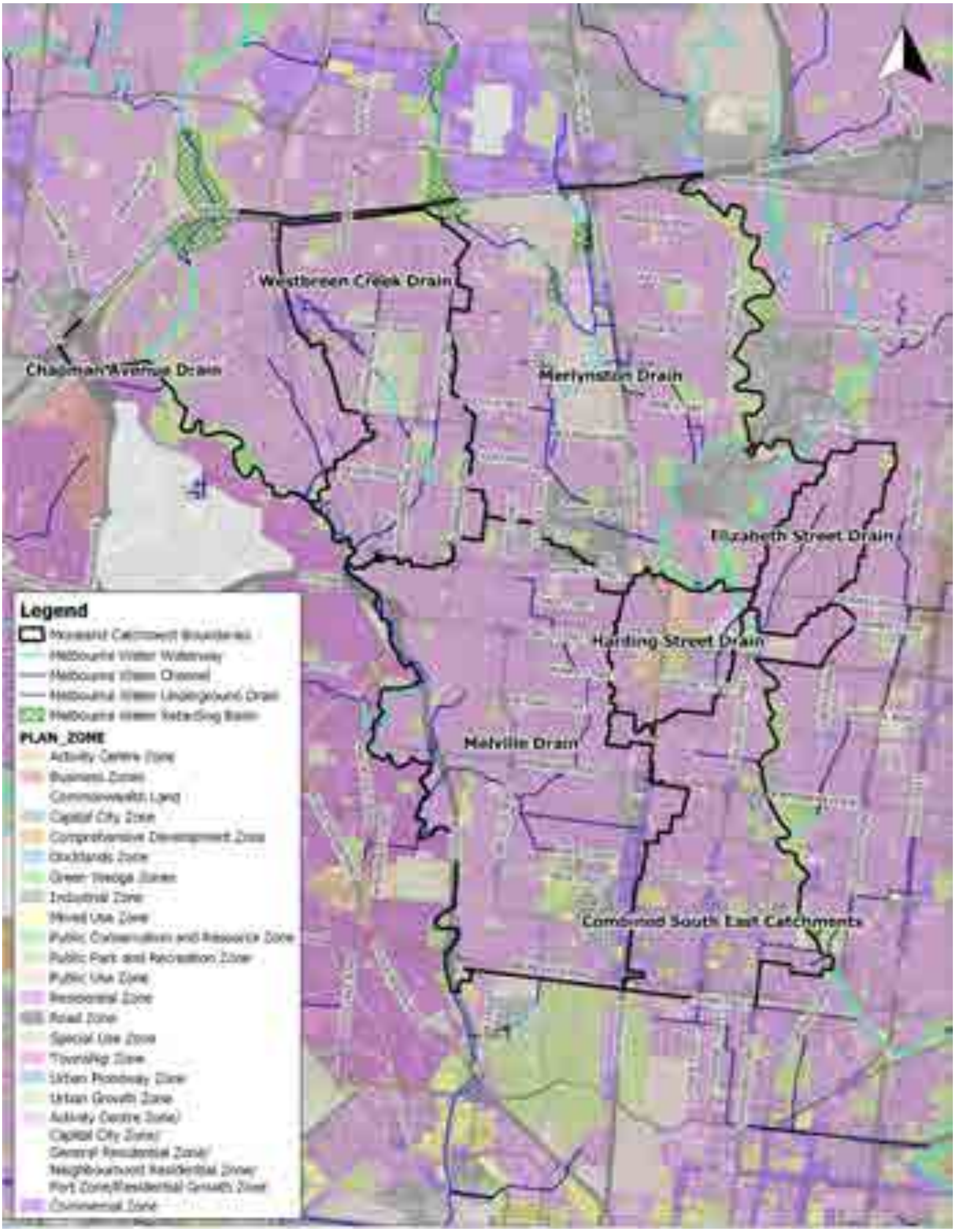


Figure 4.2: Merri-bek Council Planning Zones



4.1 CHAPMAN AVENUE MAIN DRAIN RORB MODEL CATCHMENT

Chapman Avenue Main Drain is the catchment in the north-west corner of the Merri-bek Municipality. It includes catchments downstream of the Jacana Retarding Basin, including the Melbourne Water Chapman Avenue Main Drain which begins just south of Prospect Street. The catchment covers approximately 7.16 km² and is mostly residential zones. The catchment drains to the Moonee Ponds Creek, except for a small area that drains under the railway line to Mascoma Street Drain within Moonee Valley City Council (and ultimately draining back into Moonee Ponds Creek).

Table 4.1: Chapman Avenue Melbourne Water Assets

Chapman Asset	Melbourne Water Asset ID
Chapman Avenue Main Drain	4345
Jacana Retarding Basin	4350

4.2 ELIZABETH STREET MAIN DRAIN RORB MODEL CATCHMENT

The Elizabeth Street Main Drain catchment sits predominantly within the municipality of Darebin with its lower reaches entering Merri-bek City Council. The catchment is 2.14 km² and is situated in a predominantly residential zone. The drain discharges to Merri Creek on its southern front.

Table 4.2: Elizabeth Street Melbourne Water Assets

Elizabeth Street Asset	Melbourne Water Asset ID
Elizabeth Street Main Drain	4433

4.3 HARDING STREET MAIN DRAIN RORB MODEL CATCHMENT

Harding Street Main Drain is a small catchment within the suburb of Coburg roughly 2.3 km². The catchment includes a combination of residential and activity zone types. The Melbourne Water drain begins along Harding Street on the eastern side of Sydney Road and ends up in Merri Creek to the east.

Table 4.3: Harding Street Melbourne Water Assets

Harding Street Asset	Melbourne Water Asset ID
Harding Street Main Drain	4434

4.4 MELVILLE DRAIN RORB MODEL CATCHMENT

The Melville Main Drain and the surrounding inner-city suburbs of Coburg, Pascoe Vale South, Brunswick West & Brunswick are located approximately 8 km north of Melbourne in a predominantly residential zone. The catchment is 13.5 km² in size and has three main stormwater drains run through the area: the Melville, Albion Street & Hope Street Main Drains. The three drains converge in Brunswick West before discharging into Moonee Ponds Creek on the western border of the Municipality. The Coonans Road Main Drain which also discharges directly into Moonee Ponds Creek has also been linked to the Melville Drain for this mapping project.

Table 4.4: Melville Melbourne Water Assets

Melville Asset	Melbourne Water Asset ID
Melville Main Drain	4320
Hope Street Main Drain	4321
Albion Street Main Drain	4322
Coonan's Road Main Drain	4325

4.5 MERLYNSTON CREEK RORB MODEL CATCHMENT

Merlynston Creek catchment within Merri-bek City Council is the north-east section of the municipality. It covers all areas downstream from the Commonwealth Serum Laboratories (CSL) Retarding Basin and the Campbellfield Creek Retarding Basin to Merri Creek. The catchment covers 15.98 km² and includes a mixture of residential, industrial and public use zones (specifically Coburg cemetery).

Table 4.5: Merlynston Creek Melbourne Water Assets

Merlynston Creek Asset	Melbourne Water Asset ID
Merlynston Main Drain	4450
South Street Drain	4451
Middle Street Drain	4452
Lynch Road Main Drain	4453
Major Road Drain	4455
Commonwealth Serum Laboratories Retarding Basin/Box Forest Road Retarding Basin	4460
Campbellfield Creek Retarding Basin/Campbellfield Creek	4461
Fawkner North Drain	4462
Fawkner East Drain	4471

4.6 MERLYNSTON CREEK EXTERNAL RORB MODEL CATCHMENTS

External catchments from Hume City Council drain into Merri-bek City Council's Merlynston Creek catchment. The catchments include Maffra Street Drain and Hume City Council's portion of Merlynston Creek and Campbellfield Creek. The catchments are located north of the Western Ring Road.

The Merlynston Creek catchment includes the Maffra Street drain and covers an of area 8.85 km² within Hume City Council. The land use is predominately residential and industrial zoned land. Campbellfield Creek catchment is 3.54 km² in size and the land use is a mixture of residential, industrial, and open space zones.

Table 4.6: Merlynston Creek Melbourne Water Assets (Hume City Council)

Merlynston Creek Asset	Melbourne Water Asset ID
Commonwealth Serum Laboratories Retarding Basin	4460
Army Camp Retarding Basin	4460
National Business Park Retarding Basin	4460
Merlynston Creek	4460
Maffra Street Drain	4453

Table 4.7: Campbellfield Creek Melbourne Water Assets

Campbellfield Creek Asset	Melbourne Water Asset ID
Campbellfield Creek Retarding Basin	4461
Campbellfield Creek	4461
Fawkner North Drain	4462

4.7 COMBINED SOUTH-EAST CATCHMENTS RORB MODEL CATCHMENT

The south-east catchment is located in the south-east areas of Merri-bek and drain to Merri Creek (south of the Harding Street Drain Catchment). They cover approximately 6.7 km² of predominantly residential zones.

Table 4.8: South-East Catchment Melbourne Water Assets

South East Catchment Asset	Melbourne Water Asset ID
Merri Creek (Lower)	4420
Glenlyon Road Drain	4423
The Avenue Main Drain	4435

4.8 WESTBREEN CREEK RORB MODEL CATCHMENT

Westbreen Creek is the waterway that runs through the centre of Merri-bek through the Northern Golf Club. It covers approximately 7.1 km² and is predominately zoned for residential land use. The creek changes between piped and overland flow throughout the catchment and includes the following Melbourne Water Assets:

Table 4.9: Westbreen Creek Melbourne Water Assets

Westbreen Creek Asset	Melbourne Water Asset ID
Westbreen Creek	4340
Acacia Street Drain	4341
Cardinal Road Drain	4342
West Street Drain	4343
Moonee Ponds Creek (Upper)	4350

5 OVERVIEW OF THE MODELLING APPROACH

The flood modelling undertaken for this study was completed in accordance with ARR 2019 and Melbourne Water's Flood Mapping and Technical Specifications (September 2020).

The objective of the hydrological modelling was generally to produce rainfall excess hyetographs for each subarea delineated within the study area. These are then used as inputs into the TUFLOW hydraulic model to undertake flow routing and to estimate flood dynamics within the modelled catchment. The flows from two large external catchments on Merlynston Creek and Campbellfield Creek were applied to the North East Catchments TUFLOW model as routed flows from the external catchment RORB models. As noted in Section 2.3, modelling of Moonee Ponds Creek, Edgars Creek, Merri Creek and Gladstone Park Drain is outside the scope of the current study. Deliverables for this study exclude areas impacted by flooding from these waterways and assets.

The existing hydrologic models were originally developed in accordance with ARR 2016. This has been updated as part of this study in RORB to be in accordance with ARR 2019. The rainfall-excess hydrographs were produced for all subareas within the study catchment for the 1 %, 2 %, 5 %, 10 % and 20 % AEP storm events for base case and 1 %, 10 % and 20 % AEP climate change conditions for all required storm durations and a full ensemble set of ten temporal patterns for this stage of the project.

Section 6 provides further details on the hydrological modelling while, **Appendix A** provides a detailed description of the hydrological model development and the key assumptions made.

The hydraulic models were originally developed in accordance with ARR 2016 as part of the Council 2018 flood mapping project. The models have been updated as part of this study to be in accordance with ARR 2019 and the Melbourne Water flood mapping technical specification (September 2020). As part of the 2018 flood study for Council the TUFLOW models were run for all catchments within the study area for the 1 %, 5 %, 10 % and 20 % AEP storm events for base case and 1 %, 10 % and 20 % AEP climate change conditions after the initial study, as agreed with Council for all critical storm durations and all temporal patterns. Given the updates to the models are generally fairly minor it was expected that the critical temporal patterns would not change significantly as a result of the model updates. To test these assumptions the updated Chapman (CHAP) model was run for 1 % AEP event 60 min duration for all 10 temporal patterns. A comparison of the results demonstrates that overall the flood depths produced by the full set of temporal patterns are very similar to those produced by the temporal pattern previously selected as median (tp28), with an absolute difference of less than 5 mm for over 90 % of the model cells and an absolute difference of less than 10 mm for over 96 % of model cells.

Section 7 provides further details on the hydraulic modelling while, **Appendix C** provides a detailed description of the hydraulic model development, including temporal pattern selection and key assumptions made.

6 HYDROLOGICAL MODELLING

RORB is an interactive runoff and streamflow routing program that calculates catchment losses and streamflow hydrographs resulting from rainfall events.

The RORB hydrologic models detailed in this report are developed to produce inflow hydrographs for 1D/2D TUFLOW hydraulic models. The TUFLOW models were created to estimate flood patterns within the study area and are also in the process of being revised to include ARR2019 methodologies and new LiDAR as outlined in Section 2.2.

The RORB models developed for this project are initial loss/continuing loss (IL/CL) models. The user is able to define the land use in each sub-catchment by adjusting the proportion of Effective Impervious Area (EIA), and Indirectly Connected Area (ICA) areas. After deducting losses, it converts the hyetograph to 'hydrographs' of rainfall-excess on the sub-areas. The rainfall excess from each sub-catchment is then routed from the centroid of that sub-catchment, along the main stream, and then to the next downstream node where the runoff hydrograph is combined. For this study, the RORB models were used to produce rainfall excess hydrographs only and the routing of flows was undertaken using the TUFLOW hydraulic flood model (with the exception of the external Merlynston Creek and Campbellfield Creek RORB model, which has been setup as a routed RORB model.).

The hydrological modelling was performed using the latest version of RORB software available (version 6.45) in accordance with ARR 2019 and Melbourne Water's Flood Mapping Projects Guidelines and Technical Specifications (September 2020).

6.1 METHODOLOGY OVERVIEW

The following steps outline the overall process in updating the existing conditions RORB models for the study area and to create outputs which will be utilised in the subsequent hydraulic modelling.

- Delineate overall catchment boundary and sub-catchment boundaries
- Assign fraction impervious values (Total Impervious Area – TIA) for each sub-catchment
- Create RORB nodes and reaches connecting the delineated sub-catchments to a single outfall
- Develop MapInfo tables of the key RORB inputs (catchment boundary, sub-catchment boundaries, nodes and reaches) using MiRORB
- Export MiRORB MapInfo tables to create the baseline graphical catchment file (.catg) for use in RORB
- Calculate the loss values for each land surface type (Effective Impervious Area – EIA, and Indirectly Connected Area – ICA)
- Calculate the area component of each delineated sub-catchment for each land surface type (EIA / ICA)
- Create a graphical catchment file for each land surface type (EIA / ICA) with each subarea comprising the associated area component only (this step was undertaken to correctly apply calculated losses for each surface type)
- Obtain rainfall data from the Bureau of Meteorology (BoM)
- Calculate the storm pre-burst losses for each event / duration (using 75% Preburst based on the Benchmarking ARR2019 for Victoria Technical Report)
- Assess requirements (if any) with regards to Areal Reduction Factor (ARF), temporal rainfall patterns and spatial rainfall patterns as based on catchment area (and other factors as required)
- Run RORB models for the base case scenario 20 %, 10 %, 5 %, 2 % 1 % AEP events
- Run RORB models for the climate change (increased rainfall intensity) scenario 1 %, 10 % and 20 % AEP events
- Extract rainfall excess hydrographs from the RORB models for application in the TUFLOW hydraulic model

Appendix A provides a detailed summary of the RORB Hydrologic Model Development, including details regarding catchment delineation and model parameters.

7 HYDRAULIC MODELLING

TUFLOW is a combined one-dimensional (1D) and two-dimensional (2D) dynamic hydraulic modelling software package used to estimate flood water levels, extents, flows and other hydraulic variables for a range of scenarios and design events

The TUFLOW models covering the Merri-bek Council area were broken into 4 models including RORB inflows from the following models:

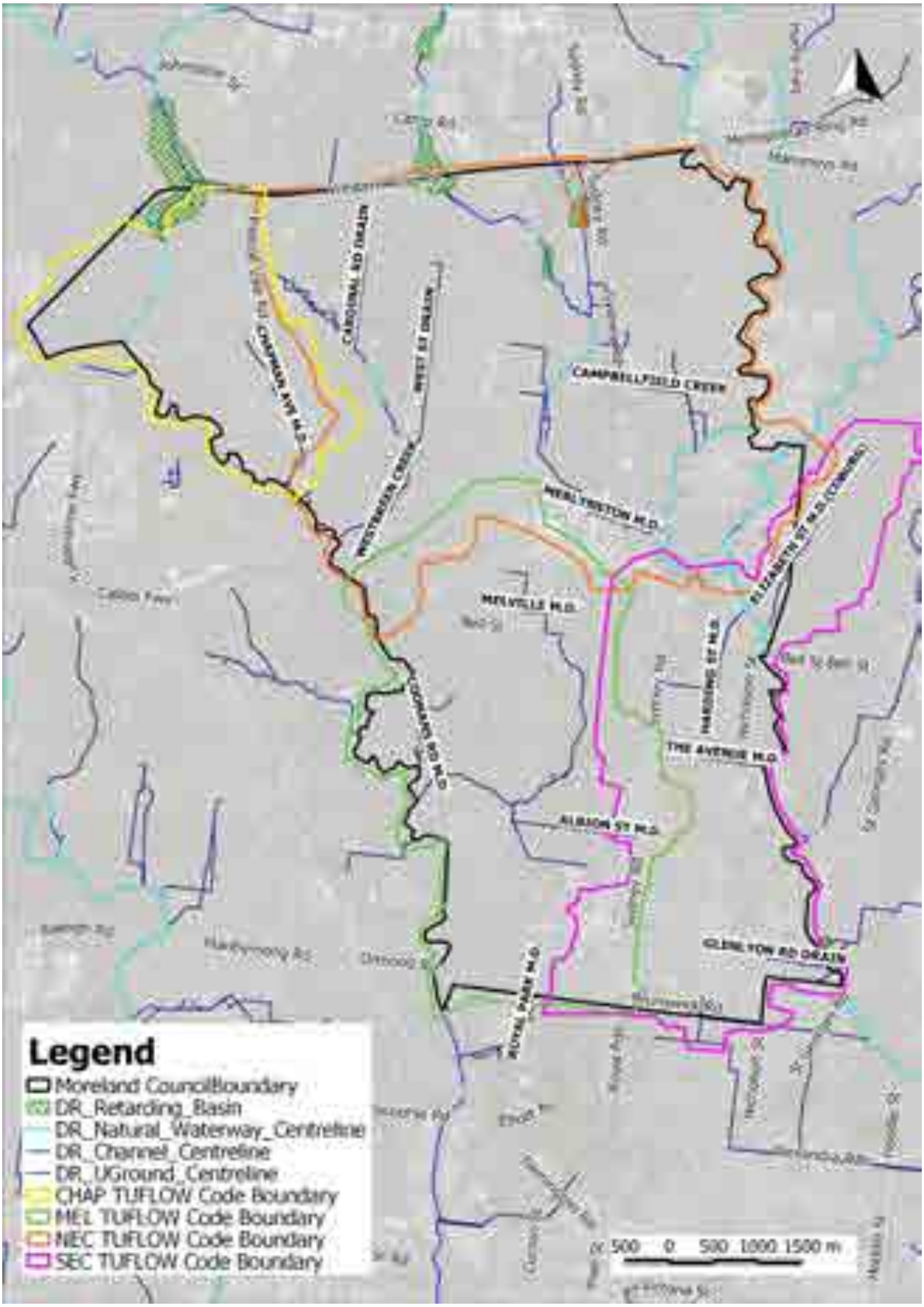
Table 7.1: TUFLOW Model Breakdown

TUFLOW Models	RORB Models
Chapman (CHAP)	Chapman Avenue Main Drain (CHAP), Melbourne Water Moonee Ponds Creek Model
Melville (MEL)	Melville Drain (MEL), Merlynston Creek (MERL), South-East Catchments (SEC), Westbreen Creek (WBC)
North East Catchments (NEC)	Elizabeth Street Main Drain (MEL), Melville Drain (MEL), Merlynston Creek (MERL), Merlynston Creek External (EX_NEC), Westbreen Creek (WBC)
South East Catchments (SEC)	Elizabeth Street Main Drain (MEL), Harding Street Main Drain (HAR), Melville Drain (MEL), Merlynston Creek (MERL), South-East Catchments (SEC), Westbreen Creek (WBC)

Figure 7.1 displays the TUFLOW code boundaries used for this study. There is considerable overlap between the hydraulic model code boundaries as the direction of overland flow and direction of the underground drains are often not the same. The catchment is also very flat and so the overland flow paths are not concentrated to valley floors but rather spread out throughout the gridded street alignment. The final results are only taken from a single model with overlapping results discarded in the final deliverables to ensure a single set of consistent results.

The hydraulic modelling was performed using the latest version of TUFLOW software available at the time of the model runs (2020-01-AB-iDP-w64) in accordance with ARR 2019 and Melbourne Water’s Flood Mapping Projects Guidelines and Technical Specifications (September 2020).

Figure 7.1: TUFLOW Model Breakdown



7.1 METHODOLOGY OVERVIEW

The modelling undertaken as part of this study includes Merri-bek City Council and Melbourne Water drainage assets, and some Darebin City Council drainage assets in the Elizabeth Street Main Drain Catchment.

The following steps outline the tasks undertaken to develop the TUFLOW models for the study catchments and to obtain results and outputs which were used for flood mapping:

- Generate Digital Elevation Model (DEM) from DELWP LiDAR captured in 2017-18.
- Apply the inflow hydrographs generated in RORB for the range of storm durations and temporal patterns for the modelled storm events including both the rainfall excess hydrographs and routed inflow hydrographs.
- Input surface roughness (materials layer) based on existing conditions defined initially based on current planning zone land uses and refined based on aerial photographs.
- Input a separate manning's roughness layer with manning's value of 0.5 to represent individual residential and industrial building footprints. These extents were defined by Melbourne Water's building footprints GIS layer (dated November 2018). Additional building footprints were also digitised and added to the layer in order to represent new developments missing from the provided GIS layer.
- Input and verify data for the 1-D network (pits and pipes) based on GIS data supplied by Council and GIS data and some drawings supplied by Melbourne Water.
- Set 1-D and 2-D boundary conditions for to link pipes / pits to the 3-D domain and downstream boundaries for pipes and overland flowpaths where required.
- Run the TUFLOW model for the standard storm durations for modelled storm events against the temporal patterns listed in Table 7.2. These durations will be checked and compared against the sensitivity test to ensure critical temporal patterns are run for all modelled events and the table may be revised if required.
- Prepare flood maps including peak flood depth plots, flood extents and peak flood water surface levels.

Table 7.2: Storm Duration and Temporal Pattern Summary

Duration	1 % and 2 % AEP Temporal Pattern	5 % and 10 % AEP Temporal Pattern	20 % AEP Temporal Pattern
10 minute	26	16	1
15 minute	28	17	8
30 minute	28	18	6
60 minute	28	18	6
120 minute	25	17	9
180 minute	28	15	4
360 minute	28	17	6
720 minute	29	11	6

Appendix C provides further technical details relating to the development of the TUFLOW hydraulic model.

8 FLOOD MAPPING

Gridded flood mapping outputs for peak depth, water surface elevation, velocity and hazard have been delivered to Melbourne Water and Council for all AEP events that were modelled using TUFLOW Classic. This data has been delivered in ASCII format in GDA 94, Zone 55 MGA projection.

Table 8.1 provides a summary of all the deliverables provided to Melbourne Water for their areas of authority for the entire study area. Files and file types (i.e., MapInfo format) are named and provided as per the 2020 Melbourne Water Flood Mapping Guidelines.

The following appendices contain flood maps which have been produced with the outputs of the final TUFLOW Classic runs:

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

8.1 FLOOD EXTENTS

For each AEP event and scenario, the TUFLOW results for the range of storm durations modelled have been combined to identify the maximum result at each modelled cell. Melbourne Water's filtering guidelines have then been applied to the maximum depth grids to create flood extents.

Points are included in the development of the flood extent if the following conditions are satisfied:

- Depth ≥ 0.05 metres
- Isolated areas of flooding < 100 square metres excluded from the flood extent
- Surrounded dry islands (or high points) ≤ 100 square metres and considered to be flooded and are included in the flood extent.

Melbourne Water's method for flood extent creation using Feature Manipulation Engine (FME) to create a smoothed flood extent has also been adopted.

Flood extents for each AEP and scenario have been delineated between 'Council' and 'Melbourne Water' flood extents to identify the responsible drainage authority however, as per the project scope, flood extents within Melbourne Water areas only have been manually altered. Melbourne Water flood extents are generally also delineated into the categories of flooding from 'underground drains' and 'waterways'.

In some areas, the flood extents produced by applying the filtering criteria and using the FME process were discontinuous. Interrogation of the raw modelling outputs showed that in some of these areas, the discontinuous sections of the flood extent were connected by wet cells, which may have been filtered from the flood extent due to low depths of flow.

The flood extents have subsequently been manually adjusted and refined to:

- Connect some of the discontinuous areas of the flood extent, where the model identifies that the disconnected areas are connected by wet cells with a depth of less than 50 mm. An example of where this can occur is if ponded water is dropping off a ledge, flowing down a very steep embankment or overtopping a road the depth can reduce to less than 50 mm but the flow path is still continuous.
- Remove some areas where the flood extent was being included due to the modelling approach of applying flows directly to the 2D domain, but the flood extent did not represent part of the major flow path but was rather a minor lateral inflow.

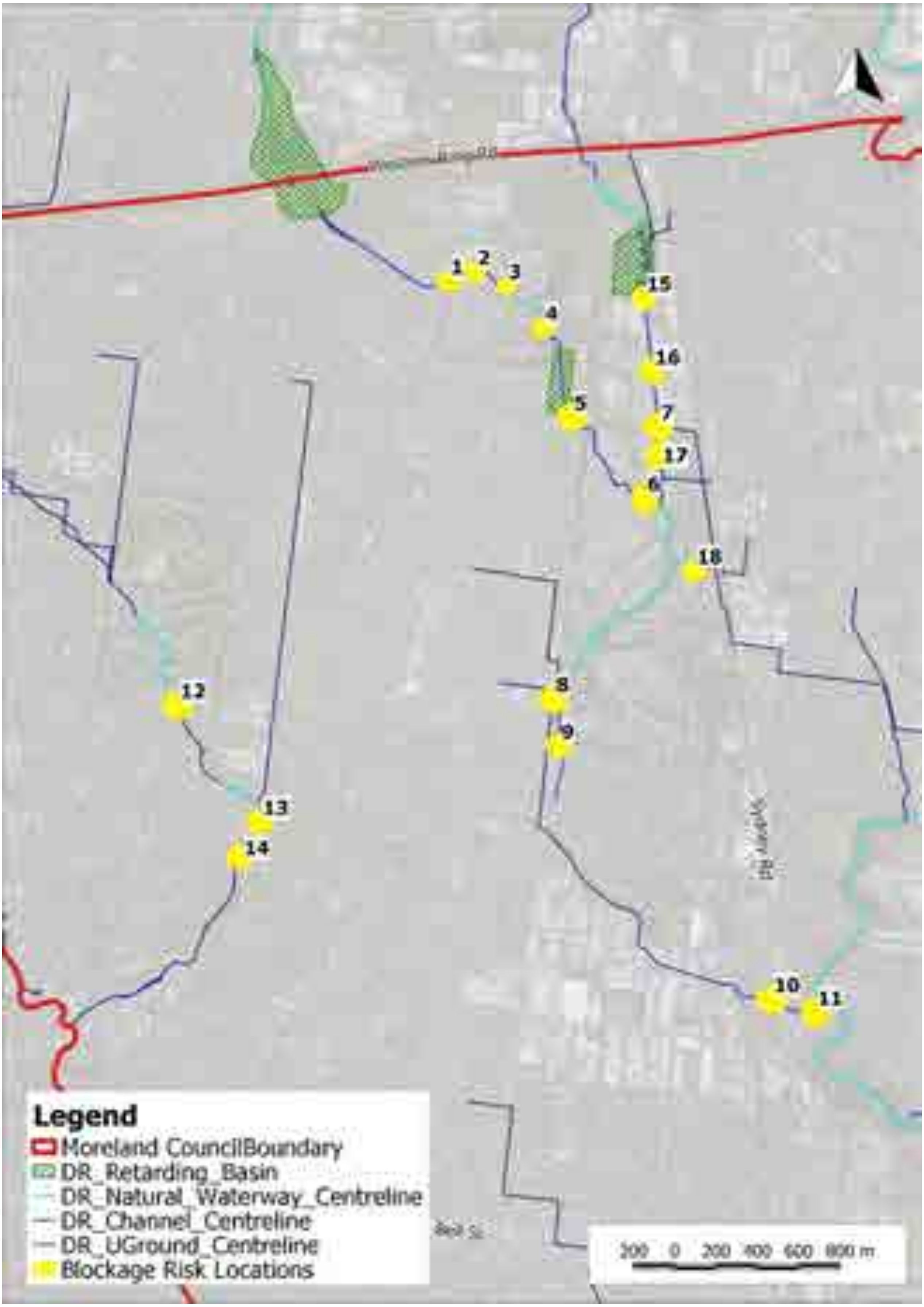
Table 8.1: Summary of Flood Mapping Deliverables

Flood Mapping Deliverables *(Refer to the 2020 Melbourne Water Flood Mapping Guidelines)*	File Naming Convention *(for climate change scenarios, append "CC_x_" to the start of file name where "x" refers to the modelling scenario)*	Modelling Scenario A (Base Case)					Modelling Scenario D (Climate Change 3 – Increase Rainfall Intensity)		
		20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP	20 % AEP	10 % AEP	1 % AEP
Flood Extent	Flood_Extent_<AEP>_Pct_UG_Drains.tab Flood_Extent_<AEP>_Pct_Waterways.tab Flood_Extent_<AEP>_Pct_Council.tab	Y	Y	Y	Y	Y	Y	Y	Y
Flood Contours	Flood_Contour_<AEP>_Pct_UG_Drains.tab Flood_Contour_<AEP>_Pct_Waterways.tab Flood_Contour_<AEP>_Pct_Council.tab	Y	Y	Y	Y	Y	Y	Y	Y
Level of Service	Level_of_Service.tab					Y			Y
Flood Study Area	Flood_Studies.tab Flood_Studies_Council.tab					Y			Y
Flood Hazard / Safety (ARR 2019)	HAZARD.tab					Y			Y
Flood Affected Parcels	Parcels_Flooded_UG_Drains.tab Parcels_Flooded_Waterways.tab Parcels_Flooded_Council.tab					Y			Y
Flood Affected Building Footprints	Building_Footprints_UG_Drains.tab Building_Footprints_Waterways.tab Building_Footprints_Council.tab					Y			Y
One Metre Grid Points	Points_1m_<AEP>_Pct.tab	Y	Y	Y	Y	Y	Y	Y	Y
Plot Output (PO) Lines	Plot_Output_Lines.tab	Y	Y	Y	Y	Y	Y	Y	Y

8.2 BLOCKAGE ASSESSMENT

ARR 2019 provides the framework to assess blockage risk of culverts. Engeny has assessed the blockage risk of 18 Melbourne Water key structures within Merri-bek City Council. Figure 8.1 shows the locations of the culverts which have been assessed for the blockage risk. These locations were the ones deemed to have the highest risk within the study area and are all located within the North-East Catchment in Merri-bek. The other catchments (CHAP, MEL and SEC) only contain underground drains which drain out to Merri Creek and Moonee Ponds Creek. The risk of pit blockage was not assessed as part of this study other than at retarding basin outfalls.

Figure 8.1: Blockage Assessment Locations



The likelihood of blockage for each of the locations in this study was found to be in the low to medium category. Buildings adjacent to a blockage location should not be impacted by flooding in the event of a blockage as the roads under which the culverts pass will overtop before existing dwellings on the adjacent properties would be impacted. Any properties in close proximity to the culvert crossings that are less than 500 mm higher than the road have been deemed “likely” to be impacted by increased risk of flooding above floor levels. The gullies and flow paths are also well defined both upstream and downstream of the blockage locations which helps to contain any flooding in the event of a blockage.

The blockage assessment has identified that dwellings at 7 locations may be impacted by increased flooding above their floors. It is recommended that Melbourne Water consider blockage flood modelling of these sites to confirm the impacts (if any) that blockage may have on flood levels at these dwellings. A summary of the culvert blockage risk/consequence is summarised in Table 8.2 below and the detailed blockage risk assessment forms are located in **Appendix F.**

Table 8.2: Blockage Risk Summary

Location #	Location	Debris Blockage Risk Summary	Sediment Blockage Risk Summary	Increased Risk of Flooding above Floor Levels
1	May Street	Medium	Low	Likely
2	Wills Lane	Medium	Low	Unlikely
3	Bass Avenue	Medium	Low	Unlikely
4	Mitchell Circuit	Medium	Low	Unlikely
5	Box Forest Road #1	Medium	Low	Likely
6	Seventh Avenue	Medium	Low	Unlikely
7	Box Forest Road #2	Low	Low	Unlikely
8	Sussex Street	Low	Low	Unlikely
9	Boundary Road	Low	Low	Likely
10	Sydney Road	Low	Low	Likely
11	Convent Court	Low	Low	Likely
12	Rhodes Parade	Low	Low	Likely
13	Arndt Road	Low	Low	Unlikely
14	Zenith Street	Low	Low	Likely
15	Sages Rd #1	Low	Low	Unlikely
16	Sages Rd #2	Low	Low	Unlikely
17	Fawkner Memorial Park	Low	Low	Unlikely
18	Railway	Low	Low	Unlikely

9 CONCLUSIONS/RECOMMENDATIONS

Melbourne Water engaged Engeny Water Management to complete flood mapping of their entire municipality in accordance with ARR 2019 methodologies to help inform planning for future development and management of the urban drainage system.

Existing conditions flood mapping was undertaken for the 1%, 2%, 5%, 10%, 20% AEP storm events for current day climate conditions as well as the 1%, 10% and 20% AEP 2100 climate conditions.

Engeny has provided Melbourne Water with final deliverables for the Chapman Avenue Catchment, the Melville Main Drain Catchment and the South-East Catchments. Whereas draft deliverables have been provided for the North-East Catchments for Melbourne Water's review.

Following the completion of this study it is recommended that Melbourne Water and Council consider the following next steps and future projects:

1. Photograph and record the debris height of flooding that occurs within the municipality in order to further verify the results of the flood models created for this study and future flood mapping studies.
2. Consider undertaking floor level survey of predicted flood affected properties / dwellings to help identify potential properties / dwellings at risk of above floor level flooding. This information could be used to help understand the flood risk profile of the catchments and also to assess the annual average damages that flooding is likely to cause within the catchment.
3. Use the flood model outputs to update the planning scheme to assist with future redevelopments and subdivisions that will over time help to improve the flood resilience of the properties across the municipality.
4. Consider adopting the climate change scenario results to inform the planning scheme update.
5. Provide flood data to VicSES and other like authorities for flood emergency planning purposes.

10 QUALIFICATIONS

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

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

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

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

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

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

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

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

g) This Report does not provide legal advice.

11 REFERENCES

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

Melbourne Water Corporation, 2020, *Flood Mapping Projects – Guidelines and Technical Specification September 2020*

Engeny Water Management, *Merri-bek City Council Flood Mapping and Modelling Project*, December 2018

BMT WBM, *Merlynston Main Drain Flood Mapping Hydrology Report*, May 2010

Appendix A:
RORB Hydrologic Model Development

A.1 CATCHMENT AND SUB-CATCHMENT DELINEATION AND REACH ALIGNMENTS

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

- The DEM generated from the available 2017-18 LiDAR data and terrain contours created from the DEM (for consideration of predicted 1 % AEP overland flow paths).
- drainage asset locations and alignment (for consideration of piped flows).
- land use identified in the Victorian Planning Scheme.
- property boundaries.
- aerial photography.

The figures below show the delineation of the study catchments, as modelled in RORB along with modelled nodes and reach alignments. The subareas were delineated taking into consideration both pipe flow and overland flow. Where possible, due consideration for the predicted 1 % AEP overland flow paths has been incorporated in developing the model layout, however a higher priority has been applied to the piped catchment and to keeping consistent land uses in the same sub area. This has been done to improve the accuracy of the flood modelling once the rainfall excess runoff hydrographs are used as an input to the TUFLOW hydraulic flood modelling. Where possible, each subarea has been delineated to adopt a single land use type to avoid averaging losses for different land uses over a subarea in RORB.

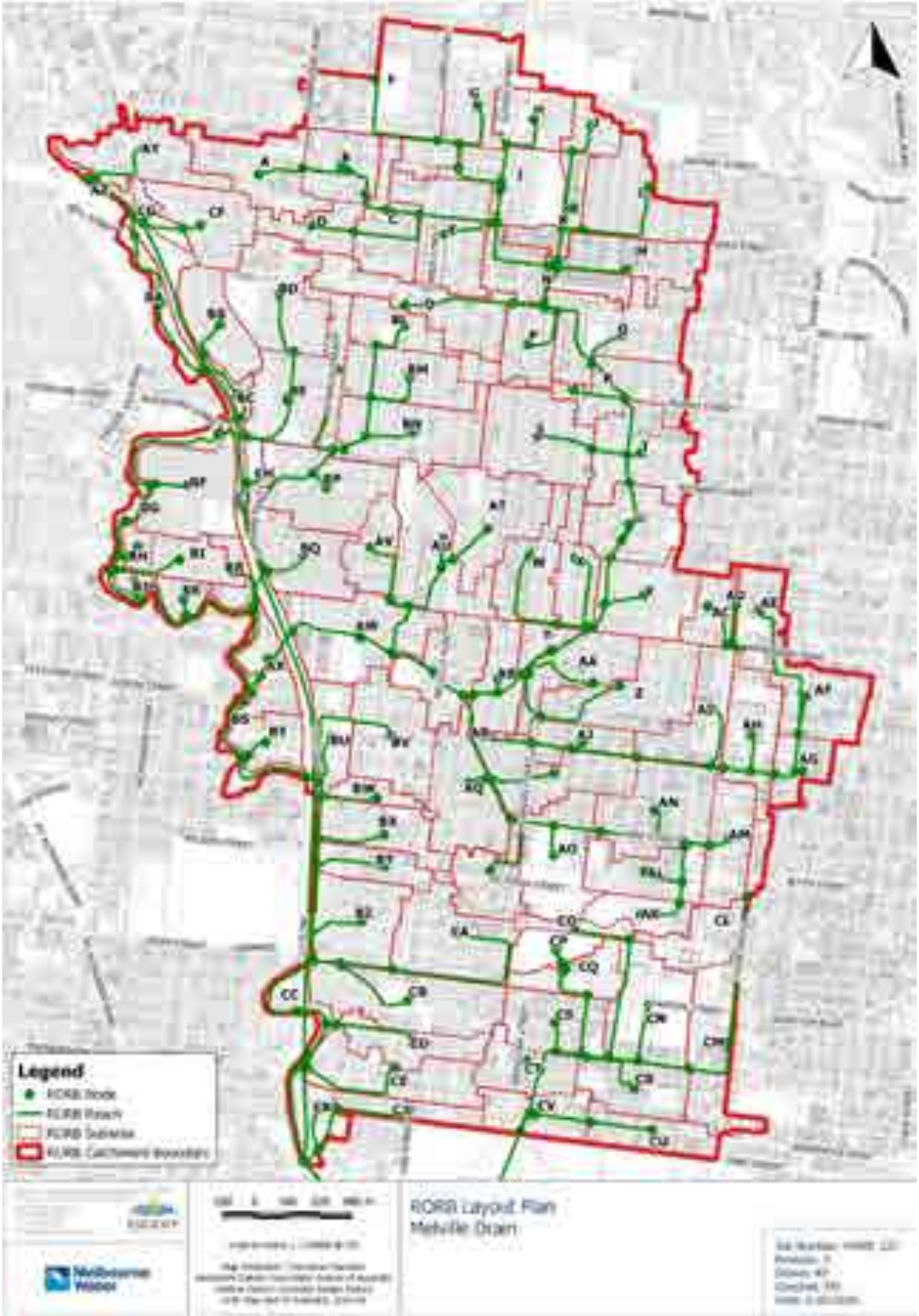
Where flow routing was performed in RORB, reach types were selected to adequately represent the actual flow path. Where RORB was used to generate rainfall-excess hydrographs only, reach types are not considered in the calculations and were set to 'natural'.

Appendix Figure A. 1: Chapman Main Drain RORB Layout

Appendix Figure A. 2: Elizabeth Street Main Drain RORB Layout

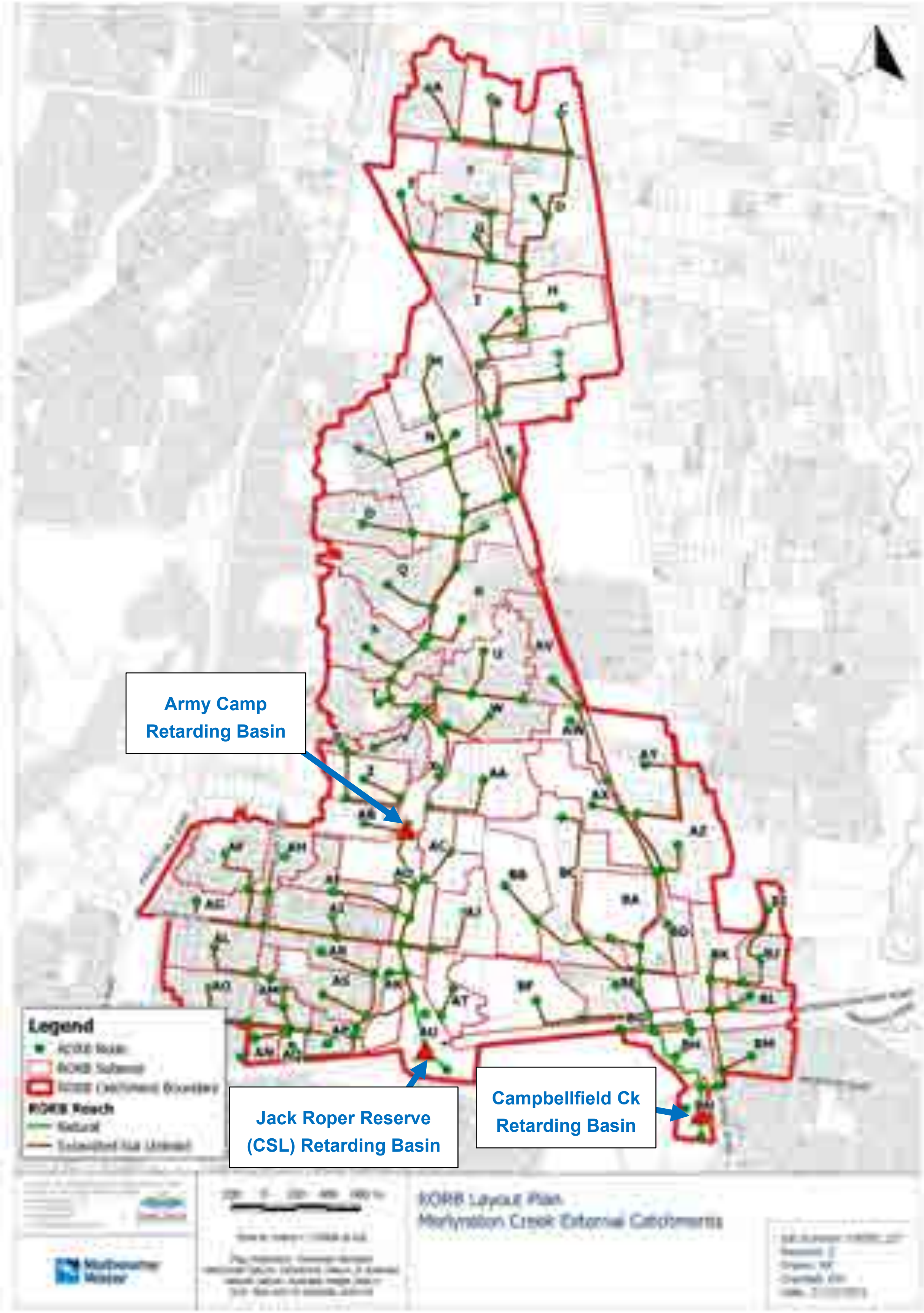
Appendix Figure A. 3: Harding Street Main Drain RORB Layout

Appendix Figure A. 4: Melville Drain RORB Layout



Appendix Figure A. 5: Merlynston Creek RORB Layout

Appendix Figure A. 6: Merlynston Creek External Catchments RORB Layout



Appendix Figure A. 7: Combined South-East Catchments RORB Layout

Appendix Figure A. 8: Westbreen Creek RORB Layout

A.2 FRACTION IMPERVIOUS

The initial fraction impervious (FI) values were assigned at a parcel scale based on the recommended values for different planning zones (Appendix M of Melbourne Water's Flood Mapping Projects Guidelines and Technical Specifications - September 2020). The FI applied at parcel scale was then further reviewed and refined based on 2017-18 aerial photography with consideration of both zoned land use and current development levels. Subarea FI (Total Impervious Area – TIA) was then calculated as a weighted average of imperviousness of the different land parcels comprising the subarea.

A.3 LOSSES

ARR 2019 provides a methodology to calculate initial loss and continuing loss values for different land uses. Losses in the RORB hydrological model were assigned based on three surface types:

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

The Total Impervious Area (TIA) of each subarea was calculated as per the fraction impervious methodology described in **Section A.2**. With regards to losses, subareas were considered to comprise the following surface types based on land use:

- Pervious area only – large drainage or waterway corridors, urban bushland, and golf courses
- ICA only – urban parklands and sports fields
- EIA and ICA – residential, commercial, and industrial land use, aged care facilities, schools, and mixed-use zones. The split between EIA and ICA was calculated based on the ratio of EIA/TIA as follows:
  - Residential / educational / schools / mixed-use – EIA/TIA ratio: 70 % (ARR 2019 suggests 50 to 70 %). A ratio on the higher end of the recommended range was adopted for this study following a review of the aerial imagery which depicted a rather densely impervious catchment.
  - Industrial / commercial – EIA/TIA ratio of 90 % (ARR 2019 provides limited data, with EIA/TIA ratios ranging from 77 % to 94 % in one study and 74 % to 98 % in another. Given that a review of the aerial imagery indicates the majority of commercial and industrial parcels in the catchment to comprise large buildings and asphalt carparks, a ratio of 90 % was considered reasonable).
  - For each of the subareas, the remaining portion of area was determined to comprise ICA.

Appendix Table A. 1 summarises the loss values adopted for each surface type modelled within this study. Engeny adopted data hub losses (IL/CL) for our previous modelling for Council and received feedback that the flooding shown in the model matches well to the flooding history within the municipality. For example, there was a recent flood event in Michael Street, Brunswick which received a lot of press coverage, the flood modelling produced results very similar to what was experienced in the actual storm and so Council have a high degree of confidence in the flood modelling. Given this we are not proposing to make any changes to the initial and continuing loss values used or to undertake any further sensitivity analysis or investigation of losses.

Appendix Table A. 1: Summary of Adopted Loss Values by Surface Type

Surface Type	Initial Loss (IL)	Continuing Loss (CL)
Effective Impervious Area (EIA)	1.5 mm (ARR 2019 recommends an IL of 1-2 mm)	0 mm/h (ARR 2019 states that CL for EIA can be assumed to be zero)
Indirectly Connected Area (ICA)	8.4 mm (ARR 2019 recommends an IL 60-80 % of the rural IL)	1.9 mm/h (ARR 2019 recommends a CL of 2.5 mm/h for south-east Australia, with a range of 1-3 mm/h. Engeny has adopted the rural continuous loss value). The recommended 2.5 mm/h continuing loss was higher than the rural continuing loss, this is not a correct assumption given the differing surface types. The datahub information is the best information available to inform this study, therefore the 1.9 mm/h value was considered appropriate.
Pervious Area	12 mm (In the absence of local information, ARR 2019 recommends adopting the loss value for rural catchments)	1.9 mm/h (In the absence of local information, ARR 2019 recommends adopting the loss value for rural catchments)

A.4 CATCHMENT STORAGES

Three large storages are located within Merlynston Creek's external catchments:

- Commonwealth Serum Laboratories Retarding Basin
- Army Camp Retarding Basin
- Campbellfield Creek Retarding Basin

The storages attenuate catchment flows and have a major influence on downstream catchments. They have been included in the RORB modelling of the external Merlynston Creek catchments to accurately capture downstream flows. The model is intended to be used as input for Merlynston Creek TUFLOW inflows.

Storage Asset	1% AEP Storage Volume	Outlet Configuration	Source of Information
Commonwealth Serum Laboratories Retarding Basin	480,000 m^3	Low flow outlet pipe size: 760 mm Low flow outlet pipe slope: 1.13 % Low flow outlet pipe length: 68.82 m Low flow outlet pipe invert: 92.44 mAHD Low flow Spillway elevation: 102.19 mAHD Low flow Spillway length: 7.18 m High flow Spillway elevation: 102.9 mAHD High flow Spillway length: 60.0 m	Melbourne Water drawings
Army Camp Retarding Basin	190,000 m^3	Low flow outlet pipe size: 1200 mm Low flow outlet pipe slope: 3.59 % Low flow outlet pipe length: 81.0 m Low flow outlet pipe invert: 114.0 mAHD Low flow Spillway elevation: 121.4 mAHD Low flow Spillway length: 9.58 m High flow Spillway elevation: 122.77 mAHD High flow Spillway length: 171.0 m	Melbourne Water drawings

Storage Asset	1% AEP Storage Volume	Outlet Configuration	Source of Information
Campbellfield Creek Retarding Basin	121,000 m^3	Low flow outlet pipe size: 750 mm Low flow outlet pipe slope: 0.028 % Low flow outlet pipe length: 2.2 m Low flow outlet pipe invert: 80.24 mAHD Low flow Spillway elevation: 83.9 mAHD Low flow Spillway length: 5.65 m High flow Spillway elevation: 86.03 mAHD High flow Spillway length: 200 m	Melbourne Water drawings

A.5 INTENSITY-FREQUENCY-DURATION (IFD)

A.5.1 Base Case

The IFD information was sourced from the Bureau of Meteorology (BoM) using the online IFD request tool. The coordinates used for the tool were based on the geographic centroid of each catchment modelled. The resultant IFDs are shown below.

Appendix Table A. 2: Chapman Main Drain Design Rainfall Depths in Millimetres (mm) for the Base Case Scenario (37.7125 S 144.9125 E)

Duration	Annual Exceedance Probability (AEP)				
	20 %	10 %	5 %	2 %	1 %
10 minutes	11.4	14	16.7	20.7	24
15 minutes	13.9	17.1	20.4	25.3	29.4
30 minutes	18.4	22.5	27	33.5	38.9
1 hour	23.2	28.3	33.8	42	49
2 hours	28.9	35.2	42	52.1	60.9
3 hours	33	40.1	47.9	59.4	69.4
6 hours	42.3	51.4	61.2	75.7	88.1
12 hours	55.1	67	79.7	97.9	113

Appendix Table A. 3: Elizabeth Street Drain Design Rainfall Depths in Millimetres (mm) for the Base Case Scenario (37.7375 S 144.9875 E)

Duration	Annual Exceedance Probability (AEP)				
	20 %	10 %	5 %	2 %	1 %
10 minutes	11.5	14.1	16.9	21.3	25
15 minutes	14	17.2	20.8	26.1	30.8
30 minutes	18.5	22.8	27.4	34.4	40.6
1 hour	23.4	28.5	34.2	42.8	50.2
2 hours	29	35.1	41.9	52	60.8
3 hours	33.1	39.8	47.3	58.5	68.2
6 hours	42	50.4	59.4	72.9	84.6
12 hours	54.3	65.1	76.5	93.3	107

Appendix Table A. 4: Harding Street Main Drain Design Rainfall Depths in Millimetres (mm) for the Base Case Scenario (37.7375 S 144.9625 E)

Duration	Annual Exceedance Probability (AEP)				
	20 %	**10 %**	**5 %**	**2 %**	**1 %**
10 minutes	11.4	14.1	16.9	21.1	24.7
15 minutes	14	17.2	20.7	25.8	30.3
30 minutes	18.5	22.7	27.3	34.1	40
1 hour	23.4	28.5	34.1	42.6	49.8
2 hours	29.1	35.2	41.9	52	60.8
3 hours	33.1	40	47.5	58.8	68.5
6 hours	42.1	50.7	59.9	73.7	85.5
12 hours	54.6	65.7	77.4	94.5	109

Appendix Table A. 5: Melville Drain Design Rainfall Depths in Millimetres (mm) for the Base Case Scenario (37.7625 S 144.9375 E)

Duration	Annual Exceedance Probability (AEP)				
	20 %	10 %	5 %	2 %	1 %
10 minutes	11.5	14	16.8	20.8	24.2
15 minutes	14	17.2	20.5	25.5	29.7
30 minutes	18.6	22.7	27.2	33.8	39.4
1 hour	23.5	28.6	34.1	42.2	49.2
2 hours	29.2	35.3	41.9	51.7	60.1
3 hours	33.2	40	47.4	58.3	67.7
6 hours	42	50.4	59.4	72.8	84.2
12 hours	54	64.8	76.1	92.7	107

Appendix Table A. 6: Merlynston Creek Design Rainfall Depths in Millimetres (mm) for the Base Case Scenario (37.7125 S 144.9625 E)

Duration	Annual Exceedance Probability (AEP)				
	20 %	10 %	5 %	2 %	1 %
10 minutes	11.4	14	16.9	21.1	24.8
15 minutes	13.9	17.2	20.7	25.9	30.4
30 minutes	18.4	22.7	27.3	34.2	40.2
1 hour	23.2	28.4	34.1	42.7	50.2
2 hours	28.9	35.2	42	52.4	61.6
3 hours	33	40	47.8	59.4	69.6
6 hours	42.1	50.9	60.6	74.9	87.3
12 hours	54.7	66.2	78.5	96.3	111

Appendix Table A. 7: Merlynston Creek External Catchments Design Rainfall Depths in Millimetres (mm) for the Base Case Scenario (37.6625 S 144.9375 E)

Duration	Annual Exceedance Probability (AEP)				
	20 %	10 %	5 %	2 %	1 %
10 minutes	11.2	13.8	16.6	20.7	24.1
15 minutes	13.7	16.9	20.3	25.3	29.5
30 minutes	18.1	22.2	26.7	33.3	38.9
1 hour	22.8	27.9	33.5	41.8	49
2 hours	28.5	34.9	41.8	52.2	61.2
3 hours	32.8	40.1	48	59.9	70.3
6 hours	42.5	52	62.3	77.6	90.8
12 hours	56.3	68.9	82.6	102	119

Appendix Table A. 8: Combined South-East Catchments Design Rainfall Depths in Millimetres (mm) for the Base Case Scenario (37.7625 S 144.9875 E)

Duration	Annual Exceedance Probability (AEP)				
	20 %	10 %	5 %	2 %	1 %
10 minutes	11.5	14.1	16.9	21.1	24.8
15 minutes	14.1	17.2	20.7	25.9	30.5
30 minutes	18.6	22.8	27.4	34.2	40.2
1 hour	23.5	28.6	34.1	42.4	49.6
2 hours	29.2	35.1	41.6	51.3	59.7
3 hours	33.2	39.8	46.9	57.6	66.7
6 hours	42	50.1	58.7	71.5	82.4
12 hours	54	64.4	75.3	91.2	105

Appendix Table A. 9: Westbreen Creek Design Rainfall Depths in Millimetres (mm) for the Base Case (37.7125 S 144.9375 E)

Duration	Annual Exceedance Probability (AEP)				
	20 %	**10 %**	**5 %**	**2 %**	**1 %**
10 minutes	11.4	14	16.8	20.9	24.4
15 minutes	13.9	17.1	20.5	25.6	29.9
30 minutes	18.4	22.6	27.1	33.8	39.5
1 hour	23.2	28.4	34	42.4	49.6
2 hours	28.9	35.2	42	52.3	61.2
3 hours	33	40.1	47.8	59.5	69.5
6 hours	42.3	51.3	61	75.5	87.9
12 hours	55.1	66.8	79.4	97.5	113

A.5.2 Climate Change

The influence of climate change was modelled as an increase in rainfall intensity, with the climate change scenario modelled for the 1 %, 10 % and 20 % AEP events as per ARR 2019 guidance. An **18.5 %** increase in rainfall intensity was adopted for flood modelling under the climate change scenario as per discussion with Melbourne Water.

A.6 AREAL REDUCTION FACTORS (ARF)

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

ARR 2019 provides procedures for the calculation of ARFs for catchments up to 30,000 square kilometres and durations up to and including 7 days.

The ARF to be applied to design rainfall is a function of the total area of the catchment, the duration of the design rainfall event and AEP.

The process used to calculate ARF was undertaken according to the relevant procedure described in ARR 2019:

- For catchments less than 1 square kilometre, the ARF can be set to 1, giving no reductions in the design rainfall.
- For catchments between 1 square kilometre and 10 square kilometres, the recommended procedure to determine the ARF for each AEP and duration up to and including 12 hours is to:

6. Compute the ARF for a 10 km^2 catchment using ARR 2019's Equation 2.4.1 (shown below) for the selected duration

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

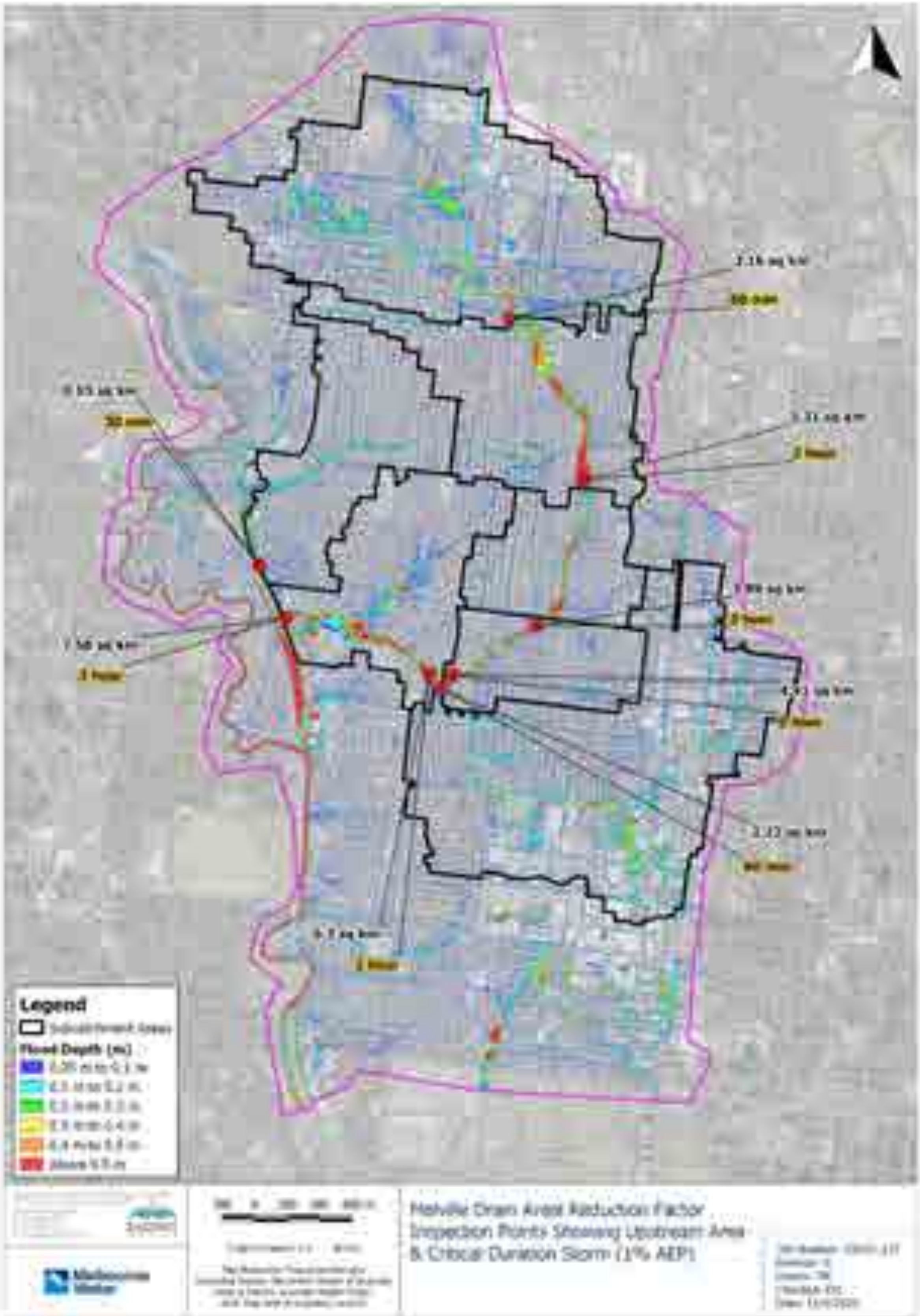
7. Interpolate the ARF for the catchment area and selected duration using ARR 2019's Equation 2.6.2 (as follows)

$$ARF = 1 - 0.6614(1 - ARF_{10})(Area^{0.4} - 1)$$

ARF's for the Harding Street Main Drain, Combined South-East Catchments, Elizabeth Street Main Drain and Chapman Main Drain either had catchments to the Melbourne Water Drain less than 1 square kilometre, a total catchment sizes less than 10 km^2 resulting in an ARF close to 1.0. Given an ARF close to 1.0 has negligible impact on the flood results, an ARF of 1.0 was adopted for these catchments. However, the North-East Catchments model has a total catchment size of approximately 22 km^2. Engeny has undertaken an analysis of the impact of different ARF values on flood levels within this catchment. The key outcome of the investigation is to identify appropriate ARFs to be adopted for flood mapping this catchment and ultimately influence the production of the planning scheme flood overlay. This is discussed in Section A.6.1 below.

Appendix Table A. 10 to Appendix Table A. 14 provide summaries of the ARF values calculated for each AEP based on the critical duration events identified along various sections of the Melbourne Water assets for each catchment. An example of the ARF determination is shown for the Melville Drain catchment in Appendix Figure A. 9.

Appendix Figure A. 9: ARF Determination Example



Appendix Table A. 10: ARF's for Melville Main Drain

Duration	1 %	2 %	5 %	10 %	20 %
10	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00	1.00
30	1.00	1.00	1.00	1.00	1.00
60	0.97	0.97	0.97	0.97	0.97
120	0.94	0.95	0.96	0.96	0.97
180	0.96	0.96	0.97	0.97	0.98
360	1.00	1.00	1.00	1.00	1.00
720	1.00	1.00	1.00	1.00	1.00

Appendix Table A. 11: ARF’s for Merlynston Creek

Duration	1 %	2 %	5 %	10 %	20 %
10	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00	1.00
30	1.00	1.00	1.00	1.00	1.00
60	1.00	1.00	1.00	1.00	1.00
120	0.89	0.90	0.91	0.92	0.93
180	0.89	0.90	0.91	0.92	0.93
360	0.96	0.94	0.95	0.96	0.96
720	0.98	0.97	0.97	0.97	0.97

Appendix Table A. 12: ARF's for Merlynston Creek External Catchments (Merlynston Creek)

Duration	1 %	2 %	5 %	10 %	20 %
10	0.82	0.82	0.83	0.83	0.83
15	0.85	0.85	0.86	0.86	0.86
30	0.88	0.89	0.89	0.90	0.90
60	0.90	0.91	0.92	0.92	0.93
120	0.89	0.90	0.91	0.92	0.93
180	0.89	0.90	0.91	0.92	0.93
360	0.96	0.94	0.95	0.96	0.96
720	0.98	0.97	0.97	0.97	0.97

Appendix Table A. 13: ARF's for Merlynston Creek External Catchments (Campbellfield Creek)

Duration	1 %	2 %	5 %	10 %	20 %
10	0.91	0.91	0.92	0.92	0.92
15	0.93	0.93	0.93	0.93	0.93
30	0.94	0.95	0.95	0.95	0.95
60	0.95	0.96	0.96	0.96	0.97
120	0.89	0.90	0.91	0.92	0.93
180	0.89	0.90	0.91	0.92	0.93
360	0.96	0.94	0.95	0.96	0.96
720	0.98	0.97	0.97	0.97	0.97

Appendix Table A. 14: ARF's for Westbreen Creek

Duration	1 %	2 %	5 %	10 %	20 %
10	1.00	1.00	1.00	1.00	1.00
15	1.00	1.00	1.00	1.00	1.00
30	1.00	1.00	1.00	1.00	1.00
60	1.00	1.00	1.00	1.00	1.00
120	0.96	0.97	0.97	0.97	0.98
180	1.00	1.00	1.00	1.00	1.00
360	1.00	1.00	1.00	1.00	1.00
720	1.00	1.00	1.00	1.00	1.00

A.6.1 NEC ARF Investigation

General Approach

Engeny has undertaken ARF sensitivity simulations for three key scenarios for the NEC catchment, which are summarised in Appendix Table A. 15. RORB hydrological models have been simulated with the varied catchment areas which adjusts the ARF values to be applied to the rainfall. This means that at that exact location in the catchment the ARF is representative of what is expected based on the catchment size. These different hydrographs produced based on the varying ARFs have been used to create the flow inputs into the TUFLOW hydraulic model.

Appendix Table A. 15: NEC ARF Investigation Scenarios

Scenario	Description	Purpose
1	Adopting an ARF of 1.0 for all storm durations up to 24-hour.	Identify critical storm durations and associated catchment areas at key locations.
2	Adopting an ARF based on the catchment area of Merlynston Creek, approximately at the half-way point within the TUFLOW model, equal to 15 km^2.	Quantify the impact of areal reduced rainfall on peak flood levels in larger catchment areas, critical for longer durations.
3	Adopting an ARF based on the catchment area of Merlynston Creek directly upstream of the Upfield Railway line, approximately 400 metres upstream of the convergence with Merri Creek, equal to 22 km^2 for the 3-hour storm duration only (storm duration identified critical for this location).	Quantify the impact of areal reduced rainfall on peak flood levels in larger catchment areas, critical for longer durations.

Scenario 1 Investigations

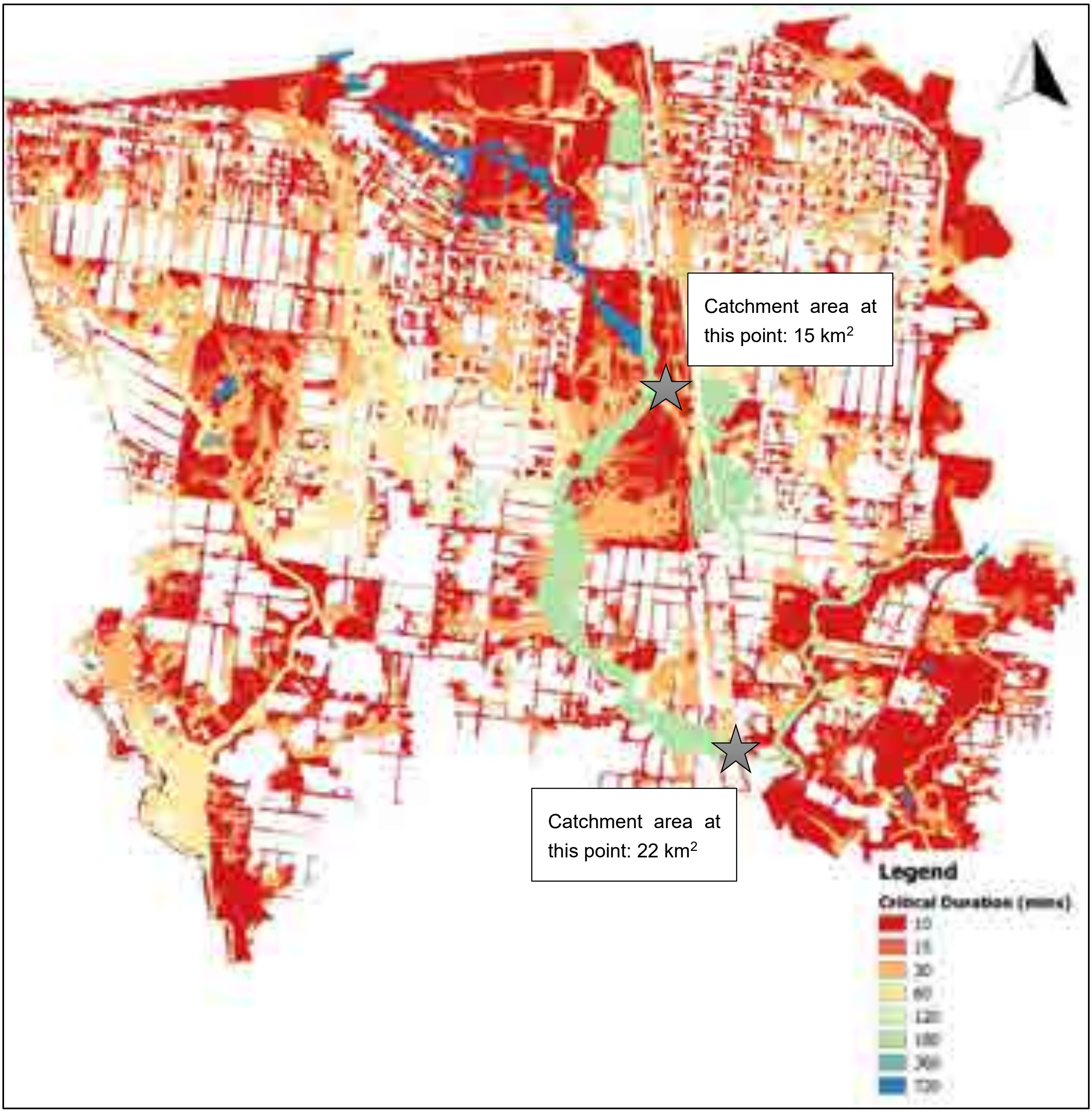
All storm simulations under Scenario 1 have adopted an ARF value of 1.0. Model simulations for Scenario 1 identified the critical durations for different catchment areas within the modelled catchment, which are summarised in Appendix Table A. 16.

Appendix Table A. 16: Scenario 1 Critical Duration and Catchment Areas

Storm Duration	Catchment Area (km^2)					
	1 % AEP CC	1 % AEP	2 % AEP	5 % AEP	10 % AEP	20 % AEP
10 min	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
15 min	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0	≤ 1.0
30 min	≤ 1.0	≤ 1.0	≤ 2.0	≤ 2.0	≤ 2.0	≤ 2.0
60 min	1.0 to 2.0	1.0 to 2.0	1.0 to 2.0	1.0 to 15.0	1.0 to 22.0	1.0 to 22.0
120 min	1.0 to 2.0	1.0 to 2.0	1.0 to 15.0	1.0 to 22.0	1.0 to 22.0	1.0 to 22.0
180 min	2.0 to 15.0	2.0 to 15.0	2.0 to 15.0	2.0 to 15.0	2.0 to 10.0	2.0 to 10.0
360 min	-	-	-	-	-	-
720 min	5.0 to 22.0	5.0 to 22.0	5.0 to 10.0	5.0 to 10.0	5.0 to 10.0	5.0 to 10.0

Appendix Figure A. 10: 1% AEP Climate Change Critical Durations (Scenario 1) presents the critical durations for Scenario 1 for the 1 % AEP with consideration of Climate Change storm event.

Appendix Figure A. 10: 1% AEP Climate Change Critical Durations (Scenario 1)



Critical durations are very similar for more frequent storm events across the modelled area however, the 60-minute and 120-minute duration storms are more prevalent along major flow paths.

Scenario 2 Investigations

ARF values adopted for Scenario 2 are summarised in Appendix Table A. 17: Scenario 2 ARF Values, which have been based on the catchment area of Merlynston Creek, approximately at the half-way point within the TUFLOW model, equal to 15 km^2, for durations 1-hour and longer.

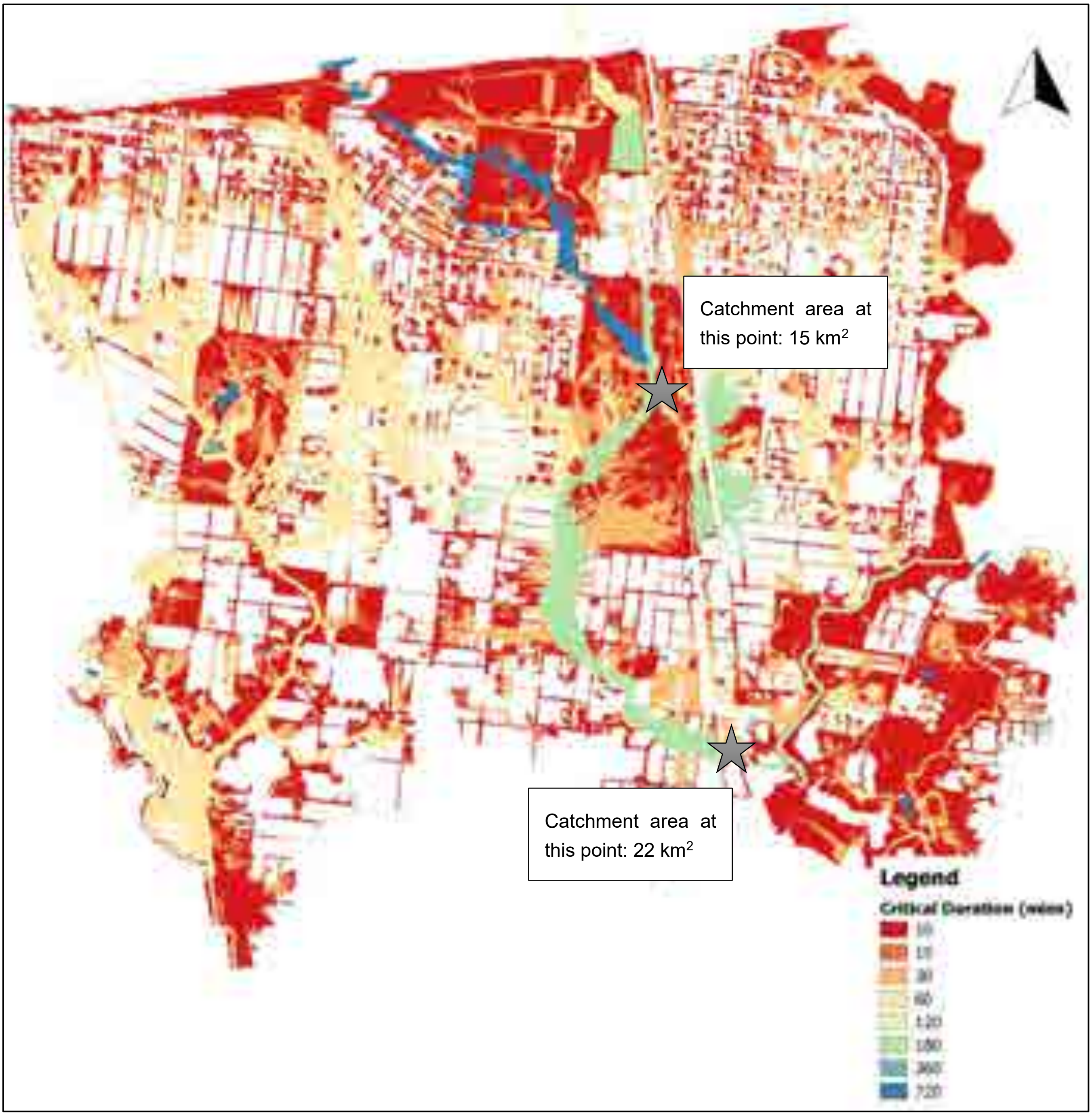
Appendix Table A. 17: Scenario 2 ARF Values

Storm Duration	Catchment Area (km^2)	Areal Reduction Factor				
		1 % AEP	2 % AEP	5 % AEP	10 % AEP	20 % AEP
10 min	15.0	0.77	0.78	0.78	0.79	0.79
15 min	15.0	0.81	0.81	0.82	0.82	0.83
30 min	15.0	0.85	0.86	0.86	0.87	0.87
60 min	15.0	0.88	0.89	0.89	0.90	0.91
120 min	15.0	0.89	0.90	0.91	0.92	0.93
180 min	15.0	0.90	0.91	0.92	0.93	0.94
360 min	15.0	0.94	0.94	0.95	0.96	0.96
720 min	15.0	0.96	0.97	0.97	0.97	0.97

This location and catchment area was adopted for this scenario to provide an averaged representation of areal reduced rainfall across the modelled catchment. It is expected to slightly underestimate flood levels in the upper reaches where catchment areas are smaller than 15 km^2, and slightly overestimate flood levels in the lower reaches where catchments areas are greater than 15 km^2.

Appendix Figure A. 11: 1% AEP Climate Change Critical Durations (Scenario 2) presents the critical durations for Scenario 2 for the 1 % AEP with consideration for Climate Change storm event.

Appendix Figure A. 11: 1% AEP Climate Change Critical Durations (Scenario 2)



Critical durations are very similar for more frequent storm events across the modelled area however, the 60-minute and 120-minute duration storms are more prevalent along major flow paths in the more frequent storm events.

Scenario 3 Investigations

ARF values adopted for Scenario 3 have been derived based on the catchment area close to the outlet of the model, directly upstream of the Upfield Railway Line approximately 400 metres upstream of Merri Creek. Engeny investigated the impacts that an ARF calculated based on the modelled catchment area to this location may have on flood levels along the main overland flow path. As mentioned above, the averaged ARF approach adopted in Scenario 2 will likely be overestimating the flood levels in lower reaches of the catchment, so Scenario 3 was adopted in an attempt to quantify this and to determine the likely more representative flood levels for the lower reaches of the modelled catchment.

A review of the flood levels predicted at this location identified that the 3-hour storm duration was more than 500mm higher than any other storm duration, so this duration was the only one assessed as part of Scenario 3. The ARF value adopted for Scenario 3 was based on the catchment area of Merlynston Creek directly upstream of the Upfield Railway line, approximately 400 metres upstream of the convergence with Merri Creek, equal to 22 km^2, resulting in an ARF of 0.89 for the 1% AEP storm event.

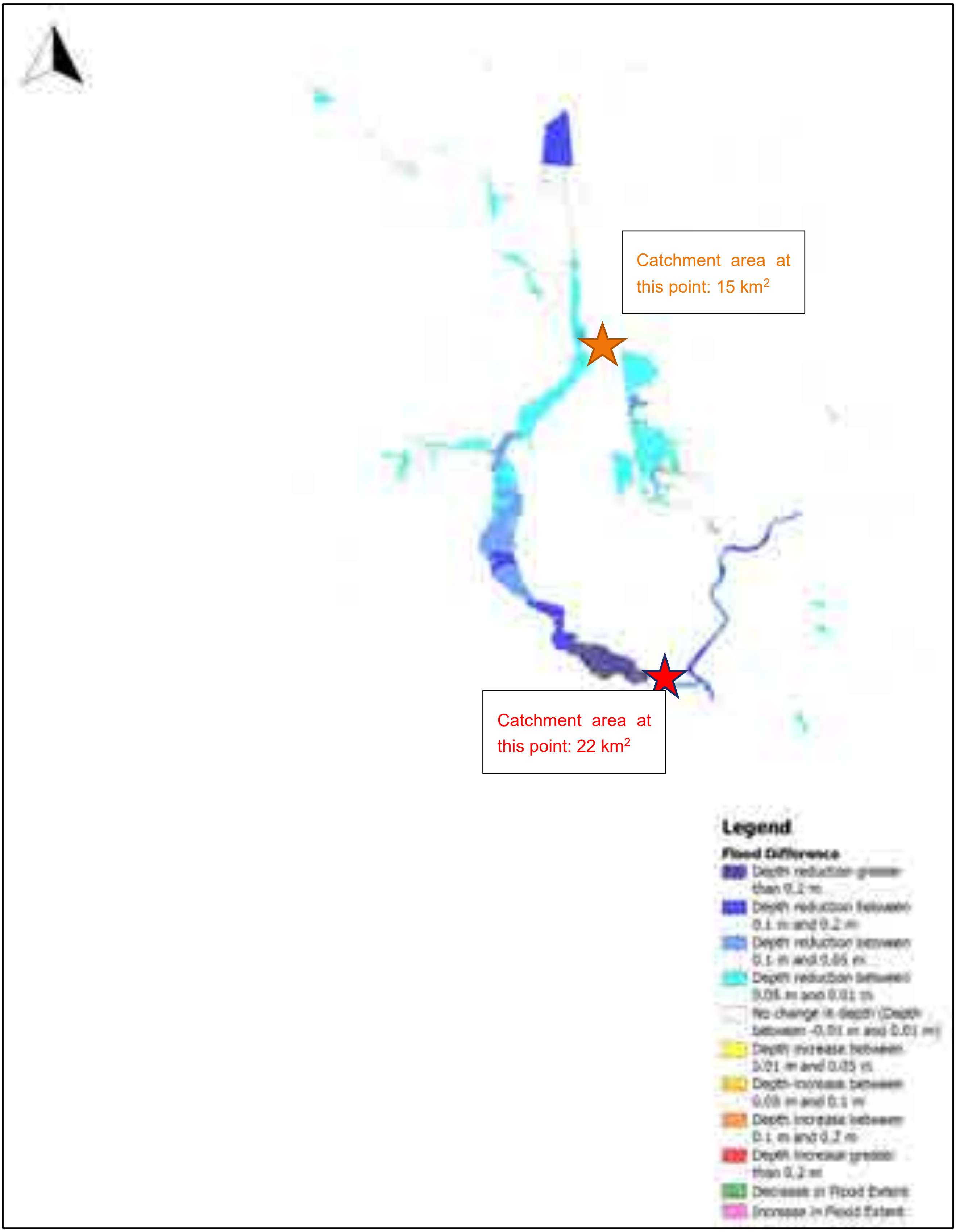
Summary and Conclusions

A comparison between Scenario 1 and Scenario 2, assessing the effect of different ARF values on peak flood level results for the 1 % AEP (with consideration of climate change, year 2100) and 1 % AEP (current day climate), we have identified the following:

1. Critical durations along the major flow paths above Melbourne Water drains do not change noticeably between Scenario 1 and Scenario 2 as a result of the ARF being adjusted (i.e. areas where the 3-hour storm is critical with an ARF of 1 is the same as when the ARF is set to a catchment area of 15 km^2.)
2. Peak flood levels throughout the modelled catchment have reduced under Scenario 2 compared to Scenario 1 as expected. In some instances, the critical duration at a particular location has slightly increased e.g. from the 10-minute to the 15-minute duration. This is due to the reduced ARF value from Scenario 2 compared to Scenario 1 which is reducing the total rainfall applied during a storm and is reducing some of the sharpness in the hydrograph, prevalent in shorter duration storm events, which is assisting in making a longer storm duration more critical. This change is noted however, isn't relevant as adopting an ARF of less than 1.0 for small catchments typically where critical durations of 10 and 15-minutes are prevalent, is not recommended by ARR2019 and is not proposed in this study.
3. The 15-minute duration has become slightly more prevalent than the 10-minute storm duration along the upper reaches of catchments and their overland flow paths. The peak flood levels in these areas critical for the 10 and 15-minute durations are generally reduced by approximately 5-10 mm for Scenario 2 compared to Scenario 1.
4. As per the above, the 60-minute duration has become slightly more prevalent than the 30-minute storm duration. The 60-minute duration is becoming the critical duration further upstream along the overland flow path (taking over the 30-minute duration) under Scenario 2 compared to Scenario 1. The peak flood levels in these areas critical for the 30 and 60-minute durations are generally reduced by approximately 10-20 mm for Scenario 2 compared to Scenario 1. However, there are 2 or 3 flow paths where flood level reductions are up to 30-50 mm.

Appendix Figure A. 12 provides a flood difference plan identifying the peak flood level difference between Scenario 2 and Scenario 1. Areas critical for short storm durations (60-minute and shorter) have been removed from the figure. This has been done as the key focus for this investigation is to look at the impacts of ARFs on the main flow path running through the centre of the model.

Appendix Figure A. 12: Scenario 2 minus Scenario 1 Flood Level Difference (afflux)



Given that critical durations have not noticeably changed at most locations across the modelled area for small catchment areas and short duration storms (up to the 1-hour duration), and the slight flood level difference along these overland flow paths between Scenario 1 and Scenario 2. Engeny believes that an ARF value of 1.0 is appropriate for storm durations of 1-hour and shorter to inform flood patterns and the production of a planning scheme.

For storm durations 2-hours and longer, while the ARF value applied to the rainfall is reasonably close to one (ranging from 0.89 to 0.96) for the 1% AEP storm event, noticeable reductions of up to 450 mm are predicted in Scenario 2 compared to Scenario 1 along major flow paths critical for these longer duration storms. The larger difference mainly occurs in areas where the outfall is constrained, for example in a retarding basin or behind a road embankment. Considering this difference in flood level for these longer duration storms, Engeny believes that adopting an ARF calculated on the average modelled catchment area of 15 km^2 is appropriate.

With regards to the afflux observed for more frequent storm events, the reduction in peak flood levels between Scenario 1 and 2 is very similar. However, due to the lower overall flood depths in the more frequent storm events, the afflux difference is also lower.

A comparison between Scenario 2 and Scenario 3, assessing the effect of different ARF values on peak flood level results for the 1 % AEP (with consideration of climate change, year 2100) and 1 % AEP (current day climate), we have identified the following:

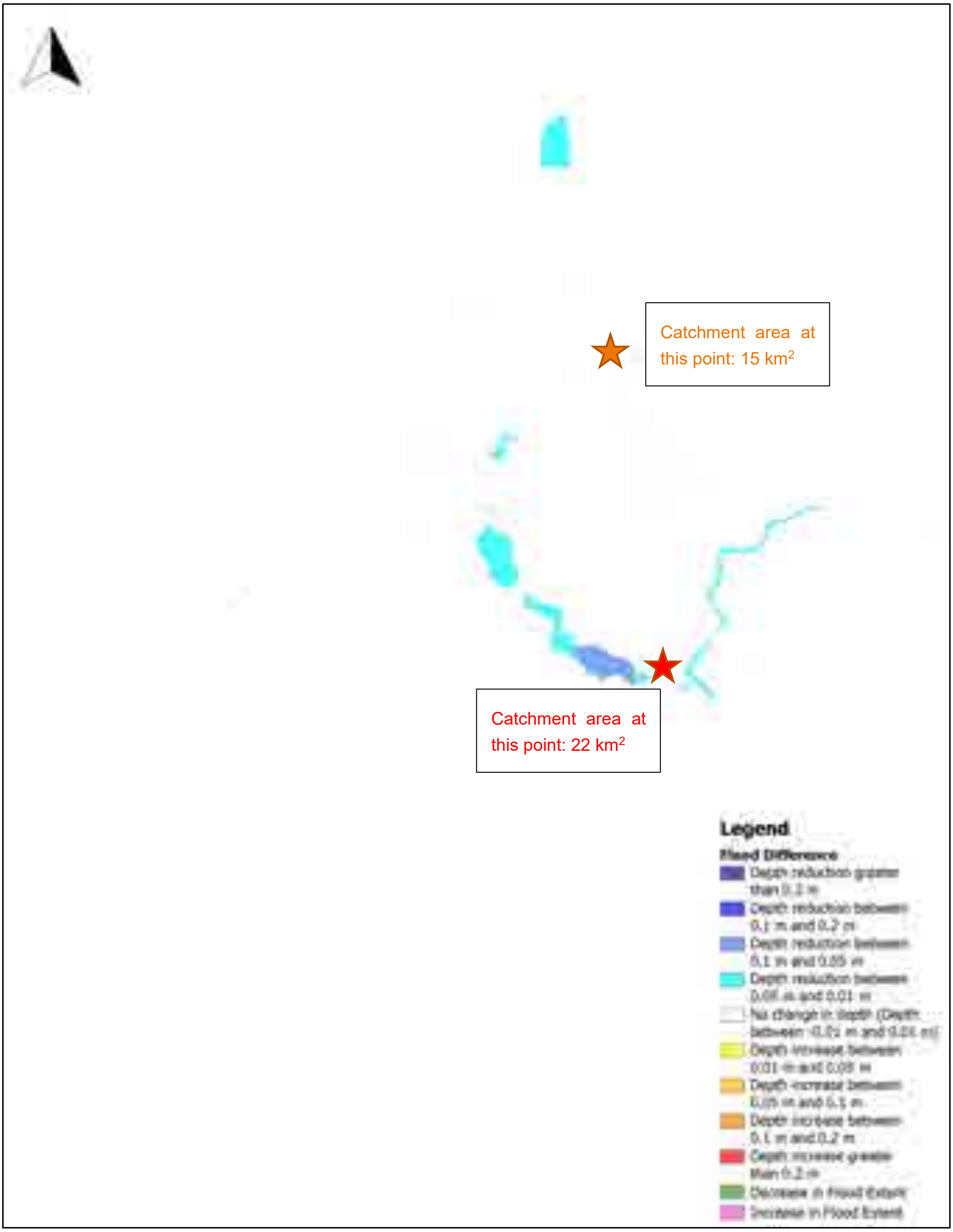
1. Peak flood levels for the 3-hour duration have changed slightly in areas where shorter durations (such as the 10 and 15-minute storm durations) were identified to be critical. However, the 3-hour duration is not producing the peak flood level at these locations so the changes are irrelevant.
2. Peak flood levels are slightly reduced under Scenario 3 compared to Scenario 2 in areas where the 3-hour storm duration is critical. Decreases in flood levels of up to approximately 60 mm are predicted directly upstream of the Upfield Railway Line approximately 400 metres upstream of Merri Creek. The change in flood levels at this location is much smaller under more frequent event such as the 10% and 20% AEP as the impact of the limited outfall capacity relative to inflow rate is much smaller.
3. Flood levels are within 10 mm between Scenario 2 and 3 in other areas where the 3-hour storm duration is critical.

Considering these findings, in areas where the 3-hour storm duration is critical, Scenario 3 and Scenario 2 produce very similar peak flood levels however, Scenario 3 is considered to be the more accurate result at the very downstream end of the catchment.

This investigation has identified that the 2-hour and 6-hour storm durations are not critical for the vast majority of the modelled catchment in major events such as the 1% AEP. This is the case for each of the three ARF modelling scenarios therefore, ultimately the ARF applied to these storm durations does not have direct impact on the peak flood depths for the 1% AEP. The 2-hour storm duration is more prevalent along main overland flow paths in more frequent (minor) storm events. Assessing the impact of different ARF values on flood levels in these storms predicts slight changes in peak flood levels in areas. Given the approximate catchment areas of flow paths where the 2-hour is critical during minor storm events, the ARF values determined for Scenario 2 are considered most appropriate. The 6-hour storm duration is not identified as a critical storm duration at any location for any storm magnitude event therefore, an ARF based Scenario 2 is considered sufficient for this catchment. The 12-hour storm duration has only been identified as critical directly downstream of the Jack Roper Reserve (CSL) Retarding Basin. The catchment area that results in this critical duration consistently across the three ARF modelling scenarios is approximately 9.0 km^2. Therefore, the ARF values determined as part of Scenario 2 are believed to be most appropriate.

Appendix Figure A. 13 provides a flood difference plan identifying the peak flood level difference between Scenario 3 and Scenario 2.

Appendix Figure A. 13: Scenario 3 minus Scenario 2 Flood Level Difference (afflux)



Following this investigation into the impacts of ARF values on peak flood levels in the NEC catchment, Engeny concludes and proposes the following methodology, which aligns with industry recommended approaches:

1. Adopting an ARF value of 1.0 is appropriate for storm durations 1-hour and shorter.
2. Adopting an ARF value based on the average modelled catchment area of 15 km^2 is appropriate for the 2-hour, 6-hour and 12-hour storm durations.
3. Adopting an ARF value based on the modelled catchment area of Merlynston Creek directly upstream of the Upfield Railway line, approximately 400 metres upstream of the convergence with Merri Creek, equal to 22 km^2 is appropriate for the 3-hour storm duration.

A.7 CONSIDERATION OF MODEL TIMESTEP

ARR 2019 (Book 5, Chapter 3.7.3) states that *"the definition of Continuing Loss as the threshold rate above which rainfall excess is generated, means that it is dependent upon the timestep. This is because as the timestep reduces there is an increased likelihood that there will be some timesteps in which the rainfall depth is less than the Continuing Loss rate threshold. Thus to achieve the same volume of rainfall excess the Continuing Loss will typically need to be increased for shorter timesteps."* Continuing loss is typically provided by the ARR DataHub in mm/hr, and further to the above statement, ARR states that *"If a different timestep* (other than an hour) *is to be adopted in design then the continuing loss should be adjusted accordingly."*

Engeny's recent flood mapping experiences have indicated that for urban catchments (such as those present within the City of Merri-bek), the adjustment of continuing loss for timestep has resulted in negligible impact on total rainfall depths and thus derived rainfall excess. To prove this, Engeny has undertaken an investigation for the City of Merri-bek municipality to determine the likely impacts on total rainfall depths and thus derived rainfall excess. The following summarises the process undertaken:

1. Calculate the total rainfall depth on varying model timesteps based on the rainfall data storm timestep (i.e. 5-minute, 10-minute, 15-minute etc) for all ARR2019 standard duration storms up to and including the 12-hour for the 20 % and 1 % AEP storm events.
2. Calculate the total rainfall depth for adjusted 1-hour timesteps for all ARR2019 standard duration storms up to and including the 12-hour for the 20 % and 1 % AEP storm events.
3. Compare the calculated total rainfall depths from Step 1 to Step 2, assuming the same continuing loss rate. This has been done by determining the quantitative change in total rainfall depths (i.e. millimetres) and the percentage change in total rainfall depths.

For example, the 1 % AEP 10-minute temporal pattern 25 storm calculations and comparisons of total rainfall depths are presented below:

- Total storm rainfall depth is 24.3 mm (as per BoM IFD data for Merri-bek municipal area)
- Applying a loss of 1.9 mm (the entire hourly continuing loss amount), results in a residual total rainfall depth of 22.4 mm. While applying a varied model timestep (in this instance, 5-minutes as this results in the largest difference in total rainfall depths compared to the 1-hour timestep) results in a loss of 0.158 mm/timestep and a total loss of 0.32 mm for the duration of the storm event. This results in a residual 23.98 mm of total rainfall depth.
- The difference in total rainfall depths between the two methods is approximately 1.58 mm, which is equal to 7.1 %.

The following summarises the key assumptions and findings of the investigation:

1. The investigation has considered the rural pervious losses only, which are the ones that would be most impacted by the difference in timestep. A similar analysis could be undertaken for Indirectly Connected Areas (ICA) areas however, it would simply show a smaller difference. The rural loss conditions represent the largest possible difference for continuing loss with varied timesteps.
2. Effective Impervious Areas (EIA) portions of a catchment are assumed to have zero continuing loss and therefore, adjusting the continuing loss for timestep would have zero impact.
3. Storm initial loss has not been included as part of this investigation, as this is not impacted by timestep.
4. ARR DataHub suggests that the rural storm initial loss is 12 mm and the rural continuing loss is 1.9 mm/hr, as per the Merri-bek municipal centroid co-ordinates.

5. For storm durations of 1-hour and less, the full timestep loss of 1.9 mm rather than a fraction of the 1.9 mm/hr continuing loss has been applied. As a result, adjusting continuing loss for timestep has the greatest proportional impact on the 10-minute storm duration as it takes off “too much” loss relative to a 5-minute continuing loss timestep. From a percentage increase in rainfall depths standpoint, this is a 7 % increase in 1 % AEP 10-minute rainfall depths. This is further exacerbated in the 20 % AEP due to lower total rainfall depths (26 % increase in 20 % AEP 10-minute rainfall depths). However, in terms of actual rainfall depths it is fairly minor (0-3mm for the 20 % AEP and 0-2mm for the 1 % AEP).
6. For these short duration (less than 1-hour) storm events (particularly the 20 % AEP, where there is the highest percentage difference in total rainfall depths), the storm initial loss will have a much larger impact on total rainfall depths. The rural storm initial loss is 12 mm for the Merri-bek municipal area. This exceeds the total rainfall depths for the 20 % AEP 10-minute and 15-minute duration storms, while taking out a significant portion of the 30-minute duration storm event also (which is calculated to have a 15 % increase in total rainfall depths when only continuing losses are considered).
7. For durations 1-hour and longer for the 1 % AEP, percentage increases can be considered fairly negligible (<2 %) and it is also temporal pattern dependent (i.e. only certain patterns are impacted). Percentage increases in total rainfall depth using a 5-minute timestep in longer durations (>1-hour) exceeded ~2 % in the 6-hour event for select temporal patterns. However, when considering urban flood modelling, such long durations storm events are typically not critical (Engeny’s 2018 flood mapping study confirms this is the case for Merri-bek). Again, impacts in the 20 % AEP have a greater proportional impact because of lower total rainfall depths. However, the actual depth increases are minimal (0-3 mm).
8. Following the completion of the investigation, Engeny consider the impact of timestep of continuing loss to be negligible for urban catchments (such as those modelled as part of this study) and therefore, Engeny have not adjusted the suggested ARR DataHub rural continuing loss rate.

A spreadsheet containing calculations which informed the findings of this investigation is provided in **Appendix B**.

A.8 PRE-BURST RAINFALLS

While the design rainfall values (IFDs) from the Bureau of Meteorology are for bursts, the initial loss values from the ARR Data Hub are for complete storms, not bursts. In order to calculate the initial loss for the design rainfalls (IL_B), the initial loss value for the complete storms (IL_S) was reduced by the 75th percentile pre-burst depth (as agreed with Melbourne Water):

$$IL_B = IL_S - Preburst\ rainfall\ depth\ (mm)$$

Initial burst losses were applied in RORB as duration factors, which were calculated as ratios between a burst initial loss (IL_B) for each duration and AEP and storm initial loss (IL_S). For example, the duration factor for the 1 % AEP storm of 60 minutes duration was determined as follows:

$$Duration\ Factor\ (1\ \%\ AEP, 60\ minute) = \frac{IL_S - Preburse\ rainfall\ depth}{IL_S} = \frac{12\ mm - 9.5\ mm}{12\ mm} = 0.21$$

As pre-burst depths are not provided for storm durations of less than 60 minutes, the pre-burst rainfall is assumed to be the same for durations of 60 minutes and shorter in accordance with Appendix H of Melbourne Water’s Flood Mapping Projects Guidelines and Technical Specifications (September 2020).

During the RORB modelling process, it was identified that the individual storm “.out” results files were incorrectly reporting the ICA initial loss being applied to the RORB model. An ICA IL of 8.4 mm/h was shown to have been applied however, testing of the RORB model determined that the duration factor adjusted ICA IL was correctly being applied.

The pre-burst duration factors adopted for each catchment is summarised below:

Appendix Table A. 18: Summary of Adopted Pre-burst Duration Factors for Chapman Main Drain

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.05	0.00	0.00	0.00	0.01
15 minutes	0.05	0.00	0.00	0.00	0.01
30 minutes	0.05	0.00	0.00	0.00	0.01
1 hour	0.05	0.00	0.00	0.00	0.01
2 hours	0.00	0.00	0.00	0.00	0.00
3 hours	0.00	0.00	0.00	0.00	0.00
6 hours	0.48	0.00	0.00	0.00	0.00
12 hours	0.61	0.12	0.00	0.00	0.00

Appendix Table A. 19: Summary of Adopted Pre-burst Duration Factors for Elizabeth Street Main Drain

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.33	0.08	0.00	0.00	0.00
15 minutes	0.33	0.08	0.00	0.00	0.00
30 minutes	0.33	0.08	0.00	0.00	0.00
1 hour	0.33	0.08	0.00	0.00	0.00
2 hours	0.00	0.00	0.00	0.00	0.00
3 hours	0.01	0.00	0.00	0.00	0.00
6 hours	0.44	0.00	0.00	0.00	0.00
12 hours	0.64	0.12	0.00	0.00	0.00

Appendix Table A. 20: Summary of Adopted Pre-burst Duration Factors for Harding Street Main Drain

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.33	0.08	0.00	0.00	0.00
15 minutes	0.33	0.08	0.00	0.00	0.00
30 minutes	0.33	0.08	0.00	0.00	0.00
1 hour	0.33	0.08	0.00	0.00	0.00
2 hours	0.00	0.00	0.00	0.00	0.00
3 hours	0.01	0.00	0.00	0.00	0.00
6 hours	0.44	0.00	0.00	0.00	0.00
12 hours	0.64	0.12	0.00	0.00	0.00

Appendix Table A. 21: Summary of Adopted Pre-burst Duration Factors for Melville Main Drain

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.28	0.07	0.00	0.00	0.09
15 minutes	0.28	0.07	0.00	0.00	0.09
30 minutes	0.28	0.07	0.00	0.00	0.09
1 hour	0.28	0.07	0.00	0.00	0.09
2 hours	0.00	0.00	0.00	0.00	0.00
3 hours	0.00	0.00	0.00	0.00	0.00
6 hours	0.26	0.00	0.00	0.00	0.00
12 hours	0.52	0.20	0.00	0.00	0.00

Appendix Table A. 22: Summary of Adopted Pre-burst Duration Factors for Merlynston Creek

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.33	0.08	0.00	0.00	0.00
15 minutes	0.33	0.08	0.00	0.00	0.00
30 minutes	0.33	0.08	0.00	0.00	0.00
1 hour	0.33	0.08	0.00	0.00	0.00
2 hours	0.00	0.00	0.00	0.00	0.00
3 hours	0.01	0.00	0.00	0.00	0.00
6 hours	0.44	0.00	0.00	0.00	0.00
12 hours	0.64	0.12	0.00	0.00	0.00

Appendix Table A. 23: Summary of Adopted Pre-burst Duration Factors for Merlynston Creek External Catchments

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.33	0.08	0.00	0.00	0.00
15 minutes	0.33	0.08	0.00	0.00	0.00
30 minutes	0.33	0.08	0.00	0.00	0.00
1 hour	0.33	0.08	0.00	0.00	0.00
2 hours	0.00	0.00	0.00	0.00	0.00
3 hours	0.01	0.00	0.00	0.00	0.00
6 hours	0.44	0.00	0.00	0.00	0.00
12 hours	0.64	0.12	0.00	0.00	0.00

Appendix Table A. 24: Summary of Adopted Pre-burst Duration Factors for Combined South-East Catchments

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.13	0.00	0.00	0.00	0.05
15 minutes	0.13	0.00	0.00	0.00	0.05
30 minutes	0.13	0.00	0.00	0.00	0.05
1 hour	0.13	0.00	0.00	0.00	0.05
2 hours	0.18	0.00	0.00	0.00	0.00
3 hours	0.18	0.02	0.00	0.00	0.00
6 hours	0.29	0.00	0.00	0.00	0.00
12 hours	0.50	0.19	0.00	0.00	0.00

Appendix Table A. 25: Summary of Adopted Pre-burst Duration Factors for Westbreen Creek

Duration	20 % AEP	10 % AEP	5 % AEP	2 % AEP	1 % AEP
10 minutes	0.33	0.08	0.00	0.00	0.00
15 minutes	0.33	0.08	0.00	0.00	0.00
30 minutes	0.33	0.08	0.00	0.00	0.00
1 hour	0.33	0.08	0.00	0.00	0.00
2 hours	0.00	0.00	0.00	0.00	0.00
3 hours	0.01	0.00	0.00	0.00	0.00
6 hours	0.44	0.00	0.00	0.00	0.00
12 hours	0.64	0.12	0.00	0.00	0.00

A.9 RAINFALL TEMPORAL PATTERNS

ARR 2019 temporal patterns for the Southern Slopes Mainland were downloaded from the ARR Data Hub and adopted for all RORB models. ARR 2019 states that point temporal patterns should be used for catchments less than 75 square kilometres. Each catchment size was considerably less than 75 square kilometres and therefore point temporal patterns were adopted. The full set of ten temporal patterns was used for hydrological modelling in RORB.

A.10 RAINFALL SPATIAL PATTERNS

As the individual catchment areas does not exceed 20 square kilometres, a uniform spatial rainfall pattern was used in accordance with ARR 2019 and Melbourne Water's Flood Mapping Projects Guidelines and Technical Specifications (September 2020).

A.11 MODEL CALIBRATION AND VALIDATION

Gauged data was not available for any of Melbourne Water's waterways or underground drains within the Merri-bek municipality. As such, calibration of flows was unable to be undertaken for catchments included in this study.

The external Merlynston Catchment RORB model is intended to generate routed inflows to use in the Merlynston hydraulic TUFLOW model. Engeny has assessed a series of k_c values, previous hydrologic studies and validation equations to validate the RORB model for this use. Appendix Table A. 27, Appendix Table A. 28, Appendix Table A. 29 presents the flow rates estimated using Melbourne Water provided standard flow equations against relevant industry validation equations such as rule of thumb and DNRE regression analysis and Melbourne Water's Merlynston ARR2016 RORB Model.

The Merlynston Creek catchment contains the Army Camp retarding basin at roughly the mid point between the top of the catchment and the inflow point to the Commonwealth Serum Laboratories (CSL) retarding basin. As the validation calculation methods do not account for the influence of retarding basins, it is important that in this validation exercise, the Army Camp retarding basin is removed from the RORB model. Appendix Table A. 26 presents flows derived from the external Merlynston Catchment RORB model without the Army Camp retarding basin.

Appendix Table A. 26: Merlynston Creek Flow Comparison at inflow to CSL RB for 1 % AEP event (Army Camp RB removed)

No	Formula	Application	Source	k_c	Discharge (m³/s)
1	$k_c = 0.49 \times A^{0.65}$	Areas with annual rainfall < 800 mm	ARR2019	2.00	110.8
2	$k_c = 2.57 \times A^{0.45}$	Areas with annual rainfall > 800 mm	ARR2019	6.81	45.9
3	$k_c = 2.2 \times A^{0.5}$	General	RORB Manual	6.50	47.8
4	$k_c = 1.25 \times d_{av}$	Victoria	Pearse et al. (2002)	4.16	67.5
5	$k_c = 1.19 \times A^{0.65}$	Yarra and Maribyrnong areas	Melbourne Water	4.00	69.0
6	$k_c = 1.53 \times A^{0.65}$	South East area	Melbourne Water	5.04	59.3
7	Rule of Thumb Q = 10 m³/s per 100 ha	Urban	Melbourne Water		87.3
8	DNRE $Q = 10.29 \times A^{0.71}$	Urban	Nickoloau / vont Steen		47.9

Melbourne Water's previous RORB model of Merlynston Creek was calibrated using the Rational Method. Appendix Figure A. 14 summarises the comparison of their calibrated RORB model results to the Rational Method at Camp Road (upstream of CSL retarding basin). It is worth highlighting that the BMT WBM RORB model was validated to the rational method calculation with the retarding basins included in the model. The Rational method does not account for retarding basins in the catchment and these should have been removed from the model before the validation was undertaken. By leaving the retarding basins in the model and relying on a validation to the Rational method, the outputs from the BMT WBM RORB model are overestimating the flows that would be expected in this catchment and so are not being used for validation in this study.

Appendix Figure A. 14: Rational Method and MW RORB comparisons for Merlynston Main Drain (BMT WBM, 2010)

Flow Path	100 yr ARI Estimated Peak Discharge (m3/s)		
	Rational Method	Rational Method (using tc from Jayasuriya Method)	RORB
Outlet	116.6	105.9	127.06
Outlet (Partial Area)	127.8	-	
Confluence	98.1	73.8	120.45
Confluence (Partial Area)	106.1	-	
Camp Rd	64	45.8	61.42

In Merlynston Creek, k_c equations 4 and 5 provide the best match to the flow rates estimated being between the values produced by the rule of thumb and DNRE methodologies. The equations estimated a flow of 67.5 m³/s and 69 m³/s respectively, and provide a close match to BMT's Rational Method calculation of 64 m³/s. Engeny has adopted equation 5 for the calculation of k_c in this catchment as:

- It is the slightly higher and more conservative flow estimate of equations 4 and 5 which both provide a close match to the previous Rational method flow estimate
- The catchment is located with the Yarra River catchment and so the equation should be directly compatible

- It is above the DNRE flow estimation but below the rule of thumb method, of that two validation methods the DNRE is regarded as having a better basis so adopting a flow which is higher than that estimate is considered conservative.

Appendix Table A. 27 shows the flows into the CSL retarding basin once the Army Camp retarding basin is added back into the RORB model.

Appendix Table A. 27: Merlynston Creek Flow Comparison at inflow to CSL RB (Army Camp RB included)

No	Formula	Application	Source	k_c	Discharge (m^3/s)
1	$k_c = 0.49 \times A^{0.65}$	Areas with annual rainfall < 800 mm	ARR2019	2.00	59.8
2	$k_c = 2.57 \times A^{0.45}$	Areas with annual rainfall > 800 mm	ARR2019	6.81	30.5
3	$k_c = 2.2 \times A^{0.5}$	General	RORB Manual	6.50	31.3
4	$k_c = 1.25 \times d_{av}$	Victoria	Pearse et al. (2002)	4.16	39.6
5	$k_c = 1.19 \times A^{0.65}$	Yarra and Maribyrnong areas	Melbourne Water	4.00	40.9
6	$k_c = 1.53 \times A^{0.65}$	South East area	Melbourne Water	5.04	36.0
7	Rule of Thumb Q = 10 m^3/s per 100 ha	Urban	Melbourne Water		87.3
8	DNRE $Q = 10.29 \times A^{0.71}$	Urban	Nickoloau / vont Steen		47.9

From the flow values in Appendix Table A. 28 we can see that the general Victoria equation (#4) and Yarra and Maribyrnong areas equation (#5) provide the closest match in Campbellfield Creek. Equation 4 estimates a flow of 29.8 m^3/s and equation 5 estimates a flow of 31.8 m^3/s. Both of these estimated flows are above the DNRE regression analysis estimated flow of 25.3 m^3/and below the rule of thumb's estimated flow of 35.5 m^3/s. This is similar to the results in the Merlynston Creek Catchment. Equations 4 and 5 once again produce similar results. Given that the catchment is located with the Yarra River catchment the application of equation 5 is directly relevant, Engeny has adopted equation 5 for the calculation of k_c in this catchment. This is also consistent with the method for estimating k_c which has been adopted in the Merlynston Creek Catchment. Given that k_c represents physical catchment characteristics and that the Campbellfield Creek and Merlynston Creek catchments have very similar physical characteristics we would expect to be able to use the same validation approach is each catchment.

Appendix Table A. 28: Campbellfield Creek Flow Comparison at inflow to Campbellfield Creek RB

No	Formula	Application	Source	k_c	Discharge (m^3/s)
1	$k_c = 0.49 \times A^{0.65}$	Areas with annual rainfall < 800 mm	ARR2019	1.12	54.5
2	$k_c = 2.57 \times A^{0.45}$	Areas with annual rainfall > 800 mm	ARR2019	4.55	19.6
3	$k_c = 2.2 \times A^{0.5}$	General	RORB Manual	4.15	21.2
4	$k_c = 1.25 \times d_{av}$	Victoria	Pearse et al. (2002)	2.59	29.8
5	$k_c = 1.19 \times A^{0.65}$	Yarra and Maribyrnong areas	Melbourne Water	2.42	31.8
6	$k_c = 1.53 \times A^{0.65}$	South East area	Melbourne Water	3.07	26.4
7	Rule of Thumb Q = 10 m^3/s per 100 ha	Urban	Melbourne Water		35.5
8	DNRE $Q = 10.29 \times A^{0.71}$	Urban	Nickoloau / vont Steen		25.3

The use of equation 5 is further supported as k_c / d_{av} ratios fall within the expected ranges for RORB hydrological models. Appendix Table A. 29 presents this comparison.

Appendix Table A. 29: k_c / d_{av} Comparison

Catchment	Yarra and Maribyrnong k_c	k_c / d_{av}	Pearse et al., 2002 k_c / d_{av}	Yu, 1989 k_c / d_{av}	CRCCH k_c / d_{av}
Merlynston Creek	4.00	1.20	1.25	0.96	1.14
Campbellfield Creek	2.42	1.17			

For the sake of comparison BMT WBM's RORB model of Merlynston Creek was rerun to comparing peak flows at the intended Campbellfield Creek RB and CSL RB inflow locations. Appendix Table A. 30 presents flows derived from both models (Engeny using k_c Equation 5).

Appendix Table A. 30: Engeny RORB and Melbourne Water RORB Model Comparison

Location	Yarra and Maribyrnong k_c	Engeny RORB Model Discharge (m^3/s)	Melbourne Water Merlynston Creek RORB Model Discharge (m^3/s)
Campbellfield Creek at inflow to Campbellfield Creek RB	4.00	31.8	44.3
Merlynston Creek at inflow to CSL RB	2.42	40.9	56.2

Melbourne Water's peak flows present higher flows than Engeny. This is due to BMT's validation of the RORB model where storages have mistakenly been included and as discussed above, this is leading to the BMT WBM model over estimating flows. Consequently, the k_c utilised in Melbourne Water's RORB have produced flows that are too high.

Appendix B:
Consideration of RORB Model Timestep

This sheet presents 20% AEP ARR2016 design rainfalls for

Individual patterns for various durations are presented as column charts and cumulative plots .
Intensities are also presented in blocks that can be imported into programs.
The ten 2016 patterns are from the 'frequent' category

20% AEP, 10 Minute Rainfall Patterns

Duration (minutes) 10 | Original Depth (mm) 11.40 | Climate Adjusted Depth (mm) 11.40 | Intensity (mm/h) 68.40

5 min Timestep

Depth (mm) for Temporal Pattern

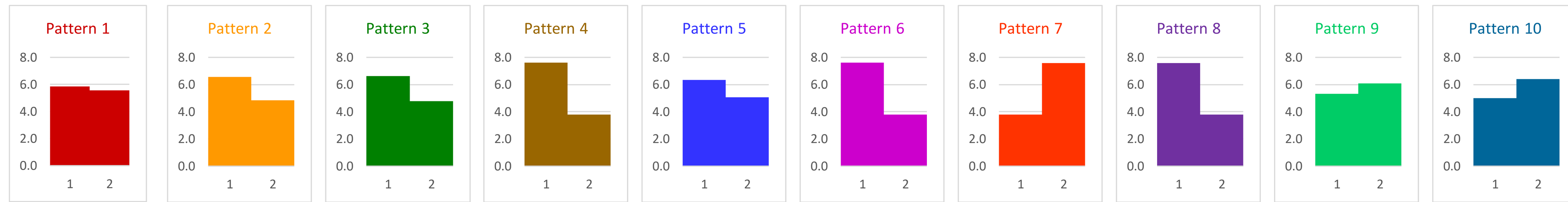
Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
5	5.84	6.56	6.61	7.60	6.35	7.60	3.80	7.60	5.30	5.00
10	5.56	4.85	4.79	3.80	5.05	3.80	7.60	3.80	6.10	6.40
5 Min Timestep Rainfall Depth	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40	11.40

CL (mm/hr) 1.9 | CL(mm/timestep) 0.158333

5 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	1	2	3	4	5	6	7	8	9	10	
	5.69	6.40	6.46	7.44	6.19	7.45	3.65	7.44	5.15	4.85	
	5.40	4.69	4.63	3.64	4.90	3.64	7.44	3.65	5.94	6.24	
5 Min Timestep Rainfall Depth - CL (mm)	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	11.08	1.90
1 hour timestep Rainfall Depth (mm)	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	9.50	
Total Rainfall Depth Difference (mm)	1.583333	1.583333	1.583333	1.583333	1.583333	1.583333	1.583333	1.583333	1.583333	1.583333	
% Increase in Total Rainfall Depth using a 5 minute Timestep	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	16.7	



20% AEP, 15 Minute Rainfall Patterns

Duration (minutes) 15 | Original Depth (mm) 14.00 | Climate Adjusted Depth (mm) 14.00 | Intensity (mm/h) 56.00

5 min Timestep

Depth (mm) for Temporal Pattern

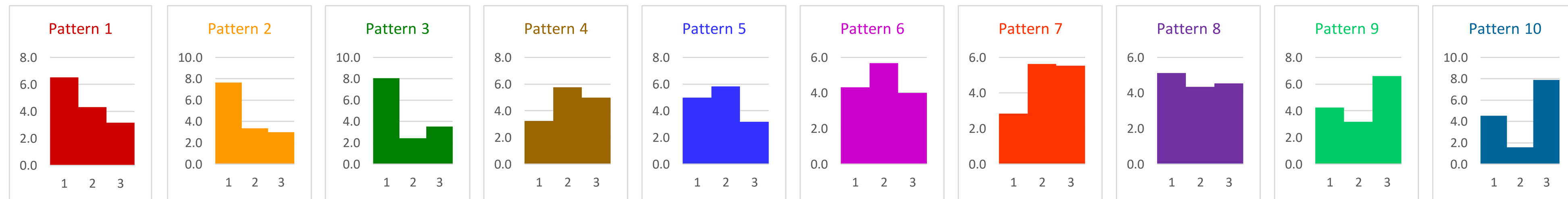
Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
5	6.51	7.65	8.04	3.25	5.00	4.33	2.84	5.13	4.23	4.55
10	4.33	3.36	2.43	5.76	5.81	5.68	5.63	4.34	3.17	1.57
15	3.15	2.99	3.53	4.99	3.19	4.00	5.53	4.53	6.60	7.88
5 Min Timestep Rainfall Depth	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00	14.00

CL (mm/hr) 1.9 | CL(mm/timestep) 0.158333

5 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	6.36	7.50	7.88	3.09	4.84	4.17	2.68	4.97	4.07	4.39	
	4.17	3.20	2.27	5.60	5.66	5.52	5.47	4.18	3.01	1.41	
	2.99	2.83	3.37	4.83	3.03	3.84	5.37	4.38	6.45	7.72	
5 Min Timestep Rainfall Depth - CL (mm)	13.53	13.53	13.53	13.53	13.53	13.53	13.53	13.53	13.53	13.53	3.30
1 hour timestep Rainfall Depth (mm)	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	10.70	
Total Rainfall Depth Difference (mm)	2.825	2.825	2.825	2.825	2.825	2.825	2.825	2.825	2.825	2.825	
% Increase in Total Rainfall Depth using a 5 minute Timestep	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	26.4	



20% AEP, 30 Minute Rainfall Patterns

Duration (minutes) 30 | Original Depth (mm) 18.50 | Climate Adjusted Depth (mm) 18.50 | Intensity (mm/h) 37.00

5 min Timestep

Depth (mm) for Temporal Pattern

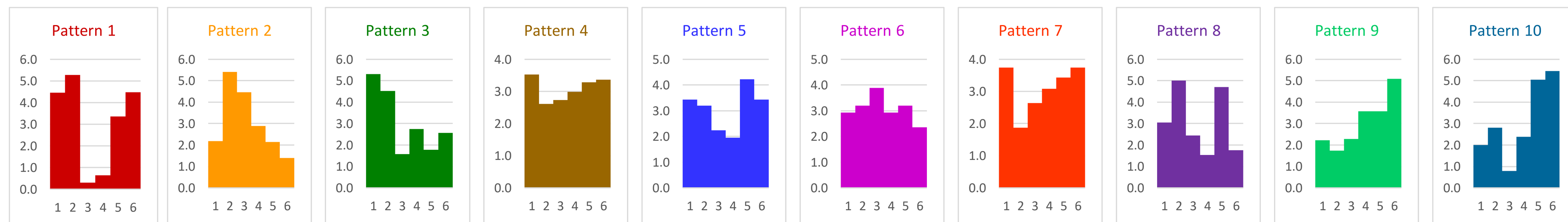
Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
5	4.45	2.18	5.32	3.53	3.44	2.92	3.74	3.06	2.22	2.01
10	5.27	5.42	4.53	2.61	3.21	3.20	1.87	5.00	1.75	2.81
15	0.29	4.46	1.57	2.73	2.25	3.89	2.64	2.44	2.29	0.80
20	0.64	2.90	2.75	2.99	1.95	2.92	3.08	1.54	3.58	2.38
25	3.37	2.15	1.77	3.28	4.22	3.20	3.43	4.71	3.58	5.05
30	4.48	1.40	2.56	3.37	3.44	2.36	3.74	1.76	5.09	5.45
5 Min Timestep Rainfall Depth	18.50	18.50	18.50	18.50	18.50	18.50	18.50	18.50	18.50	18.50

CL (mm/hr) 1.9 | CL(mm/timestep) 0.158333

5 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	4.29	2.02	5.16	3.38	3.28	2.76	3.58	2.90	2.06	1.85	
	5.11	5.26	4.37	2.45	3.05	3.04	1.71	4.84	1.59	2.65	
	0.13	4.30	1.42	2.57	2.09	3.74	2.48	2.28	2.13	0.64	
	0.48	2.74	2.60	2.83	1.79	2.76	2.92	1.38	3.42	2.22	
	3.21	1.99	1.61	3.12	4.06	3.04	3.27	4.55	3.42	4.89	
	4.32	1.24	2.40	3.21	3.28	2.21	3.58	1.60	4.93	5.29	
5 Min Timestep Rainfall Depth - CL (mm)	17.55	17.55	17.55	17.55	17.55	17.55	17.55	17.55	17.55	17.55	3.30
1 hour timestep Rainfall Depth (mm)	15.20	15.20	15.20	15.20	15.20	15.20	15.20	15.20	15.20	15.20	
Total Rainfall Depth Difference (mm)	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	2.35	
% Increase in Total Rainfall Depth using a 5 minute Timestep	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	15.5	



20% AEP, 60 Minute (1 Hour) Rainfall Patterns

Duration (minutes) 60 | Original Depth (mm) 23.40 | Climate Adjusted Depth (mm) 23.40 | Intensity (mm/h) 23.40

5 min Timestep

Depth (mm) for Temporal Pattern

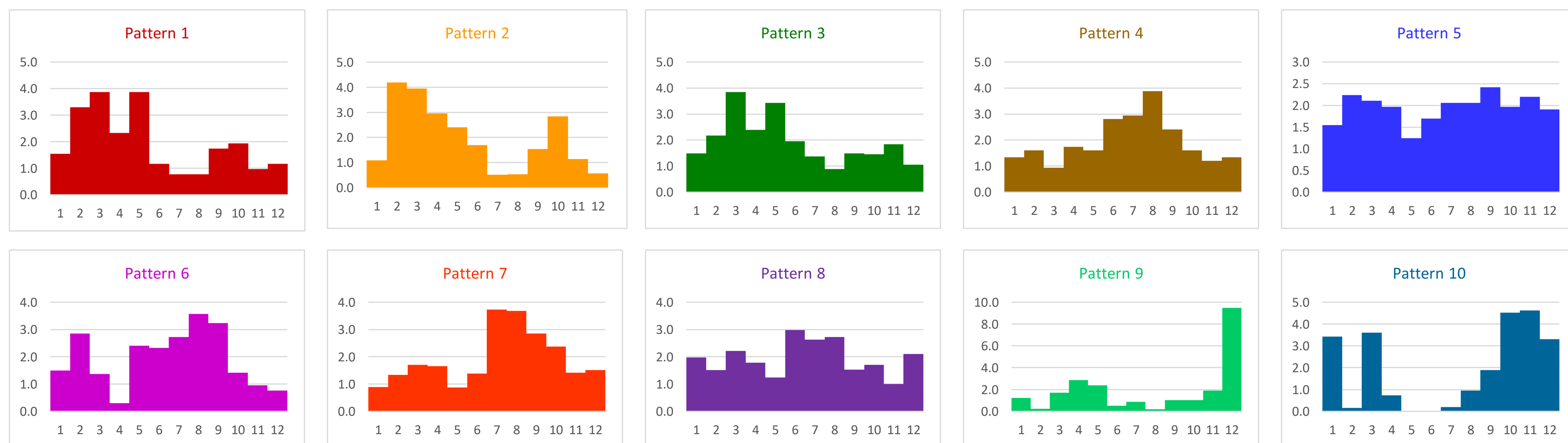
Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
5	1.54	1.09	1.49	1.34	1.54	1.50	0.89	1.98	1.21	3.43
10	3.29	4.19	2.18	1.61	2.24	2.85	1.34	1.52	0.24	0.16
15	3.87	3.94	3.85	0.94	2.11	1.36	1.70	2.21	1.71	3.61
20	2.32	2.95	2.40	1.74	1.97	0.30	1.66	1.78	2.85	0.73
25	3.87	2.40	3.44	1.61	1.24	2.40	0.87	1.24	2.38	0.00
30	1.16	1.69	1.95	2.81	1.69	2.33	1.39	2.98	0.52	0.00
35	0.77	0.51	1.37	2.94	2.06	2.72	3.72	2.63	0.86	0.19
40	0.77	0.53	0.89	3.88	2.06	3.58	3.68	2.73	0.18	0.94
45	1.74	1.54	1.49	2.41	2.42	3.23	2.85	1.53	1.03	1.89
50	1.93	2.85	1.45	1.61	1.97	1.41	2.38	1.70	1.03	4.53
55	0.97	1.14	1.84	1.20	2.20	0.95	1.42	1.00	1.90	4.62
60	1.16	0.57	1.06	1.34	1.90	0.76	1.50	2.10	9.50	3.30
5 Min Timestep Rainfall Depth	23.40	23.40	23.40	23.40	23.40	23.40	23.40	23.40	23.40	23.40

CL (mm/hr) 1.9 | CL(mm/timestep) 0.158333

5 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	1.39	0.93	1.33	1.18	1.38	1.34	0.73	1.82	1.05	3.27	
	3.13	4.03	2.02	1.45	2.08	2.70	1.18	1.36	0.08	0.00	
	3.71	3.78	3.69	0.78	1.95	1.20	1.54	2.05	1.55	3.45	
	2.16	2.79	2.24	1.58	1.81	0.15	1.50	1.62	2.69	0.57	
	3.71	2.24	3.28	1.45	1.08	2.24	0.71	1.08	2.22	0.00	
	1.00	1.53	1.79	2.65	1.54	2.17	1.23	2.82	0.36	0.00	
	0.62	0.35	1.22	2.78	1.90	2.56	3.56	2.47	0.70	0.03	
	0.62	0.37	0.73	3.72	1.90	3.42	3.52	2.57	0.02	0.78	
	1.58	1.38	1.33	2.25	2.26	3.07	2.69	1.37	0.88	1.73	
	1.77	2.69	1.29	1.45	1.81	1.26	2.22	1.54	0.88	4.37	
	0.81	0.98	1.69	1.04	2.04	0.80	1.26	0.84	1.74	4.47	
	1.00	0.41	0.90	1.18	1.74	0.60	1.35	1.94	9.34	3.14	
5 Min Timestep Rainfall Depth - CL (mm)	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.82	1.90
1 hour timestep Rainfall Depth (mm)	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	21.50	
Total Rainfall Depth Difference (mm)	0	0	0	0	0	0	0	0	0	0.316667	
% Increase in Total Rainfall Depth using a 5 minute Timestep	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	



20% AEP, 120 Minute (2 Hour) Rainfall Patterns

Duration (minutes) 120 | Original Depth (mm) 29.10 | Climate Adjusted Depth (mm) 29.10 | Intensity (mm/h) 14.55

5 min Timestep

Depth (mm) for Temporal Pattern

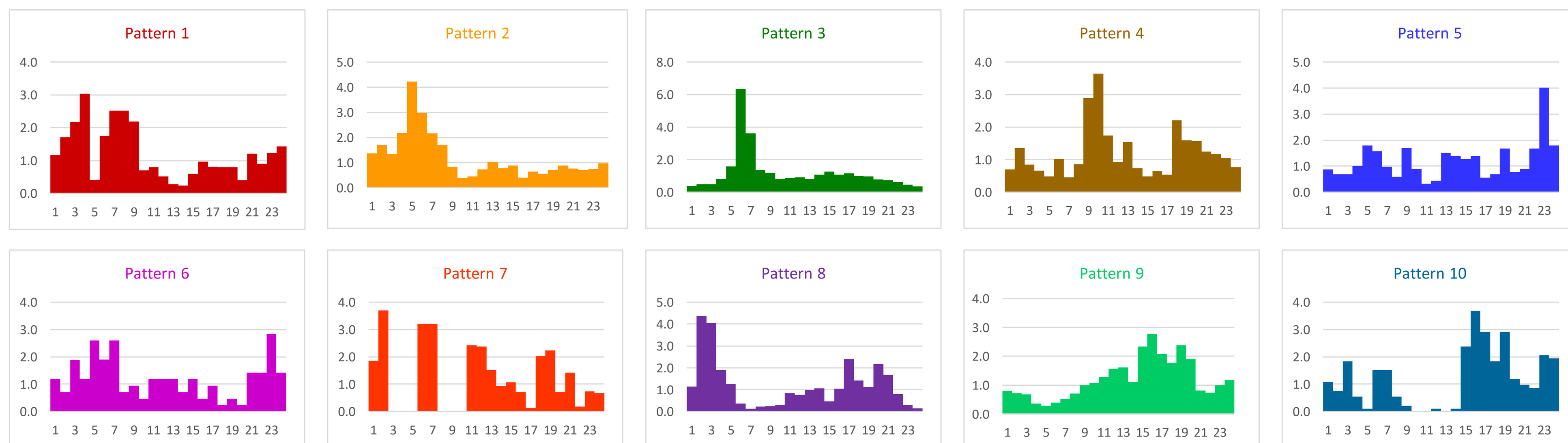
Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
5	1.16	1.38	0.38	0.70	0.87	1.18	1.84	1.14	0.79	1.09
10	1.71	1.71	0.48	1.36	0.69	0.71	3.70	4.36	0.72	0.76
15	2.17	1.33	0.49	0.85	0.70	1.89	0.00	4.05	0.68	1.84
20	3.03	2.18	0.80	0.65	1.00	1.18	0.00	1.89	0.36	0.54
25	0.41	4.23	1.59	0.49	1.79	2.60	0.00	1.25	0.28	0.11
30	1.75	2.98	6.36	1.02	1.57	1.89	3.20	0.37	0.39	1.51
35	2.51	2.17	3.61	0.45	0.97	2.60	3.20	0.12	0.53	1.51
40	2.52	1.71	1.36	0.86	0.59	0.71	0.00	0.23	0.70	0.54
45	2.19	0.84	1.19	2.89	1.70	0.95	0.00	0.24	1.00	0.22
50	0.70	0.39	0.81	3.64	0.88	0.47	0.00	0.30	1.08	0.00
55	0.79	0.45	0.85	1.74	0.31	1.18	2.42	0.83	1.28	0.00
60	0.52	0.72	0.90	0.92	0.44	1.18	2.38	0.76	1.57	0.11
65	0.27	1.02	0.81	1.54	1.50	1.18	1.52	0.98	1.62	0.00
70	0.24	0.77	1.08	0.74	1.39	0.71	0.93	1.06	1.12	0.11
75	0.60	0.88	1.25	0.48	1.27	1.18	1.07	0.47	2.35	2.38
80	0.96	0.40	1.08	0.65	1.39	0.47	0.71	1.04	2.78	3.68
85	0.81	0.63	1.16	0.54	0.55	0.95	0.14	2.39	2.08	2.92
90	0.79	0.56	1.00	2.21	0.68	0.24	2.03	1.41	1.76	1.84
95	0.80	0.71	0.97	1.59	1.67	0.47	2.24	1.13	2.39	2.92
100	0.40	0.88	0.79	1.57	0.77	0.24	0.71	2.18	1.90	1.19
105	1.20	0.77	0.74	1.25	0.89	1.42	1.42	1.67	0.81	0.97

CL (mm/hr) 1.9 | CL(mm/timestep) 0.158333

5 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

1.00	1.22	0.22	0.54	0.71	1.02	1.69	0.98	0.64	0.93
1.55	1.55	0.32	1.20	0.53	0.55	3.54	4.20	0.56	0.60
2.01	1.17	0.33	0.69	0.54	1.73	0.00	3.89	0.52	1.68
2.87	2.02	0.64	0.49	0.84	1.03	0.00	1.73	0.21	0.38
0.25	4.07	1.43	0.33	1.63	2.44	0.00	1.09	0.12	0.00
1.59	2.82	6.20	0.86	1.41	1.73	3.04	0.21	0.23	1.35
2.35	2.01	3.45	0.29	0.82	2.44	3.04	0.00	0.37	1.35
2.36	1.55	1.20	0.70	0.44	0.55	0.00	0.07	0.55	0.38
2.03	0.68	1.03	2.73	1.54	0.79	0.00	0.08	0.84	0.06
0.54	0.23	0.66	3.48	0.72	0.32	0.00	0.14	0.92	0.00
0.63	0.29	0.69	1.58	0.16	1.03	2.26	0.67	1.12	0.00
0.36	0.56	0.74	0.76	0.28	1.03	2.22	0.60	1.42	0.00
0.12	0.86	0.66	1.38	1.34	1.03	1.37	0.82	1.46	0.00
0.09	0.62	0.92	0.58	1.24	0.55	0.77	0.90	0.96	0.00
0.44	0.72	1.09	0.32	1.11	1.03	0.91	0.31	2.19	2.22
0.80	0.24	0.92	0.49	1.24	0.32	0.55	0.88	2.62	3.52
0.65	0.48	1.00	0.38	0.39	0.79	0.00	2.23	1.92	2.76
0.63	0.40	0.84	2.06	0.53	0.08	1.87	1.26	1.61	1.68
0.64	0.55	0.81	1.43	1.51	0.32	2.08	0.97	2.23	2.76
0.24	0.73	0.63	1.41	0.61	0.08	0.55	2.02	1.74	1.03
1.04	0.61	0.58	1.09	0.74	1.26	1.26	1.51	0.65	0.82



Time	1	2	3	4	5	6	7	8	9	10
110	0.91	0.70	0.62	1.16	1.67	1.42	0.18	0.80	0.74	0.86
115	1.23	0.74	0.45	1.04	4.01	2.84	0.74	0.31	1.00	2.05
120	1.43	0.98	0.35	0.77	1.79	1.42	0.67	0.14	1.18	1.95
5 Min Timestep Rainfall Depth	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10	29.10

	1	2	3	4	5	6	7	8	9	10
	0.75	0.54	0.46	1.00	1.51	1.26	0.02	0.64	0.59	0.71
	1.07	0.58	0.29	0.89	3.85	2.68	0.59	0.15	0.84	1.90
	1.27	0.82	0.19	0.61	1.63	1.26	0.51	0.00	1.02	1.79
5 Min Timestep Rainfall Depth - CL (mm)	25.30	25.30	25.30	25.30	25.30	25.30	26.27	25.35	25.30	25.93
1 hour timestep Rainfall Depth (mm)	25.30	25.30	25.30	25.30	25.30	25.30	25.30	25.30	25.30	25.30
Total Rainfall Depth Difference (mm)	0.00	0.00	0.00	0.00	0.00	0.00	0.97	0.05	0.00	0.63
% Increase in Total Rainfall Depth using a 5 minute Timestep	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.2	0.0	2.5

20% AEP, 180 Minute (3 Hour) Rainfall Patterns

CL (mm/hr) 1.9 CL(mm/timestep) 0.475

Duration (minutes) 180 | Original Depth (mm) 33.10 | Climate Adjusted Depth (mm) 33.10 | Intensity (mm/h) 11.03

15 min Timestep

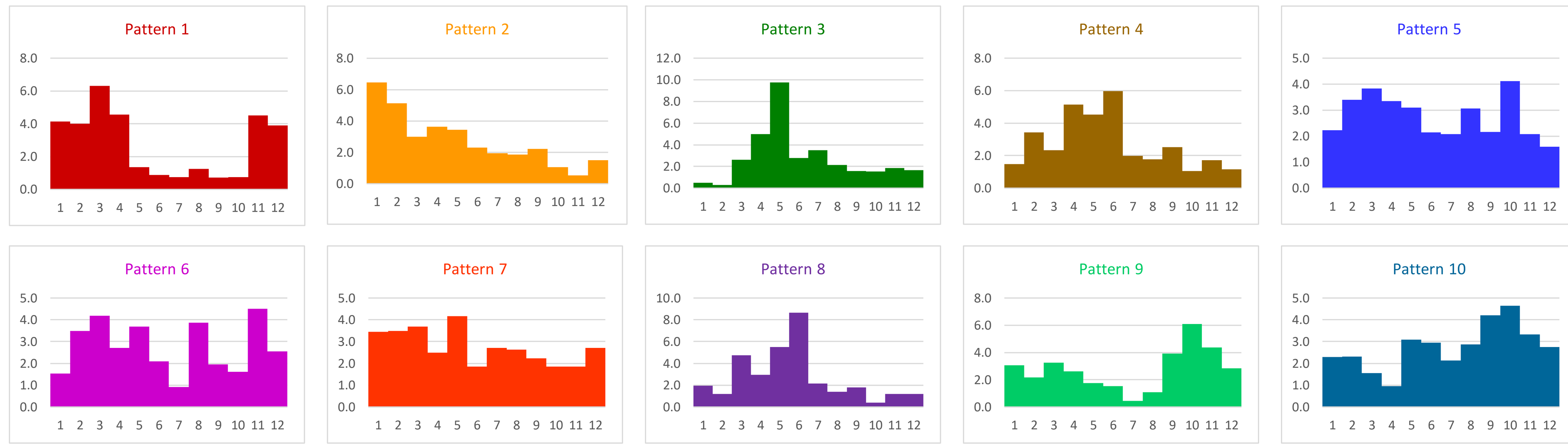
Depth (mm) for Temporal Pattern

Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
15	4.13	6.46	0.47	1.47	2.23	1.54	3.45	1.97	3.05	2.28
30	4.00	5.13	0.27	3.42	3.40	3.48	3.49	1.18	2.18	2.31
45	6.30	3.00	2.60	2.35	3.83	4.18	3.69	4.73	3.27	1.56
60	4.55	3.62	4.97	5.15	3.34	2.70	2.49	2.96	2.61	0.96
75	1.36	3.45	9.75	4.54	3.09	3.69	4.17	5.52	1.74	3.10
90	0.88	2.30	2.76	5.97	2.14	2.10	1.84	8.67	1.53	2.95
105	0.75	1.95	3.50	1.99	2.07	0.91	2.70	2.17	0.44	2.13
120	1.24	1.86	2.14	1.77	3.07	3.87	2.62	1.38	1.09	2.88
135	0.71	2.21	1.59	2.53	2.17	1.95	2.23	1.77	3.92	4.21
150	0.74	1.06	1.54	1.05	4.11	1.62	1.86	0.39	6.10	4.65
165	4.52	0.54	1.84	1.71	2.07	4.50	1.85	1.18	4.36	3.33
180	3.91	1.51	1.66	1.16	1.60	2.55	2.71	1.18	2.83	2.75
15 Min Timestep Rainfall Depth	33.10	33.10	33.10	33.10	33.10	33.10	33.10	33.10	33.10	33.10

15 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	1	2	3	4	5	6	7	8	9	10
	3.66	5.99	0.00	1.00	1.75	1.07	2.97	1.49	2.57	1.81
	3.52	4.65	0.00	2.95	2.92	3.01	3.01	0.71	1.70	1.84
	5.83	2.53	2.13	1.87	3.35	3.71	3.21	4.25	2.79	1.08
	4.07	3.15	4.49	4.67	2.86	2.23	2.02	2.48	2.14	0.48
	0.89	2.98	9.28	4.06	2.62	3.22	3.70	5.04	1.27	2.62
	0.41	1.83	2.29	5.49	1.66	1.62	1.37	8.19	1.05	2.47
	0.28	1.47	3.02	1.52	1.59	0.44	2.23	1.69	0.00	1.65
	0.77	1.39	1.67	1.30	2.59	3.40	2.15	0.91	0.61	2.40
	0.23	1.74	1.12	2.05	1.69	1.47	1.76	1.30	3.44	3.74
	0.27	0.59	1.06	0.57	3.64	1.15	1.39	0.00	5.62	4.17
	4.04	0.06	1.37	1.23	1.59	4.03	1.38	0.71	3.88	2.85
	3.43	1.03	1.18	0.68	1.12	2.07	2.23	0.71	2.36	2.27
5 Min Timestep Rainfall Depth - CL (mm)	27.40	27.40	27.60	27.40	27.40	27.40	27.40	27.48	27.44	27.40
1 hour timestep Rainfall Depth (mm)	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40	27.40
Total Rainfall Depth Difference (mm)	0	0	0.20194	0	0	0	0	0.08111	0.03808	0
% Increase in Total Rainfall Depth using a 15 minute Timestep	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.3	0.1	0.0



20% AEP, 360 Minute (6 Hour) Rainfall Patterns

CL (mm/hr) 1.9 CL(mm/timestep) 0.475

Duration (minutes) 360 | Original Depth (mm) 42.10 | Climate Adjusted Depth (mm) 42.10 | Intensity (mm/h) 7.02

15 min Timestep

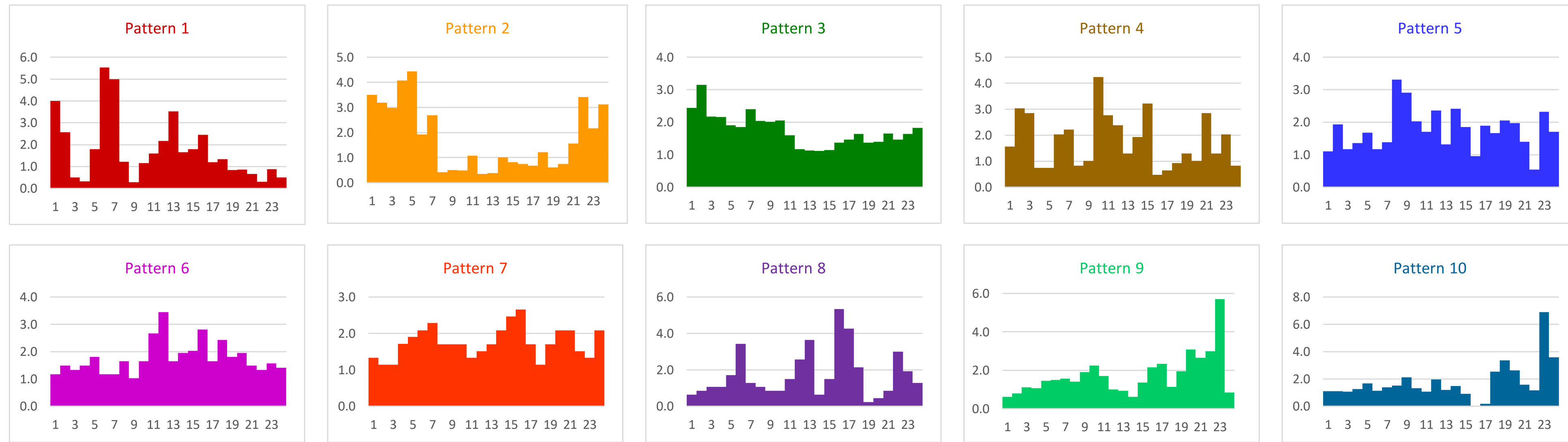
Depth (mm) for Temporal Pattern

Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
15	4.00	3.51	2.43	1.56	1.10	1.17	1.33	0.64	0.61	1.09
30	2.56	3.19	3.15	3.03	1.92	1.49	1.14	0.85	0.79	1.08
45	0.50	2.98	2.17	2.85	1.17	1.33	1.14	1.07	1.11	1.05
60	0.32	4.07	2.15	0.74	1.36	1.49	1.71	1.07	1.07	1.24
75	1.80	4.44	1.90	0.74	1.68	1.80	1.90	1.71	1.45	1.67
90	5.52	1.92	1.85	2.02	1.17	1.17	2.09	3.42	1.51	1.12
105	4.98	2.68	2.40	2.21	1.38	1.17	2.28	1.28	1.57	1.40
120	1.23	0.42	2.04	0.83	3.31	1.64	1.71	1.07	1.41	1.51
135	0.29	0.51	2.01	1.01	2.90	1.02	1.71	0.85	1.91	2.11
150	1.15	0.49	2.05	4.23	2.02	1.64	1.71	0.85	2.24	1.33
165	1.59	1.07	1.59	2.76	1.71	2.66	1.33	1.49	1.70	1.05
180	2.16	0.35	1.16	2.39	2.36	3.44	1.52	2.56	0.99	1.97
195	3.51	0.39	1.12	1.30	1.32	1.64	1.71	3.63	0.92	1.18
210	1.65	1.01	1.12	1.93	2.41	1.96	2.08	0.64	0.61	1.48
225	1.80	0.82	1.14	3.22	1.84	2.03	2.47	1.49	1.36	0.91
240	2.44	0.74	1.36	0.47	0.95	2.82	2.66	5.34	2.16	0.00
255	1.19	0.67	1.47	0.64	1.89	1.64	1.71	4.27	2.34	0.18
270	1.34	1.21	1.64	0.92	1.66	2.42	1.14	2.14	1.14	2.54
285	0.84	0.61	1.37	1.29	2.05	1.80	1.71	0.21	1.94	3.36
300	0.87	0.75	1.39	1.01	1.97	1.96	2.08	0.43	3.09	2.63
315	0.67	1.55	1.65	2.85	1.39	1.49	2.08	0.85	2.65	1.57
330	0.30	3.41	1.47	1.29	0.53	1.33	1.52	2.99	2.98	1.15
345	0.88	2.16	1.64	2.02	2.31	1.57	1.33	1.92	5.70	6.90
360	0.51	3.13	1.82	0.83	1.71	1.41	2.08	1.28	0.84	3.57
15 Min Timestep Rainfall Depth	42.10	42.10	42.10	42.10	42.10	42.10	42.10	42.10	42.10	42.10

15 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	1	2	3	4	5	6	7	8	9	10
	3.52	3.03	1.96	1.08	0.62	0.70	0.86	0.16	0.14	0.62
	2.09	2.71	2.68	2.56	1.45	1.01	0.67	0.38	0.32	0.61
	0.02	2.51	1.70	2.38	0.69	0.86	0.67	0.59	0.63	0.58
	0.00	3.59	1.68	0.26	0.88	1.01	1.23	0.59	0.59	0.77
	1.33	3.97	1.42	0.26	1.20	1.33	1.42	1.23	0.97	1.20
	5.05	1.44	1.37	1.55	0.69	0.70	1.61	2.94	1.03	0.64
	4.51	2.21	1.93	1.73	0.91	0.70	1.81	0.81	1.10	0.92
	0.75	0.00	1.57	0.35	2.84	1.17	1.23	0.59	0.94	1.03
	0.00	0.04	1.53	0.54	2.43	0.54	1.23	0.38	1.44	1.64
	0.67	0.02	1.58	3.75	1.55	1.17	1.23	0.38	1.77	0.86
	1.11	0.60	1.12	2.28	1.23	2.19	0.85	1.02	1.23	0.58
	1.68	0.00	0.69	1.91	1.88	2.97	1.04	2.09	0.51	1.50
	3.04	0.00	0.65	0.82	0.84	1.17	1.23	3.16	0.45	0.70
	1.18	0.54	0.64	1.45	1.94	1.48	1.61	0.16	0.14	1.00
	1.33	0.35	0.67	2.74	1.37	1.56	1.99	1.02	0.88	0.43
	1.97	0.27	0.89	0.00	0.47	2.34	2.18	4.87	1.68	0.00
	0.72	0.20	0.99	0.17	1.41	1.17	1.23	3.80	1.86	0.00
	0.86	0.73	1.16	0.44	1.19	1.95	0.66	1.66	0.66	2.07
	0.37	0.13	0.90	0.81	1.58	1.33	1.23	0.00	1.47	2.88
	0.39	0.28	0.92	0.54	1.50	1.48	1.61	0.00	2.61	2.16
	0.19	1.08	1.18	2.38	0.91	1.01	1.61	0.38	2.18	1.10
	0.00	2.94	0.99	0.81	0.06	0.86	1.04	2.52	2.51	0.68
	0.40	1.68	1.16	1.55	1.84	1.09	0.85	1.45	5.23	6.43
	0.03	2.65	1.34	0.35	1.23	0.94	1.61	0.81	0.37	3.09
5 Min Timestep Rainfall Depth - CL (mm)	31.21	30.96	30.70	30.71	30.70	30.70	30.70	31.01	30.70	31.47
1 hour timestep Rainfall Depth (mm)	30.70	30.70	30.70	30.70	30.70	30.70	30.70	30.70	30.70	30.70
Total Rainfall Depth Difference (mm)	0.50722	0.26304	0	0.00769	0	0	0	0.30587	0	0.76897
% Increase in Total Rainfall Depth using a 15 minute Timestep	1.7	0.9	0.0	0.0	0.0	0.0	0.0	1.0	0.0	2.5



20% AEP, 720 Minute (12 Hour) Rainfall Patterns

CL (mm/hr) 1.9 CL(mm/timestep) 0.95

Duration (minutes) 720 | Original Depth (mm) 54.50 | Climate Adjusted Depth (mm) 54.50 | Intensity (mm/h) 4.54

30 min Timestep

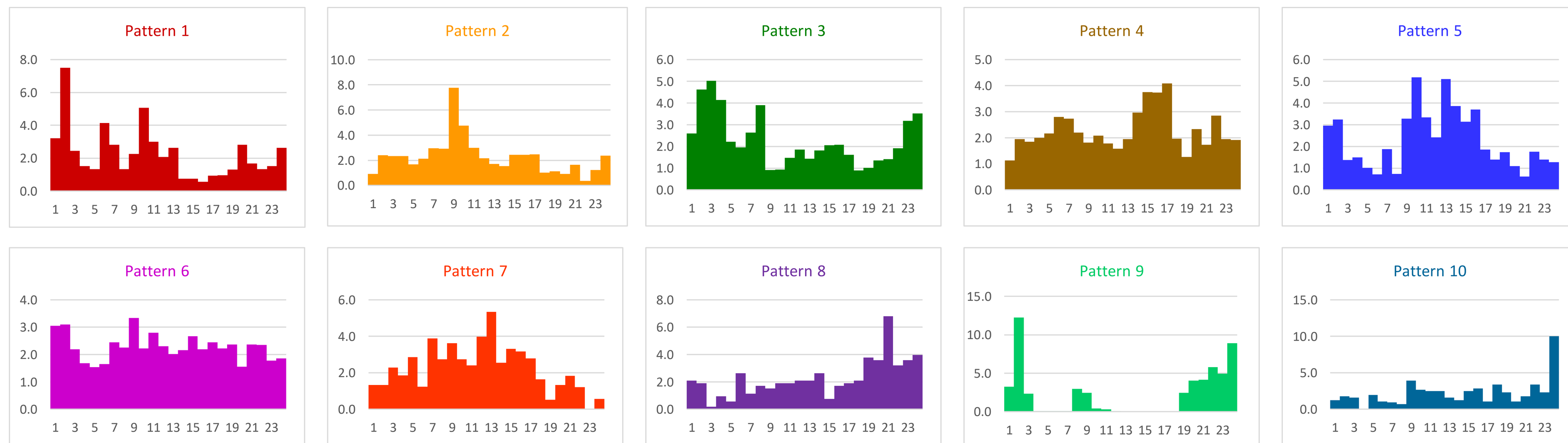
Depth (mm) for Temporal Pattern

Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
30	3.20	0.92	2.60	1.13	2.96	3.06	1.33	2.08	3.24	1.24
60	7.51	2.39	4.62	1.95	3.24	3.09	1.34	1.89	12.22	1.78
90	2.44	2.32	5.03	1.85	1.37	2.19	2.29	0.19	2.34	1.61
120	1.51	2.33	4.14	1.99	1.49	1.68	1.85	0.94	0.07	0.00
150	1.32	1.68	2.21	2.16	1.01	1.54	2.87	0.57	0.07	1.97
180	4.14	2.11	1.95	2.80	0.72	1.65	1.22	2.64	0.07	1.07
210	2.81	2.95	2.63	2.73	1.87	2.44	3.87	1.13	0.07	0.90
240	1.32	2.90	3.89	2.19	0.73	2.25	2.74	1.69	2.98	0.71
270	2.25	7.78	0.90	1.81	3.28	3.33	3.62	1.51	2.44	3.93
300	5.06	4.76	0.93	2.09	5.19	2.22	2.74	1.89	0.41	2.68
330	3.00	2.99	1.48	1.78	3.34	2.79	2.41	1.89	0.32	2.50
360	2.08	2.16	1.85	1.58	2.41	2.31	3.99	2.08	0.05	2.50
390	2.63	1.72	1.43	1.94	5.11	2.01	5.34	2.08	0.00	1.61
420	0.76	1.52	1.82	2.96	3.86	2.16	2.55	2.64	0.00	1.25
450	0.75	2.44	2.05	3.74	3.13	2.67	3.31	0.75	0.00	2.50
480	0.56	2.43	2.08	3.73	3.69	2.19	3.17	1.69	0.00	2.86
510	0.94	2.46	1.61	4.09	1.86	2.44	2.79	1.89	0.00	1.07
540	0.95	1.02	0.89	1.96	1.39	2.22	1.65	2.08	0.00	3.40
570	1.31	1.12	1.01	1.26	1.74	2.37	0.51	3.77	2.47	2.32
600	2.81	0.92	1.35	2.33	1.09	1.56	1.34	3.58	4.02	1.07
630	1.69	1.64	1.41	1.72	0.60	2.36	1.84	6.79	4.16	1.79
660	1.32	0.35	1.92	2.84	1.76	2.35	1.20	3.20	5.80	3.40
690	1.51	1.21	3.17	1.94	1.39	1.78	0.00	3.58	4.92	2.33
720	2.63	2.37	3.52	1.92	1.28	1.86	0.57	3.96	8.87	10.00
30 Min Timestep Rainfall Depth	54.50	54.50	54.50	54.50	54.50	54.50	54.50	54.50	54.50	54.50

30 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	1	2	3	4	5	6	7	8	9	10
	2.25	0.00	1.65	0.18	2.01	2.11	0.38	1.13	2.29	0.29
	6.56	1.44	3.67	1.00	2.29	2.14	0.39	0.94	11.27	0.83
	1.49	1.37	4.08	0.90	0.42	1.24	1.34	0.00	1.39	0.66
	0.56	1.38	3.19	1.04	0.54	0.73	0.90	0.00	0.00	0.00
	0.37	0.73	1.26	1.21	0.06	0.59	1.92	0.00	0.00	1.02
	3.19	1.16	1.00	1.85	0.00	0.70	0.27	1.69	0.00	0.12
	1.86	2.00	1.68	1.78	0.92	1.49	2.92	0.18	0.00	0.00
	0.37	1.95	2.94	1.24	0.00	1.30	1.79	0.74	2.03	0.00
	1.30	6.83	0.00	0.86	2.33	2.38	2.67	0.56	1.49	2.98
	4.11	3.81	0.00	1.14	4.24	1.27	1.79	0.94	0.00	1.73
	2.05	2.04	0.53	0.83	2.39	1.84	1.46	0.94	0.00	1.55
	1.13	1.21	0.90	0.63	1.46	1.36	3.04	1.13	0.00	1.55
	1.68	0.77	0.48	0.99	4.16	1.06	4.39	1.13	0.00	0.66
	0.00	0.57	0.87	2.01	2.91	1.21	1.60	1.69	0.00	0.30
	0.00	1.49	1.10	2.79	2.18	1.72	2.36	0.00	0.00	1.55
	0.00	1.48	1.13	2.78	2.74	1.24	2.22	0.74	0.00	1.91
	0.00	1.51	0.66	3.14	0.91	1.49	1.84	0.94	0.00	0.12
	0.00	0.07	0.00	1.01	0.44	1.27	0.70	1.13	0.00	2.45
	0.36	0.17	0.06	0.31	0.79	1.42	0.00	2.82	1.52	1.37
	1.86	0.00	0.40	1.38	0.14	0.61	0.39	2.63	3.07	0.12
	0.74	0.69	0.46	0.77	0.00	1.41	0.89	5.84	3.21	0.84
	0.37	0.00	0.97	1.89	0.81	1.40	0.25	2.25	4.85	2.45
	0.56	0.26	2.22	0.99	0.44	0.83	0.00	2.63	3.97	1.38
	1.68	1.42	2.57	0.97	0.33	0.91	0.00	3.01	7.92	9.05
5 Min Timestep Rainfall Depth - CL (mm)	32.49	32.35	31.83	31.70	32.50	31.70	33.47	33.05	43.00	32.93
1 hour timestep Rainfall Depth (mm)	32.30	31.70	31.76	31.70	31.87	31.70	33.09	32.47	40.70	32.27
Total Rainfall Depth Difference (mm)	0.19	0.65	0.06	0.00	0.62	0.00	0.39	0.58	2.31	0.66
% Increase in Total Rainfall Depth using a 30 minute Timestep	0.6	2.1	0.2	0.0	2.0	0.0	1.2	1.8	5.7	2.0



This sheet presents 1% AEP ARR2016 design rainfalls for

Individual patterns for various durations are presented as column charts and cumulative plots .
Intensities are also presented in blocks that can be imported into programs.
The ten 2016 patterns are from the 'frequent' category

1% AEP, 10 Minute Rainfall Patterns

Duration (minutes) 10 | Original Depth (mm) 24.30 | Climate Adjusted Depth (mm) 24.30 | Intensity (mm/h) 145.80

5 min Timestep

Depth (mm) for Temporal Pattern

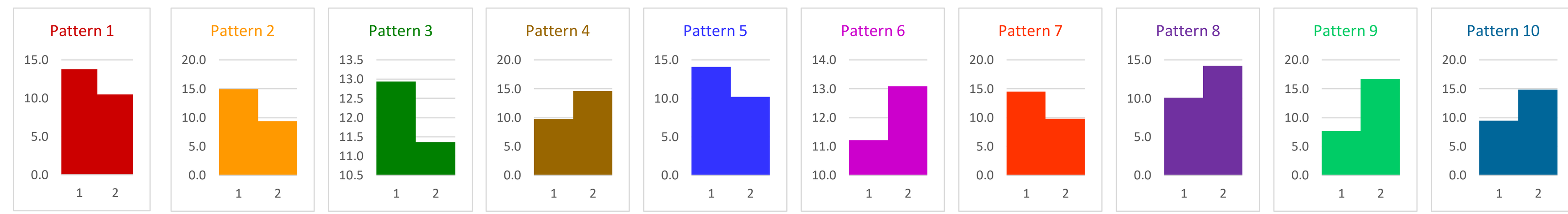
Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
5	13.78	14.93	12.94	9.72	14.12	11.21	14.49	10.05	7.67	9.45
10	10.52	9.37	11.36	14.58	10.18	13.09	9.81	14.25	16.63	14.85
5 Min Timestep Rainfall Depth	24.30	24.30	24.30	24.30	24.30	24.30	24.30	24.30	24.30	24.30

CL (mm/hr) 1.9 | CL(mm/timestep) 0.158333

5 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	1	2	3	4	5	6	7	8	9	10	
	13.62	14.77	12.78	9.56	13.96	11.06	14.33	9.89	7.51	9.29	
	10.36	9.21	11.20	14.42	10.02	12.93	9.65	14.09	16.47	14.69	
5 Min Timestep Rainfall Depth - CL (mm)	23.98	23.98	23.98	23.98	23.98	23.98	23.98	23.98	23.98	23.98	1.90
1 hour timestep Rainfall Depth (mm)	22.40	22.40	22.40	22.40	22.40	22.40	22.40	22.40	22.40	22.40	
Total Rainfall Depth Difference (mm)	1.583333	1.583333	1.583333	1.583333	1.583333	1.583333	1.583333	1.583333	1.583333	1.583333	
% Increase in Total Rainfall Depth using a 5 minute Timestep	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	



1% AEP, 15 Minute Rainfall Patterns

Duration (minutes) 15 | Original Depth (mm) 29.80 | Climate Adjusted Depth (mm) 29.80 | Intensity (mm/h) 119.20

5 min Timestep

Depth (mm) for Temporal Pattern

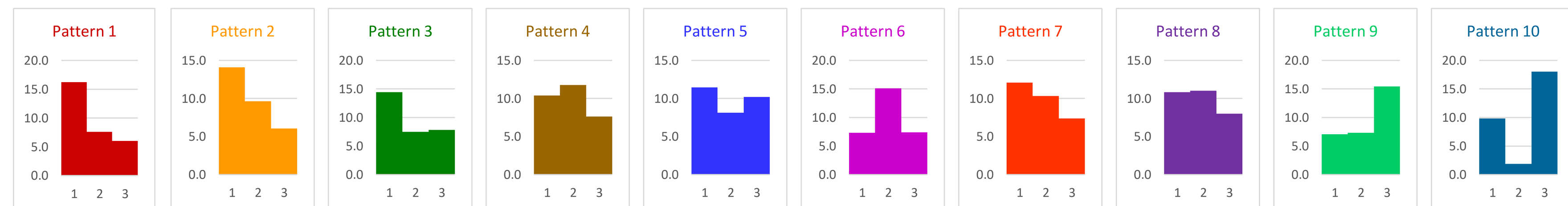
Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
5	16.21	14.08	14.45	10.39	11.43	7.29	12.10	10.80	7.05	9.87
10	7.58	9.64	7.51	11.76	8.14	15.14	10.32	11.01	7.32	1.87
15	6.01	6.08	7.84	7.65	10.23	7.38	7.38	7.99	15.43	18.06
5 Min Timestep Rainfall Depth	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80	29.80

CL (mm/hr) 1.9 | CL(mm/timestep) 0.158333

5 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	1	2	3	4	5	6	7	8	9	10	
	16.05	13.93	14.29	10.23	11.27	7.13	11.94	10.64	6.89	9.71	
	7.43	9.48	7.35	11.60	7.98	14.98	10.16	10.86	7.16	1.71	
	5.85	5.92	7.69	7.49	10.07	7.22	7.22	7.83	15.27	17.90	
5 Min Timestep Rainfall Depth - CL (mm)	29.33	29.33	29.33	29.33	29.33	29.33	29.33	29.33	29.33	29.33	1.90
1 hour timestep Rainfall Depth (mm)	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	27.90	
Total Rainfall Depth Difference (mm)	1.425	1.425	1.425	1.425	1.425	1.425	1.425	1.425	1.425	1.425	
% Increase in Total Rainfall Depth using a 5 minute Timestep	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	



1% AEP, 30 Minute Rainfall Patterns

Duration (minutes) 30 | Original Depth (mm) 39.50 | Climate Adjusted Depth (mm) 39.50 | Intensity (mm/h) 79.00

5 min Timestep

Depth (mm) for Temporal Pattern

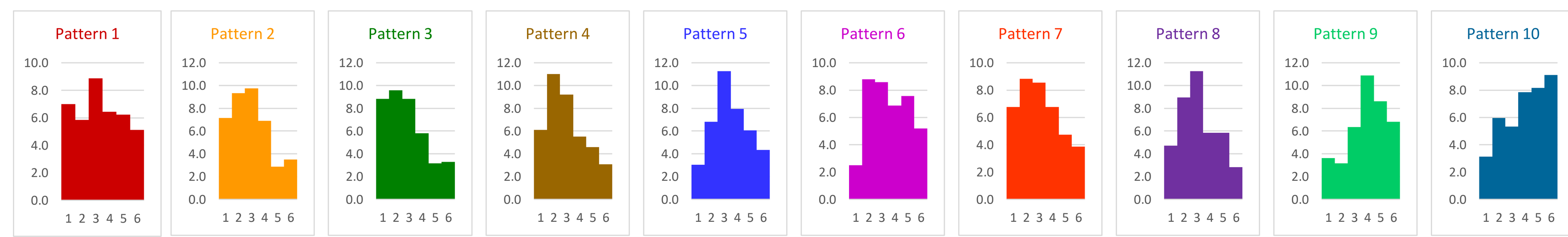
Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
5	6.99	7.17	8.81	6.12	3.06	2.48	6.75	4.71	3.63	3.14
10	5.86	9.33	9.60	11.02	6.83	8.78	8.84	8.97	3.18	5.96
15	8.88	9.76	8.81	9.19	11.27	8.58	8.54	11.26	6.36	5.33
20	6.43	6.89	5.82	5.51	7.94	6.88	6.77	5.87	10.90	7.84
25	6.24	2.87	3.15	4.59	6.06	7.58	4.74	5.87	8.63	8.15
30	5.10	3.48	3.31	3.06	4.35	5.20	3.86	2.82	6.81	9.09
5 Min Timestep Rainfall Depth	39.50	39.50	39.50	39.50	39.50	39.50	39.50	39.50	39.50	39.50

CL (mm/hr) 1.9 | CL(mm/timestep) 0.158333

5 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	1	2	3	4	5	6	7	8	9	10	
	6.83	7.01	8.65	5.96	2.90	2.33	6.60	4.55	3.47	2.98	
	5.70	9.17	9.44	10.87	6.67	8.62	8.68	8.81	3.02	5.80	
	8.73	9.60	8.65	9.03	11.11	8.42	8.38	11.10	6.20	5.17	
	6.27	6.73	5.66	5.35	7.79	6.73	6.62	5.71	10.74	7.68	
	6.08	2.71	2.99	4.44	5.90	7.42	4.58	5.71	8.47	7.99	
	4.95	3.33	3.15	2.90	4.19	5.04	3.70	2.67	6.65	8.93	
5 Min Timestep Rainfall Depth - CL (mm)	38.55	38.55	38.55	38.55	38.55	38.55	38.55	38.55	38.55	38.55	1.90
1 hour timestep Rainfall Depth (mm)	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	37.60	
Total Rainfall Depth Difference (mm)	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	
% Increase in Total Rainfall Depth using a 5 minute Timestep	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	



1% AEP, 60 Minute (1 Hour) Rainfall Patterns

Duration (minutes) 60 | Original Depth (mm) 49.50 | Climate Adjusted Depth (mm) 49.50 | Intensity (mm/h) 49.50

5 min Timestep

Depth (mm) for Temporal Pattern

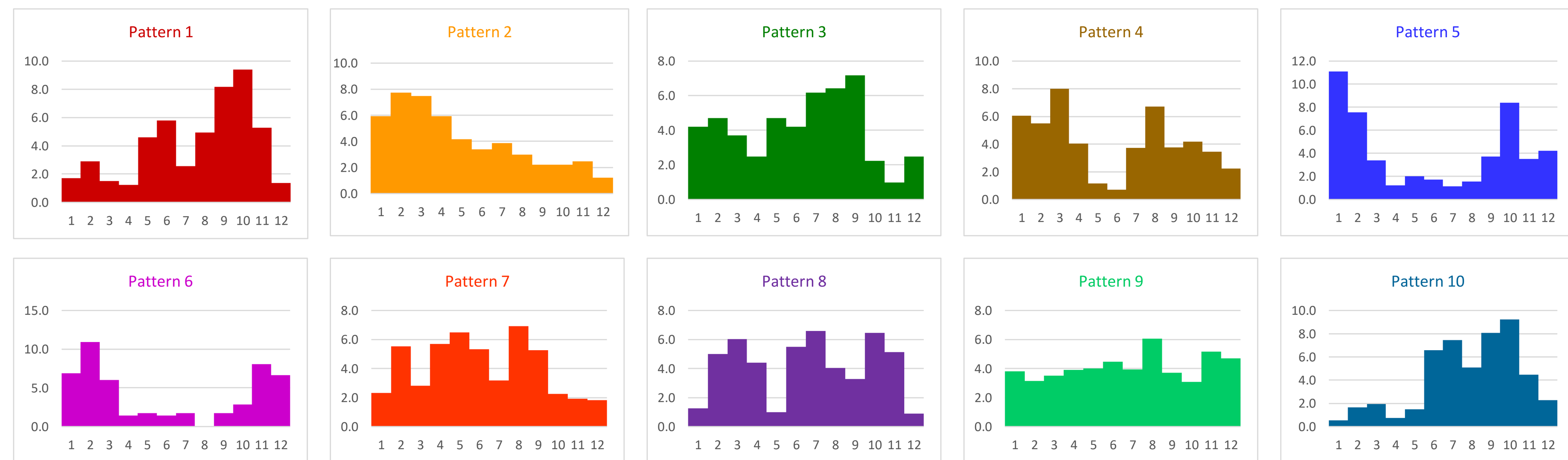
Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
5	1.71	5.92	4.21	6.04	11.09	6.91	2.30	1.24	3.82	0.55
10	2.90	7.75	4.70	5.51	7.54	10.93	5.54	4.98	3.15	1.65
15	1.49	7.47	3.71	7.98	3.38	6.04	2.82	6.01	3.49	1.93
20	1.24	5.94	2.48	4.05	1.24	1.44	5.70	4.40	3.92	0.74
25	4.61	4.15	4.70	1.14	2.00	1.73	6.49	0.98	3.99	1.49
30	5.80	3.38	4.21	0.72	1.71	1.44	5.34	5.48	4.47	6.56
35	2.56	3.86	6.19	3.74	1.15	1.73	3.17	6.60	3.94	7.45
40	4.95	2.99	6.44	6.70	1.57	0.00	6.92	4.05	6.06	5.07
45	8.19	2.19	7.18	3.75	3.71	1.73	5.25	3.29	3.70	8.05
50	9.39	2.19	2.23	4.18	8.40	2.88	2.25	6.45	3.08	9.24
55	5.29	2.46	0.99	3.45	3.49	8.06	1.91	5.13	5.18	4.47
60	1.37	1.21	2.48	2.23	4.22	6.62	1.80	0.88	4.71	2.29
5 Min Timestep Rainfall Depth	49.50	49.50	49.50	49.50	49.50	49.50	49.50	49.50	49.50	49.50

CL (mm/hr) 1.9 | CL(mm/timestep) 0.158333

5 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	1	2	3	4	5	6	7	8	9	10	
	1.55	5.76	4.05	5.89	10.93	6.75	2.14	1.08	3.66	0.39	
	2.74	7.59	4.54	5.36	7.38	10.78	5.39	4.83	2.99	1.49	
	1.34	7.32	3.55	7.83	3.22	5.89	2.66	5.86	3.34	1.77	
	1.08	5.78	2.32	3.89	1.08	1.28	5.54	4.24	3.76	0.58	
	4.45	3.99	4.54	0.99	1.84	1.57	6.33	0.82	3.83	1.33	
	5.64	3.22	4.05	0.56	1.55	1.28	5.18	5.32	4.31	6.40	
	2.40	3.70	6.03	3.58	1.00	1.57	3.01	6.44	3.78	7.30	
	4.79	2.83	6.28	6.54	1.41	0.00	6.76	3.89	5.90	4.91	
	8.03	2.03	7.02	3.59	3.55	1.57	5.09	3.13	3.54	7.90	
	9.23	2.03	2.07	4.02	8.24	2.72	2.09	6.30	2.92	9.08	
	5.13	2.30	0.83	3.29	3.34	7.90	1.75	4.97	5.02	4.32	
	1.21	1.05	2.32	2.07	4.06	6.46	1.64	0.72	4.55	2.13	
5 Min Timestep Rainfall Depth - CL (mm)	47.60	47.60	47.60	47.60	47.60	47.76	47.60	47.60	47.60	47.60	1.90
1 hour timestep Rainfall Depth (mm)	47.60	47.60	47.60	47.60	47.60	47.60	47.60	47.60	47.60	47.60	
Total Rainfall Depth Difference (mm)	0	0	0	0	0	0.158333	0	0	0	0	
% Increase in Total Rainfall Depth using a 5 minute Timestep	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	



1% AEP, 120 Minute (2 Hour) Rainfall Patterns

Duration (minutes) 120 | Original Depth (mm) 60.70 | Climate Adjusted Depth (mm) 60.70 | Intensity (mm/h) 30.35

5 min Timestep

Depth (mm) for Temporal Pattern

Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
5	1.08	0.72	0.41	2.32	0.98	3.88	2.23	3.24	1.26	3.41
10	1.24	0.88	0.08	0.04	3.62	1.67	2.93	3.24	2.08	3.41
15	1.37	2.16	1.40	0.20	4.64	1.04	1.90	2.18	2.02	3.41
20	2.94	2.79	2.77	5.73	3.67	5.74	1.90	2.18	1.61	2.99
25	5.75	3.36	3.31	7.21	2.88	3.61	1.90	3.31	2.05	1.31
30	3.12	6.19	2.97	5.23	3.31	3.33	2.24	3.31	2.45	1.31
35	2.07	4.47	5.10	8.36	4.80	2.99	2.42	2.25	2.25	0.64
40	4.71	6.79	8.67	0.33	0.29	1.28	1.72	2.25	1.90	0.20
45	5.03	5.98	8.29	3.57	0.14	1.07	1.55	0.00	1.40	0.20
50	4.86	3.79	5.65	2.43	0.74	3.64	2.24	0.00	0.82	0.20
55	6.14	3.79	2.51	2.19	2.03	3.45	3.10	0.00	0.96	0.20
60	3.06	3.24	0.64	1.12	3.27	4.48	2.07	0.00	1.18	0.39
65	2.49	3.05	0.22	0.81	3.04	1.12	1.38	9.92	2.59	0.73
70	1.59	2.77	0.55	1.95	3.82	0.30	2.07	9.92	3.75	1.57
75	1.57	2.15	0.51	0.88	3.50	2.97	2.07	1.19	4.10	1.25
80	1.77	1.88	0.60	8.60	5.14	1.33	2.42	1.19	4.10	4.64
85	2.36	1.04	0.73	3.28	5.37	3.22	2.42	2.78	4.10	4.64
90	2.49	1.73	0.22	1.28	3.59	3.94	2.07	2.78	3.92	4.64
95	1.96	0.55	0.86	0.19	1.86	1.24	4.83	1.92	4.29	4.64
100	1.15	0.91	0.86	2.62	2.45	2.62	4.14	1.92	4.61	3.77
105	0.72	0.84	2.00	0.04	0.80	3.31	4.14	1.92	3.27	4.93
110	0.82	0.50	2.84	0.06	0.21	0.92	2.42	1.92	2.10	4.93
115	1.37	0.48	3.57	0.90	0.21	0.79	3.45	1.65	2.25	4.93
120	1.05	0.63	5.95	1.37	0.32	2.76	3.10	1.65	1.66	2.34
5 Min Timestep Rainfall Depth	60.70	60.70	60.70	60.70	60.70	60.70	60.70	60.70	60.70	60.70

CL (mm/hr) 1.9 | CL(mm/timestep) 0.158333

5 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	1	2	3	4	5	6	7	8	9	10
	0.92	0.56	0.25	2.16	0.82	3.73	2.08	3.08	1.10	3.25
	1.09	0.72	0.00	0.00	3.47	1.51	2.77	3.08	1.92	3.25
	1.21	2.00	1.24	0.04	4.49	0.89	1.74	2.02	1.86	3.25
	2.79	2.63	2.61	5.57	3.51	5.58	1.74	2.02	1.46	2.83
	5.59	3.20	3.16	7.05	2.72	3.45	1.74	3.15	1.89	1.15
	2.96	6.03	2.81	5.07	3.16	3.17	2.08	3.15	2.29	1.15
	1.91	4.32	4.94	8.20	4.64	2.83	2.26	2.09	2.09	0.49
	4.55	6.63	8.51	0.17	0.13	1.12	1.57	2.09	1.74	0.04
	4.87	5.82	8.13	3.41	0.00	0.91	1.40	0.00	1.24	0.04
	4.70	3.63	5.49	2.28	0.58	3.48	2.08	0.00	0.66	0.04
	5.98	3.63	2.35	2.03	1.88	3.29	2.94	0.00	0.80	0.04
	2.90	3.08	0.48	0.96	3.11	4.32	1.91	0.00	1.03	0.24
	2.33	2.89	0.06	0.66	2.88	0.96	1.22	9.76	2.43	0.58
	1.43	2.62	0.39	1.80	3.67	0.14	1.91	9.76	3.59	1.41
	1.41	1.99	0.35	0.72	3.34	2.81	1.91	1.03	3.94	1.09
	1.61	1.72	0.44	8.44	4.98	1.17	2.26	1.03	3.94	4.49
	2.20	0.89	0.57	3.13	5.21	3.06	2.26	2.62	3.94	4.49
	2.33	1.57	0.06	1.12	3.43	3.78	1.91	2.62	3.76	4.49
	1.80	0.39	0.70	0.03	1.70	1.09	4.67	1.76	4.13	4.49
	0.99	0.75	0.70	2.46	2.29	2.46	3.98	1.76	4.45	3.61
	0.56	0.69	1.84	0.00	0.64	3.16	3.98	1.76	3.11	4.78
	0.66	0.35	2.68	0.00	0.05	0.76	2.26	1.76	1.94	4.78
	1.21	0.32	3.41	0.75	0.05	0.63	3.29	1.49	2.09	4.78
	0.89	0.47	5.80	1.21	0.16	2.60	2.94	1.49	1.50	2.18
5 Min Timestep Rainfall Depth - CL (mm)	56.90	56.90	56.97	57.24	56.92	56.90	56.90	57.53	56.90	56.90
1 hour timestep Rainfall Depth (mm)	56.90	56.90	56.90	56.90	56.90	56.90	56.90	56.90	56.90	56.90
Total Rainfall Depth Difference (mm)	0.00	0.00	0.07	0.34	0.02	0.00	0.00	0.63	0.00	0.00

% Increase in Total Rainfall Depth using a 5 minute Timestep	0.0	0.0	0.1	0.6	0.0	0.0	0.0	1.1	0.0	0.0

CL (mm/hr) 1.9 CL(mm/timestep) 0.475

1% AEP, 180 Minute (3 Hour) Rainfall Patterns

Duration (minutes) 180

Original Depth (mm) 68.60

Climate Adjusted Depth (mm) 68.60

Intensity (mm/h) 22.87

15 min Timestep

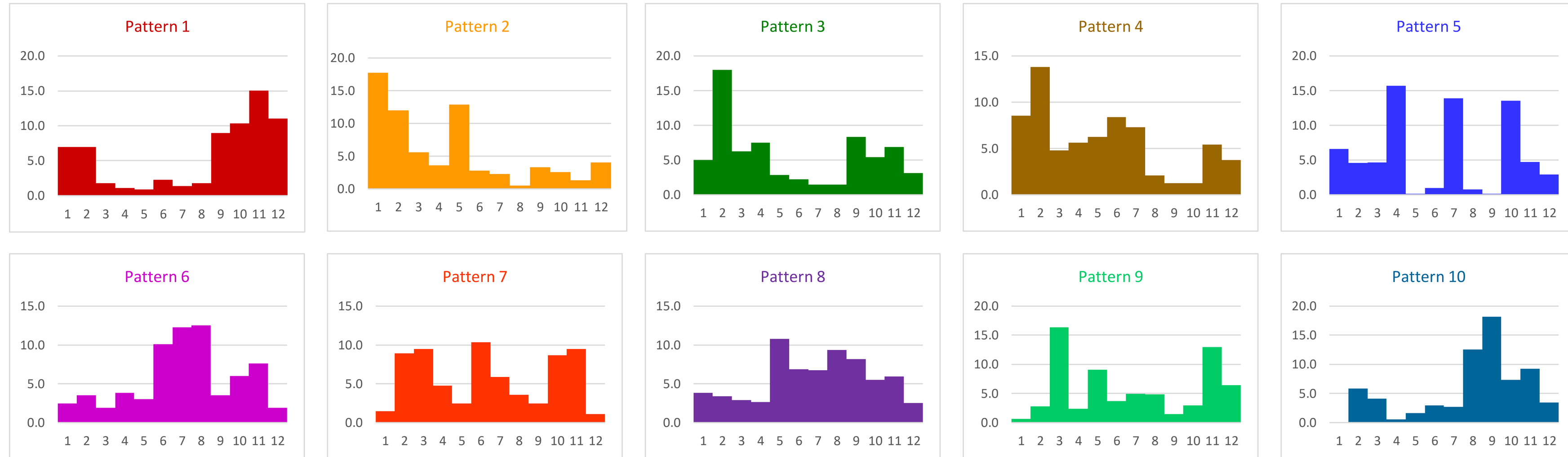
Depth (mm) for Temporal Pattern

Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
15	6.98	17.77	5.02	8.57	6.61	2.44	1.45	3.81	0.62	0.00
30	6.97	12.00	17.99	13.80	4.58	3.54	8.93	3.42	2.83	5.84
45	1.80	5.62	6.28	4.81	4.66	1.91	9.45	2.89	16.35	4.10
60	1.13	3.57	7.53	5.65	15.69	3.81	4.77	2.63	2.37	0.54
75	0.90	12.88	2.83	6.28	0.11	3.00	2.44	10.80	9.06	1.63
90	2.25	2.79	2.20	8.37	0.96	10.07	10.38	6.85	3.72	2.96
105	1.35	2.28	1.46	7.32	13.93	12.25	5.88	6.72	4.97	2.73
120	1.80	0.48	1.45	2.09	0.79	12.52	3.59	9.34	4.85	12.53
135	8.99	3.32	8.37	1.26	0.12	3.54	2.44	8.16	1.45	18.21
150	10.34	2.57	5.44	1.26	13.55	5.99	8.66	5.54	2.99	7.33
165	15.07	1.30	6.90	5.44	4.72	7.62	9.47	5.93	12.94	9.24
180	11.02	4.03	3.14	3.77	2.90	1.91	1.13	2.50	6.46	3.48
15 Min Timestep Rainfall Depth	68.60	68.60	68.60	68.60	68.60	68.60	68.60	68.60	68.60	68.60

15 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	6.50	17.30	4.55	8.09	6.13	1.97	0.97	3.34	0.15	0.00
	6.49	11.52	17.51	13.33	4.10	3.06	8.46	2.94	2.35	5.37
	1.32	5.14	5.80	4.33	4.18	1.43	8.98	2.42	15.88	3.63
	0.65	3.09	7.06	5.17	15.21	3.34	4.30	2.16	1.89	0.06
	0.42	12.40	2.35	5.80	0.00	2.52	1.97	10.32	8.58	1.16
	1.78	2.31	1.72	7.89	0.49	9.60	9.90	6.37	3.24	2.49
	0.88	1.80	0.99	6.84	13.45	11.78	5.40	6.25	4.49	2.26
	1.32	0.01	0.98	1.62	0.31	12.04	3.11	8.87	4.38	12.06
	8.52	2.85	7.89	0.78	0.00	3.06	1.97	7.69	0.97	17.73
	9.87	2.10	4.96	0.78	13.07	5.51	8.19	5.06	2.52	6.85
	14.60	0.82	6.43	4.96	4.24	7.15	9.00	5.45	12.46	8.77
	10.55	3.56	2.66	3.29	2.43	1.43	0.65	2.03	5.99	3.01
5 Min Timestep Rainfall Depth - CL (mm)	62.90	62.90	62.90	62.90	63.62	62.90	62.90	62.90	62.90	63.38
1 hour timestep Rainfall Depth (mm)	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90	62.90
Total Rainfall Depth Difference (mm)	0	0	0	0	0.72362	0	0	0	0	0.475
% Increase in Total Rainfall Depth using a 15 minute Timestep	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0	0.8



CL (mm/hr) 1.9 CL(mm/timestep) 0.475

1% AEP, 360 Minute (6 Hour) Rainfall Patterns

Duration (minutes) 360

Original Depth (mm) 85.90

Climate Adjusted Depth (mm) 85.90

Intensity (mm/h) 14.32

15 min Timestep

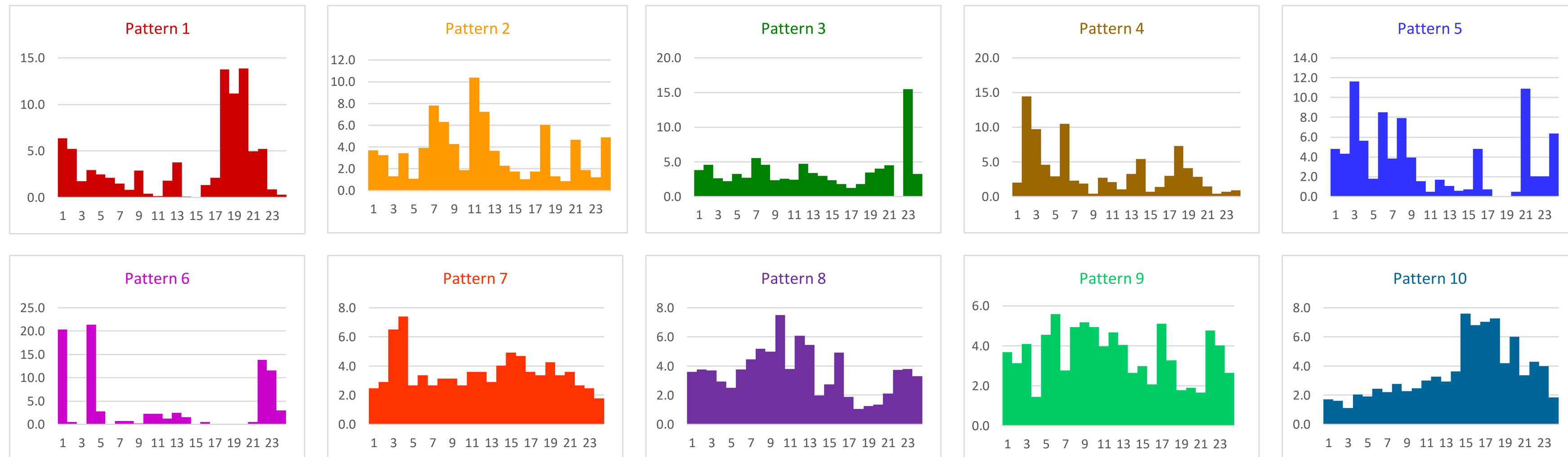
Depth (mm) for Temporal Pattern

Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
15	6.37	3.72	3.85	2.03	4.79	20.35	2.47	3.60	3.69	1.73
30	5.21	3.24	4.60	14.45	4.31	0.51	2.91	3.76	3.12	1.62
45	1.73	1.33	2.63	9.75	11.63	0.00	6.50	3.69	4.09	1.12
60	2.96	3.44	2.25	4.57	5.65	21.35	7.40	2.93	1.44	2.05
75	2.47	1.08	3.29	2.90	1.80	2.77	2.69	2.50	4.55	1.92
90	2.14	3.90	2.72	10.47	8.52	0.00	3.37	3.77	5.58	2.46
105	1.48	7.79	5.56	2.27	3.84	0.76	2.69	4.46	2.77	2.20
120	0.82	6.31	4.60	1.86	7.92	0.76	3.14	5.19	4.95	2.77
135	2.88	4.25	2.35	0.39	3.96	0.25	3.14	4.99	5.19	2.28
150	0.42	1.89	2.53	2.71	1.57	2.26	2.69	7.49	4.95	2.47
165	0.16	10.37	2.45	2.10	0.48	2.26	3.59	3.81	3.97	3.01
180	1.81	7.22	4.69	1.06	1.68	1.25	3.59	6.07	4.66	3.26
195	3.78	3.66	3.38	3.28	1.08	2.51	2.91	5.46	4.04	2.95
210	0.09	2.28	3.01	5.39	0.60	1.50	4.04	1.98	2.65	3.63
225	0.00	1.74	2.35	0.69	0.72	0.00	4.93	2.76	2.99	7.61
240	1.32	1.04	1.79	1.36	4.80	0.50	4.71	4.93	2.07	6.81
255	2.14	1.77	1.22	3.01	0.72	0.00	3.59	1.87	5.12	7.04
270	13.74	6.06	1.79	7.29	0.00	0.00	3.37	1.07	3.28	7.26
285	11.16	1.30	3.48	4.10	0.00	0.00	4.26	1.25	1.78	4.19
300	13.87	0.86	4.05	2.83	0.48	0.00	3.37	1.34	1.90	6.01
315	4.97	4.66	4.51	1.46	10.91	0.50	3.59	2.11	1.67	3.38
330	5.22	1.87	0.00	0.42	2.04	13.81	2.69	3.74	4.78	4.30
345	0.87	1.23	15.51	0.66	2.04	11.55	2.47	3.81	4.03	3.99
360	0.28	4.88	3.29	0.87	6.35	3.02	1.80	3.32	2.65	1.85
15 Min Timestep Rainfall Depth	85.90	85.90	85.90	85.90	85.90	85.90	85.90	85.90	85.90	85.90

15 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	5.90	3.24	3.37	1.55	4.32	19.87	1.99	3.12	3.22	1.25
	4.74	2.76	4.12	13.97	3.84	0.03	2.44	3.29	2.64	1.15
	1.25	0.86	2.15	9.27	11.16	0.00	6.03	3.21	3.61	0.64
	2.49	2.97	1.78	4.09	5.18	20.88	6.93	2.45	0.97	1.58
	1.99	0.61	2.81	2.43	1.32	2.29	2.21	2.02	4.08	1.45
	1.66	3.42	2.25	10.00	8.05	0.00	2.89	3.30	5.11	1.98
	1.00	7.32	5.08	1.79	3.36	0.28	2.21	3.98	2.29	1.72
	0.35	5.84	4.13	1.38	7.44	0.28	2.67	4.71	4.47	2.30
	2.40	3.78	1.88	0.00	3.48	0.00	2.67	4.52	4.71	1.80
	0.00	1.41	2.06	2.23	1.10	1.78	2.21	7.02	4.47	1.99
	0.00	9.89	1.97	1.62	0.01	1.78	3.12	3.34	3.49	2.53
	1.34	6.74	4.22	0.58	1.21	0.78	3.12	5.60	4.19	2.78
	3.30	3.18	2.91	2.81	0.61	2.03	2.44	4.99	3.56	2.47
	0.00	1.81	2.53	4.92	0.13	1.03	3.56	1.51	2.17	3.16
	0.00	1.27	1.88	0.21	0.25	0.00	4.46	2.28	2.51	7.14
	0.85	0.56	1.31	0.88	4.33	0.02	4.23	4.46	1.60	6.34
	1.66	1.29	0.74	2.53	0.25	0.00	3.12	1.40	4.64	6.57
	13.26	5.59	1.31	6.82	0.00	0.00	2.89	0.59	2.81	6.78
	10.68	0.82	3.00	3.62	0.00	0.00	3.79	0.78	1.30	3.72
	13.40	0.38	3.57	2.36	0.01	0.00	2.89	0.87	1.42	5.54
	4.50	4.18	4.03	0.99	10.43	0.02	3.12	1.64	1.19	2.90
	4.75	1.40	0.00	0.00	1.56	13.34	2.21	3.26	4.30	3.83
	0.39	0.75	15.04	0.19	1.56	11.08	1.99	3.33	3.55	3.51
	0.00	4.40	2.81	0.39	5.87	2.54	1.32	2.84	2.17	1.37
5 Min Timestep Rainfall Depth - CL (mm)	75.92	74.50	74.98	74.64	75.45	78.05	74.50	74.50	74.50	74.50
1 hour timestep Rainfall Depth (mm)	74.50	74.50	74.50	74.50	75.20	76.40	74.50	74.50	74.50	74.50
Total Rainfall Depth Difference (mm)	1.42151	0	0.475	0.14254	0.2526	1.65089	0	0	0	0
% Increase in Total Rainfall Depth using a 15 minute Timestep	1.9	0.0	0.6	0.2	0.3	2.2	0.0	0.0	0.0	0.0



CL (mm/hr) 1.9 CL(mm/timestep) 0.95

1% AEP, 720 Minute (12 Hour) Rainfall Patterns

Duration (minutes) 720

Original Depth (mm) 109.00

Climate Adjusted Depth (mm) 109.00

Intensity (mm/h) 9.08

30 min Timestep

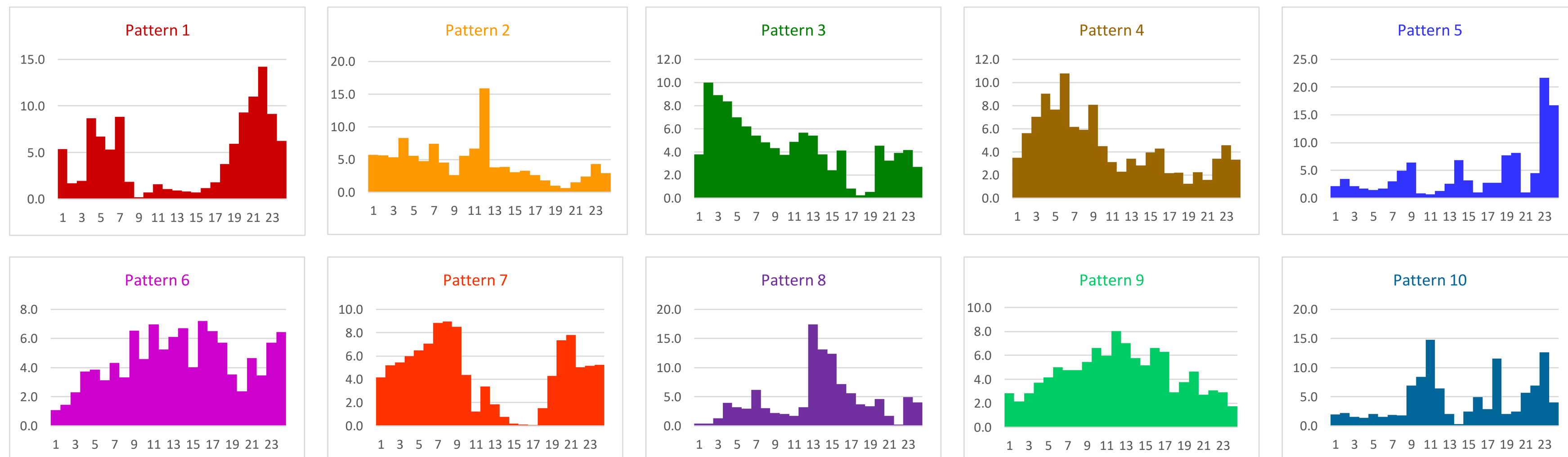
Depth (mm) for Temporal Pattern

Time (minutes)	1	2	3	4	5	6	7	8	9	10
0										
30	5.35	5.72	3.79	3.49	2.16	1.07	4.16	0.36	2.82	1.96
60	1.68	5.67	10.01	5.64	3.43	1.45	5.19	0.36	2.16	2.26
90	1.94	5.33	8.91	7.05	2.15	2.32	5.44	1.28	2.83	1.58
120	8.65	8.27	8.36	9.05	1.71	3.72	5.98	3.99	3.73	1.42
150	6.71	5.57	7.01	7.66	1.50	3.87	6.46	3.23	4.15	2.04
180	5.31	4.76	6.20	10.79	1.71	3.14	7.06	2.95	4.99	1.56
210	8.82	7.40	5.40	6.16	3.01	4.34	8.83	6.17	4.76	1.92
240	1.84	4.53	4.83	5.93	4.94	3.32	8.95	3.07	4.77	1.84
270	0.20	2.58	4.33	8.08	6.44	6.55	8.50	2.23	5.45	6.92
300	0.73	5.57	3.76	4.49	0.86	4.59	4.39	2.04	6.63	8.39
330	1.61	6.66	4.85	3.13	0.64	6.97	1.24	1.75	5.98	14.79
360	1.09	15.85	5.66	2.28	1.29	5.24	3.37	3.23	8.03	6.40
390	0.93	3.79	5.40	3.40	2.57	6.11	1.84	17.43	7.03	2.06
420	0.83	3.85	3.77	2.83	6.87	6.71	0.77	13.17	5.76	0.34
450	0.73	3.03	2.43	3.93	3.22	4.03	0.19	12.39	5.17	2.44
480	1.17	3.27	4.13	4.31	1.07	7.20	0.10	7.22	6.63	4.93
510	1.79	2.58	0.83	2.17	2.79	6.50	0.09	5.57	6.31	2.84
540	3.76	1.79	0.26	2.21	2.79	5.71	1.54	3.67	2.90	11.59
570	5.92	0.99	0.53	1.25	7.73	3.53	4.31	3.36	3.76	2.03
600	9.31	0.63	4.53	2.22	8.15	2.38	7.35	4.62	4.65	2.45
630	11.01	1.49	3.25	1.58	1.07	4.64	7.80	1.68	2.71	5.70
660	14.22	2.41	3.90	3.41	4.50	3.47	5.02	0.21	3.08	6.89
690	9.15	4.31	4.17	4.59	21.67	5.70	5.17	4.97	2.92	12.63
720	6.26	2.93	2.69	3.35	16.73	6.43	5.24	4.05	1.75	4.02
30 Min Timestep Rainfall Depth	109.00	109.00	109.00	109.00	109.00	109.00	109.00	109.00	109.00	109.00

30 min Timestep - Continuing Loss removed

Depth (mm) for Temporal Pattern

	4.40	4.77	2.84	2.54	1.21	0.12	3.21	0.00	1.87	1.01
	0.73	4.72	9.06	4.69	2.48	0.50	4.24	0.00	1.21	1.31
	0.99	4.38	7.96	6.10	1.20	1.37	4.49	0.33	1.88	0.63
	7.70	7.32	7.41	8.10	0.76	2.77	5.03	3.04	2.78	0.47
	5.76	4.62	6.06	6.71	0.55	2.92	5.51	2.28	3.20	1.09
	4.36	3.81	5.25	9.84	0.76	2.19	6.11	2.00	4.04	0.61
	7.87	6.45	4.45	5.21	2.06	3.39	7.88	5.22	3.81	0.97
	0.89	3.58	3.88	4.98	3.99	2.37	8.00	2.12	3.82	0.89
	0.00	1.63	3.38	7.13	5.49	5.60	7.55	1.28	4.50	5.97
	0.00	4.62	2.81	3.54	0.00	3.64	3.44	1.09	5.68	7.44
	0.66	5.71	3.90	2.18	0.00	6.02	0.29	0.80	5.03	13.84
	0.14	14.90	4.71	1.33	0.34	4.29	2.42	2.28	7.08	5.45
	0.00	2.84	4.45	2.45	1.62	5.16	0.89	16.48	6.08	1.11
	0.00	2.90	2.82	1.88	5.92	5.76	0.00	12.22	4.81	0.00
	0.00	2.08	1.48	2.98	2.27	3.08	0.00	11.44	4.22	1.49
	0.22	2.32	3.18	3.36	0.12	6.25	0.00	6.27	5.68	3.98
	0.84	1.63	0.00	1.22	1.84	5.55	0.00	4.62	5.36	1.89
	2.81	0.84	0.00	1.26	1.84	4.76	0.59	2.72	1.95	10.64
	4.97	0.04	0.00	0.30	6.78	2.58	3.36	2.41	2.81	1.08
	8.36	0.00	3.58	1.27	7.20	1.43	6.40	3.67	3.70	1.50
	10.06	0.54	2.30	0.63	0.12	3.69	6.85	0.73	1.76	4.75
	13.27	1.46	2.95	2.46	3.55	2.52	4.07	0.00	2.13	5.94
	8.20	3.36	3.22	3.64	20.72	4.75	4.22	4.02	1.97	11.68
	5.31	1.98	1.74	2.40	15.78	5.48	4.29	3.10	0.80	3.07
5 Min Timestep Rainfall Depth - CL (mm)	87.54	86.52	87.43	86.20	86.60	86.20	88.86	88.12	86.20	86.81
1 hour timestep Rainfall Depth (mm)	87.32	86.48	87.01	86.20	86.20	86.20	88.09	87.39	86.20	86.20
Total Rainfall Depth Difference (mm)	0.22	0.04	0.42	0.00	0.40	0.00	0.76	0.73	0.00	0.61
% Increase in Total Rainfall Depth using a 30 minute Timestep	0.2	0.0	0.5	0.0	0.5	0.0	0.9	0.8	0.0	0.7



Appendix C:

TUFLOW Hydraulic Model Development

C.1 DIGITAL ELEVATION MODEL (DEM)

Engeny used Department of Land Water and Planning (DELWP) provided LiDAR data to generate a Digital Elevation Model (DEM) for all the Merri-bek catchments. The LiDAR used is from the 2017-18 Melbourne dataset, the most recent LiDAR data available at the commencement of the project. The resultant DEM is displayed in Figure 4.1.

C.1.1 TUFLOW 2D Cell Size

A 3-metre cell size has been adopted for all the hydraulic models to model overland flow paths. 3 m provides a reasonable balance between accuracy and modelling computation effort and run times.

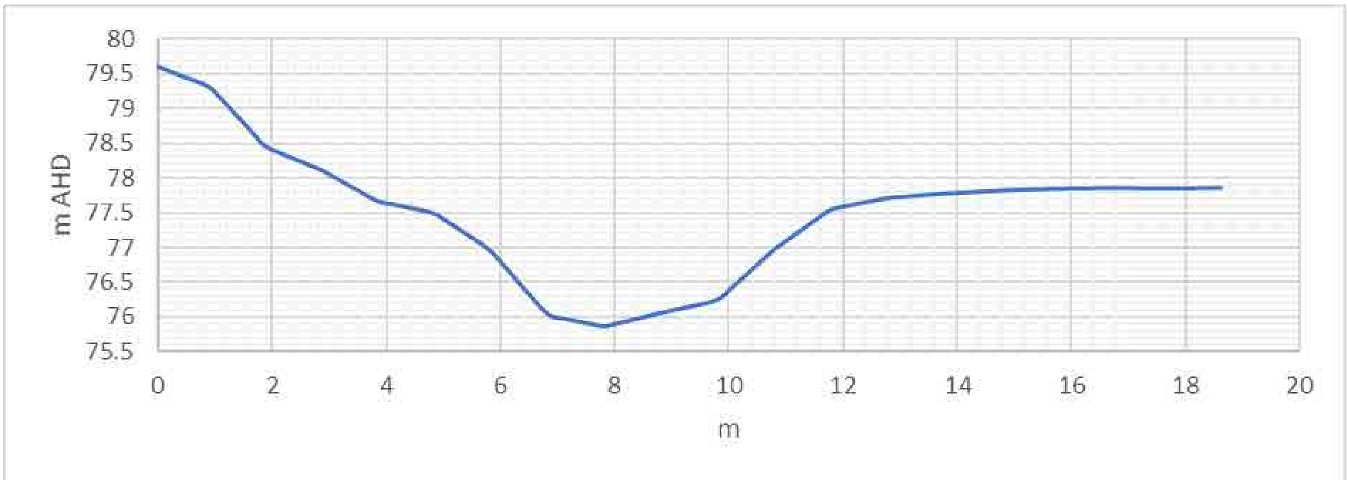
C.1.2 Representation of Waterways

The study area includes a number of Melbourne Water managed drains and waterways, including the following:

- Acacia Street Drain
- Campbellfield Creek
- Edgars Creek
- Elizabeth Street Main Drain (Coburg)
- Fawkner East Drain
- Lynch Road Main Drain
- Major Road Drain
- Merlynston Creek
- Merlynston Creek Main Drain
- Merri Creek (Upper)
- Moonee Ponds Creek (Lower)
- Moonee Ponds Creek (Upper)
- Westbreen Creek

These waterways have been modelled in the 2-D. Appendix Figure C. 1 depicts a typical cross section for Melbourne Water's Campbellfield Drain downstream of Campbellfield Creek Retarding Basin.

Appendix Figure C. 1: Typical Cross Section for Campbellfield Creek



Edgars Creek, Merri Creek and Moonee Ponds Creek were not modelled as part of this study.

C.2 1-D NETWORK DATA

C.2.1 Melbourne Water Underground Drainage

Engeny obtained GIS data of the existing Melbourne Water stormwater network as well as available design drawings and as-constructed plans. This data was used to refine the modelled definition of Melbourne Water's drainage system. Underground drainage data was also sourced from previous Melbourne Water flood models in The SEC, NEC, and MEL catchments.

C.2.2 Council Drainage

Merri-bek City Council provided a copy of its pit and pipe asset data in GIS format. This data was used to represent Council's drainage system in the hydraulic model. Additionally, Darebin City Council pit and pipe asset data from Melbourne Water's previous Elizabeth Street Drain TUFLOW model were also applied in the revised modelling.

C.2.3 Pipe Methodology

The following outlines the key tasks, methods and assumptions adopted by Engeny regarding the 1-D pipe network data:

- The pipe data provided in some areas had missing diameters and inverts, to avoid undertaking site visits for hundreds of assets (sometimes in hard to access locations) engineering judgement has been used to fill in the majority of the following data gaps. The following assumptions used to estimate the pipe sizes were agreed with Melbourne Water:
  - Where the pipe diameter was missing for a single pipe but the upstream and downstream diameters were available, the missing pipe diameter was assumed to be the same size.
  - If the pipe was within a road reserve and had no other upstream pipes a diameter of 300 millimetres was applied.
- Pipes were snapped together where they were found to be graphically disconnected
- Pipe directions were corrected as necessary to ensure that all pipes were digitised in the correct direction (ie downstream towards outfall).
- Engeny performed a cover check to detect "above ground pipes" using the DEM. All pit locations were checked to ensure there was sufficient cover, minimum 600 millimetres of cover, were possible.
- It is assumed all pipes grade down towards the outfall with an average pipe grade of 1 in 268. Pipe inverts were updated to reflect this.
- A Manning's roughness value of 0.013 was adopted for the concrete underground drainage pipes and road culverts.
- The Engelund method of automatically created manholes has been used for determining pit losses. This approach considers the incoming pipe invert levels, diameters and pipe bends.
- In instances where there is a drop in height between two pipes that are connected via a pit, i.e. the upstream pipe enters above the outfall pipe, TUFLOW may not create a manhole for loss calculation purposes. A check message, "CHECK 1402 - More than one culvert connected but could not create manhole at Node "XXX" is usually shown in these cases. The pressure head loss coefficients for pits (denoted Ku) are usually assumed proportional to the velocity head at the entrance of the downstream pipe. Empirical studies have estimated these losses and produced various loss coefficients for a range of pit and pipe layouts that account for lateral flow, through flow, and/or both. In instances where a manhole could not be created and as such TUFLOW has not applied losses, Engeny has adopted a K value of 2. A K value of 2 was deemed to provide a conservative loss value that is applicable to a range of drainage junction layouts and is in line with recommendations provided by Melbourne Water for recent flood mapping studies. This has been applied to all underground pipes within the TUFLOW model by adopting an entry and exist loss of 1 each (K/2). This widespread application to underground pipes is suitable as the value would only be adopted in the model calculations when no manhole is created but would otherwise be overwritten by the Engelund calculated losses when a manhole can be created. The following provides a summary of the losses applied when no manhole is created:
  - 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 coefficients for underground pipes = 1
  - Exit loss coefficients for underground pipes = 1

- For headwall / endwall structures, loss coefficients vary based on their structure type and shape. The Federal Highway Administration's Hydraulic Design of Highway Culverts Manual (1985) indicates that loss coefficients can vary between 0.2 and 0.9 for headwall and endwall structures. However, the following coefficients are recommended and have been adopted for this study:
  - Entry loss coefficient for culverts = 0.5
  - Exit loss coefficient for culverts = 1.0

C.2.4 1-D Channel

There is one 1-D channel modelled in NEC catchment (downstream of the Campbellfield Creek Retarding Basin). Given the width of the channel and the size of the model grid, modelling it in 1-D domain provides a more accurate representation. The cross-sections were defined using Melbourne Water's provided design drawings.

C.2.5 Pit Methodology

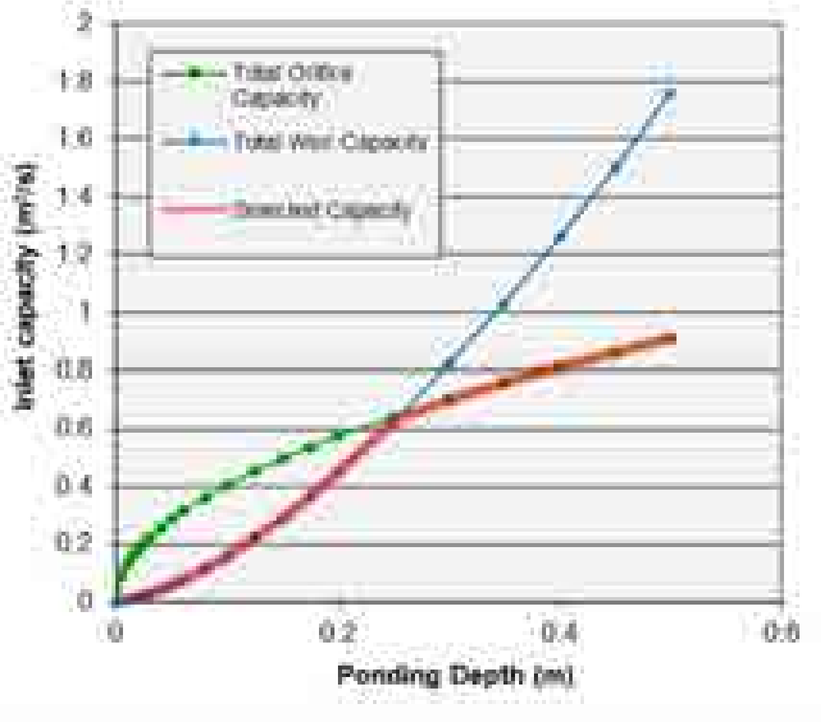
The following outlines the key tasks, methods and assumptions adopted by Engeny regarding the 1-D pit network data:

- Interrogation of the pit drainage data and Merri-bek's July 2019 Technical Notes which includes standard pit type design drawings were used to determine a series of modelled pit types. Refer to Appendix Table C. 1 for a list of all the modelled pit types.
- All pits were modelled as 'Q' pits as they provide a more accurate representation of the capacity of an inlet, based on the dimensions and type of the structure. Each key pit type is represented by a single stage-discharge relationship. The calculations are based on the Section 4.4.5.4 of HEC 22 (FHA, 2013). Refer to Appendix Figure C. 2 for an example of developed pit inlet curve for Grated Pit (small) 900mm x 600mm.
- In instances where a back-of-property pipe or upstream pipe did not have a pit at its upstream end, a junction pit was added to allow the model to apply water to the system.
- Weir pits were included into the models where appropriate if pits were surcharging at a greater velocity than expected on a case by case basis.

Appendix Table C. 1: Modelled Pit Types

Pit	TUFLOW Pit Type
Grated Pit (small) 900mm x 600mm	GP_S
Grated Pit (large) 900mm x 900mm	GP_L
Double Grated Pit	DGP
Double Side Entry Pit	GSEP
Double Grated Side Entry Pit	DGSEP
Triple Grated Side Entry Pit	TGSEP
Quadruple Grated Side Entry Pit	QGSEP
Side Entry Pit (small) 900mm opening	SEP_S
Double Side Entry Pit (1800 mm opening)	DSEP
Side Entry Pit (large) 2000mm opening	SEP_L
Triple Side Entry Pit (2700 mm opening)	TSEP
Junction Pit	JP

Appendix Figure C. 2: Pit Inlet Curve for GP_S



C.3 SURFACE ROUGHNESS

Within TUFLOW a materials layer is utilised to define surface roughness information in the model. The GIS parcel layer available from the Department of Environment, Land Water and Planning (DELWP) was used as a basis for the materials layer. The materials layer was created by assigning a Manning's roughness value to land parcels according to the land use from planning zones. The roughness values were then refined based on the land use shown in the 2018/19 aerial photographs to allow for delineation between residential areas, open space and/or carparks. These roughness values are listed in Appendix Table C. 2.

Appendix Table C. 2: Manning's n Roughness Values Adopted

Type of Zone	Manning's Roughness
Car Park / Road	0.025
Commercial & residential building footprints	0.5
Open concrete channel	0.013
Open Paddock (low/no vegetation)	0.035
Open Paddock (with moderate trees)	0.06
Open water (with emergent vegetation) - MW Flood mapping guidelines tech spec Sep 2020 [range is 0.05 to 0.08]	0.06
Open water (with no emergent vegetation) - MW Flood mapping guidelines tech spec Sep 2020 [range is 0.015 to 0.035]	0.02
Paddock with high density trees	0.09
Railway line	0.12
Remainder of parcel	0.1

C.4 BOUNDARY CONDITIONS

C.4.1 Localised Inflows

1-D Inflows

Effective Impervious Area (EIA) flows were applied directly to the underground drainage network via the 1-D boundary condition layer (1d_bc). The 1d-bc allows the EIA proportion of flow to be distributed equally across the pits within each sub-catchment polygon. Some sub-catchments from the RORB modelling were split based on area to improve the distribution of flows to pits in sub-catchments with uneven pit distributions.

2-D Inflows

Remaining localised inflows were applied as 2-D source areas (2d_sa).

Indirectly Connected Areas (ICA) sub-catchment flows have been applied using the “SA PITS” command. This was used to apply the ICA proportion of flows to the surface of each inlet pit with the sub-catchment flow divided and distributed equally to each inlet pit.

Sub-catchments without pits utilised the “SA ALL” command to distribute flows evenly across the surface of the sub-catchment. Rural and remaining EIA and ICA flow proportions were applied using this methodology. As direct rainfall approach adopted for “SA ALL” sub-areas incorporate some element of depression storages, the use of raw LiDAR data can result in overestimation of catchment losses und underestimation of surface flow (ARR 2019). To account for this issue, pre-wetting of 2-D domain was performed in the current study for “SA ALL” sub-areas. Pre-wetting involved running a model for 1 % AEP 3 hour duration storm event and using water level results from the final step when the excess of water has drained out of the model.

C.4.2 Routed Inflows

The hydraulic TUFLOW models focus on flood mapping Merri-bek City Council and Melbourne Water’s assets. Merlynston and Campbellfield Creeks both originate north of Merri-bek. Validated RORB models were created of these catchment areas and routed hydrographs applied as inflows near the Merri-bek municipal boundary.

Chapman Main Drain

A routed inflow has been applied at the upstream end of the model at the Jacana Basin to allow for the outflows of the basin to be accurately represented in case it influences the tail water in the pipe network within Merri-bek. This inflow was determined from a previous Moonee Ponds Creek RORB model provided by Melbourne Water.

North East Catchments

A revised RORB model was created as part of this study to apply routed flows into the Merri-bek area using a model with revised catchments, retarding basin outlets and ARR2019 methodology.

Two inflow locations to the TUFLOW model have been included at the outflow of the Campbellfield Creek Retarding Basin and the Commonwealth Serum Laboratories Retarding Basin. Refer to details provided in Appendix Section A.11.

C.4.3 1-D 2-D Links

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

C.4.4 1-D Links

A series of 1-D HT (head versus time) boundary conditions have been applied to pipes which exit the model. The flood levels adopted for each scenario was the obvert of the underground pipe.

C.4.5 2-D Links

A combination of 2-D CN and 2-D SX boundaries were utilised on large culverts where appropriate to ensure the capacity of the assets weren’t constrained at the inlet/ outlet.

2-D HQ (head versus flow) have been adopted where overland flow exits the model. This approach was taken to avoid water ponding against the 2-D code boundary. TUFLOW calculates the predicted outflow based on the boundary's terrain cross-section and the input longitudinal slope for the given water surface elevation.

C.5 TUFLOW PARAMETERS

C.5.1 Time Step

Engeny has adopted the following 2-D and 1-D time steps for the TUFLOW models:

- Chapman (CHAP): 2D Timestep 1, 1D Timestep 0.25
- Melville (MEL): 2D Timestep 0.75, 1D Timestep 0.125
- North-East Catchments (NEC): 2D Timestep 1, 1D Timestep 0.25 (to be confirmed following completion of model runs and checks of model health)
- South-East Catchments (SEC): 2D Timestep 1, 1D Timestep 0.25

These time steps were found to provide a good balance between achieving reasonable simulations times and ensuring model stability.

These time steps are consistent with recommendations in Melbourne Water's Flood Mapping Guidelines for a 2-D model grid size.

C.5.2 Durations and Temporal Patterns Modelled

Engeny conducted hydraulic modelling in TUFLOW for the suite of standard durations including the 10 min, 15 min, 30 min, 1 hr, 2 hr, 3 hr and 6 hr duration for the mid-loaded temporal patterns identified during the Council 2018 flood mapping study. An investigation was undertaken using the Chapman Main Drain model to confirm that the results obtained by using a previously selected mid-loaded temporal pattern (tp28) are not significantly different to those produced using a full set of 10 temporal patters. The model was run for 1 % AEP event 60 min duration for a full suite of temporal patterns using TUFLOW Classic. The results were processed to produce a grid with median flood depth values. The median flood depth values were then compared to flood depth values produced by a single temporal pattern (tp28). The results of this comparison are presented in Appendix Table C. 3 and Appendix Figure C. 3. Overall, the results indicate that the flood depths produced by the full set of temporal patterns are very similar to those produced by the previously selected temporal pattern, with an absolute difference of less than 5 mm for over 90 % of model cells and an absolute difference of less than 10 mm for over 96 % of model cells. The largest differences are observed within Moonee Ponds Creek which is not modelled in detail in the current study and will be excluded from deliverables.

Appendix Table C. 3: Flood Depth Difference Summary (1 % AEP, 60 min)

Flood Depth Difference (median of 10 tps minus tp28)	Percentage of Model Cells
Less than -0.05 m	0.0
-0.05 m to -0.01 m	0.4
-0.01 m to -0.005 m	0.3
-0.005 m to 0.005 m	90.7
0.005 m to 0.01 m	5.3
0.01 m to 0.05 m	3.0
More than 0.05 m	0.2

Appendix Figure C. 3: Flood Depth Difference Map (1% AEP, 60 min)

C.6 QUALITY ASSURANCE

C.6.1 Model Review

The TUFLOW model was reviewed at different stages of its development using Quality Assurance (QA) processes developed by Engeny. The QA processes are designed to provide confidence that consistent best practice modelling has been applied and that the model is as accurate as reasonably possible.

An internal review of the TUFLOW hydraulic model was undertaken by a suitably qualified principal engineer as part of the QA process where a final review is also scheduled to occur prior to the production of formal draft deliverables. The QA forms will be provided along with the TUFLOW models.

C.6.2 Checks, Warning and Errors

The TUFLOW messages layers were inspected for any residual checks, warnings and/error messages for the 1 % AEP event. Appendix Table C. 4 provides a list of the residual checks and warnings messages and justification for their remainder in the flood model. All remaining warning messages were deemed negligible and not adversely affecting the modelling results. No errors occurred during any of the simulation runs.

Appendix Table C. 4: Checks and Warnings Summary

Reference Code	Warning/Check Message	Justification for Residual Warning / Check Message	Number of Occurrences CHAP	MEL	NEC	SEC
1100	WARNING: Structure X crest / invert (X.XXX) is below bed (Y.YYY) of primary upstream/downstream channel Y.	The 1D structure's invert / bed lies below the bed of the primary upstream and / or downstream channel. This means the downstream end of the upstream pipe is discharging above the upstream end of the downstream pipe (ie there is a drop in the pit). This is typical in underground drainage systems and has been ignored.	406	788	1263	535
1313	WARNING: No inlet culvert connected to Manhole "X". Manhole not used / applied.	1D manhole object is not snapped to an inlet or outlet culvert. Manhole not being used. This occurred because there are two outlet pipes connected to a single pit. This message has been ignored.	0	4	4	3
1401	CHECK: 1 culvert(s) not used for determining losses at Manhole "X". Check culvert inverts and directions.	TUFLOW could not find a snapped point at the end because the pipe is discharging into the waterway (ie. the end is dangling), but the line has at least one snapped point elsewhere along the line. A 2D boundary condition with an SX type has been applied so this check message can be ignored.	21	127	54	85
1402	CHECK: More than one culvert connected but could not create manhole at Node "X". Check culvert inverts and directions.	Check produced when either of the following occurs: • If incoming culvert enters above the obvert of the highest outlet, the culvert is not included in the manhole loss calculations. • If there is only 1 incoming pipe with the invert above the obvert of the outlet culvert, the incoming culvert is ignored and with no inlet culvert to the node a manhole is not possible. • The drop in height between the upstream pipe and downstream pipe is too deep for manhole losses to be calculated. At manholes where losses cannot be created the following losses will apply to the pipe data: • 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 coefficients for underground pipes = 1 • Exit loss coefficients for underground pipes = 1	2	9	20	12
2118	CHECK/WARNING: Lowered SX ZC Zpt by X.XXm to 1D node bed level.	The drop between the outlet pipe to the ground surface is below 0.5 m. The message has been ignored as it does not affect flooding results.	29	13	86	10

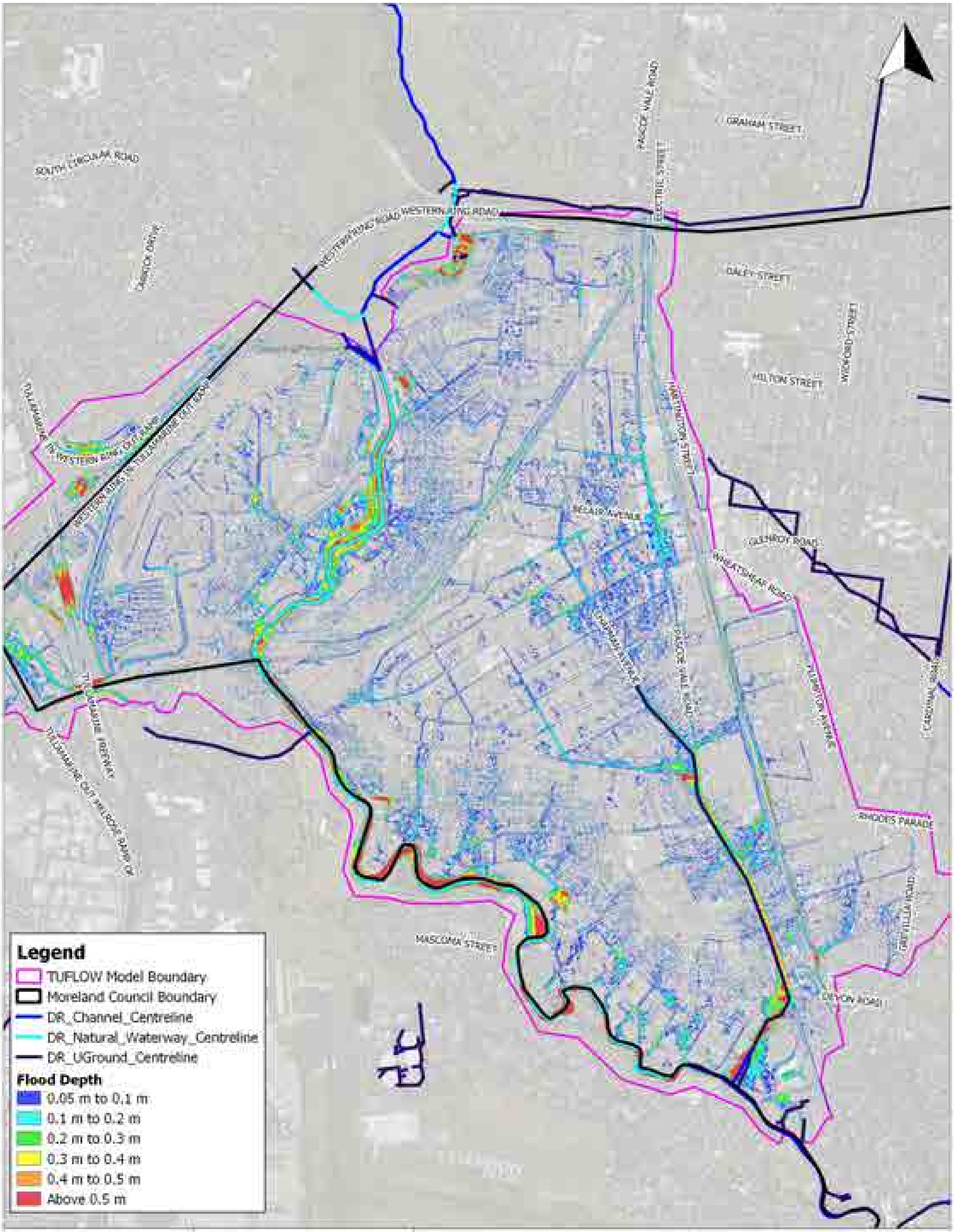
C.7 ASSUMPTIONS AND LIMITATIONS

The following assumptions and limitations apply to the modelling and outputs, including the flood maps.

- Road kerbing was not explicitly represented within the TUFLOW model beyond what is captured in the LiDAR data and TUFLOW grid. In many circumstances this approach is considered to provide a reasonable representation of this system, however there are some circumstances, such as where a road is aligned on the contour of a steep hill, where the kerb and channel system might be underestimated. This can result in breakaway flows impacting properties that in reality, are protected by the kerb and channel system.
- The LiDAR terrain data used as a basis for the TUFLOW DEM has some limitations that may impact the flood modelling results including the vertical and horizontal accuracy of the data.

- Where pipe inverts were not available it has been assumed that all pipes have 0.6 m of cover at pits and that they all grade downhill towards the outfall.
- The piped drainage system was based on the GIS data provided by Council and Melbourne Water. Drainage plans have been provided to Engeny for some locations within the catchment however, limitations and inaccuracies associated with the original GIS data could impact the results of the flood modelling.

Appendix D:
Flood Depth Maps



ENGENY

Melbourne Water

150 0 150 300 450 m

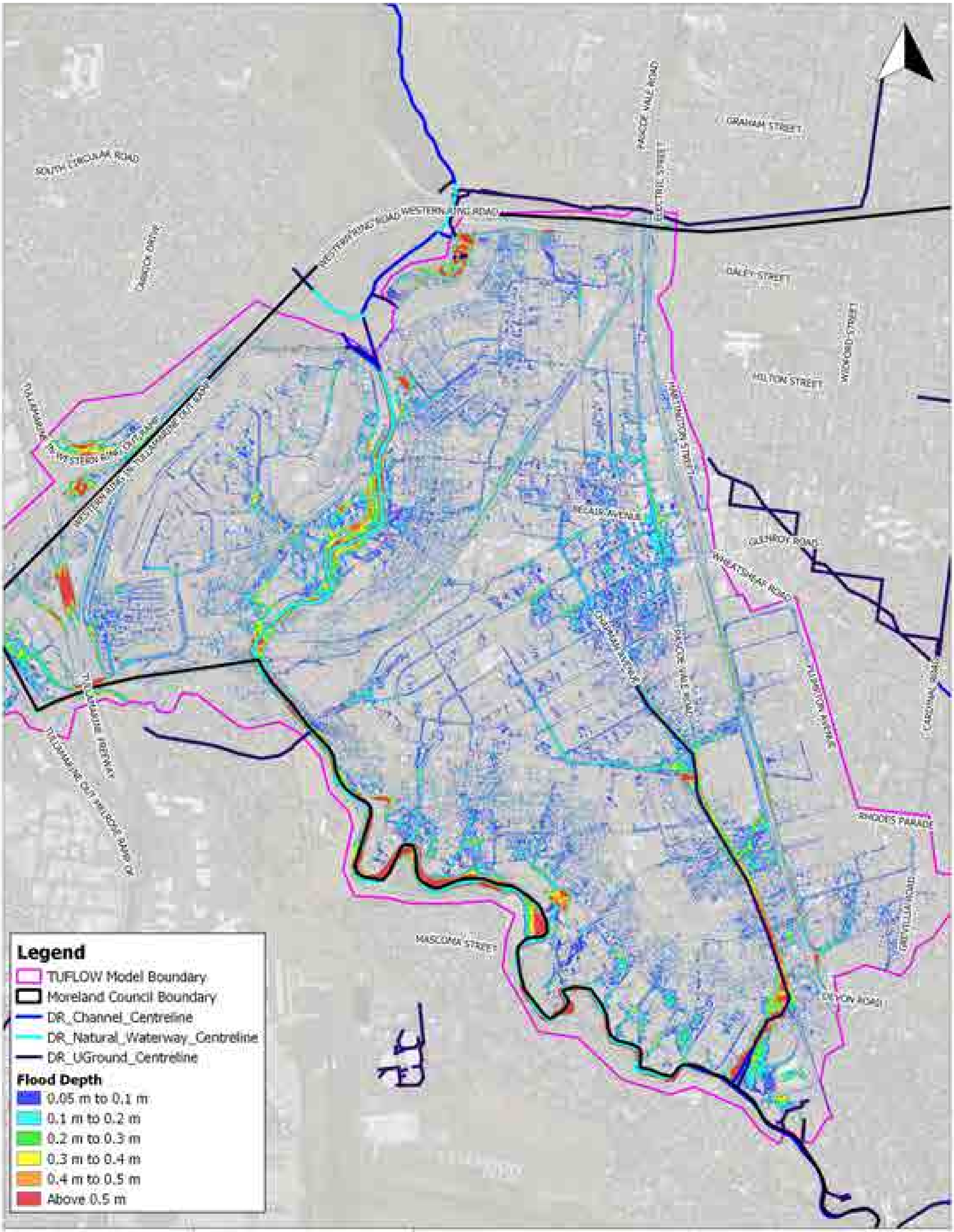
Scale in metres (1:13000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

1% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

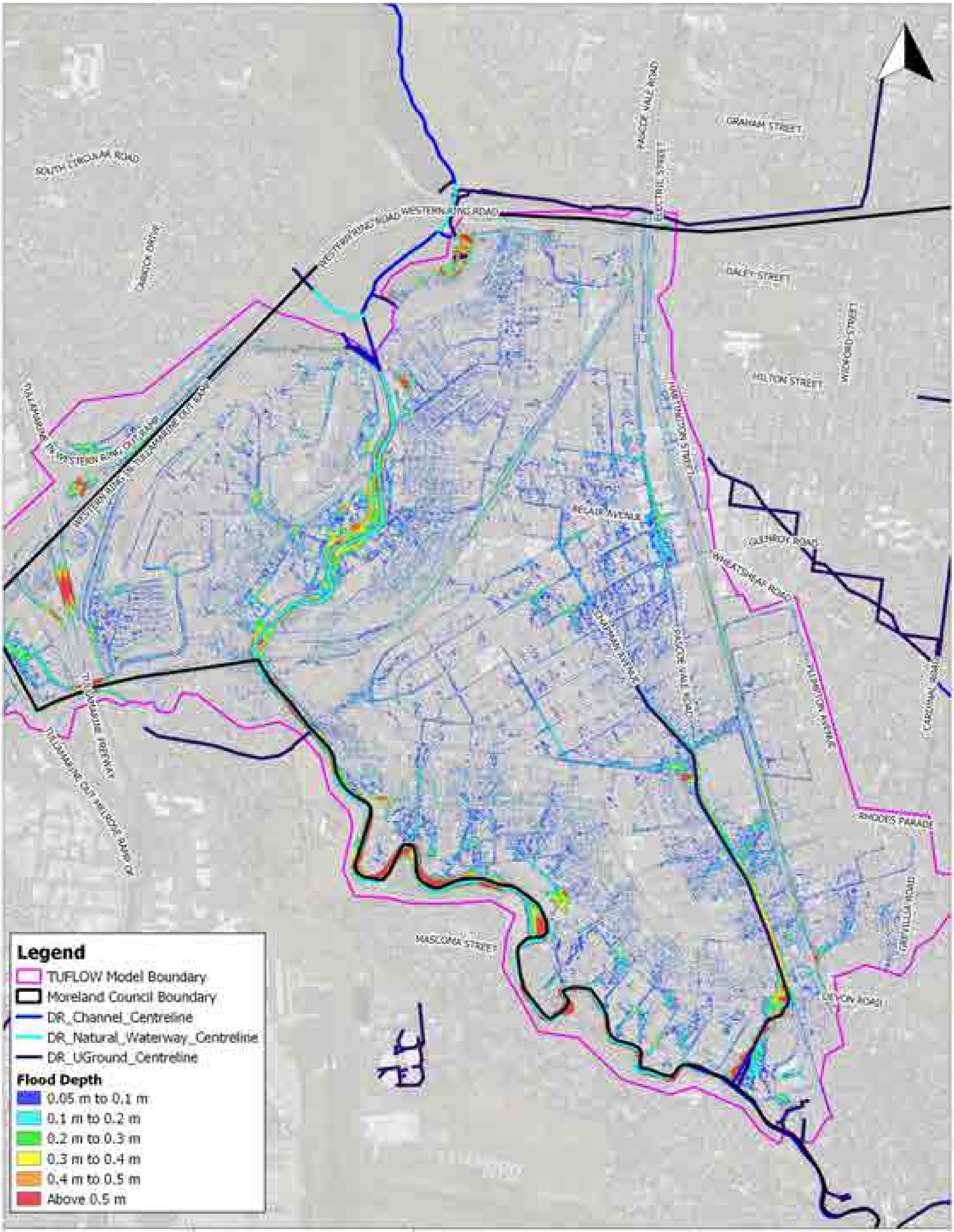
Scale in metres (1:13000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

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

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

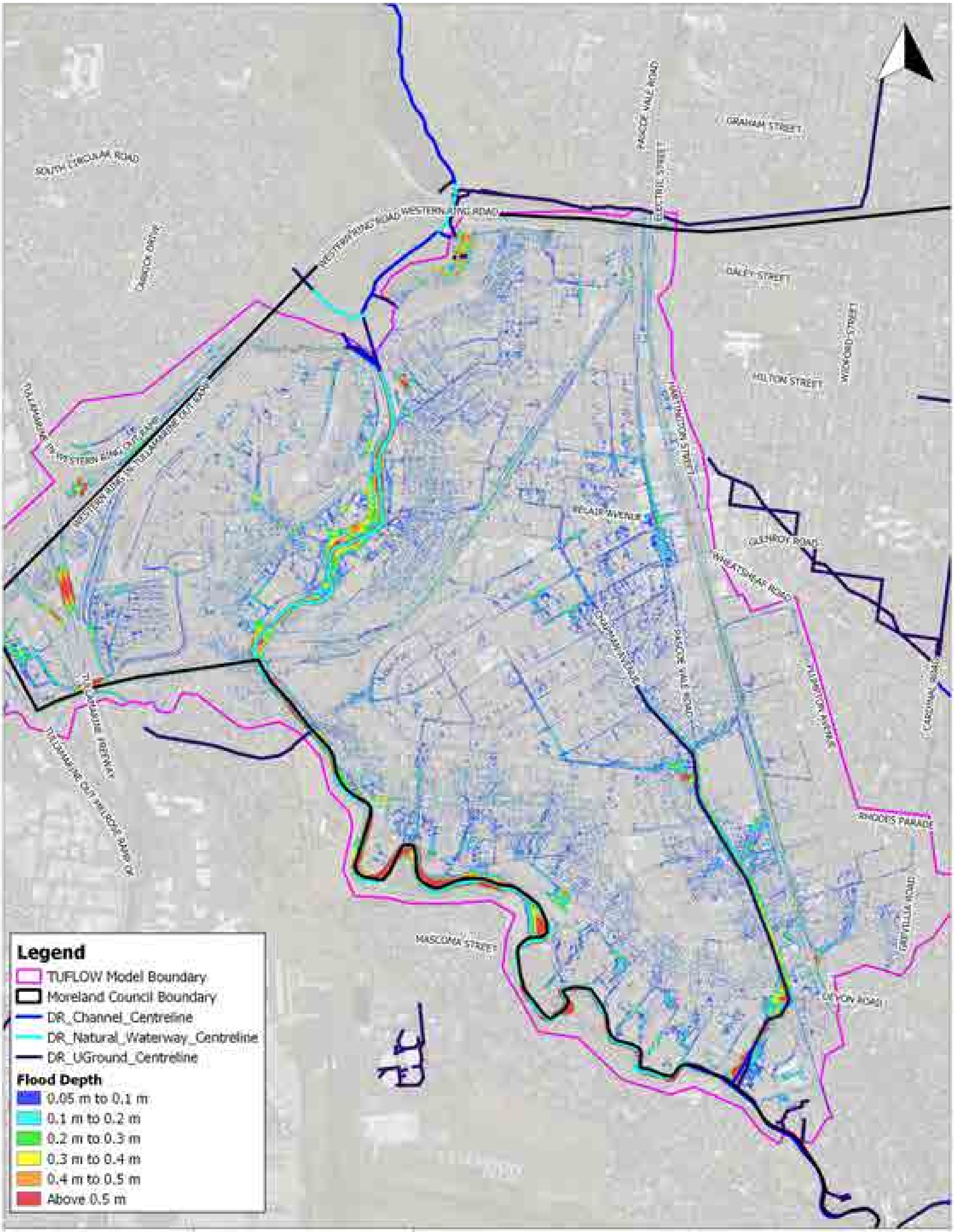
Scale in metres (1:10000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

2% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: KF
Checked: DH
Date: 4/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

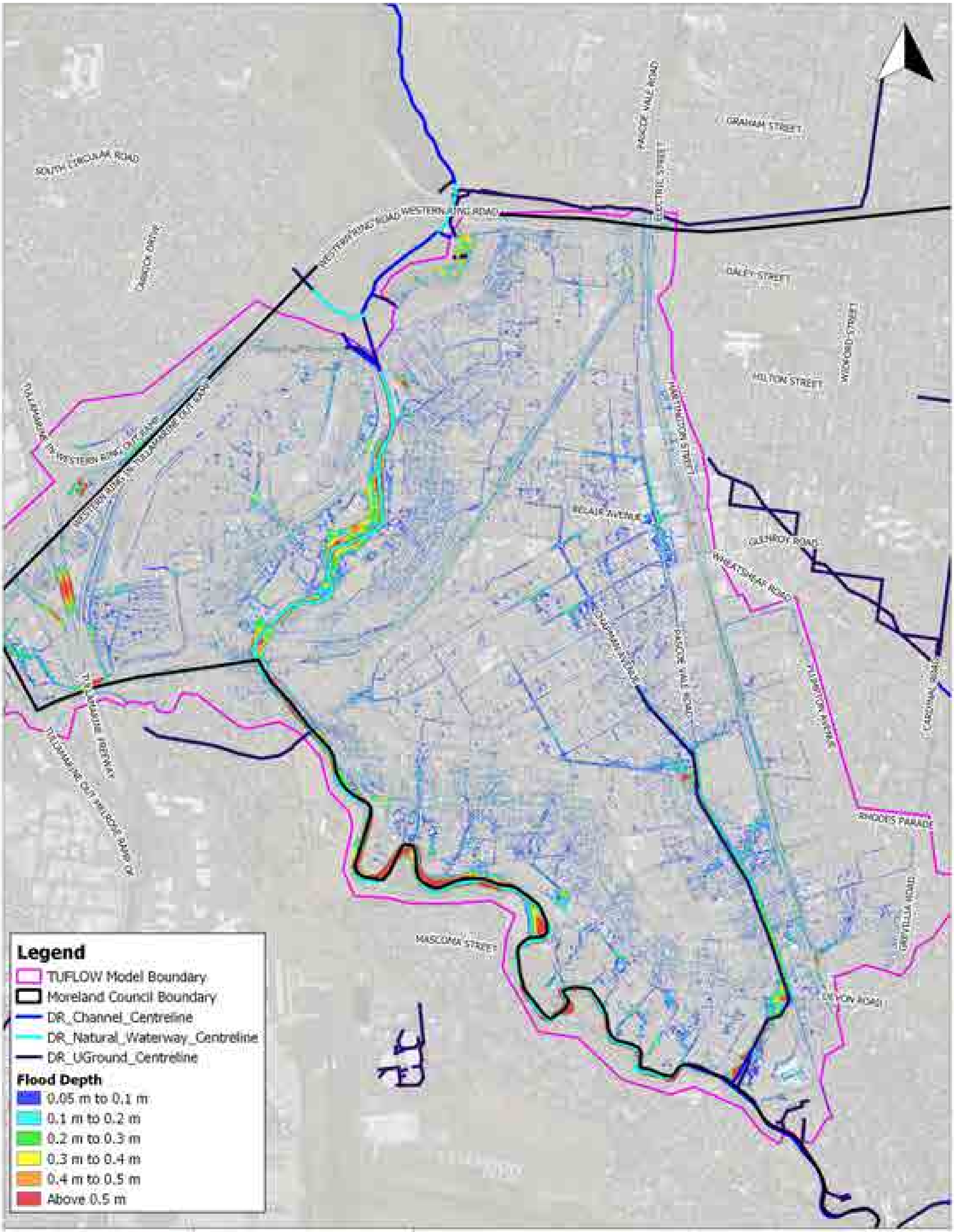
Scale in metres (1:13000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

5% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

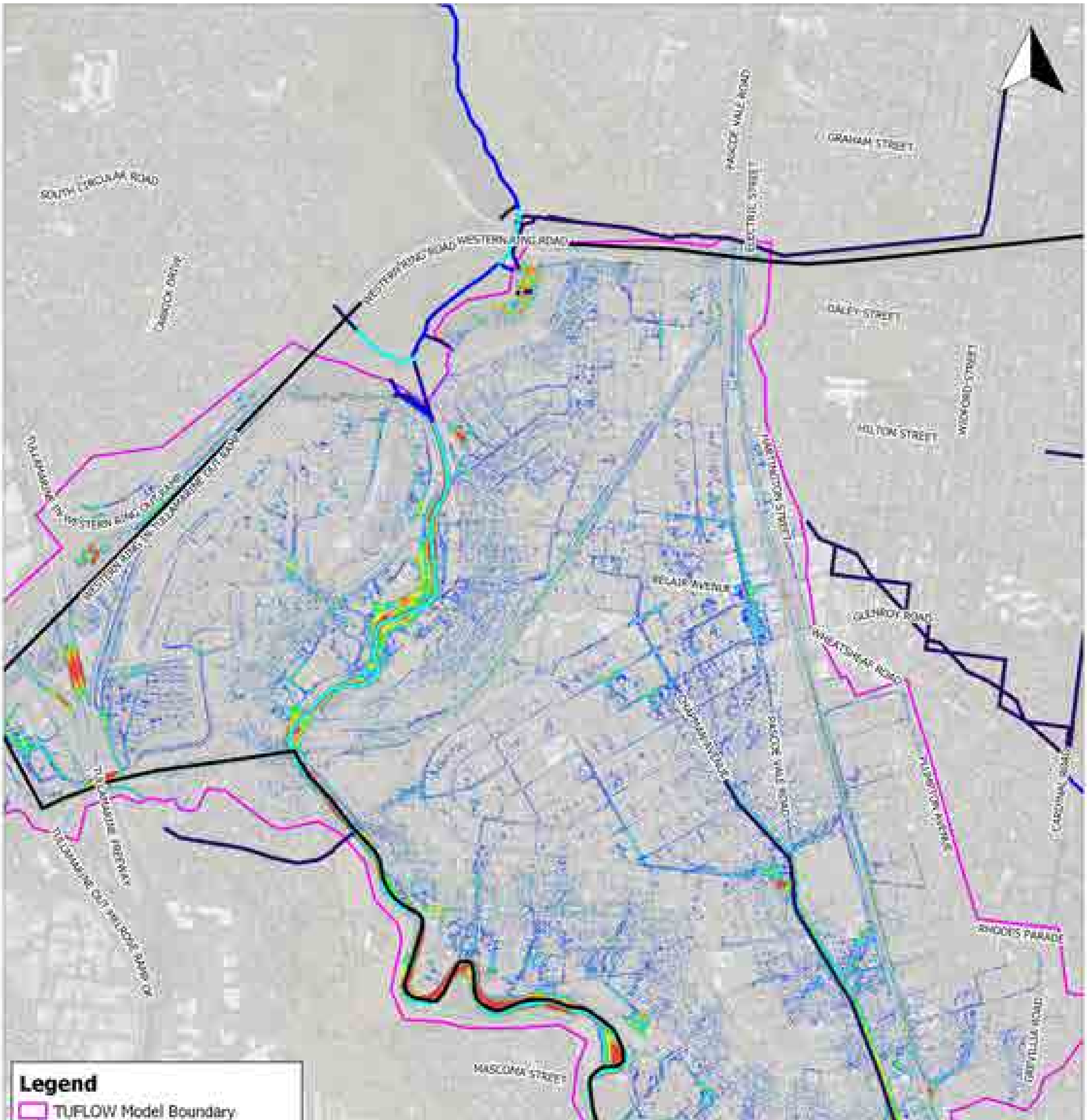
Scale in metres (1:10000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

10% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

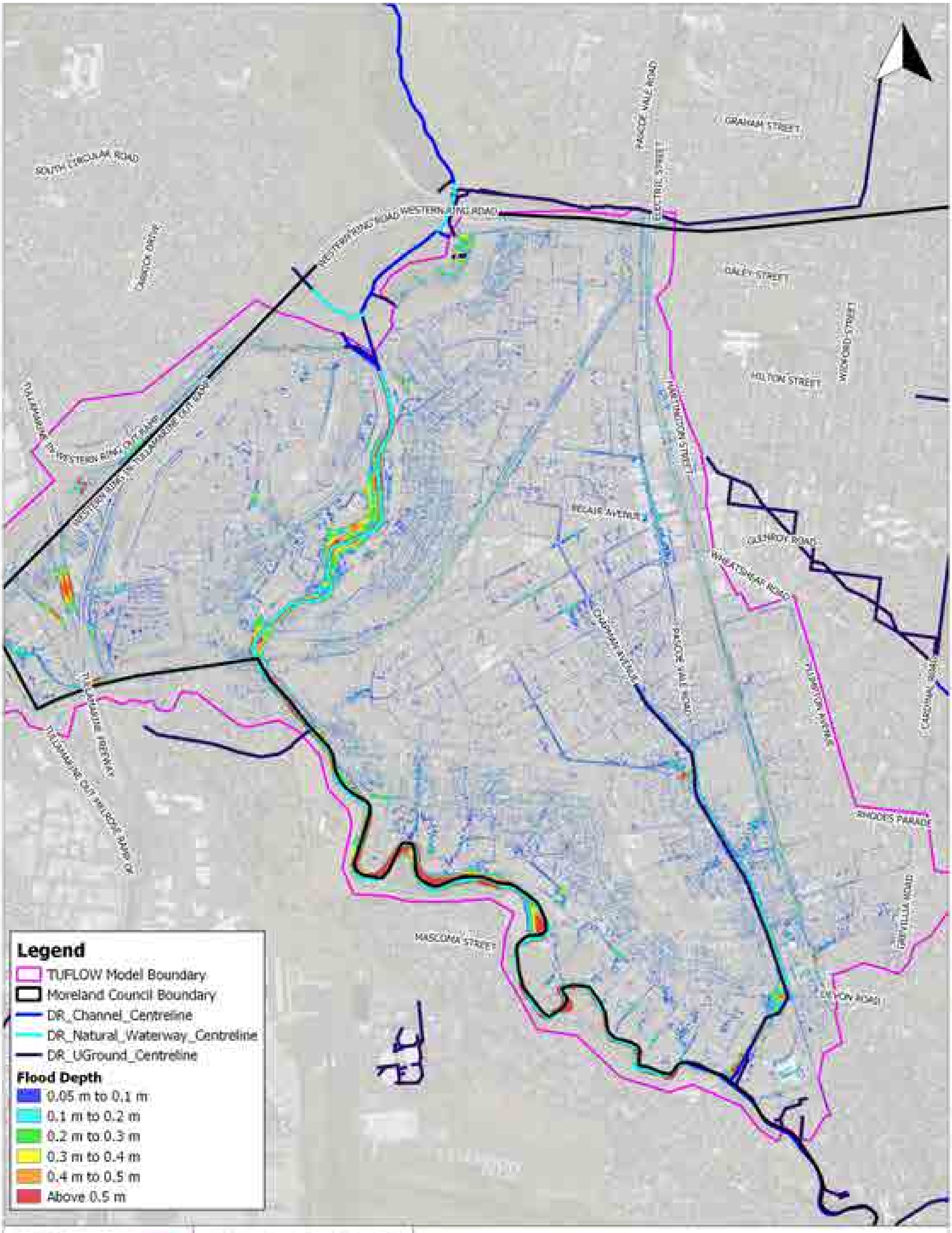
Scale in metres (1:13000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

10% AEP Peak Flood Depth Climate Change (Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: KF
Checked: DH
Date: 4/2/2022



150 0 150 300 450 m

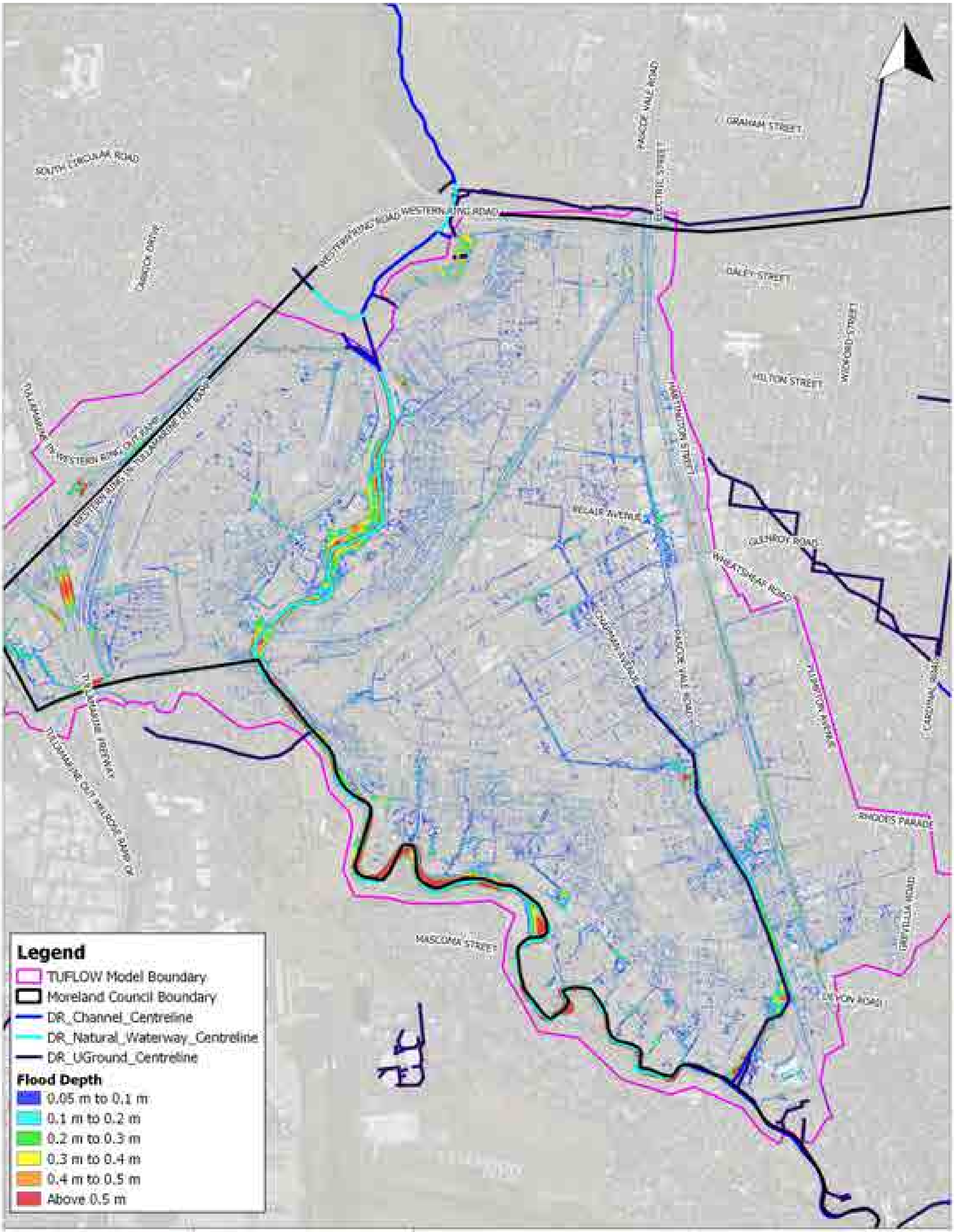
Scale in metres (1:10000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

20% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

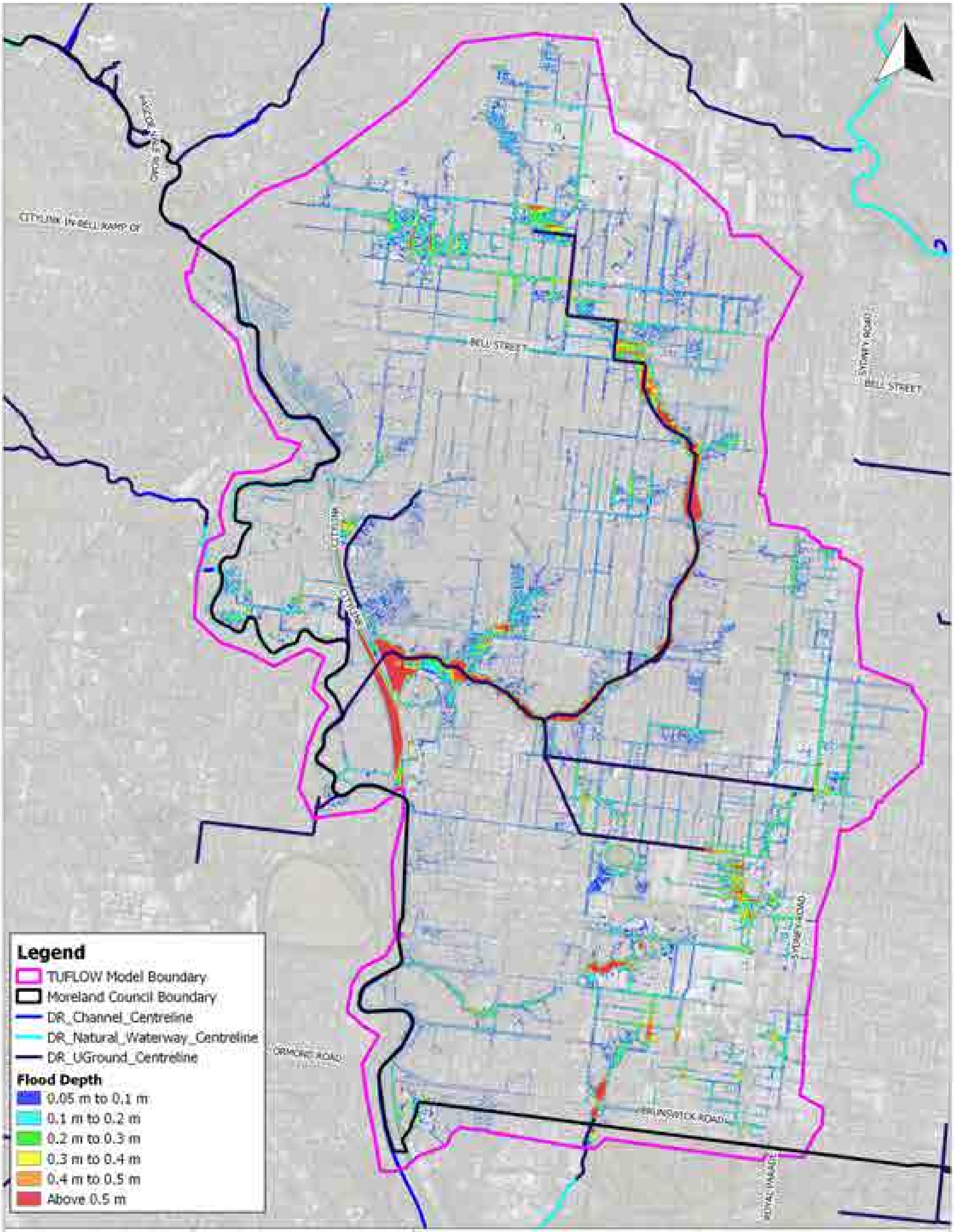
Scale in metres (1:10000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

20% AEP Peak Flood Depth Climate Change (Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



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Scale in metres (1:18000 @ A3)

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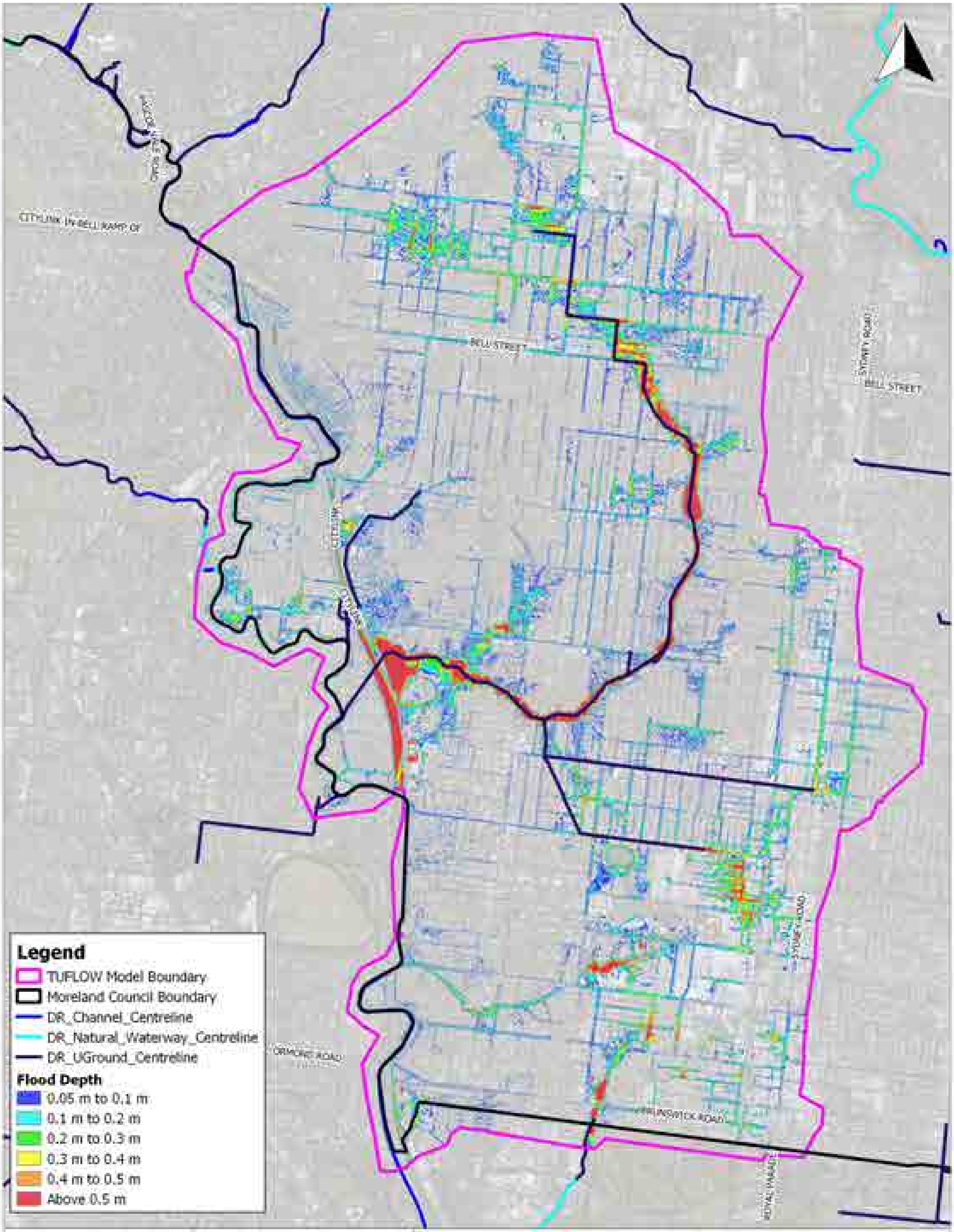
Vertical Datum: Australia Height Datum
Grid: Map Grid of Australia, Zone 55

Moreland Flood Mapping
Melville Main Drain Catchment

1% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



ENGENY

Melbourne Water

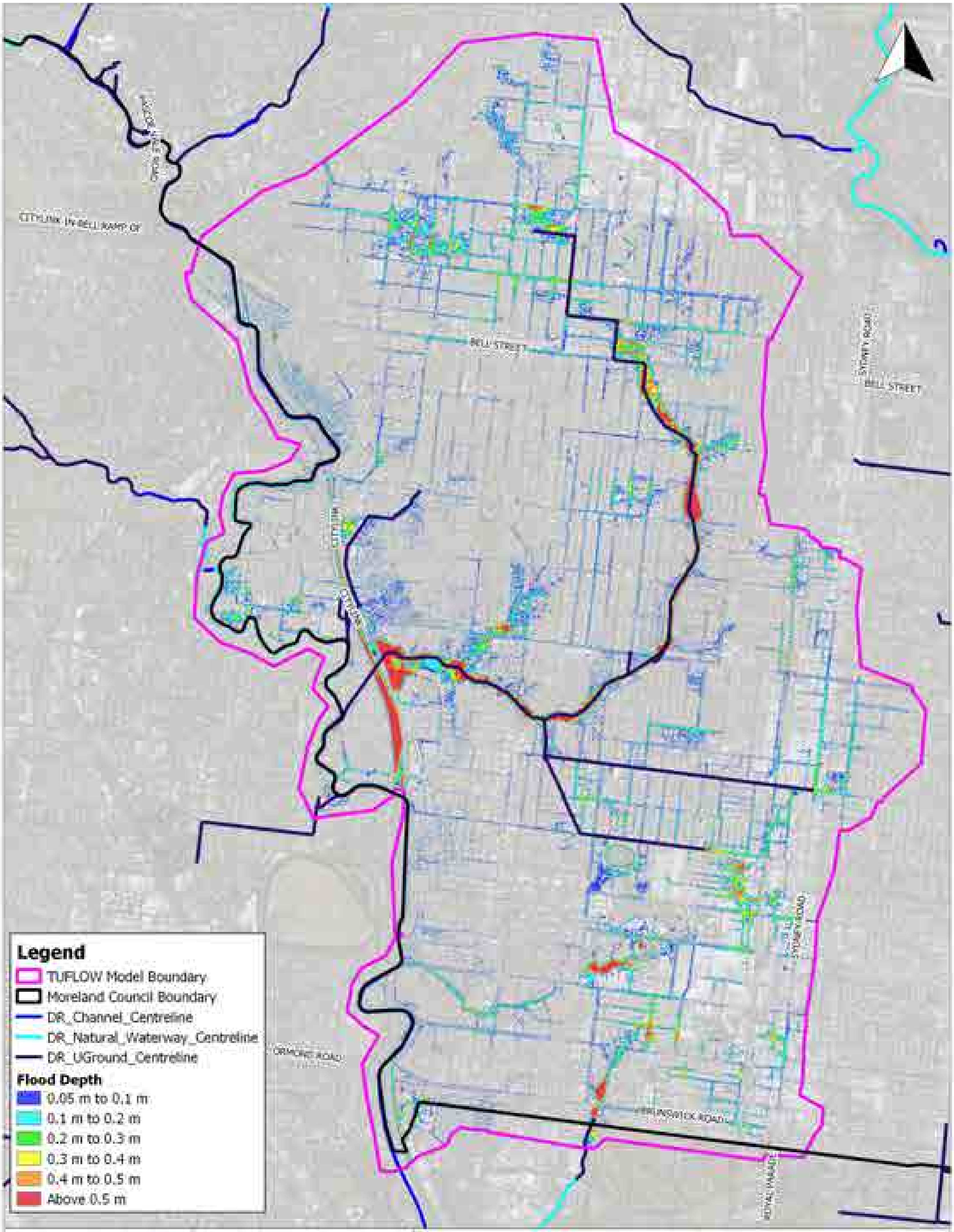
Scale in metres (1:10000 @ A3)

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

Moreland Flood Mapping
Melville Main Drain Catchment

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

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



150 0 150 300 450 m

Scale in metres (1:18000 @ A3)

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

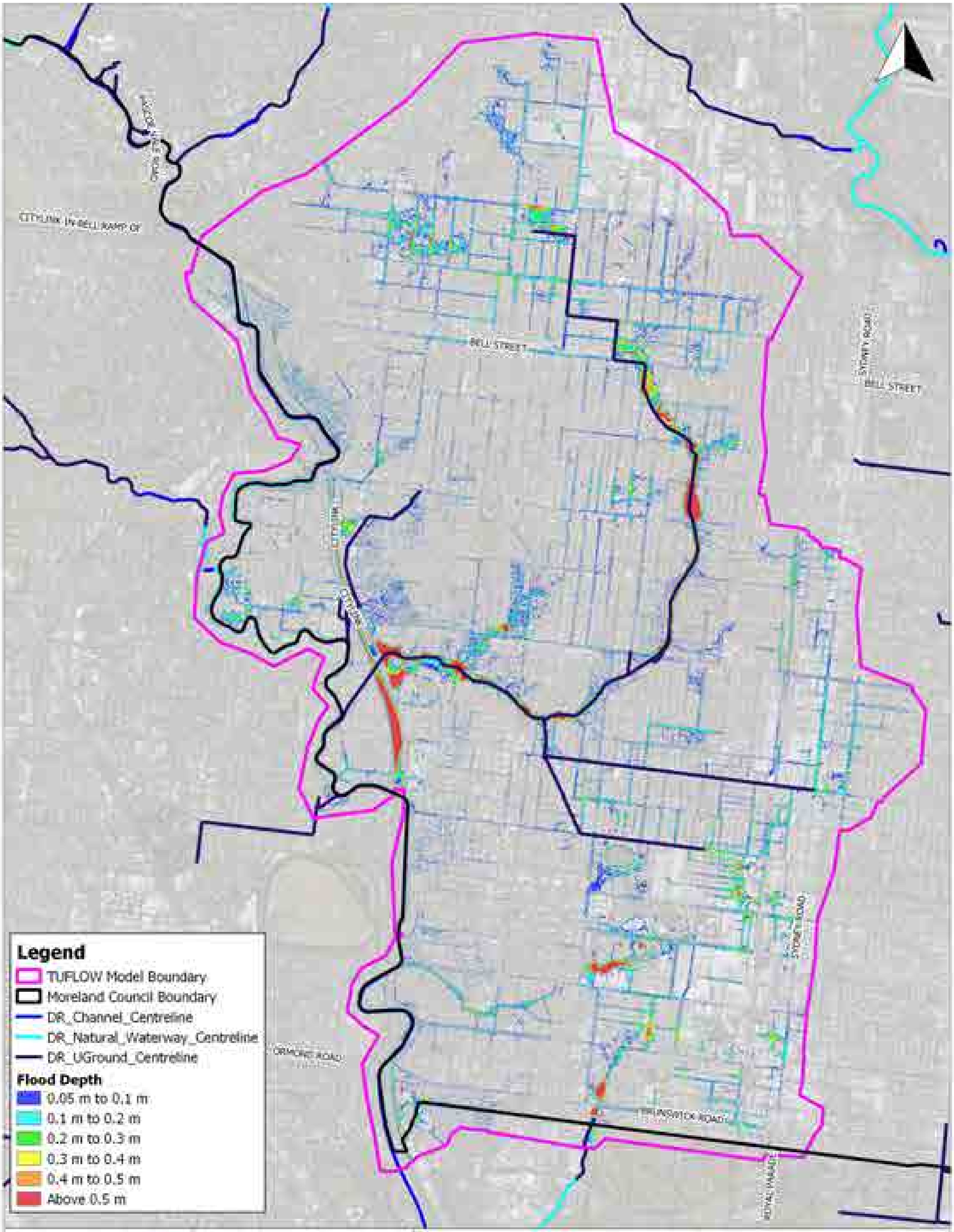
Melbourne Water

ENGENY

Moreland Flood Mapping
Melville Main Drain Catchment

2% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



150 0 150 300 450 m

Scale in metres (1:18000 @ A3)

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

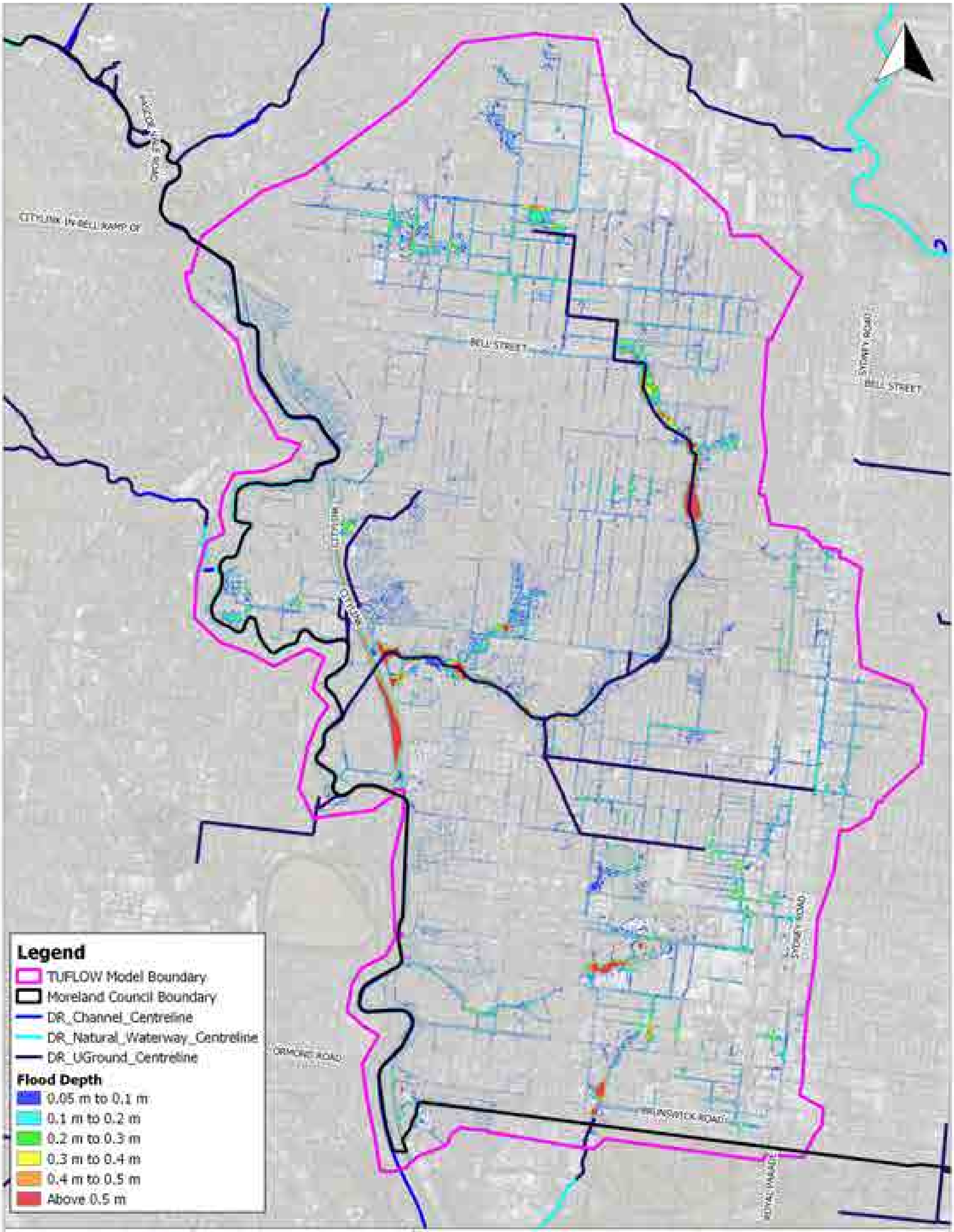
ENGENY

Melbourne Water

Moreland Flood Mapping
Melville Main Drain Catchment

5% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



150 0 150 300 450 m

Scale in metres (1:18000 @ A3)

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

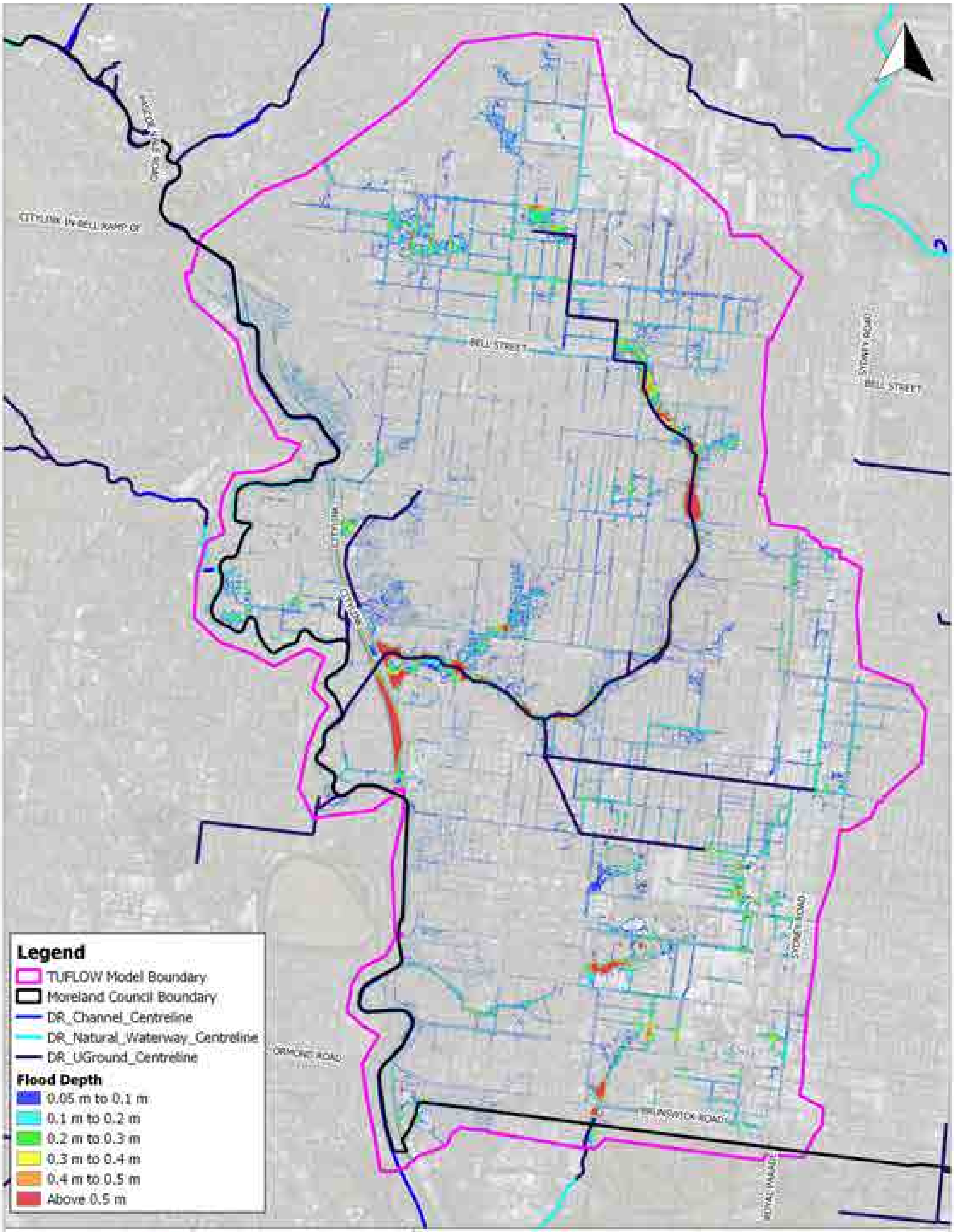
ENGENY

Melbourne Water

Moreland Flood Mapping
Melville Main Drain Catchment

10% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

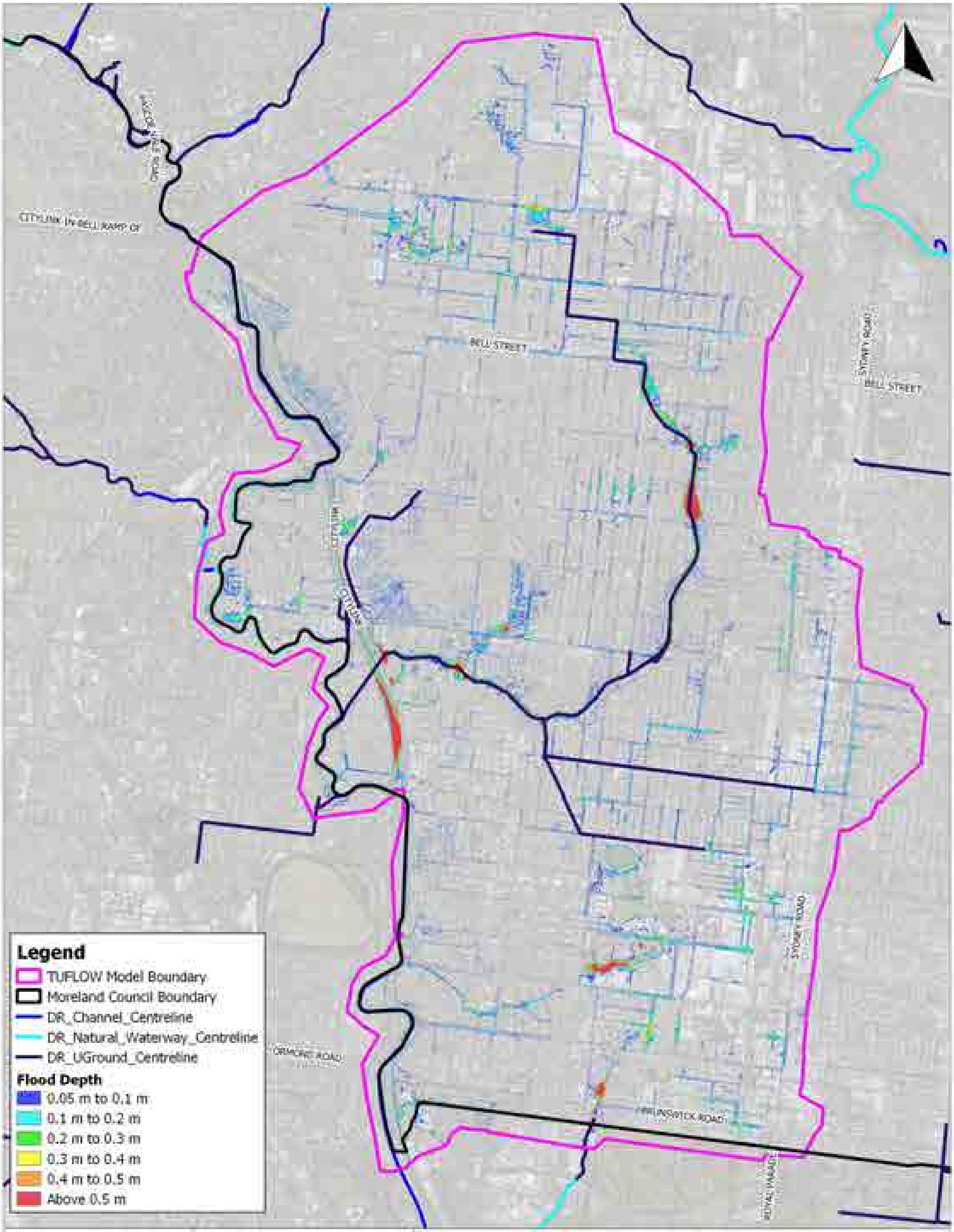
Scale in metres (1:18000 @ A3)

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

Moreland Flood Mapping
Melville Main Drain Catchment

10% AEP Peak Flood Depth Climate Change (Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



Scale in metres (1:18000 @ A3)

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

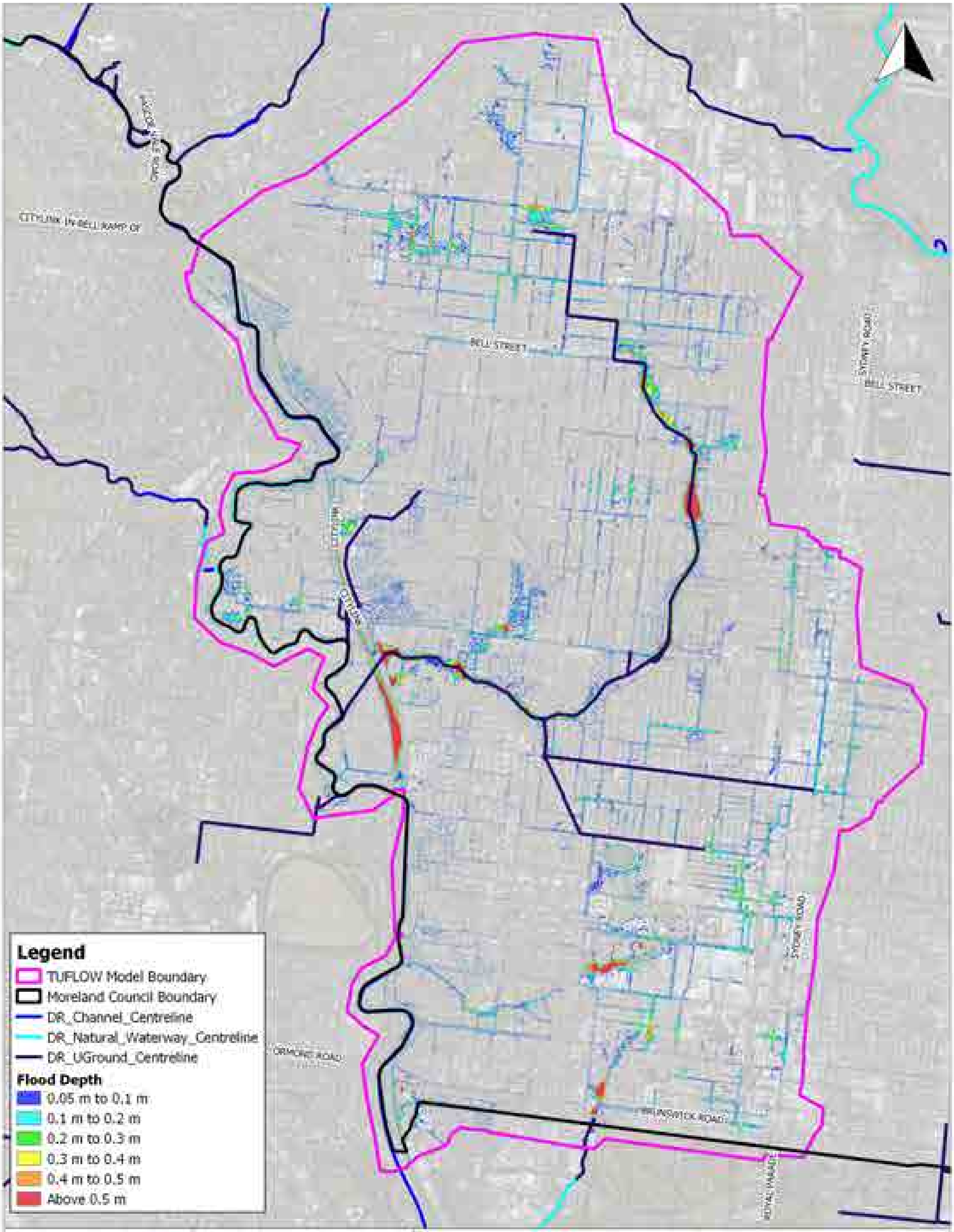
ENGENY

Melbourne Water

Moreland Flood Mapping
Melville Main Drain Catchment

20% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

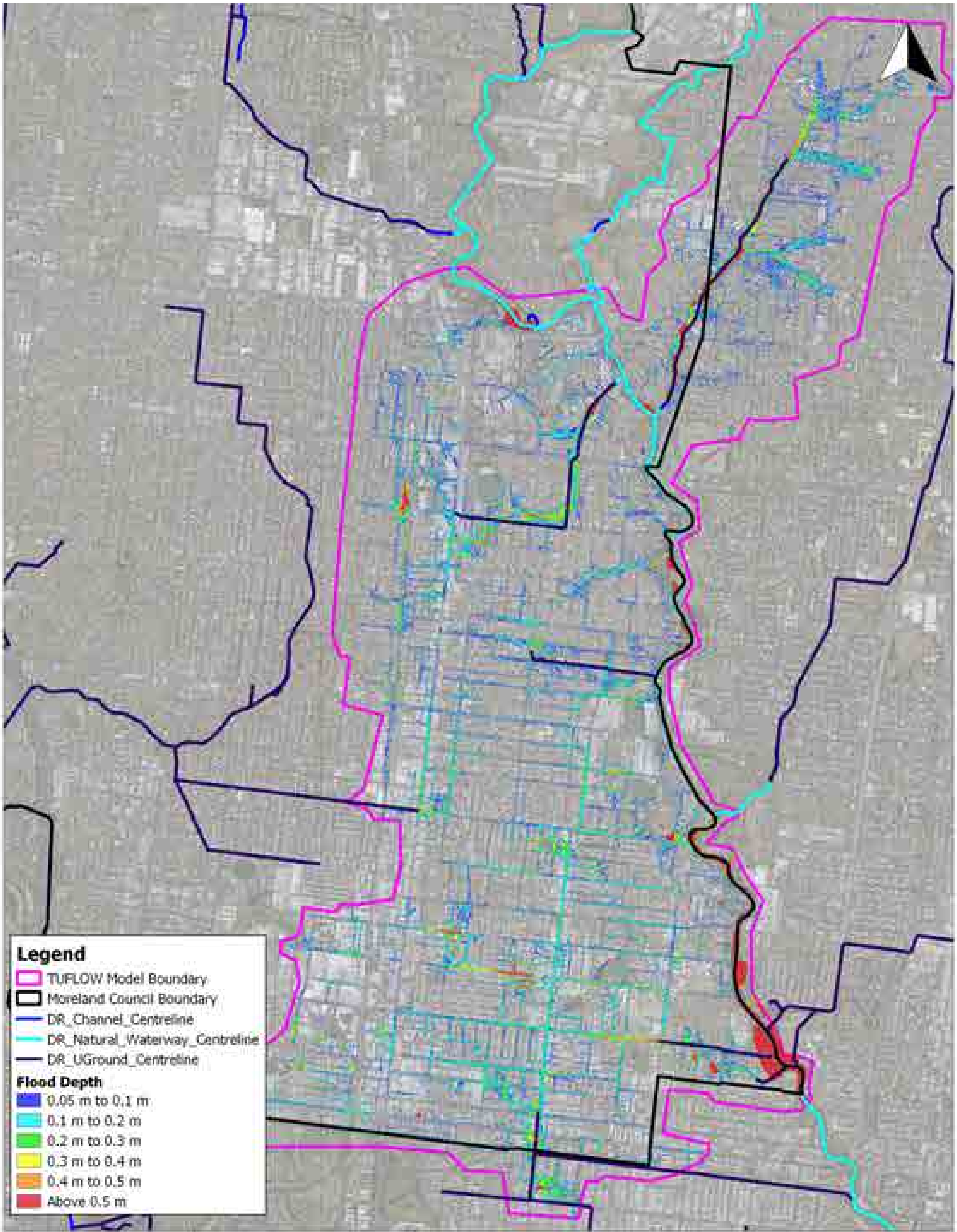
Scale in metres (1:18000 @ A3)

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

Moreland Flood Mapping
Melville Main Drain Catchment

20% AEP Peak Flood Depth Climate Change (Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



350 0 350 700 m

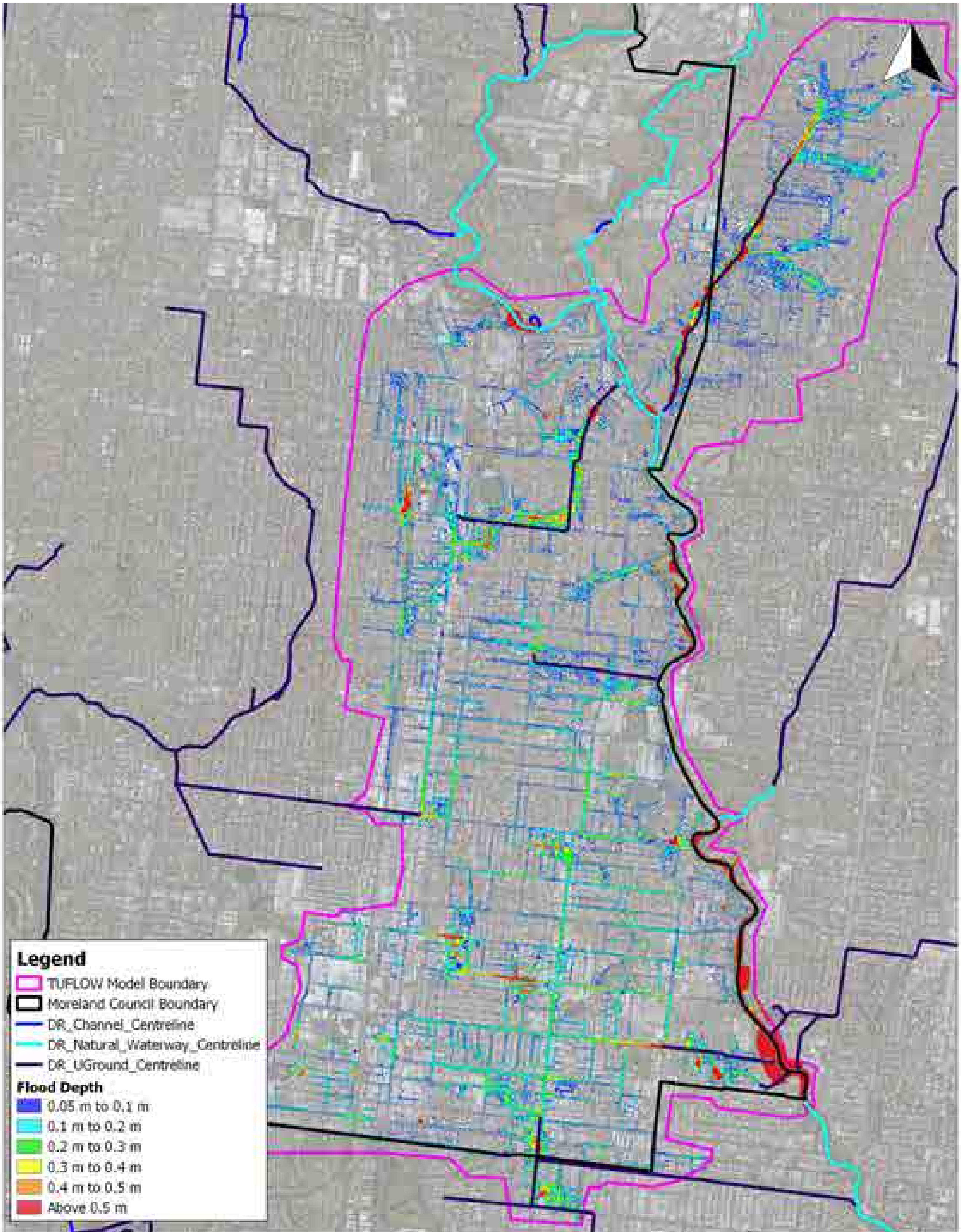
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

1% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

350 0 350 700 m

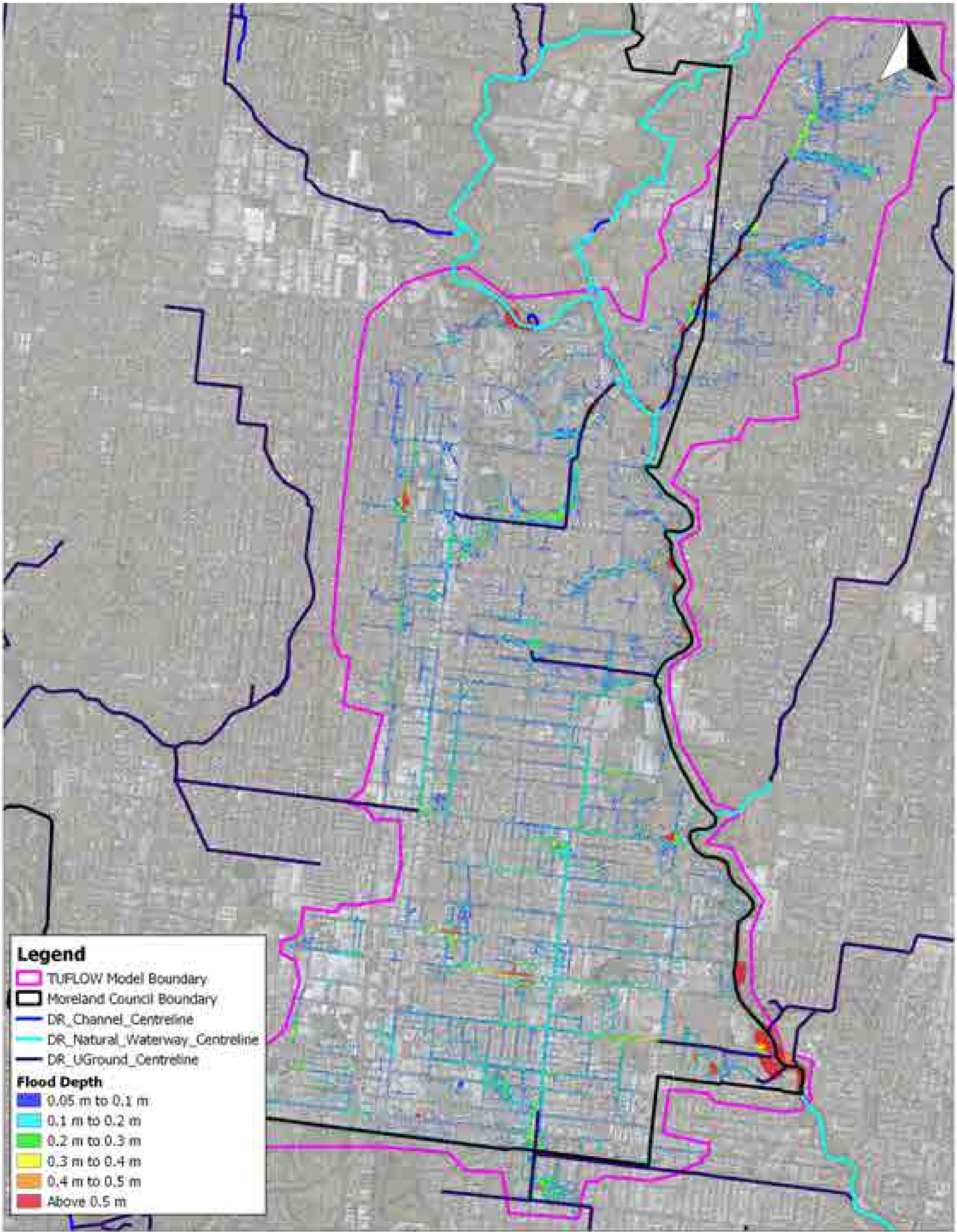
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

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

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



Scale in metres (1:20,000@ A3)

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

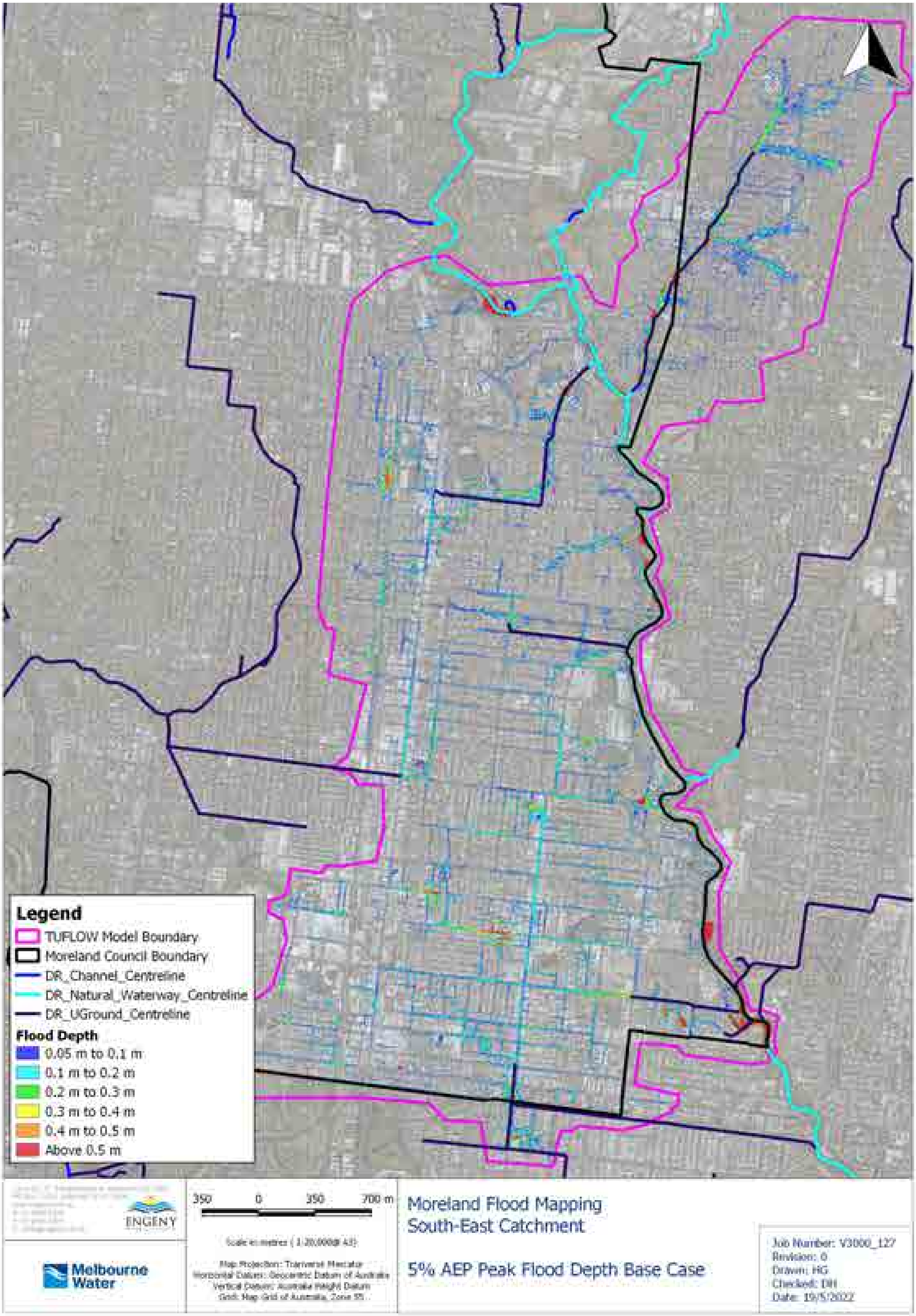
ENGENY

Melbourne Water

Moreland Flood Mapping
South-East Catchment

2% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



Moreland Flood Mapping
South-East Catchment

5% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
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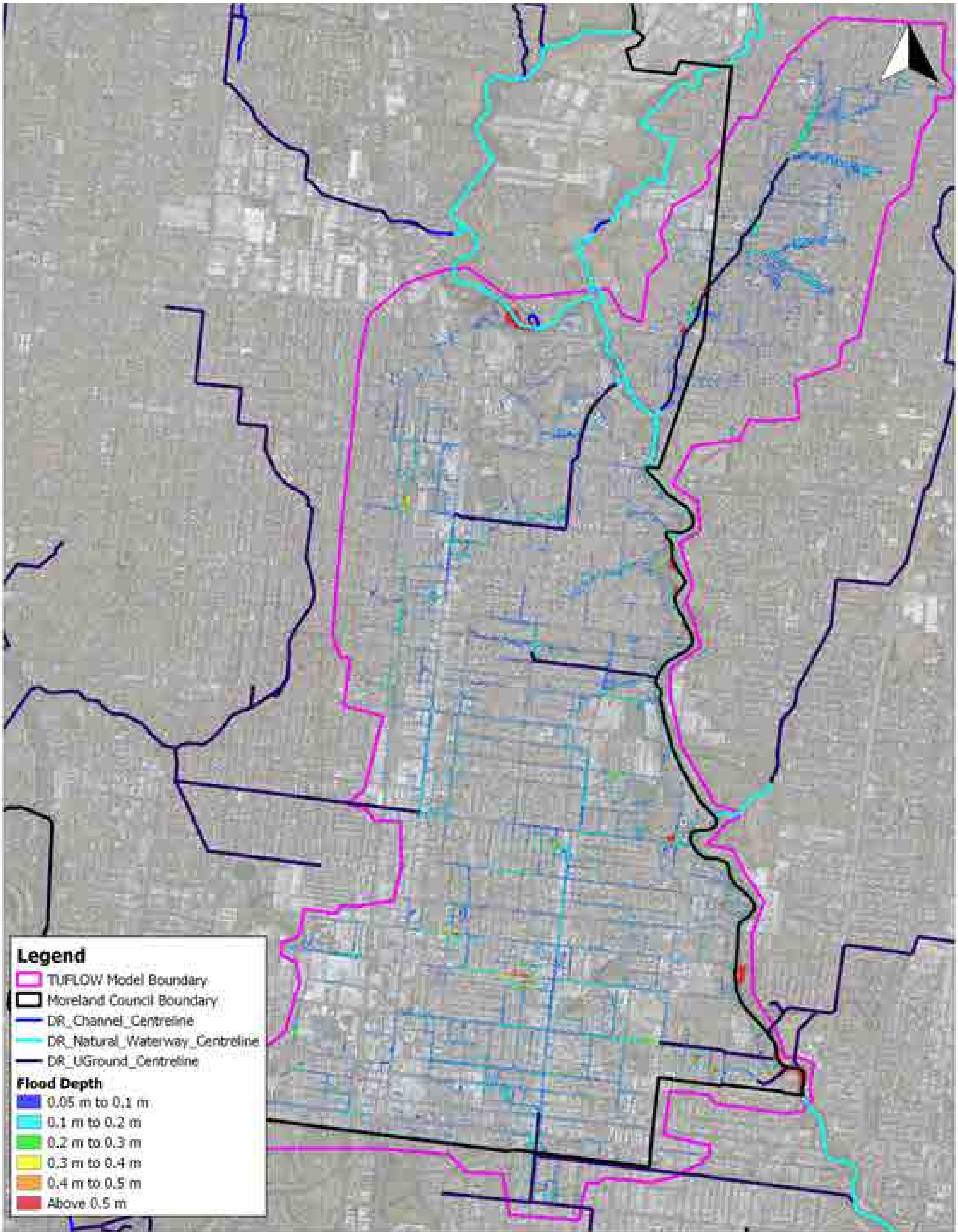
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

350 0 350 700 m

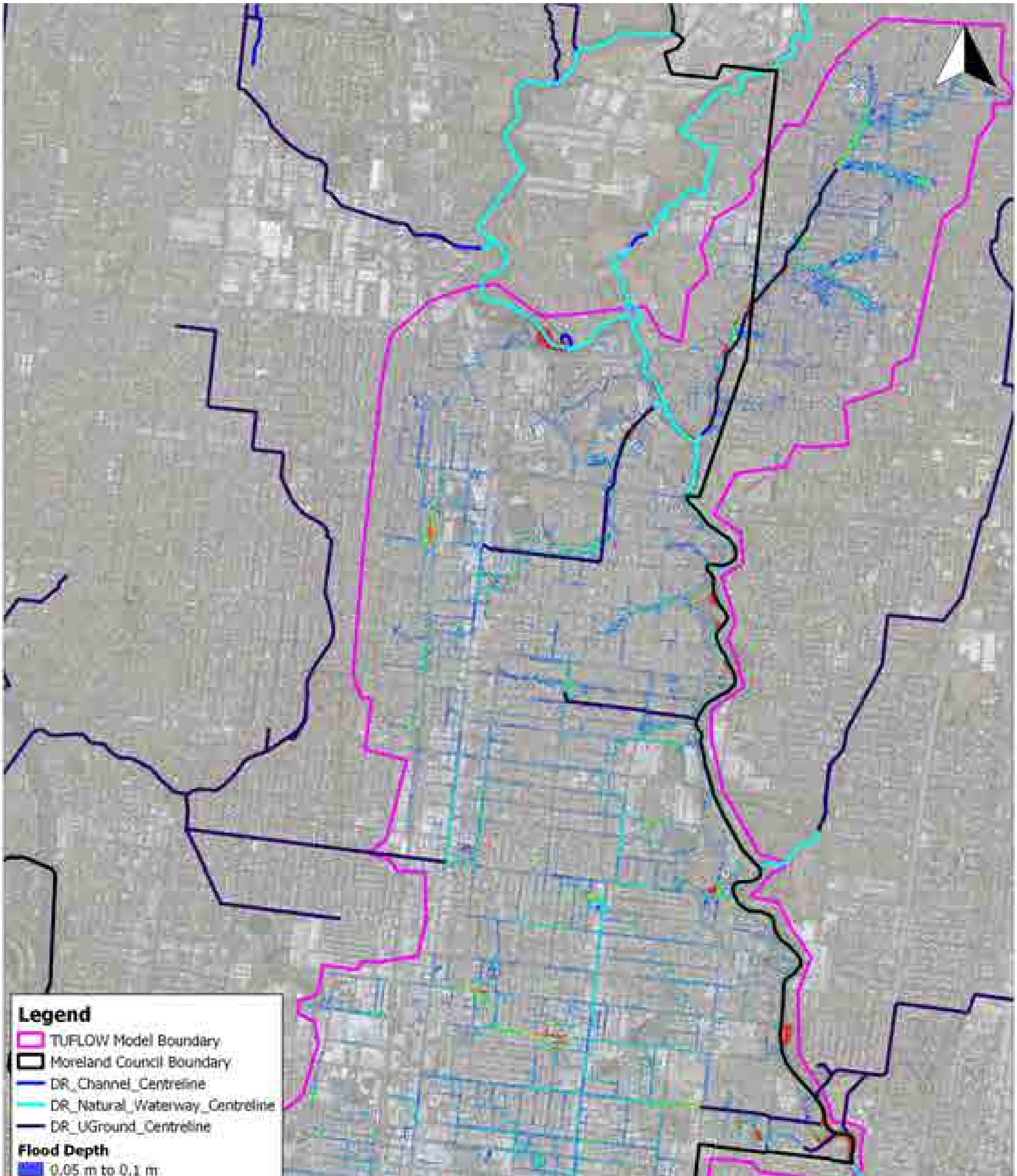
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

10% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

350 0 350 700 m

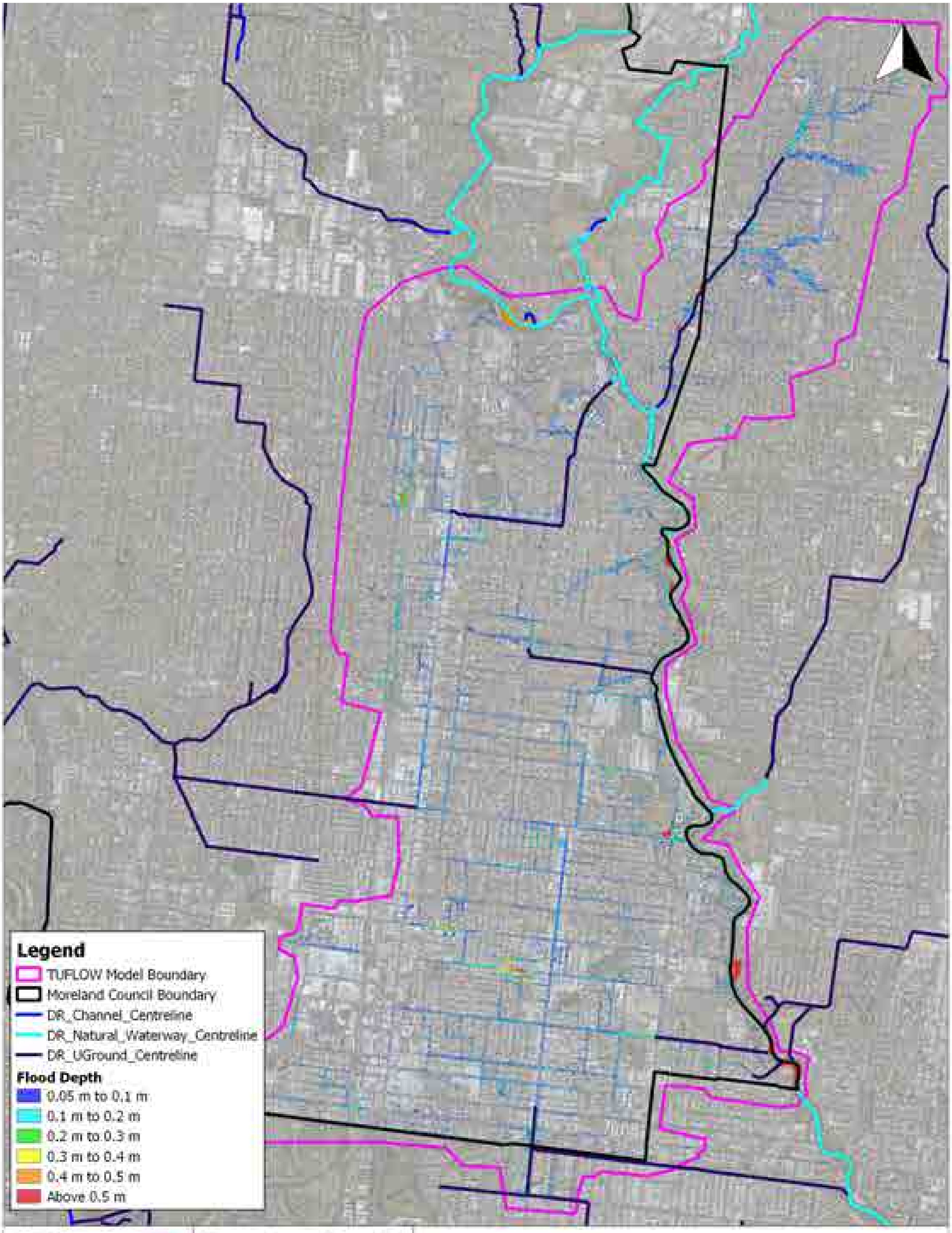
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

10% AEP Peak Flood Depth Climate Change (Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

350 0 350 700 m

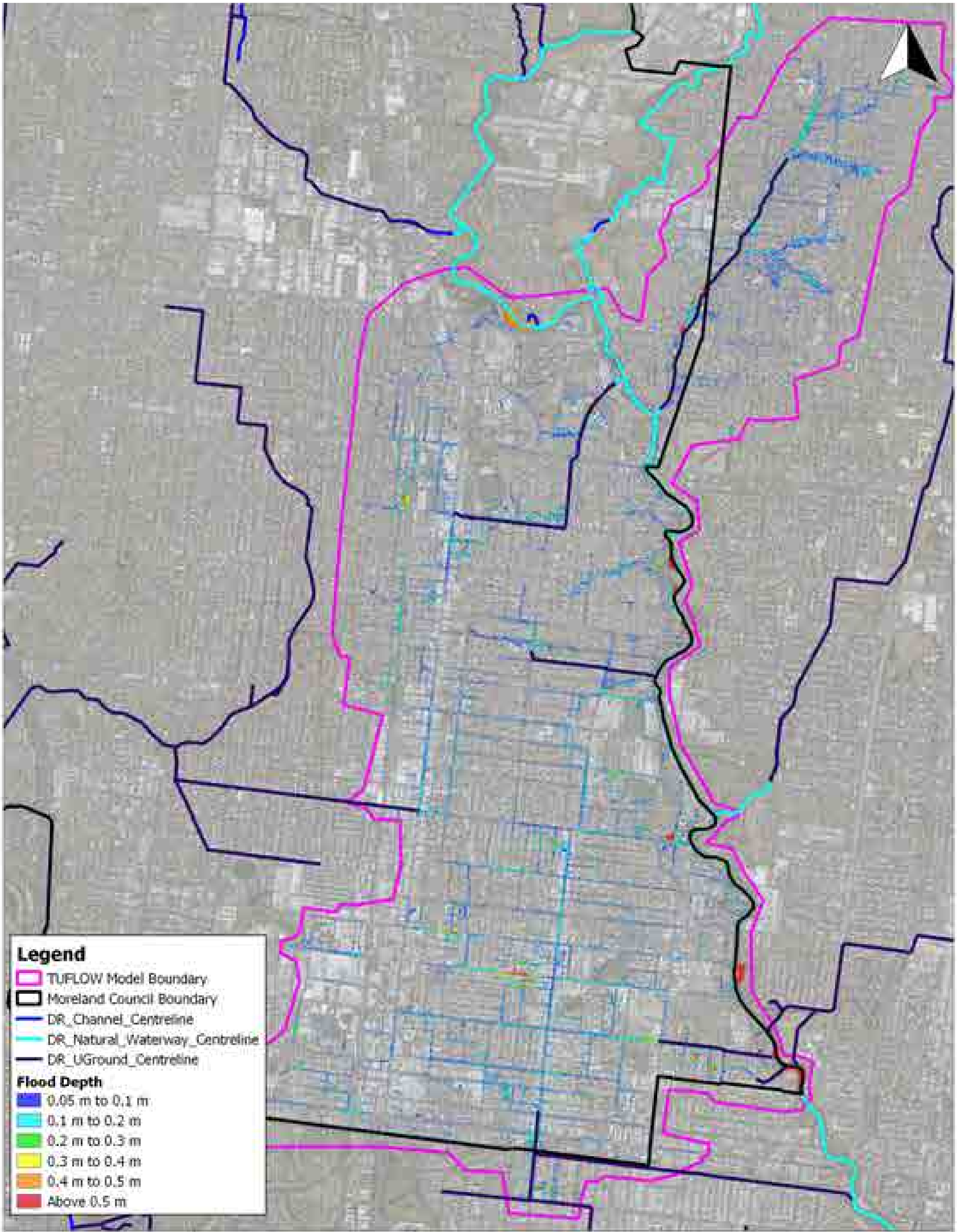
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

20% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

350 0 350 700 m

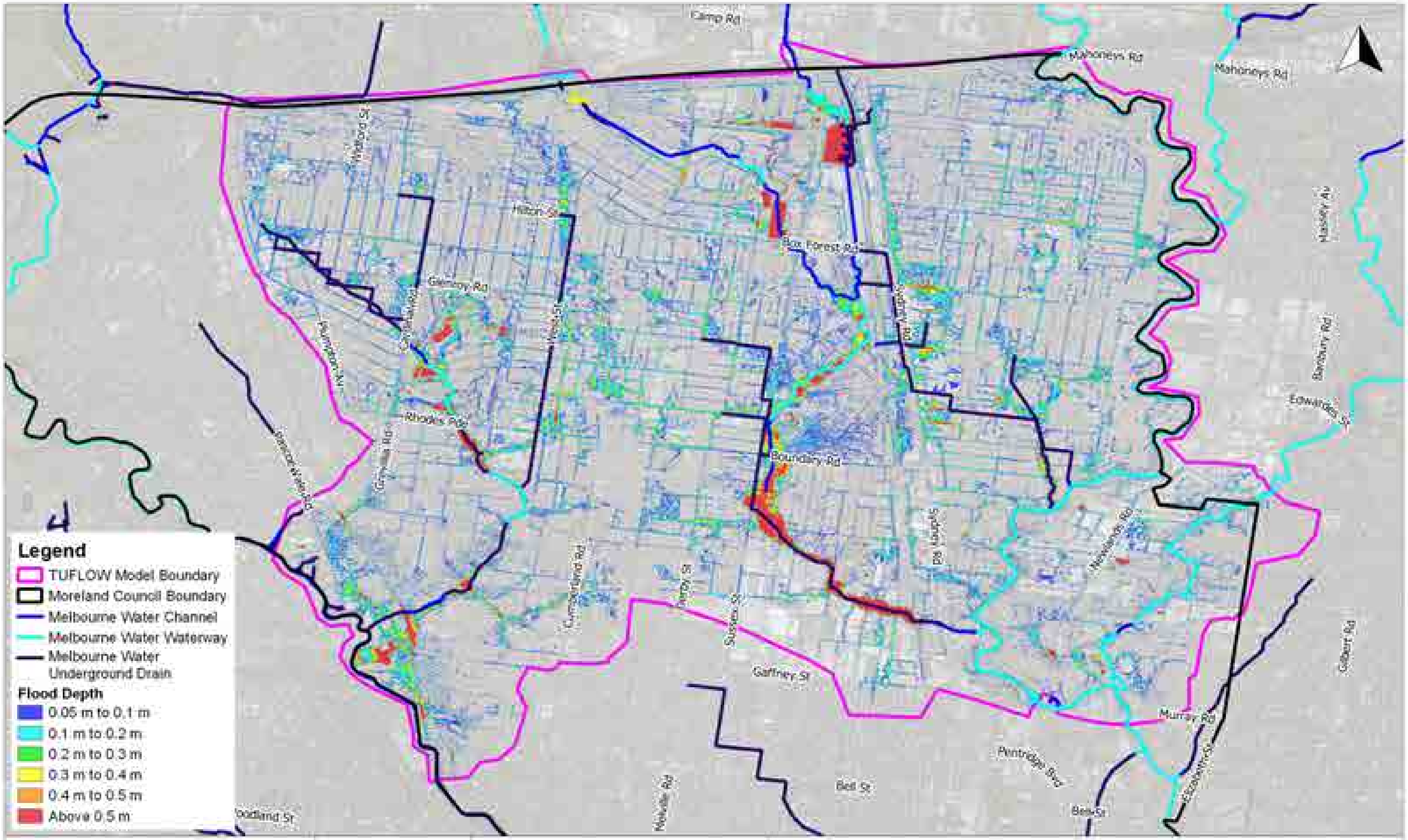
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

20% AEP Peak Flood Depth Climate Change (Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



Level 34, Tenancy 6, 360 Elizabeth St
Melbourne VIC 3000
PO Box 12103, A'Beckett St
VIC 8006
www.engeny.com.au
P: 03 9888 6978
F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

Melbourne Water

250 0 250 500 750 1000 m

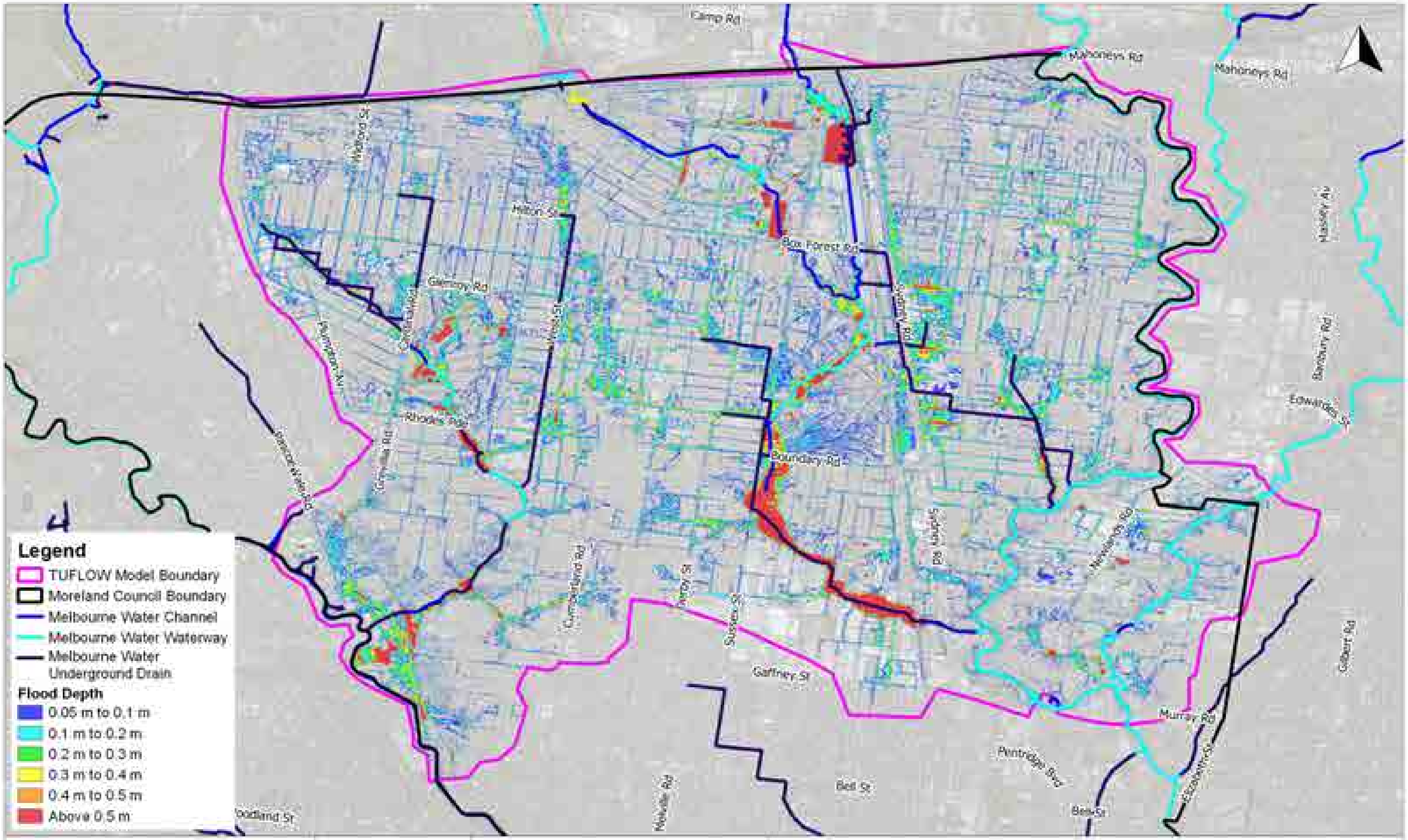
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

1% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: KS
Checked: DH
Date: 7/11/2022



ENGENY

Melbourne Water

250 0 250 500 750 1000 m

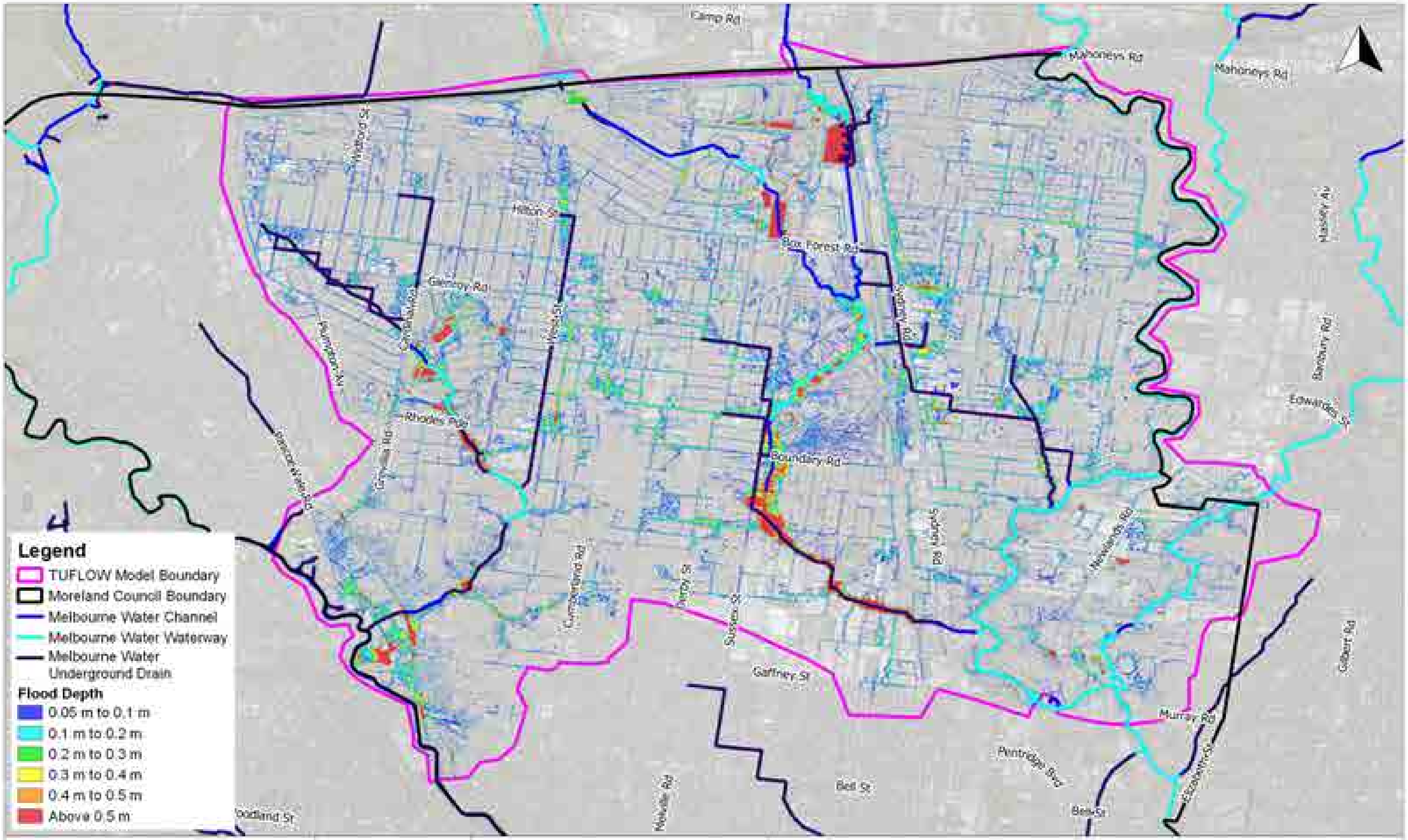
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

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

Job Number: V3000_127
Revision: D
Drawn: KS
Checked: DH
Date: 7/11/2022



Level 34, Tenancy 5, 360 Elizabeth St
Melbourne VIC 3000
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P: 03 9888 6978
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E: melb@engeny.com.au

ENGENY

Melbourne Water

250 0 250 500 750 1000 m

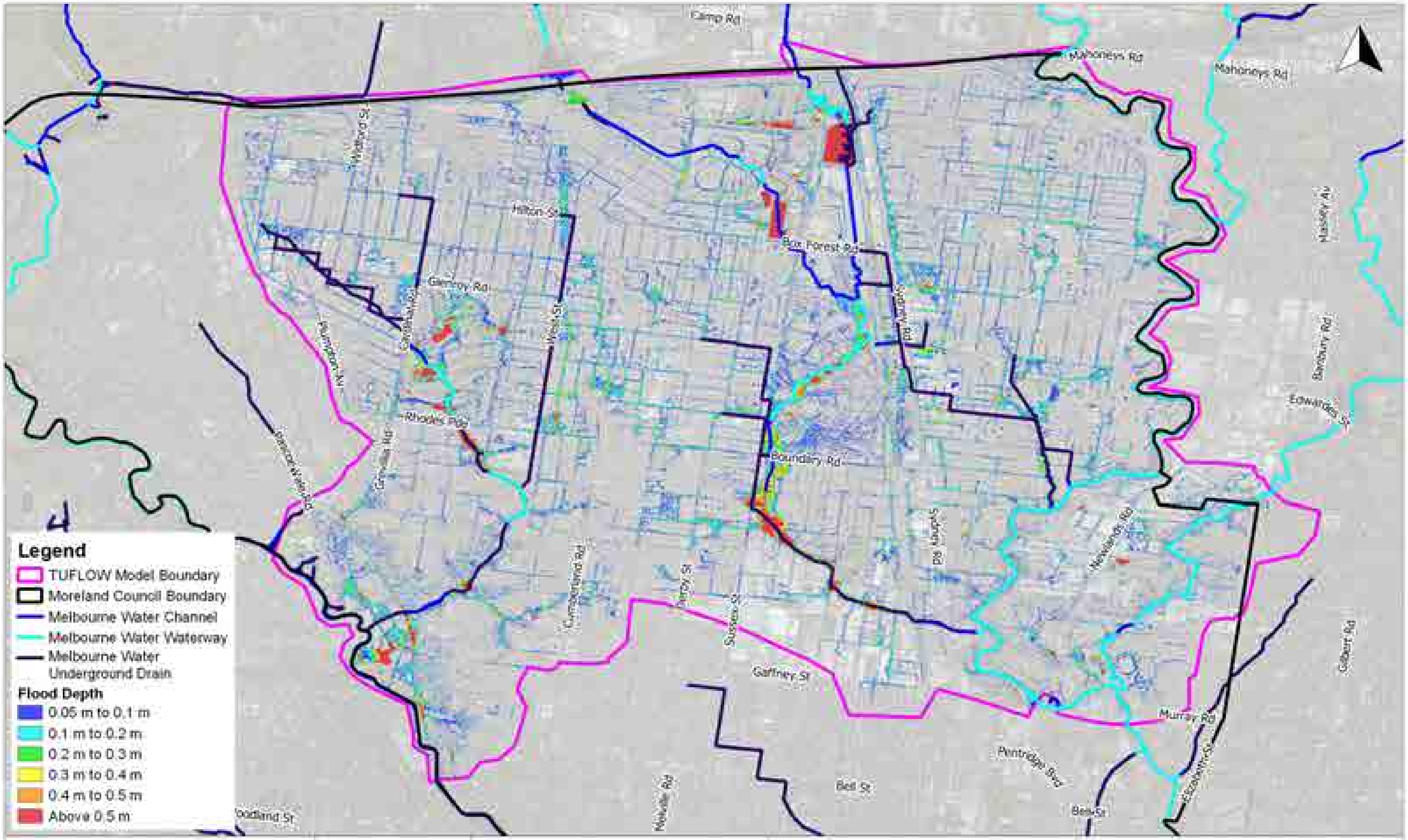
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

2% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: D
Drawn: KS
Checked: DH
Date: 7/11/2022



ENGENY

Melbourne Water

250 0 250 500 750 1000 m

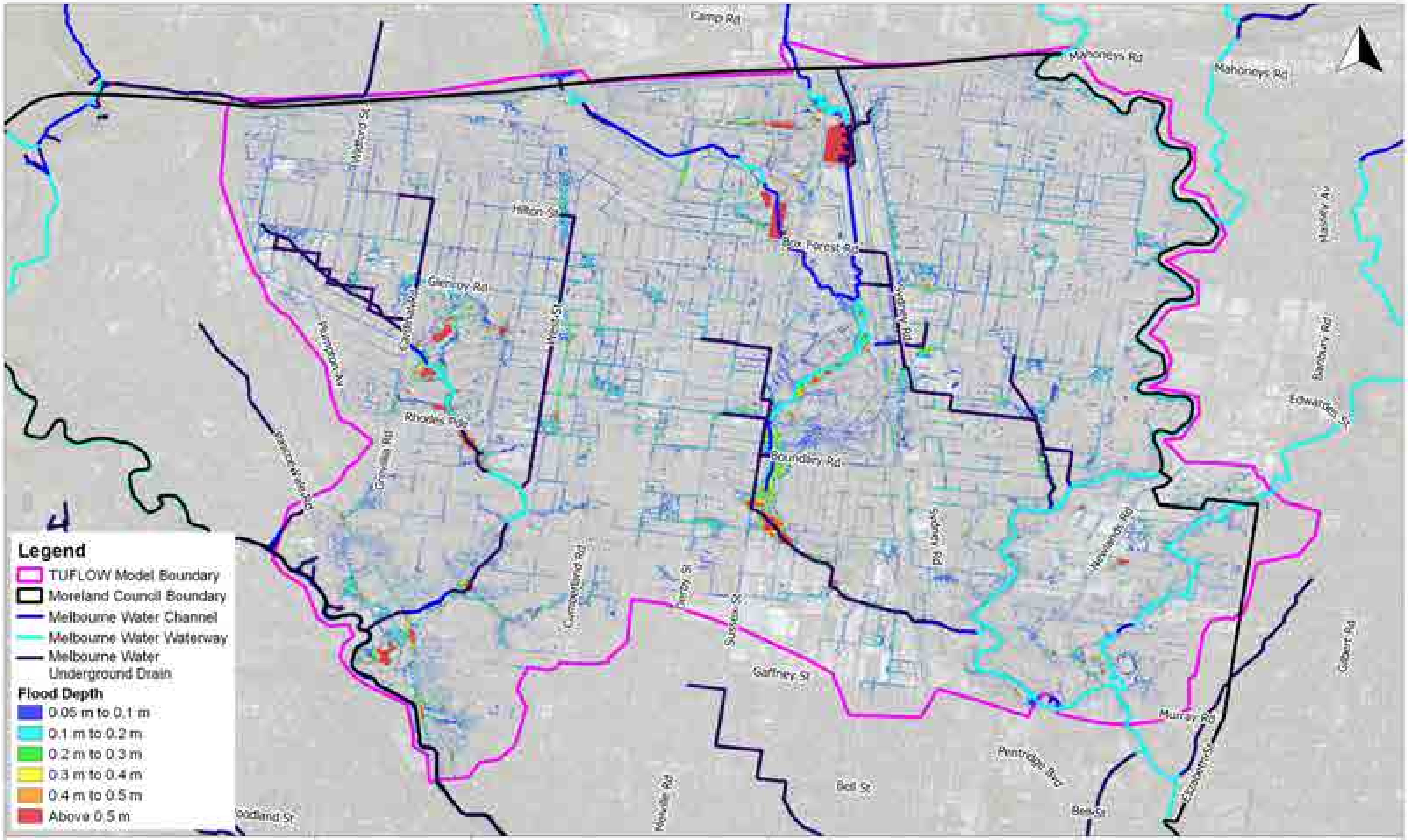
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

5% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: 0
Drawn: KS
Checked: DH
Date: 7/11/2022



ENGENY

Melbourne Water

250 0 250 500 750 1000 m

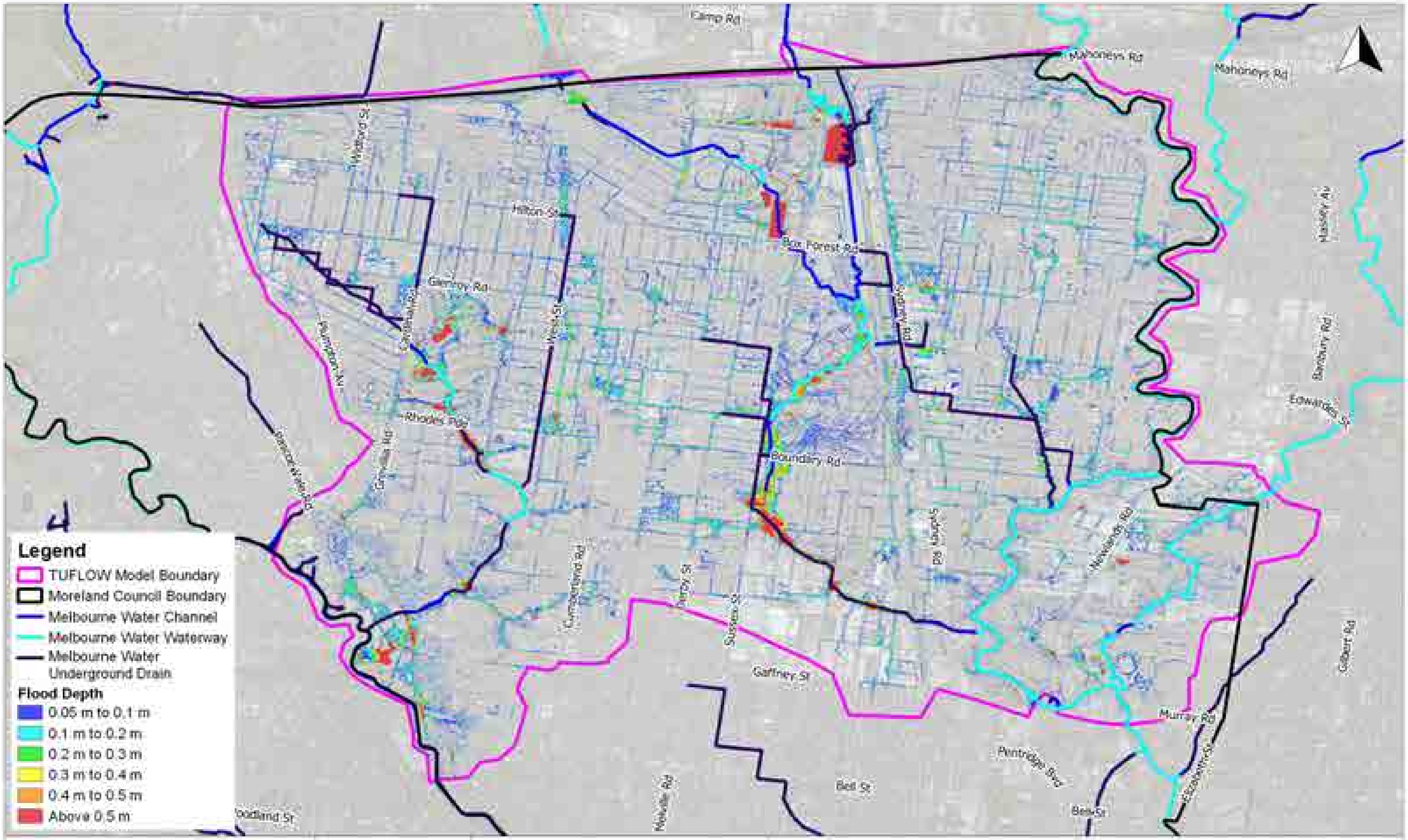
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

10% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: D
Drawn: KS
Checked: DH
Date: 7/11/2022



ENGENY

Melbourne Water

250 0 250 500 750 1000 m

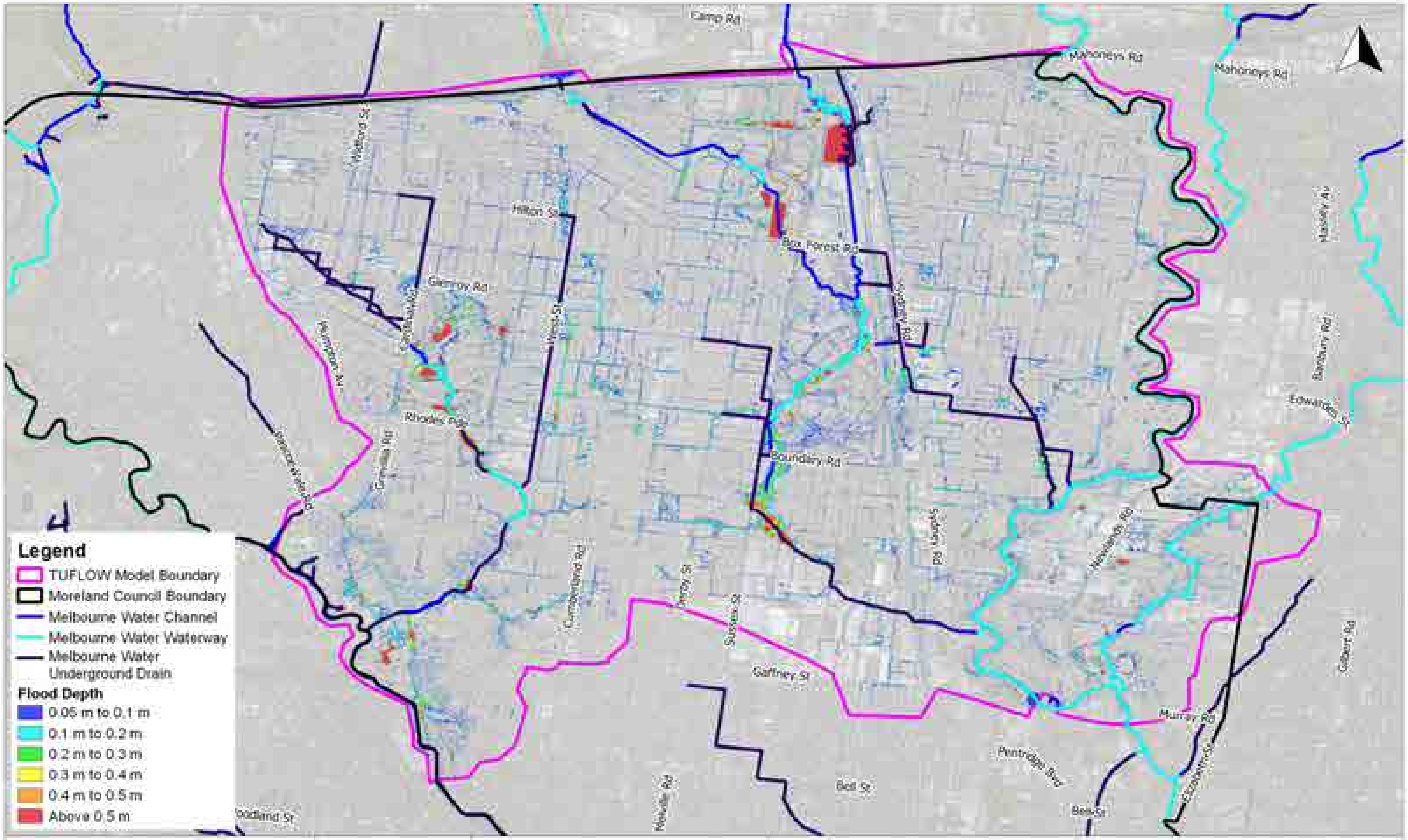
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

10% AEP Peak Flood Depth Climate Change (Scenario D)

Job Number: V3000_127
Revision: D
Drawn: KS
Checked: DH
Date: 7/11/2022



ENGENY

Melbourne Water

250 0 250 500 750 1000 m

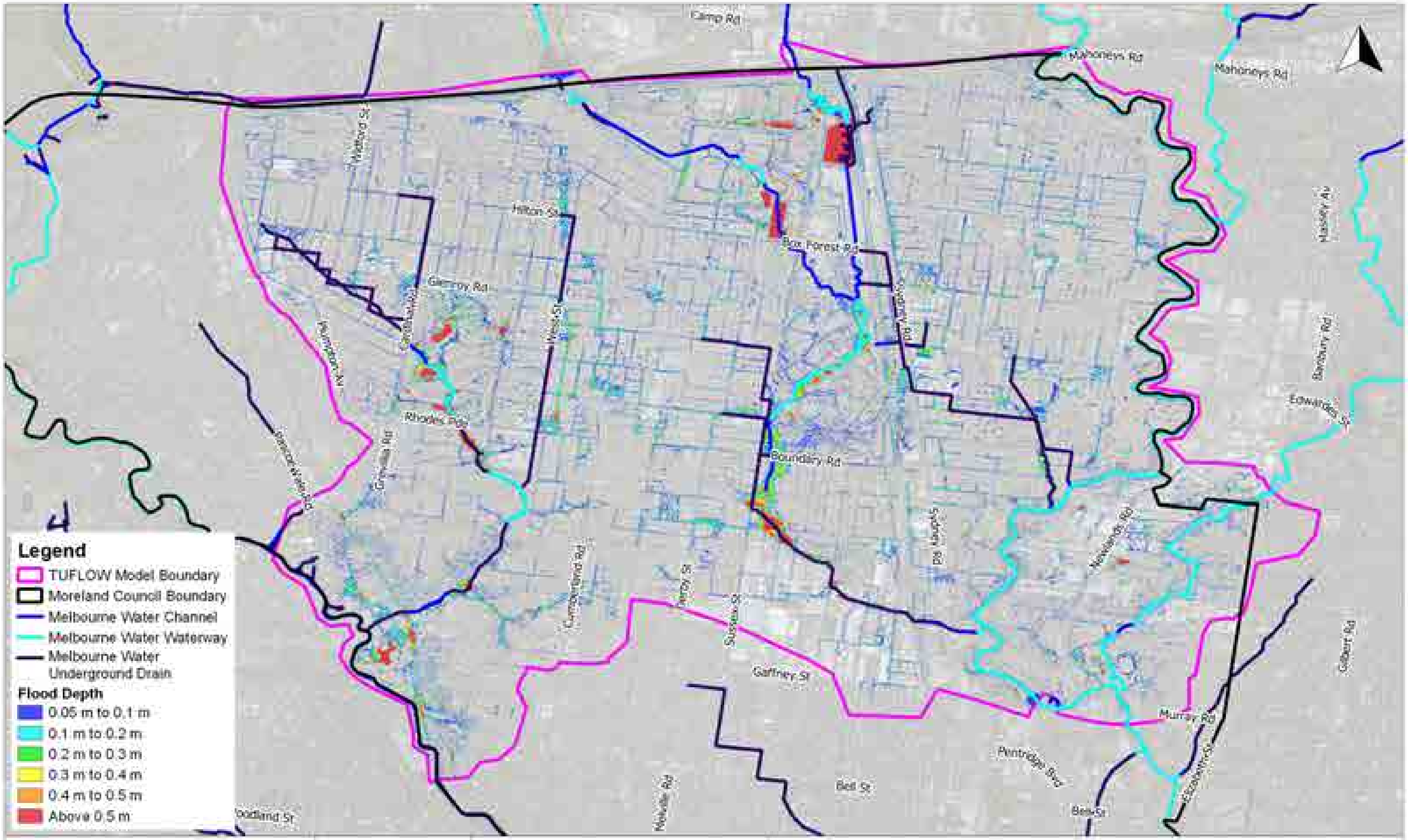
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

20% AEP Peak Flood Depth Base Case

Job Number: V3000_127
Revision: D
Drawn: KS
Checked: DH
Date: 7/11/2022



Melbourne VIC 3000

ENGENY

Melbourne Water

250 0 250 500 750 1000 m

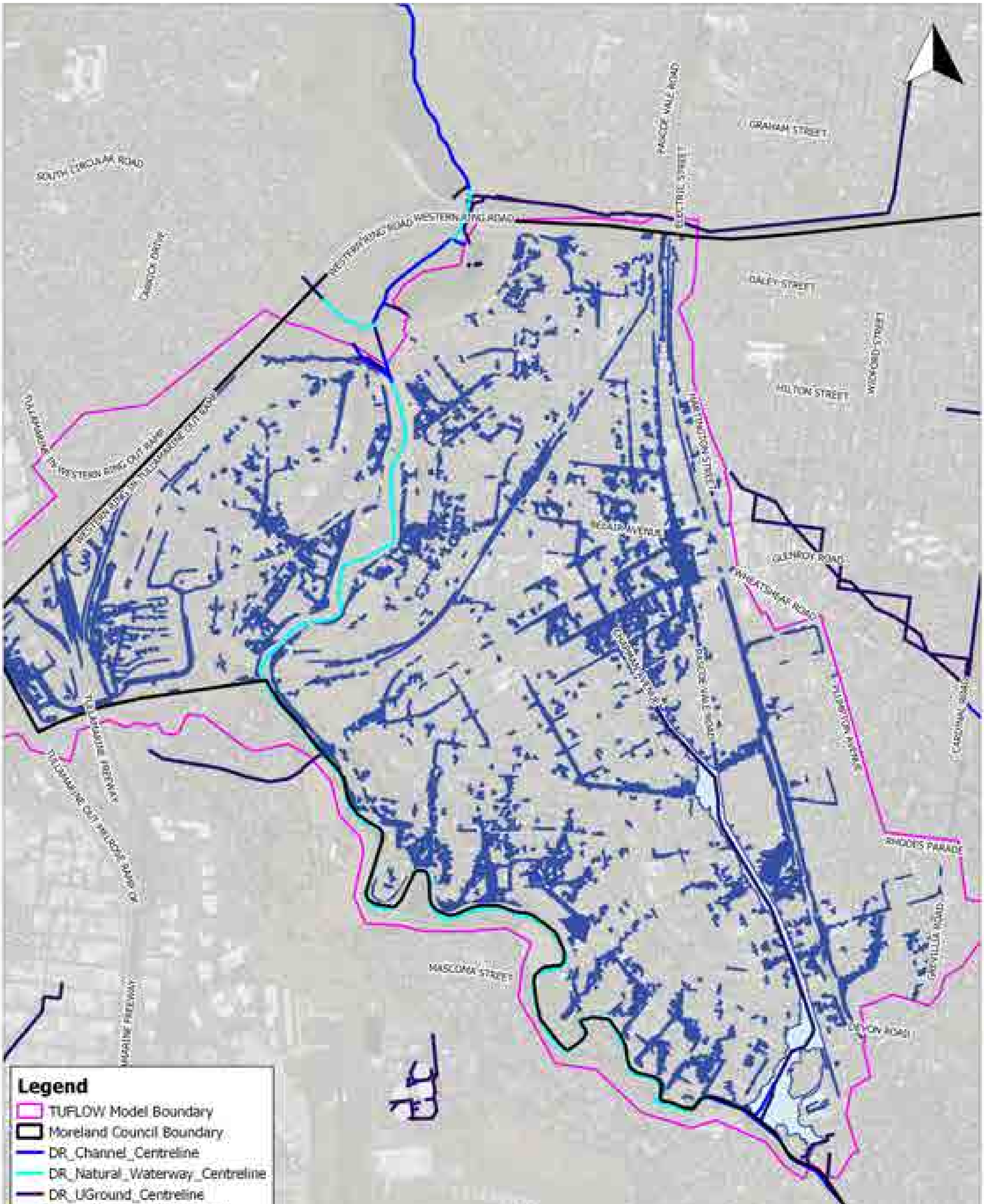
Scale in metres (1:15000 @ A3)

Moreland Flood Mapping
North East Catchments

20% AEP Peak Flood Depth Climate Change (Scenario D)

Job Number: V3000_127
Revision: D
Drawn: KS
Checked: DH
Date: 7/11/2022

Appendix E:
Flood Extent Maps



150 0 150 300 450 m

Scale in metres (1:13000 @ A3)

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

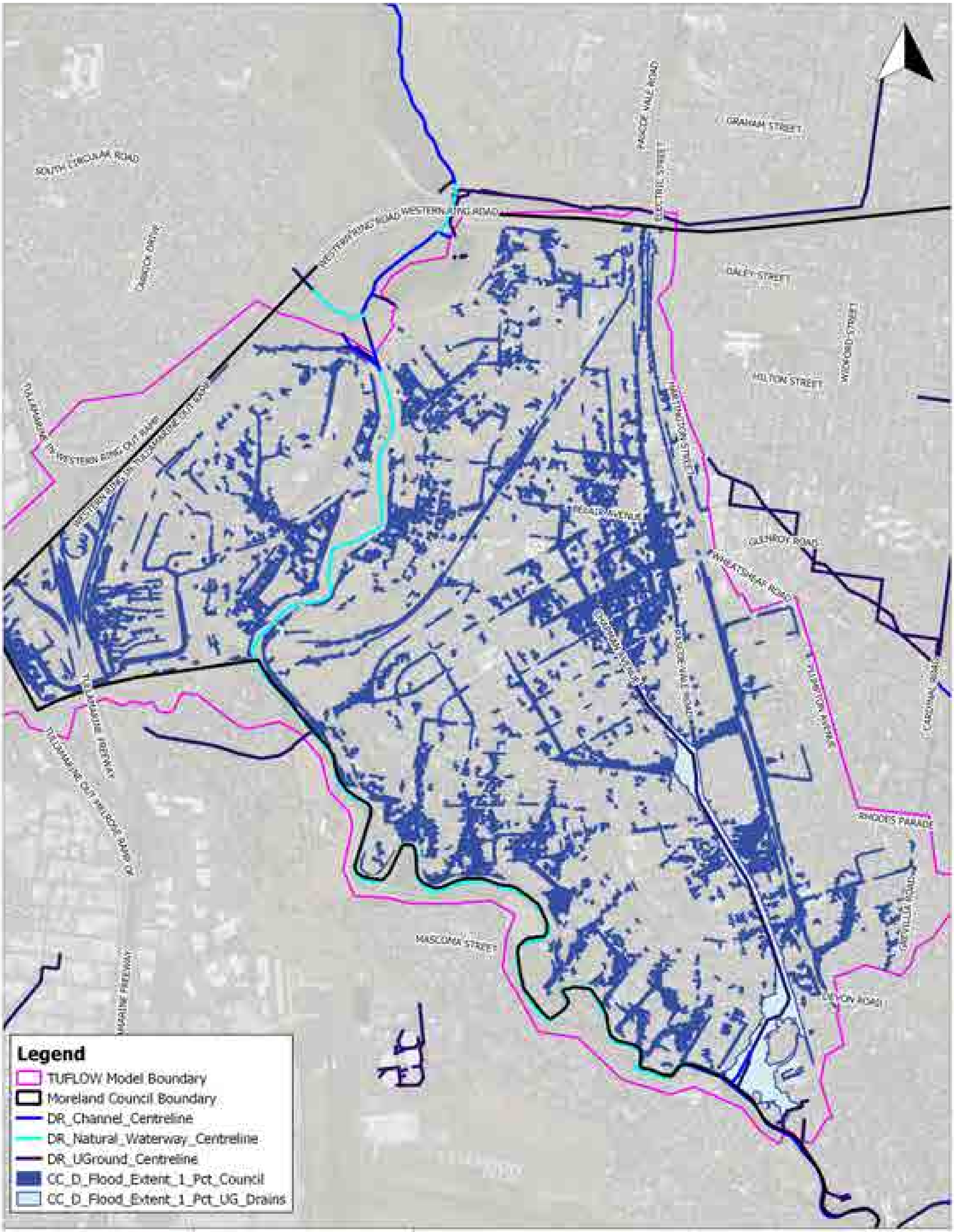
ENGENY

Melbourne Water

Moreland Flood Mapping
Chapman Main Drain Catchment

1 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



150 0 150 300 450 m

Scale in metres (1:13000 @ A3)

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

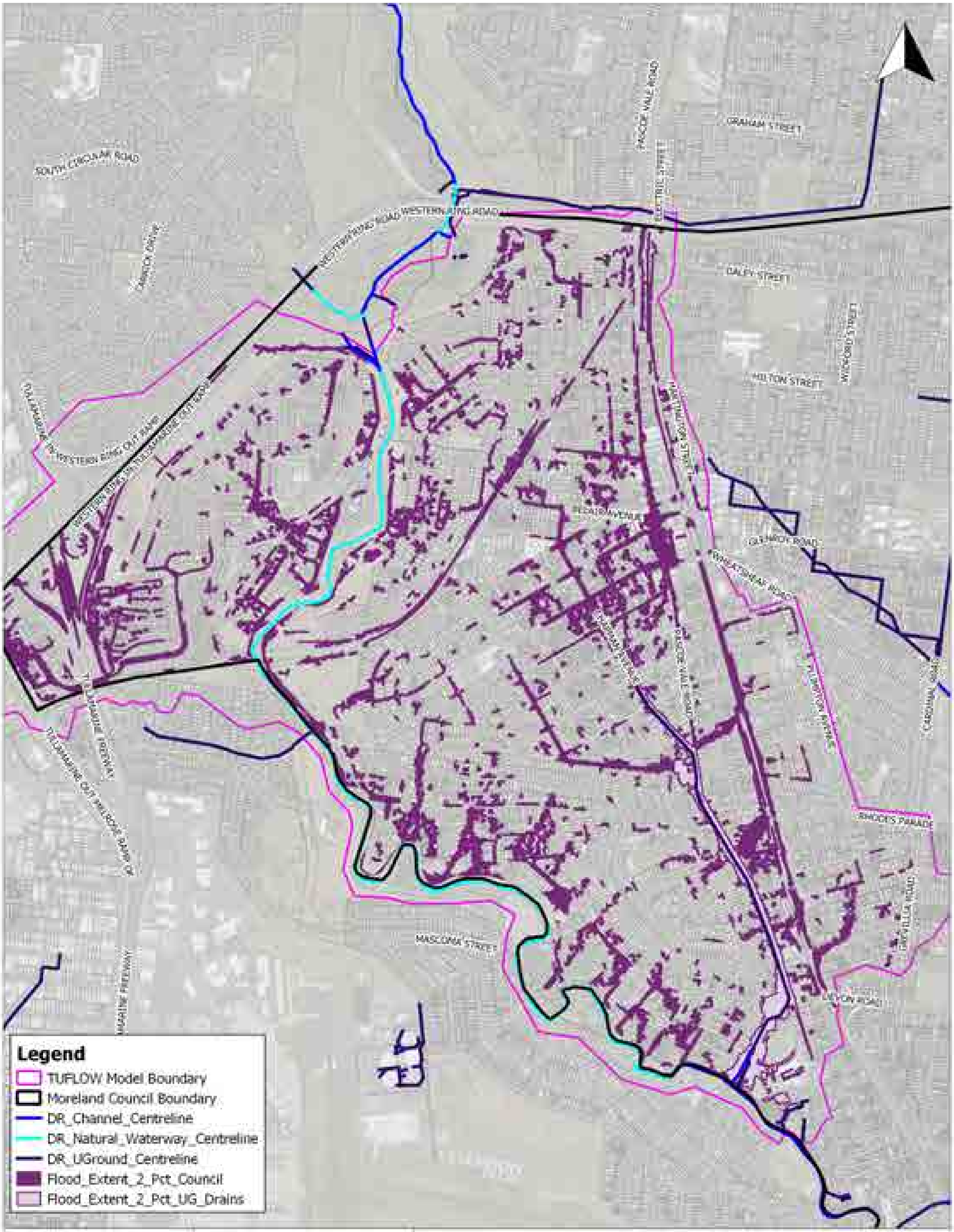
ENGENY

Melbourne Water

Moreland Flood Mapping
Chapman Main Drain Catchment

1 % AEP Flood Extent Climate Change (Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



ENGENY

150 0 150 300 450 m

Scale in metres (1:13000 @ A3)

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

Melbourne Water

Moreland Flood Mapping
Chapman Main Drain Catchment

2 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022

ENGENY

Melbourne Water

150 0 150 300 450 m

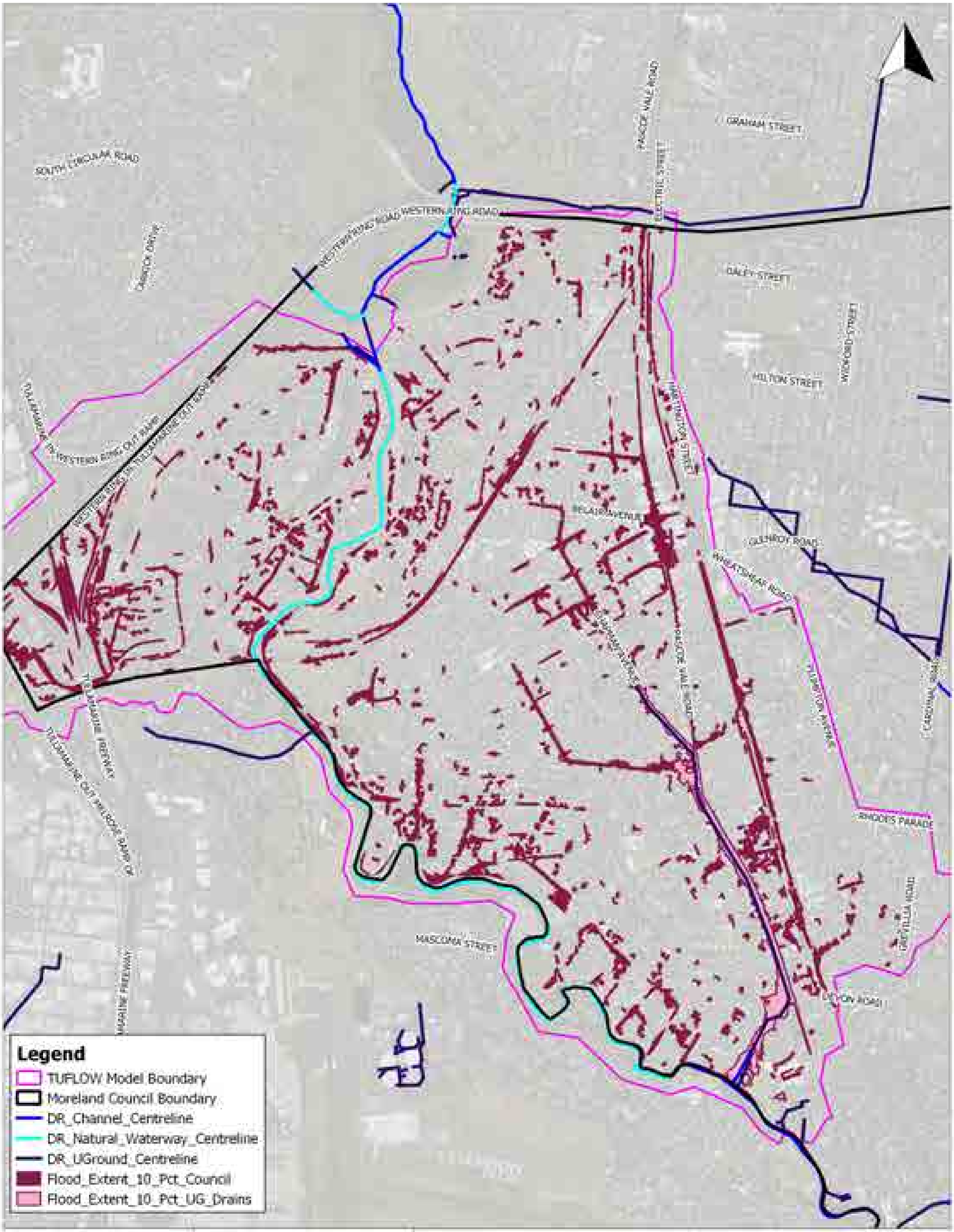
Scale in metres (1:13000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

5 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



150 0 150 300 450 m

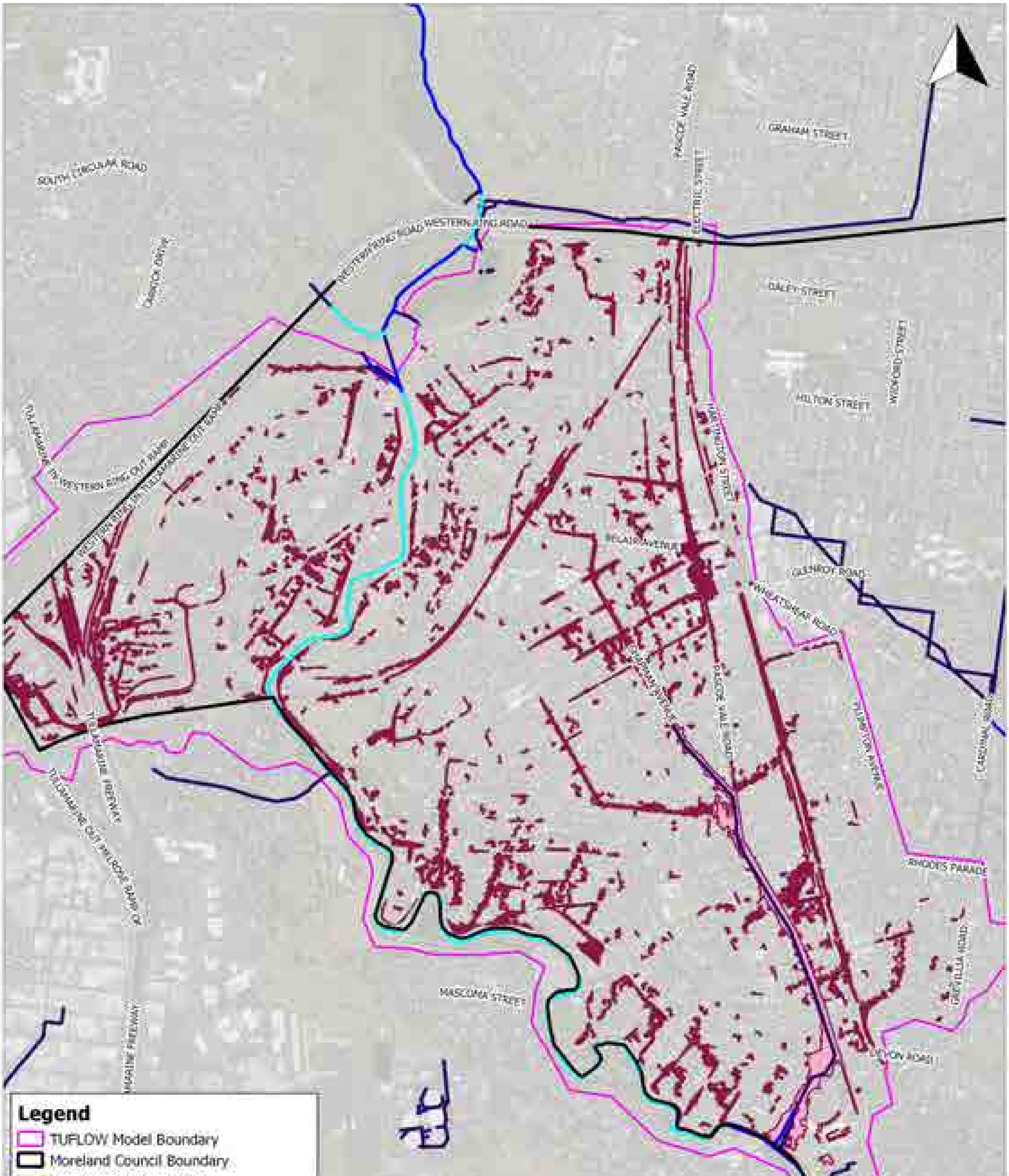
Scale in metres (1:13000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

10 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

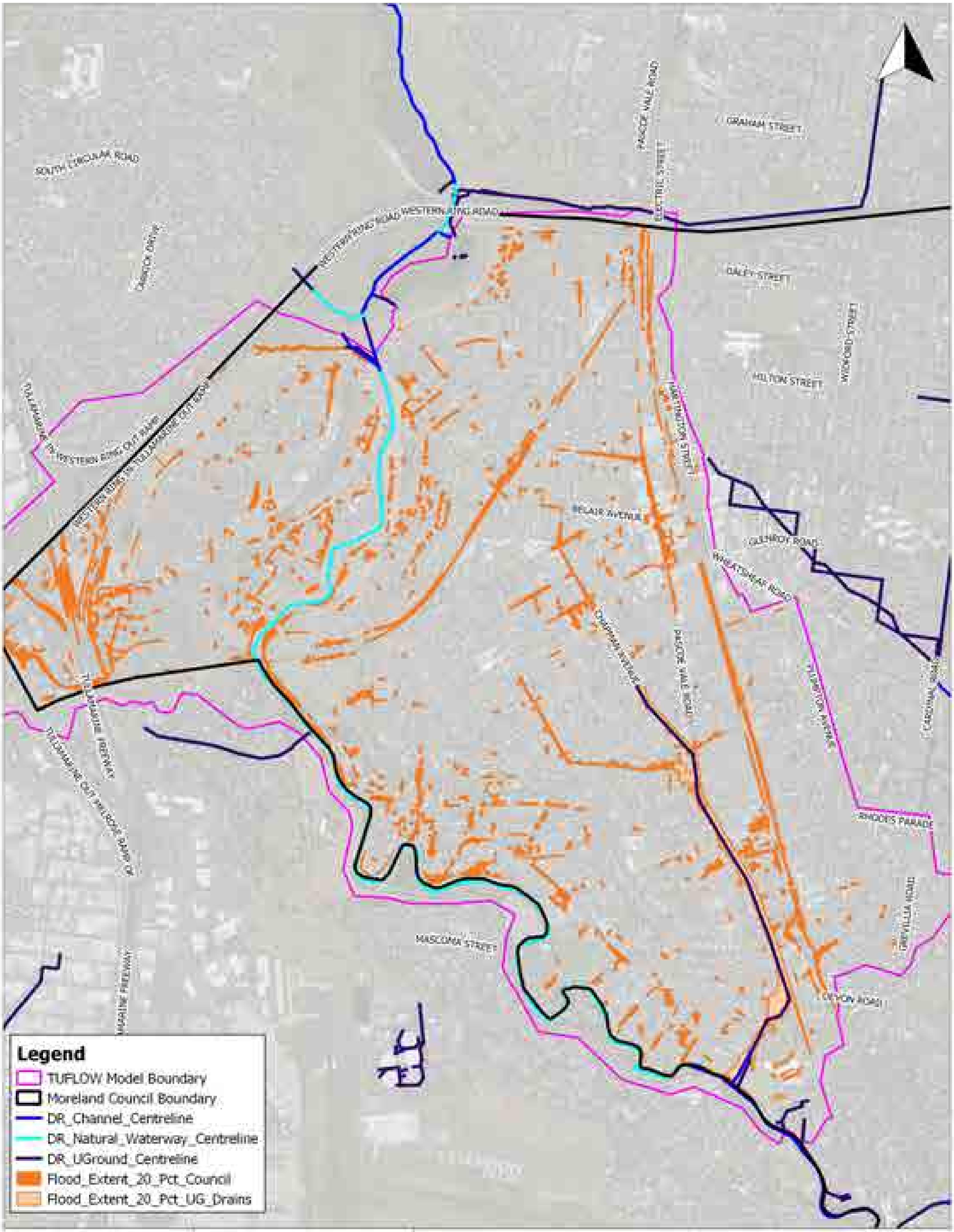
Scale in metres (1:10000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

10 % AEP Flood Extent Climate Change
(Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

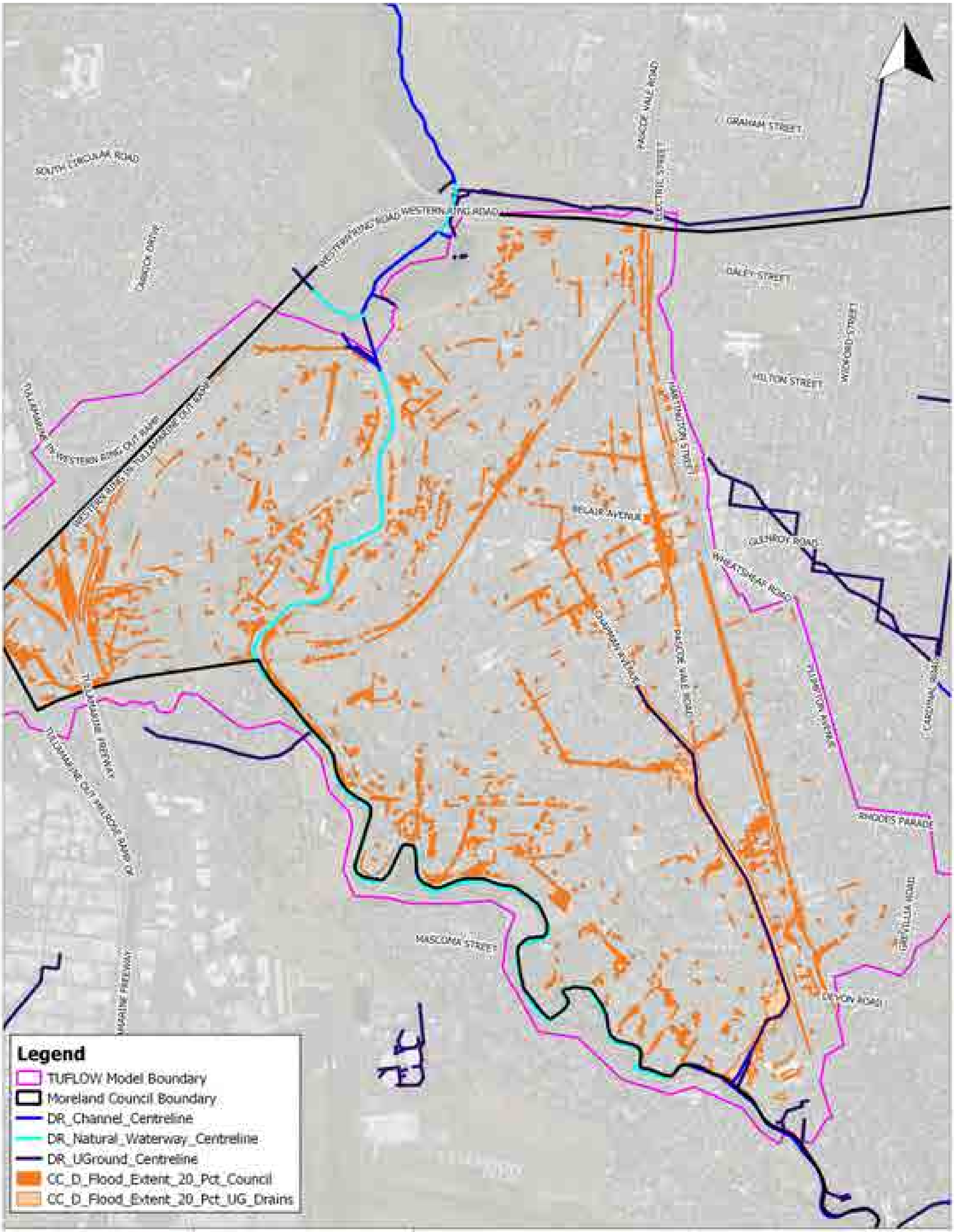
Scale in metres (1:10000 @ A3)

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

Moreland Flood Mapping
Chapman Main Drain Catchment

20 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022



150 0 150 300 450 m

Scale in metres (1:13000 @ A3)

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

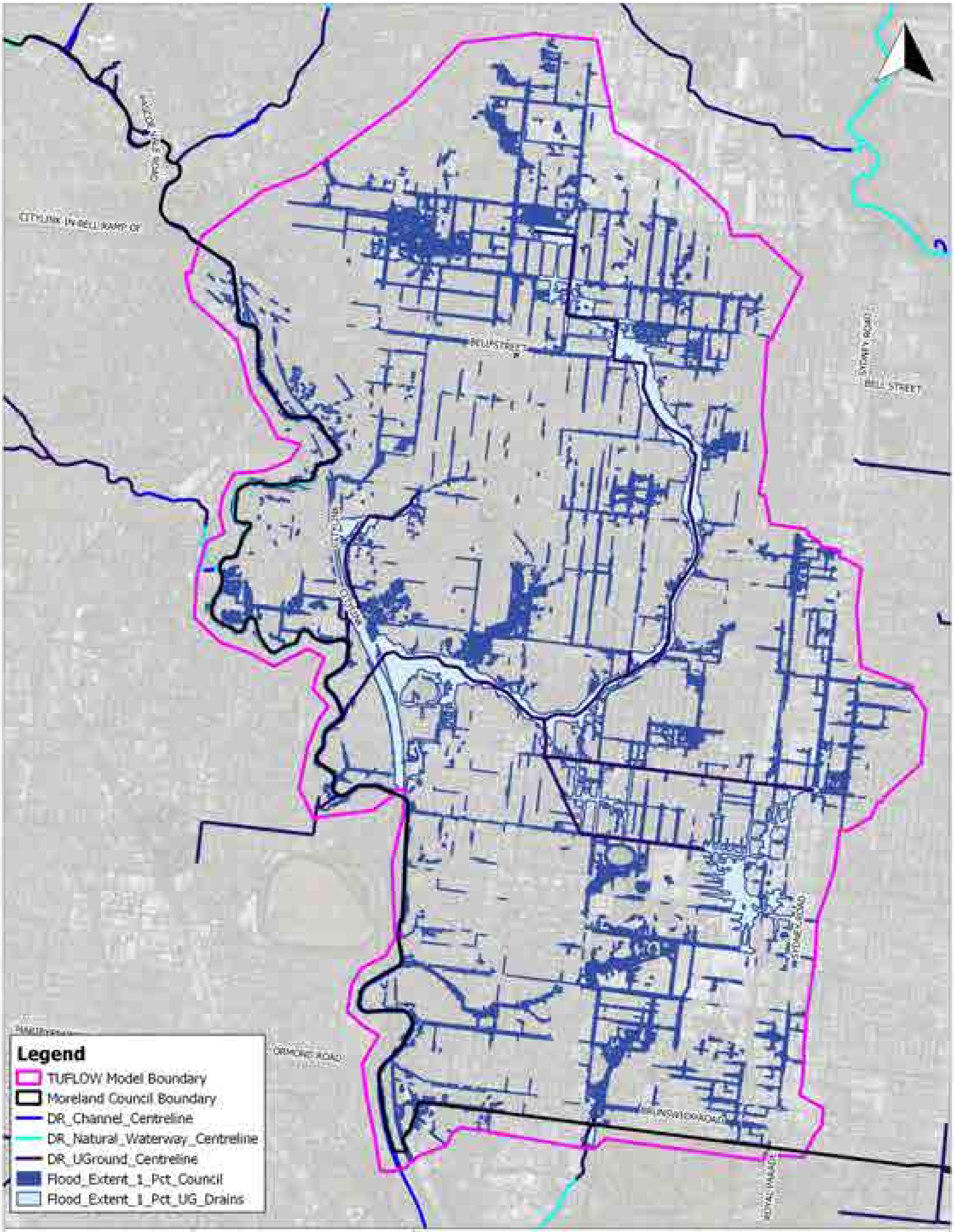
Moreland Flood Mapping
Chapman Main Drain Catchment

20 % AEP Flood Extent Climate Change (Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: KP
Checked: DH
Date: 4/2/2022

ENGENY

Melbourne Water



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

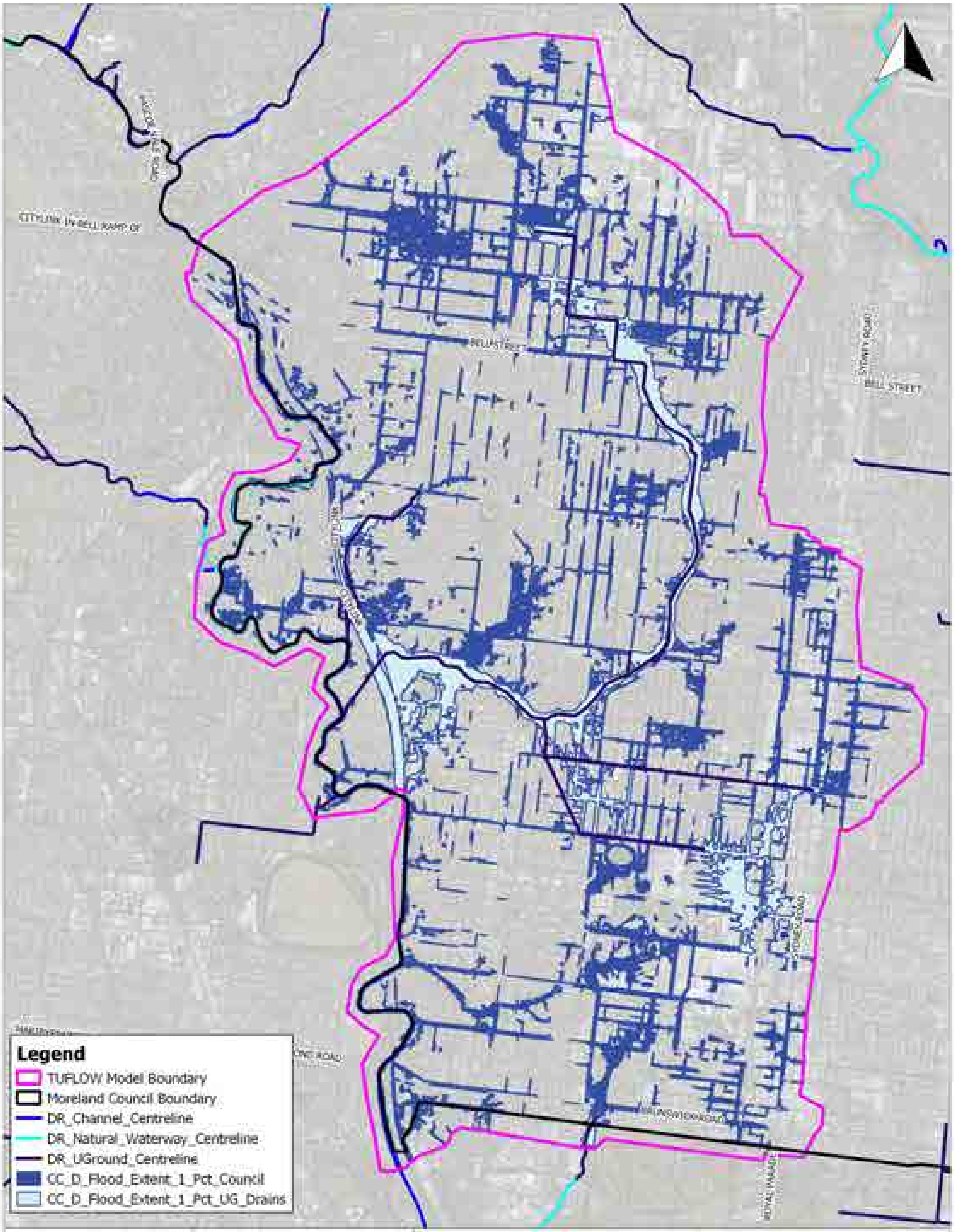
ENGENY

Melbourne Water

Moreland Flood Mapping
Melville Main Drain Catchment

1% AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

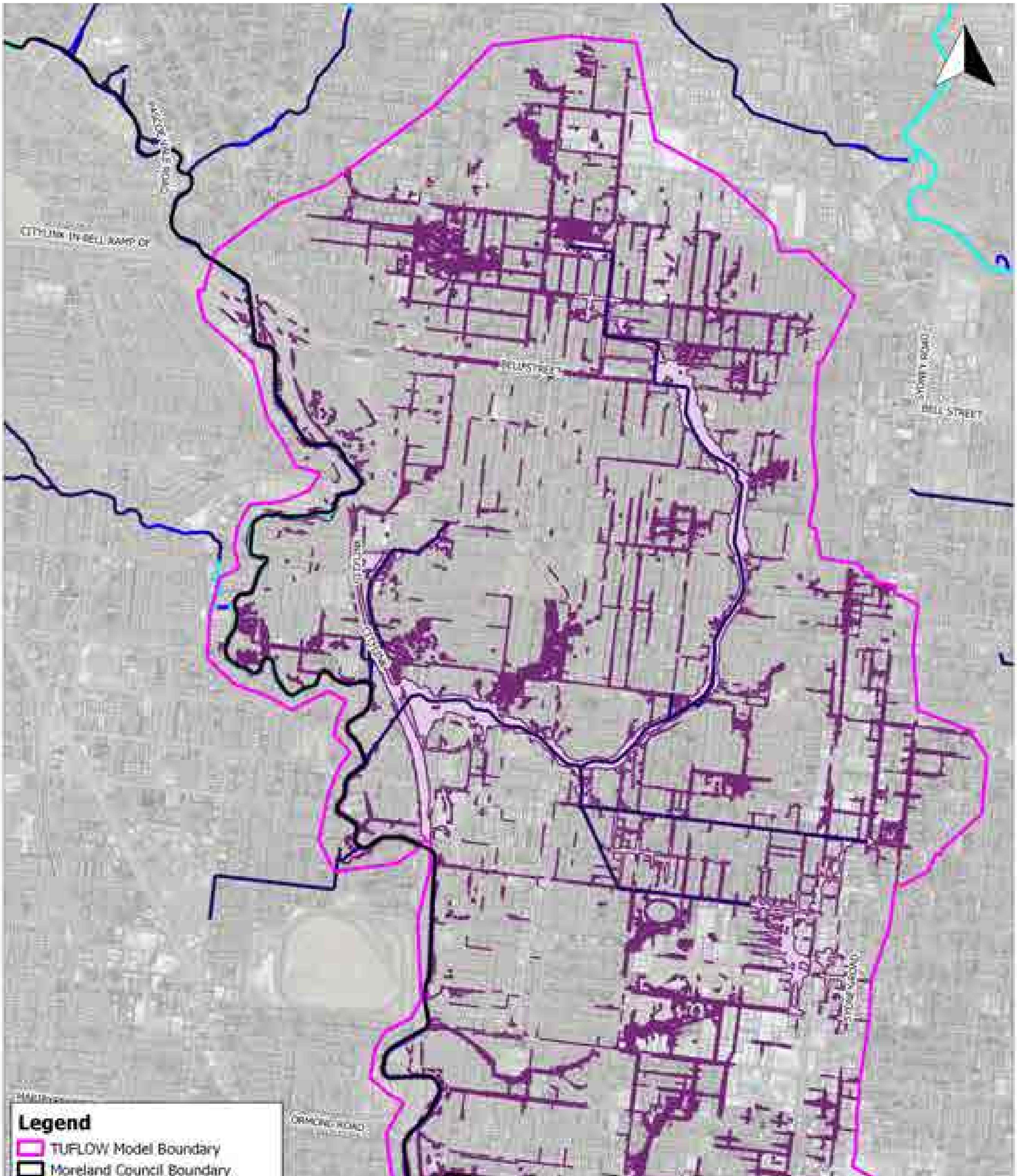
Scale in metres (1:18000 @ A3)

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

Moreland Flood Mapping
Melville Main Drain Catchment

1% AEP Flood Extent Climate Change
(Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



ENGENY

Melbourne Water

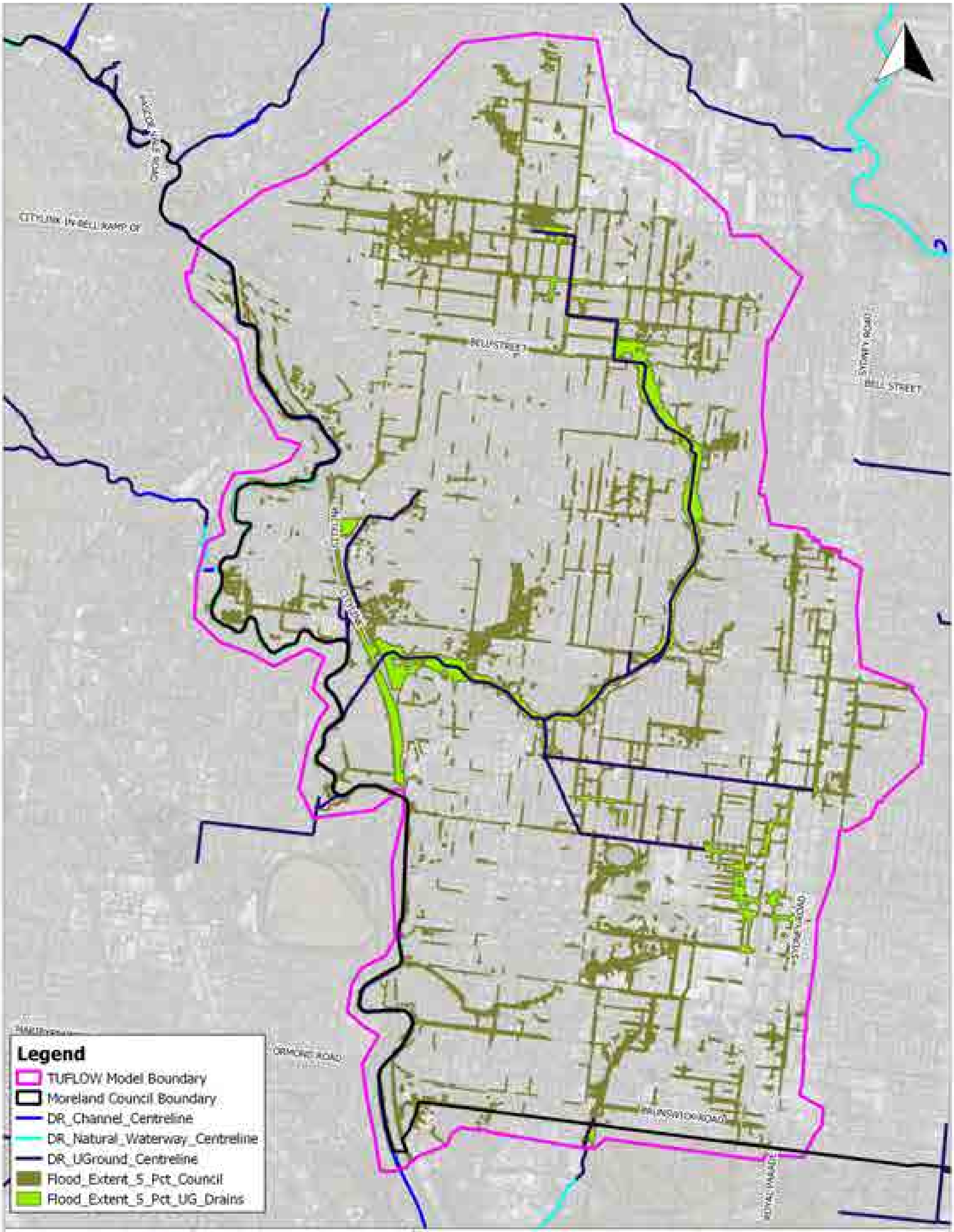
150 0 150 300 450 m

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

Moreland Flood Mapping
Melville Main Drain Catchment

2% AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



150 0 150 300 450 m

Scale in metres (1:18000 @ A3)

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

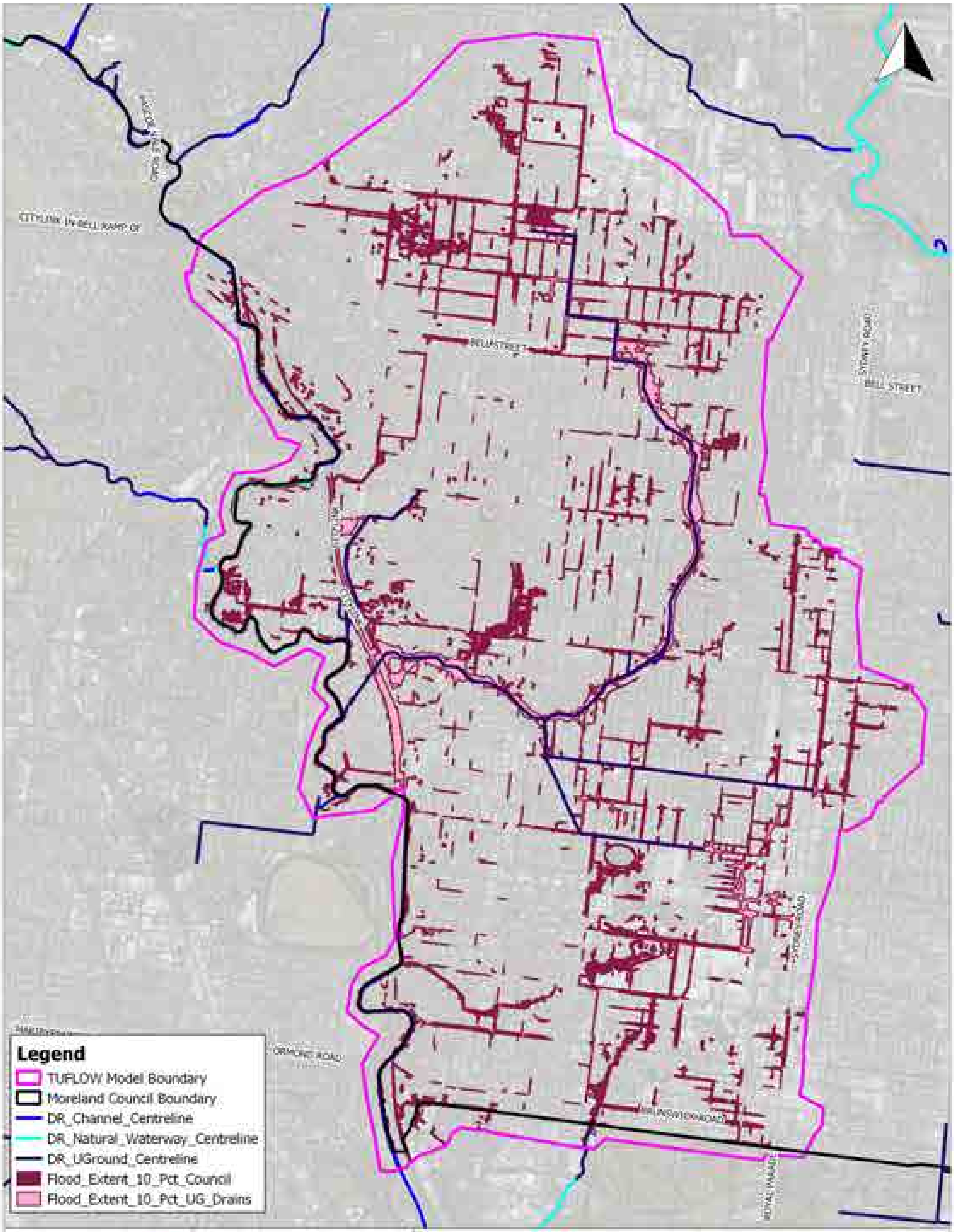
ENGENY

Melbourne Water

Moreland Flood Mapping
Melville Main Drain Catchment

5% AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



150 0 150 300 450 m

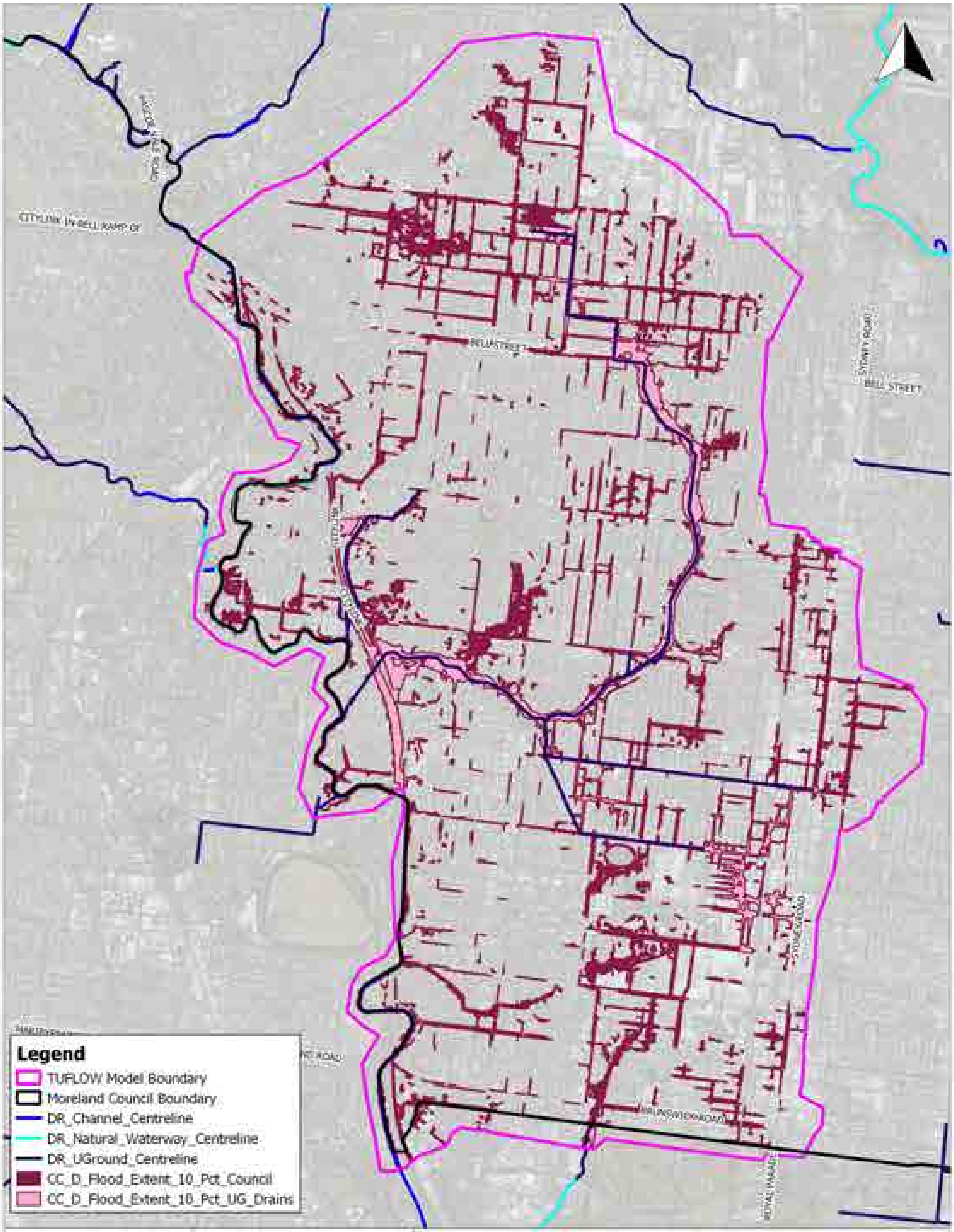
Scale in metres (1:18000 @ A3)

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

Moreland Flood Mapping
Melville Main Drain Catchment

10% AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



ENGENY

Melbourne Water

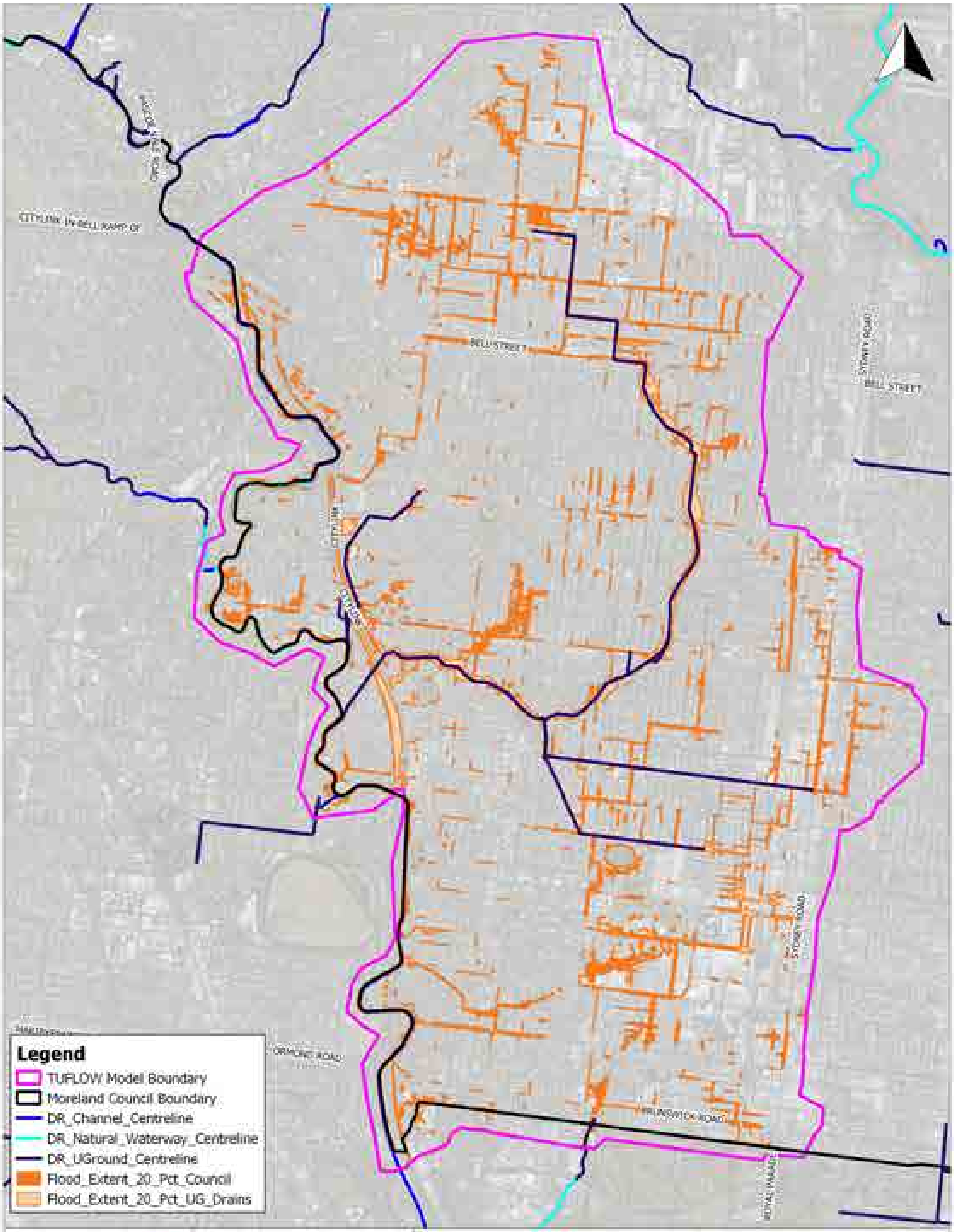
Scale in metres (1:18000 @ A3)

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

Moreland Flood Mapping
Melville Main Drain Catchment

10% AEP Flood Extent Climate Change
(Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



150 0 150 300 450 m

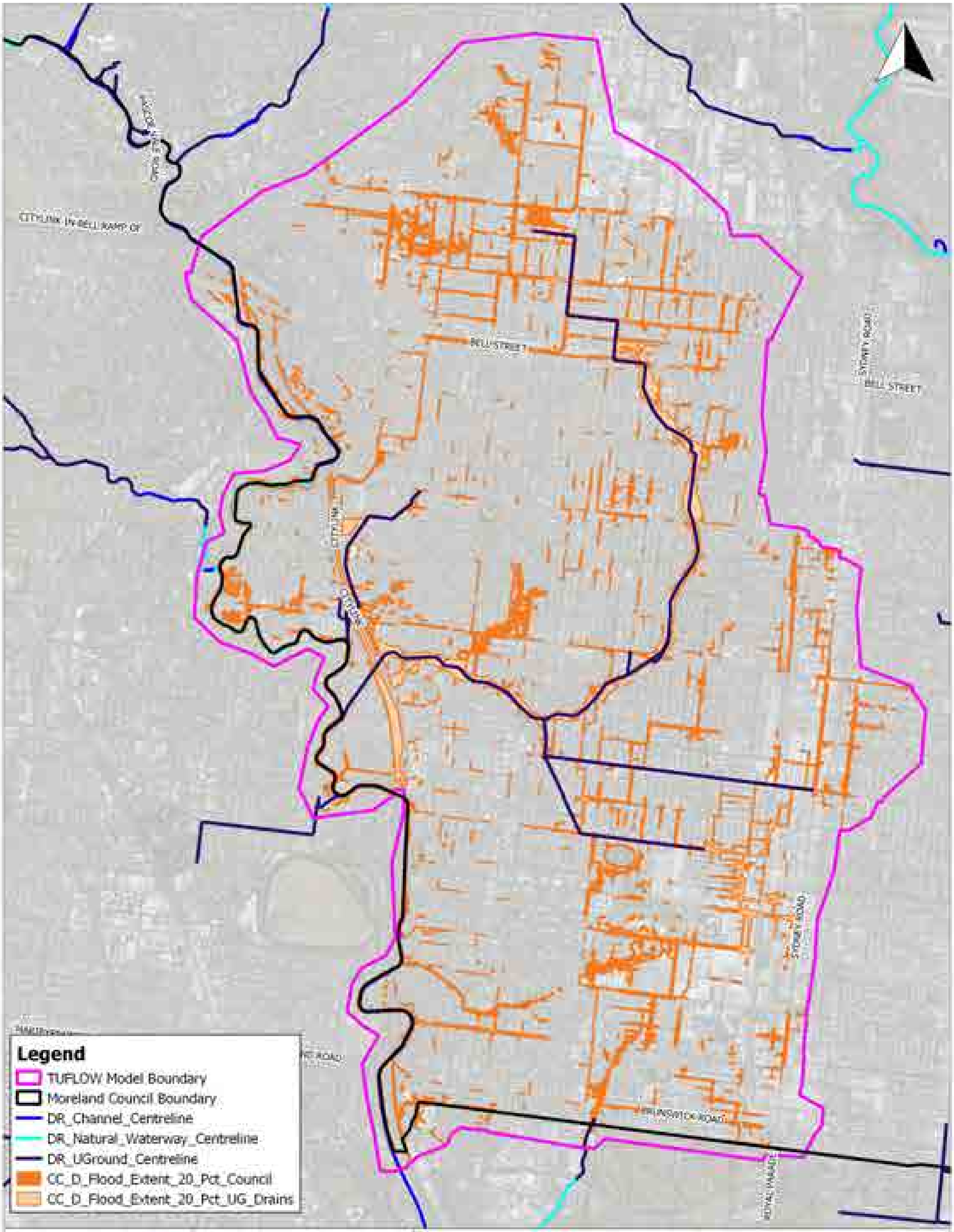
Scale in metres (1:18000 @ A3)

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

Moreland Flood Mapping
Melville Main Drain Catchment

20% AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



ENGENY

Melbourne Water

150 0 150 300 450 m

Scale in metres (1:18000 @ A3)

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia
Vertical Datum: Australia Height Datum
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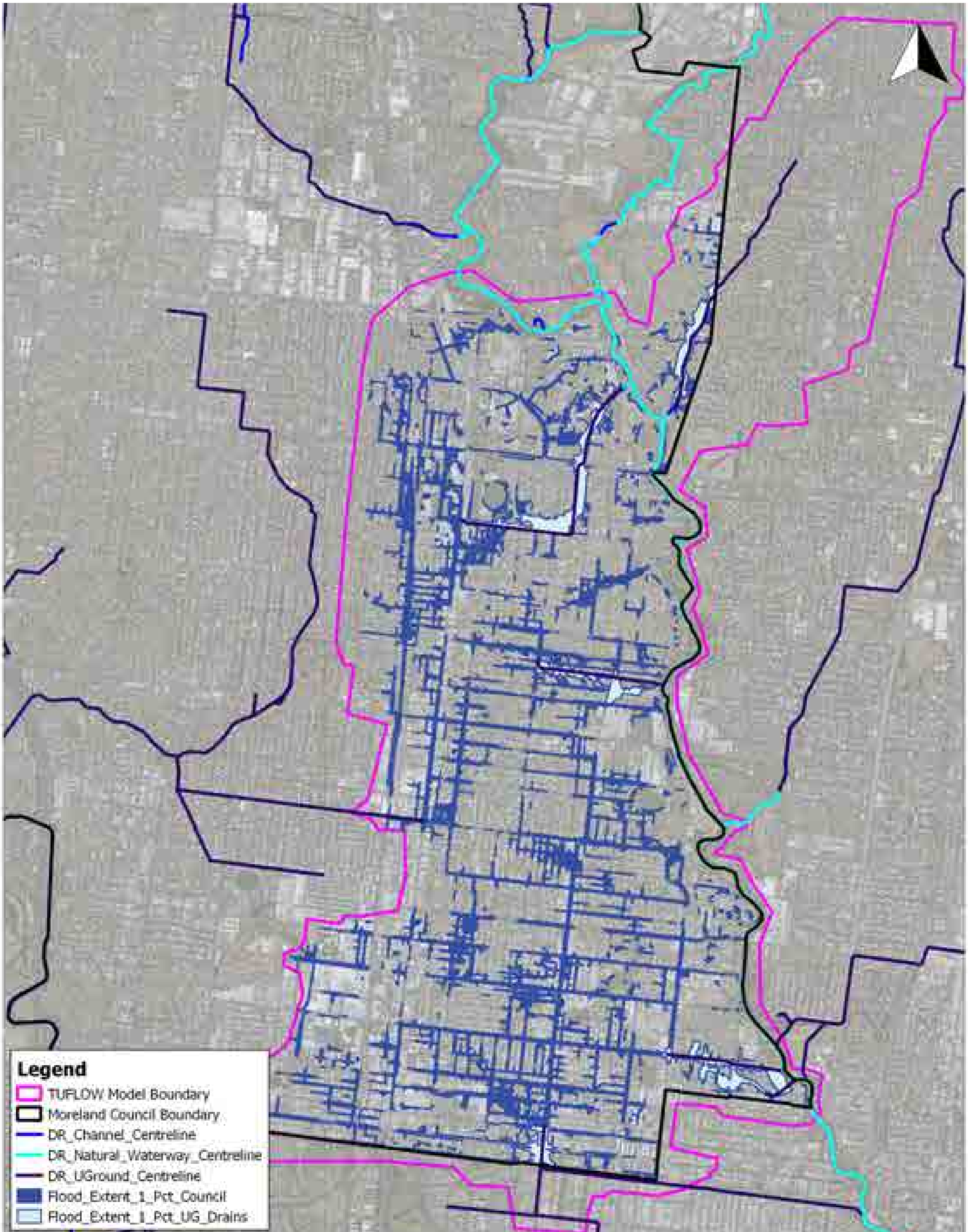
Moreland Flood Mapping
Melville Main Drain Catchment

20% AEP Flood Extent Climate Change
(Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 28/2/2022



ENGENY

Melbourne Water

350 0 350 700 m

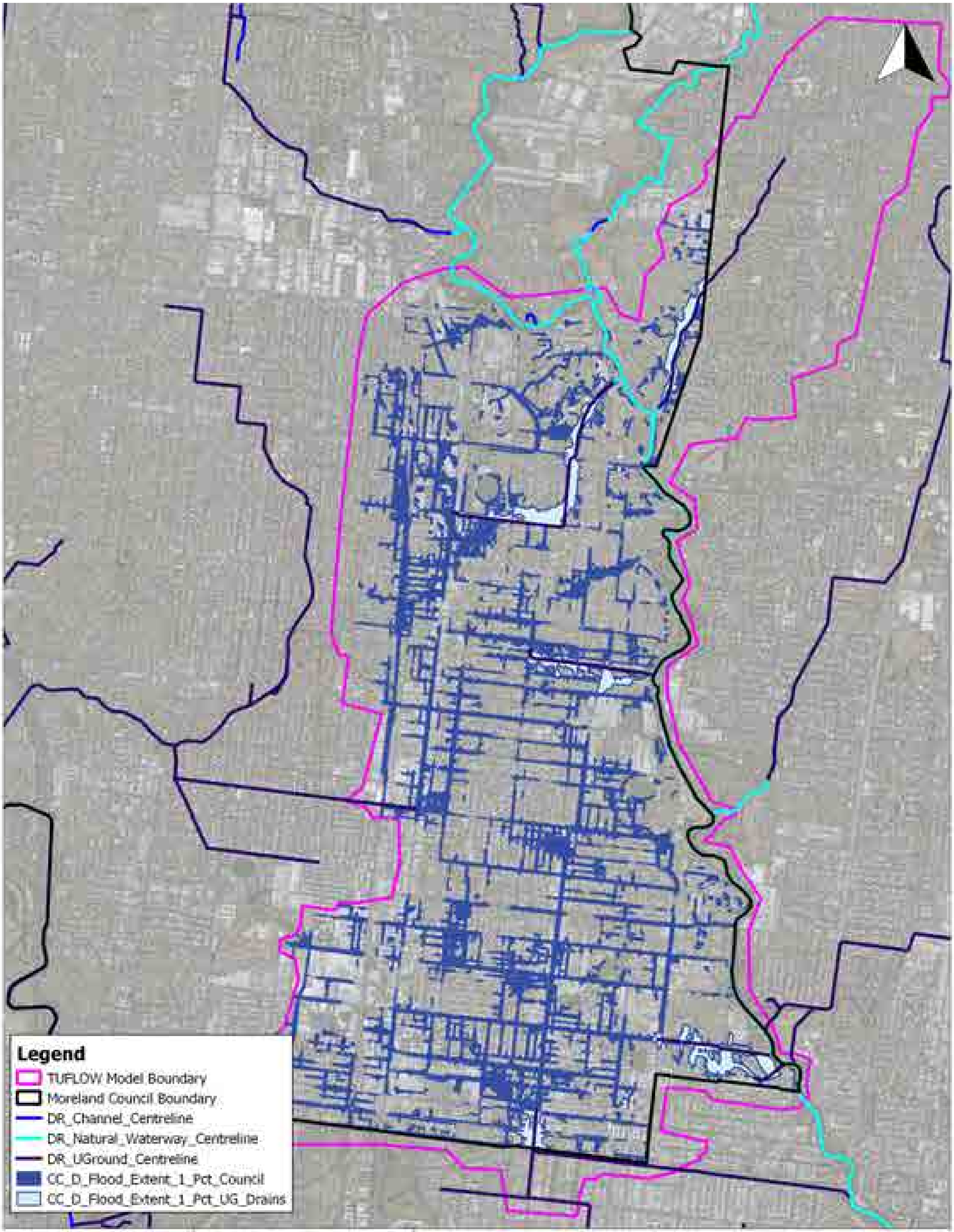
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

1 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



350 0 350 700 m

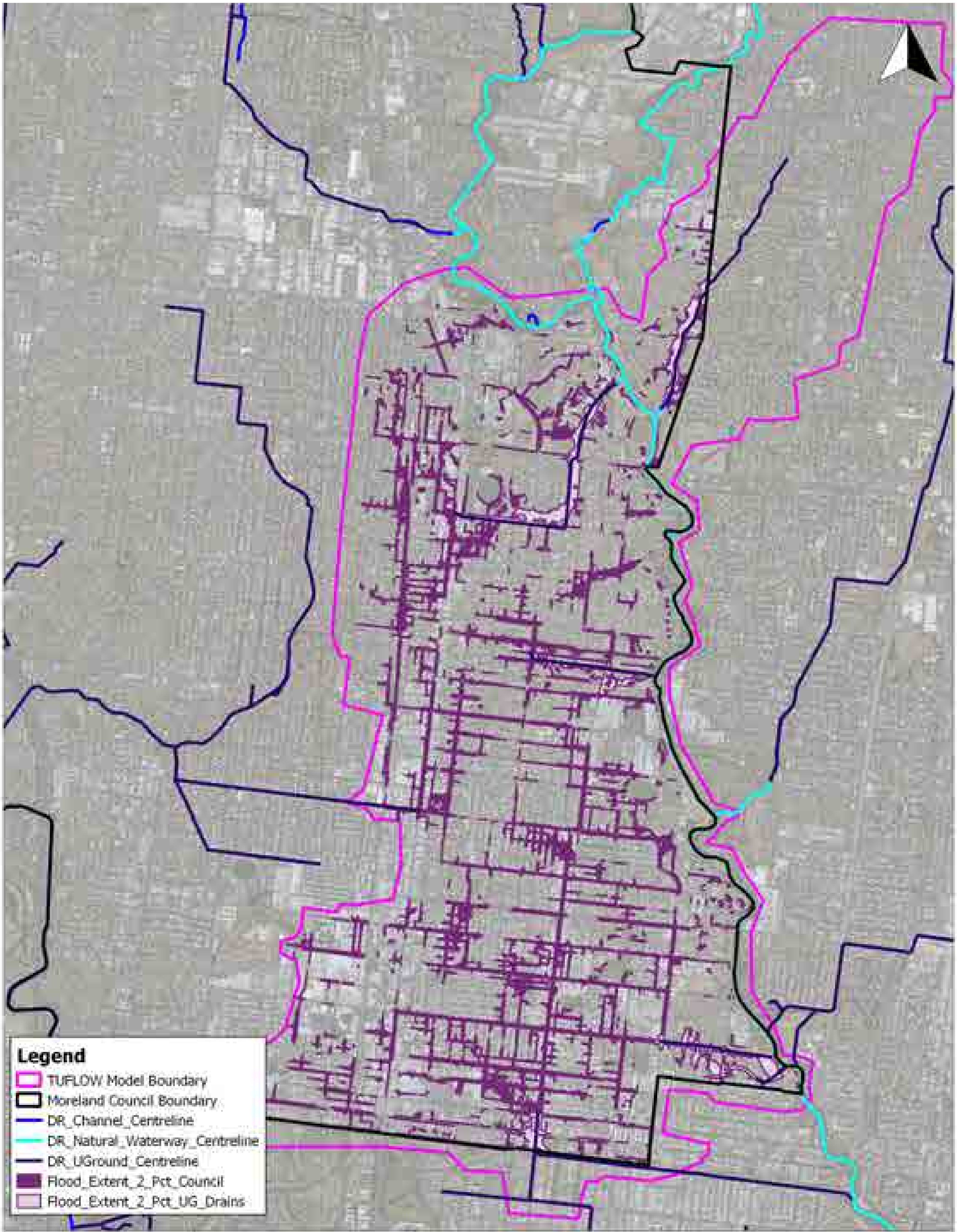
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

1 % AEP Flood Extent Climate Change
(Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

350 0 350 700 m

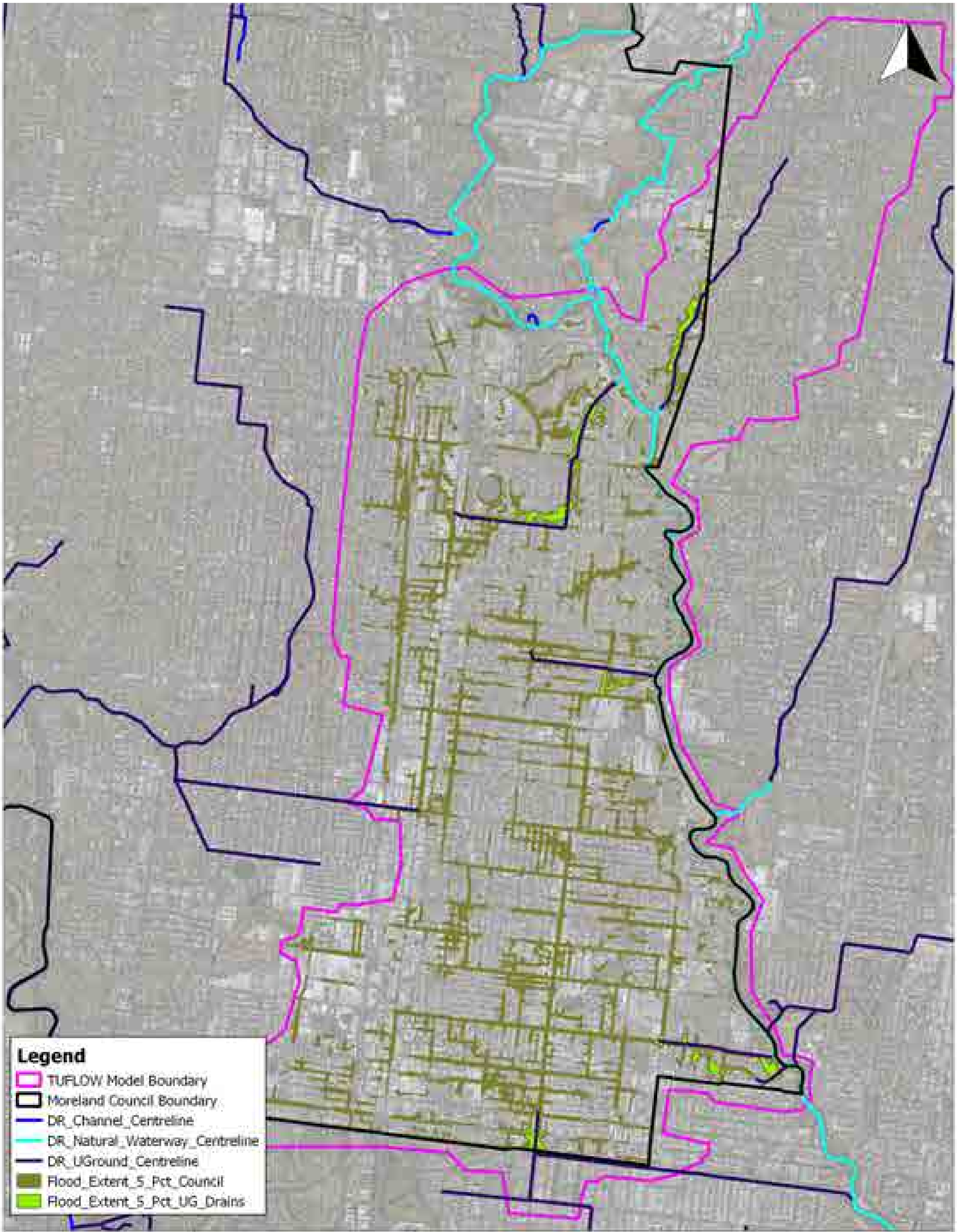
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

2 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

350 0 350 700 m

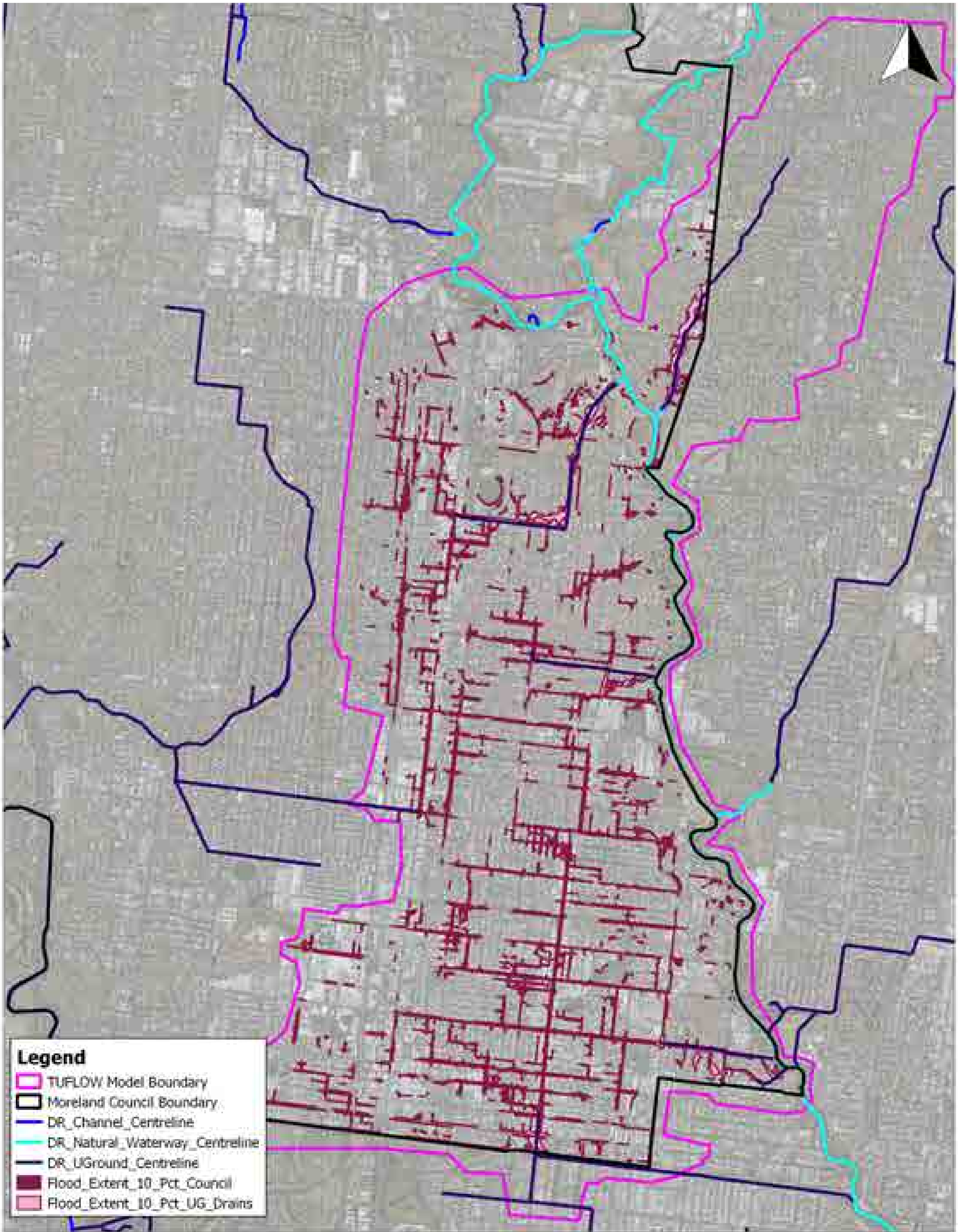
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

5 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

350 0 350 700 m

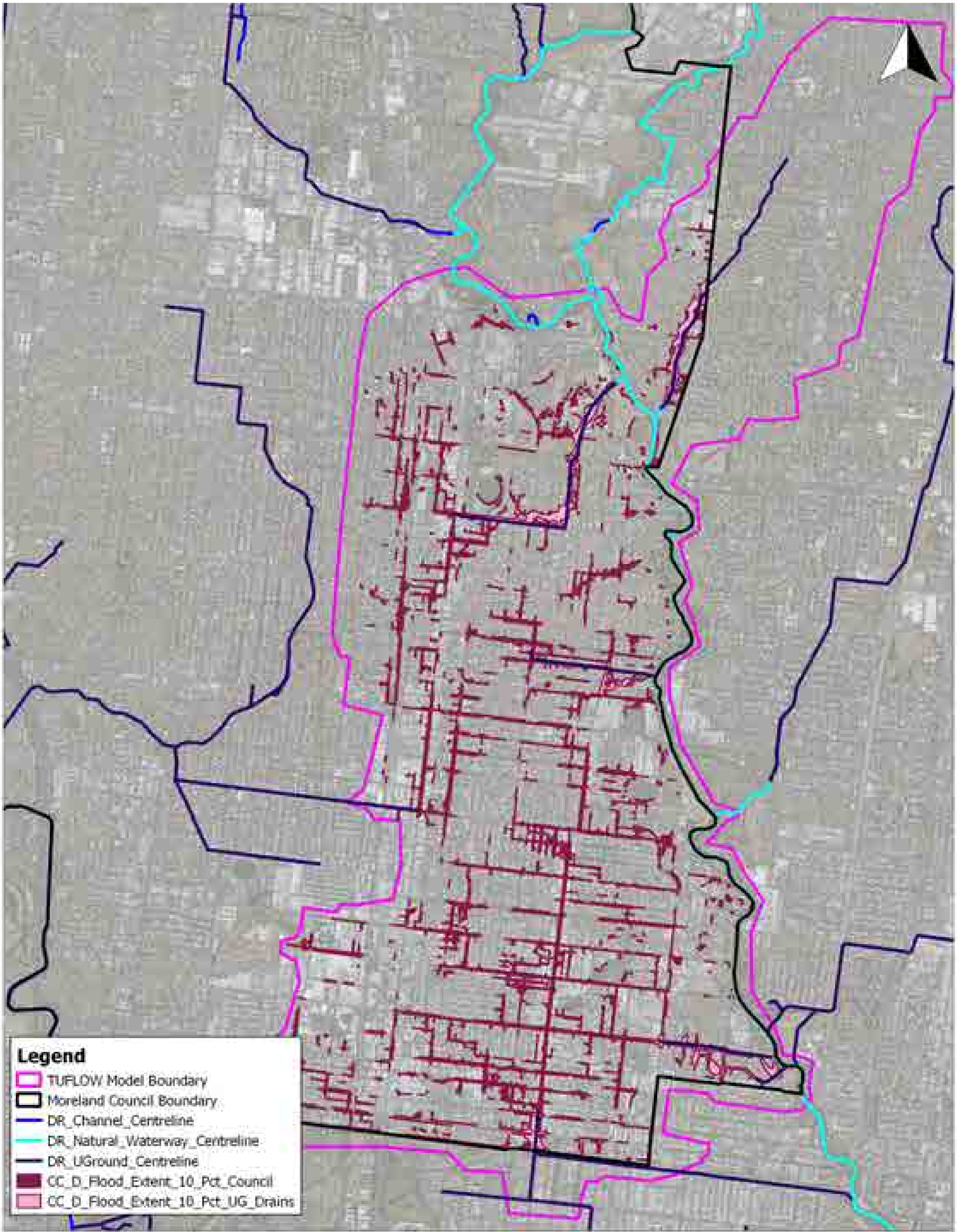
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

10 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

350 0 350 700 m

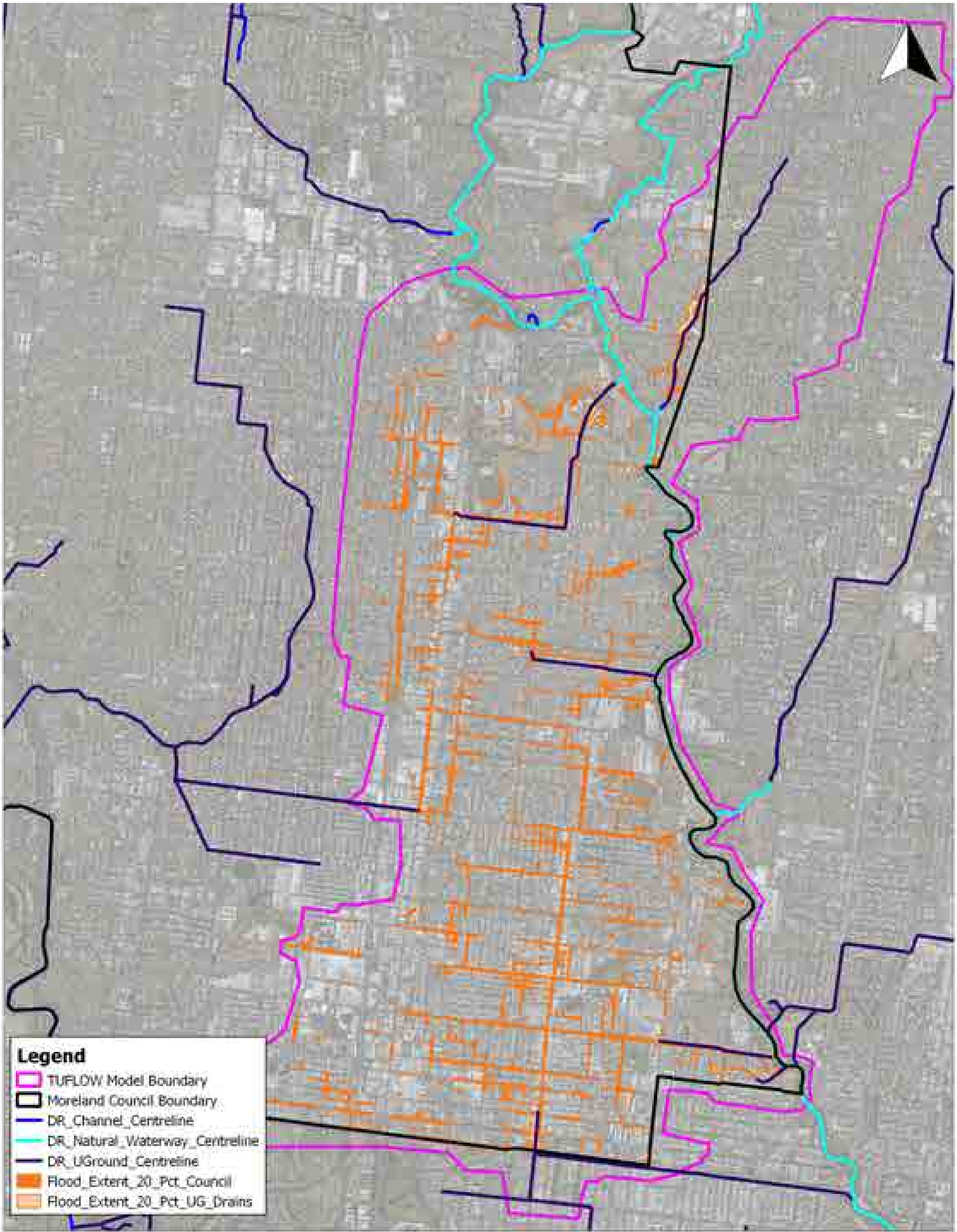
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

10 % AEP Flood Extent Climate Change (Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

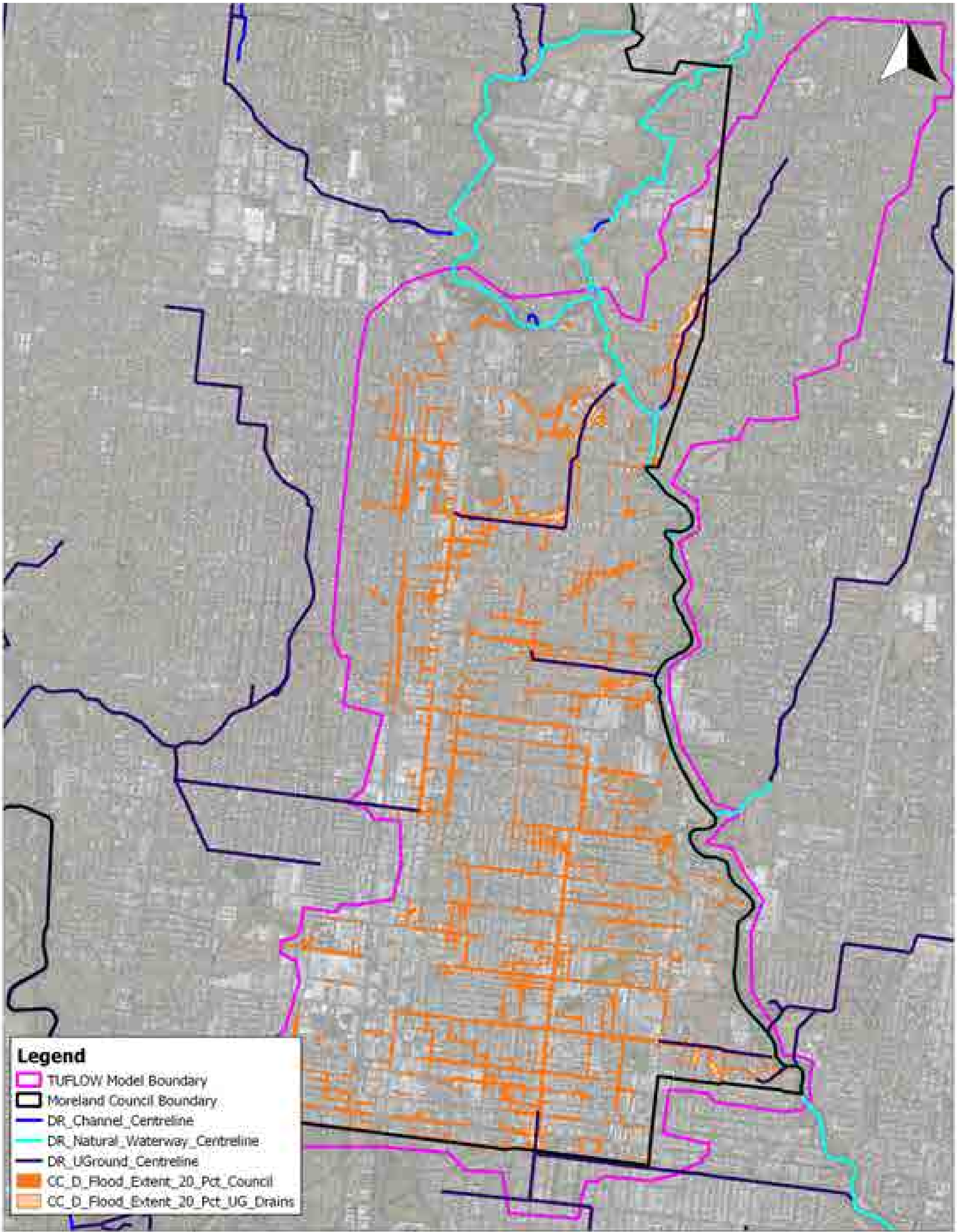
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

20 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

350 0 350 700 m

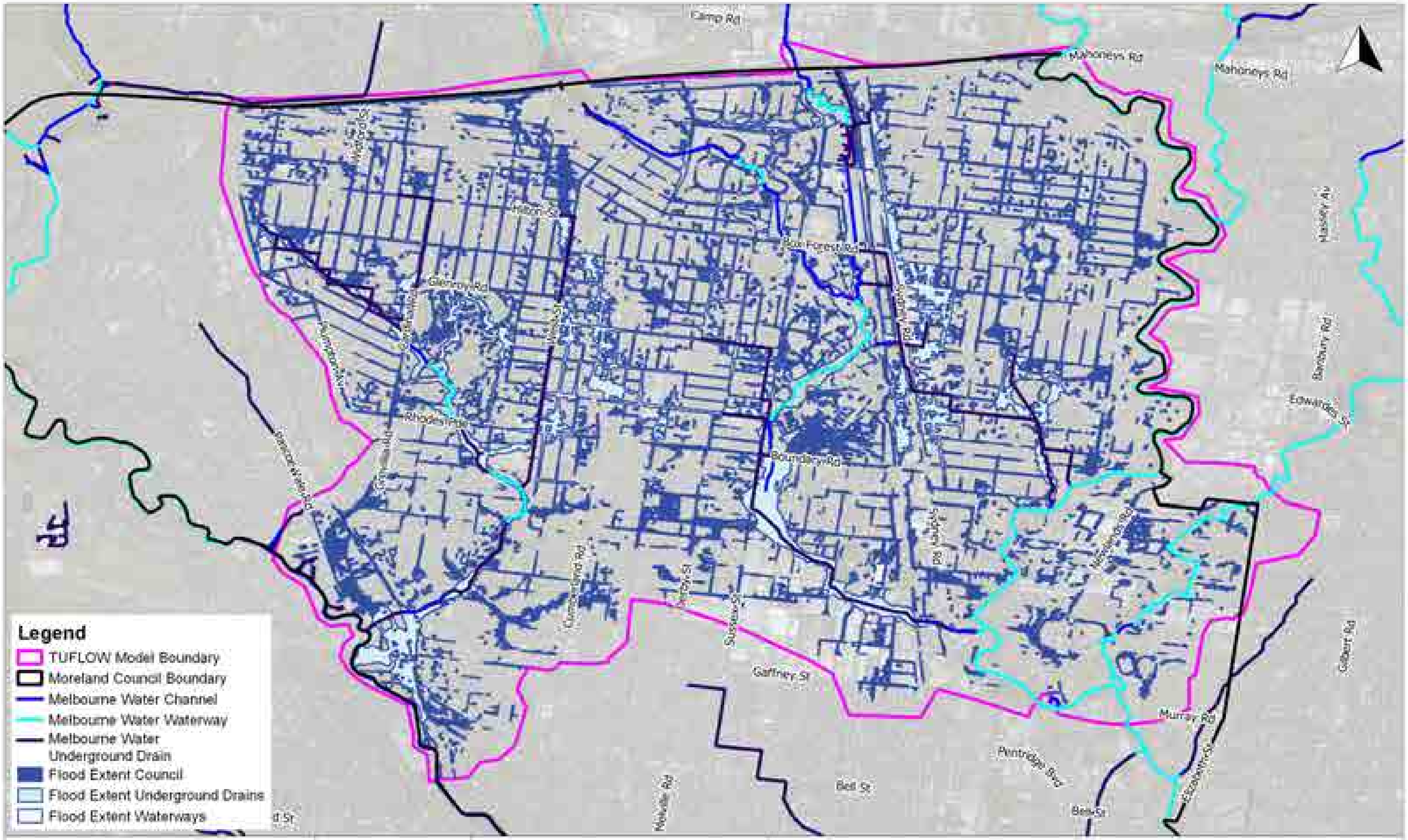
Scale in metres (1:20,000@ A3)

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

Moreland Flood Mapping
South-East Catchment

20 % AEP Flood Extent Climate Change
(Scenario D)

Job Number: V3000_127
Revision: 0
Drawn: HG
Checked: DH
Date: 19/5/2022



ENGENY

Melbourne Water

250 0 250 500 750 1000 m

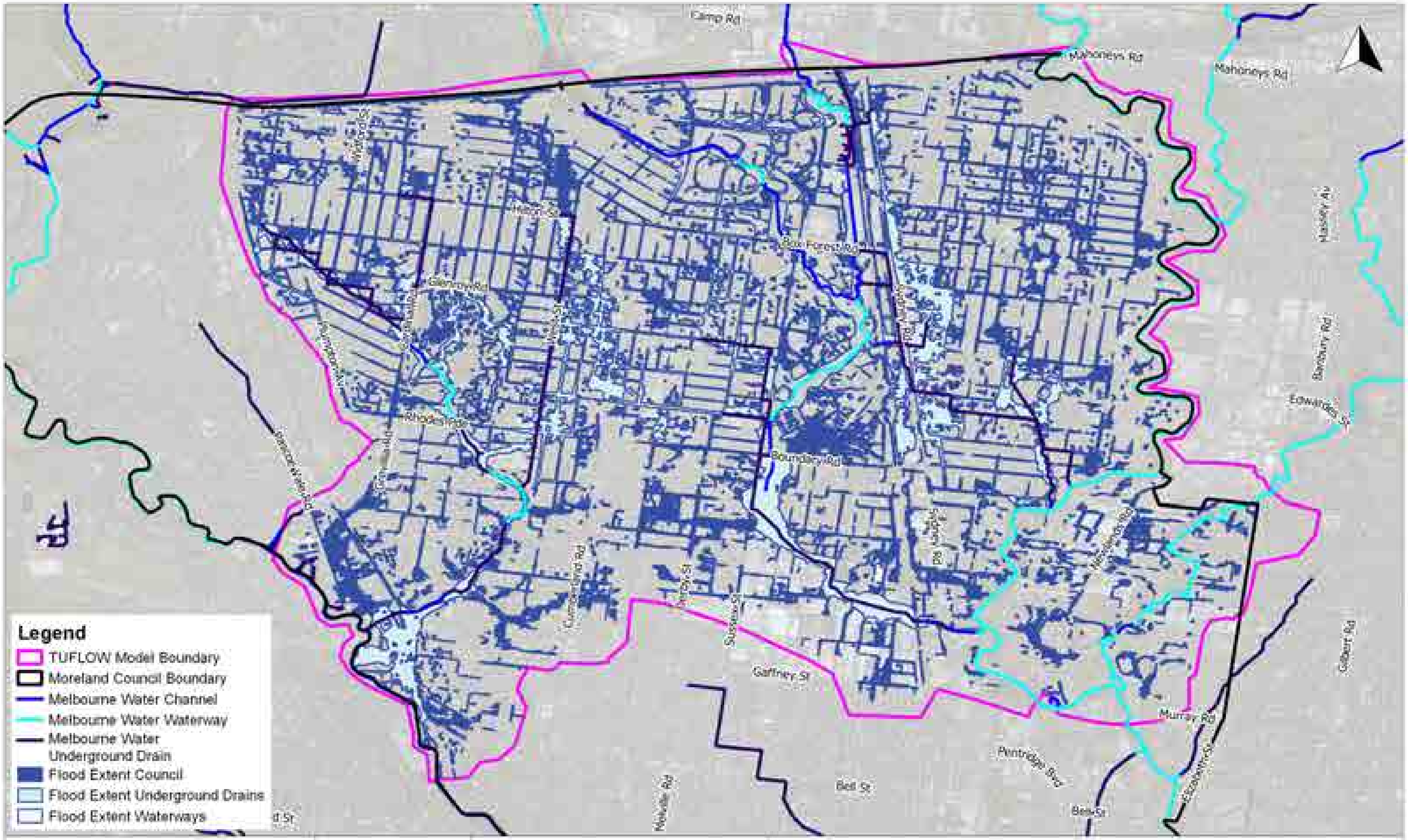
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

1 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: KS
Checked: DH
Date: 7/11/2022



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VIC 8006
www.engeny.com.au
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F: 03 9830 2601
E: melb@engeny.com.au

ENGENY

Melbourne Water

250 0 250 500 750 1000 m

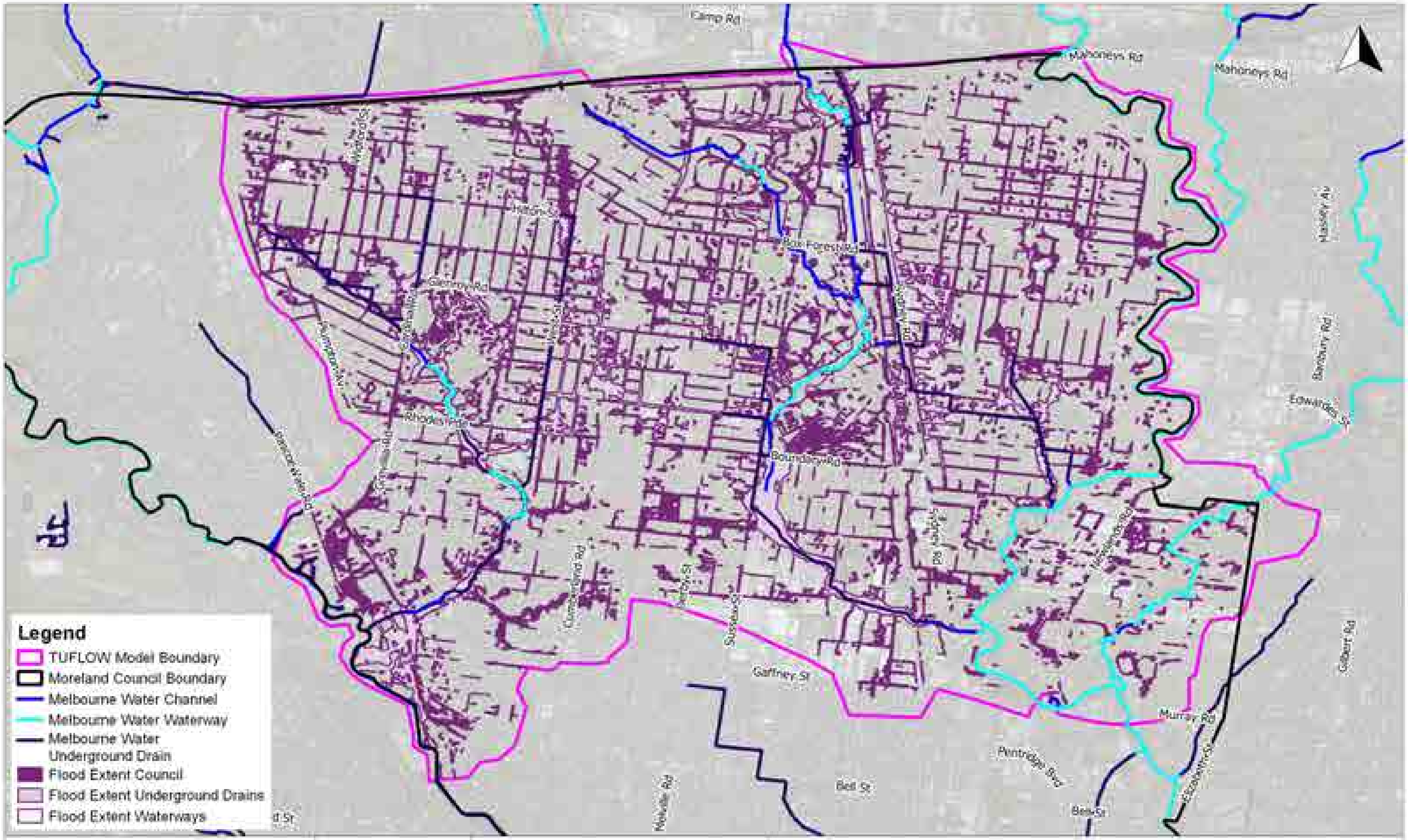
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

1 % AEP Flood Extent Climate Change
(Scenario D)

Job Number: V3000_127
Revision: D
Drawn: KS
Checked: DH
Date: 7/11/2022



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E: mail@engeny.com.au

ENGENY

Melbourne Water

250 0 250 500 750 1000 m

Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

2 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: KS
Checked: DH
Date: 7/11/2022

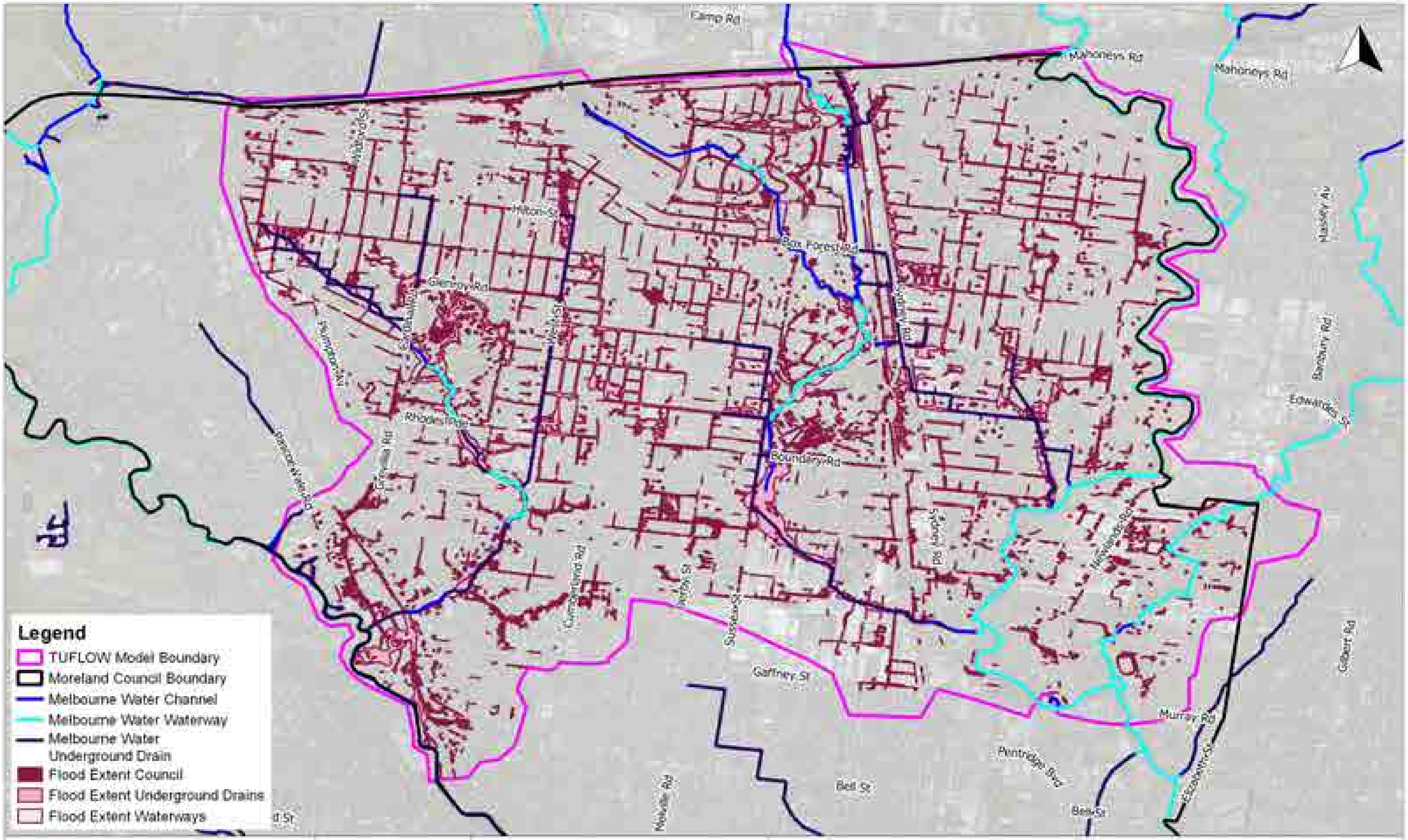
250 0 250 500 750 1000 m

Scale in metres (1:15000 @ A3)

Moreland Flood Mapping
North East Catchments

5 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: KS
Checked: DH
Date: 7/11/2022



ENGENY

Melbourne Water

250 0 250 500 750 1000 m

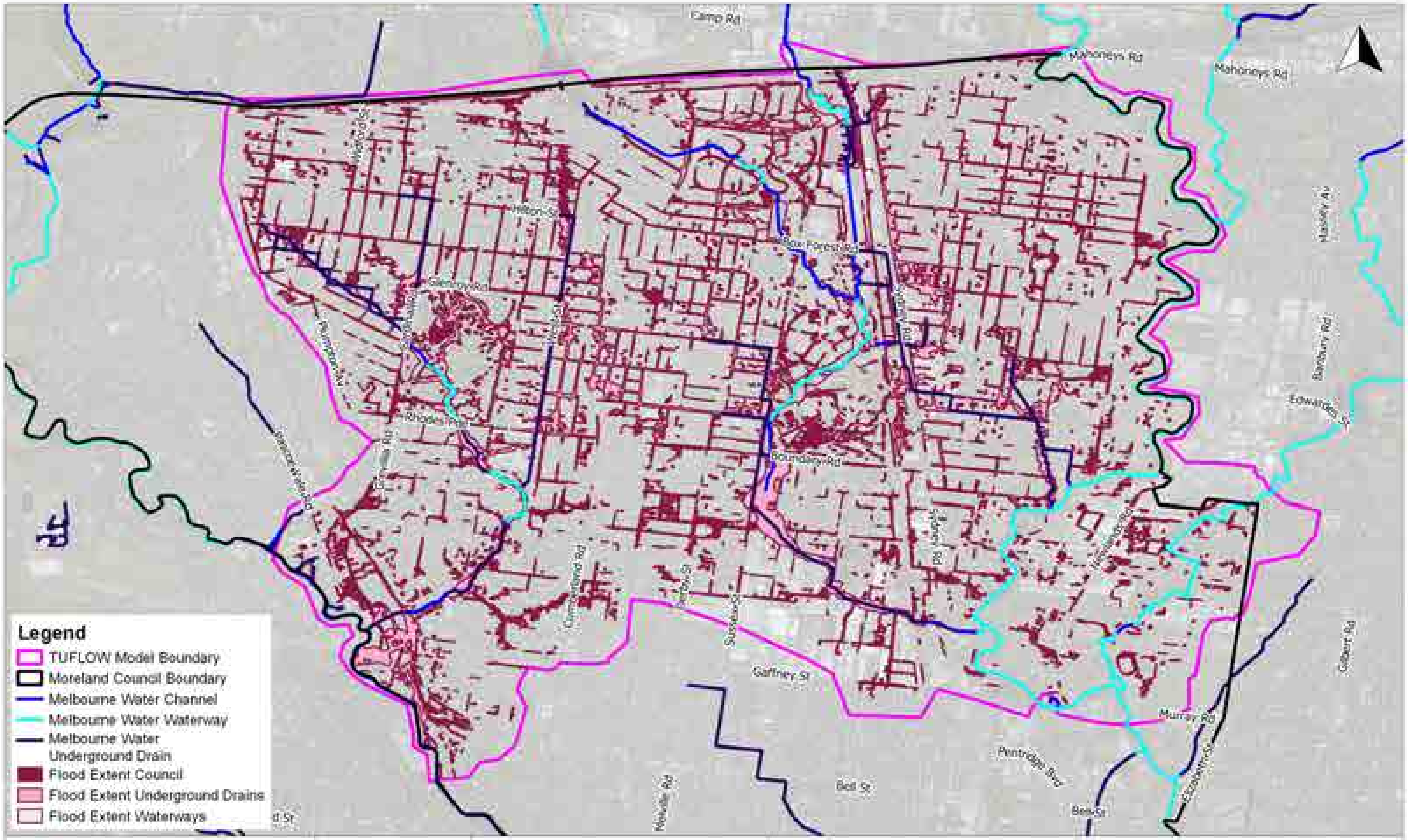
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

10 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: KS
Checked: DH
Date: 7/11/2022



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E: mailbox@engeny.com.au

ENGENY

Melbourne Water

250 0 250 500 750 1000 m

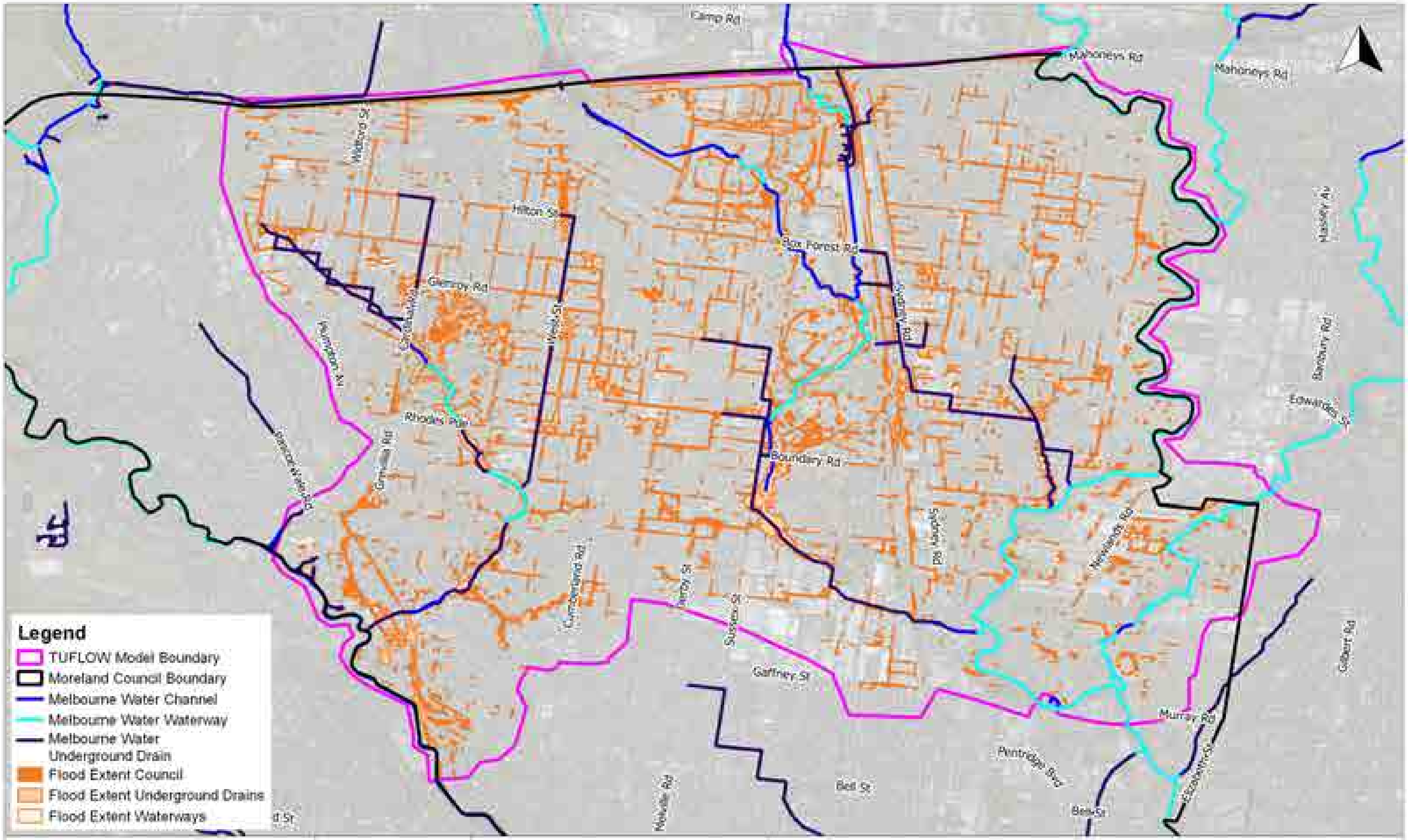
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping North East Catchments

10 % AEP Flood Extent Climate Change (Scenario D)

Job Number: V3000_127
Revision: D
Drawn: KS
Checked: DH
Date: 7/11/2022



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P: 03 9888 6978
F: 03 9830 2601
E: mail@engeny.com.au

ENGENY

Melbourne Water

250 0 250 500 750 1000 m

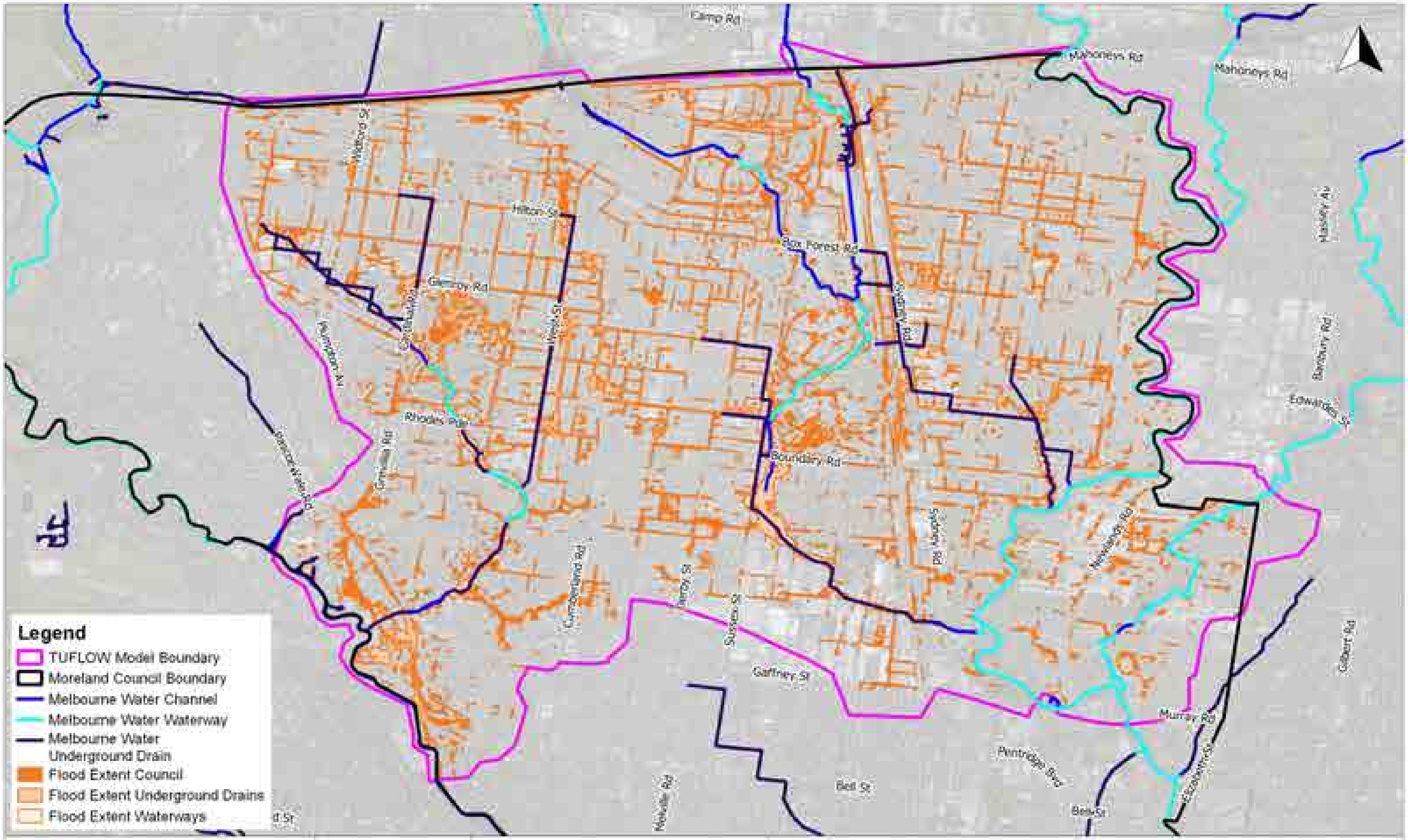
Scale in metres (1:15000 @ A3)

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

Moreland Flood Mapping
North East Catchments

20 % AEP Flood Extent Base Case

Job Number: V3000_127
Revision: 0
Drawn: KS
Checked: DH
Date: 7/11/2022



250 0 250 500 750 1000 m

Scale in metres (1:15000 @ A3)

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

ENGENY

Melbourne Water

Moreland Flood Mapping
North East Catchments

20 % AEP Flood Extent Climate Change (Scenario D)

Job Number: V3000_127
Revision: D
Drawn: KS
Checked: DH
Date: 7/11/2022

Appendix F:

Detailed Blockage Risk Assessment Forms

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project: Moreland Flood Mapping
Structure/Drawing: Location 1 - May Street
Location & LGA: Moreland
Designer/Engineer: KP
Checked by: GO
Date: 3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	907	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.5	(m)
Inlet Clear Height **(D)**	1.5	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	3	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	M	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	MMM	LMM	
1% Debris Potential	MED	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
$W < L_{10}$	100%	50%	25%
$L_{10} <= W <= 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	MED	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Med	10%	Low	0%
<0.5% [>1:200]	High	20%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project: Moreland Flood Mapping
Structure/Drawing: Location 2 - Wills Lane
Location & LGA: Moreland
Designer/Engineer: KP
Checked by: GO
Date: 3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	907	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.875	(m)
Inlet Clear Height **(D)**	1.875	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	3.4	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	M	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	MMM	LMM	
1% Debris Potential	MED	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
$W < L_{10}$	100%	50%	25%
$L_{10} <= W <= 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	MED	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Med	10%	Low	0%
<0.5% [>1:200]	High	20%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 3 - Bass Avenue
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	907	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.875	(m)
Inlet Clear Height **(D)**	1.875	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	6.4	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	M	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	MMM	LMM	
1% Debris Potential	MED	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
W < L_{10}	100%	50%	25%
L_{10} <= W <= 3*L_{10}	20%	10%	0%
W > 3*L_{10}	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	MED	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Med	10%	Low	0%
<0.5% [>1:200]	High	20%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 4 - Mitchell Circuit
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	932	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.875	(m)
Inlet Clear Height **(D)**	1.875	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	7.8	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	M	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	MMM	LMM	
1% Debris Potential	MED	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
$W < L_{10}$	100%	50%	25%
$L_{10} <= W <= 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	MED	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Med	10%	Low	0%
<0.5% [>1:200]	High	20%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 5 - Box Forest Road #1
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details

Catchment Area:	1020	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.575	(m)
Inlet Clear Height **(D)**	1.575	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	5	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP

Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	M	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	MMM	LMM	
1% Debris Potential	MED	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)

Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)

AEP Adjusted Debris Potential At Structure (Inlet)

Control Dimension	High	Med	Low
$W < L_{10}$	100%	50%	25%
$L_{10} <= W <= 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)

Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)

AEP Adjusted Sediment Potential At Structure (barrel)

Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%

	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	MED	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Med	10%	Low	0%
<0.5% [>1:200]	High	20%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 6 - Seventh Avenue
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	1038	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	5.03	(m)
Inlet Clear Height **(D)**	1.37	(m)
Check W/D<=3	3.7	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	5.4	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	M	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	MMM	LMM	
1% Debris Potential	MED	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
$W < L_{10}$	100%	50%	25%
$L_{10} <= W <= 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	MED	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Med	0%	Low	0%
<0.5% [>1:200]	High	10%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 7 - Box Forest Road #2
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	361	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.35	(m)
Inlet Clear Height **(D)**	1.35	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	6.3	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	L	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	LMM	LMM	
1% Debris Potential	LOW	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
$W < L_{10}$	100%	50%	25%
$L_{10} <= W <= 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	**Inlet (Debris)**		**Barrel (Sediment)**	
Event AEP(%) [1:yr]	LOW	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	25%	Low	0%
5%-0.5% [1:20 - 1:200]	Low	25%	Low	0%
<0.5% [>1:200]	Med	50%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 8 - Sussex Street
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	1451	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	3.04	(m)
Inlet Clear Height **(D)**	3.04	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	8.4	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	L	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	LMM	LMM	
1% Debris Potential	LOW	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
$W < L_{10}$	100%	50%	25%
$L_{10} <= W <= 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	LOW	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Low	0%	Low	0%
<0.5% [>1:200]	Med	10%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 10 - Sydney Road
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	2119	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	4.2	(m)
Inlet Clear Height **(D)**	1.9	(m)
Check W/D<=3	2.2	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	10.6	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	L	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	LMM	LMM	
1% Debris Potential	LOW	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
W < L_{10}	100%	50%	25%
L_{10} <= W <= 3*L_{10}	20%	10%	0%
W > 3*L_{10}	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	LOW	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Low	0%	Low	0%
<0.5% [>1:200]	Med	10%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 11 - Convent Court
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	2120	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.95	(m)
Inlet Clear Height **(D)**	1.95	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	13.1	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	L	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	LMM	LMM	
1% Debris Potential	LOW	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
W < L_{10}	100%	50%	25%
L_{10} <= W <= 3*L_{10}	20%	10%	0%
W > 3*L_{10}	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	LOW	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Low	0%	Low	0%
<0.5% [>1:200]	Med	10%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 12 - Convent Court
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	271	ha or km2
Source Area (&Landuse):	Predominantly urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.8	(m)
Inlet Clear Height **(D)**	1.8	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	5.4	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	L	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	LMM	LMM	
1% Debris Potential	LOW	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
$W < L_{10}$	100%	50%	25%
$L_{10} <= W <= 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	**Inlet (Debris)**		**Barrel (Sediment)**	
Event AEP(%) [1:yr]	LOW	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Low	0%	Low	0%
<0.5% [>1:200]	Med	10%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 13 - Arndt Road
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	488	ha or km2
Source Area (&Landuse):	Predominantly urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.98	(m)
Inlet Clear Height **(D)**	1.98	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	13.7	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	L	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	LMM	LMM	
1% Debris Potential	LOW	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
$W < L_{10}$	100%	50%	25%
$L_{10} <= W <= 3*L_{10}$	20%	10%	0%
$W > 3*L_{10}$	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	LOW	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Low	0%	Low	0%
<0.5% [>1:200]	Med	10%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 14 - Zenith Street
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	505	ha or km2
Source Area (&Landuse):	Predominantly urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.95	(m)
Inlet Clear Height **(D)**	1.95	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	16	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	L	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	LMM	LMM	
1% Debris Potential	LOW	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
W < L_{10}	100%	50%	25%
L_{10} <= W <= 3*L_{10}	20%	10%	0%
W > 3*L_{10}	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	**Inlet (Debris)**		**Barrel (Sediment)**	
Event AEP(%) [1:yr]	LOW	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Low	0%	Low	0%
<0.5% [>1:200]	Med	10%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 15 - Sages Rd #1
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	342	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.8	(m)
Inlet Clear Height **(D)**	1.8	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	4.5	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	L	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	LMM	LMM	
1% Debris Potential	LOW	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
W < L_{10}	100%	50%	25%
L_{10} <= W <= 3*L_{10}	20%	10%	0%
W > 3*L_{10}	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	LOW	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Low	0%	Low	0%
<0.5% [>1:200]	Med	10%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project: Moreland Flood Mapping
Structure/Drawing: Location 16 - Sages Rd #2
Location & LGA: Moreland
Designer/Engineer: KP
Checked by: GO
Date: 3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	347	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	5	(m)
Inlet Clear Height **(D)**	1.25	(m)
Check W/D<=3	4.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	4.5	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	L	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	LMM	LMM	
1% Debris Potential	LOW	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
W < L_{10}	100%	50%	25%
L_{10} <= W <= 3*L_{10}	20%	10%	0%
W > 3*L_{10}	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	LOW	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Low	0%	Low	0%
<0.5% [>1:200]	Med	0%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

BLOCKAGE CALCULATIONS - ARR (2016) Book 6 Chapter 6

Project:	Moreland Flood Mapping
Structure/Drawing:	Location 17 - Fawkner Memorial Park
Location & LGA:	Moreland
Designer/Engineer:	KP
Checked by:	GO
Date:	3/02/2022

User Defined Text & Parameters

Side notes: S=Section, T=Table in ARR Bk6 Ch6

STEP 1: Setup Details		
Catchment Area:	361	ha or km2
Source Area (&Landuse):	industrial/commercial and urban	S6.3.3
Inlet Blockage Data (floating /non-floating debris)		
Description:	Sticks and small fallen tree limbs	
How assessed:	desktop and visual assessment at site	
Inlet Clear Width **(W)**	1.5	(m)
Inlet Clear Height **(D)**	1.5	(m)
Check W/D<=3	1.0	(m/m) S6.4.4.8
L_{10}	1.5	(m) S6.4.4.1
Barrel Blockage Data (sediment & bedload)		
Description:	Sand	
How assessed:	desktop and visual assessment at site	
D_{50}	2	(mm)
Barrel velocity **(V)**	6.3	(m/s)

STEP 2: Debris Potential at Structure for 1% AEP			
Blockage Location	Inlet (debris)	Barrel (sediment)	
Availability (H,M,L)	L	L	S6.4.4.2 & T6.6.1
Mobility (H,M,L)	M	M	S6.4.4.3 & T6.6.2
Transportability (H,M,L)	M	M	S6.4.4.4 & T6.6.3
Combined Result	LMM	LMM	
1% Debris Potential	LOW	LOW	S6.4.4.5 & T6.6.4

STEP 3: AEP Adjusted Debris Potential (S6.4.4.6 & T6.6.5)			
Event AEP(%) [1:yr]	HIGH	MED	LOW
>5% [<1:20]	Med	Low	Low
5%-0.5% [1:20 - 1:200]	High	Med	Low
<0.5% [>1:200]	High	High	Med

STEP 4: Inlet Blockage Level (S6.4.4.7 & T6.6.6)			
AEP Adjusted Debris Potential At Structure (Inlet)			
Control Dimension	High	Med	Low
W < L_{10}	100%	50%	25%
L_{10} <= W <= 3*L_{10}	20%	10%	0%
W > 3*L_{10}	10%	0%	0%

STEP 5: Likelihood of Sediment Deposition in Barrel (T6.6.7)					
Sediment (Type & D_{50})	Clay/Silt	Sand	Gravel	Cobbles	Boulders
Structure Velocity (m/s)	<=0.04mm	>0.04-2mm	>2-63mm	>63-200mm	>200mm
>=3.0	*low*	*low*	*low*	*low*	*med*
1.0 to < 3.0	*low*	*low*	*low*	*med*	*med*
0.5 to < 1.0	*low*	*low*	*low*	*med*	*high*
0.1 to < 0.5	*low*	*low*	*med*	*high*	*high*
< 0.1	*low*	*med*	*high*	*high*	*high*

STEP 6: Depositional Blockage Levels (T6.6.8)			
AEP Adjusted Sediment Potential At Structure (barrel)			
Likelihood of Deposition	High	Med	Low
high	100%	60%	25%
med	60%	40%	15%
low	25%	15%	0%

STEP 7: BLK-DES%	Inlet (Debris)		Barrel (Sediment)	
Event AEP(%) [1:yr]	LOW	STEP 4	LOW	STEP 6
>5% [<1:20]	Low	0%	Low	0%
5%-0.5% [1:20 - 1:200]	Low	0%	Low	0%
<0.5% [>1:200]	Med	10%	Med	15%

STEP 8: RISK ASSESSMENT & SENSITIVITY ANALYSIS

ASSESS:

1). Extreme blockage consequences using 2*BDES% (S6.4.4.11)

2). Worse case downstream flooding using "All Clear" case (S6.4.5)

If CONSEQUENCES HIGH:

Flood Study: Review blockage parameters. Notify asset owner.

Design: Review blockage parameters. Mitigate Risk. **(see S6.6)**

ENGENY
WATER MANAGEMENT

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