Officer South Employment Hydrological Report

Pre-Development Hydrological Assessment

Rev2 | DRAFT

14 September 2023

Melbourne Water

Officer South Employment Hydrological Report

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Document history and status

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Contents

Executive Summary

This report details the outcomes of a combined hydrological/hydraulic assessment for the Officer South Employment Precinct (Precinct Structure Plan, (PSP)). An existing RORB hydrological model was re-configured to represent 2010 catchment conditions whilst hydraulic models in TUFLOW were developed to understand the overland flow characteristics within the area, specially within the PSP area and in Cardinia Creek, Gum Scrub Creek and Officer South Road Drain. A calibration process was adopted using available gauge information which derived the following parameters for the pre-development RORB model:

- k_c Chasemore Road on Cardinia Creek: 20.5, Initial loss 25 mm, continuing loss 2.5 mm/hr
- k_c Gum Scrub Creek at Princes Highway: 5.5, initial loss 25 mm, continuing loss 3 mm/hr
- k_c remainder of the model: 8.45, Initial loss 25 mm, continuing loss 3 mm/hr

Investigations using TUFLOW identified the following:

- Officer South Drain has limited capacity however it is influenced by blockages, off-take structures, diversions, vegetation and the location of crossings. Modelling indicates it is likely that during the pre-development conditions of 2010 a significant portion of the Officer South Drain flows would exceed the capacity of the drain and flow east towards to Gum Scrub Creek.
- During a 1% AEP flood event there maybe locations along Cardinia Creek where there are breakout flows into the PSP area.
- The capacity of the drainage channels and creeks is generally limited leading to the engagement of the floodplain for relatively frequent events. The ability to drain the area around Ballarto Road is considered to be constrained by both a low hydraulic gradient and limited outlet capacity. Ballarto Road itself operations as an informal levee.

1. Introduction

Jacobs together with Spiire has been engaged by Melbourne Water (MW) to undertake the Functional Designs of Retarding Basins, Wetlands, Waterway and Drainage Outfalls for the Officer South and Lower Gum Scrub Creek Development Service Schemes, collectively the Officer Employment Precinct Structure Plan (PSP). The design of these stormwater assets is to be guided by the hydrological and hydraulic model to ensure that flood risk will be mitigated in both frequent and infrequent events in the project area in the future.

This assessment details the data review process and the method adopted for establishing pre-development hydrological conditions within the catchment area. Predevelopment conditions have been classified as representing the level of development in 2010. The established hydrological conditions broadly align with current standards, including Australian Rainfall & Runoff 2019 (Ball J, Babister M, et, al, 2019 and the Melbourne Water Technical Specifications (2020) (hereafter referred to as “MW Tech Specs”). Any deviations from these standards are documented in the report. A combined hydrological model (RORB)/hydraulic model (TUFLOW) assessment has been adopted to complete the works to identify key overland flow paths. The assessment has been tailored to adopt existing information including existing models and rainfall and stream gauge data to develop a robust assessment.

Key objectives include:

- Understanding pre-development overland flow paths in the area around the PSP
- Establishing pre-development flows as the base-line targets.

1.1 Limitations

The sole purpose of this report and the associated services performed by Jacobs is to provide an assessment of pre-development hydrological conditions over the project area in accordance with the terms of the contract between Jacobs and Melbourne Water.

In preparing this report, Jacobs has relied upon and presumed accurate certain information (or absence thereof). Except as otherwise stated, Jacobs has not attempted to verify the accuracy or completeness of any such information.

Jacobs makes no warranty or guarantee, whether expressed or implied, with respect to the data reported or to the findings, observations and conclusions expressed in this report. Further, such data, findings, observations, and conclusions are based solely upon information provided to Jacobs at the time of the engagement.

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

2. Background

The Officer South Employment Precinct Structure Plan (OSE PSP) is located in the south eastern growth corridor approximately 65km south east of Melbourne (Figure 2-1). The site is influenced by three catchments upstream of the Princes Freeway; Cardinia Creek, Officer South Drain and Lower Gum Scrubs Creek.

The Officer South area is characterised by flat terrain with the land generally sloping from the north-west to south-east towards Western Port Bay. The upstream catchment north of Princess Freeway consists of a combination of urbanised areas including the suburbs of Beaconsfield and Officer and hilly rural areas in the upper Cardinia catchment. The upstream area has undergone a reasonable level of urban development from 2010 to 2021.

There are three primary waterways/drains in the area which defines the PSP. Cardinia Creek to the west, Officer South Drain in the centre and Lower Gum Scrub Creek to the east. Officer South Drain flows into Cardinia Creek and Lower Gum Scrub Creek flows in a southern direction into the Koo Wee Rup Flood Projection District outfall.

Flows from Cardinia Creek are likely to be primarily contained within the waterway; however, this assessment will aim determine the level of interaction with the PSP and area downstream of the PSP. Officer South Drain and Lower Gum Scrub Creek operate as large table drains, conveying frequent flows downstream. More infrequent events exceed the capacity of these drains and engage the floodplain.

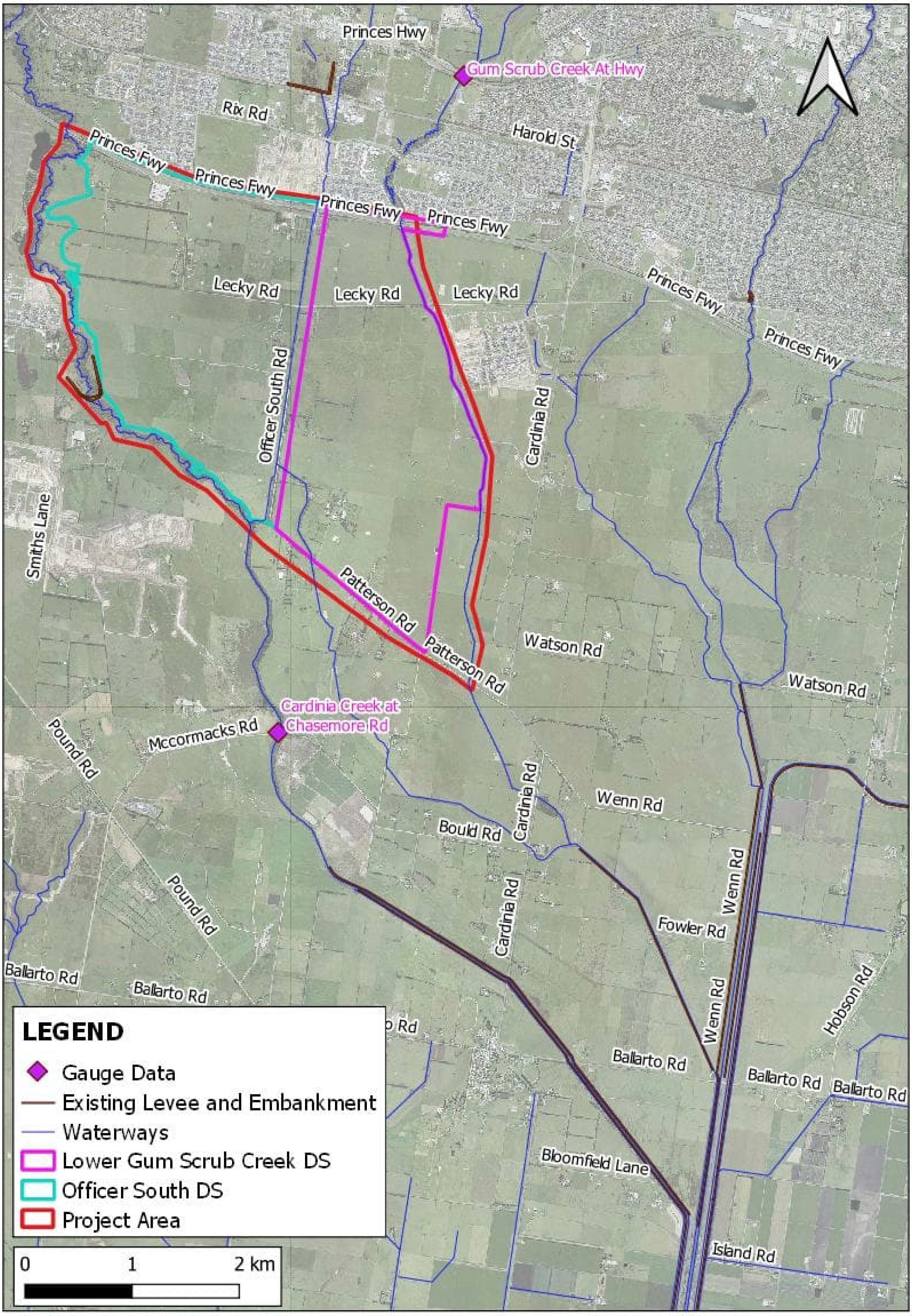


Figure 2-1: Location of Officer South Employment Precinct Structure Plan.

3. Site Visit

A site visit was completed on 22 March 2021 where representatives from MW, Spiire and Jacobs were present. During the site visit the following was noted:

- The area is in a current state of flux with development occurring to the north, east, west of the future precinct. The future extension of Thompsons Road will be located through the site which will also include the addition of on and off ramps on at the Officer South Road/Princes Freeway intersection.
- An anecdotal overview of existing flooding issues in the area, primarily downstream of the PSP between Patterson Road and Ballarto Road, was provided by the MW service delivery leader for the area.
- There is currently a development in this area known as Kaduna Park Estate. During the site visit it was noted the eastern section between the development and Cardinia Road consisted of an apparent wetland system draining east into Cardinia Road Drain and Toomuc Creek.

4. Data review

Data was provided to the project team, including LiDAR, aerial imagery, survey, existing RORB models, streamflow and rainfall gauge data. The Information provided by Melbourne Water for the assessment includes:

Hydrological models:
- RORB models developed by Storm Water Solutions in for the PSP (2020) and the Cardinia Outfall System (2021)

Hydraulic models:
- Cardinia Creek HEC-RAS model
- Pipe data supplied by Engeny

Reports:
- Various previous studies in the area and for the PSP

Aerial Imagery:
- Both 2020 and 2009 aerial tiles

6-minute instantaneous flow and Pluviograph gauge data:
- 228228 - Cardinia Creek at Chasemore Road, Cardinia Township
- 228365A – Gumscrub creek at Princess Highway, Officer
- 228382A – Cardinia Creek Drop Structure, Officer South

Tidal gauge data from 228339

LiDAR and survey data (*list not extensive*):
- LiDAR: Both 2017 and 2009 datasets. Metadata not provided.
- MW reference SE080057/56 – details and cross sections of Gum Scrub Creek, Officer South, Cross sections and Detail Survey Plan, sm urban consulting group 2008
- MW reference SE130090/SES1795 Cross Section Survey of Deep Creek Catch, Cardinia Creek Catch and others, Aurecon 2013
- MW reference SE950019 – bridge survey pdfs in the region
- MW reference SE030117 Cross section survey for the Geomorphology Study of Cardinia Creek from 2004 (completed by Connell Wagner
- MW reference SE0100014 – Cross section survey between Cardinia Creek and Deep Creek from Ballarto Road to Western Port (completed by Connell Wagner in 2001).
- Additional survey on Cardinia creek and at the Cardinia Creek Drop Structure

Other:
- Reservoir storage information for Beaconsfield

5. RORB model review

RORB (version 6.45) existing conditions and future conditions models for the project area developed by Stormy Water Solution (SWS, 2020) were provided as part of the assessment. The extent of the RORB model is presented in figure below (Figure 5-1) which covers an area of 141km^2. These models provided design flows to aid in a high-level concept design of stormwater assets which forms the basis of this PSP project. Other objectives of these model were (as referenced in SWS, 2020):

- To define design flow rates in the watercourses through and adjacent to the OSE PSP being Cardinia creek, Gum Scrub Creek and Officer Road Drain,
- To assess the impact of the diversion of all flows (up to and including the 1% AEP flows) in Officer Road Drain directly to Cardinia Creek.

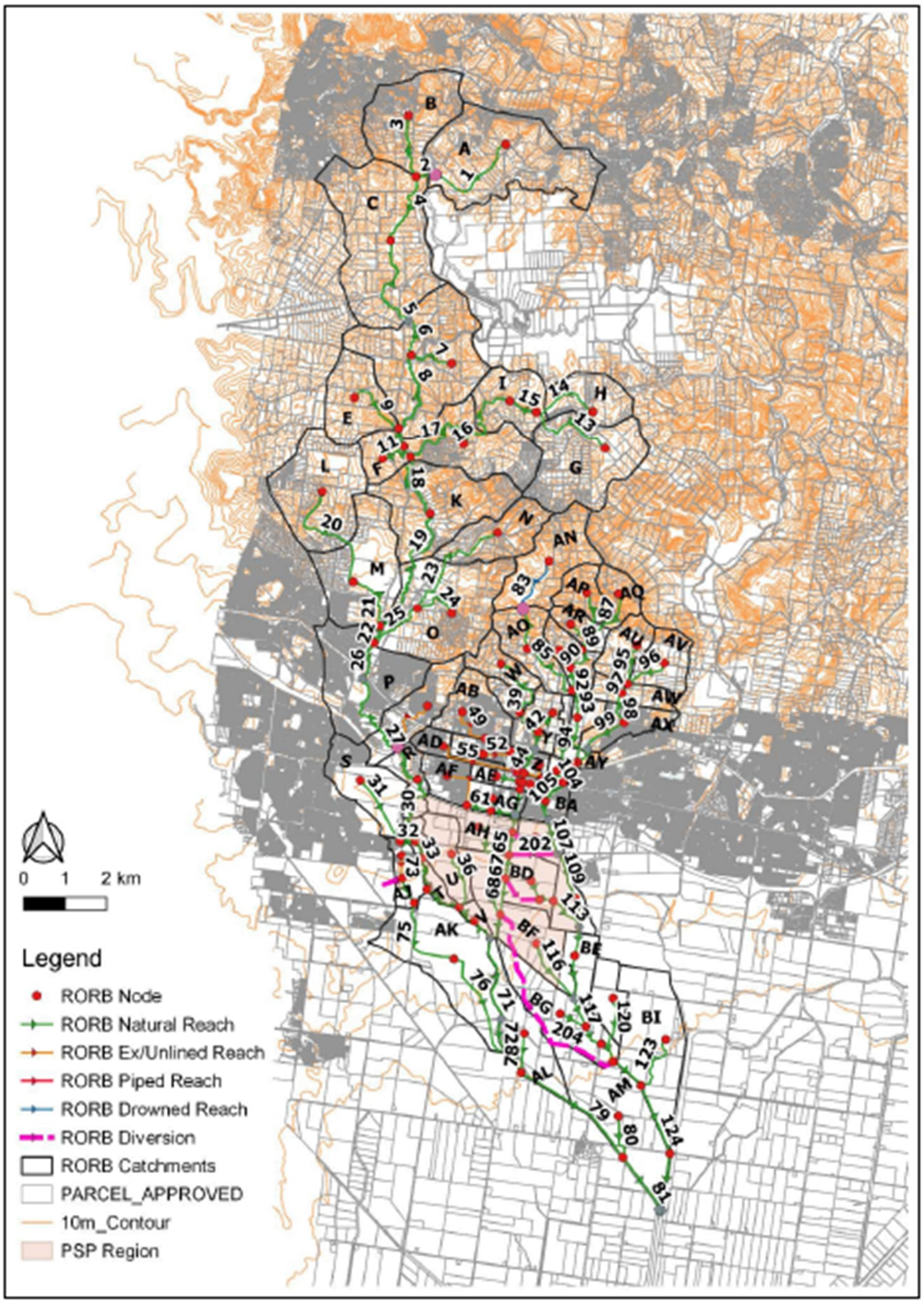


Figure 5-1: RORB Model from SWS (2020)

The following documents the findings from a review of the existing conditions RORB model setup (note some of these were identified in the SWS (2020) report:

- ‘Existing conditions’ represent October 2020
- The model consists of three primary creeks, Cardinia Creek, Officer South Drain and Lower Gum Scrubs Creek. No gauges were used to calibrate/validate the outputs.

Model structure/build

- Sub catchment size range is larger than RORB setup recommendations.
- Reach types generally align with aerial imagery including natural types for creeks and watercourses, unlined for major DS pipe alignments (i.e. overland) and drowned out for retarding basins. Excavated type reaches should be converted to type 2 as per the Specs.
- The RORB model does not include Cardinia Road Drain or Toomuc Creek which is located directly to the east of the catchment.
- The drop structure/retarding basin on Cardinia Creek is missing from the RORB model
- There’s no outflow from Cardinia Reservoir. It is assumed this is because it’s a regulated storage and not designed to discharge into Cardinia Creek for events up to the 1% with climate change.
- For areas downstream of Princes Hwy the RORB sub catchments should be further split into smaller subareas to more appropriately represent the area.
- Retarding Basins located in the upstream reaches on only have one-two subareas upstream, which is generally not preferred in a RORB model configuration.
- The model consists of five retarding basins include Aura Vale Lake, Cardinia Creek RB, Clay Pit RB, Grasslands RB and Beaconsfield Reservoir.
- The adopted fraction impervious values are based on ARR 1987 not the Effective Impervious Areas/ Indirectly Connected Areas/ Pervious Areas (EIA/ICA/PA) approach as per the current MW Tech Specs.
- The RORB model does not include Cardinia Road Drain which is located directly to the east of the catchment.
- The model consists of diversions;
  - ID 201: Located downstream of Princes Freeway on Officer South Drain: The first 0.6m^3/s Officer Road Drain continues south, all other flows spill towards Gum Scrub Creek connecting in at Lecky Road.
  - ID 203: Location on Officer Road Drain: the first 1.5 m^3/s of Officer Road Drain flows continue south, all other flows spill towards Gum Scrub Creek at the electricity easement.
  - ID 204: Location on Officer Road Drain: the first 1.1 m^3/s of Officer Road Drain flows continue south, all other flows spill towards Gum Scrub Creek, connecting in east of Cardinia Road.
- The diversions are also ‘moving’ and not ‘routing’ large flows to other locations which may not be desirable.

Model Parameters

- The adopted RORB model k_c of 23.3 is based on the MWC Southeast Areas equation with a catchment area of 141.2km^2, d_{av} = 22.46km and k_c/d_{av} ratio = 1.04. There are no interstation areas in the model.
- The RORB model does not include Cardinia Road Drain which is located directly to the east of the catchment.
- Adopted initial losses:
  - 10mm compared to ARR 2019 recommendation of 25mm (60-80%) ~17mm), however it is noted the IL has been recommended by MW and factors in pre-burst rainfall.
- Areal Reduction Factors applied to the whole RORB catchment area and not tailored to the PSP area..
- Pre-burst rainfall was not included in the model runs.

- A spatial pattern was not applied but investigated and reported on.
- As detailed by SWS (2020) areal temporal patterns were adopted assuming the Cardinia Creek catchment area. The PSP area and the upstream catchments on Officer South Drain and Lower Gum Scrubs Creek require point temporal patterns.

6. RORB model updates

Based on discussions with Melbourne Water it was decided that the existing conditions would be reclassified as "pre-development" conditions and set to represent a period during 2010. This would also align with a Cardinia Creek fish study completed by Jacobs in 2020. By adopting this approach, it would enable MW to appropriately understand the pre-development conditions and specifically the nature of the downstream flooding in frequent events.

To represent the pre-development conditions the method in Figure 6-1 was adopted. This method aimed to utilise numerous hydrological and hydraulic techniques to understand the floodplain.

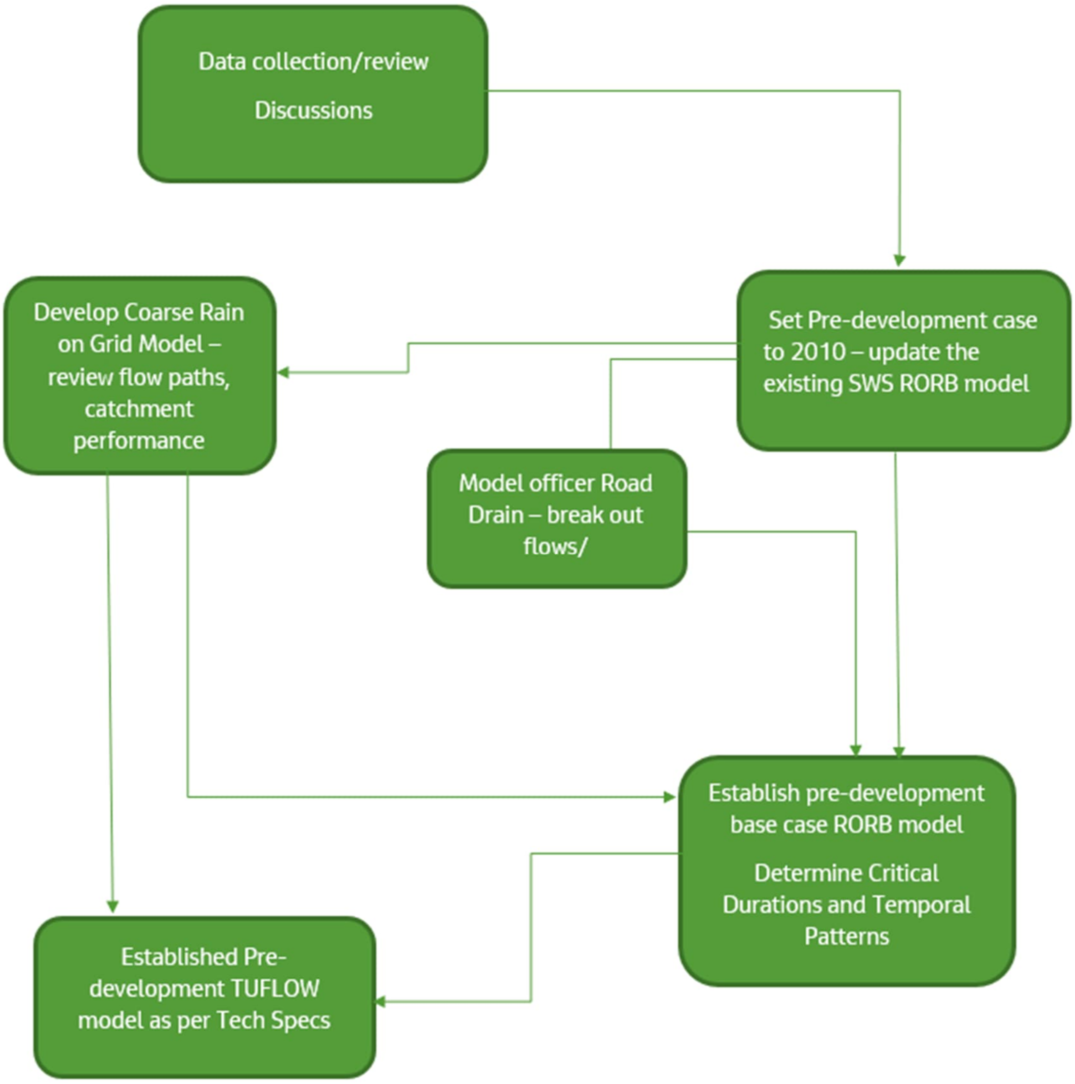


Figure 6-1: Adopted method for establishing pre-development flows

7. Coarse Rain on Grid model

A coarse TUFLOW rain on grid model was built using 2009 LiDAR for the area to identify key overland flow paths within the upstream catchment area for frequent flow events. Model inputs and parameters are summarised in Table 7-1.

Table 7-1: Coarse Rain on Grid TUFLOW model

<table>
<tr><th>Setup Item</th><th>Adopted Setup</th></tr>
<tr><td>TUFLOW Version</td><td>2020-10-AA</td></tr>
<tr><td>Purpose</td><td>Definition overland flow paths, estimate peak flows compared to RORB</td></tr>
<tr><td>Grid Size</td><td>5 m, Sub grid sampling adopted, Cell wet/dry depth = 0.002, No map cut-off depth applied</td></tr>
<tr><td>Terrain and Modifications</td><td>2009 LiDAR, minor modification to remove bridges/overland flow blockages. Refer to Figure 7-1 and Figure 6-3 for model extent.
To assist in digitisation of RORB sub areas and identify overland flow paths the code boundary was extended south to Cardinia creek and the model was run for the 1% 720 min storm.</td></tr>
<tr><td>Initial water level</td><td>Not adopted, sensitivity tested.</td></tr>
<tr><td>Losses</td><td>ARR 2019 Data hub, Initial Loss: 25 mm, Continuing Loss: 4.4 mm/h
Losses factored down to consider median pre-burst values
Average Pervious Area loss across AEPs ~ 23.3 mm
Average ICA loss across AEPs ~ 15.8 mm/h</td></tr>
<tr><td>Manning’s values and initial losses</td><td>Refer to Figure 7-3, roughness values based on 2010 aerial imagery
<table>
<tr><th>Manning's N</th><th>Initial Loss</th><th>Continuing Loss</th><th>Description</th></tr>
<tr><td>0.05</td><td>23.3</td><td>2.5</td><td>Open pervious areas moderate vegetation (shrubs - light)</td></tr>
<tr><td>0.02</td><td>1.5</td><td>0</td><td>Paved roads/carpark/driveways</td></tr>
<tr><td>0.035</td><td>23.3</td><td>2.5</td><td>Open pervious area minimal vegetation</td></tr>
<tr><td>0.1</td><td>15.8</td><td>2.5</td><td>Residential -Rural (lower density)</td></tr>
<tr><td>0.1</td><td>15.8</td><td>2.5</td><td>Railway line</td></tr>
<tr><td>0.06</td><td>23.3</td><td>2.5</td><td>Waterway/channel - dense veg</td></tr>
<tr><td>0.05</td><td>23.3</td><td>2.5</td><td>Waterway/channel - medium veg</td></tr>
<tr><td>0.05</td><td>15.8</td><td>2.5</td><td>Residential - medium/low density</td></tr>
<tr><td>0.1</td><td>23.3</td><td>2.5</td><td>Open pervious area - thick veg (trees)</td></tr>
<tr><td>0.025</td><td>0</td><td>0</td><td>Lakes and water bodies</td></tr>
<tr><td>0.3</td><td>1.5</td><td>0</td><td>Industrial/commercial</td></tr>
<tr><td>0.03</td><td>15.8</td><td>2.5</td><td>Waterways/minimal veg</td></tr>
</table></td></tr>
<tr><td>Temporal patterns</td><td>50% AEP: 10 temporal patterns run for each duration from 360min to 1440min.
20% AEP: 10 temporal patterns run for each duration from 270min to 1800min.</td></tr>
</table>

	10% AEP: 10 temporal patterns run for each duration from 270min to 1440min. 5% AEP: 10 temporal patterns run for each duration from 270 min to 720min. 1% AEP: 10 temporal patterns run for each duration from 360 min to 720min.
Areal Reduction Factor	0.95 adopted - ranges from 0.9 to 0.97 for the modelled durations and AEPs
Boundaries	Uniform 2d_rf (rainfall), HQ on the downstream (southern) boundary
Rainfall Data	Point rainfall at -38.066, 145.411

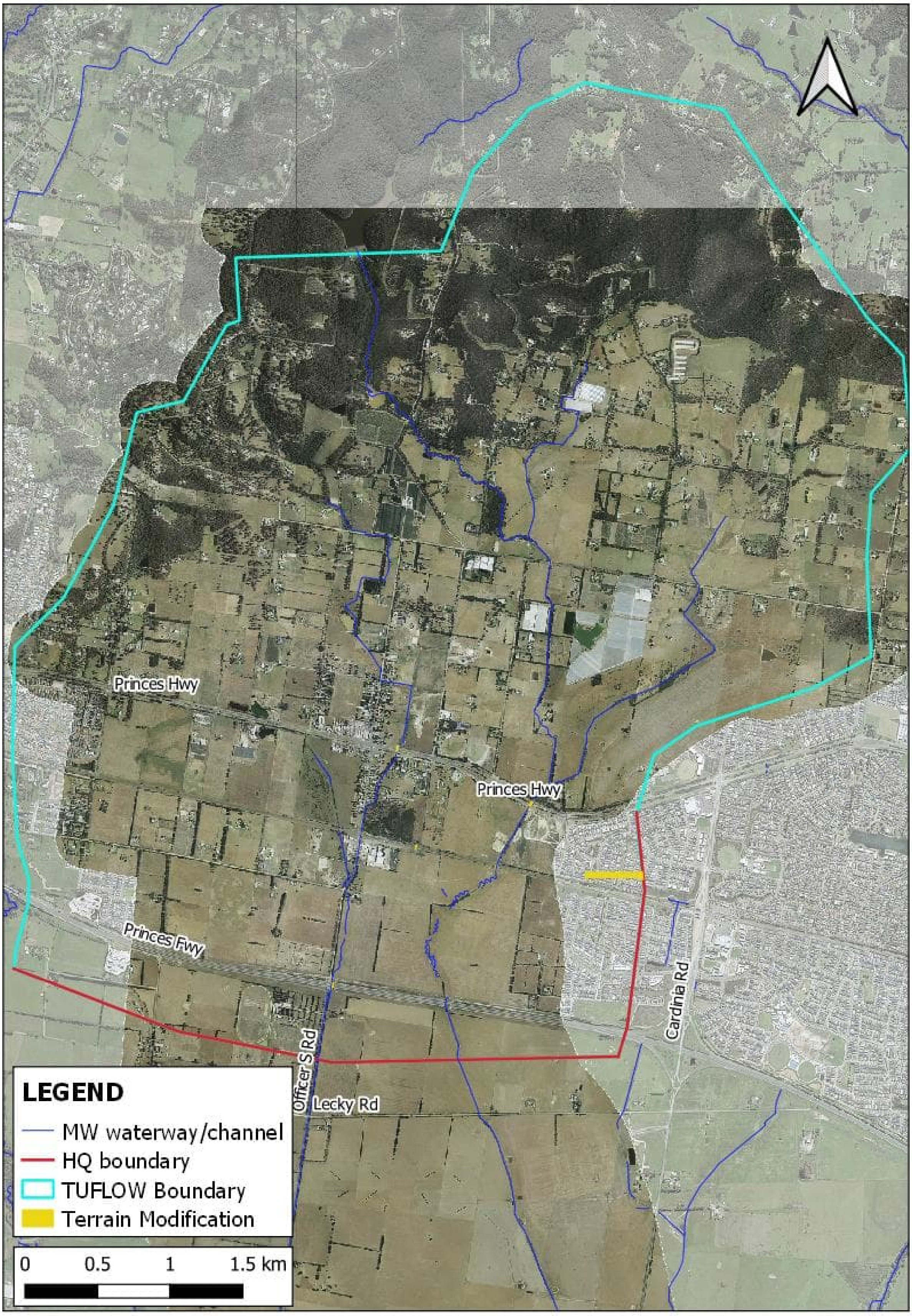


Figure 7-1: Rain on Grid model extent (with 2009 Aerial Imagery)

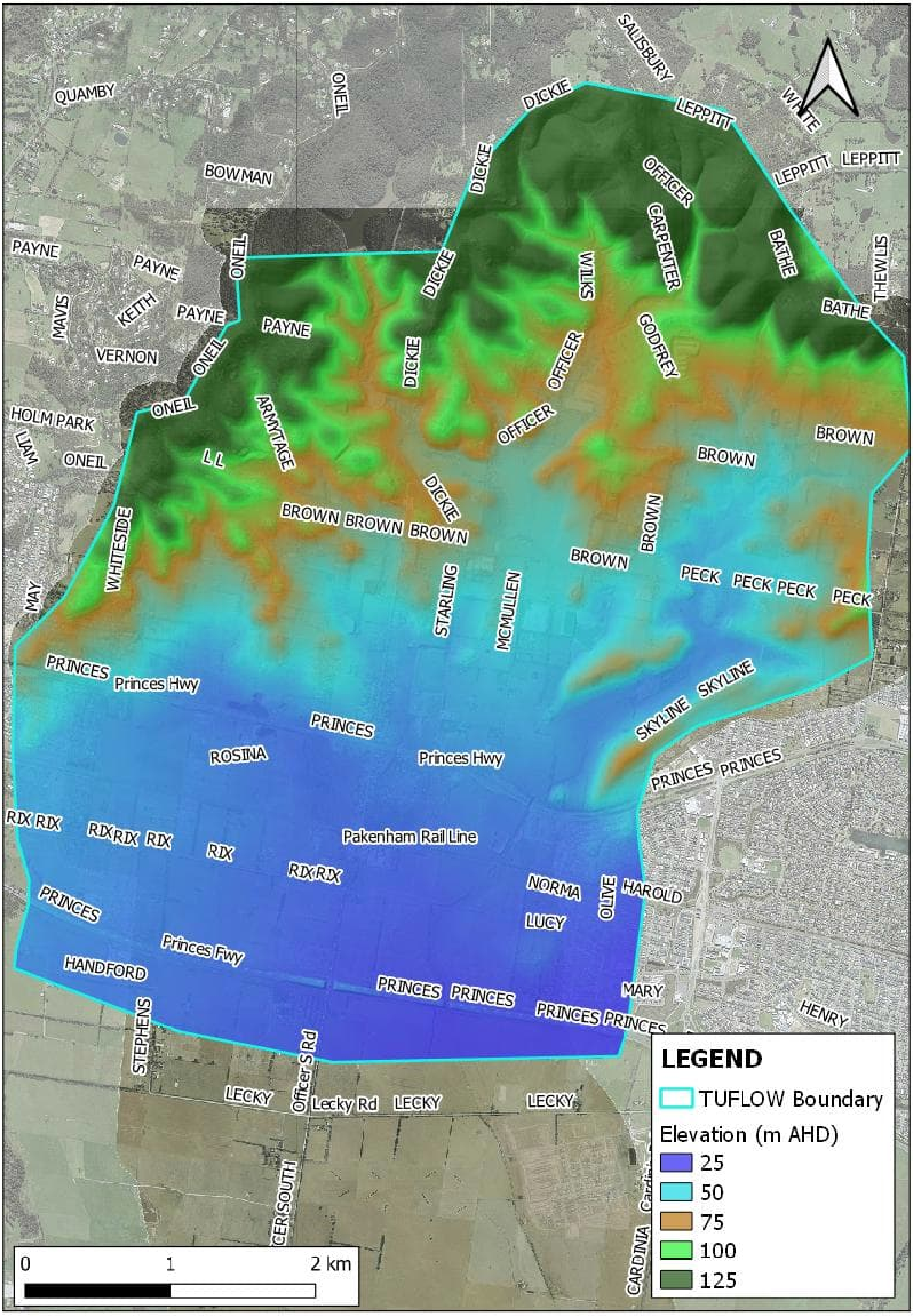


Figure 7-2: Rain on Grid TUFLOW model terrain

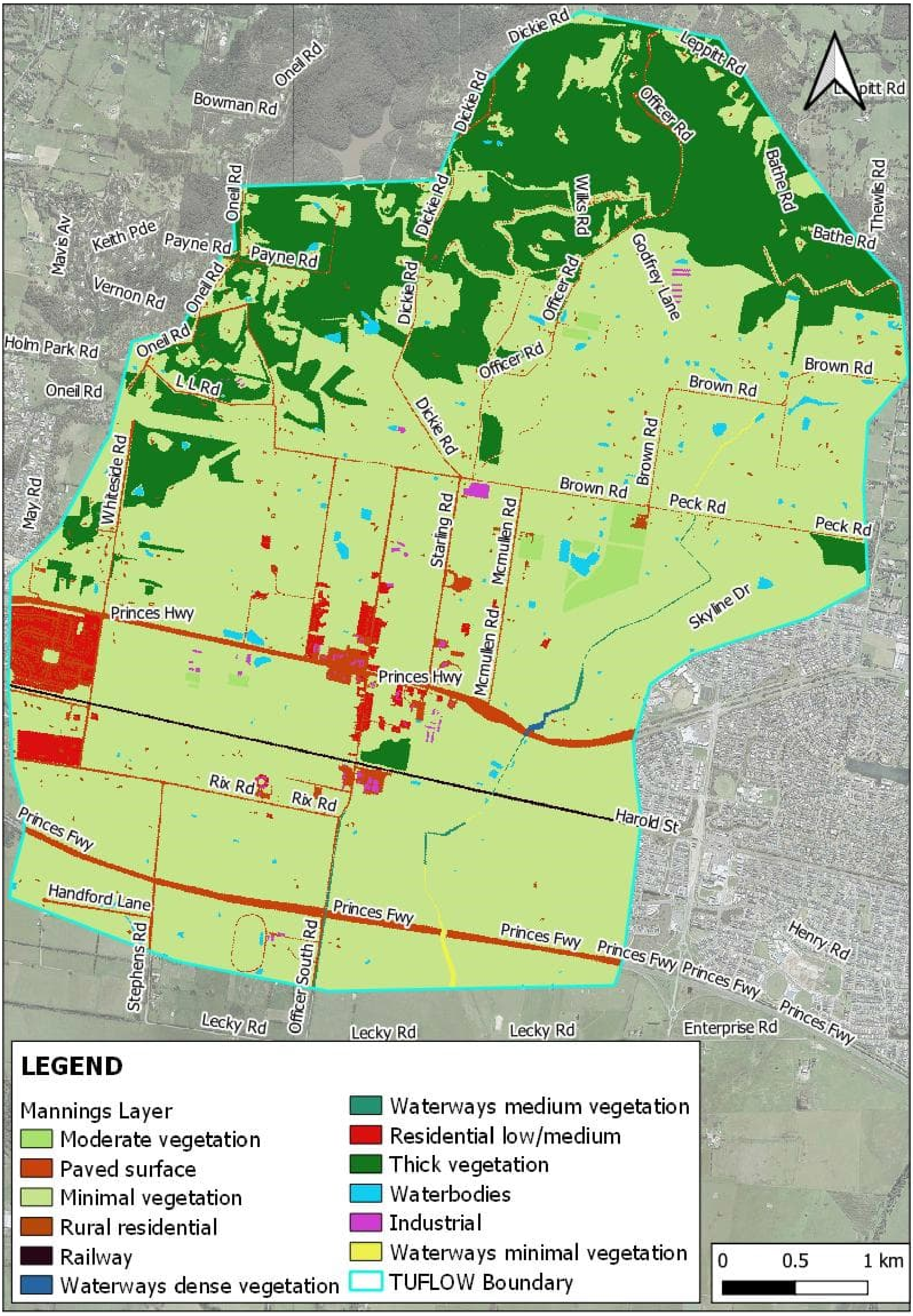


Figure 7-3: Rain on Grid Manning's Layer

7.1.1 Rain on Grid TUFLOW model results

The results of the assessment are presented in Table 7-2 and Table 7-3. The following is noted:

- Officer South Drain has limited capacity and excess flows drain east towards Gum Scrub Creek. Infrastructure such as the Princes Highway, Pakenham Rail Line and Prince Freeway also influence the overland flow paths.
- There is a reasonable amount of storage within the catchment due to farm dams and behind road and rail infrastructure.
- The 540 min (9hr) storm generally results in the critical duration event (based on peak water level) along Gum Scrub Creek and Officer South Drain particularly near the Princes Freeway (inflow point to the PSP).

The 50% and 20% AEP flood depth maps are shown in Figure 7-7 and Figure 7-8, respectively.

Table 7-2: Estimates of the critical duration from the Coarse TUFLOW Rain on Grid model

AEP	Critical duration along Gum Scrub Creek and Officer South Drain (based on max water levels)	Median temporal patterns
50%	540 min	TP 4,5,6
20%	540min	TP, 3,4,6,7
10%	540min	TP 2, 7, 9
5%	540 min, some 360min	TP 2, 6,7
1%	540 min	TP 8, 5

Table 7-3: Peak flow (m^3/s) Estimates from the Coarse TUFLOW Rain on Grid model (Figure 7-4)

Point	Location	50%	20%	10%	5%	1%
1	Gum Scrub Creek upstream Princes Highway	1	3.6	6	9	21
2	Gum Scrub Creek downstream Princes Highway	2	6.8	10	15	34
3	Gum Scrub Creek Rail	1.9	4.6	6	8	14
4	Gum Scrub Creek at Princes Freeway	2.8	9	15.5	22	42
5	Officer South Drain at Princes Highway	1.5	3.6	5	7	12
6	Officer South Drain downstream Rail	0.4	1.5	5	7.1	14
7	Officer South Drain at Princes Freeway	0.3	1	1.4	1.6	2.5
8	Officer South Drain to Gum Scrub Creek- a	1.1	2.5	4	6.5	17.5

9	Officer South Drain to Gum Scrub Creek - b	0.15	0.7	1.7	3	7
10	Officer South Drain to Gum Scrub Creek - c	0.23	1.3	4	5.2	10

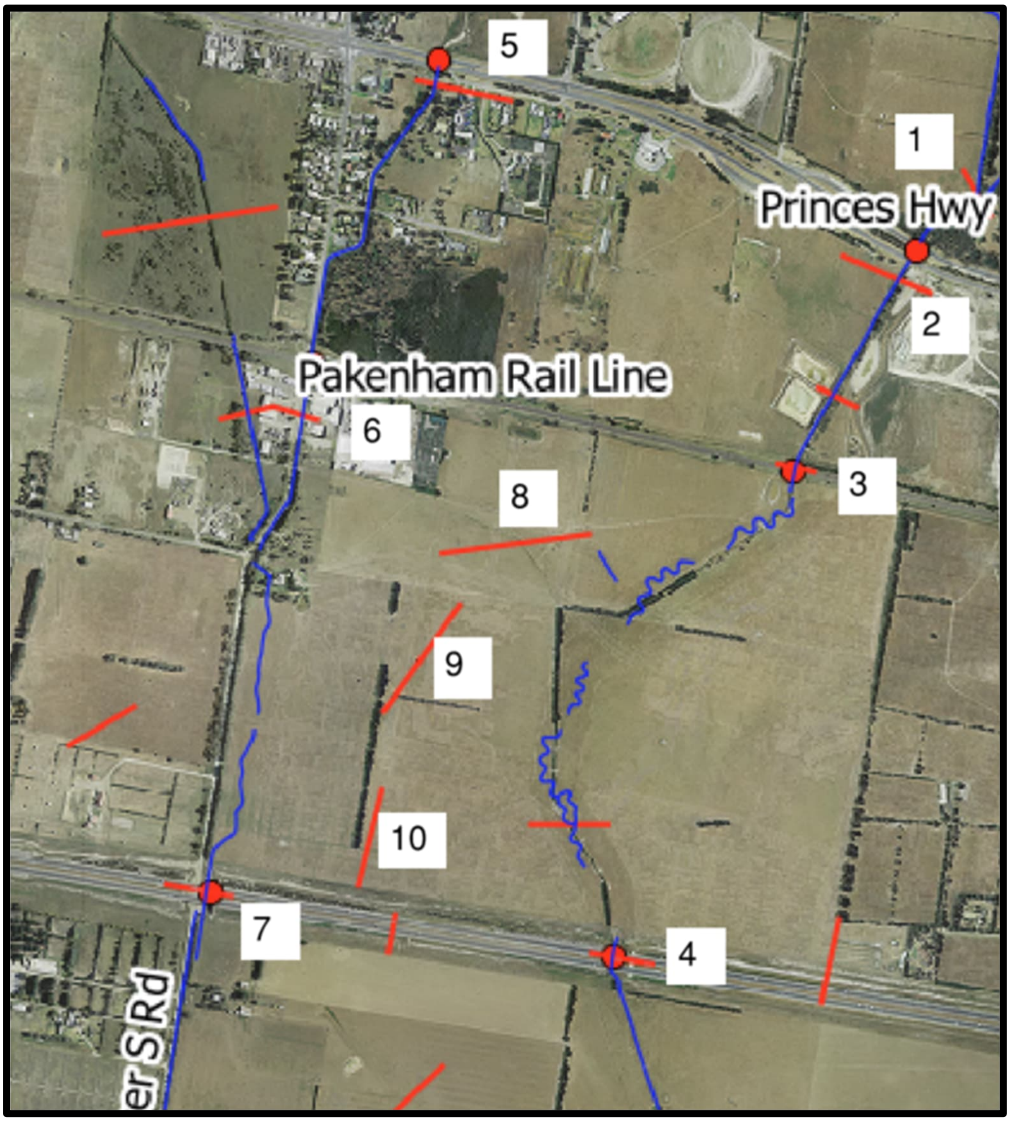


Figure 7-4: Report locations for the RoG model

7.1.2 Rain on Grid sensitivity

Sensitivity testing where an initial water level was added to the model including infilling farm dams was completed. Hydrographs from the critical duration and temporal pattern for the 1% AEP and 50% AEP events are presented in Figure 7-5 and Figure 7-6 at the Princes Highway crossing. The sensitivity testing indicates infilling catchment farm dams with an initial water level in the coarse road on grid TUFLOW model increases the peak flow and runoff volume estimates. For the 1% AEP test increases are relatively minor and do not alter the results significantly. For the more frequent 50% AEP there is a noticeable difference. The results of this assessment likely indicate peak flows in the catchment are sensitive to the antecedent water levels in farm dams in the upstream catchment specifically for frequent flood events.

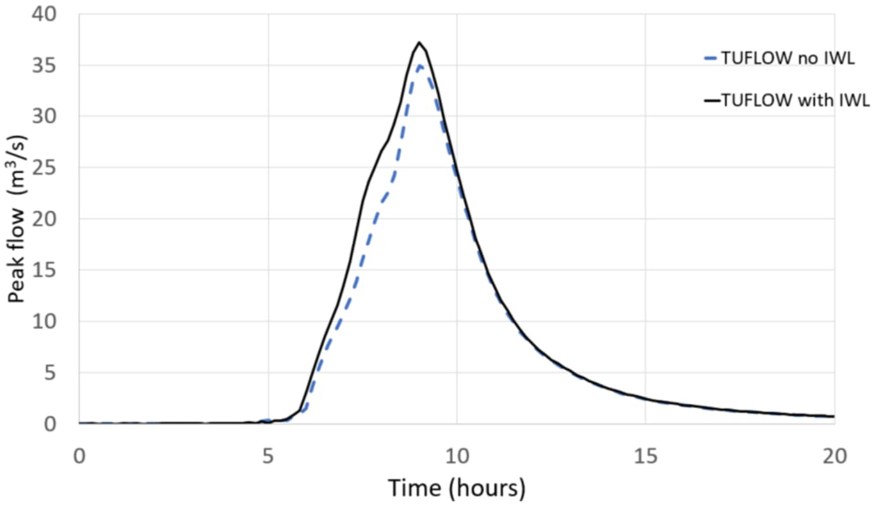


Figure 7-5: Sensitivity testing – adopting an initial water level in farm dams, peak 1% AEP flow at the Princes Highway

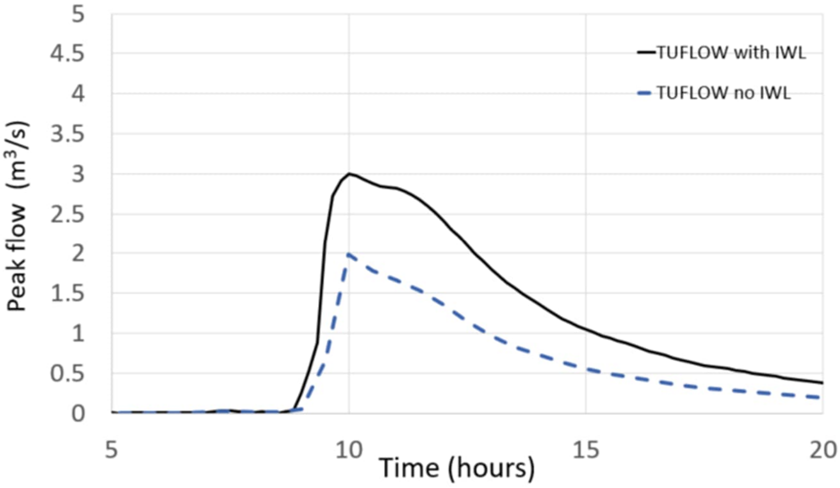


Figure 7-6: Sensitivity testing – adopting an initial water level in farm dams, peak 50% AEP flow at the Princes Highway

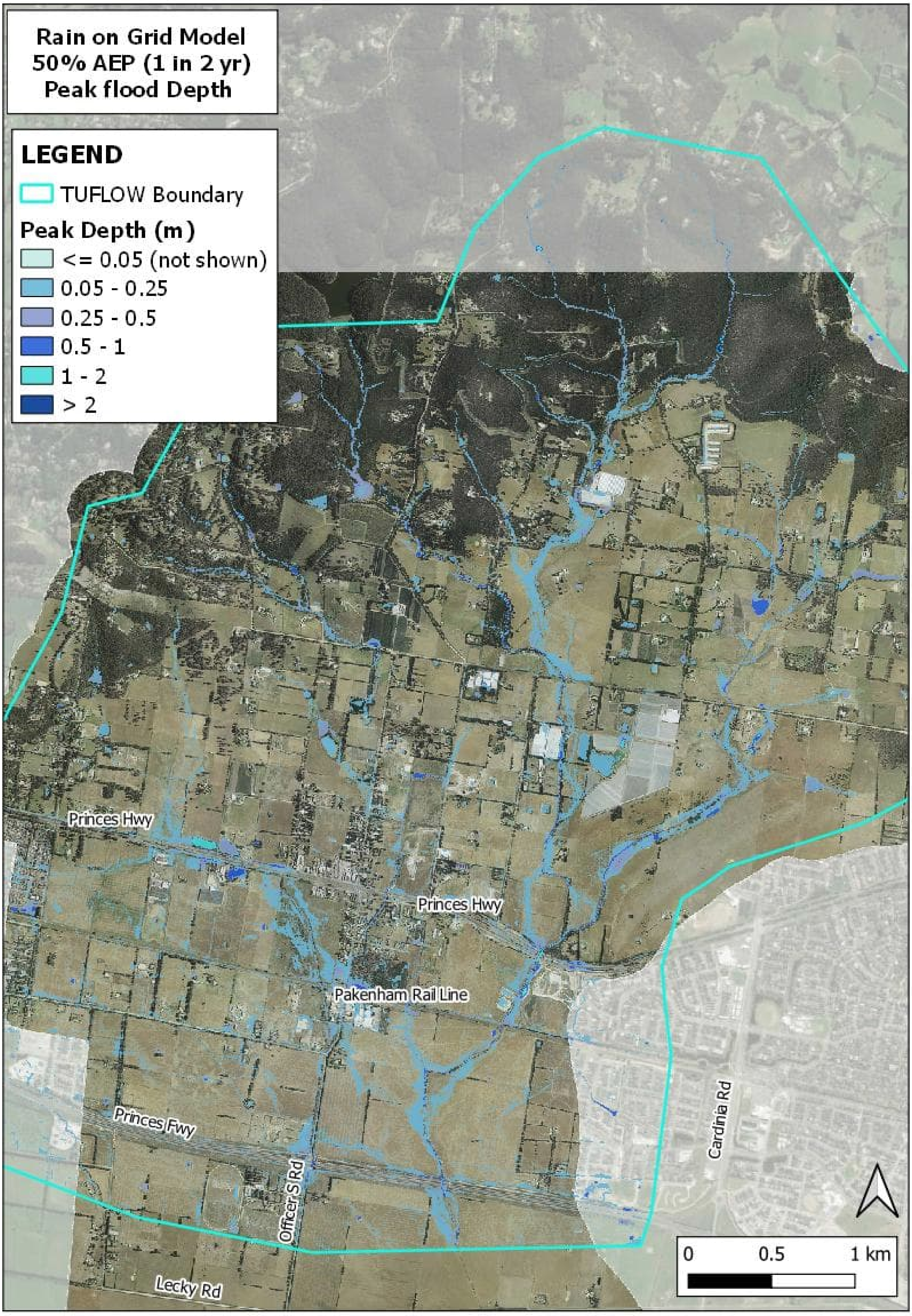


Figure 7-7: 50% AEP Peak flood depth (m)

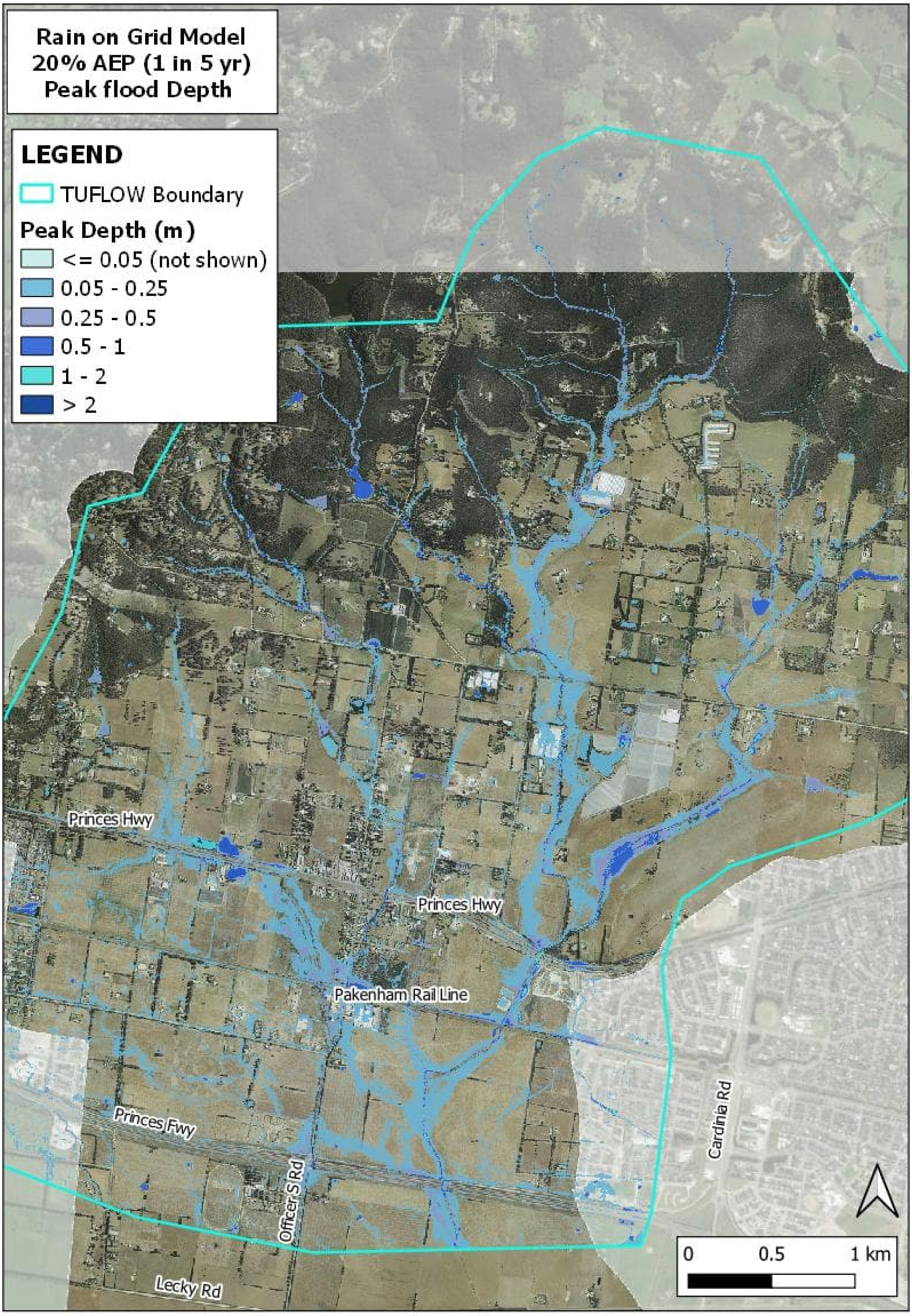


Figure 7-8: 20% AEP Peak Flood Depth (m)

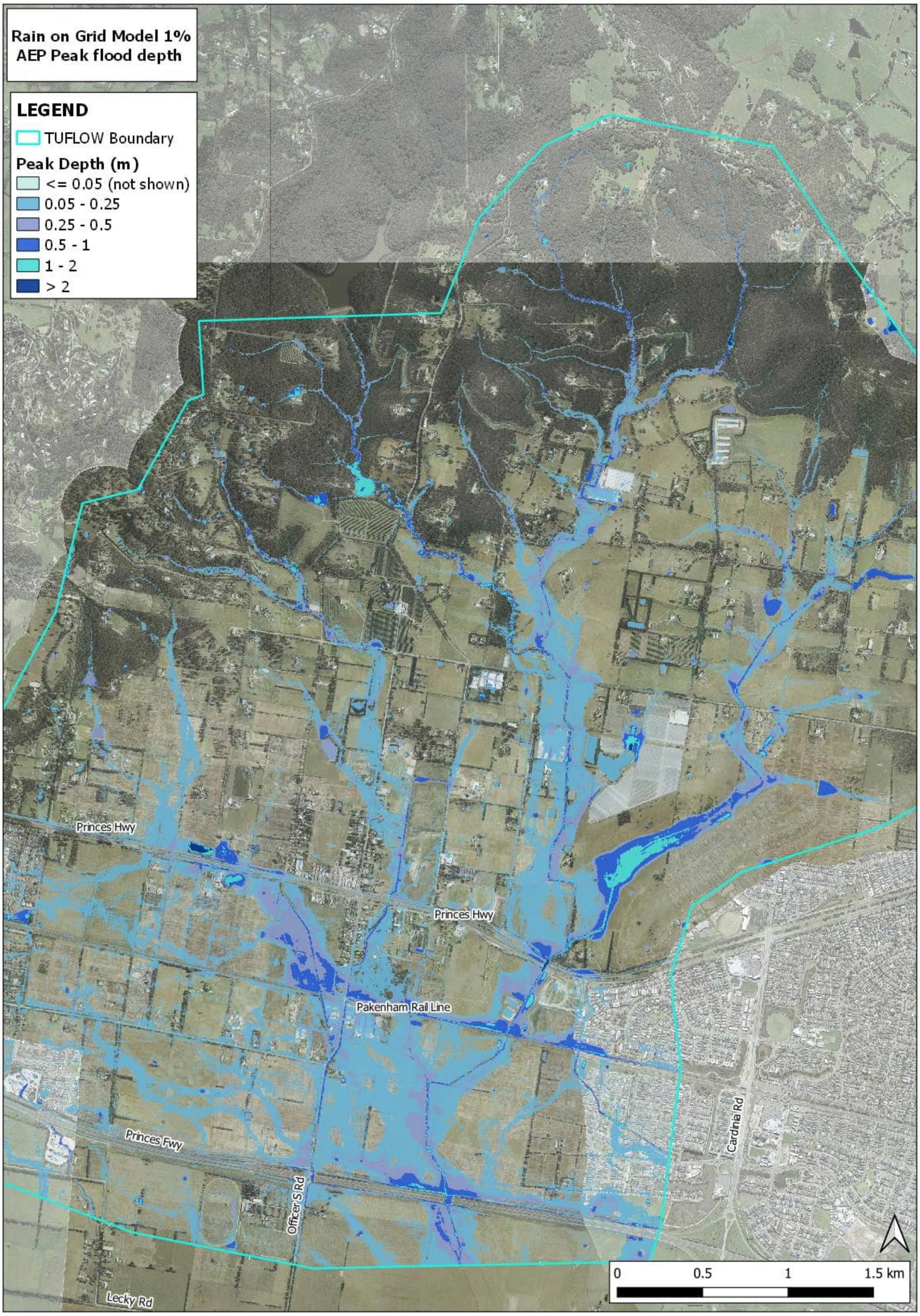


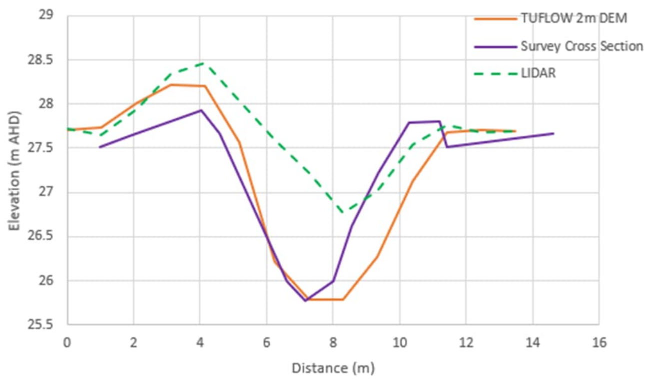
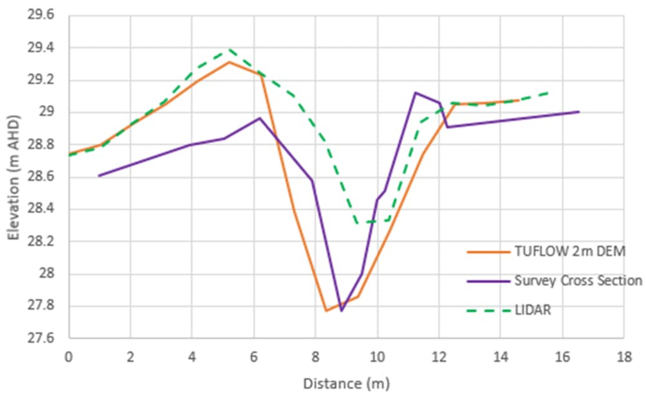
Figure 7-9: 1% AEP Peak Flood Depth (m)

8. Officer South Drain – Capacity

As the Officer South Drain is a key flow path for the PSP, additional investigations were undertaken to assess the capacity. Based on 2010 aerial imagery, LiDAR and survey information the capacity of the drain will be influenced by numerous elements including the channel profile, shape, and blockages such as crossings and debris. Locations of where overland flows enter the system will also have an influence. A simplistic Nomograph calculation of the Lecky Road culverts on Officer South Road Drain indicated the likely capacity is in the order of 10-12 m^3/s assuming outlet-controlled conditions.

To ascertain how the drain would likely perform along the length from downstream of the rail line to the Cardinia Creek outlet a TUFLOW 2 m HPC model was set up using steady state flows (Figure 8-1). Details of the model setup are provided in Table 8-1.

Table 8-1: Officer South Drain TUFLOW model

Setup Item	Adopted Setup
TUFLOW Version	2020-10-AA
Purpose	Estimate drain capacity and outflow locations.
Grid Size	2 m
Terrain and Modifications	Model extent presented in Figure 8-1. Gully line used for Officer South Drain. Survey points from SE080056 (*officer South Road Drain – Cardinia Creek Upstream to Rix Road Officer South, SM Urban Consulting – August 2008*) adopted to estimate the invert of the channel. Sample Cross sections are provided in the images below.  Cross section upstream of Lecky Road  Cross section upstream of Princes Freeway

<table>
<tr><td>Initial water level</td><td>Not adopted</td></tr>
<tr><td>Losses</td><td>Not applicable</td></tr>
<tr><td>Manning’s values and initial losses</td><td>
<table>
<tr><th>Manning's N</th><th>Description (Figure 8-2)</th></tr>
<tr><td>0.2</td><td>Residential – urban (higher density)</td></tr>
<tr><td>0.05</td><td>Open pervious areas moderate vegetation (shrubs - light)</td></tr>
<tr><td>0.02</td><td>Paved roads/carpark/driveways</td></tr>
<tr><td>0.035</td><td>Open pervious area minimal veg (primary value)</td></tr>
<tr><td>0.1</td><td>Residential -Rural (lower density) (parcel)</td></tr>
<tr><td>0.1</td><td>Railway line</td></tr>
<tr><td>0.06</td><td>Waterway/channel - dense veg</td></tr>
<tr><td>0.05</td><td>Waterway/channel - medium veg</td></tr>
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<tr><td>0.3</td><td>Industrial/commercial</td></tr>
<tr><td>0.03</td><td>Waterways/minimal veg</td></tr>
</table>
</td></tr>
<tr><td>Boundary</td><td>Constant inflow of 11 m^3/s and $20m^3/s$ tested. Four inflow points added along the drain.</td></tr>
</table>

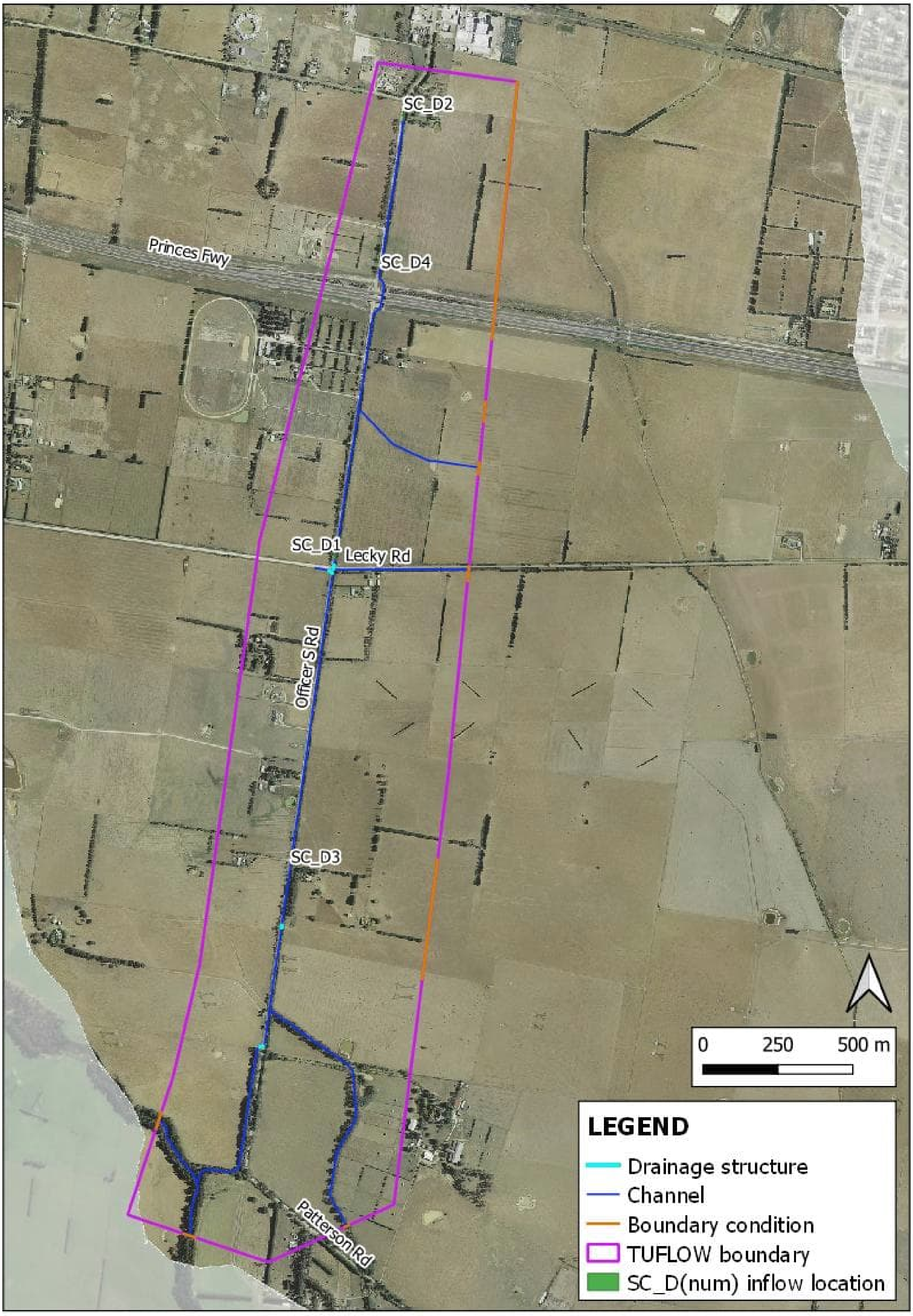


Figure 8-1: Steady state TUFLOW model used to estimate Officer South Drain capacity.

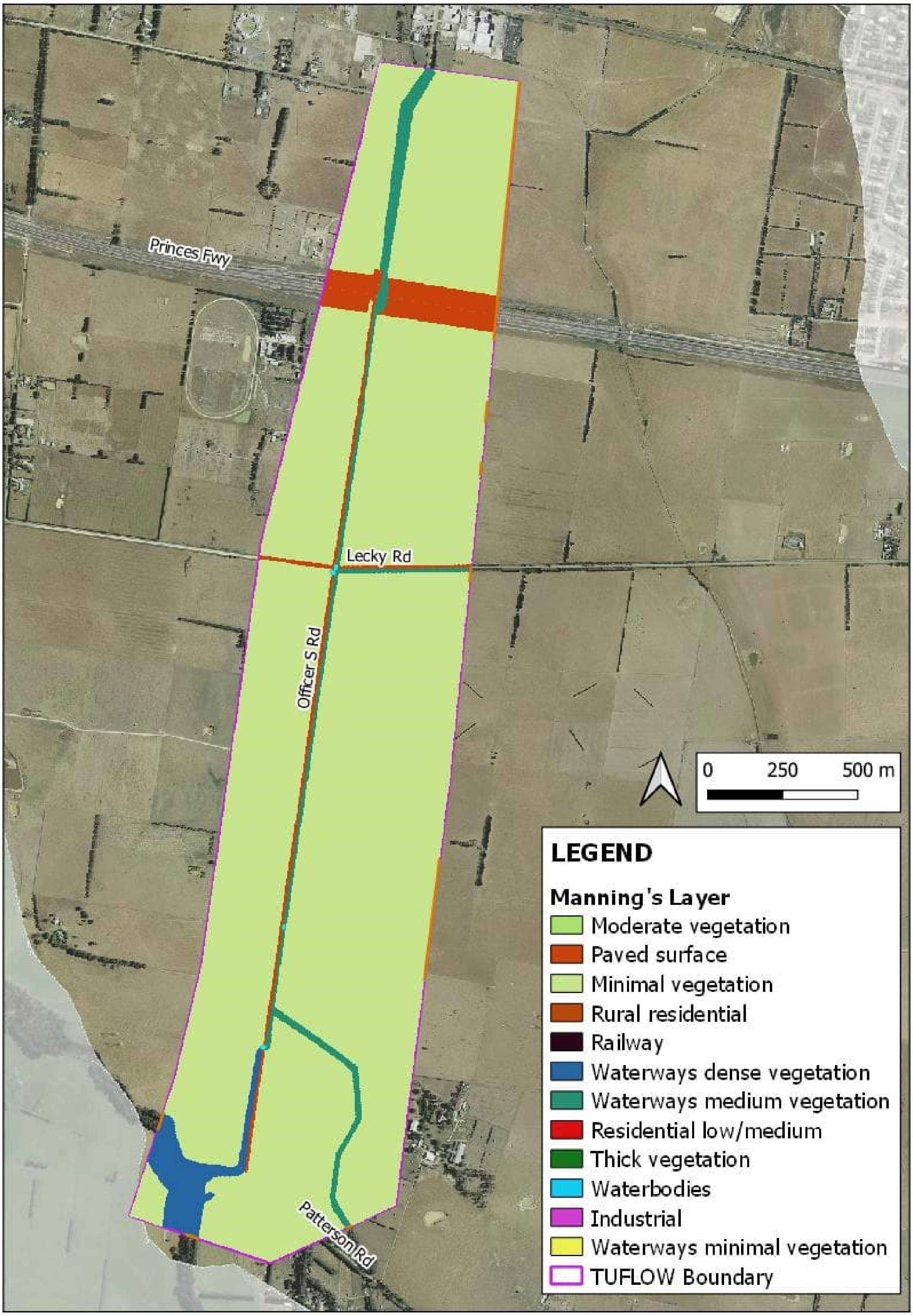


Figure 8-2: Manning's Layer for the Officer South Drain Model

8.1.1 Officer Drain capacity assessment results

The estimate of the spatial location of breakout flows is presented in Figure 8-3, the following is noted regarding the breakout flows:

- Upstream of the Princes Freeway - the cross section of the drain s reduces in areas as it passes under the Freeway. The estimated capacity is in the range of 1.5-3 m^3/s before flows breakout. There is likely to be about 3m^3/s capacity upstream of this. Passing through flows peak at about 2-3m^3/s though that includes outside the channel banks
- Downstream of the freeway capacity is about 4-5 m^3/s that reduces towards Lecky Road to about 3-4 m^3/s.
- Downstream of Lecky road varies from 1.5m^3/s to 4 m^3/s various breakouts
- At Patterson Road the capacity is approximately 4-5m^3/s, though this could be more if an offtake structure didn't divert flows to the east.
- The capacity of the culverts appears to the limited by other factors, i.e. under a sensitivity test of increased manning's values in the channel the Lecky Road culverts reduced from peak of 8 m^3/s to 6m3/s.
- The capacity of the channel is sensitive to the debris and vegetation in the channel and localised increases in roughness may results in reduced capacities.

The information from the assessment above was used to revise the diversions in applied to the RORB model.

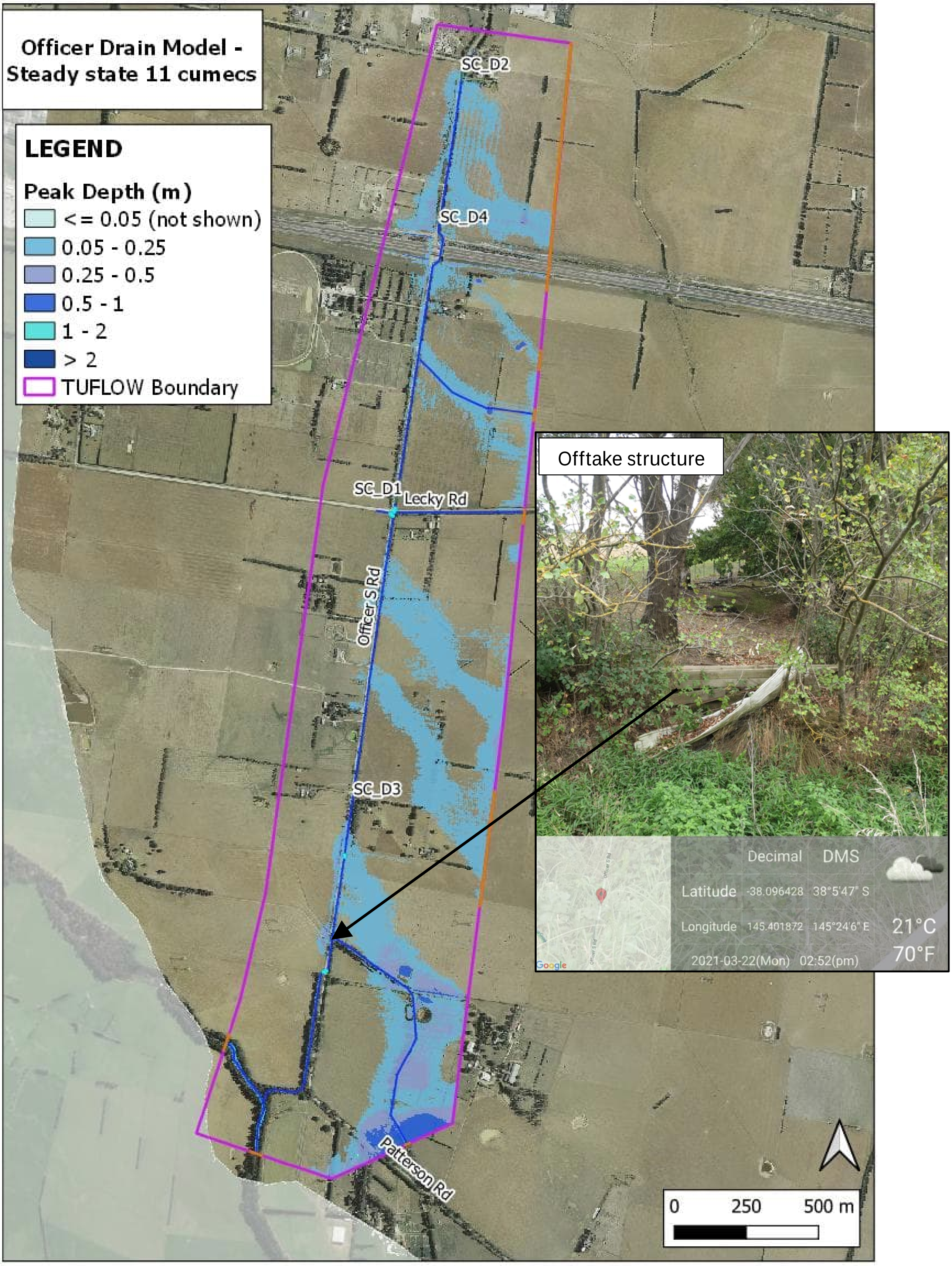


Figure 8-3: Estimated Breakout Points along Officer South Drain

9. Revised RORB Catchment Files

Based on the TUFLOW assessment completed the RORB catchment files was revised. Changes are detailed below. Examples of overland flows paths and connections are presented in Figure 9-1, Figure 9-2 and Figure 9-3. It is noted there is a balance between the hydraulic and hydrological models regarding the representation of the catchment. TUFLOW is better equipped to determine cross sub catchment overland flow paths but requires a significant increase in modelling time to compared to RORB.

Model structure

- Sub-area, reach and node changes:
  - Connect reach AD to AC, add node, reduce the area of AD, increase the area of AC, reposition AF reach, reposition AG reaches, recalculate BA reaches, reposition reach Z, Split AH, U, AI, AB, BC/BE, change BD/BC/BF/BE areas, delete reach 113.
  - Reconfigure all areas and reaches downstream of the PSP based on overland flows (Figure 9-4).
  - Interstation areas were added to the model, one at Chasemore Road on Cardinia Creek and another at Gum Scrub Creek at the Princes Freeway, the resultant d_{av} values are;
    - Chasemore Road $d_{av} = 22$
    - Gum Scrub Creek $d_{av} = 4.09$
    - Remainder of the model $d_{av} = 6.76$
- The impervious fractions have not been updated to the MW Tech Specs requirements (Appendix M – Impervious Fraction Values Guide) where the catchment is split into EIA/ICA and DC areas. This was not updated at the request of MW as for highly developed catchments adopting a fraction impervious value instead of an EIA/ICA/DC was considered to results in more conservative peak flow estimates. An investigation into this is presented in Appendix A.

Retarding Basins/Dams

- Revised Beaconsfield Dam curve based on information provided by MW
- Removed Clay pit RB
- Removed Grasslands RB
- Although there is evidence that infrastructure within the floodplain manipulates the flooding regime, storages behind the Princes Highway, Freeway and the Pakenham Rail Line have not been added to the RORB model. This was at the request of MW, noting that TUFLOW will also model some of these storages.

Farm dams

Adding five large farm dams into the RORB model was investigated however it was found to show little change to the modelling results specifically for the 1% AEP event and thus was not included in the model updates.

Diversions and cross catchment flows

- The diversions added to the model were discussed as diverting primary overland flows between catchments isn't the method typically used in RORB. Generally, the cross catchment diversions such as channels and pipes are represented as the diversion, for example the Officer South Drain be modelled as the diversion as opposed to the natural overland flow path. However, to keep consistency with previous assessments and to aid in the future works assessment it has not been altered. Sensitivity testing was also completed on the impact of the diversions which is presented in Section 9.7.2. The diversions added to the model include:
  - Downstream of the Pakenham Rail line on Officer South Drain – Drain capacity is 3 m^3/s divert all other flows to Gum Scrub Creek (Sub area BA)
  - Through the Princes Freeway – capacity of 2.5 m^3/s

- Upstream of Lecky Road – capacity approx. 3.5 m^3/s
- Downstream of Lecky Road capacity of 2 and 4 m^3/s

The revised RORB layout is presented in Figure 9-4 and Figure 9-5.

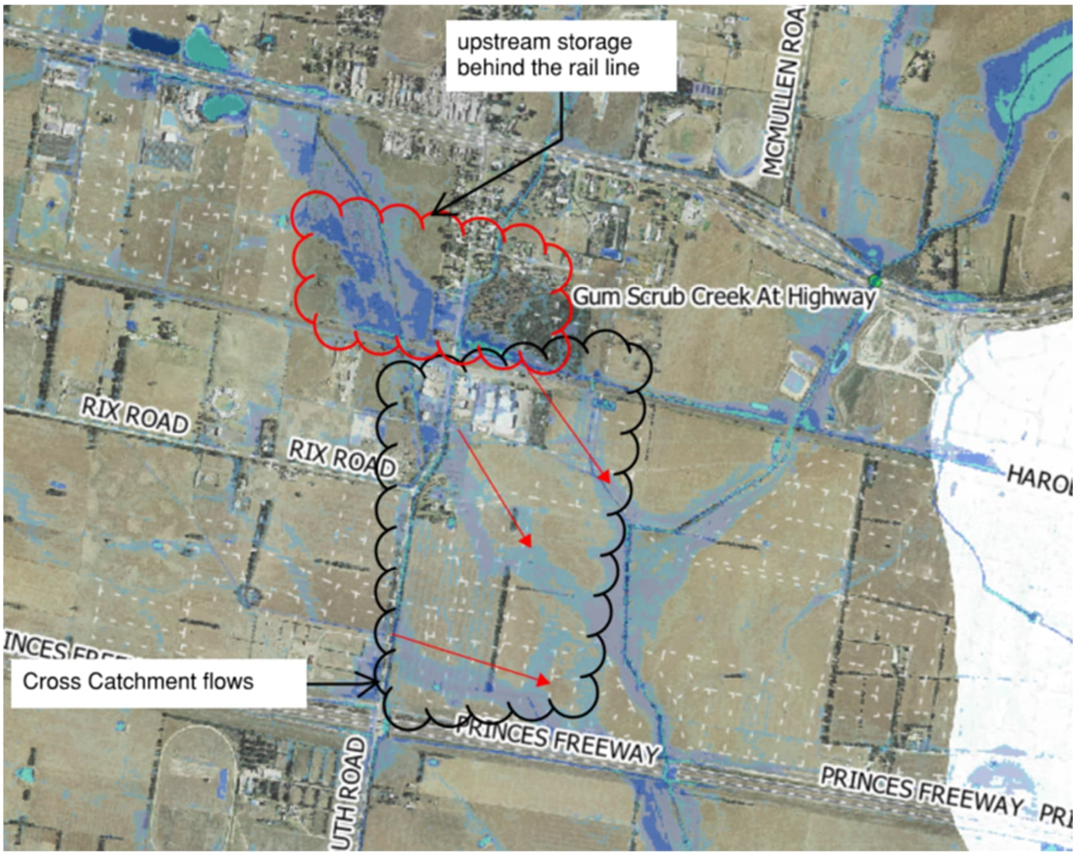


Figure 9-1: Diversions and overland flow paths upstream of Princes Freeway (1% AEP example)

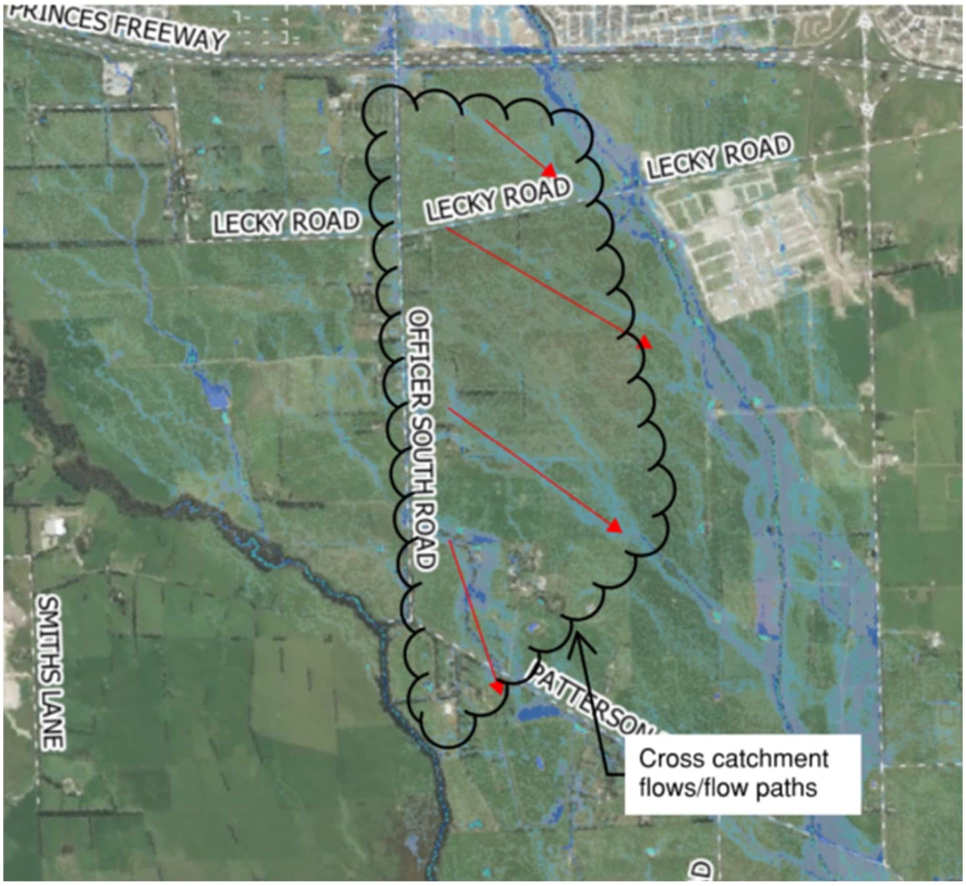


Figure 9-2: Overland flow paths and diversion downstream of the Princes Freeway (1% AEP example)

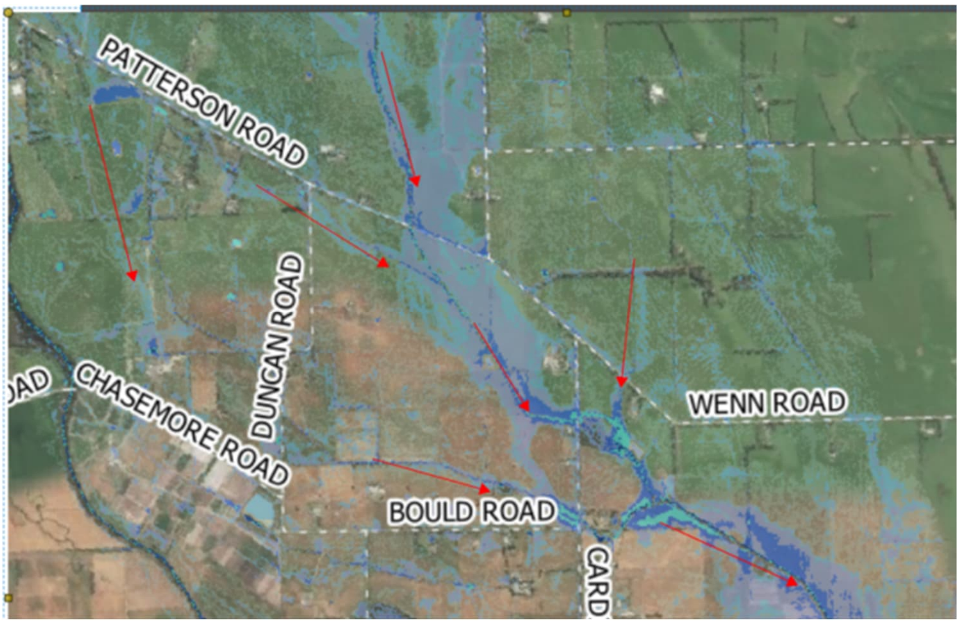


Figure 9-3: Revised flow paths downstream of the PSP (1% AEP example)

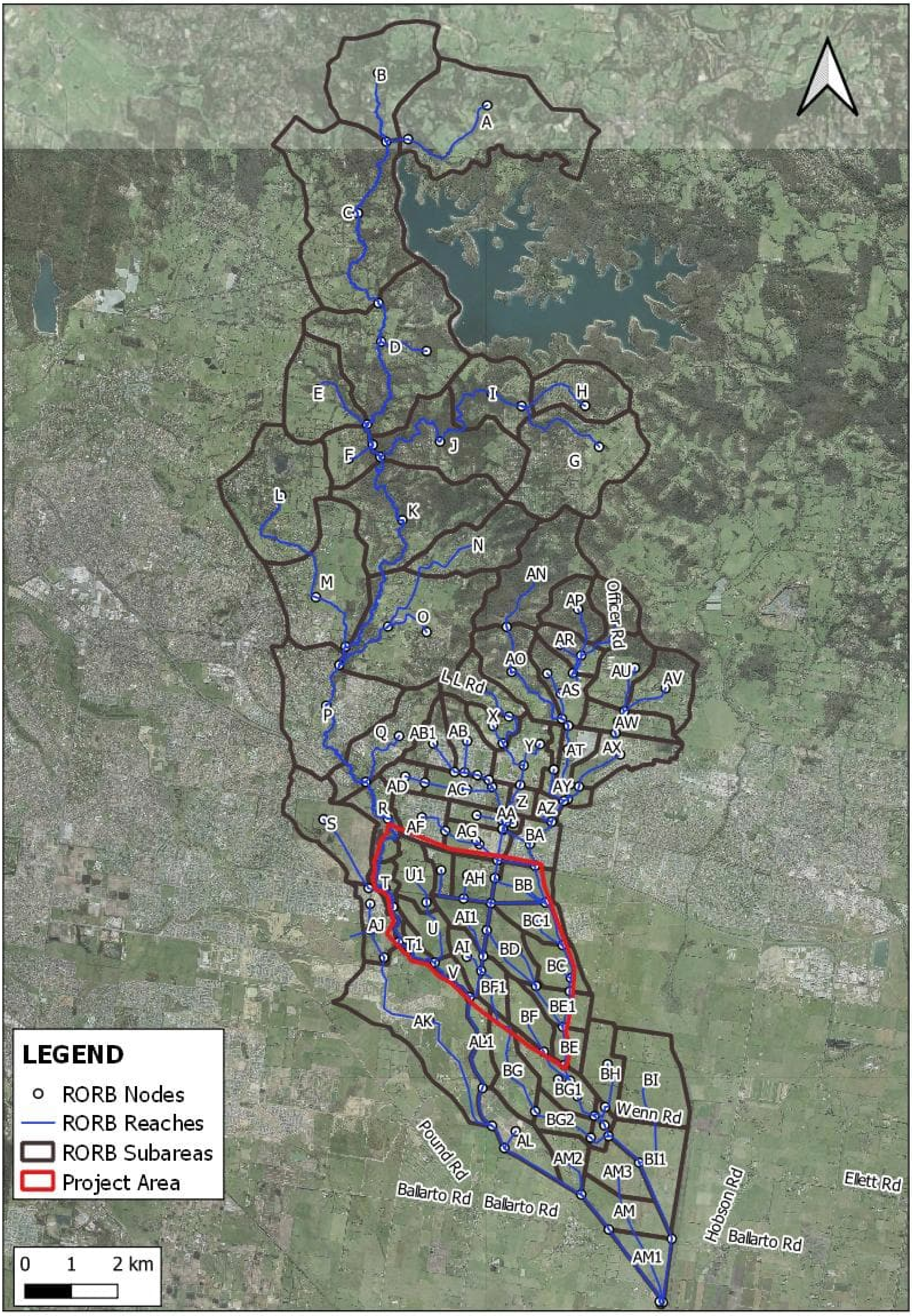


Figure 9-4: Revise RORB subareas

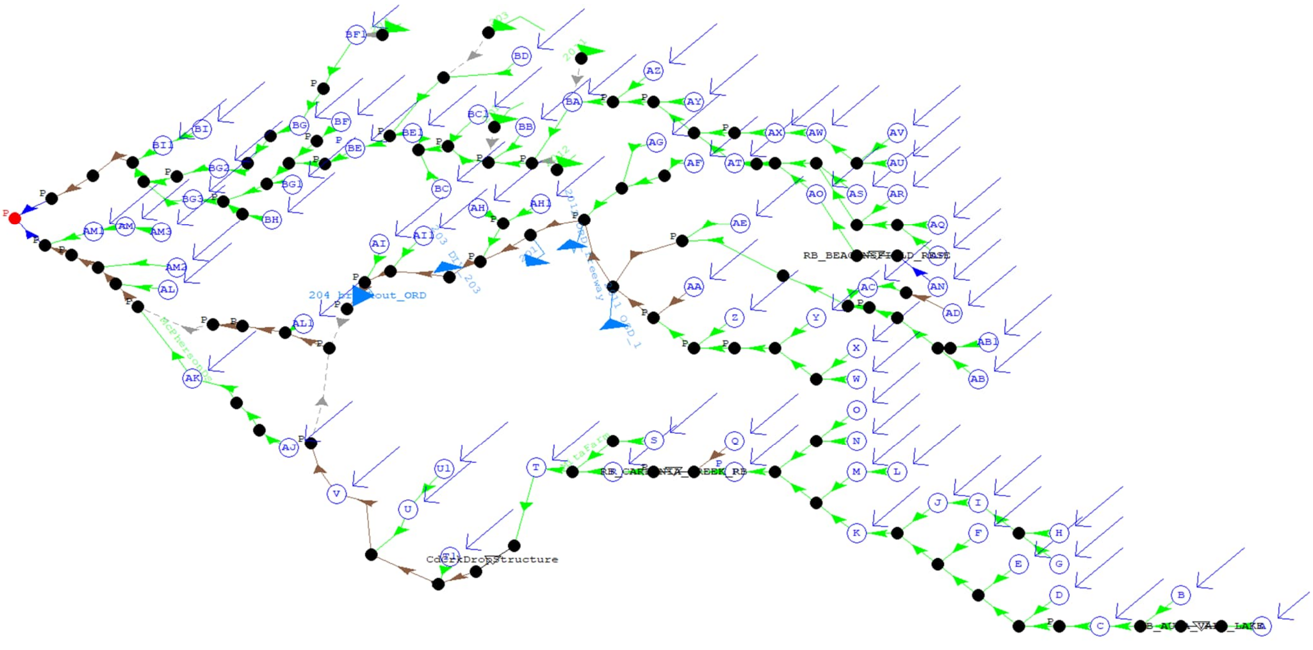


Figure 9-5: Revised RORB catg file

9.1 Flood Frequency Analysis

Within the catchment area there are three flow gauges:

- 228228 – Cardinia Creek and Chasemore Road
- 228365 – Gum Scrub Creek at Princes Highway
- 228382 – Cardinia Creek at Drop Structure

The first two gauges were considered for a flood frequency analysis. Gauge 228382 was not considered as it is upstream of 228228 which would provide a more suitable representation of flows in Cardinia Creek downstream of the PSP.

The purpose of at-site FFA is to determine flood quantiles of design flood peaks. At-site flood frequency analysis (FFA) was undertaken at the relevant gauges. At-site FFA was completed in accordance guidance outlined in Book 3 Chapter 2 of Australian Rainfall and Runoff (Kuczera and Franks, 2019) using the Bayesian Framework incorporated into the Flike software package.

This involved:

- Extracting the Annual Maximum series for the water year (January to December)
- Fitting a statistical distribution in Flike (Log Pearson Type 3 or Generalised Extreme Value)
  - Censoring low flows
  - Incorporating prior parameter information from the RFFE model (this was excluding for Chasemore Road given there is development upstream of the catchment).
- Producing food quantiles (peak flows verses probability)

The resulting flood frequency curves are presented in the sections below.

9.1.1 Cardinia Creek at Chasemore Road (228228)

The Cardinia Creek gauge at Chasemore Road is located downstream of the Chasemore Road bridge (Figure 2-1). The gauge consists of approximately 47 years of data and is of suitable quality. It is noted that Cardinia Creek is a regulated catchment however released flows from Cardinia Reservoir are unlikely to influence the FFA assessment due the low flows released.

The resulting flood frequency curves are shown in Figure 9-6 and the resulting quantiles are listed in Table 9-1.

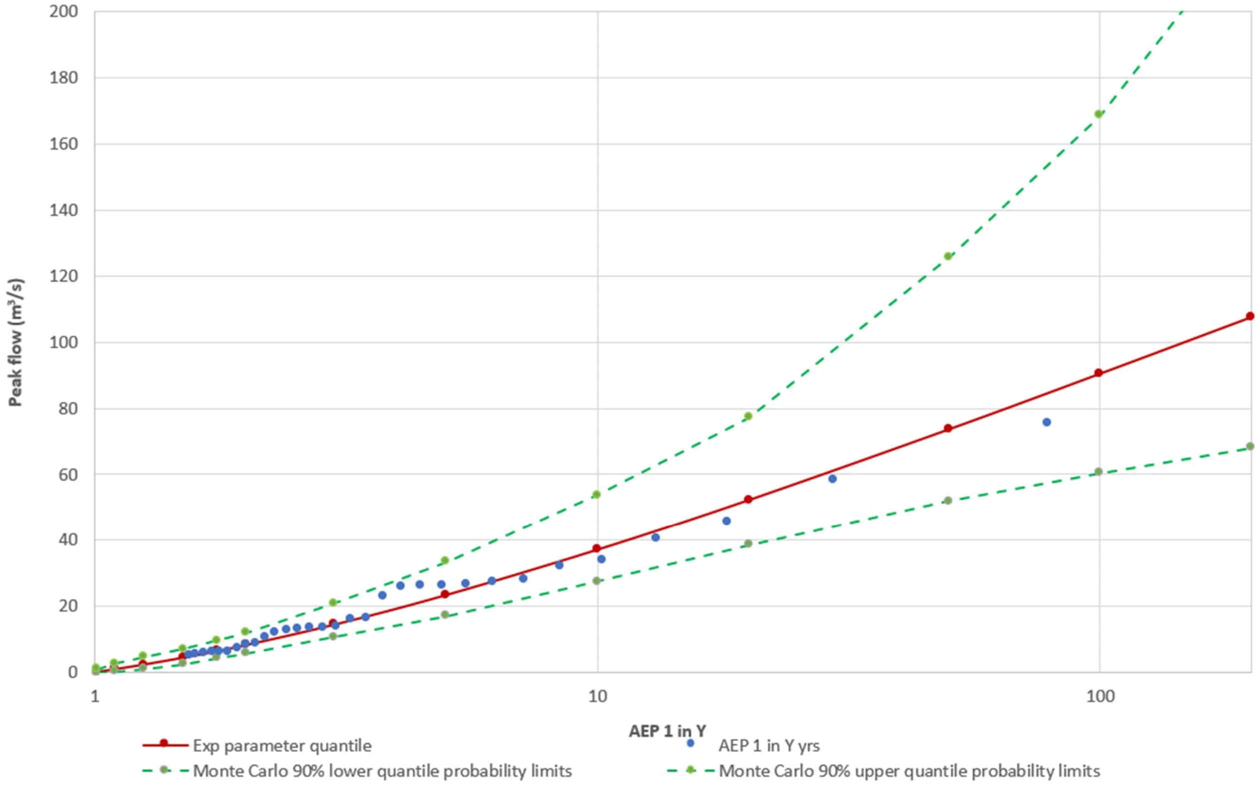


Figure 9-6: Flood frequency curve for gauge 228228 - Chasemore Road, Bayesian - PILF 5 m^3/s (Probable Influential Low Flows of 5 m^3/s removed)

Table 9-1: Flood frequency results for gauge 228228 - Chasemore Road, Bayesian - PILF 5 m^3/s

AEP event	Expected parameter quantile	Monte Carlo 90% lower quantile probability limits	Monte Carlo 90% upper quantile probability limits
50%	8.3	5.8	12.0
20%	23.4	17.1	33.5
10%	37.2	27.4	53.6
5%	52.3	38.5	77.2
2%	73.7	51.9	125.6
1%	90.6	60.5	168.6

9.1.2 Gum Scrub Creek at Princess Highway (228365)

The Gum Scrub Creek gauge is located between the east and west bound carriageways of Princes Highway (Figure 2-1). The gauge consists of approximately 40 years of data. Based on available imagery the gauge is located between two sets of box culverts on Gum Scrub Creek (Figure 9-7 and Figure 9-8). It is considered these structures and the freeway would limit the capacity of the gauge to produce an appropriate rating curve. As such, this gauge is not considered suitable for levels typically more than 2 m, which approximately equates to flows in the region of 1.5-4 m^3/s based on the rating curve. Although a detailed assessment of the rating curve hasn't been completed it would be expected for flows beyond this range would interact significantly with the surrounding infrastructure (Figure 9-9).

The resulting flood frequency curves are shown in Figure 9-10 and the resulting quantiles are listed in Table 9-2.

Figure 9-7: Gum Scrub Creek gauge (yellow) visible between east-bound and west-bound carriages of the Princes Highway (2009 aerial imagery

Figure 9-8: Gum Scrub Creek gauge (yellow) visible from Streetview between east-bound and west-bound carriages of the Princes Highway (Bing Street view)

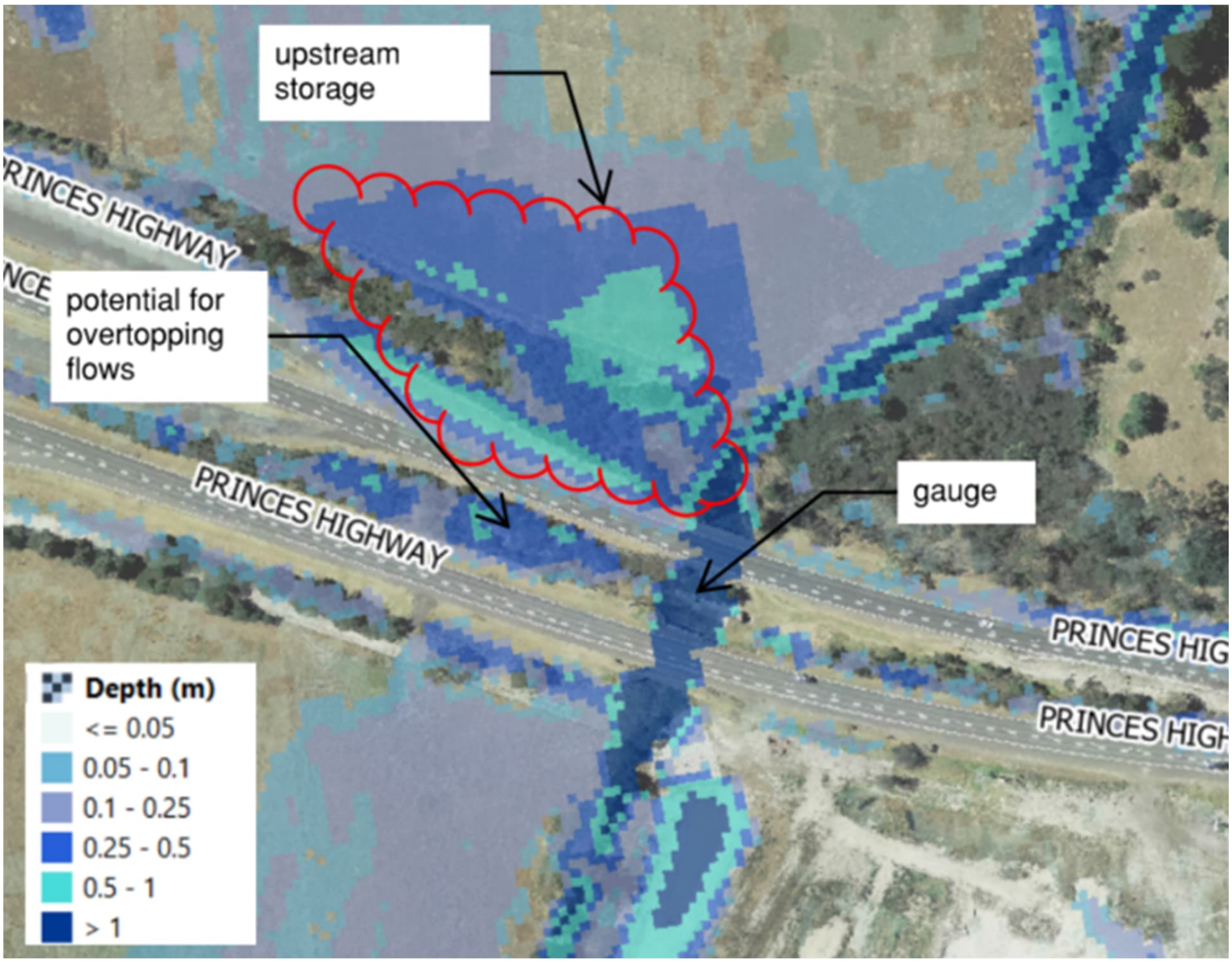


Figure 9-9: 10% 540min (9hr) storm

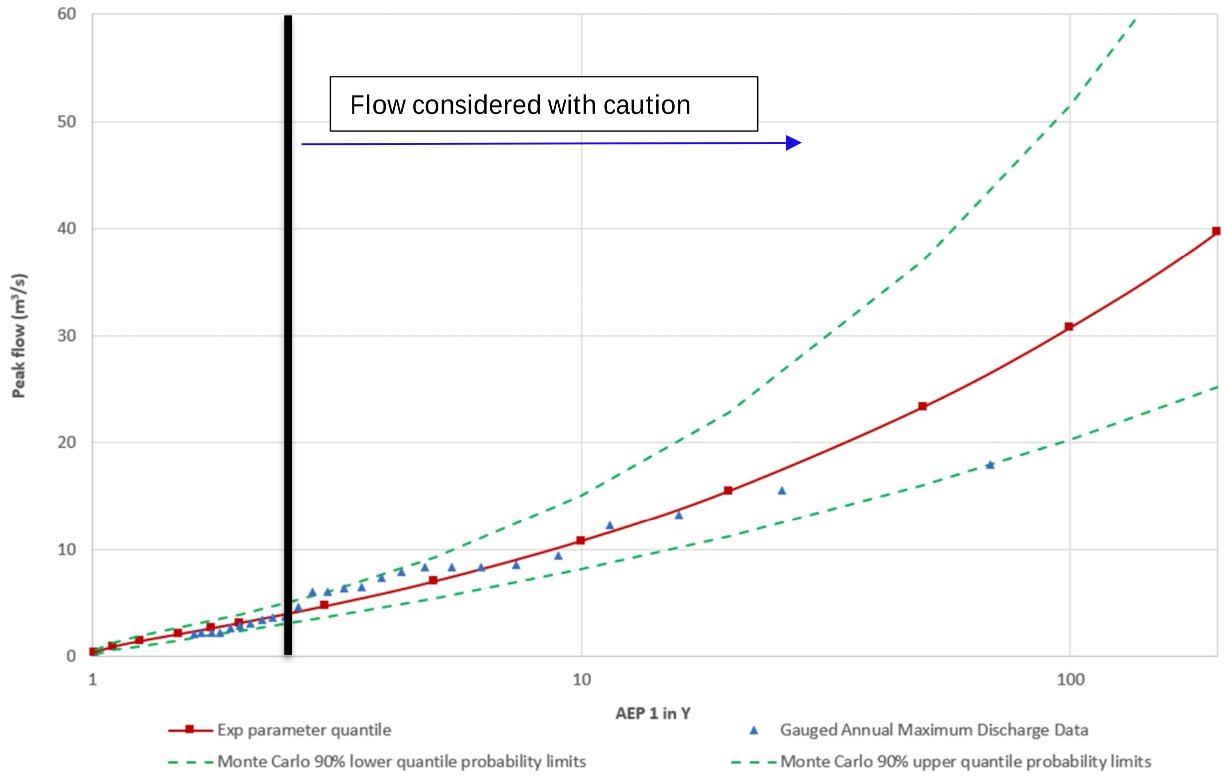


Figure 9-10: Flood frequency curve for gauge 228365 – Gum Scrub Creek, Bayesian - PILF 2 m^3/s Probable Influential Low Flows of 2 m^3/s removed)

Table 9-2: Flood frequency results for gauge 228365 – Gum Scrub Creek, Bayesian - PILF 2 m^3/s

AEP event	Expected parameter quantile	Monte Carlo 90% lower quantile probability limits	Monte Carlo 90% upper quantile probability limits
50%	3.1	2.4	3.9
20%*	7.0	5.4	9.2
10%*	10.8	8.1	15.0
5%*	15.5	11.2	22.8
2%*	23.3	16.0	37.0
1%*	30.7	20.3	51.5

*values beyond estimated reliability level

9.2 Calibration

A calibration/validation process was completed using the available information and updated RORB model. This involved:

- Selecting events to calibrate the RORB k_c values – with the aim of matching the shape, peak and volume.
- Adopting the selected k_c value and simulation RORB in Monte Carlo Mode to calibrate the losses to the FFA curve.

9.2.1 Calibration – Chasemore Road

To calibrate to the Chasemore Road gauge, an interstation area was added to the RORB model at Chasemore Road. The upstream area is approximately 95 km^2 and consists of the Cardinia Creek and Officer South Road Drain catchments. The RORB parameter d_{av} for the catchment is 22. km. In order to distribute spatial patterns rainfall, gauge information upstream was adopted and Thiessen Polygons were used to determine the portions of rainfall across the RORB sub-catchments (Figure 9-11). Additional daily rainfall gauge data was download from the BoM website for 86261 Beaconsfield Upper and 86299 Berwick (Buchanan Road).

The events selected for the calibration process are detailed in Table 9-3. The events were selected from a similar time period (last 10-15 years) however it is noted the millennium drought occurred over this time which may influence the losses and performance of the catchment. Based on the information presented in Table 9-3, there is significant spatial variability across the Cardinia catchment and the rainfall experienced at the Chasemore Road gauge varies compared to the readings in the upstream sections of the catchment.

Ideally the RORB model would have been run in "FIT" mode with fix losses however RORB would not run due to the diversions.

Based on the calibration process the following was noted:

- It was difficult to match the timing of the catchment.
- Peaks, volumes and slope could generally be matched.
- Lower flow events typically required a higher k_c value.

Using the calibration process the proposed kc value for this section of the catchment is 20.5. The calibration parameters selected to best fit the observed flows for each event are provided in Table 9-4. This k_c is considered comparable to other values that would be expected based on regional estimates and other assessments (Table 9-6).

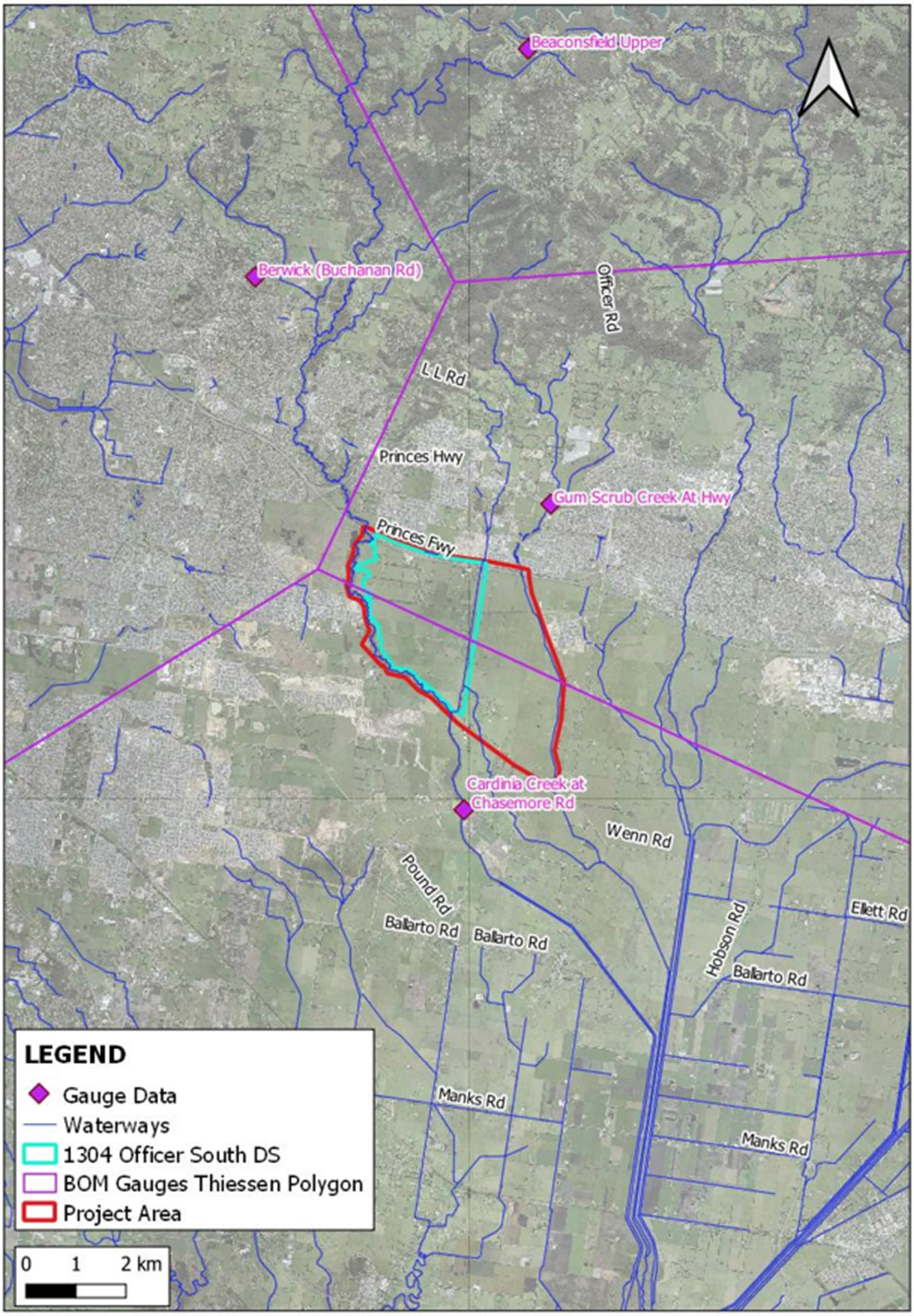


Figure 9-11: Distribution of spatial patterns rainfall via Thiessen Polygons approach

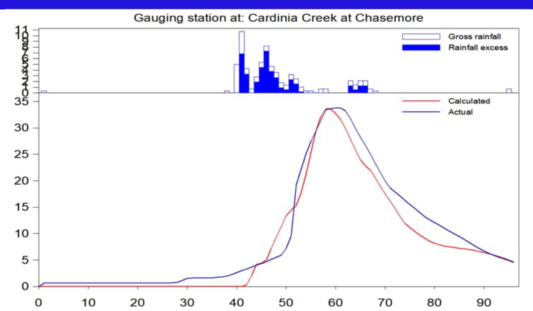
Table 9-3: Events selected for use in the calibration process.

Event	Date	Peak flow at Chasemore Road (m^3/s)	Pluvial data Chasemore Road - Total rainfall (mm)	Gum Scrub Creek at Prince Highway total rainfall (mm)	Berwick (Buchanan Road) 86299 Total Rainfall (mm)	Beaconsfield Upper 86261 Total Rainfall (mm)
1	28/7/1996-31/7/1996	33.8	38	62.51	86	115.1
2	12/11/2004-16/11/2004	27.3	39.4	52.6	64.7	52.6
3	2/2/2005-5/2/2005	28	121	158.4	172.8	158.4
4	30/10/2010-5/11/2010	16.8	58.4	77.8	75	77.8

Table 9-4: Calibration parameters selected to best fit the observed flows for each event.

Parameter	Event 1	Event 2	Event 3	Event 4
k_c	21.5	21	20.5	25
Pervious IL	10	14	70	55
Pervious CL	1	0.1	07	0.1
Notes	Good fit	Reasonable fit, matches peak but not volume, steepness matched with a lower k_c.	Reasonable fit to peak, high losses required, something likely wrong with the gauge data.	Reasonable fit, timing is off, but the shape match is suitable..

Table 9-5: Calibration RORB output plots for each event.

Event	Output plot
Event 1	

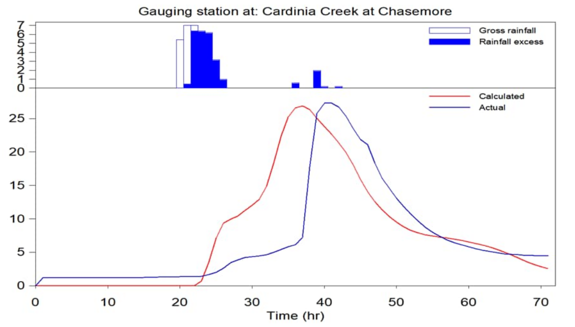
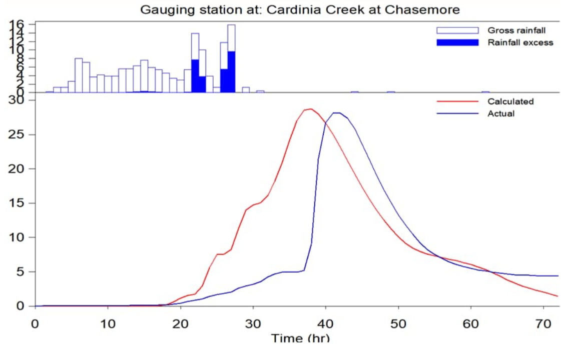
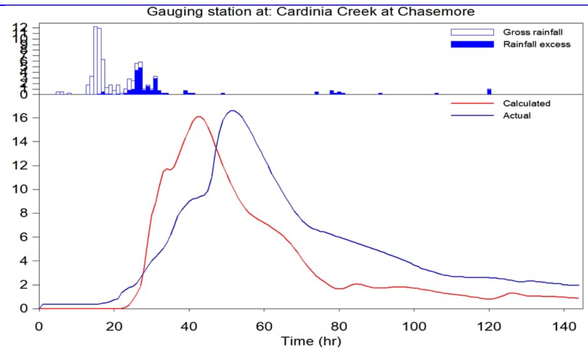
Event 2	
Event 3	
Event 4	

Table 9-6: RORB k_c calibration value and comparison to other assessment approaches and regional equations.

Method	k_c Estimate
Calibration	20.5
Stormy Water Solutions	23.3
MW $k_c = 2.37 \times A^{0.45}$ (>800mm rainfall)	21.3
MW $k_c = 2.2 \times A^{0.5}$ (RORB general)	21.3
k_c = 1.25 dav (Pearse et al. 2002)	27.6
$k_c = 1.53 \times A^{0.55}$ (South East Vic – DVA)	18.6
k_c - 2.07 x dav (Pearse et al. High)	45.6
Toomuc Creek (Engineers Australia, 2013) ratio (kc = 12, dav = 8.94)	29.5

9.2.2 Calibration – Gum Scrub Creek

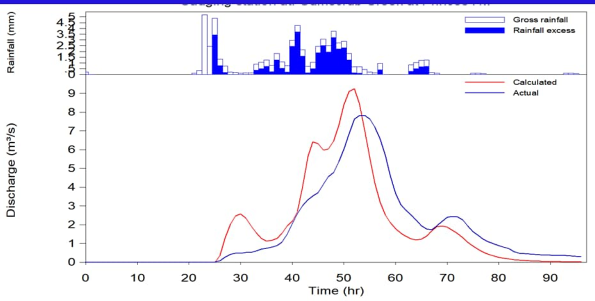
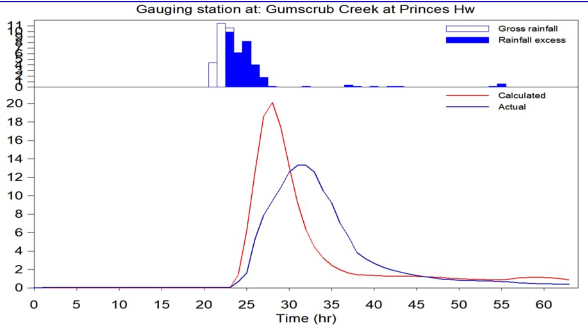
As detailed in Section 9.1.2 there is low reliability on the Gum Scrub Creek gauge flow values. Despite this, the same events detailed in Table 9-3 were tested in RORB model to understand how the model would perform. This was completed by setting up an interstation area at the Gum Scrub Creek gauge. The upstream area is approximately 17 km^2, with the d_{av} at 4.05 km. The Thiessen Polygons analysis did not determine significant spatial variability and a uniform spatial pattern was applied.

Discussions with Melbourne Water and sensitivity testing resulted in the preference to adopt a k_c that would produce conservative results based on this a k_c of 5.5 was selected as the preferred routing parameter. A comparison of the selected k_c to regional method estimates is presented in Table 9-9. The adopted k_c value aligns with the nearby Toomuc Creek catchment. The performance of the adopted k_c value against selected storm events is provided in Table 9-7 and Table 9-8. The adopted k_c does results in more peaky flows and it was difficult to match the selected storms.

Table 9-7: Performance of adopted routing parameter against observed flows events

Parameter	Event 1	Event 2	Event 3	Event 4
k_c	5.5	5.5	5.5	5.5
Pervious IL	10	18	20	25
Pervious CL	FIT mode	FIT mode	FIT mode	FIT mode
Notes	ok fit to shape. Lower k_c results in peakier flow.	ok fit, peakier and less volume than the gauge data.	ok fit, peakier and less volume than the gauge data.	Poor fit

Table 9-8: Calibration RORB output plots for each event.

<table>
<tr><th>Event</th><th>Output plot</th></tr>
<tr><td>Event 1</td><td>
</td></tr>
<tr><td>Event 2</td><td>
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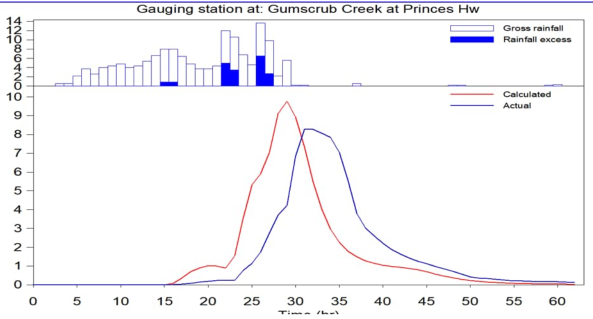
<tr><td>Event 3</td><td>
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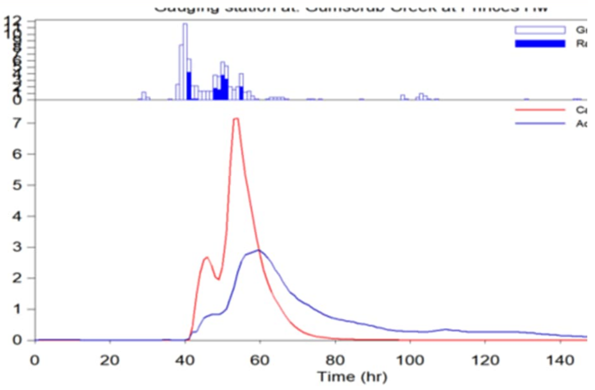
<tr><td>Event 4</td><td>
</td></tr>
</table>

Table 9-9: RORB k_c calibration value and comparison to other assessment approaches and regional equations.

Method	K_c Estimate
Adopted	5.5
Stormy Water Solutions	23.3
MW $k_c = 2.37 \times A^{0.45}$ (>800mm rainfall)	9.2
MW $k_c = 2.2 \times A^{0.5}$ (RORB general)	9.07
k_c = 1.25 dav (Pearse et al. 2002)	5.06
$k_c = 1.53 \times A^{0.55}$ (South East Vic – DVA)	7.27
k_c - 2.07 x dav (Pearse et al. High)	8.4
Toomuc Creek (Engineers Australia, 2013) ratio (kc = 12, dav = 8.94)	5.5

9.2.3 Selection of routing parameters

Based on the calibration assessment, the following routing parameters were adopted for the RORB model:

- Interstation area – Chasemore Road: k_c =21.5, k_c/dav = 21.5/22 = 1 (approx.)
- Interstation area – Gum Scrub Creek at Princes Highway: k_c = 5.5, k_c/dav =5.5/4.09 = 1.3

For the remainder of the model area the d_{av} is 6.76 km and a k_c value of 8.45 has been selected. The range of values using regional estimates are provided in Table 9-10. This value aligns with the Pearse value and is similar to the Toomuc Creek ARR 2019 k_c/d_{av} estimate, which is the catchment to the east.

Table 9-10: RORB model adopted k_c and comparison to other assessment approaches and regional equations.

Method	K_c	K_c/d_{av}
Adopted	8.45	1.25
MW $k_c = 2.37 \times A^{0.45}$ (>800mm rainfall)	11.9	1.2
MW $k_c = 2.2 \times A^{0.5}$ (RORB general)	12.1	1.2
k_c = 1.25 dav (Pearse et al. 2002)	8.45	1.25
$k_c = 1.53 * A^{0.55}$ (South East Vic – DVA)	10	1.0
k_c - 2.07 x dav (Pearse et al. High)	14	2.1
Toomuc creek (Engineers Australia, 2013) ratio (kc = 12, dav = 8.94)	9	1.3

9.2.4 Validation to the FFA information – Chasemore Road

Using the adopted *kc* parameters the RORB model was run in Monte Carlo model to establish a suitable set of losses. The following is noted:

- ARR 2019 Data hub Initial Loss recommendation (pervious areas) = 24
- ARR 2019 Data hub Continuing Loss recommendation (pervious areas) = 4.4
- The RORB model was run assuming aerial temporal patterns (assuming 100 km^2) and a non-uniform spatial pattern. ARF values factored to the catchment area upstream of the gauge

- Pre-burst rainfall patterns were included in the simulation.
- The results of the best fit to the FFA curve are presented in Figure 9-12. This modelling scenario includes the losses detailed in Table 9-11. The resulting flows are given in Table 9-12.
- The adopted losses fit well to the FFA curve at Chasemore Road.

Table 9-11: RORB losses adopted that produce best fit to FFA curve at Chasemore Road and comparison to losses recommended in MW Tech Specs).

Method	Pervious Area
Calibration	Initial Loss = 25 (mm), Continuing Loss = 2.5 (mm/hr)

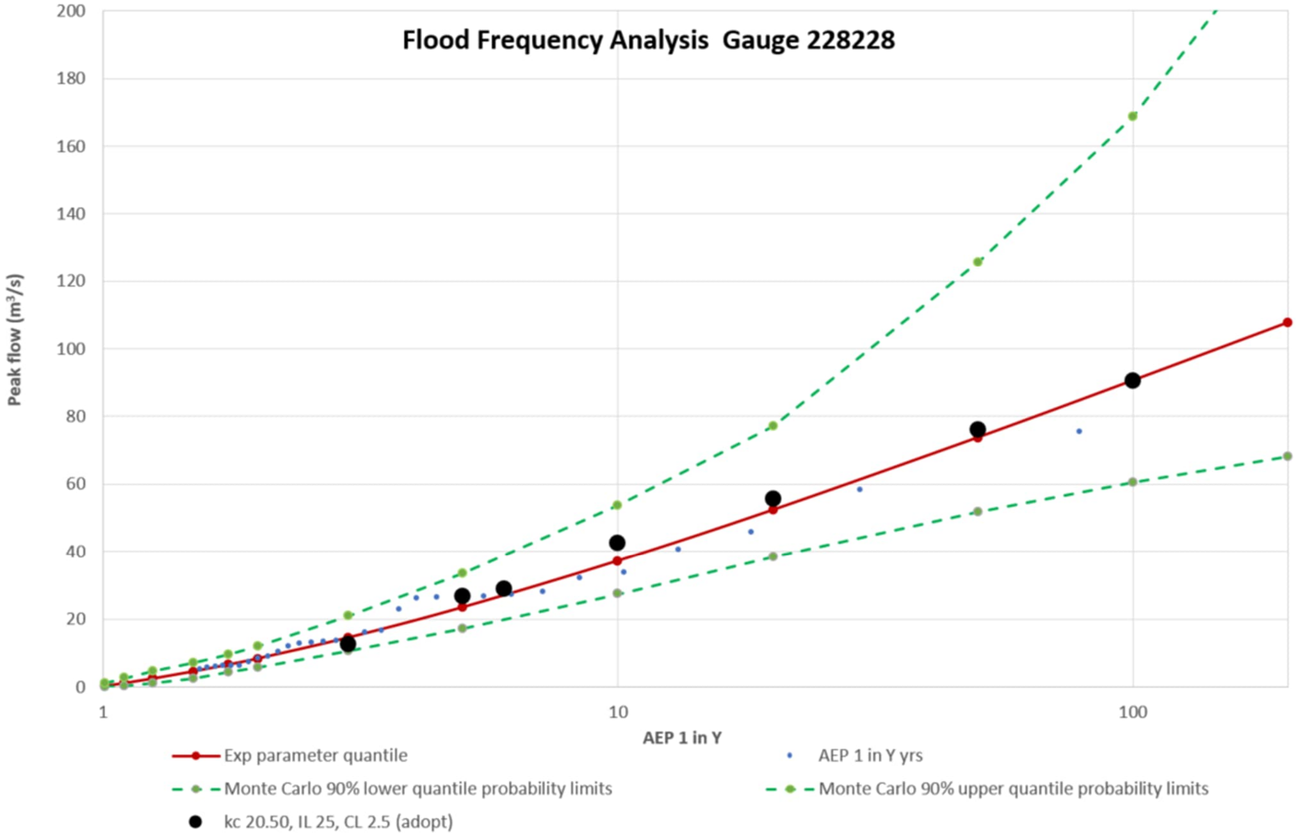


Figure 9-12: Results of the best fit losses calibration to the Chasemore Road FFA curve.

Table 9-12: Resulting RORB flows and critical duration from the losses calibration to the Chasemore Road FFA.

AEP (1 in Y)	Flow (m^3/s)	Critical Duration (hr)
2	8.6	12
5	26	18
10	42	18
20	55	18
50	76	18
100	90.5	18

9.2.5 Verification at Gum Scrub Creek

The suitability of adopting the gauge information at the Gum Scrub Creek gauge is documented in section 9.1.2. Despite the low reliability it has been used to establish an understanding of the model performance. Figure 9-13 provides a plot of the RORB flows against the FFA flows. The model results are with adopted losses of 25 (initial loss) and 3 (continuing loss). The continuing loss was altered from the Chasemore Road gauge as it was found 3 mm/hr provided estimates more aligned to the confidence intervals.

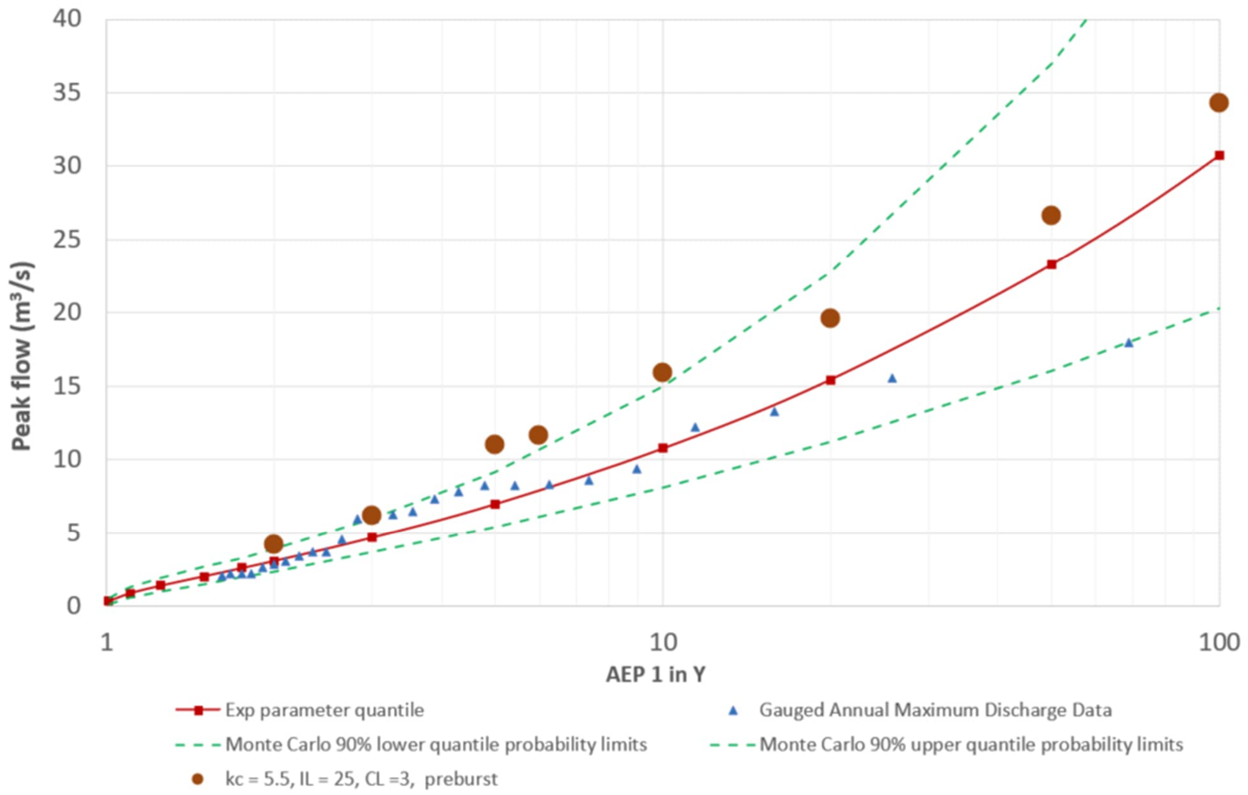


Figure 9-13: Results of adopted losses and routing parameters RORB verification against the Gum Scrub Creek at Princes Highway FFA curve.

9.2.6 Comparison to the Rain on Grid model

As detailed in Section 7.1.1, a Rain on Grid model was simulated for the upper reaches of the catchment to compare to the RORB model performance. The performance at the Gum Scrub Creek crossing at Princes Highway against the FFA and RORB results is presented in Figure 9-14. Flows are also presented in Table 9-13. The modelling shows the peak flows for the 1% AEP are similar whilst the TUFLOW model produces lower flows for the more frequent events. This is likely due to the influence of farm dams as detailed in 7.1.2. The peak flow along Gum Scrub Creek at the Princes Highway estimated by the RORB and TUFLOW Rain on Grid model are presented in Figure 9-15 and Figure 9-16. The estimates indicate there is reasonable alignment between the two modelling technics in estimating the 1% AEP peak flow and volumes.

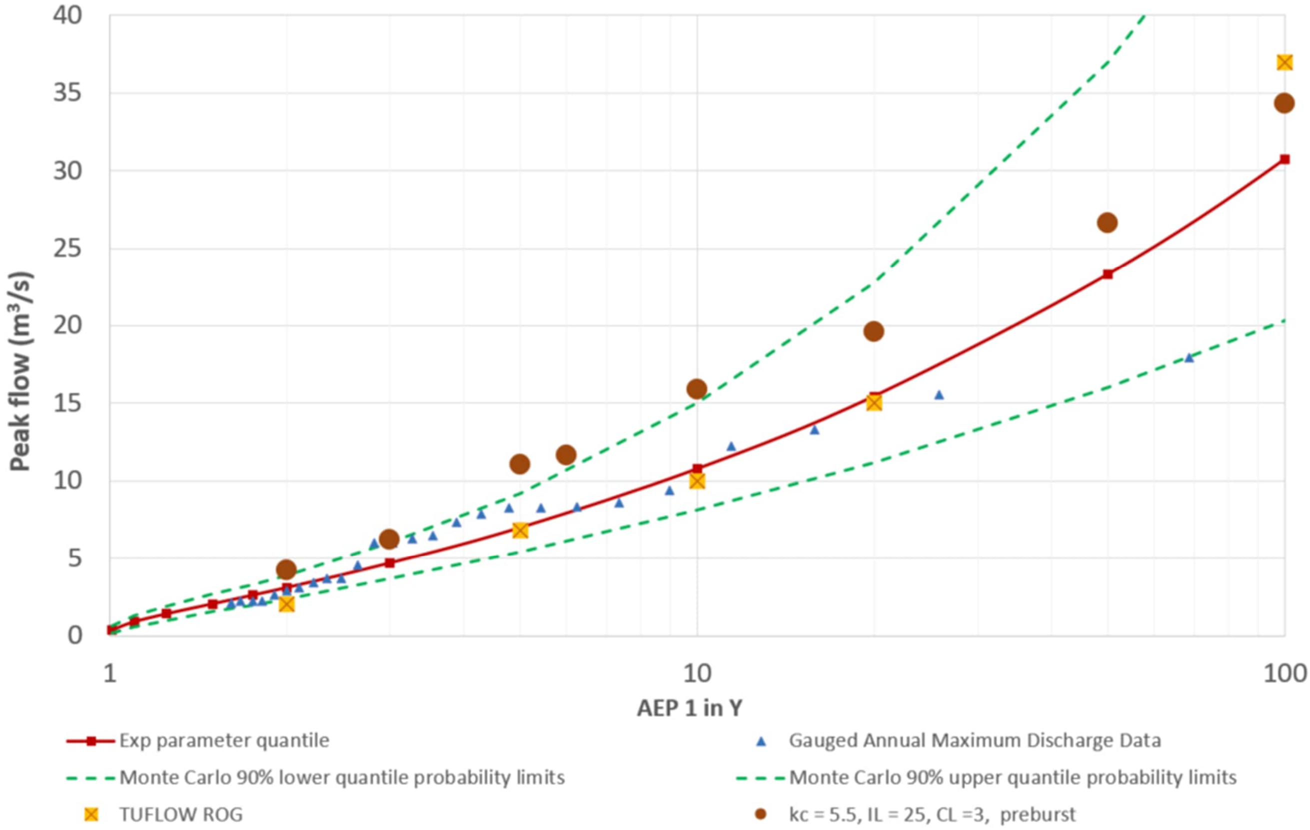


Figure 9-14: RORB model performance at Gum Scrub Creek at Princes Highway comparison against the FFA and TUFLOW Rain on Grid results.

Table 9-13: RORB model flows at Gum Scrub Creek at Princes Highway comparison against the FFA and TUFLOW Rain on Grid results

	FFA Values	RORB		Coarse TUFLOW Rain on Grid (RoG)	
AEP (1 in Y)	Flow (m^3/s)	Flow (m^3/s)	Critical Duration (hr)	Flow (m^3/s)	Critical duration (hr)
2	3.1	4	9	2	9
5	7.0	11	9	6.8	9
10	10.8	16	9	10	9
20	15.5	19.5	9	15	9
50	23.3	25	12	-	-
100	30.7	34	9	34	9

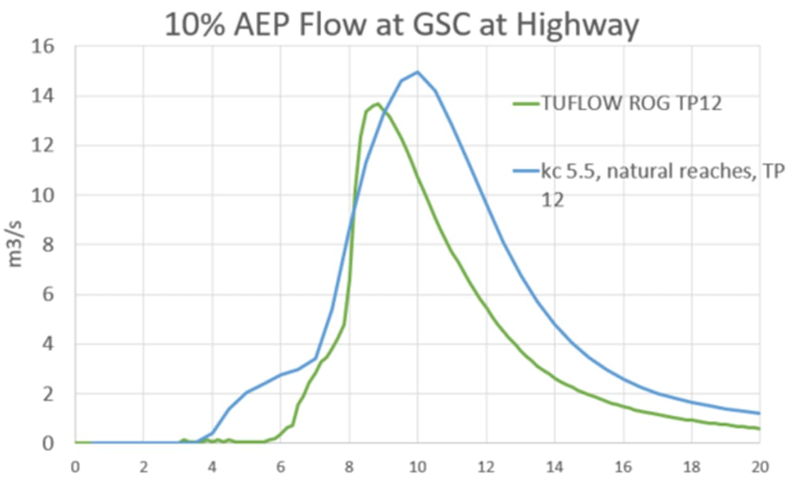


Figure 9-15: RORB and TUFLOW Rain on Grid 10% Peak flow comparison

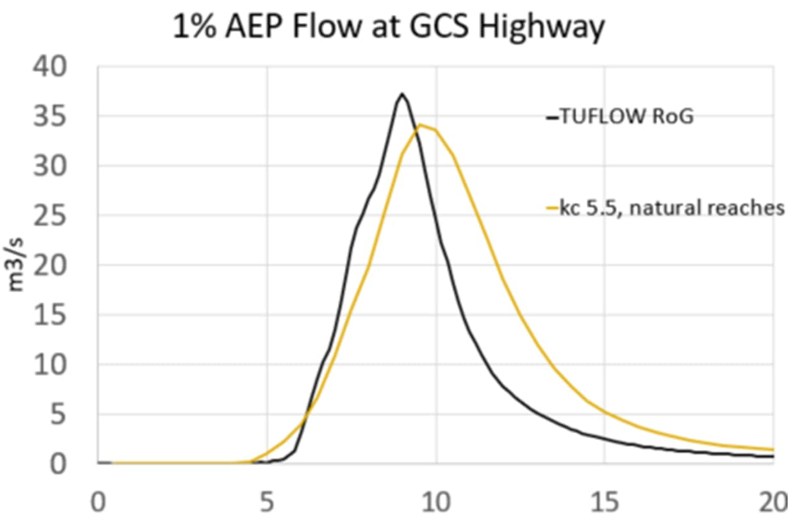


Figure 9-16: RORB and TUFLOW Rain on Grid 1% Peak flow comparison

9.3 Design Inputs

The aim of developing design flows is to establish inputs into TUFLOW which can then be used to establish flood levels and demonstrate how the PSP will influence flooding downstream. The development of the hydraulic model for the assessment is discussed further in Section 10, however the aim is to derive adopted inputs for Cardinia Creek, Officer South Drain and Gum Scrub Creek. As the outlet of the PSP considers several catchments, the assessment should consider the different input requirements based on ARR 2019 recommendations. This is detailed in Table 9-14.

Table 9-14: Design Storms ARR inputs

Location	Comment	Area (km^2)	ARF	Spatial Pattern	Temporal patterns
Cardinia Creek upstream Princes Fwy	Interaction with PSP on the western side and downstream. PSP flows merge with Cardinia Creek downstream.	74	Factors to match Chasemore Road FFA calibration	Non-uniform	Point or areal
Officer South Drain upstream princes Fwy	Flows pass directly through Officer South and the PSP.	10	Factors based on area of both GS and officer	Uniform	Point
Lower Gum Scrub Creek upstream Princes Hwy	Flows pass directly through the PSP	18.3	Factors based on area of GC and officer	Uniform	Point
Subareas within the PSP and on the downstream		Total area approx. 30 km^2 Each sub area approx. 1 to 2 km^2	Adjusted for 1-2km^2 area	Point (for each sub area)	Point
McPherson and Minta farm Inputs into Cardinia creek	Inflows are on the western bank of Cardinia Creek	< 10	Factors based on area of both GS and officer	Uniform	Point

9.3.1 IFD Information and Pre-Burst

The adopted Intensity-Frequency-Duration (IFD) rainfall depths (ARR 2019) were extracted from the ARR Data Hub. The Data Hub and IFD data is provided in Appendix A.

The ARR19 Data Hub provided median pre-burst depths for the catchment were adopted using the inbuilt RORB read-in function. The temporal pattern for the pre-burst values were adjusted as required. This assessment has applied the pre-burst depths in RORB using the temporal patterns based on Minty and Meighan (1999).

9.3.2 Areal Reduction Factors

Areal Reduction Factors (ARF) based on the ARR 2019 Data hub values were applied in RORB to the point rainfall depths to account for intensity variations based on catchment size.

9.3.3 Design Temporal Patterns

Cardinia Creek

Areal temporal patterns for the catchment area based on a 100 km^2 catchment were adopted for the assessment.

Officer/Gum Scrub Creek and PSP

Point temporal patterns were obtained from the ARR Data Hub (30 for each of the durations using the rare, frequent and intermediate AEP range of event frequencies).

Temporal patterns are randomly selected from a sample of the “Southern Slopes” temporal patterns relevant to the catchment area and duration of the storm in RORB (Ball et al., 2019) and applied during the Monte Carlo simulation runs. Temporal patterns were filtered using the method in RORB. This assessment has applied the pre-burst depths in RORB using the temporal patterns based on Minty and Meighan (1999).

For climate change events the rainfalls were factored up by 18.5%.

9.3.4 Design Spatial Patterns

Cardinia Creek

Considerable variation was found in the rainfall depths across the Cardinia Creek catchment due to its elongated shape and the relatively large changes in elevation from south to north (upper catchment receives more rainfall than the lower catchment) and hence non-uniform spatial rainfall pattern was calculated and updated.

Spatial patterns were determined by calculating the mean aerial rainfall depth for 1% AEP for different storm durations to better represent the distribution of rainfall throughout the catchment. BOM IFD gridded 1% AEP rainfall data for different storm durations were used to determine the mean IFD rainfall depth for each sub-area according to the IFD grid values the sub-area encompassed (expressed in RORB as a % of the whole-catchment IFD rainfall).The spatial pattern in design rainfall was subsequently applied in RORB by specifying the % of the whole-catchment IFD rainfall for each sub-area and event duration. The adopted spatial pattern is provided in Appendix A.

Officer/Gum Scrub Creek and PSP

A Uniform spatial was adopted over this area.

9.4 Cardinia Road Drain and Toomuc Creek

The RORB model review identified the provided RORB model does not include flows from the Cardinia Road Drain and Toomuc Creek and the Deep Creek catchments. How these flows interaction and the specific influences is unknown and is primarily considered outside the scope of works. However in order to ascertain if there is an interaction it was agreed with MW that indicative flows would be included hence estimates have been incorporated into the hydraulic model. MW provided the SWS RORB model for the Cardinia Outfall system which includes flows from this catchment. In order to generate outputs, the RORB model was re-run with the following parameters:

- Uniform spatial patterns (it is noted due to the area a spatial pattern should be adopted however this was not investigated by SWS and not included in the calculation of the flows for this assessment).
- Point temporal patterns
- Pre-burst temporal pattern
- Kc = 23.3 (SWS, 2021)

- Initial loss of 25 mm and continuing loss of 3 mm/hr (as per the neighbouring catchments)

Routed outputs for Toomuc Creek, Deep Creek and Cardinia Road Drain were added into the TUFLOW model detailed in section 10.

9.5 RORB Outputs

The design inputs for the two catchment areas were run in RORB using the Monte Carlo option. The results are presented in Table 9-15. In order develop TUFLOW inputs the RORB model was then re-run in Ensemble mode.

Table 9-15: RORB design output results

Location (peak hydrograph)	Peak flow (m^3/s)/Critical Duration					
	63.21% (1 in 1.58 year)	50% (1 in 2 yr)	20% (1 in 5 year)	10%	5%	1%
(27) Upstream Princes HWY	6.6 (12hr)	8.7 (12hr)	28 (18hr)	41 (18hr)	54 (18hr)	90.1 (18hr)
(05) upstream officer diversion	0.8 (4.5hr)	1.9 (9hr)	4.9 (9hr)	6.6 (9hr)	8.3(4.5hr)	13.1 (12hr)
(02) Downstream rail Officer	1.5(4.5hr)	3.1 (9hr)	6.9 (9hr)	9.8 (3hr)	13.1 (2hr)	19.7 (2hr)
(47) Gum Scrub Creek Rail line	0.4 (9hr)	2.7 (9hr)	10.7 (9hr)	15.5 (9hr)	20 (9hr)	33 (12hr)

9.6 Comparison to Previous Assessments

A comparison to the SWS (2020) model outputs is presented in Table 9-16. With the change in the model setup and diversions there is a change in the flows through the PSP. Despite this the overall catchment flows are similar at the model outlet.

Table 9-16: Comparison to the SWS (2020) assessment

Location	SWS – 2020 assessment 1% AEP peak flow (m^3/s)	2022 Jacobs/Spiire Assessment 1% AEP peak flow (m^3/s)
Cardinia Creek Immediately upstream of the confluence with Officer Road Drain	81.2 (18hr)	89 (18hr)
Officer Road Drain at the Freeway	25.7 (12 hr)	13.6 (2hr)
Gum Scrub Creek at the Freeway	40.4 (12 hr)	57.8 (12hr)
Gum Scrub Creek at the Lecky Road	62.7 (12 hr)	70 (12hr)
Gum Scrub Creek at Patterson Road	71.6 (12 hr)	61 (12hr)

Combined Cardinia Creek and Gum Scrub Creek at the Confluence	134.5 (18 hr)	127 (18hr)

9.7 Sensitivity

The following section details the sensitivity analysis completed on the RORB parameters. The results of the sensitivity assessment are presented in Table 9-17.

9.7.1 Adopting ARR 1987 inputs

This sensitivity test included adopting the following inputs:

- ARR 1987 IFD data – based on the supplied SWS file
- .catg file with fraction impervious
- Uniform spatial pattern
- Losses based on IL = 25, CL = 3.3
- No pre-burst
- ARF set to Siriwardena and weinmann – Cardinia Creek set to 100km^2

9.7.2 No diversions

Although diversions have been included in the RORB model they are inherently transforming the RORB model from a hydrological model to a semi water balance/hybrid hydraulic representation as they are transferring overland flows from Officer South Drain to Gum Scrub Creek. The RORB model was re-run assuming no diversions. The model was run in Monte Carlo.

9.7.3 SWS parameters

The SWS (2020) parameters we applied to the .catg file including:

- Kc/dav = 1.04, hence kc =22.9 (Chasemore Road), 4.3 (Gum Scrub Creek), 10.5 (remainder of the model)
- Initial Loss = 10 (accounts for preburst (not added in RORB)), CL = 2.5,

Table 9-17: Sensitivity Assessment results

AEP	Location	Adopted RORB set	ARR 1987	No Diversions	SWS Parameters
1%	Cardinia Creek at Chasemore Road	88.5 (18hr)	87.3 (24 hr)	81.1 (24 hr)	92.5(18hr)
10%	Cardinia Creek at Chasemore Road	37 (18hr)	34.5 (24 hr)	35.7 (12hr)	42 (18hr)
1%	Officer Princes Freeway	12.4 (9hr)	14 (9 hr)	38.2 (9hr)	14.2 (2hr)
10%	Officer Princes Freeway	7.47(6hr)	8.6 (9hr)	19.4 (6hr)	8.9 (2hr)
1%	GSC Princes Freeway	60 (12hr)	70 (9hr)	25.8 (12hr)	102 (2hr)
10%	GSC Princes Freeway	24.1 (9hr)	31 (9hr)	11.7 (9hr)	52.6 (2hr)

10. Hydraulic Modelling

The RORB outputs in the upstream sections of the catchment have been used to establish inputs a TUFLOW model of the PSP and the downstream area. The purpose of the modelling is to determine existing outflows from the PSP and identify the following:

- Where there are breakout flows from Cardinia Creek into the floodplain.
- Generally, the flooding downstream of the PSP in the Cardinia township area.

Inherently there is a level of repetitiveness between the RORB and TUFLOW model however the approach adopted has aimed to develop a robust assessment method.

Model version and setup

TUFLOW version 2020-10-AA has been adopted for the assessment. The TUFLOW model has adopted the HPC quadtree option which allows for different grid sizes to be model across the TUFLOW domain. This option is useful for the catchment as there are large areas of overland sheet flow in paddocks with flows concentrated in narrow creeks and channel. The quadtree option has adopted a 8m, 4m, 2m grid size with paddock modelled as 8m, Cardinia Creek as 4m and Officer South Drain and Gum Scrub Creek model at a 2 m resolution. The 2 m grid resolution has also been adopted where critical roads overtop such as Ballarto Road. To establish critical durations and temporal patterns across the catchment a 10 m grid model of the catchment was also developed. This enabled a large number of runs to be simulated in a relatively condensed time frame.

Terrain Data and Modifications

The base of the model was built of LiDAR provided by MW for 2009. In addition to this point survey information along Gum Scrub creek, Officer South Drain (detailed in section 8), and Cardinia Creek was enforced in the model using Gully break lines. No levee crest levels have been re-enforced in the model.

Layered flow constrictions have been used to model bridge decks. Inverts levels and bridge deck thicknesses were assumed based on either survey information or appropriate assumptions. The assumed bridge loss losses were based on the recommendations in the Technical Guidelines – Hydrologic and Hydraulic Modelling' by Queensland Department of Transport and Main Roads (October 2019).

The terrain data and modifications are presented in Figure 10-2.

Pipe data

Available culvert/pipe data was provided by Melbourne Water. The survey information was also used to confirm inverts and sizes. The culverts at the Cardinia Creek Drop Structure were added based on available survey information.

Boundary Conditions

RORB routed hydrographs were applied at the upstream model extent and rainfall excess hydrographs applied overland flow path regions. Rainfall excess hydrographs from RORB were positioned and applied along streamlines and located in overland flow path areas identified in the Coarse Rain on Grid modelling (Section 7). None of the routed hydrographs applied in RORB include the diversions added to the RORB model, that is, all of the inputs are upstream of the diversions. This has enabled TUFLOW to establish the diversions.

An initial water level layer has also been adopted which primarily fills up farm dams within the catchment. HQ boundaries have been adopted through the model where flows interact with the code boundary. At the request of Melbourne Water, a tidal curve has been adopted on the downstream boundary. MW provided tidal data from 1/1/2020 to 5/05/2021 for gauge 228399 – Western Port Tide Gauge at Evans Inlet Tooradin.   A representative time series for this gauge has been developed for application into the model. This is presented in Figure 10-1. It is noted this curve may not represent the high tide and low tides throughout the year. Additional sensitivity testing and refinement to the tidal level is to be completed. This includes expanding the downstream model boundary to ensure inter-catchment interactions and breakout flows are accommodated in this modelling.

The boundary conditions are presented in Figure 10-3.

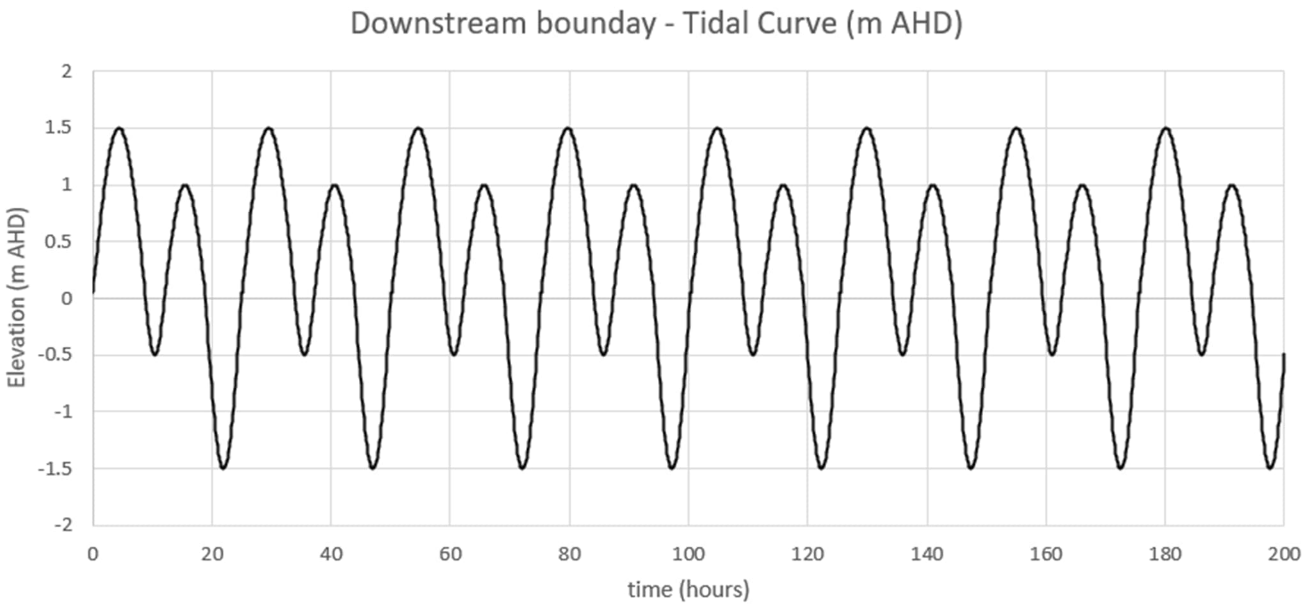


Figure 10-1: Representative Tidal Curve (m AHD)

Manning's Roughness

The adopted roughness values are provided in Table 10-1 and presented in Figure 10-4.

Table 10-1: Adopted Manning's Values

Manning's N	Description
0.2	Residential – urban (higher density)
0.05	Open pervious areas moderate vegetation (shrubs - light)
0.02	Paved roads/carpark/driveways
0.04	Open pervious area minimal veg
0.1	Residential -Rural (lower density) (parcel)
0.1	Railway line
0.06	Waterway/channel - dense veg
0.05	Waterway/channel - medium veg
0.05	Residential - medium/low density
0.1	Open pervious area - thick veg (trees)
0.025	Lakes and water bodies
0.3	Industrial/commercial
0.03	Waterways/minimal veg

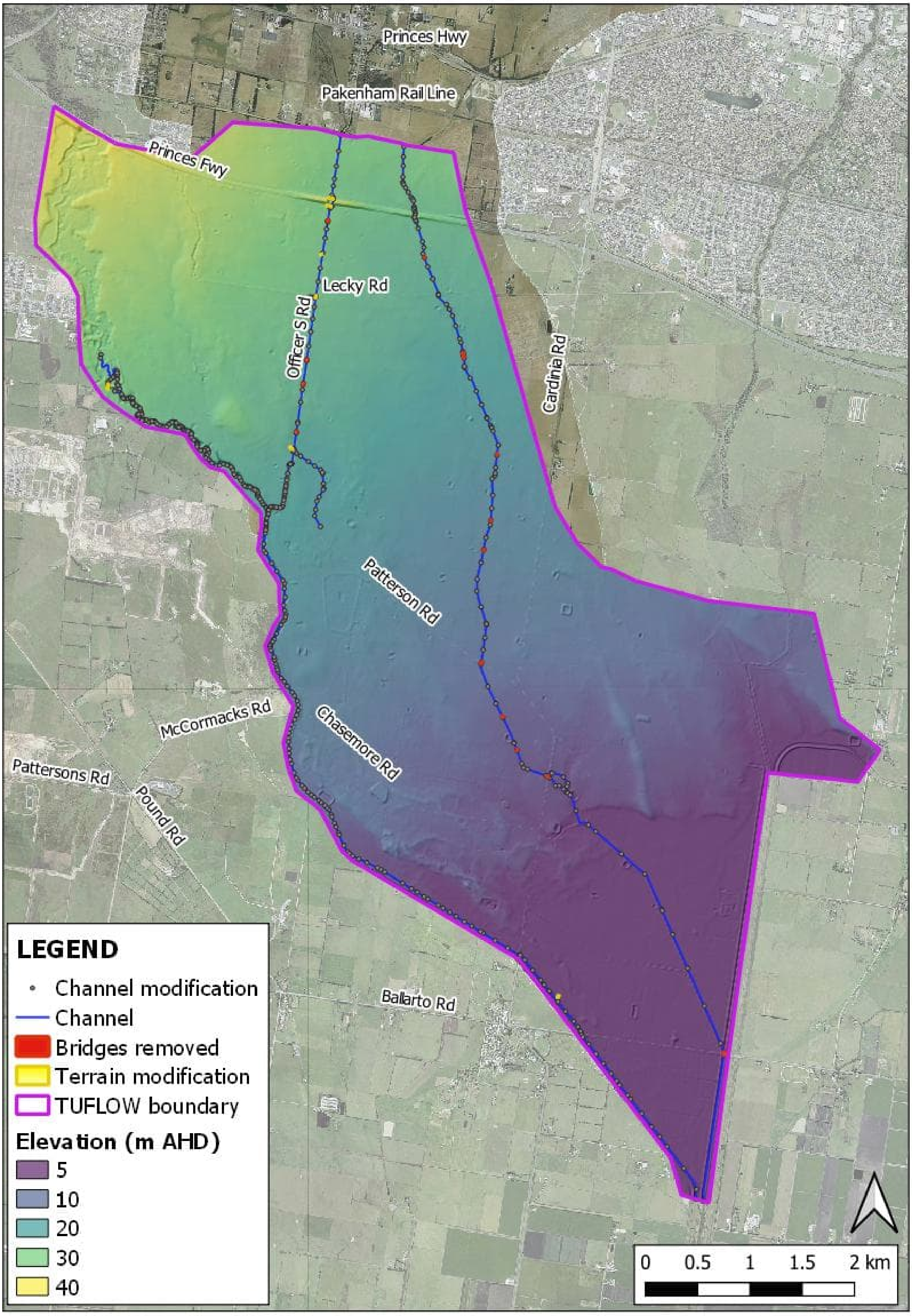


Figure 10-2: TUFLOW Terrain Model

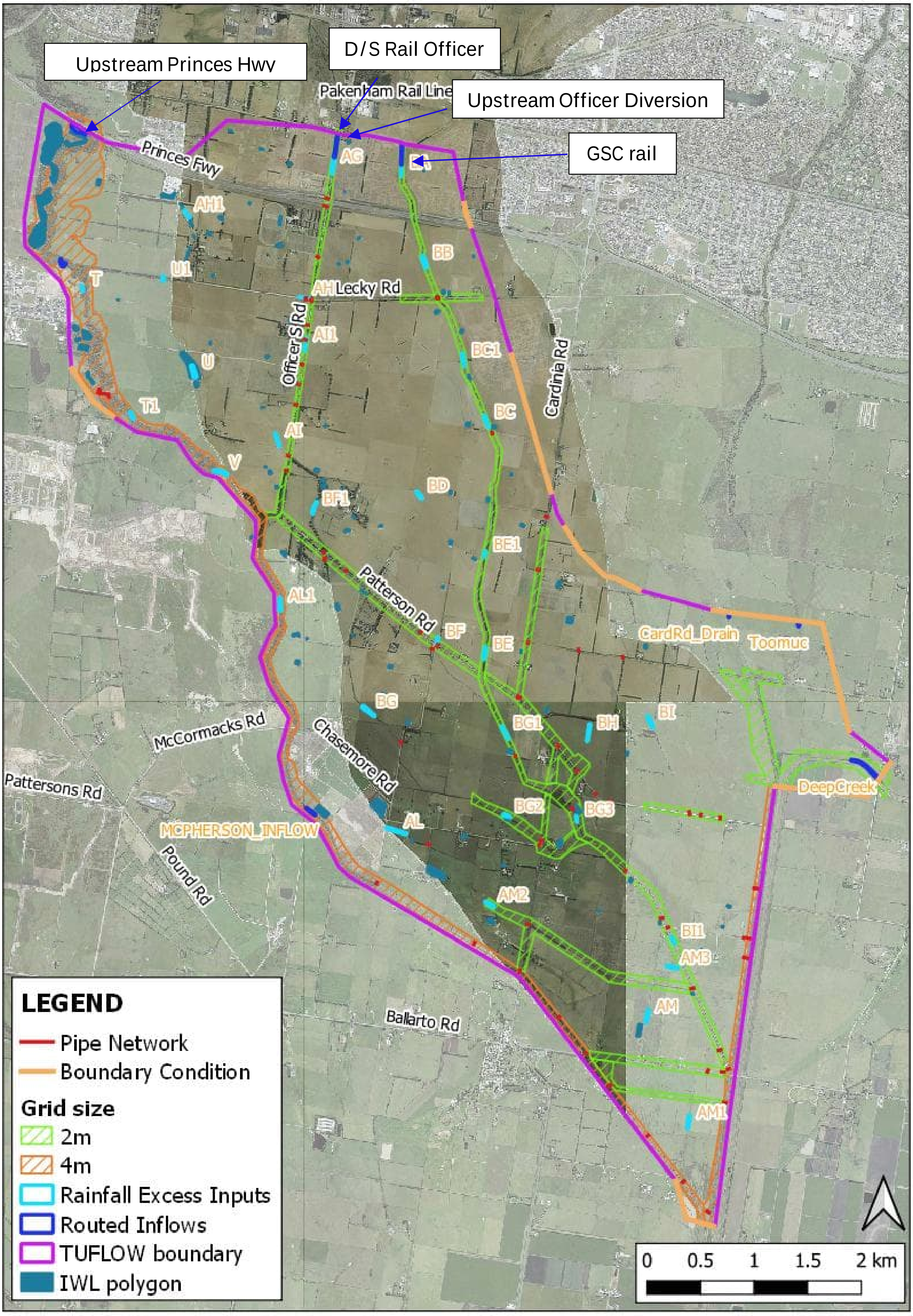


Figure 10-3: TUFLOW Boundary setup

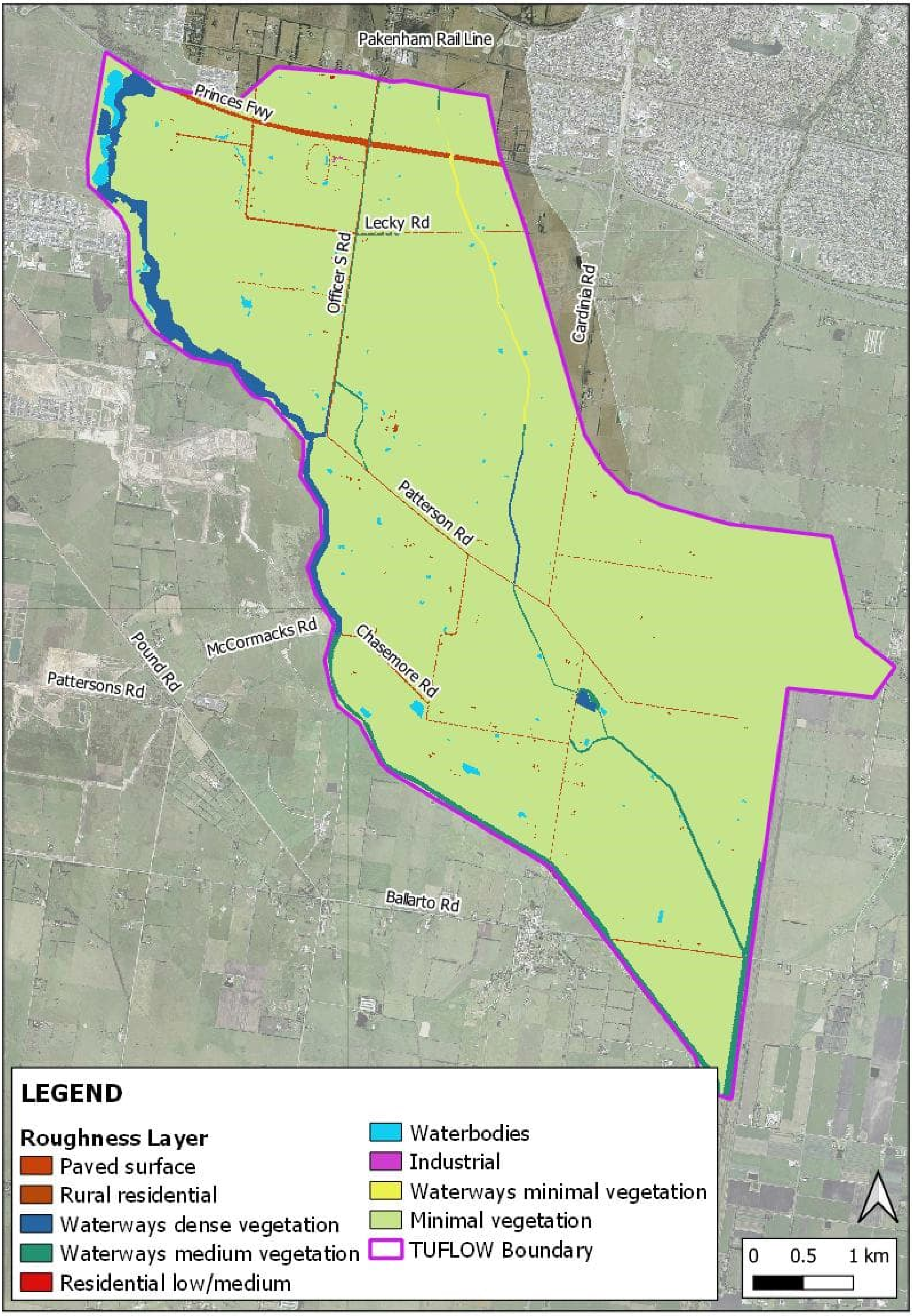


Figure 10-4: Adopted Roughness layer

10.1 Modelled Scenarios and critical temporal patterns and durations

To establish critical durations and temporal patterns across the catchment a 10m grid version of the TUFLOW model was simulated for the pre-development durations and temporal patterns documented in Table 10-2. Critical durations and temporal patterns were determined at points of interest in the catchment. These locations are presented in Figure 10-5. The following process was adopted to establish the critical durations and temporal patterns for modelling in the quadtree model:

- A median water level grid was established for each duration based on the ten temporal patterns simulated.
- For every duration modelled the median grids were used to create a representative maximum water level grid for each AEP.
- The points in Figure 10-5 were used to sample the maximum water level grid for each AEP. The corresponding storm duration associated with the peak water level was then identified.
- For each storm duration identified as critical the median water level grid was evaluated to establish which temporal patterns would result in the peak water levels. Appropriate temporal patterns were then selected to represent each duration.

The selection of critical durations and temporal patterns for each event are provided in Table 10-3. Where required and to minimise complexity a single representative temporal pattern was selected for each duration. The selection of the temporal pattern was based on what was critical at the future PSP outlet and downstream. The durations and temporal patterns in Table 10-3 were then simulated in the quadtree TUFLOW model. The results of these simulations are presented in the next section.

Table 10-2: Modelled events

AEP	Durations Modelled
Pre-development	
63pt2% (approx. 1 in 1 year)	1hr, 1.5hr, 2hr, 3hr, 4.5hr, 6hr, 9hr, 12hr Ten temporal patterns per duration simulated
50% (approx. 1 in 2 year)	2hr, 3hr, 4.5hr, 6hr, 9hr, 12hr Ten temporal patterns per duration simulated
20% (1 in 5 year)	2hr, 3hr, 4.5hr, 6hr, 9hr, 12hr, 18hr Ten temporal patterns per duration simulated
10% (1 in 10 year)	2hr, 3hr, 4.5hr, 6hr, 9hr, 12hr, 18hr Ten temporal patterns per duration simulated
5% (1 in 20 year)	2hr, 3hr, 4.5hr, 6hr, 9hr, 12hr, 18hr Ten temporal patterns per duration simulated
1% (1 in 100 year)	2hr, 3hr, 4.5hr, 6hr, 9hr, 12hr, 18hr, 24hr, 36hr Ten temporal patterns per duration simulated
Climate change scenario	
10% with increase in rainfall intensity	Critical 10% events
10% with increase in rainfall intensity and sea level rise (+0.8 m to the downstream tidal curve)	Critical 10% events

1% with increase in rainfall intensity	Critical 1% events
1% with increase in rainfall intensity and sea level rise (+0.8 m to the downstream tidal curve)	Critical 1% events

Table 10-3: Critical Durations and temporal patterns

AEP	Critical Durations and Temporal Patterns
63pt2% (approx. 1 in 1 year)	9 hour TP7
50% (approx. 1 in 2 year)	9 hour TP3, 4.5 hour TP5
20% (1 in 5 year)	2 hour TP2, 4.5hour TP7, 9 hour TP4, 18hour TP2
10% (1 in 10 year)	3 hour TP 14, 9hour TP12, 12 hour TP 17, 18 hour TP 16
5% (1 in 20 year)	2 hour TP15, 4.5hour TP19, 9 hour TP20, 18hour TP12
1% (1 in 100 year)	2 hour TP25, 4.5hour TP22, 12hour TP29, 24 hour TP30

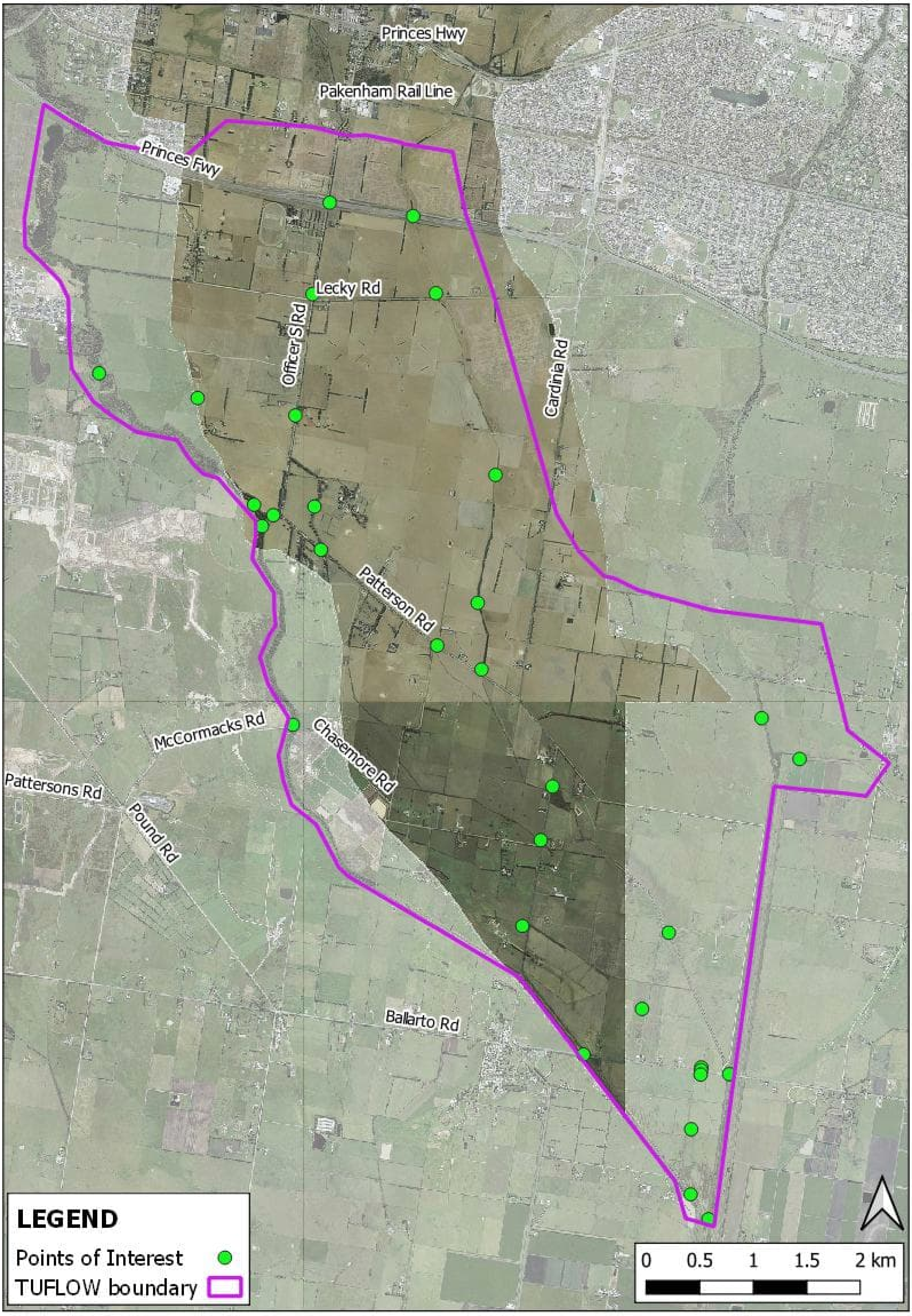


Figure 10-5: Points of Interest

10.2 Pre-development model results

Peak flow estimates and the corresponding critical storm duration for each AEP are provided in Table 10-4. Peak flood depth and level maps are provided in Appendix B. The proposed flow criteria downstream of the PSP is provided in Table 10-5. The following is noted regarding the flooding in the PSP and downstream region:

- The flood maps contain flows from Gum Scrub Creek, Officer South Road Drain and Cardinia Creek. The flows from Cardinia Road Drain, Toomuc Creek and Deep Creek are indicative only. Future model updates will refine the model outputs over this area.
- Princes Freeway likely to operates as an informal storage in the catchment, trapping overland flows. Any overland flows that do not flow south through the two drainage lines my flow across into the next catchment.
- There are numerous overland flow paths with the general flow direction south-east. Flow congregates towards Gum Scrub Creek and inundates the region to adjacent to Cardinia Road.
- Many of the roads in the area i.e., Cardinia Road, Patterson Road, Ballarto Road operate as informal flow barriers, trapping flows upstream before they are overtopped.
- The capacity of Officer South Drain and Gum Scrub Creek is limited and breakout flows are likely in frequent events.
- The flood maps in frequent events (i.e. the 63.2% AEP and 50% AEP) are sensitive to where overland flows have been applied. In these frequent events regions downstream of Patterson Road may be inundated by more distributed flooding.
- North of Princes Freeway there is a breakout of flows along Officer South Road Drain. South of the freeway breakout flows towards the east were likely to occur at Lecky Road and a diversion drain further south.
- There is an overland flow path in the western side of the catchment that discharges to Cardinia Creek.
- The influence of the eastern catchments such as Cardinia Road Drain, Toomuc Creek and Deep Creek is mostly associated with capacity constraints in the receiving drainage channel. There is unlikely to be a direct interaction with breakout overland flows.
- Under the modelled climate change scenarios there is likely to be a 20-30% increase in peak flows. The influence of sea level rise will be dependent on the peak water levels from Western Port Bay. Higher peak level assumptions will likely alter the results presented in this report.
- The modelling is likely indicating an over estimation of magnitude of low flows in Gum Scrub Creek.

The following in noted regarding the interaction with Cardinia creek and the floodplain:

- In the 1% AEP event there is likely to be a breakout flow from the Cardinia Creek drop structure into the PSP.
- Break out flows are also likely to occur downstream of Chasemore Road, the modelling indicates these may occur in the 20% AEP event.
- Longer durations tend to dominate downstream the downstream (Ballarto Road) as the peak flood levels become more volume dependent.

Next steps

Table 10-4: Peak flow estimates (m^3/s) and critical durations

TUFLOW model Plot output location reference	Location	63pt2 % AEP	50% AEP	20% AEP	10% AEP	10% with 18.5% rainfall increase *	5% AEP	1% AEP	1% with 18.5% rainfall increase*
OSR_Freeway	Flow through Officer South Drain at Princes Freeway	0.9 (9hr)	1.0 (9hr)	1.4 (9hr)	1.5 (9hr)	1.6 (2hr)	1.7 (9hr)	1.8 (4.5hr)	2.0 (4.5hr)
GSC_Freeway	Gum Scrub Creek at Freeway	5.8 (9hr)	9.9 (9hr)	20.0 (9hr)	28 (9hr)	38 (9hr)	40 (9hr)	48 (12hr)	59 (4.5hr)
GSC_Lekyrd	Gum Scrub Creek Leaky Road	4.2 (9hr)	4.9 (9hr)	6.4 (9hr)	8.1 (9hr)	10 (9hr)	10.6 (9hr)	13 (12hr)	15 (12hr)
Ord_Lekyrd	Officer South Drain Lecky Road	0.9 (9hr)	1.0 (9hr)	1.4 (9hr)	1.8 (3hr)	2.1 (9hr)	2.4 (9hr)	2.5 (4.5hr)	2.9 (4.5hr)
82	Breakout from OSD to GSC	no flow	no flow	No flow	0.7 (9hr)	1.63 (3hr)	1.6 (2hr)	5.8 (2hr)	9.0 (2hr)
29	Gum Scrub Creek end of PSP	4.5 (9hr)	9 (9hr)	19.1 (9hr)	27 (9hr)	37 (9hr)	39 (9hr)	51 (12hr)	63 (12hr)
4	Gum Scrub Creek Paterson Road	3.5 (9hr)	8.5 (9hr)	18.5 (9hr)	27 (9hr)	36 (9hr)	39 (9hr)	52 (12hr)	66 (12hr)
15	Officer South Drain into Cardinia Creek	1.5 (9hr)	1.5 (9hr)	1.7 (9 hr)	1.7 (3hr)	1.8 (3hr)	1.7 (2hr)	1.8 (4.5hr)	1.9 (4.5hr)
14	Overland flows into Cardinia Creek	No flow	0.6 (9hr)	2.4 (4.5hr)	3.6 (9hr)	4.8 (3hr)	4.6 (4.5hr)	7 (2hr)	9 (2hr)
81	Breakout flow/diversion on Officer South Drain where there is a diversion structure	1.6 (9hr)	1.6 (9hr)	3.6 (4.5 hr)	4.3 (3hr)	5.1 (3hr)	4.2 (9hr)	7.6 (2hr)	9.4 (2hr)
82	Breakout flow/diversion on Officer South Drain at Paterson Road	0.6 (9hr)	0.9 (9hr)	1.6 (9hr)	2 (9hr)	3 (9hr)	4.3 (9hr)	4.6 (4.5hr)	6.7 (2hr)
CardCrk3	Cardinia Creek upstream OSD inflow	6.5	9.3 (9hr)	26.4 (18hr)	40 (12hr)	57 (12hr)	57 (18hr)	92 (24 hr)	113 (12hr)
5	Cardinia Creek at Chasemore Road	6.8	9.3 (9hr)	27.5(18hr)	41 (12hr)	58 (12hr)	58 (18hr)	93 (24hr)	114 (12hr)
2	Gum Scrub Creek Cardinia Road	3.0	7.9 (9hr)	16.1 (9hr)	22 (12hr)	28 (9hr)	29 (9hr)	38 (12hr)	44 (12hr)

*No changes in water level were observed between the increase in rainfall intensity and increase in rainfall intensity plus sea level rise.

Table 10-5: Proposed PSP flow criteria

Location of criteria point	63pt2 % AEP	50% AEP	20% AEP	10% AEP	10% with 18.5% rainfall	5% AEP	1% AEP	1% with 18.5% rainfall
Gum Scrub Creek at Paterson Road	3.5	9	15	27	36	39	52	66
Officer South Drain and catchment overland flows into Cardinia Creek	2	2	4	5.3	6.6	6.3	9	11
Overland flows at Paterson Road between South Drain and Gum Scrub Creek	0.5	1	1.6	2	3	4.5	5	7

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Appendix A.

A.1 IFD Data

Cardinia Creek Catchment design rainfall IFD Lat: -38.0375 Long: 145.3875

Duration	Annual Exceedance Probability (AEP)										
	63.2%	50%	20%	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%
15 min	9.86	13.9	16.7	19.6	23.7	27	31.5	37.3	42.2	47.6	9.86
20 min	11.2	15.7	18.9	22.2	26.8	30.5	35.6	42.1	47.6	53.6	11.2
25 min	12.3	17.2	20.7	24.2	29.1	33.1	38.5	45.6	51.5	58	12.3
30 min	13.2	18.4	22.1	25.9	31	35.1	40.9	48.3	54.6	61.4	13.2
45 min	15.5	21.3	25.5	29.6	35.2	39.5	45.9	54.2	61.1	68.7	15.5
1 hour	17.2	23.5	28	32.4	38.2	42.7	49.5	58.4	65.9	74	17.2
1.5 hour	19.9	26.9	31.8	36.6	42.8	47.5	55.1	65	73.3	82.3	19.9
2 hour	22.2	29.7	34.8	39.9	46.5	51.5	59.8	70.6	79.6	89.4	22.2
3 hour	25.7	34.1	39.8	45.4	52.8	58.4	68	80.3	90.7	102	25.7
4.5 hour	29.9	39.4	45.8	52.2	60.8	67.5	78.7	93.2	105	119	29.9
6 hour	33.3	43.8	50.9	58	67.9	75.6	88.4	105	119	134	33.3
9 hour	38.7	51	59.4	67.9	80.2	89.8	105	125	142	160	38.7
12 hour	43	56.9	66.5	76.3	90.7	102	120	142	161	182	43
18 hour	49.6	66.2	78	90.2	108	123	143	170	192	217	49.6
24 hour	54.5	73.4	87.1	101	122	139	162	191	216	243	54.5
30 hour	58.4	79.2	94.6	111	134	152	178	211	239	269	58.4
36 hour	61.7	84.1	101	118	143	163	191	225	254	285	61.7

Officer South and Gum Scrub Creek design Rainfall IFD -38.045, 145.423

Duration	Annual Exceedance Probability (AEP)										
	63.2%	50%	20%	10%	5%	2%	1%	0.5%	0.2%	0.1%	0.05%
15 min	9.82	13.8	16.6	19.5	23.6	26.8	31.3	37.1	42	47.4	9.82
20 min	11.2	15.6	18.8	22.1	26.6	30.3	35.3	41.8	47.3	53.4	11.2
25 min	12.2	17.1	20.6	24.1	29	32.8	38.3	45.3	51.2	57.8	12.2
30 min	13.2	18.4	22	25.8	30.8	34.9	40.6	48	54.3	61.2	13.2
45 min	15.4	21.3	25.4	29.5	35	39.3	45.6	53.9	60.9	68.5	15.4
1 hour	17.1	23.5	27.9	32.3	38	42.5	49.2	58.1	65.6	73.8	17.1
1.5 hour	19.9	26.9	31.7	36.5	42.6	47.3	54.9	64.8	73.1	82.2	19.9
2 hour	22.1	29.6	34.8	39.8	46.3	51.4	59.6	70.4	79.5	89.4	22.1
3 hour	25.7	34.1	39.8	45.4	52.7	58.3	67.8	80.3	90.7	102	25.7
4.5 hour	29.9	39.4	45.9	52.2	60.8	67.5	78.8	93.3	106	119	29.9
6 hour	33.3	43.8	51	58.1	68	75.7	88.5	105	119	135	33.3
9 hour	38.8	51.1	59.6	68.1	80.5	90.2	106	126	143	161	38.8
12 hour	43.1	57.1	66.8	76.6	91.2	103	120	143	162	184	43.1
18 hour	49.7	66.5	78.4	90.7	109	124	145	171	194	220	49.7
24 hour	54.7	73.8	87.6	102	123	140	163	193	218	246	54.7
30 hour	58.7	79.7	95.2	111	135	154	180	214	242	272	58.7
36 hour	62	84.6	102	119	144	165	193	228	257	289	62

A.2 Data Hub results (Cardinia Creek catchment)

Australian Rainfall & Runoff Data Hub - Results

Input Data

Longitude	145.387
Latitude	-38.038

Data

River Region

Division	South East Coast (Victoria)
River Number	5
River Name	Bunyip River

Layer Info

Time Accessed	11 March 2021 05:25PM
Version	2016_v1

ARF Parameters

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

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

Short Duration ARF

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

Layer Info

Time Accessed	11 March 2021 05:25PM
Version	2016_v1

Storm Losses

Note: Burst Loss = Storm Loss - Preburst

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

ID	23095.0
Storm Initial Losses (mm)	25.0
Storm Continuing Losses (mm/h)	4.4

Layer Info

Time Accessed	11 March 2021 05:25PM
Version	2016_v1

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

code	SSmainland
Label	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	11 March 2021 05:25PM
Version	2016_v2

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

code	SSmainland
arealabel	Southern Slopes (Vic/NSW)

Layer Info

Time Accessed	11 March 2021 05:25PM
Version	2016_v2

BOM IFDs

Click here (http://www.bom.gov.au/water/designRainfalls/revised-ifd/?year=2016&coordinate_type=dd&latitude=-38.0375&longitude=145.3875&sdmin=true&sdhr=true&sdday=true&user_label=) to obtain the IFD depths for catchment centroid from the BoM website

Layer Info

Time Accessed	11 March 2021 05:25PM

Median Preburst Depths and Ratios

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	2.9 (0.167)	2.4 (0.101)	2.0 (0.073)	1.7 (0.053)	1.4 (0.036)	1.1 (0.026)
90 (1.5)	3.6 (0.182)	2.8 (0.105)	2.3 (0.072)	1.8 (0.049)	1.2 (0.028)	0.8 (0.016)
120 (2.0)	2.5 (0.113)	2.0 (0.068)	1.7 (0.049)	1.4 (0.036)	1.8 (0.039)	2.1 (0.041)
180 (3.0)	2.4 (0.095)	2.8 (0.082)	3.0 (0.076)	3.2 (0.071)	2.7 (0.051)	2.3 (0.039)
360 (6.0)	1.9 (0.057)	2.8 (0.064)	3.4 (0.067)	4.0 (0.069)	5.1 (0.075)	5.9 (0.078)
720 (12.0)	0.4 (0.009)	2.7 (0.047)	4.2 (0.064)	5.7 (0.075)	6.3 (0.069)	6.7 (0.066)
1080 (18.0)	0.7 (0.015)	2.1 (0.031)	3.0 (0.038)	3.8 (0.042)	4.6 (0.043)	5.2 (0.042)
1440 (24.0)	0.0 (0.000)	1.4 (0.019)	2.3 (0.027)	3.2 (0.032)	4.0 (0.032)	4.5 (0.032)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.1 (0.001)	0.5 (0.004)	0.8 (0.005)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.001)	0.2 (0.001)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

Layer Info

Time Accessed	11 March 2021 05:25PM
Version	2018_v1
Note	Preburst interpolation methods for catchment wide preburst has been slightly altered. Point values remain unchanged.

Interim Climate Change Factors

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

Layer Info

Time Accessed	11 March 2021 05:25PM
Version	2019_v1
Note	ARR recommends the use of RCP4.5 and RCP 8.5 values. These have been updated to the values that can be found on the climate change in Australia website.

Baseflow Factors

Downstream	0
Area (km2)	615.385216
Catchment Number	11225
Volume Factor	0.396362
Peak Factor	0.152054

Layer Info

Time Accessed	11 March 2021 05:25PM
Version	2016_v1

Download TXT (downloads/d72f3cb4-2b49-4b34-80e7-77a1adc1c7c7.txt)

Download JSON (downloads/2eac2283-63da-4cf7-99f4-7f111e8fde5a.json)

Generating PDF... (downloads/0ef1c7ac-9355-4374-9a0c-1c14cda5bc8d.pdf)

A.3 Data Hub Results – Pre-burst for the PSP area

3/11/2021 Results | ARR Data Hub

Median Preburst Depths and Ratios

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

min (h)\AEP(%)	50	20	10	5	2	1
60 (1.0)	2.2 (0.130)	2.0 (0.084)	1.9 (0.065)	1.7 (0.052)	1.4 (0.036)	1.2 (0.026)
90 (1.5)	3.6 (0.182)	2.8 (0.105)	2.3 (0.072)	1.8 (0.049)	2.1 (0.048)	2.3 (0.047)
120 (2.0)	2.5 (0.113)	2.5 (0.086)	2.6 (0.074)	2.6 (0.065)	2.0 (0.042)	1.5 (0.029)
180 (3.0)	3.2 (0.125)	3.1 (0.092)	3.0 (0.077)	3.0 (0.066)	2.6 (0.050)	2.3 (0.040)
360 (6.0)	2.2 (0.068)	3.1 (0.074)	3.8 (0.077)	4.4 (0.078)	5.0 (0.077)	5.5 (0.076)
720 (12.0)	0.2 (0.005)	0.9 (0.017)	1.3 (0.022)	1.8 (0.025)	4.1 (0.048)	5.8 (0.061)
1080 (18.0)	0.0 (0.000)	0.5 (0.008)	0.8 (0.011)	1.1 (0.014)	1.5 (0.016)	1.8 (0.016)
1440 (24.0)	0.0 (0.000)	0.1 (0.002)	0.2 (0.002)	0.2 (0.003)	0.7 (0.006)	1.0 (0.008)
2160 (36.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.1 (0.000)	0.1 (0.001)
2880 (48.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)
4320 (72.0)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)	0.0 (0.000)

A.4 Fraction Impervious Values

SubArea	Impervious Fraction (IF)	EIA Factor	ICA Factor	PA Factor
A	0.1	0.06	0.04	0.9
B	0.1	0.06	0.04	0.9
C	0.1	0.06	0.04	0.9
D	0.05	0.03	0.02	0.95
E	0.05	0.03	0.02	0.95
F	0.05	0.03	0.02	0.95
G	0.2	0.12	0.88	0
H	0.05	0.03	0.02	0.95
I	0.05	0.03	0.02	0.95
J	0.2	0.12	0.88	0
K	0.05	0.03	0.02	0.95
L	0.3	0.18	0.82	0
M	0.3	0.18	0.82	0
N	0.2	0.12	0.88	0
O	0.3	0.18	0.82	0
P	0.75	0.45	0.55	0
Q	0.6	0.36	0.64	0
R	0.1	0.06	0.04	0.9
S	0.2	0.12	0.88	0
T	0.1	0.06	0.04	0.9
U	0.1	0.06	0.04	0.9
V	0.1	0.06	0.04	0.9
W	0.05	0.03	0.02	0.95
X	0.1	0.06	0.04	0.90
Y	0.2	0.12	0.88	0
Z	0.2	0.12	0.88	0
AA	0.2	0.12	0.88	0
AB	0.1	0.06	0.04	0.9
AC	0.1	0.06	0.04	0.9
AE	0.1	0.06	0.04	0.9
AF	0.2	0.12	0.88	0
AG	0.1	0.06	0.04	0.9
AH	0.1	0.06	0.04	0.9
AI1	0.1	0.06	0.04	0.9
AJ	0.1	0.06	0.04	0.9
AK	0.1	0.06	0.04	0.9
AL1	0.1	0.06	0.04	0.9
AM2	0.1	0.06	0.04	0.9
AN	0.05	0.03	0.02	0.95

SubArea	Impervious Fraction (IF)	EIA Factor	ICA Factor	PA Factor
AN	0.05	0.03	0.02	0.95
AO	0.1	0.06	0.04	0.9
AP	0.05	0.03	0.02	0.95
AQ	0.05	0.03	0.02	0.95
AR	0.1	0.06	0.04	0.9
AS	0.1	0.06	0.04	0.9
AT	0.1	0.06	0.04	0.9
AU	0.1	0.06	0.04	0.9
AV	0.1	0.06	0.04	0.9
AW	0.1	0.06	0.04	0.9
AX	0.1	0.06	0.04	0.9
AY	0.1	0.06	0.04	0.9
AZ	0.1	0.06	0.04	0.9
BA	0.1	0.06	0.04	0.9
BB	0.1	0.06	0.04	0.9
BC	0.1	0.06	0.04	0.9
BD	0.1	0.06	0.04	0.9
BE	0.1	0.06	0.04	0.9
BF1	0.1	0.06	0.04	0.9
BG	0.1	0.06	0.04	0.9
BH	0.1	0.06	0.04	0.9
BI	0.1	0.06	0.04	0.9
AB1	0.2	0.12	0.88	0
AD	0.75	0.45	0.55	0
BC1	0.1	0.06	0.04	0.9
BE1	0.1	0.06	0.04	0.9
AH1	0.1	0.06	0.04	0.9
AI	0.1	0.06	0.04	0.9
BF	0.1	0.06	0.04	0.9
BG2	0.1	0.06	0.04	0.9
BG1	0.1	0.06	0.04	0.9
BG3	0.1	0.06	0.04	0.9
BI1	0.1	0.06	0.04	0.9
AL	0.1	0.06	0.04	0.9
AM3	0.1	0.06	0.04	0.9
AM	0.1	0.06	0.04	0.9
AM1	0.1	0.06	0.04	0.9
U1	0.1	0.06	0.04	0.9
T1	0.1	0.06	0.04	0.9

A.5 Sensitivity of EIA/ICA/DC and Fraction impervious values

This sensitivity assessment investigated the difference between adopting an impervious fraction and the ARR 2019 approach of EIA/ICA/DC. The assessment was completed using the post development RORB model provided by SWS with minor modifications made. The simulate a comparison between both the method ARR 2019 rainfall, pre-burst values and other inputs were kept the same. The following was altered:

- The losses adopted for the TIA method were 25 IL CL 3 mm/hr
- The losses adopted for the DC/IDC method;
  - PA IL 25 mm CL: 3 mm/h
  - DC: IL 1 mm, CL: 0 mm/h
  - IDC IL 17.4 mm, CL: 2.3 mm/h

PSP sub-catchment split of fraction impervious values:

	Method TIA	Method DC/IDC		
PSP Subarea	TIA	DC	IDC	PA
BF	0.9	0.8	0.2	0
BC	0.9	0.8	0.2	0
AI2	0.9	0.8	0.2	0
U1	0.9	0.8	0.2	0
U	0.9	0.8	0.2	0
AI	0.9	0.8	0.2	0
AI1	0.9	0.8	0.2	0
BC1	0.9	0.8	0.2	0
BD	0.9	0.8	0.2	0
BB	0.85	0.7	0.3	0
AH	0.85	0.7	0.3	0
BE	0.1	0.06	0.04	0.9
BC2	0.1	0.06	0.04	0.9
BA1	0.1	0.06	0.04	0.9

Figure A1 and Figure A2 provided a schematic of the difference between peak flow estimates for the 10% and 1% AEP events. Based on the assessment the following was concluded:

- Adopting the fraction impervious (Total impervious area) results in peak flows that are typically between 2-10% higher than the DC/IDC method.
- The peak flows across durations using both methods follow a similar trend.
- With respect to volumes a similar trend is observed:
  - For the 10% AEP for GSC at Patterson Rd the TIA is 5% greater than the DC/IDC method.
  - For the 1% for Officer Road outfall into Cardinia creek, 4.5 hr TP 22 the TIA volume is 8% greater than the DC/IDC method.

Based on the above it is considered if the TIA method is adopted the flows and volumes may likely be up to 10% above an ARR 2019 approach.

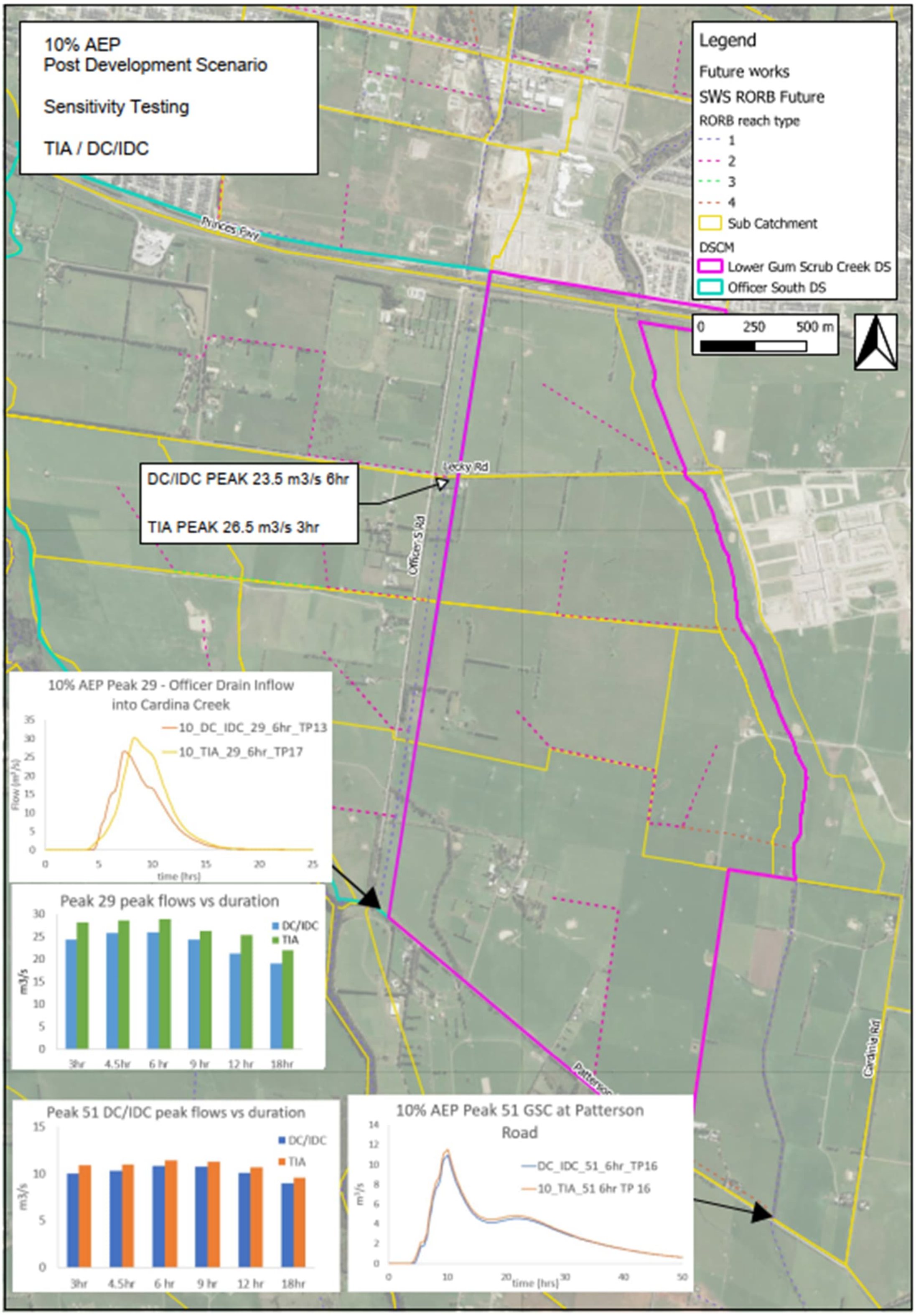


Figure A1: 10% AEP sensitivity testing of the impervious fraction method

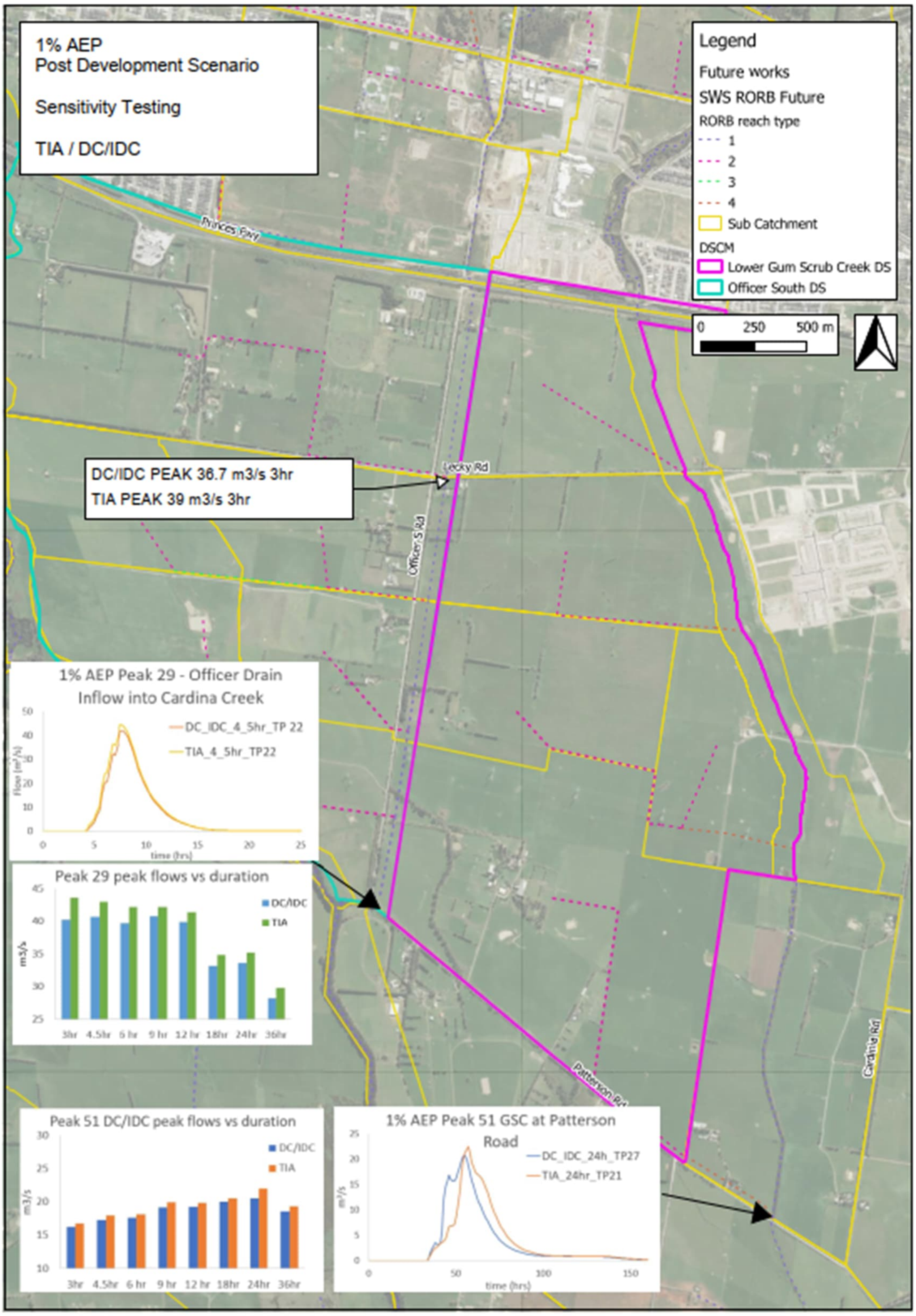


Figure A2: 1% AEP sensitivity testing of the impervious fraction method

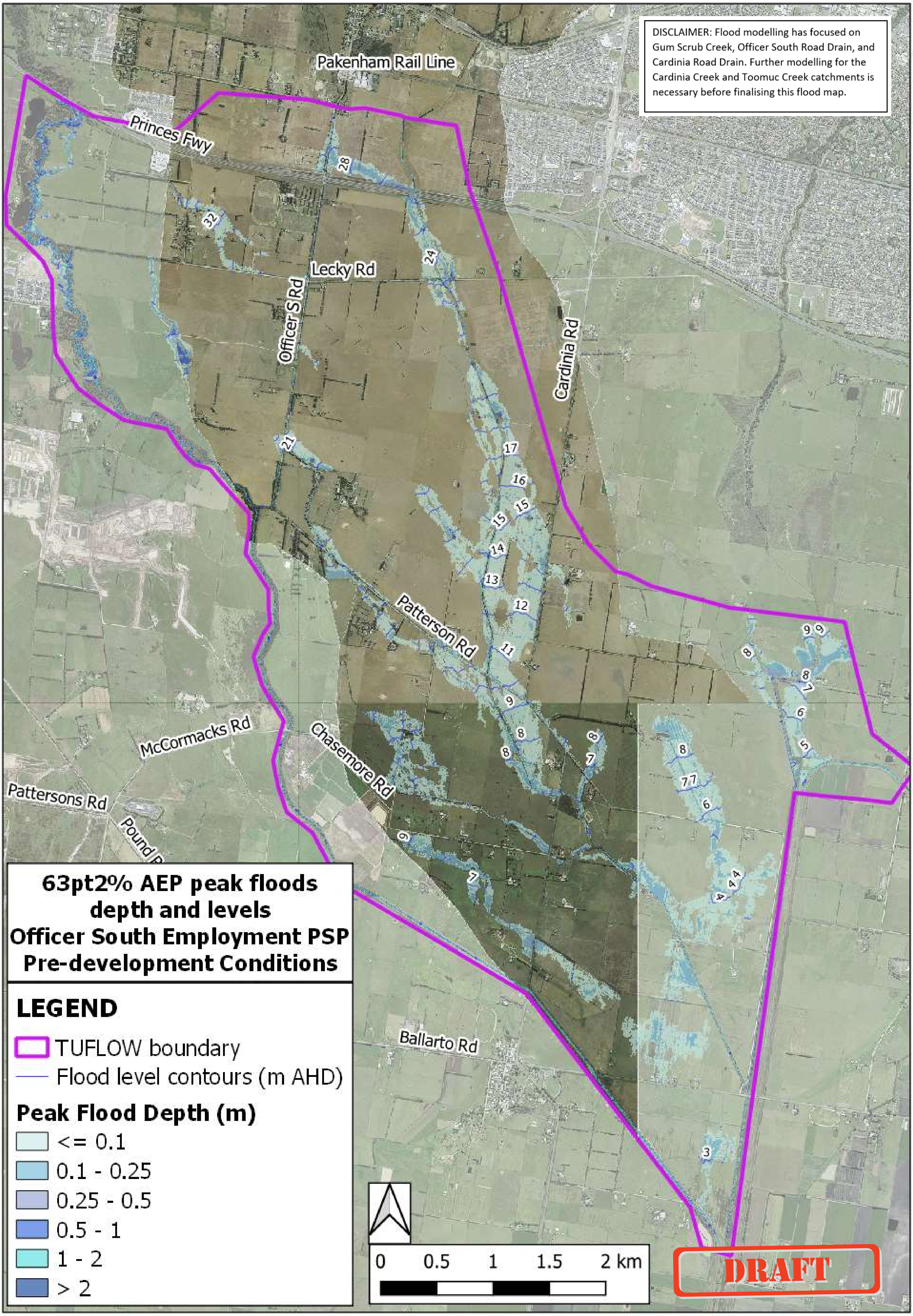
A.6 Non-uniform Spatial Patterns

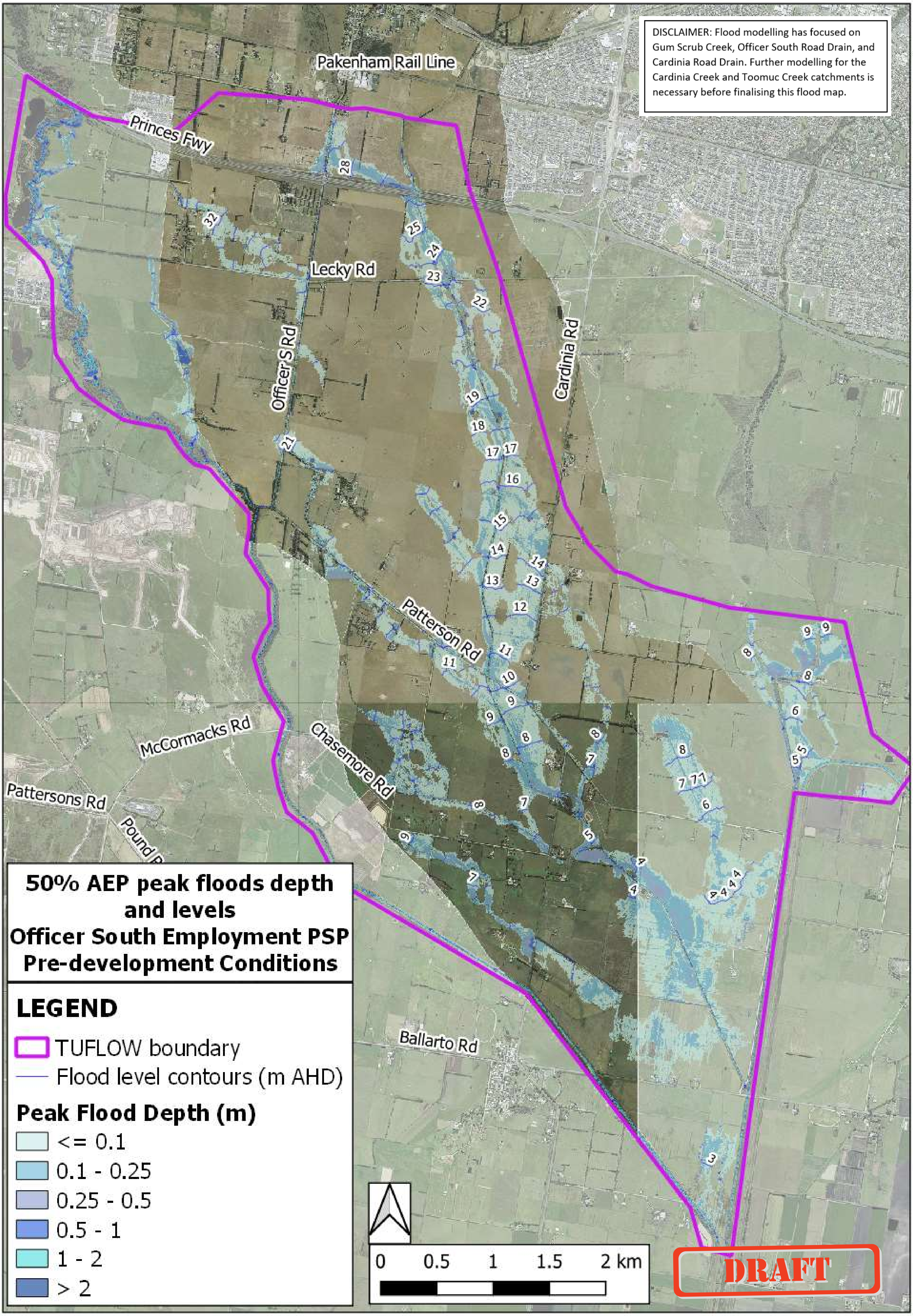
	km2	less than 30min	30min	45min	1hr	1.5hr	2h	3h	4.5hr	6hr	9hr	12h	18hr	24hr	36hr
AB1	0.92	100	102.5	102.4	102.2	101.8	101.2	100.6	99.5	98.7	97.4	96.6	95.4	94.5	94.2
AB	1.19	100	102.1	102.1	101.8	101.5	101.1	100.5	99.5	98.8	97.6	96.9	95.9	95.1	94.8
AD	0.53	100	103.5	103.3	103.0	102.4	101.7	100.7	99.2	98.1	96.4	95.3	93.6	92.5	92.2
AC	1.13	100	103.3	103.2	102.8	102.3	101.7	100.6	99.1	98.0	96.3	95.2	93.6	92.5	92.2
AE	0.51	100	103.3	103.2	102.8	102.3	101.7	100.6	99.1	98.0	96.2	95.2	93.6	92.5	92.2
W	1.17	100	99.6	99.7	99.8	99.8	100.0	100.1	100.2	100.3	100.4	100.6	100.6	100.2	100.3
X	0.64	100	100.6	100.6	100.6	100.4	100.5	100.2	99.9	99.6	99.2	99.1	98.7	98.0	98.1
Y	1.43	100	102.7	102.6	102.3	101.9	101.5	100.5	99.2	98.2	96.7	95.8	94.5	93.5	93.3
Z	0.35	100	103.2	103.1	102.7	102.2	101.7	100.5	99.0	97.9	96.2	95.1	93.6	92.5	92.2
AA	0.14	100	103.2	103.1	102.7	102.2	101.7	100.5	99.0	97.9	96.2	95.1	93.6	92.5	92.2
AF	1.14	100	103.5	103.3	103.0	102.4	101.7	100.7	99.2	98.1	96.4	95.3	93.6	92.5	92.2
AG	0.94	100	103.3	103.2	102.8	102.3	101.7	100.6	99.1	98.0	96.2	95.2	93.6	92.5	92.2
AH	0.9	100	104.4	104.3	104.1	103.2	102.4	100.7	98.7	97.1	94.8	93.4	91.3	89.9	89.6
AH1	0.46	100	104.4	104.1	103.9	103.0	102.2	100.7	98.8	97.4	95.3	93.9	92.0	90.7	90.1
AI1	0.78	100	104.6	104.5	104.3	103.3	102.5	100.7	98.7	97.0	94.7	93.2	91.1	89.6	89.2
AI	0.63	100	104.8	104.6	104.3	103.3	102.5	100.7	98.6	97.0	94.7	93.1	91.1	89.6	89.0
A	7.04	100	93.2	93.1	93.4	94.5	95.8	98.3	101.7	104.4	108.5	111.6	115.2	117.5	119.2
B	4.09	100	93.0	92.8	93.0	94.2	95.7	98.7	102.6	105.8	111.0	114.6	119.2	121.6	123.6
C	8.14	100	95.7	95.7	95.9	96.6	97.4	98.8	100.5	102.0	104.0	105.5	107.3	108.6	109.3
D	7.07	100	97.4	97.4	97.5	98.0	98.3	99.1	100.1	100.9	102.0	102.6	103.9	104.6	104.9
E	2.77	100	97.2	97.3	97.3	98.0	98.4	99.5	100.8	101.7	103.1	103.8	105.6	106.1	106.5
F	1.16	100	97.6	97.6	97.7	98.3	98.6	99.5	100.6	101.5	102.6	103.1	104.8	105.1	105.5
G	4.96	100	94.3	94.4	94.7	95.8	96.9	99.0	101.6	103.7	106.8	108.7	111.2	113.0	113.7
H	2.04	100	93.6	93.6	94.0	95.1	96.5	98.9	101.8	104.2	107.7	109.8	113.0	114.9	115.8
I	2.38	100	95.0	95.1	95.4	96.2	97.2	99.0	101.1	102.9	105.5	107.0	109.7	110.8	111.4
J	3.84	100	96.7	96.8	96.9	97.5	98.1	99.2	100.6	101.7	103.3	104.1	106.1	106.5	107.2
K	5.11	100	99.2	99.3	99.2	99.4	99.5	99.9	100.1	100.4	100.7	101.1	100.9	101.5	101.4
L	4.89	100	99.2	99.2	99.3	99.5	99.7	100.1	100.4	100.7	101.1	101.1	101.8	102.1	102.1
M	4.53	100	100.9	100.8	100.8	100.6	100.5	100.3	100.1	99.8	99.4	98.9	98.6	98.7	98.3
N	2.48	100	97.0	97.2	97.2	97.9	98.5	99.6	100.9	102.0	103.5	104.8	105.4	106.5	106.8
O	5.94	100	99.9	99.9	99.9	100.0	100.0	100.1	100.2	100.2	100.2	100.2	100.1	100.0	99.8
P	4.84	100	102.7	102.4	102.3	101.9	101.4	100.7	99.7	98.8	97.6	96.8	95.6	95.0	94.4
Q	2.37	100	102.1	102.0	101.9	101.6	101.1	100.6	99.7	99.0	97.9	97.2	96.4	95.6	95.0
R	1.14	100	103.5	103.3	103.0	102.5	101.7	100.7	99.2	98.1	96.4	95.3	93.7	92.6	92.2
S	2.62	100	103.6	103.4	103.3	102.7	101.9	100.9	99.4	98.3	96.6	95.4	94.1	92.9	92.0
T	0.58	100	104.9	104.6	104.3	103.2	102.5	100.7	98.6	97.0	94.7	93.2	91.2	89.7	89.0
T1	0.28	100	104.9	104.6	104.4	103.3	102.5	100.7	98.6	97.0	94.7	93.1	91.1	89.6	88.9
U1	1.06	100	104.5	104.2	104.0	103.0	102.2	100.7	98.8	97.3	95.2	93.7	91.8	90.4	89.9
U	0.82	100	104.9	104.6	104.4	103.3	102.5	100.7	98.6	97.0	94.7	93.1	91.1	89.6	88.9
V	0.31	100	104.9	104.6	104.4	103.3	102.5	100.7	98.6	97.0	94.6	93.0	91.0	89.5	88.8

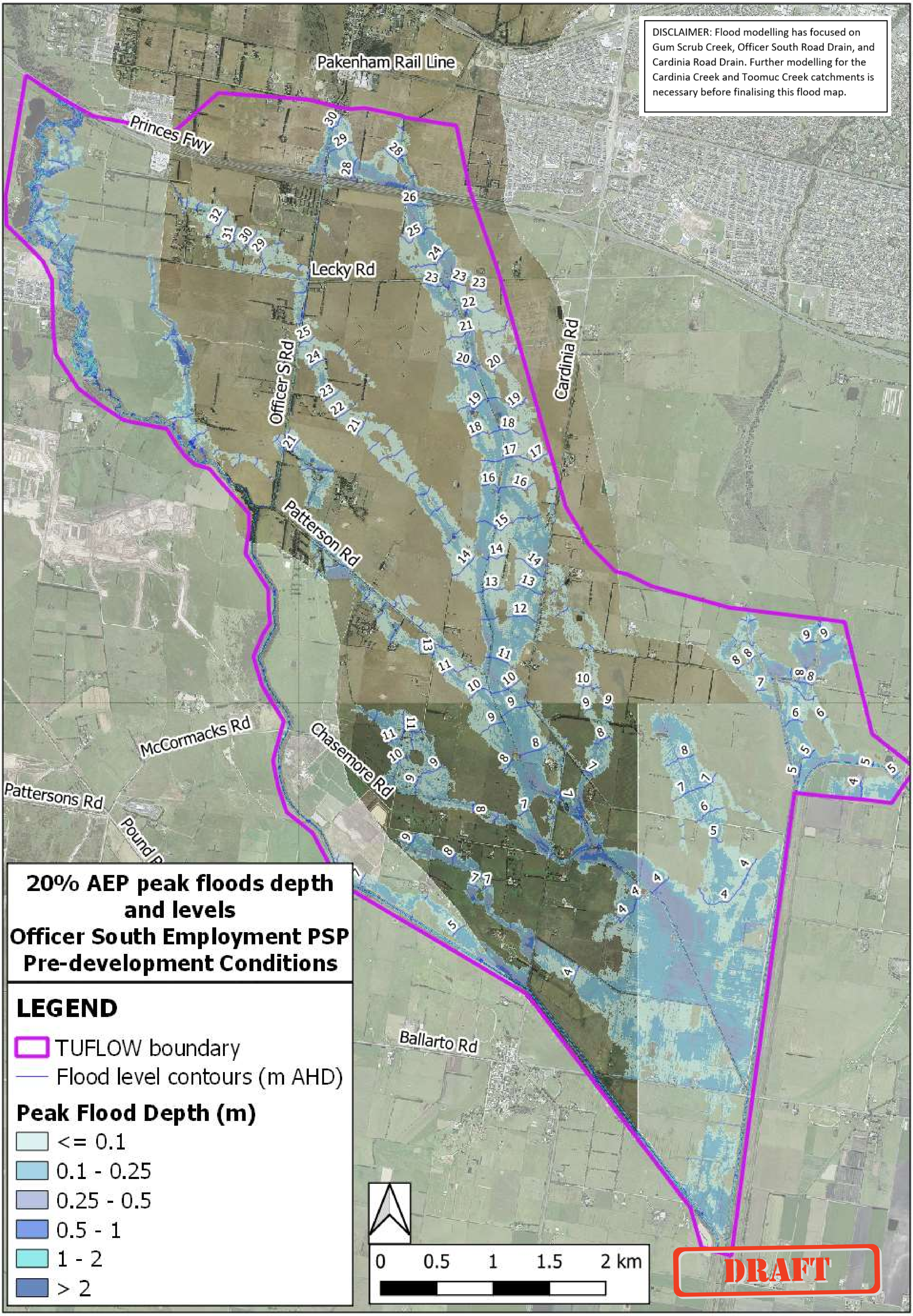
AL1	0.75	100	105.5	105.4	105.1	104.1	102.8	100.9	98.3	96.3	93.6	91.6	89.4	88.1	87.0
AJ	1.05	100	104.8	104.5	104.3	103.3	102.5	100.8	98.7	97.2	94.8	93.3	91.4	89.9	89.2
AK	5.35	100	105.5	105.1	104.9	103.7	102.7	100.7	98.3	96.5	93.8	91.9	89.4	88.1	87.5
AL	1.37	100	105.7	105.7	105.4	104.6	103.3	101.3	98.4	96.3	93.2	91.1	88.3	87.1	86.0
AM2	0.83	100	105.6	105.8	105.5	104.7	103.5	101.5	98.6	96.4	93.2	91.1	88.0	86.9	85.8
AM3	1.14	100	105.2	105.6	105.5	104.7	103.8	101.9	99.2	97.0	93.8	91.7	88.7	87.5	86.3
AM	1.31	100	105.2	105.6	105.5	104.7	103.8	101.9	99.2	97.0	93.8	91.7	88.7	87.5	86.3
AM1	0.98	100	105.2	105.8	105.9	105.3	104.4	102.4	99.4	97.1	93.6	91.2	88.1	86.4	85.4
AN	3.32	100	96.2	96.4	96.6	97.4	98.1	99.5	101.2	102.6	104.5	106.1	107.1	108.1	108.7
AO	2.16	100	99.5	99.5	99.7	99.7	99.9	100.0	100.2	100.3	100.5	100.9	100.9	100.4	100.7
AP	1.24	100	97.9	98.0	98.2	98.6	99.0	99.8	100.6	101.3	102.2	102.9	103.4	103.8	103.9
AQ	1.08	100	97.8	97.9	98.1	98.6	98.9	99.8	100.6	101.2	102.1	102.8	103.3	103.9	103.7
AR	0.85	100	99.1	99.2	99.4	99.5	99.7	100.0	100.2	100.4	100.6	100.9	100.9	100.8	100.7
AS	1.25	100	99.3	99.4	99.5	99.6	99.8	100.0	100.2	100.4	100.6	100.9	100.9	100.6	100.7
AT	0.7	100	102.2	102.3	102.0	101.7	101.3	100.5	99.3	98.5	97.1	96.2	94.9	94.2	93.8
AU	1.43	100	98.9	99.0	99.2	99.5	99.5	100.0	100.2	100.5	100.7	100.9	100.9	101.1	100.7
AV	1.67	100	98.4	98.6	98.8	99.2	99.4	100.0	100.4	100.8	101.2	101.6	101.5	102.0	101.8
AW	1.07	100	99.5	99.7	99.8	99.9	99.9	100.1	100.1	100.1	100.0	99.9	99.6	99.7	99.3
AX	1.5	100	101.7	102.0	101.8	101.6	101.3	100.5	99.5	98.6	97.4	96.6	95.2	94.7	94.2
AY	0.72	100	102.6	102.6	102.3	101.9	101.5	100.5	99.2	98.3	96.7	95.8	94.4	93.5	93.2
AZ	0.3	100	103.2	103.1	102.7	102.2	101.7	100.5	99.0	97.9	96.2	95.1	93.6	92.5	92.2
BA	0.99	100	103.3	103.3	102.9	102.4	101.8	100.6	99.0	97.8	95.9	94.8	93.2	92.1	91.8
BB	0.99	100	104.3	104.3	104.1	103.3	102.5	100.7	98.7	97.0	94.7	93.2	91.1	89.6	89.6
BC1	0.92	100	104.3	104.3	104.1	103.3	102.5	100.7	98.7	97.0	94.7	93.2	91.1	89.6	89.6
BC	1.04	100	104.3	104.3	104.1	103.3	102.5	100.8	98.8	97.1	94.8	93.3	91.1	89.7	89.6
BE1	0.89	100	105.2	105.2	104.9	104.0	102.9	101.0	98.5	96.6	93.9	92.0	89.8	88.5	87.5
BD	1.11	100	104.3	104.3	104.1	103.3	102.5	100.7	98.7	97.0	94.7	93.2	91.1	89.6	89.6
BE	0.57	100	105.2	105.2	104.9	104.0	102.9	101.0	98.5	96.6	93.8	91.9	89.7	88.4	87.3
BF	0.96	100	105.4	105.3	105.0	104.0	102.8	100.9	98.3	96.4	93.7	91.8	89.6	88.3	87.2
BG1	1.32	100	105.3	105.2	105.0	104.1	102.9	101.0	98.5	96.5	93.8	91.8	89.7	88.3	87.3
BH	1.25	100	104.6	104.8	104.6	103.9	103.0	101.4	99.0	97.2	94.4	92.5	90.3	88.9	88.3
BG3	0.37	100	105.0	105.4	105.3	104.5	103.6	101.8	99.1	97.1	93.9	91.9	89.1	87.8	86.8
BF1	0.61	100	104.8	104.8	104.5	103.6	102.6	100.8	98.5	96.7	94.2	92.5	90.4	89.0	88.4
BG	1.48	100	105.5	105.4	105.1	104.1	102.9	100.9	98.3	96.4	93.6	91.6	89.5	88.2	87.0
BG2	0.76	100	105.5	105.6	105.4	104.5	103.3	101.3	98.6	96.4	93.4	91.3	88.6	87.4	86.3
BI	2.71	100	104.6	104.9	104.7	104.0	103.1	101.5	99.1	97.2	94.4	92.5	90.2	88.8	88.1
BI1	1.95	100	105.1	105.6	105.5	104.7	103.8	101.9	99.2	97.1	93.8	91.7	88.7	87.5	86.4

Sub Area	Less than 30min	30min	45min	1 hour	1.5 hour	2 hour	3 hour	4.5 hour	6 hour	9 hour	12 hour	18 hour	24 hour	36 hour
U	100	102.5	102.2	102.2	101.5	101.2	100.7	99.2	98.5	97.3	96.5	95.6	94.8	94.3
V	100	102.5	102.3	102.2	101.5	101.2	100.7	99.2	98.4	97.3	96.4	95.4	94.6	94.2
AL1	100	103.1	103.0	102.9	102.3	101.5	100.9	98.9	97.8	96.2	95.0	93.8	93.2	92.2
AJ	100	102.4	102.1	102.1	101.5	101.2	100.8	99.3	98.6	97.5	96.7	95.9	95.0	94.5
AK	100	103.0	102.8	102.6	102.0	101.4	100.7	98.9	97.9	96.4	95.3	93.8	93.2	92.8
AL	100	103.2	103.3	103.2	102.8	102.0	101.3	99.0	97.7	95.8	94.4	92.6	92.1	91.2
AM2	100	103.2	103.4	103.3	103.0	102.2	101.5	99.2	97.8	95.8	94.4	92.4	91.9	91.0
AM3	100	102.7	103.2	103.3	103.0	102.5	101.9	99.8	98.5	96.4	95.0	93.0	92.5	91.5
AM	100	102.7	103.2	103.3	103.0	102.5	101.9	99.8	98.5	96.4	95.0	93.0	92.5	91.5
AM1	100	102.7	103.4	103.6	103.6	103.1	102.4	100.0	98.5	96.2	94.5	92.4	91.4	90.5
AN	100	94.0	94.2	94.6	95.7	96.9	99.5	101.9	104.1	107.4	109.9	112.4	114.3	115.2
AO	100	97.2	97.3	97.6	98.0	98.7	100.0	100.9	101.8	103.3	104.5	105.8	106.1	106.8
AP	100	95.6	95.8	96.1	96.9	97.7	99.8	101.2	102.8	105.0	106.6	108.4	109.8	110.1
AQ	100	95.5	95.7	96.1	96.9	97.7	99.8	101.2	102.7	105.0	106.5	108.3	109.9	110.0
AR	100	96.9	97.0	97.3	97.9	98.4	100.0	100.9	101.9	103.4	104.5	105.8	106.6	106.8
AS	100	97.0	97.1	97.4	97.9	98.5	100.0	100.9	101.9	103.4	104.5	105.8	106.4	106.8
AT	100	99.8	100.0	99.9	100.0	100.1	100.5	100.0	99.9	99.8	99.7	99.5	99.6	99.5
AU	100	96.6	96.8	97.1	97.8	98.3	100.0	100.9	102.0	103.5	104.5	105.8	106.9	106.8
AV	100	96.2	96.4	96.7	97.5	98.1	100.0	101.0	102.3	104.0	105.3	106.5	107.8	107.9
AW	100	97.2	97.4	97.7	98.2	98.7	100.1	100.7	101.5	102.8	103.5	104.5	105.4	105.2
AX	100	99.4	99.7	99.6	99.8	100.0	100.5	100.1	100.1	100.1	100.1	99.9	100.1	99.9
AY	100	100.2	100.3	100.1	100.2	100.2	100.5	99.8	99.7	99.4	99.3	99.0	98.9	98.8
AZ	100	100.8	100.7	100.6	100.5	100.4	100.5	99.7	99.4	98.8	98.5	98.1	97.8	97.8
BA	100	101.0	100.9	100.8	100.6	100.5	100.6	99.6	99.3	98.6	98.3	97.8	97.4	97.4
BB	100	101.9	102.0	101.9	101.5	101.2	100.7	99.4	98.5	97.3	96.6	95.6	94.8	95.0
BC1	100	101.9	102.0	101.9	101.5	101.2	100.7	99.4	98.5	97.3	96.6	95.6	94.8	95.0
BC	100	101.9	101.9	101.9	101.5	101.2	100.8	99.4	98.5	97.4	96.7	95.6	94.9	95.0
BE1	100	102.7	102.8	102.7	102.2	101.6	101.0	99.1	98.0	96.5	95.3	94.2	93.5	92.7
BD	100	101.9	102.0	101.9	101.5	101.2	100.7	99.4	98.5	97.3	96.6	95.6	94.8	95.0
BE	100	102.8	102.8	102.7	102.3	101.6	101.0	99.1	98.0	96.4	95.2	94.1	93.5	92.6
BF	100	102.9	102.9	102.8	102.3	101.5	100.9	99.0	97.8	96.3	95.1	94.0	93.4	92.5
BG1	100	102.8	102.9	102.8	102.3	101.6	101.0	99.1	98.0	96.4	95.2	94.1	93.4	92.5
BH	100	102.2	102.5	102.4	102.1	101.7	101.4	99.7	98.6	97.0	95.9	94.7	94.0	93.6
BG3	100	102.6	103.0	103.1	102.8	102.3	101.8	99.8	98.5	96.6	95.2	93.4	92.9	92.0
BF1	100	102.4	102.4	102.3	101.9	101.3	100.8	99.2	98.1	96.8	95.9	94.8	94.1	93.7
BG	100	103.0	103.0	102.9	102.3	101.5	100.9	98.9	97.8	96.2	95.0	93.9	93.2	92.2
BG2	100	103.1	103.2	103.1	102.7	102.0	101.3	99.2	97.9	96.0	94.6	93.0	92.5	91.5
BI	100	102.2	102.5	102.5	102.2	101.8	101.5	99.7	98.6	97.0	95.9	94.6	93.9	93.5
BI1	100	102.7	103.2	103.3	103.0	102.5	101.9	99.8	98.5	96.5	95.0	93.1	92.5	91.6

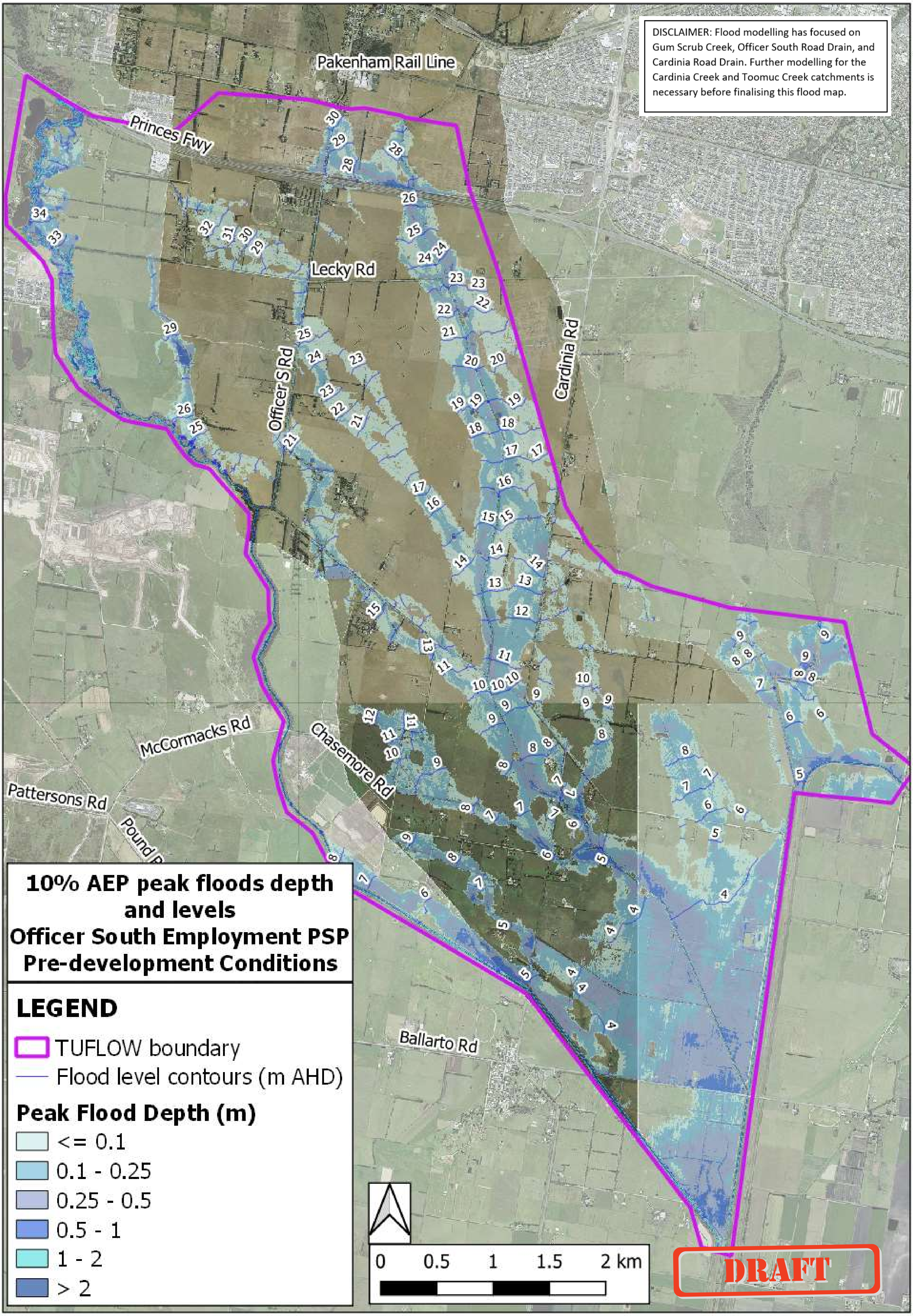
Appendix B. Peak Flood Depth and Level maps

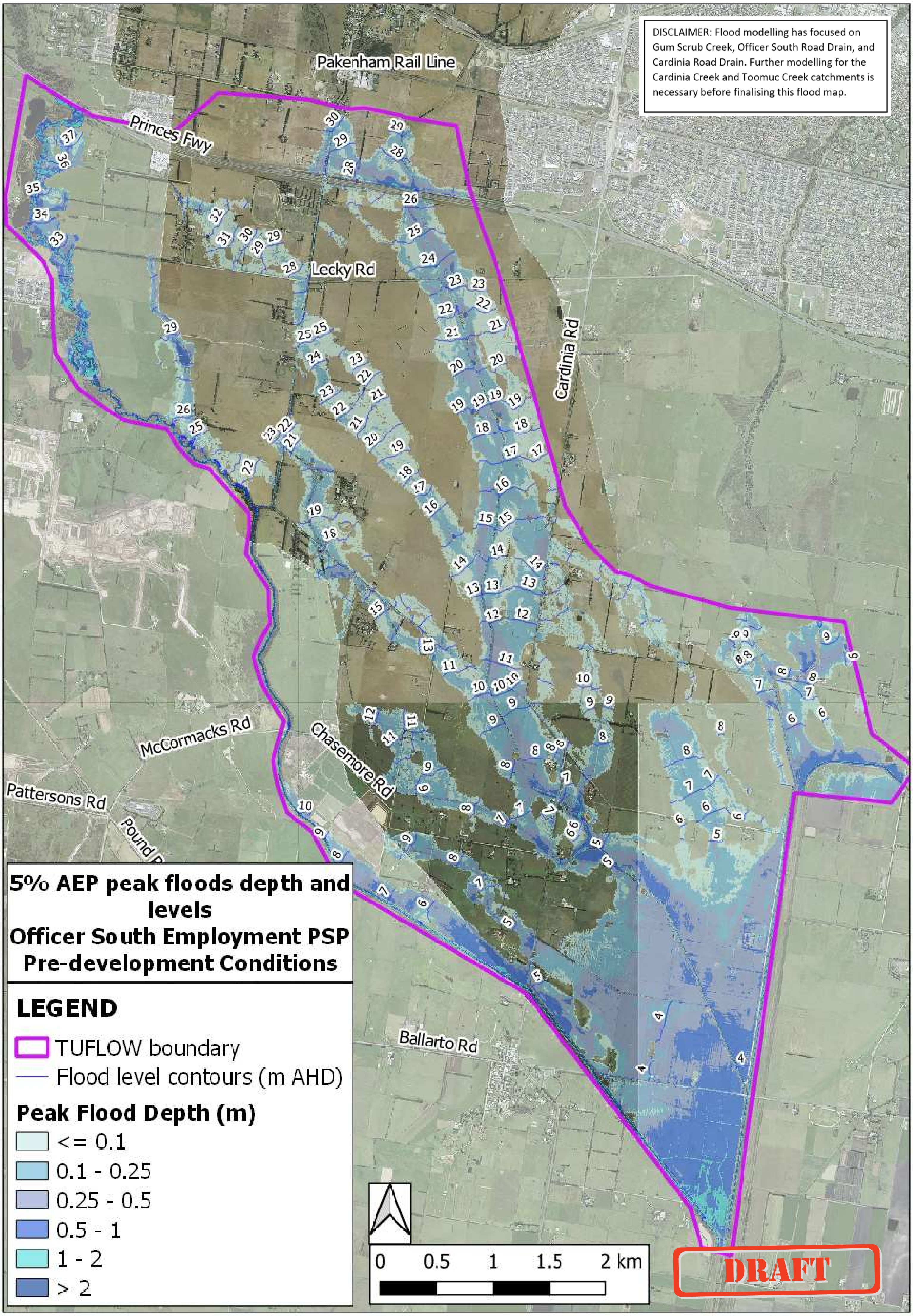

DISCLAIMER: Flood modelling has focused on Gum Scrub Creek, Officer South Road Drain, and Cardinia Road Drain. Further modelling for the Cardinia Creek and Toomuc Creek catchments is necessary before finalising this flood map.
Pakenham Rail Line
Princes Fwy
Lecky Rd
Officer S Rd
Cardinia Rd
Patterson Rd
McCormacks Rd
Chasemore Rd
Pattersons Rd
Ballarto Rd
63pt2% AEP peak floods depth and levels
Officer South Employment PSP
Pre-development Conditions
LEGEND
TUFLOW boundary
Flood level contours (m AHD)
Peak Flood Depth (m)
<= 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 1.5 2 km
DRAFT


DISCLAIMER: Flood modelling has focused on Gum Scrub Creek, Officer South Road Drain, and Cardinia Road Drain. Further modelling for the Cardinia Creek and Toomuc Creek catchments is necessary before finalising this flood map.
Pakenham Rail Line
Princes Fwy
Lecky Rd
Officer S Rd
Cardinia Rd
Patterson Rd
McCormacks Rd
Chasemore Rd
Pattersons Rd
Ballarto Rd
50% AEP peak floods depth and levels
Officer South Employment PSP
Pre-development Conditions
LEGEND
TUFLOW boundary
Flood level contours (m AHD)
Peak Flood Depth (m)
<= 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 1.5 2 km
DRAFT

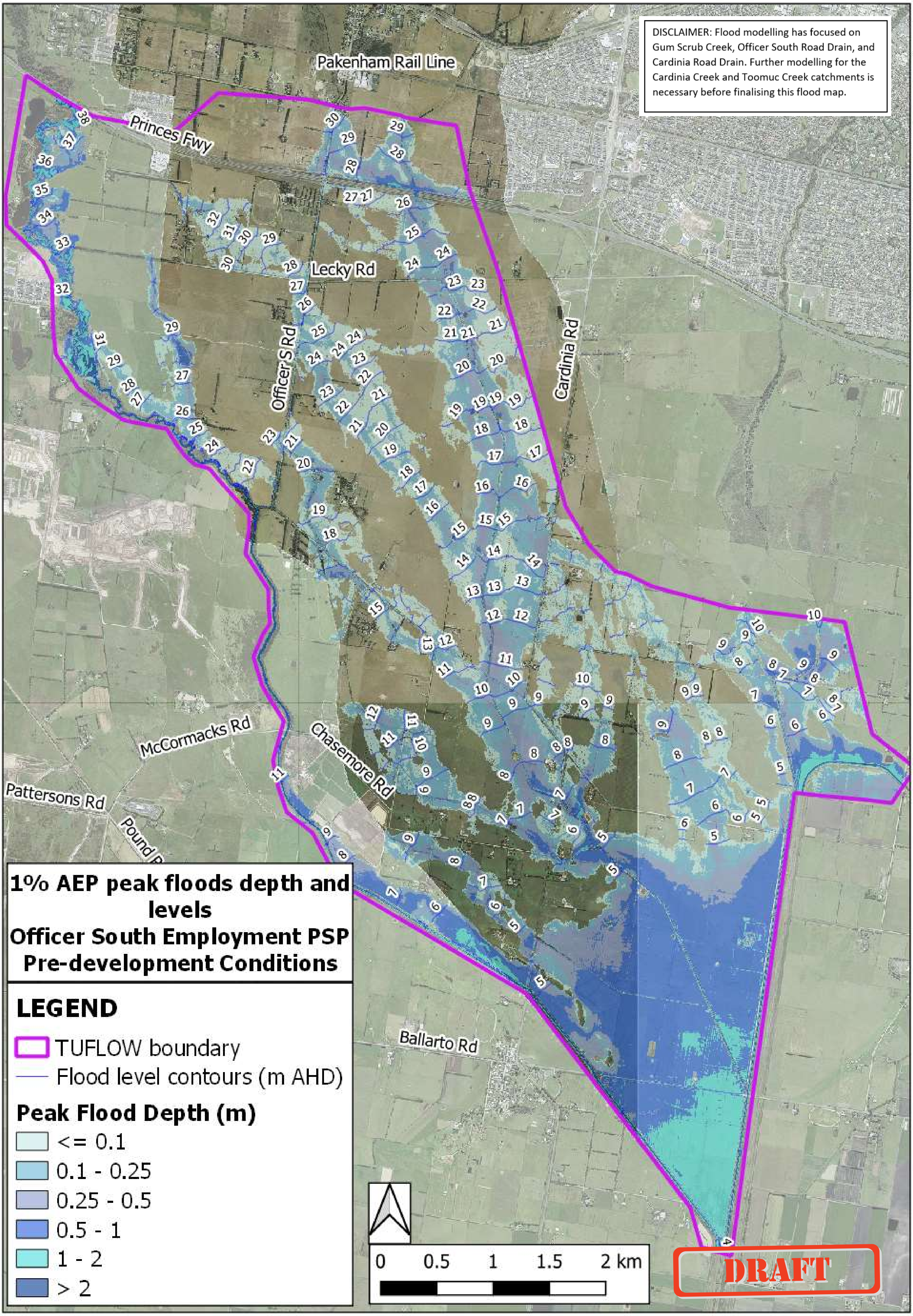


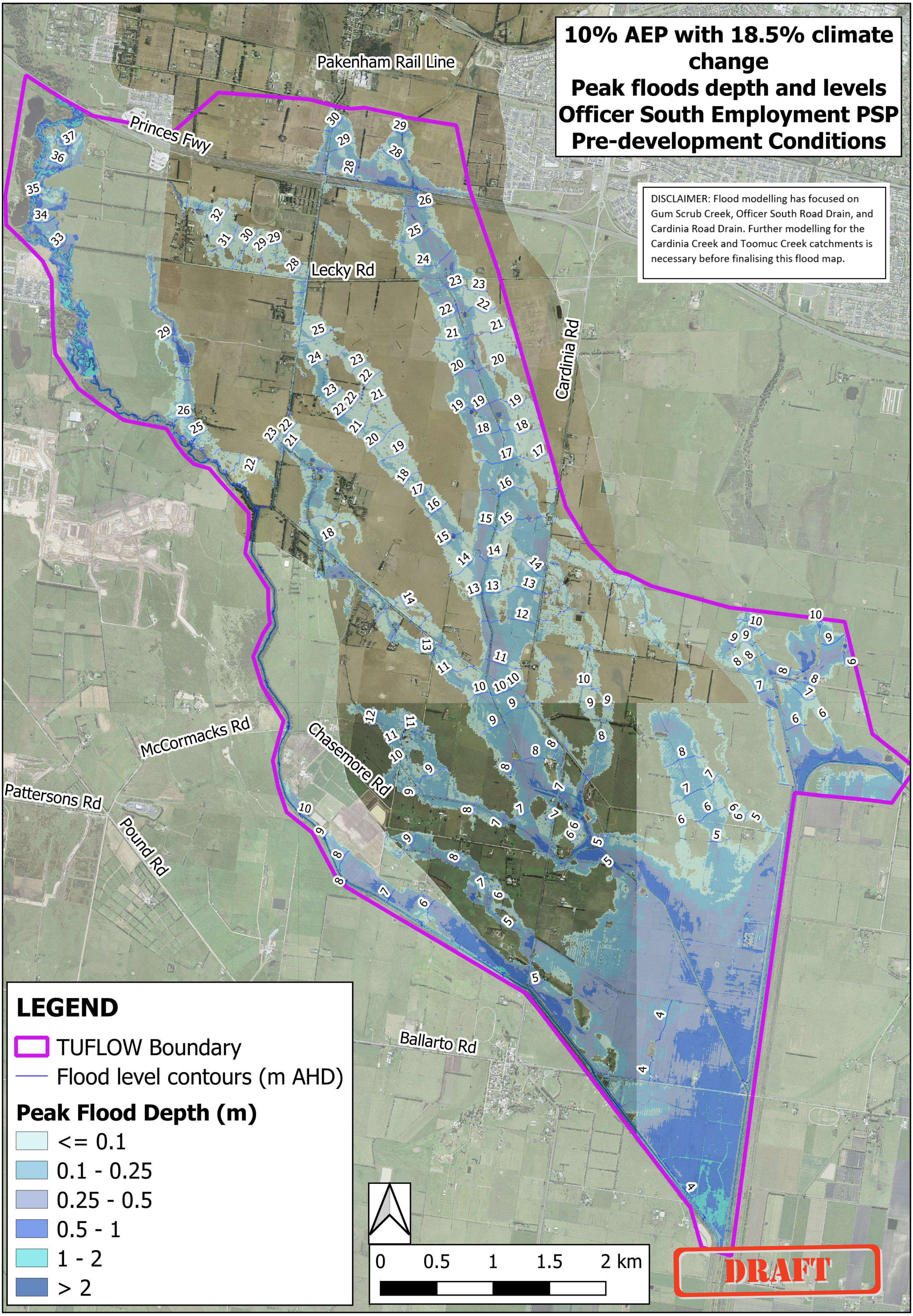
DISCLAIMER: Flood modelling has focused on Gum Scrub Creek, Officer South Road Drain, and Cardinia Road Drain. Further modelling for the Cardinia Creek and Toomuc Creek catchments is necessary before finalising this flood map.
Pakenham Rail Line
Princes Fwy
Lecky Rd
Officer S Rd
Cardinia Rd
Patterson Rd
McCormacks Rd
Chasemore Rd
Pattersons Rd
Ballarto Rd
20% AEP peak floods depth and levels
Officer South Employment PSP
Pre-development Conditions
LEGEND
TUFLOW boundary
Flood level contours (m AHD)
Peak Flood Depth (m)
<= 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2
0
0.5
1
1.5
2 km
DRAFT

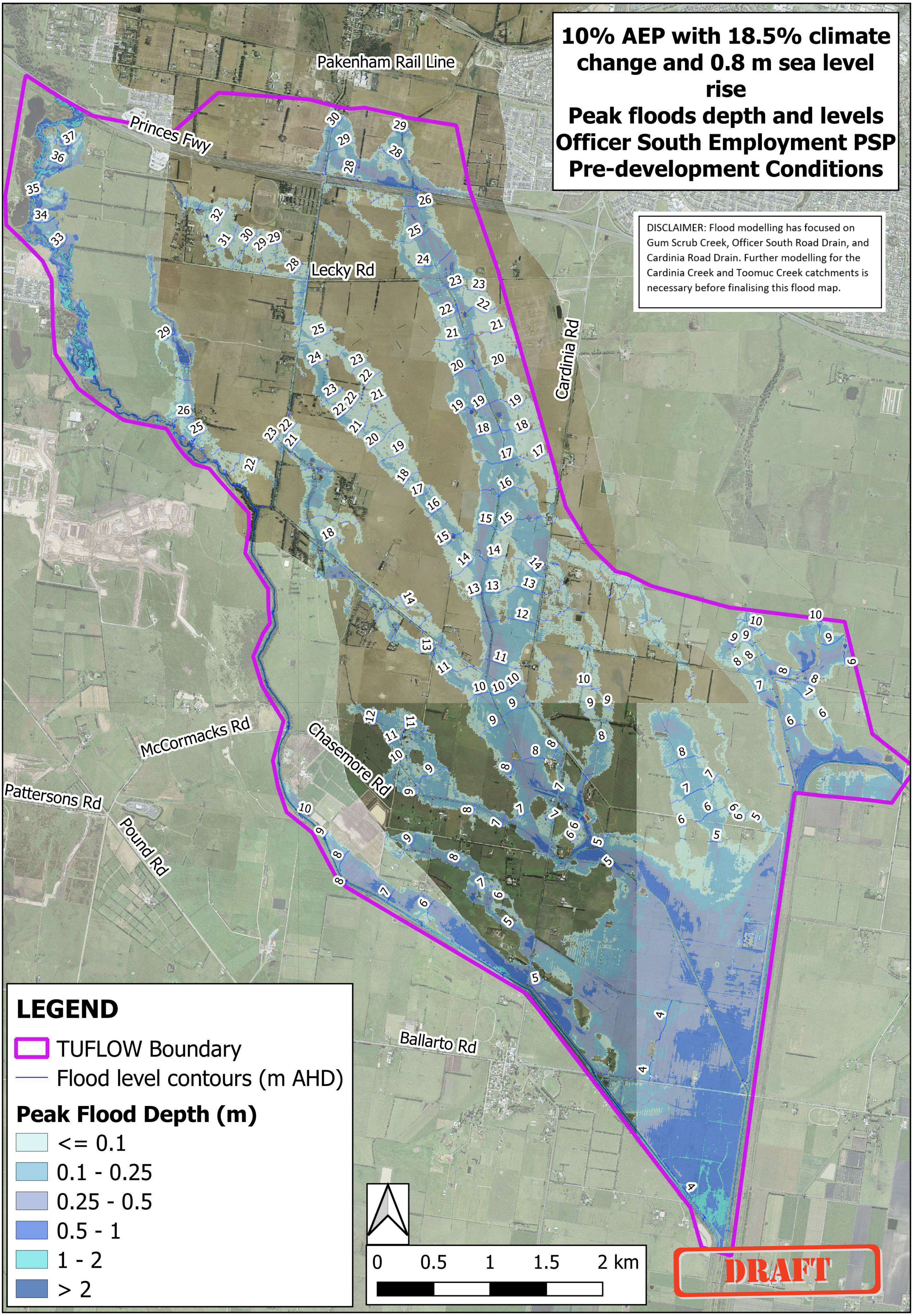

DISCLAIMER: Flood modelling has focused on Gum Scrub Creek, Officer South Road Drain, and Cardinia Road Drain. Further modelling for the Cardinia Creek and Toomuc Creek catchments is necessary before finalising this flood map.
Pakenham Rail Line
Princes Fwy
Lecky Rd
Officer S Rd
Cardinia Rd
McCormacks Rd
Chasemore Rd
Pattersons Rd
Ballarto Rd
10% AEP peak floods depth and levels
Officer South Employment PSP
Pre-development Conditions
LEGEND
TUFLOW boundary
Flood level contours (m AHD)
Peak Flood Depth (m)
<= 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 1.5 2 km
DRAFT



5% AEP peak floods depth and levels
Officer South Employment PSP
Pre-development Conditions


DISCLAIMER: Flood modelling has focused on Gum Scrub Creek, Officer South Road Drain, and Cardinia Road Drain. Further modelling for the Cardinia Creek and Toomuc Creek catchments is necessary before finalising this flood map.
Pakenham Rail Line
Princes Fwy
Lecky Rd
Officer S Rd
Cardinia Rd
McCormacks Rd
Chasemore Rd
Pattersons Rd
Pound R
Ballarto Rd
1% AEP peak floods depth and levels
Officer South Employment PSP
Pre-development Conditions
LEGEND
TUFLOW boundary
Flood level contours (m AHD)
Peak Flood Depth (m)
<= 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2
0
0.5
1
1.5
2 km
DRAFT


10% AEP with 18.5% climate change
Peak floods depth and levels
Officer South Employment PSP
Pre-development Conditions
DISCLAIMER: Flood modelling has focused on Gum Scrub Creek, Officer South Road Drain, and Cardinia Road Drain. Further modelling for the Cardinia Creek and Toomuc Creek catchments is necessary before finalising this flood map.
Pakenham Rail Line
Princes Fwy
Lecky Rd
Cardinia Rd
McCormacks Rd
Chasemore Rd
Pattersons Rd
Pound Rd
Ballarto Rd
LEGEND
TUFLOW Boundary
Flood level contours (m AHD)
Peak Flood Depth (m)
<= 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 1.5 2 km
DRAFT


10% AEP with 18.5% climate change and 0.8 m sea level rise
Peak floods depth and levels
Officer South Employment PSP
Pre-development Conditions
DISCLAIMER: Flood modelling has focused on Gum Scrub Creek, Officer South Road Drain, and Cardinia Road Drain. Further modelling for the Cardinia Creek and Toomuc Creek catchments is necessary before finalising this flood map.
Pakenham Rail Line
Princes Fwy
Lecky Rd
Cardinia Rd
McCormacks Rd
Chasemore Rd
Pattersons Rd
Pound Rd
Ballarto Rd
LEGEND
TUFLOW Boundary
Flood level contours (m AHD)
Peak Flood Depth (m)
<= 0.1
0.1 - 0.25
0.25 - 0.5
0.5 - 1
1 - 2
> 2
0 0.5 1 1.5 2 km
DRAFT

1% AEP with 18.5% climate change and 0.8 m sea level rise
Peak floods depth and levels
Officer South Employment PSP
Pre-development Conditions

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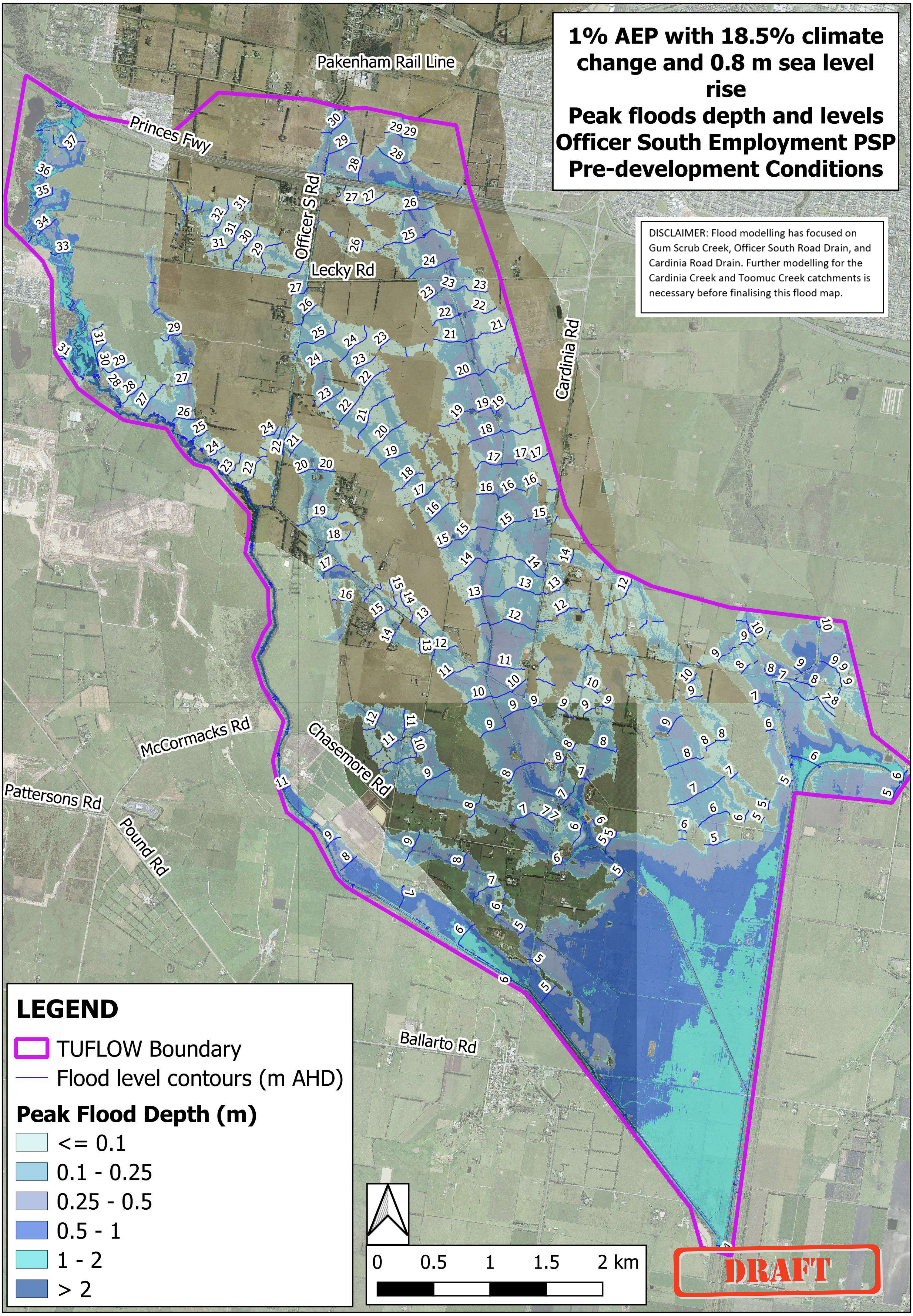

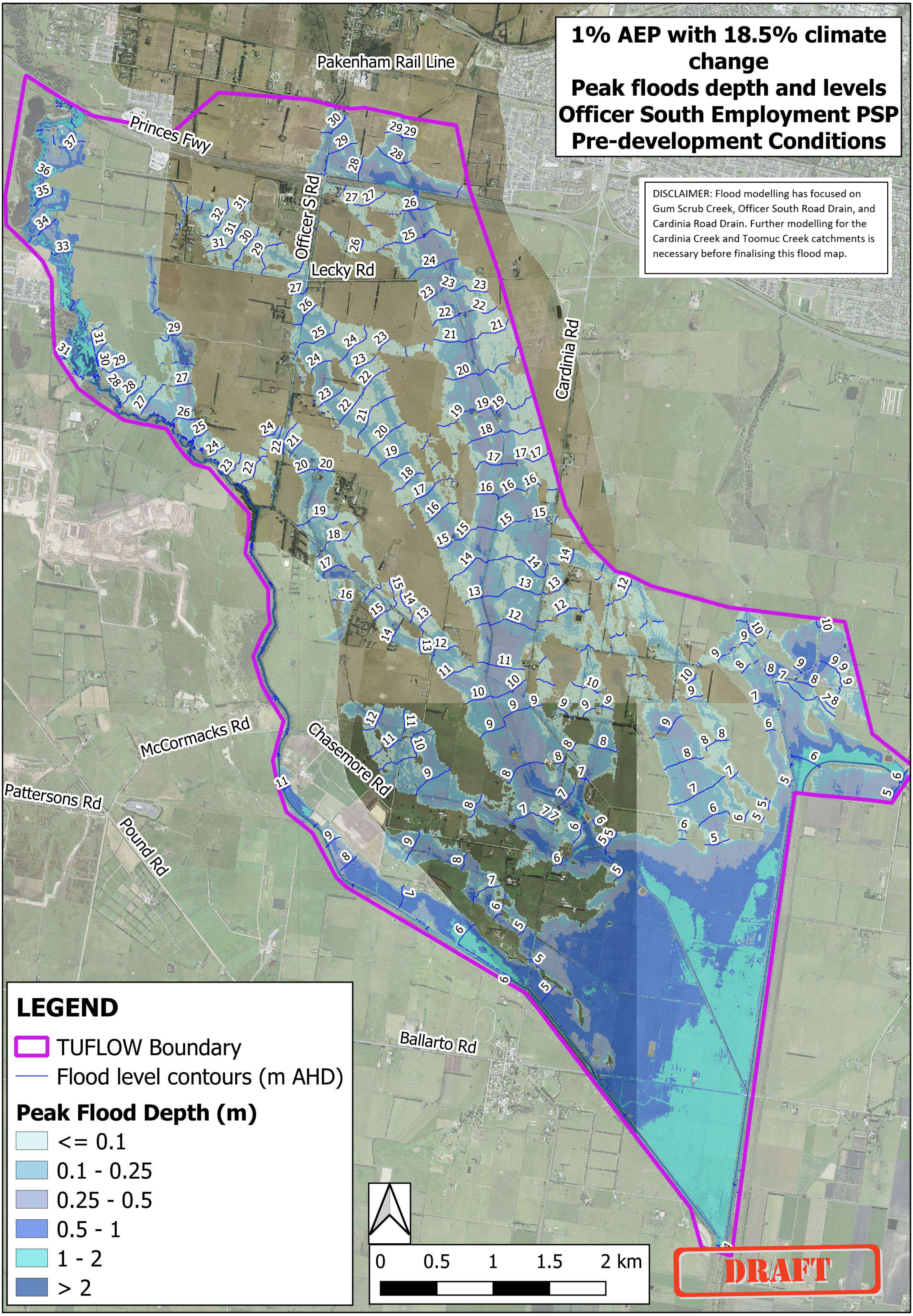
1% AEP with 18.5% climate change
Peak floods depth and levels
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