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Honeysuckle Redevelopment Area Flood Study

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Final Report

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Contents

List of Figures

List of Tables

1 Introduction

This report has been commissioned by Hunter Development Corporation (HDC) to provide updated flood risk information for the Waterfront and Cottage Creek precincts of the Honeysuckle Redevelopment Area, Newcastle West (herein referred to as the Site (refer Figure 1-1). An original Flood Management Plan was prepared for the Site by Lawson & Treloar in 1999. More recent advances in flood modelling have resulted in subsequent studies providing different estimations of flood conditions within Honeysuckle, resulting in some uncertainty with regards to flood planning for the redevelopment area.

This study serves to update flood risk information within Honeysuckle, that considers both existing and post-development flood conditions, in line with current best practice flood modelling and floodplain management.

1.1 Background Information

The Site is located within the Cottage Creek catchment, which drains to the Throsby Basin in Newcastle Harbour (see Figure 1-1 and Figure 1-2). The site is located on Honeysuckle Drive and is drained primarly by a network of subsurface stormwater pipes that discharge to either Cottage Creek or terminate directly to Newcastle Harbour. During major events, the conveyance capacity of the drainage network is exceeded resulting in the excess flow being conveyed as overland flow, particularly along Honeysuckle Drive.

The Cottage Creek catchment is an estimated 8 km^2 in size, comprised predominantly of urban residential development. The upper catchment is relatively steep, draining the ridgeline of Scenic Drive and Merewether Heights to flatter topography around National Park. The downstream end of the catchment is the commercial centre of Hunter Street and King Street, close to the proposed development site.

Flooding in the Cottage Creek catchment is generally fast and a result of the capacity of the stormwater drainage network being exceeded. Floodwaters recede quickly, however blockages of the stormwater network can prolong inundation in the area. Historically, major flooding of Cottage Creek occurred in 1988, 1990 and 2007.

A model of the catchment was previously developed for NCC (Throsby and Cottage Creeks and CBD TUFLOW model) and was used to inform the TUFLOW modelling used in this assessment. As the previous modelling was undertaken at a coarser resolution, a more detailed local model was created to adequately represent the flooding conditions and to provide reliable Flood Planning Levels (FPLs) at the development sites and public domains.

1.2 Description of Proposed Works

The site is in the western section of the Cottage Creek catchment. HDC is planning the disposal of sites in the Honeysuckle Redevelopment Area, comprising:

- administration of bulk materials, reuse and land-forming within the development site
- demolition of an existing wharf structure

- filling of the existing wharf and replacement to existing quay line with a king pile / revetment
- provision of sufficient hydraulic capacity through the reclamation via culvert structure
- landform adjustments to Public Domain corridors, which also act as floodways in an extreme event.

Title:

Site Locality

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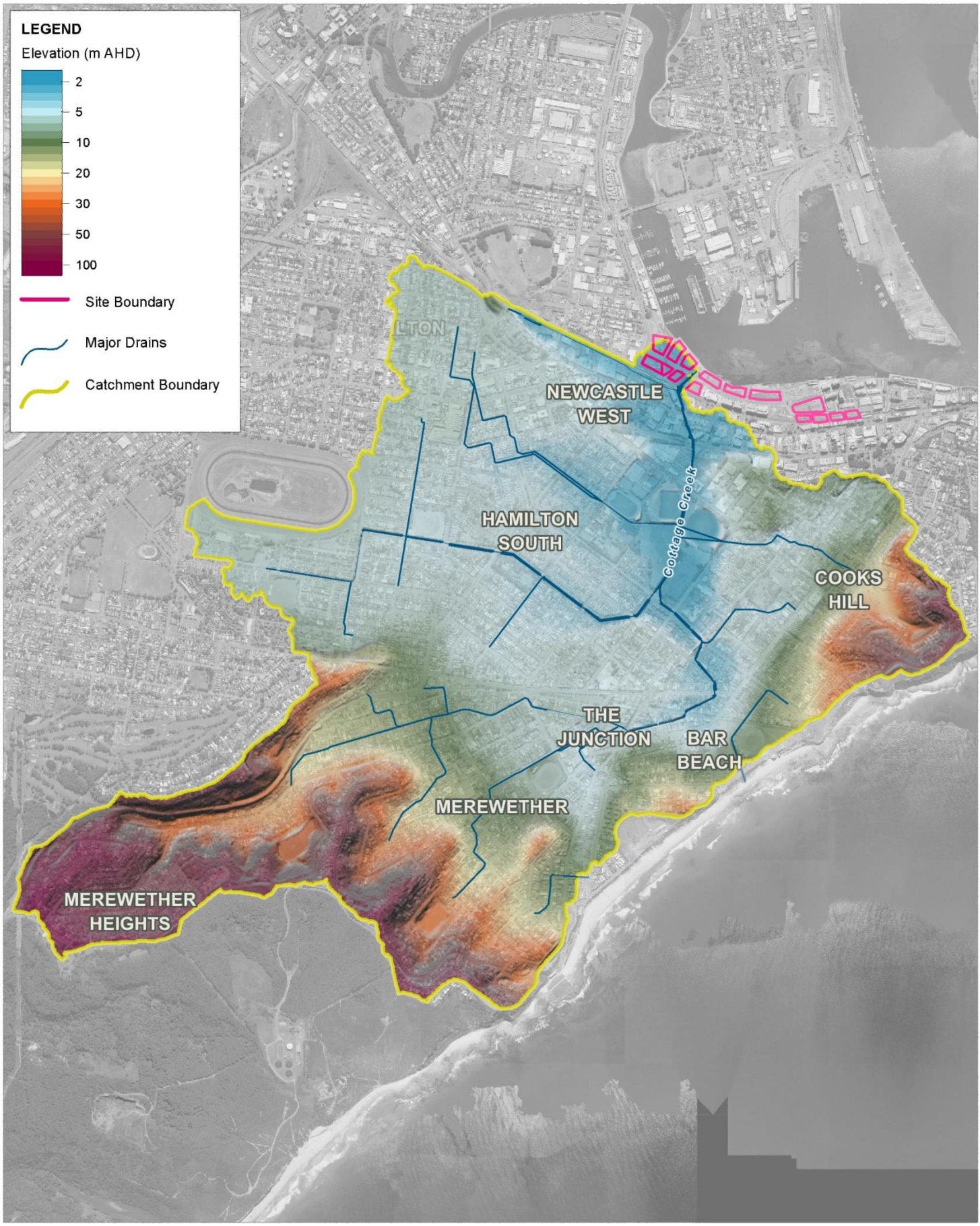

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Study Catchment and Topography

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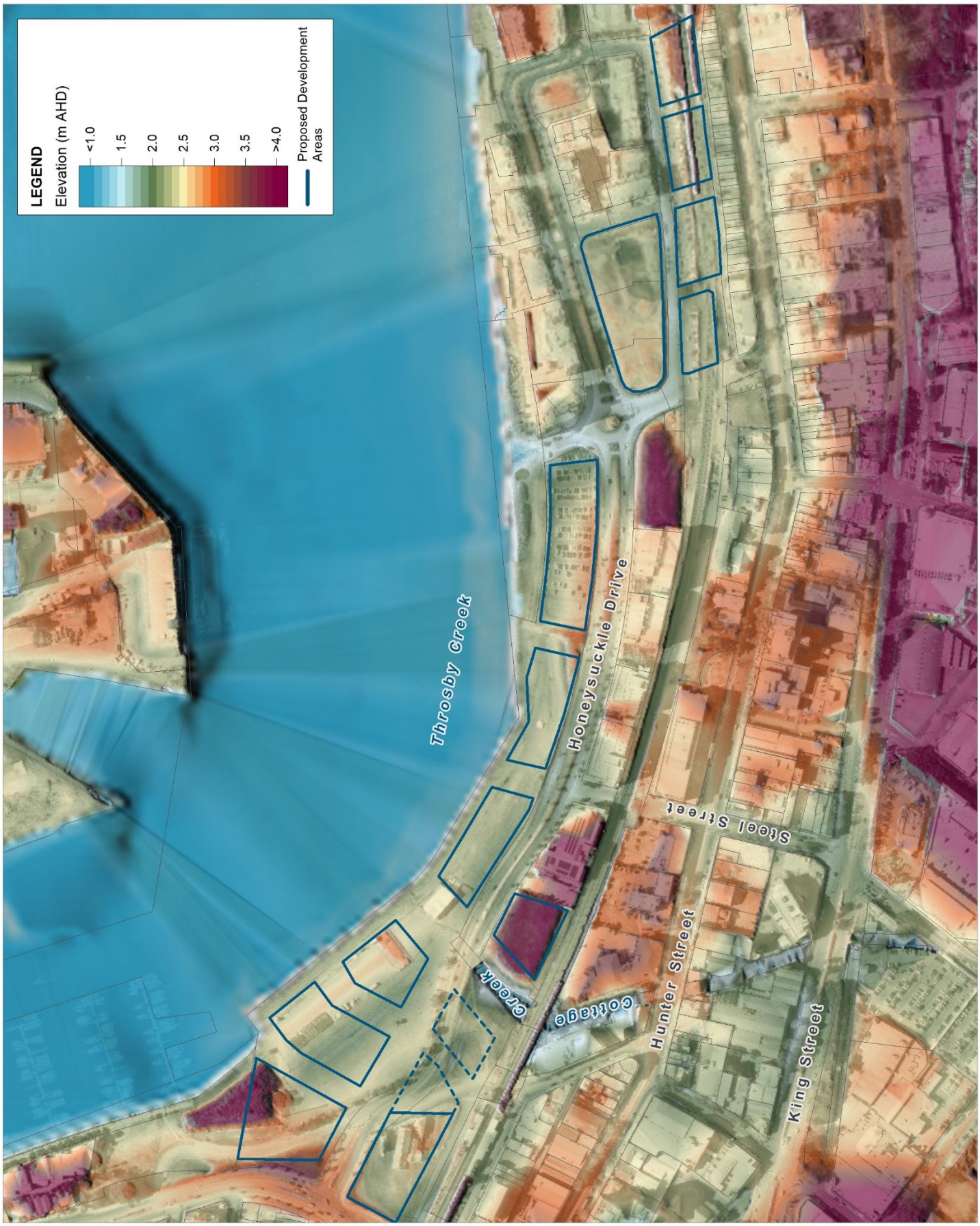

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Local Topography

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2 Model Development

2.1 Hydraulic Model

The hydraulic model used by NCC (Throsby and Cottage Creeks and CBD TUFLOW model) to define flood behaviour in the Throsby Creek catchment is now reasonably dated and at a coarser (10 m) resolution than would typically be used for modelling overland flows (BMT WBM 2008b). As such, it was deemed beneficial to develop a more detailed flood model of the area to gain a better understanding of the complex flood flow path interactions, and to reduce any uncertainties associated with the existing model representation.

The model topography was based principally on the 2014 LPI LiDAR data, in the form of a high resolution (1 m grid) digital elevation model (DEM). The full catchment topography is presented in Figure 1-2.

With consideration to the available local topographical data, and hydraulic controls, a TUFLOW 2D domain model resolution of 2 m was adopted for the modelled area. It should be noted that TUFLOW samples elevation points at the cell centres, mid-sides and corners, so a 2 m cell size results in DEM elevations being sampled every 1 m. This provides a detailed representation of overland flow distribution across the model area, as well as clearly defining important topographical features such as road and rail embankments and drainage channels.

A materials layer was developed to represent appropriate hydraulic roughness (Manning's 'n') characteristics of the various surfaces, including the Cottage Creek channel, grass, vegetation, roads, hardstand and buildings. "Z-shapes" were incorporated into the TULOW model to create 3D break lines, to better represent the key hydraulic controls within the study area. These include the solid walls of buildings, railway embankments and features such as the proposed Newcastle Light Rail alignment and Newcastle Transport Interchange.

Due to the inefficiency of a fully 2D model representation to convey flow in steep-sided concrete-lined channels, it was necessary to incorporate the open channel network of Cottage Creek as a 1D model representation dynamically linked to the 2D floodplain. Catchment runoff is conveyed within the 1D model network and then spills into the 2D floodplain areas once the channel capacity is exceeded and channel banks are overtopped. The hydraulic structures of all road crossings along the modelled reach of Cottage Creek were modelled as rectangular box culverts within the 1D model network. Channel and structure details were obtained from the existing model and appropriately incorporated into the new detailed TUFLOW model.

There is an existing sub-surface stormwater pipe network located within the modelled area which was represented as a 1D drainage network within the 2D model. These stormwater pipes vary in terms of construction type and configuration, with varying degrees of influence on local hydraulic behaviour. Incorporation of these hydraulic structures into the hydraulic model provides for simulation of the hydraulic losses associated with these structures and their influence on peak water levels within the study area.

The model boundary conditions are derived as follows:

- inflows (rainfall runoff) – inflows were derived using an XP-RAFTS hydrologic model that was developed for the Cottage Creek catchment and calibrated to the full Throsby-Cottage Creeks model at the local TUFLOW model boundaries. The model was then verified using the June 2007 calibration event. The PMF was determined using the Generalised Short Duration Method (GSDM).
- downstream boundary (Throsby Basin) – a water level boundary consistent with the existing NCC model was adopted for the downstream model boundary – a constant water level of 0.8 m AHD was applied.

The configuration of the TUFLOW hydraulic model is provided in Figure 2-1.

2.2 Hydrologic Model

The hydrologic model simulates the rate of runoff generated from rainfall in a catchment. The magnitude of runoff is dependent on several factors including:

- catchment slope, area, vegetation and urbanisation
- variations in the spatial and temporal distribution of rainfall across the catchment, and
- the antecedent moisture conditions of the catchment.

These factors were represented in the hydrologic model (XP-RAFTS) by:

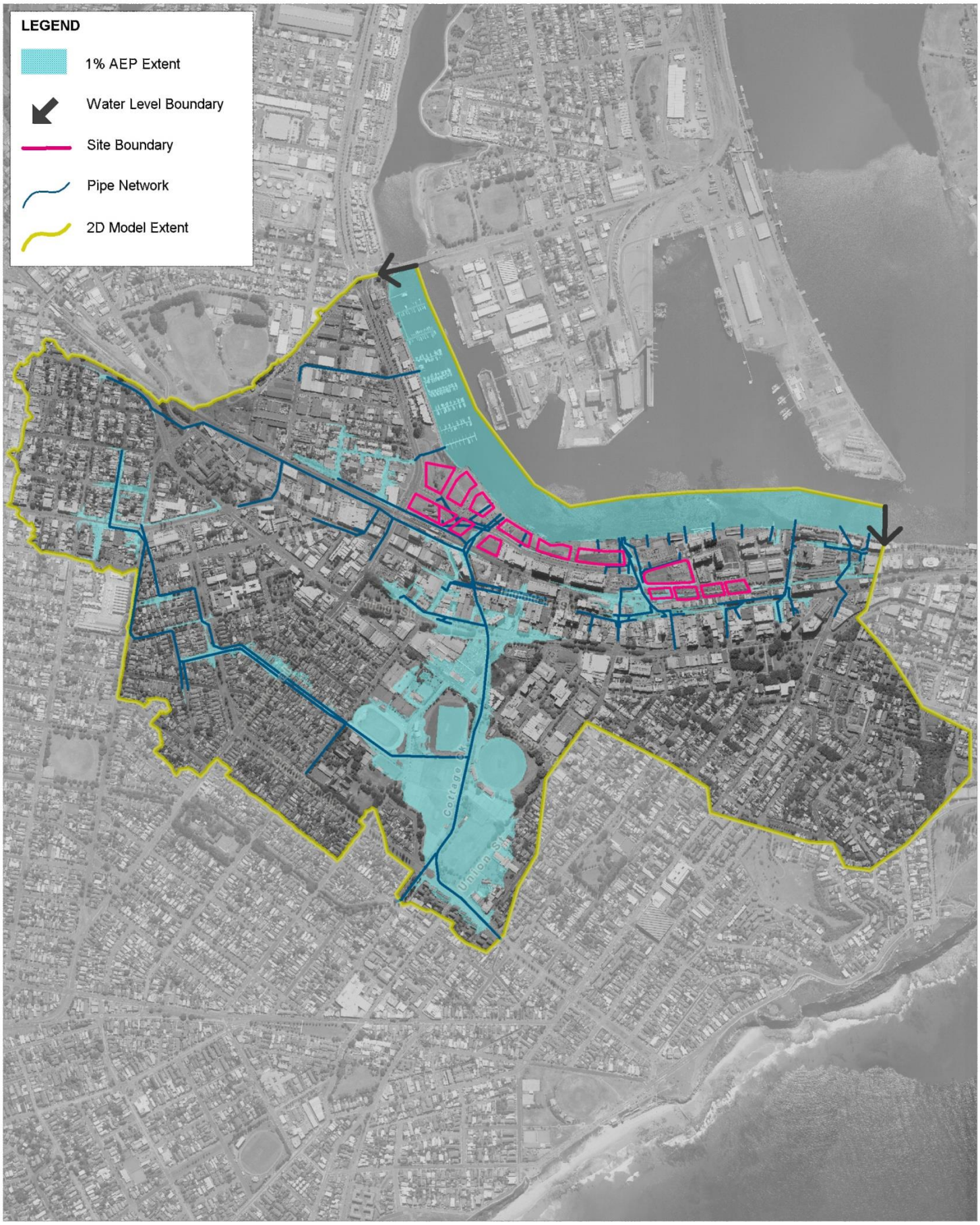
- delineation of the catchment into a network of sub-catchments with uniform slope, land use and vegetation density (as determined by aerial photography and DEMs) using CatchmentSim software
- variation of rainfall across the catchment using historical data to determine rainfall depths and intensities, and
- determining appropriate rainfall losses from the model to adequately represent the land use.

The output from the hydrological model is a series of flow hydrographs at selected locations such as at the boundaries of the hydraulic model. These hydrographs are used by the hydraulic model to simulate the passage of the flood through the Cottage Creek catchment.

2.3 ARR 2016

The ARR 2016 update was released in December 2016 and currently represents the best practice guideline for the industry. The updated procedures provide some significant changes to previous procedures. Some of the most notable changes in ARR 2016 are summarised below:

- IFD 2016 design rainfalls – the revised IFD rainfall estimates underpin the ARR 2016 release. The updated IFD analysis includes a significant period of additional rainfall data collected since the release of IFD 1987. Variation in rainfall between the 1987 and 2016 IFDs is location dependent



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TUFLOW Model Configuration

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- design rainfall losses – the estimation of initial and continuing loss rates is provided in ARR 2016 as gridded spatial data. Representative losses for catchments are extracted from the database which is a significant change from ARR 2001 whereby basic loss ranges were recommended for broad areas i.e. eastern or western NSW
- pre-burst rainfall – ARR 2016 provides procedures for pre-burst rainfalls for consideration along with design rainfall initial losses
- areal reduction factors – new equations were developed as part of ARR 2016 with regionalised parameters to define the areal reduction factor for catchments based on area and storm duration, and
- temporal patterns –each design duration now has a suite of 10 temporal patterns (opposed to a single temporal pattern) for each duration.

The change in temporal patterns provides the most significant change in design flow estimation from ARR 2001 to ARR 2016. Figure 2-2 shows the generated hydrographs for the ten temporal patterns for the 1% AEP design event to be applied under ARR 2016. The procedures for ARR 2016 provide for the selection of the temporal that gives the peak flow closest to the mean of the peak flows from all ten temporal patterns. For the 3-hour duration (the critical duration defined by ARR 2016 for the Cottage Creek catchment), the peak flow across the ten temporal patterns varies from 55 m^3/s to 89 m^3/s, with a mean of 76 m^3/s. For this duration, temporal pattern 4653 provides the peak flow closest to the mean (known as the critical temporal pattern). The ARR 2016 derived temporal pattern was approximately 10 m^3/s greater than the IFD 1987 derived temporal pattern, principally due to increased rainfall intensity estimates between the 1987 and 2016 IFDs.

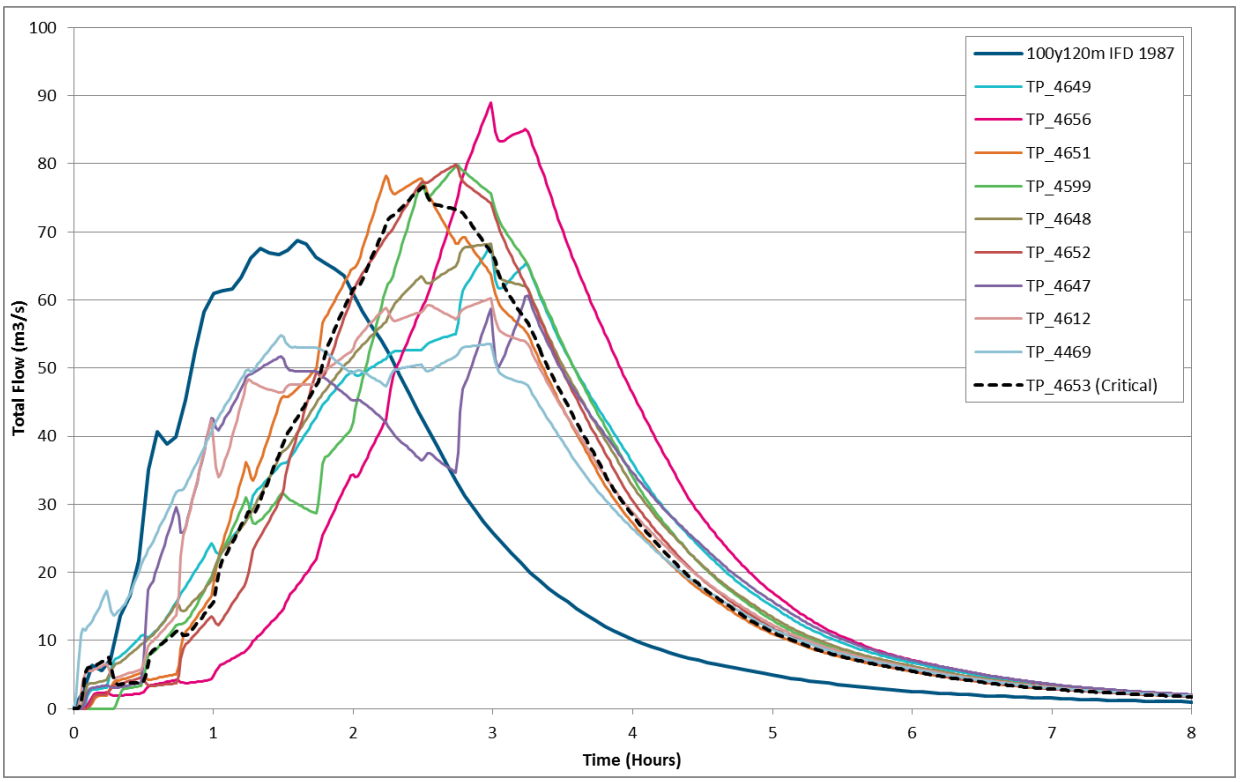


Figure 2-2 Design Hydrographs for the 1% AEP 3-hour Event

The critical duration determined using the ARR 2016 procedures was the 3-hour duration for all design events. The critical flow condition was determined at King Street, upstream of the Honeysuckle development areas. Comparison of peak flood levels derived from the ARR 2001 and ARR 2016 procedures was undertaken, as shown in Table 2-1 below. Evidently, peak flood levels increased at most of the locations due to the increase in peak flows through the catchment (see Section 2.3), however increases were up to 0.15 m near the study area. As presented in Figure 2-4, the major channels and flow paths through the catchment experience an increase in peak flood levels under ARR 2016. Conversely, the smaller local flow paths experience a decrease in peak flood levels, due to the increased length of the Cottage Creek critical flood duration being modelled.

Table 2-1 Comparison of Peak Flood Levels

Flood Event	Peak Level (m AHD)				
	Location 1 – Cottage Creek North of Railway Corridor	Location 2 – Intersection of Hunter St & National Park St	Location 3- Intersection of Steel St & Hunter St	Location 4 – Intersection of Union St and Hunter St	Location 5 – Intersection of King St & Hunter St
1% AEP ARR 2001	1.78	-	2.58	2.54	2.58
1% AEP ARR 2016	1.85 (+0.07)	2.64	2.68 (+0.10)	2.49 (-0.05)	2.68 (+0.10)

Note: Bracketed value is change in peak flood level from the ARR 2001/IFD 1987 data. Cells with '-' indicate no inundation occurred at the location.

The estimation of very rare flood events such as the 0.2% and 0.5% AEP events requires consideration of both the rare design flood events (such as the 1% AEP) and extreme flood events (such as the PMF). The ARR 2016 guidelines provide estimations of appropriate design event magnitudes of PMP based on the catchment size at the point of interest. Due to the small catchment size, a design magnitude of 0.000001 AEP was considered appropriate for the interpolation of the 0.2% and 0.5% events. The interpolation of the 0.2 and 0.5% events is shown in Figure 2-3.

2.4 Model Calibration

The hydrologic and hydraulic models were calibrated against the June 2007 event to establish the values of key model parameters and confirm that the models were capable of accurately predicting real flood events.

The following criteria are generally used to determine the suitability of historical events to use for calibration:

- the availability, completeness and quality of rainfall and flood level event data;
- the amount of reliable data collected during the historical flood information survey; and
- the variability of events – preferably events would cover a range of flood sizes.

In 2007 Newcastle experienced an East Coast Low over the 7th, 8th and 9th of June which caused sustained heavy rainfall, strong winds and large ocean waves and flash flooding. Much of the rainfall fell on the 8th June, with significant rainfall recorded throughout the Hunter and Metropolitan Districts

from the 6th to 10th of June 2007. During the event, major flooding occurred along the Hunter, Paterson and Williams Rivers. The highest 24-hour rainfall recorded for the event was 293.6 mm at the Mangrove Mountain gauge, some 100 km south of Newcastle. The Nobbys Station BoM gauge recorded 164.8 mm in 6 hours and recorded its highest rainfall for the month of June (495.8 mm) since the year 1950[1].

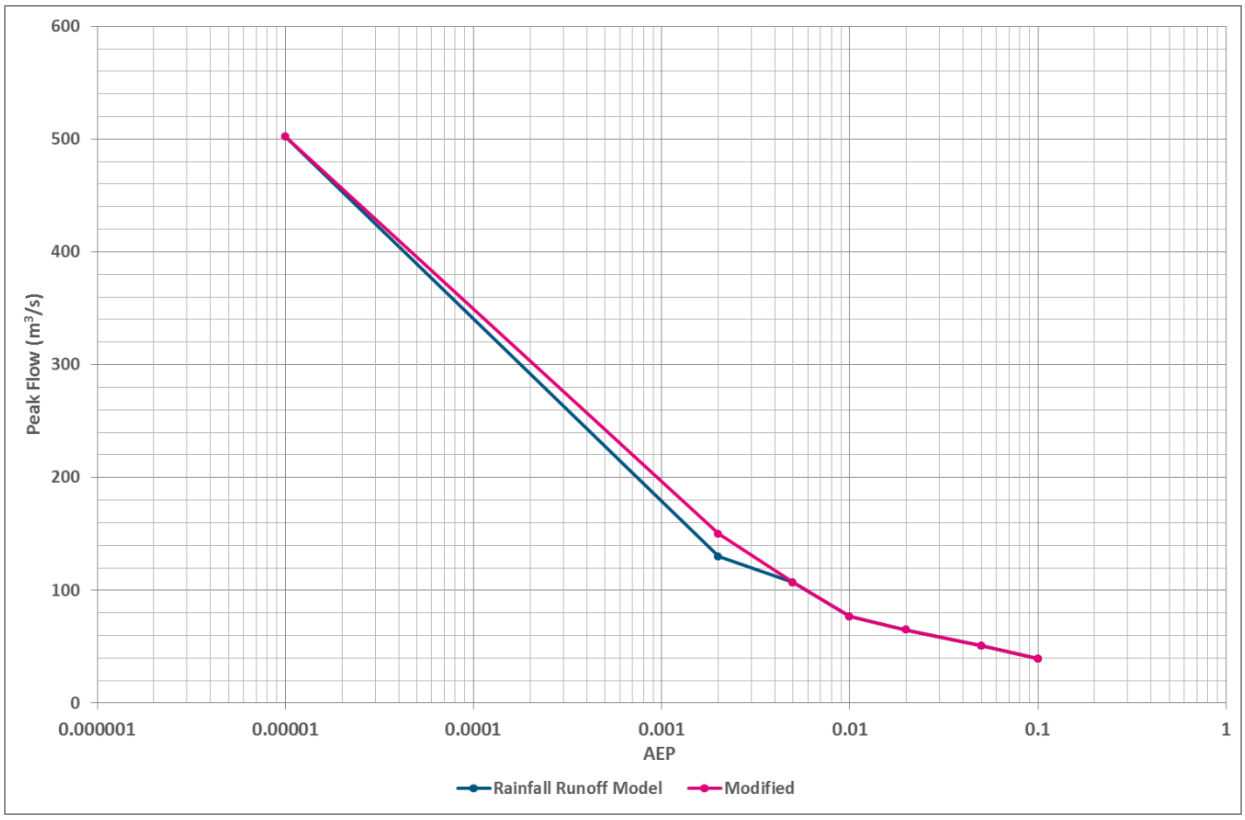
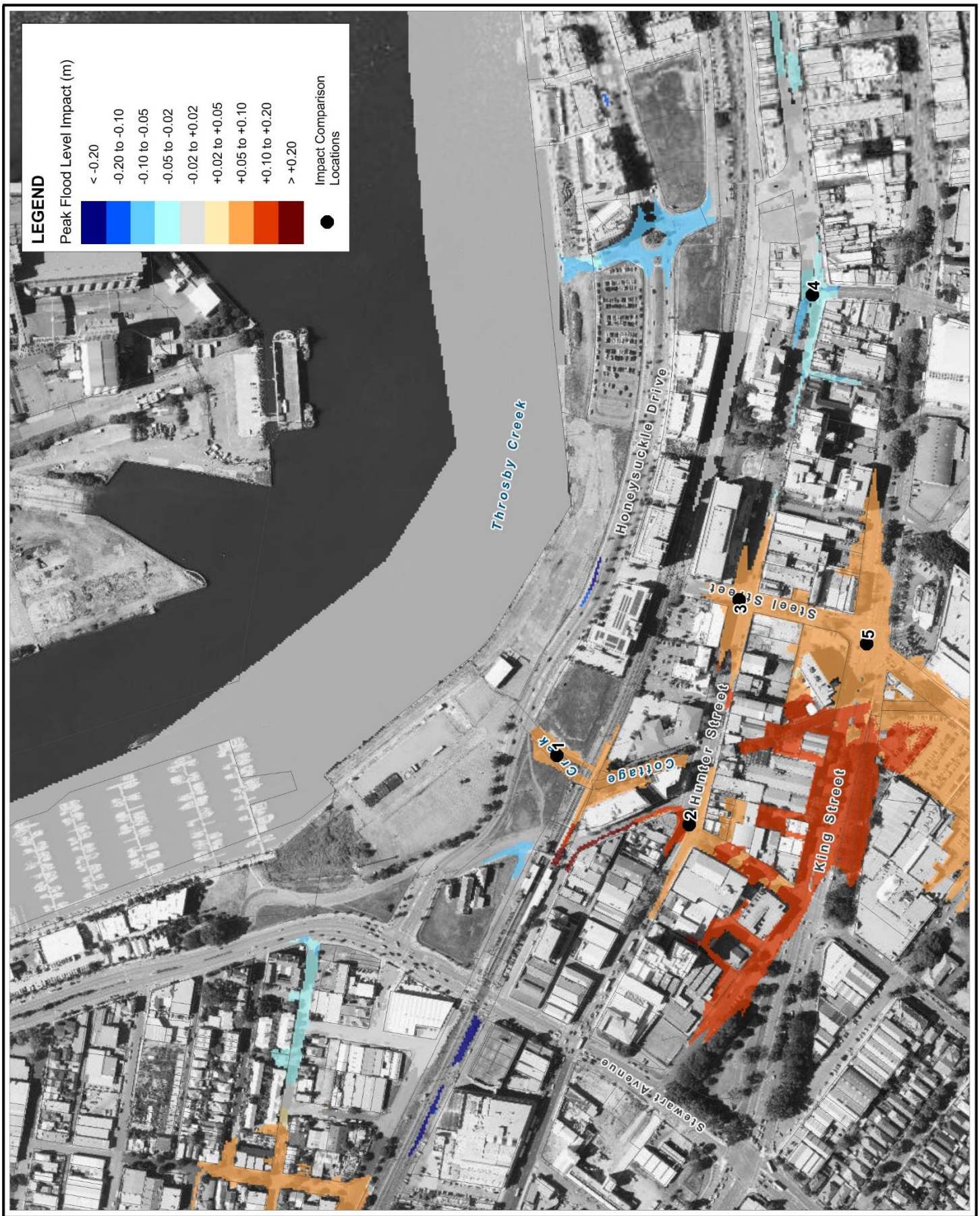


Figure 2-3 Interpolation of 0.2% and 0.5% AEP events

Following the event, significant data was collected including peak flood levels across the Newcastle region, rainfall data, photographs of blocked structures and interviews with residents. Based on the available distribution of the flood level points and rainfall data, the June 2007 and event has been selected as the calibration event. The calibration of the model is presented in Section 3.

[1] http://www.bom.gov.au/nsw/sevwx/facts/events/june-07-ecl/e1-8-9jun.shtml



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Peak Flood Level Impacts
AR&R 2016 1% AEP Design Event

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3 Model Calibration – June 2017 Event

3.1 Calibration Data

3.1.1 Rainfall Data

The June 2007 flood event resulted from widespread rainfall across the Newcastle and wider Hunter region over a period of three days, from 7 June to 9 June 2007. The event peaked in the early afternoon and evening of Friday 8 June. Daily rainfall was collected from Hunter Water Corporation (HWC) telemetric rainfall gauges located across the Newcastle and Lake Macquarie region. The recorded hourly hyetographs for the gauges closest to the study site are presented in Figure 3-1.

As shown in Table 3-1 and in Figure 3-2 and Figure 3-4, there was significant spatial variability in terms of the relative daily rainfall depths across the Newcastle area during the June 2007 event. Of note is the variability in the recorded daily rainfalls to 9am on 9 June, with suburbs receiving anywhere from 61 mm (Wallsend) to 328 mm (Croudace Bay). Areas that received the highest rainfall were in the southern Newcastle to northern Lake Macquarie area (Merewether to Belmont) with most areas recording more than 300 mm rainfall across the event. Due to the proximity of the study area to the coast the rainfall depth and temporal pattern from the Merewether gauge has principally been used for the model calibration. Rainfall across the upper catchment area was further increased to achieve calibration and is consistent with higher rainfall recorded in Merewether Heights that was provided to Council by a local resident.

Table 3-1 Daily Rainfall Depths (mm) – June 2007 Event at HWC gauges

Station Name	To 9am 8 June	To 9am 9 June	To 9am 10 June
Nobbys	78	210	1
Eleebana	74	296	17
Croudace Bay	73	328	19
Belmont	53	209	16
Jewells	61	210	27
Windale	71	284	30
Teralba	19	176	0
Merewether	69	278	0
Adamstown Heights	61	252	18
Broadmeadow	43	153	23
Stockton	28	101	0
Mayfield	38	177	10
Waratah	40	197	0
Wallsend	37	61	6
Shortland	28	73	1
Gateshead	89	309	34

To gain an appreciation of the relative intensity of the June 2007 event, the recorded rainfall depths were compared with the design IFD data (IFD 2016) for the Newcastle area (see Figure 3-2). The following comparisons to design rainfall depths can be made for the June 2007 event:

- there was spatial variability in rainfall depths and intensities across several Newcastle suburbs
- 9-hour rainfall at Merewether was between a 0.5% and 0.2% AEP event
- 6-hour rainfall at Merewether was close to a 0.1% AEP event
- 6-hour and 9-hour rainfall at Nobbys Head was close to a 2% AEP event
- 9-hour rainfall at Broadmeadow was between a 5% and 10% AEP event, and
- 6-hour rainfall at Broadmeadow was up to a 5% AEP event.

During the June 2007 event, a number of critical stormwater structures became blocked by debris such as cars, bins, rubbish and general vegetation debris. In the lower reaches of Cottage Creek at Newcastle West two shipping containers became lodged in two separate culverts along the main drainage channel (under the railway embankment and under the Hunter Street culvert) causing elevated flood levels on the upstream side and prolonged inundation (BMT WBM, 2008a). Photographs collected after the June 2007 event have been used to estimate blockage factors for key structures along Cottage Creek (see Figure 3-3).

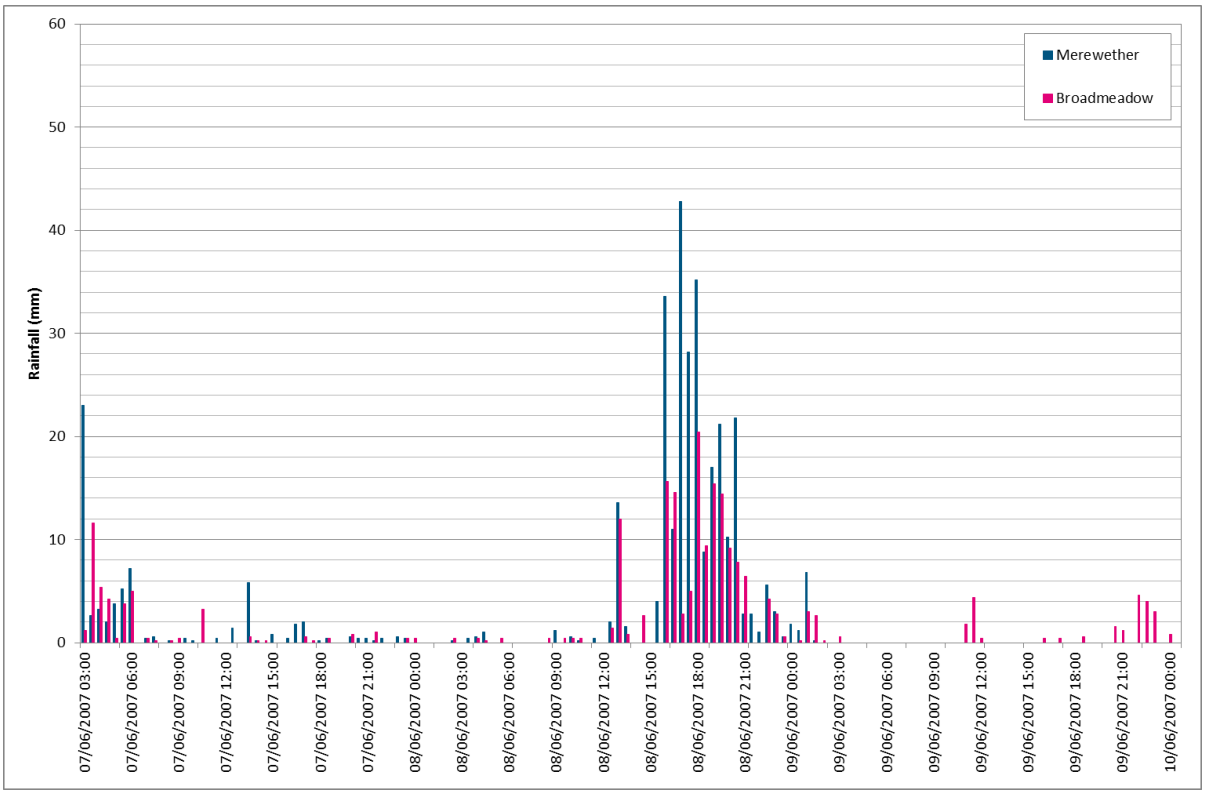


Figure 3-1 Rainfall Depths at Merewether & Broadmeadow (Cottage Creek catchment)

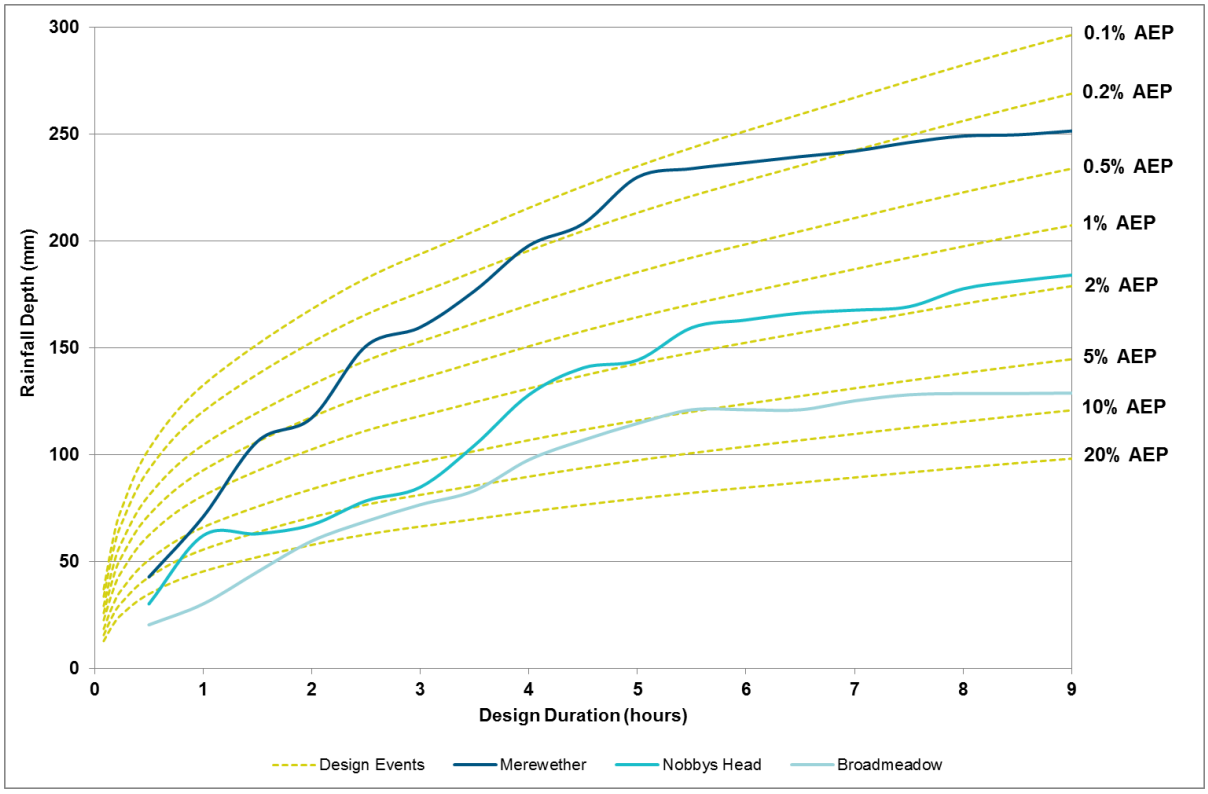
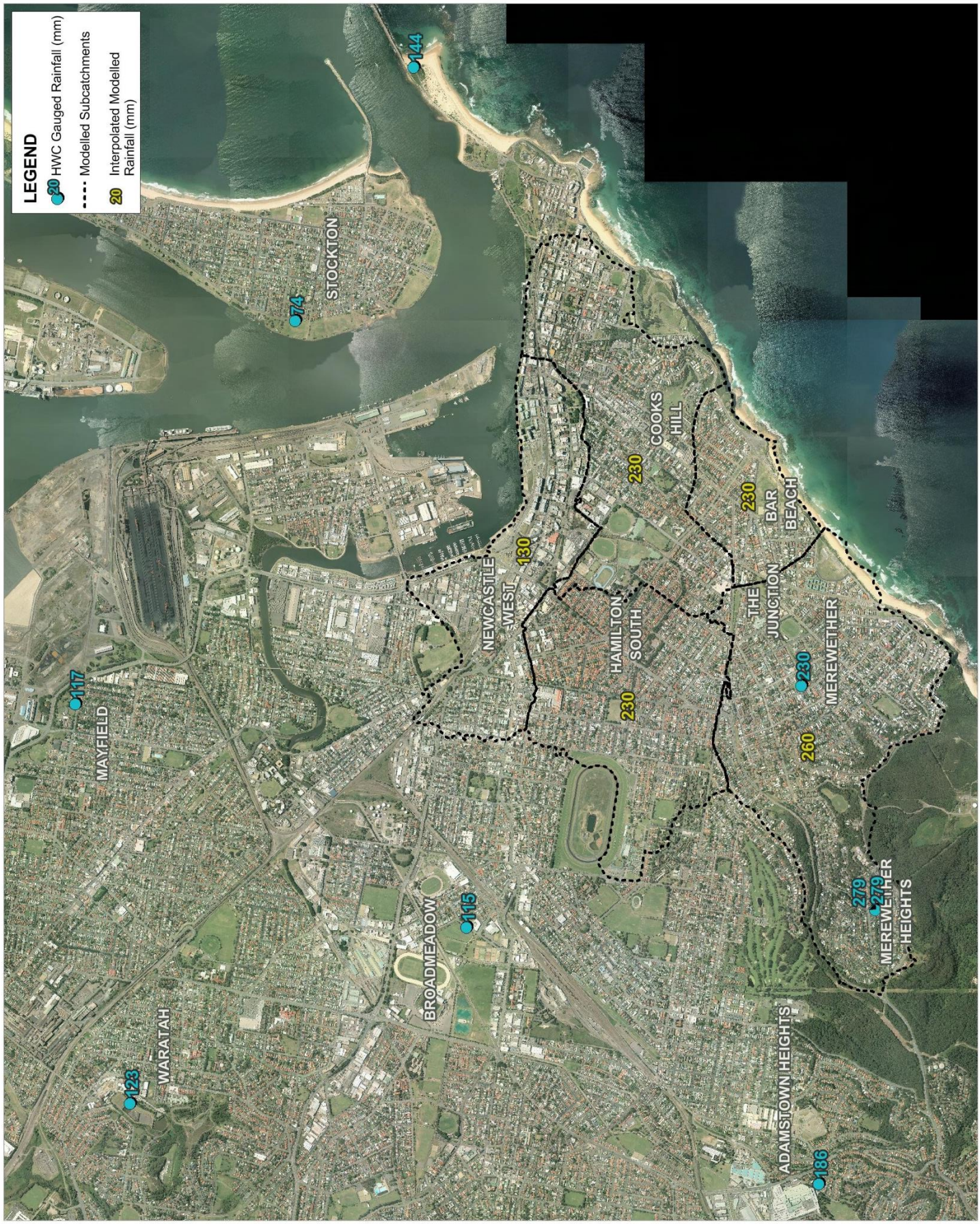


Figure 3-2 IFD (2016) Analysis of June 2017 Rainfall

Figure 3-3 Cottage Creek at Railway Embankment Blockage



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June 2007 Calibration Event Rainfall

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3.1.2 Flood Level Data

Within hours of the June 2007 event, BMT staff recorded peak flood heights at a number of locations across the Newcastle area. Subsequently, Newcastle City Council engaged BMT to undertake a formal city-wide program of flood data collection. As such, a collection of flood marks from the June 2007 event were collected in the study area and have been used for calibration of the flood model.

The levels and locations of the surveyed historical flood marks are presented in Figure 3-5.

The surveyed flood levels provide the basis for the water level calibration of the hydraulic model. A comparison of the observed and simulated water level profiles along Cottage Creek for the June 2007 event is presented in Figure 3-6.

3.1.3 Streamflow Data

Due to the urban nature of the Cottage Creek catchment and the drainage purposes of the channels along Cottage Creek, there is no available streamflow data to enable a flow hydrograph calibration to be undertaken. The available calibration data for the June 2007 event is limited to historical peak water levels and photography.

3.2 Observed & Simulated Flood Behaviour

The simulated TUFLOW flood profile for the June 2007 event is shown in Figure 3-6. During the event floodwaters from the steep upper catchment move quickly to the lower catchment, filling the local drainage network to capacity causing overland flow to occur. Floodwater drains to the Cottage Creek drainage channel from the urbanised upper catchment areas. The channel traverses National Park, King Street and Hunter Street before reaching Honeysuckle and discharging to the ocean in Newcastle Harbour. The capacity of the Cottage Creek channel was insufficient to convey the peak flood flow to the ocean outfall. As a result, low-lying areas with topographic depressions fill with water, such as along King Street. This was exacerbated by the blockage of hydraulic structures within the channel.

The simulated peak flood levels generally matched the gradient of the recorded flood level along Cottage Creek. However, flood levels were consistently low across the catchment. The available rainfall records are from the low-lying areas of the catchment. It is likely that more intense rainfall occurred across the elevated upper catchment areas to the south. This is supported by the relative rainfall intensities captured by the rainfall radar data.

To increase the modelled flood levels within National Park the upper catchment rainfall intensity was increased accordingly. Also, a blockage factor of 50% was applied to main structures along Cottage Creek to represent the actual blockages that occurred during the June 2007 event. This was consistent with data collected following the event wherein shipping containers were found to be blocking culverts along the channel. With these modifications in place, modelled flood levels across the catchment increased by approximately 0.5 m when compared to the initial simulation.

The simulated peak flood levels at key locations in the Cottage Creek catchment are presented in Table 3-2.

Title:

June 2007 Calibration Event Flood Marks

Figure: 3-5

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Table 3-2 June 2007 Surveyed Flood Levels

Location	Estimated / Surveyed Peak Flood Level (m AHD)	Simulated Flood Level (m AHD)
Cottage Creek at Parry Street	3.5	3.4
Cottage Creek at King Street	3.1	3.2
National Park (No. 2 Sportsground)	3.4	3.4
Steel Street Floodway at Honeysuckle Drive	2.5	2.4
Bellevue Street	2.8	2.8

Note – Bracketed values represent difference between estimated and simulated peak flood levels in m AHD

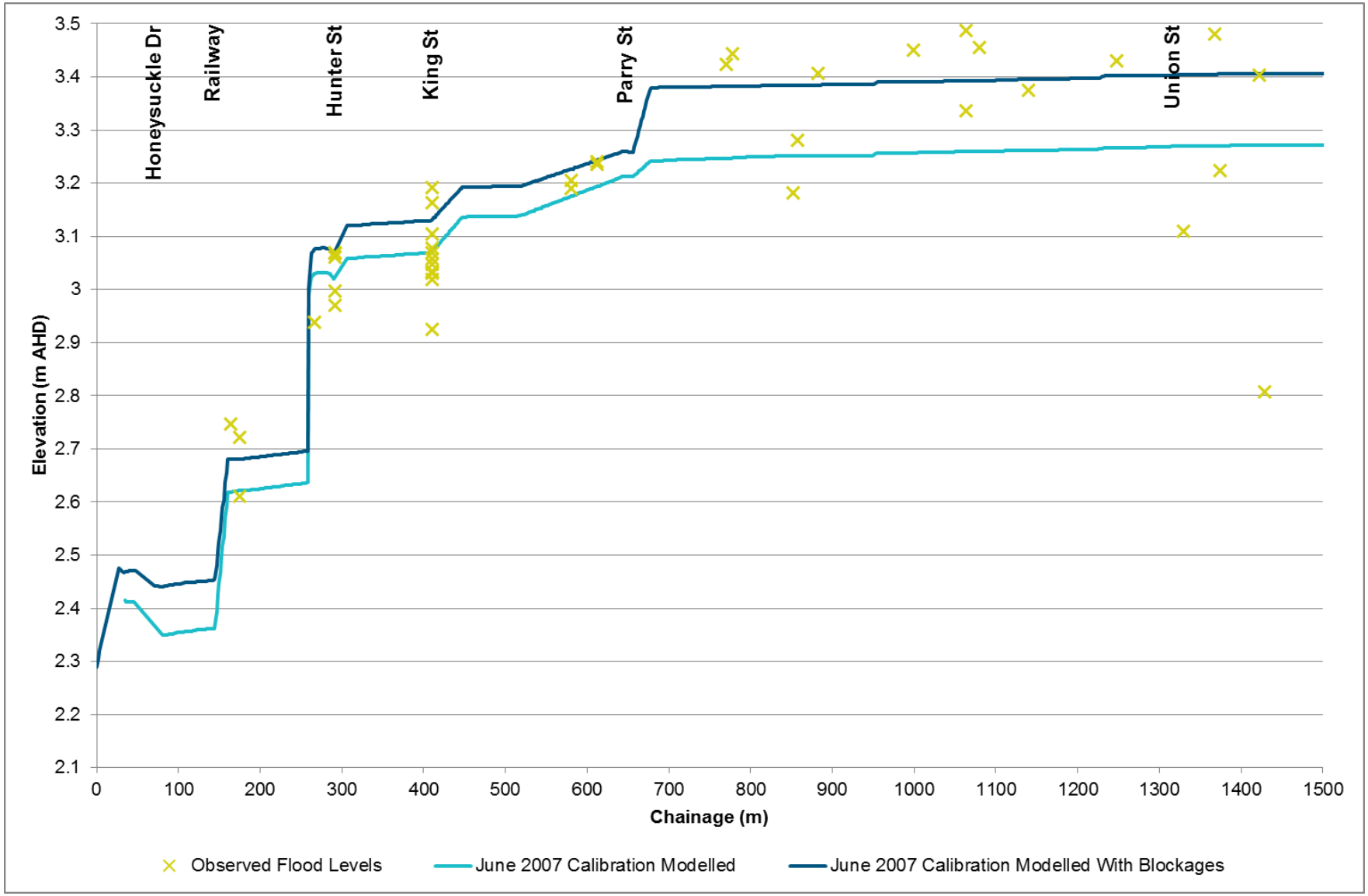


Figure 3-6 June 2007 Simulated Flood Profile

4 Design Flood Conditions

4.1 Existing Conditions

Design flood modelling was undertaken for the 10%, 5%, 2%, 1%, 0.5%, 0.2% AEP events and the Probable Maximum Flood (PMF), following the procedures outline in ARR 2016 (as discussed in Section 2.3). The modelled peak flood levels along the Honeysuckle precinct (see locations in Figure 4-1) are summarised in Table 4-1. Design flood mapping is provided in Appendix A.

Table 4-1 Modelled Existing Peak Flood Levels (m AHD)

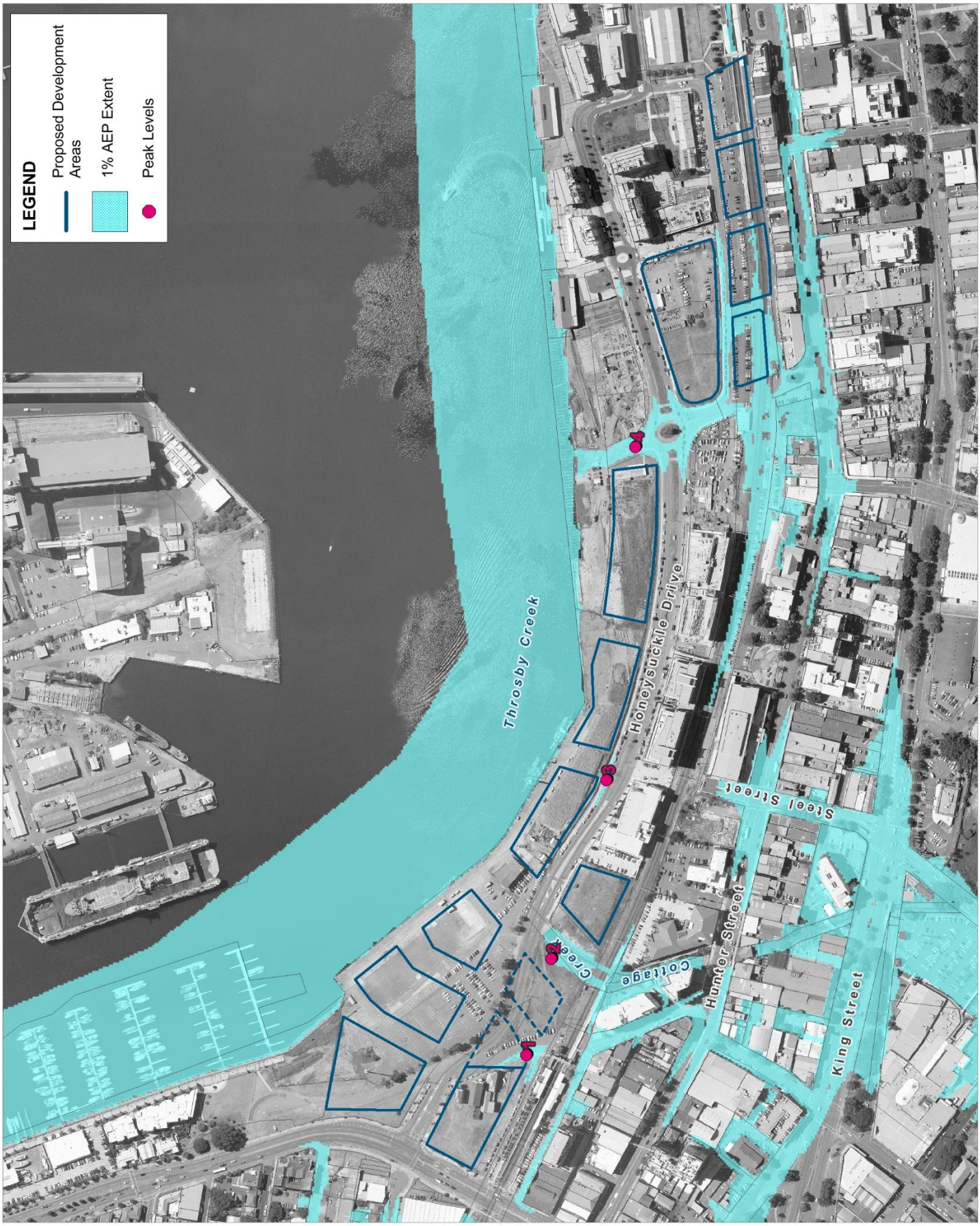
Flood Event	Peak Level (m AHD)			
	Location 1 – western end of Honeysuckle Drive	Location 2 – overland flow path west of Cottage Creek	Location 3- midway along Honeysuckle Drive	Location 4 – eastern end of Honeysuckle Drive
10% AEP	-	-	-	1.60
5% AEP	-	-	-	1.68
2% AEP	-	1.68	-	1.73
1% AEP	2.34	1.81	1.89	1.76
0.5% AEP	2.47	2.31	2.43	1.86
0.2% AEP	2.69	2.69	2.54	2.08
PMF	3.21	3.13	2.82	2.57

The site is not inundated during events up to the 0.5% AEP. During the 0.2% AEP event, minor inundation of the site occurs between Steel Street and Cottage Creek. During the PMF event inundation occurs across the entire site, as the peak flood flows are far in excess of the available drainage capacity of Cottage Creek, flowing overland through the development site and into Throsby Basin.

In addition to local catchment flooding, the study area is also potentially subject to ocean derived flooding resulting from elevated water levels within Newcastle Harbour driven by elevated ocean water levels. The adopted ocean flood levels for Newcastle Harbour, as presented in the Newcastle City-wide Floodplain Risk Management Study and Plan (BMT WBM, 2012), are shown in Table 4-2.

Table 4-2 Adopted Ocean Event Peak Flood Levels (m AHD) (BMT WBM, 2012)

Flood Event	Newcastle Harbour
10% AEP	1.35
1% AEP	2.30
PMF	3.40



Title:

Peak Level Locations

Figure: **4-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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0 50 100m
Approx. Scale

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As ocean derived flooding is effectively backwater flooding controlled by the ocean water level, the potential change in floodplain storage afforded by the proposed development would have no impact on the peak ocean event water levels in the study area. Therefore, the critical flood condition in terms of assessing the impact of the proposed development is the local catchment flooding.

4.2 Structure Blockage

The ARR national guideline document titled 'A Guide to Flood Estimation' (Ball et al, 2016) includes guidance around the assessment procedure to estimate blockage levels of structure inlet blockages to be used for design flood event modelling (refer Book 6: Flood Hydraulics – Chapter 6. Blockage of Hydraulic Structures). The ARR assessment procedure includes consideration of the following parameters/mechanisms:

- debris type and dimensions (including identification of the average length of the longest 10% of the debris that could arrive at the site (termed as L10)
- debris availability in the study area
- debris mobility
- debris transportability.

A classification is applied to each of the above components and the combination of these classifications provides a debris potential classification as presented in Table 4-3.

Table 4-3 Blockage Classification

Component	Value / Classification
L_{10}	4.5 m
Debris Availability	High
Debris Mobility	Medium
Debris Transportability	Medium
Debris Potential	Medium (HMM Combination)

Based on the debris potential classification the guideline provides an estimate of the 'most likely' inlet blockage level for a given structure inlet size as presented in Table 4-4. These estimated blockage factors were applied to culvert and bridge structures within the hydraulic model.

Table 4-4 ARR Most Likely Blockage Levels – Medium Debris Potential

Control Dimension Inlet Clear Width (W) (m)	1% AEP Medium Debris Potential at Structure	PMF High Debris Potential at Structure
$W < L_{10}$	50%	100%
$L_{10} \leq W \leq 3 \times L_{10}$	10%	20%
$W > 3 \times L_{10}$	0%	10%

The change in peak water levels with the assumed blockage conditions is summarised at key locations in Table 4-5. It is evident that the ARR Blockage scenario at the 1% AEP event provides for a similar flood condition to that of the 0.5% AEP event without consideration of structure

blockages. Increases in peak flood levels were mostly isolated to the areas immediately adjacent to the Cottage Creek channel, floodways and the roadways upstream of major blocked structures. Downstream of the rail corridor, peak flood levels in Cottage Creek were increased by a smaller magnitude due to the impediment of floodwater through the upstream culverts afforded by the blockages. As such, the control of the Cottage Creek culverts under the railway cause backwater flooding when blocked. There was a significant change in flood extent compared to the 1% AEP design event with increased inundation extents modelled along Honeysuckle Drive, the Steel Street floodway and along the rail corridor/light rail. Despite these increases in peak flood levels, the study area remains relatively free of floodwater during the 1% AEP event with blockages.

Maps showing the modelled design flood conditions under the adopted blockage scenario are provided in Appendix B.

Table 4-5 Modelled Peak Flood Levels (m AHD) for Blockage Scenario

Flood Event	Peak Level (m AHD)			
	Location 1 – western end of Honeysuckle Drive	Location 2 – overland flow path west of Cottage Creek	Location 3- midway along Honeysuckle Drive	Location 4 – eastern end of Honeysuckle Drive
1% AEP	2.34	1.81	1.89	1.76
0.5% AEP	2.47	2.31	2.43	1.86
0.2% AEP	2.69	2.69	2.54	2.08
1% AEP Blockages	2.47	1.67	2.41	1.76
PMF	3.21	3.13	2.82	2.57

4.3 Climate Change

The potential for climate change impacts is now a key consideration for floodplain management. The NSW Floodplain Development Manual (DIPNR, 2005) requires consideration of climate change in the preparation of Floodplain Risk Management Studies and Plans, with further guidance provided in:

- Floodplain Risk Management Guideline – Practical Consideration of Climate Change (DECC, 2007)
- Flood Risk Management Guide – Incorporating Sea Level Rise Benchmarks in Flood Risk Assessments (DECCW, 2010)

Key elements of future climate change (e.g. sea level rise, rainfall intensity) are therefore important considerations in the ongoing floodplain risk management.

4.3.1 Potential Future Sea Level Rise

In 2009, the NSW Government incorporated consideration of potential climate change impacts into relevant planning instruments. The NSW Sea Level Rise Policy Statement (DECCW, 2009) was

prepared to support consistent adaptation to projected sea level rise impacts. The policy statement incorporated sea level rise planning benchmarks for use in assessing potential impacts of sea level rise in coastal areas, as well as in flood risk and coastal hazard assessments. The benchmarks were a projected rise in sea level, relative to the 1990 mean sea level, of 0.4 metres by 2050 and 0.9 metres by 2100.

Subsequently, the NSW Government announced its Stage One Coastal Management Reforms (September 2012). As part of these reforms, the NSW Government no longer recommends state-wide sea level rise benchmarks for use by local councils, but instead provides councils with the flexibility to consider local conditions when determining future hazards within their LGA.

For the majority of climate change analysis undertaken in flood risk assessments within the Newcastle LGA to date, the potential impacts of sea level rise have been based on sea level rise projections from the 2009 NSW Sea Level Rise Policy Statement. It is anticipated that these sea level rise projections will remain appropriate for the purpose of this assessment.

The impact of potential future sea level rise has direct implications for the ocean event derived flood levels. However, it has minimal impact on the assessment of the Cottage Creek catchment flooding. The adoption of harbour tailwater levels in the model of between 0 m AHD and 1.1 m AHD has a negligible impact on Cottage Creek flood levels. The adoption of higher tailwater levels can begin to impact upstream flood levels, but the most appropriate coincident design condition is that of a mean sea level, as there is no direct relationship between the catchment and ocean flooding.

4.3.2 Potential Future Increase in Rainfall Intensity

Regional climate change studies (e.g. CSIRO, 2004) indicate that aside from sea level rise, there may also be an increase in the maximum intensity of extreme rainfall events. The predicted impact of climate change on rainfall conditions includes:

- increase in average annual rainfall – changes in annual rainfall conditions is unlikely to have a significant on impact on flooding regimes. However, wetter than average conditions may increase the opportunity for wet antecedent conditions at the onset of a rainfall event
- increases in rainfall intensity – climate change impacts on flood producing rainfall events are expected to show a trend for more frequent, higher intensity storms. This increase in design rainfall intensity will translate into higher peak flows and runoff volumes providing for increased flood inundation.

In 2007 the NSW Government released a guideline for practical consideration of climate change in the floodplain management process that advocates consideration of increased design rainfall intensities of up to 30%.

The Intergovernmental Panel on Climate Change (IPCC) is the leading body for the assessment of climate change globally. Since its establishment in 1988, the IPCC have released five climate change reports, the most recent of which is known as the 'Fifth Assessment Report' known as AR5 which was realised in four parts between September 2013 and November 2014. This report supersedes the four previous IPCC reports. The AR5 provides a thorough discussion about climate change science, with the outcome of the study focused strongly on the documentation of the likely impacts of climate change in the global context.

The documented impacts were representative of broad geographical regions (i.e. polar and equatorial regions) and were based on a range of future greenhouse gas emissions and concentration scenarios (IPCC, 2013). These future scenarios are referred to as known as Representative Concentration Pathways (RCPs). They focus on the 'concentrations' of greenhouse gases that lead directly to a changed climate and include a 'pathway' – the trajectory of greenhouse gas concentrations over time to reach a particular radiative forcing at 2100. The four RCPs cover a range of emission scenarios with and without climate mitigation policies. For example, RCP8.5 is based on minimal effort to reduce emissions. Particular focus is given to RCP4.5 (low emissions pathway) and RCP8.5 (high emissions pathway).

Utilising the outcomes of IPCC AR5, CSIRO and the Australian Bureau of Meteorology have prepared tailored climate change projection reports for Australian regions (known as clusters) including the East Coast region. The *East Coast Cluster Report – Climate Change Projections for Australia's Natural Resource Management Regions* (Dowdy et al, 2015). Dowdy et al. (2015) includes projected changes in heavy rainfall events including the potential increase in 20-year return period maximum 1-day rainfall as shown in Figure 4-2. The blue and purple columns in Figure 4-2 represent the RCP4.5 and RCP8.5 scenarios respectively. The relative change in the 20-year return level of maximum 1-day rainfall is approximately 18% for the low-emissions pathway (RCP4.5) and 25% for the high-emissions pathway (RCP8.5).

Consistent with these guidelines, the current recommendations for assessing the potential future climate change impacts on rainfall intensities were released as part of the Australian Rainfall and Runoff (ARR) 2016 Update. This would see around a 13% increase in design rainfall intensities for a 2100 planning horizon.

The 0.5% AEP flood condition can be compared to the 1% AEP in lieu of simulating the design flood events with an increased rainfall intensity to assess the potential impacts of future climate change. In the case of Cottage Creek, the 0.5% AEP flows are around 40% higher than those of the 1% AEP and as such provide a conservative estimate as to the potential impacts of climate change on increased rainfall intensity on the 1% AEP design flood condition.

4.4 Comparison with Lawson & Treloar (1999)

In 1999 Lawson & Treloar, in conjunction with the Department Public Works and Services and the Honeysuckle Development Corporation, completed the *Waterfront and Cottage Creek Flood Management Plan* for Newcastle City Council. Several flood levels across the site were compared to flood levels reported by Lawson & Treloar (1999) for the baseline (pre-development) and post-development conditions. Shown in Figure 4-3 is the Lawson and Treloar development layout with the corresponding lot numbers derived from the study.

As presented in Table 4-6, it is evident that there are significant differences between the Lawson & Treloar baseline flood levels and those derived in this study. The principal reason for this difference is likely to be the representation of flood storage attenuation within National Park upstream of Honeysuckle. The model representation in this study accounts for this attenuation through input of the major hydrological sub-catchments upstream of National Park. Hydrological inputs to the Lawson & Treloar model appear to be at the upstream end of the identified floodway alignments, downstream

of National Park. This provides the potential for overland flood flows through the Honeysuckle Redevelopment Area to be significantly overestimated.

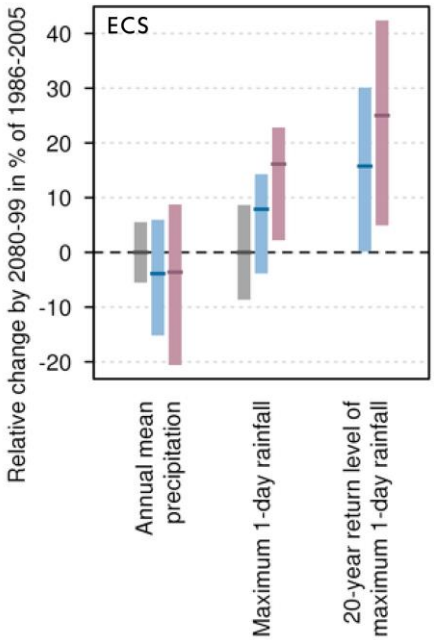


Figure 4-2 Projected Changes in Rainfall (Dowdy et al, 2015)

The modelled peak flood levels within the Lawson & Treloar study more closely correspond to those of the current study when considering the application of hydraulic structure blockages, being typically within ±0.2 m of these. Despite most locations demonstrating agreeance in the pre-development 1% AEP design flood levels with blockages, some areas still demonstrate significant differences, such as the Streel Street floodway.

Table 4-6 Comparison of Design Flood Levels (m AHD)

Location	Baseline Flood Levels (Lawson & Treloar, 1999) 1% AEP	Baseline Flood Levels (BMT, 2018) 1% AEP	Baseline Flood Levels (BMT, 2018) 1% AEP with Blockages
Cottage Creek Floodway	2.52	1.81	2.40
Steel Street Floodway	2.94	-	2.42
HWC Floodway	2.62	-	2.41
Lot C5/C6	2.45	-	2.44
Lot C7	2.45	-	-
Lot C2	2.40	1.76	2.41
Lot C3	2.18	1.87	2.24
Lot C4	2.52	1.87	2.40

Figure 4-3 Lawson & Treloar Development Layout

4.5 Comparison with Newcastle West Drainage Study

The Newcastle West Drainage provides a 1% AEP design peak flood level profile along Cottage Creek. This has been compared to the levels derived by this current study, as presented in Figure 4-4. The studies provide relatively consistent results between Hunter Street and Union Street, being within 0.1 m of agreement. However, the Newcastle West Drainage Study provides higher peak flood levels between Honeysuckle Drive and Hunter Street. This could potentially be to an assumed blockage condition within the adopted design scenario of the Newcastle West Drainage Study.

The Newcastle West Drainage Study states that for the baseline design flood simulations a blockage factor was applied to all structures, albeit typically 10% or less. This study did not apply any blockage to the structures in the baseline flood conditions (which is acknowledged as a likely scenario within the ARR 2016 guidelines) and undertook a sensitivity analysis with assumed structure blockages in accordance with ARR 2016, as discussed in Section 4.2. Due to the size of the Honeysuckle Drive bridge structure and the potential for blockage at this structure, only a 10% blockage factor was applied within the 1% AEP blockages scenario. The adopted blockage factor at this structure would have a significant impact on the modelled water levels within Cottage Creek downstream of Hunter Street.

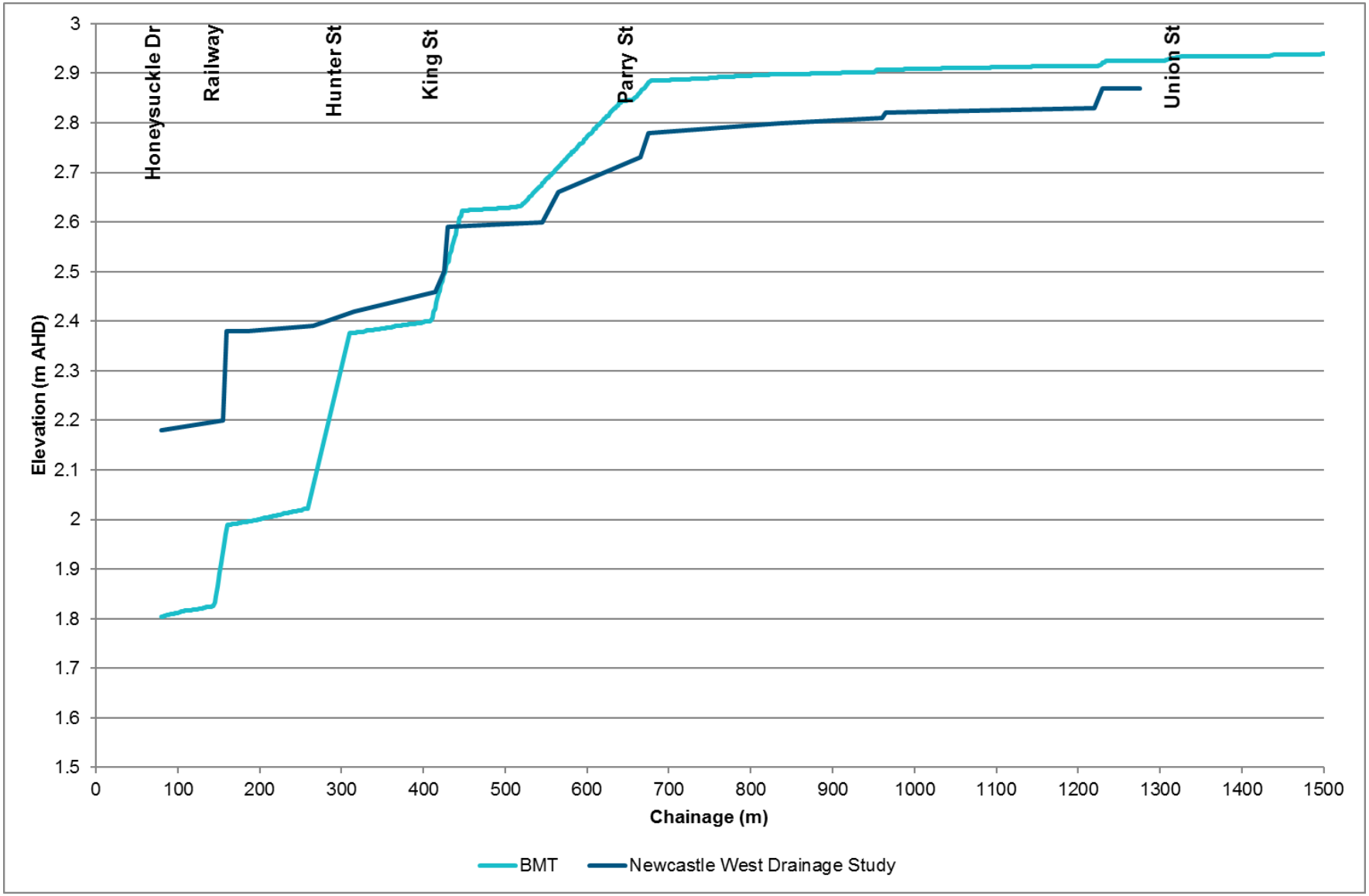


Figure 4-4 Modelled 1% AEP Flood Level Profile for Cottage Creek

5 Proposed Development Flood Impacts

The critical flood condition in terms of assessing the impact of the proposed future developments is the local catchment flooding. The proposed development would have little to no impact on the ocean design event flood levels due to the backwater nature of the ocean inundation.

The relative impact of the proposed development has been considered in terms of potential adverse impacts on the existing local catchment flood behaviour. The proposed development, consisting of commercial and mixed-use buildings interspersed with public recreation areas, involves significant alterations to the existing Cottage Creek precinct by several developments. The refined TUFLOW model was altered to represent the post-development site conditions including the proposed development areas. “Z-shapes” were incorporated into the model to better represent the hydraulic control of these proposed development areas.

As noted in Section 4.1, the study area is predominantly impacted during events greater than the 0.5% AEP event, with more frequent flood events being largely contained by Cottage Creek. The flood impact assessment has therefore focussed on the rare flood events as minor to no impacts are experienced during smaller events given that the flood extents do not significantly inundate the study area. Blockages of hydraulic structures have also been applied in order to increase the overland flows through the site and better identify any potential impacts associated with the proposed development.

5.1 Proposed Development (HDC Preliminary Layout)

The proposed development layout was modelled using a number of concept drawings provided by HDC. Mapping of the peak flood level impacts and flood hazards is presented in Appendix C.

Details modelled in the HDC Preliminary Layout scenario include:

- available design details for the Newcastle Light Rail
- ground elevations in the development area set to 2.3 m AHD, consistent with the proposed seawall level
- proposed development layout
- Steel Street floodway set to 2.3 m AHD
- removal of the HWC floodway

The HWC floodway, as identified by Lawson & Treloar, is only active for extreme flood events such as the PMF and flood impact assessments within previous versions of this document have demonstrated that the removal of the HWC floodway has a negligible impact on the overall modelled flood conditions.

Post-development flood modelling was undertaken for the 1%, 0.5%, 0.2% AEP events with structure blockages and the Probable Maximum Flood (PMF), following the procedures outline in ARR 2016 (as discussed in Section 2.3).

The modelled development scenario results in peak flood level impacts that are largely contained within the site. The impacts of the layout are up to +0.20 m along Honeysuckle Drive and the Steel

Street floodway. The floor levels of existing buildings within Honeysuckle have been set at or above 3.2 m AHD and as such are unaffected by any increased flood level.

At the 1% AEP event there is a minor increase in modelled flood levels along Cottage Creek downstream of Hunter Street. However, the flood levels for the existing adjacent buildings remain unchanged, as it is the overland flood waters that drive the peak levels at this location, rather than those in Cottage Creek, which are around 1 m lower.

The nature of modelled flood level impacts at the 0.5% AEP and 0.2% AEP events. However, at the 0.2% AEP event there is a broader impact to adjacent properties around the Honeysuckle Central area. Given the rarity of the flood event being considered (0.2% AEP with blockages) and the relatively minor scale of the impacts (~ 30 mm), the nature of this modelled impact is not considered to be significant.

There is also a modelled flood impact of around 70 mm within Wickham at the 0.2% AEP event with blockages. This impact is in a location where the peak level is driven by the volume of flood water, rather than from peak flows. This makes modelled flood levels at this location highly sensitive to small changes in flood behaviour. At the 0.5% AEP event the modelled flood levels in Wickham are similar in the existing and developed scenarios and at the 1% AEP event the developed scenario shows a small reduction in peak flood levels. This indicates an overall net balance of modelled flood risk within Wickham.

A summary of the modelled peak flood levels for the existing and developed scenarios with structure blockages is provided in Table 2-1, with reference locations being consistent with those in Figure 4-1.

5.2 Comparison with Lawson & Treloar

The main outcomes of the Lawson & Treloar 1999 study were that the Waterfront and Cottage Creek Precincts would not adversely impact adjacent lands when fully developed and upstream controls dominate flood behaviour, i.e. the steep upper catchments feeding into the Cottage Creek catchment. The modelling undertaken as part of this study confirms these findings. However, in its current layout (as per the Lawson and Treloar concept), development in the catchment will impact on adjacent areas to the north-west of the site (i.e. Wickham) if floodways and flow paths are not adequately maintained. It is understood that a future re-design of the public space is planned, which may seek to address these impacts.

As shown in Table 5-2 below, the post-development flood levels derived from the Lawson & Treloar 1999 study show significant inconsistencies with the flood levels modelled in this study. The modelled differences in peak flood level are again likely attributed to the model inflow boundary locations. The Lawson & Treloar model boundaries appear to be located downstream of National Park and therefore peak flood flows may be overestimated. The impact on modelled flood levels appear to be further exacerbated when constrained within the defined floodway extents by the proposed development.

Table 5-1 Change in Flood Levels (m) for the HDC Preliminary Layout (with Blockages)

Flood Event	Peak Level (m AHD)			
	Location 1 – western end of Honeysuckle Drive	Location 2 – overland flow path west of Cottage Creek	Location 3- midway along Honeysuckle Drive	Location 4 – eastern end of Honeysuckle Drive
1% AEP (pre-development)	2.47	1.67	2.41	1.76
1% AEP (post-development)	2.47	2.37 (+0.75)	2.50 (+0.09)	1.77 (+0.01)
0.5% AEP (pre-development)	2.53	2.16	2.48	1.98
0.5% AEP (post-development)	2.54 (+0.01)	2.41 (+0.25)	2.68 (+0.20)	2.00 (+0.02)
0.2% AEP (pre-development)	2.69	2.64	2.56	2.18
0.2% AEP (post-development)	2.76 (+0.07)	2.73 (+0.09)	2.84 (+0.28)	2.25 (+0.06)
PMF (pre-development)	3.21	3.13	2.82	2.57
PMF (post-development)	3.48 (+0.27)	3.41 (+0.28)	3.41 (+0.59)	2.82 (+0.25)

Note: Bracketed value is change in peak flood level from base design conditions

Table 5-2 Comparison to Lawson & Treloar Post-Development Flood Levels

Location	Post-Development Flood Levels (Lawson & Treloar, 1999) 1% AEP	Post-Development Flood Levels (Lawson & Treloar, 1999) PMF	Post-Development Flood Levels (BMT, 2018) 1% AEP	Post-Development Flood Levels (BMT, 2018) 1% AEP with Blockages	Post-Development Flood Levels (BMT, 2018) PMF
Cottage Creek Floodway	2.52	3.05	2.30	2.38	3.41
Steel Street Floodway	2.94	4.06	-	2.47	3.27
HWC Floodway	2.62	3.65	-	-	3.44
Lot C5/C6	2.45	2.77	-	2.40	3.49
Lot C7	2.45	2.77	-	-	3.46
Lot C2	2.40	3.55	1.77	2.50	3.43
Lot C3	2.18	3.45	1.73	2.50	3.45
Lot C4	2.52	3.05	1.91	2.50	3.38

6 Flood Planning Requirements

The key flood planning requirements for future development in the study area have been derived from the post-development design flood modelling that was undertaken for the 1%, 0.5%, 0.2% AEP events and the Probable Maximum Flood (PMF), following the procedures outline in ARR 2016 (as discussed in Section 2.3).

6.1 Flood Impact Categorisation

The Flood Impact Categorisation undertaken as part of the Newcastle City-Wide Floodplain Risk Management Study and Plan categorises areas of floodplain that act as floodways or areas of flood storage. Council's DCP (2012) effectively allows development in flood fringe areas, prohibits development within floodways and limits the filling of flood storage areas to 20%.

The Flood Impact categories as defined in the Floodplain Development Manual are:

- floodway - areas that convey a significant portion of the flow. These are areas that, even if partially blocked, would cause a significant increase in flood levels or a significant redistribution of flood flows, which may adversely affect other areas
- flood storage - areas that are important in the temporary storage of the floodwater during the passage of the flood. If the area is substantially removed by levees or fill it will result in elevated water levels and/or elevated discharges. Flood storage areas, if completely blocked would cause peak flood levels to increase by 0.1m and/or would cause the peak discharge to increase by more than 10%, and
- flood fringe - remaining area of flood prone land, after floodway and flood storage areas have been defined. Blockage or filling of this area will not have any significant effect on the flood pattern or flood levels.

The adopted flood impact categorisation using Council's thresholds is defined in Table 6-1.

Table 6-1 Flood Impact Categories

Category	1% AEP	PMF	Commentary
Floodway	velocity * depth > 0.3	velocity * depth > 1.0	Areas and flow paths where a significant proportion of floodwaters are conveyed (including all bank-to-bank creek sections).
Flood Storage	velocity * depth < 0.3 & depth > 0.5 m	velocity * depth < 1.0 & depth > 1.0 m	Areas where floodwaters accumulate before being conveyed downstream. These areas are important for detention and attenuation of flood peaks.
Flood Fringe	velocity * depth < 0.3 & depth < 0.5 m	velocity * depth < 1.0 & depth < 1.0 m	Areas that are low-velocity backwaters within the floodplain. Filling of these areas generally has little consequence to overall flood behaviour.

Flood Impact Categorisation mapping is provided for the 1% AEP and PMF events in Figure D-8 and Figure D-9 respectively.

During the 1% AEP design event the study area remains free of inundation with areas of floodway mostly restricted to Cottage Creek. During the PMF event most of the study is categorised as flood fringe which has minor implications on flood behaviour when filled/developed. However, there are several additional overland floodways activated to convey water through to the harbour, including:

- in the vicinity of Cottage Creek
- along Steel Street
- along Worth Place

These are areas that convey the most flow through the catchment. There are some areas of flood storage driven by local topographic depressions located mostly within vacant lots and along the Honeysuckle Drive alignment. However, given that there is no existing development further downstream, the preservation of flood storage areas is not required to attenuate catchment runoff.

6.2 Flood Hazard

The Best Practice Flood Risk Management approach to flood hazard mapping (D. McLuckie et. al., 2014) classifies the floodplain into six distinct hazard zones (H1 to H6) based on thresholds of flood depth, velocity and depth-velocity product (see Figure 6-1). The adopted thresholds identify when modelled flood conditions would present a risk to people, vehicles and building construction types. A description of each hazard threshold is provided in Table 6-2.

The key factors influencing flood hazard or risk are:

- size of the flood
- flood depth and velocity
- flood Readiness
- rate of rise - effective warning time
- duration of inundation
- obstructions to flow, and
- access and evacuation.

6.2.1 Adopted Flood Hazard Categories

The flood hazard categories adopted for the Cottage Creek catchment are presented in Figure C-5 for the 1% AEP event. The high flood hazard areas are mostly localised to the channels of Cottage Creek which are classified as H6 and H5 hazard areas. Isolated areas of H4 hazards are located in flood storage areas. However, as the site is not inundated during the 1% AEP event, there are no modelled flood hazard impacts onsite.

Table 6-2 Flood Hazard Classification Thresholds

Hazard Classification	Description
H1	Relatively benign flow conditions. No vulnerability constraints.
H2	Unsafe for small vehicles.
H3	Unsafe for all vehicles, children and the elderly.
H4	Unsafe for all people and vehicles.
H5	Unsafe for all people and vehicles. Buildings require engineering design and construction.
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure.

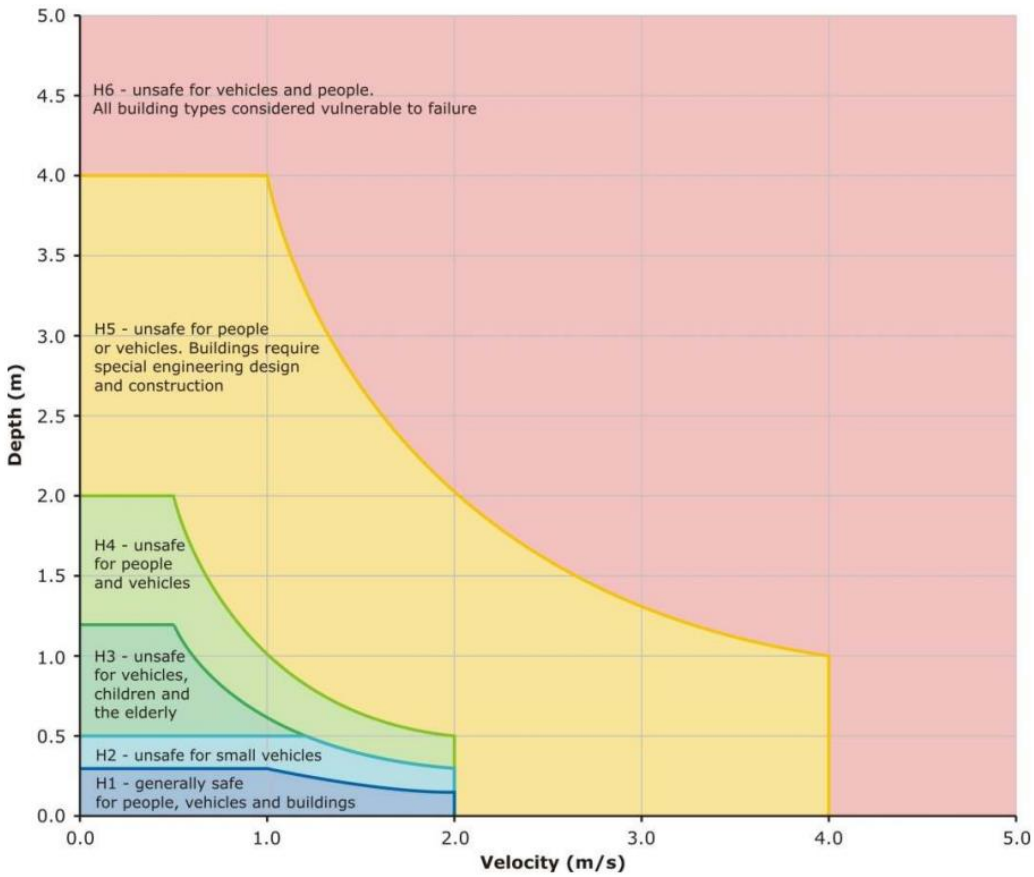


Figure 6-1 Hydraulic Hazard as a Function of Depth and Velocity

Similarly, during the PMF (presented in Figure C-8) high flood hazard areas (H5 and H6) are mostly confined to the main floodways along Steel Street, Cottage Creek and Worth Place, and along the roadways. Flood storage areas within the western portion of the development area are classed as H4. However as identified, changes to these storage areas is unlikely to impact on the surrounding areas due to the lack of development downstream.

6.3 Risk to Property Hazard

The combination of flood depths and flood velocities can be used to assess the risk to property and life based on the hydraulic behaviour of the flood event. Situations where flood depths are shallow, but velocities are high can be just as critical as situations where flood depths are large, but velocities are low.

The risk to property is principally addressed through the application of an appropriate FPL. However, the development must also be compatible with the risk to property hazard to minimise structural damage during the event of a flood. Section 4.01.03 of Council's DCP specifies a list of criteria that must be met to manage the risk to property.

Table 6-3 outlines the risk to property categories adopted by Council's DCP.

The risk to property is principally addressed through the application of an appropriate FPL. However, the development must also be compatible with the risk to property hazard to minimise structural damage during the event of a flood. Section 4.01.03 of Council's DCP specifies a list of criteria that must be met to manage the risk to property.

Table 6-3 Risk to Property Hazard Classification Thresholds

Hazard Classification	Description
P1	Parked or moving cars remain stable
P2	Parked or moving heavy vehicles remain stable
P3	Suitable for light construction (e.g. timber frame, masonry and brick veneer)
P4	Suitable for heavy construction (e.g. steel frame, reinforced concrete)
P5	Hydraulically unsuitable for normal building construction

Due to the low Risk to Property classification of the study area (most of which is flood-free at the 1% AEP event – see Figure D-6), many of the requirements will be readily satisfied. In relation to development of the Site, it is likely to be potential parking provision that may be more problematic, in terms of addressing the following requirements:

- Garage floor levels are no lower than the 1% Annual Exceedance Probability Event. However, it is recognised that in some circumstances this may be impractical due to vehicular access constraints. In these cases, garage floor levels are as high as practicable.
- Basement garages may be acceptable where all potential water entry points are at or above the probable maximum flood (PMF), excepting that vehicular entry points can be at the FPL. In these cases, explicit points of refuge are accessible from the carpark in accordance with the provisions for risk to life set out below.
- Electrical fixtures such as power points, light fittings and switches are located above the FPL unless they are on a separate circuit (with earth leakage protection) to the rest of the building.

6.4 Risk to Life Hazard

In addition to hydraulic behaviour, risks to life are influenced by the flooding mechanism (i.e. flash, river or ocean), as well as the availability of an evacuation route. Generally, evacuation can be expected in areas impacted by riverine or ocean flooding. As such, the risks to life in these areas are low. Flash flooding, however, can represent a significant risk, as there is generally little time to respond or evacuate. If there is an evacuation route available consisting of a continuously rising route to flood free land (above the PMF level), then the risk during a flash flood situation is less than if no route was available.

Risks to life categorisation adopted by Newcastle City Council has been developed taking into account both the availability for evacuation and the hydraulic behaviour, as presented in Table 6-4.

The Risks to Life criteria are determined based on PMF conditions. These extreme flood conditions are adopted as the FDM (2005) is explicit in requiring risks to life to be considered and managed over the full range of flood events (i.e. up to the most extreme conditions, or PMF).

Table 6-4 Risk to Life Hazard Classification Thresholds

Hazard Classification	Description
L1	Sufficient time to evacuate using formal community evacuation plans. Not relevant to flash flooding scenarios.
L2	Short duration flash flooding circumstances where there is an obvious escape route to flood free land and where enclosing waters during the PMF are suitable for wading or heavy vehicles. On site flood refuge **not** necessary and normal light frame residential building are appropriate.
L3	Short duration flash flooding with no warning time and no obvious escape route to flood free land with enclosing waters during the PMF which are suitable for wading or heavy vehicles. On site flood refuge **not** necessary and normal light frame residential buildings and appropriate.
L4	Short duration flash flooding with no warning time and enclosing waters during the PMF **not** suitable for wading or heavy vehicles. On site refuge is necessary and heavy frame construction or suitable structural reinforcement may be required.
L5	Short duration flash flooding with no warning time and enclosing waters during the PMF unsuitable for normal heavy building construction. Therefore, not possible to construct flood-free refuge. The risk to life is considered extreme and the site is unsuitable for habitation.

The short response time afforded by flooding from local catchment runoff means that much of the Site has a relatively high risk to life, as presented in Figure D-7. The L4 classification requires the provision of on-site flood-free refuge. The refuge areas require the following:

- the minimum on-site refuge level is the level of the PMF. On-site refuges are designed to cater for the number of people reasonably expected on the development site and are provided with emergency lighting.

- on-site refuges are of a construction type able to withstand the effects of flooding. Design certification by a practising structural engineer that the building is able to withstand the hydraulic loading due to flooding (at the PMF).

Some areas of the L4 classification may be suitable for typical light constructions, but others may require a heavy construction type such as steel and reinforced concrete. The flood-free refuge areas are often provided on the first floor of flood-affected buildings. However, the requirements for flood emergency response planning are more straightforward if the ground floor level is situated above the PMF.

6.5 Flood Planning Levels

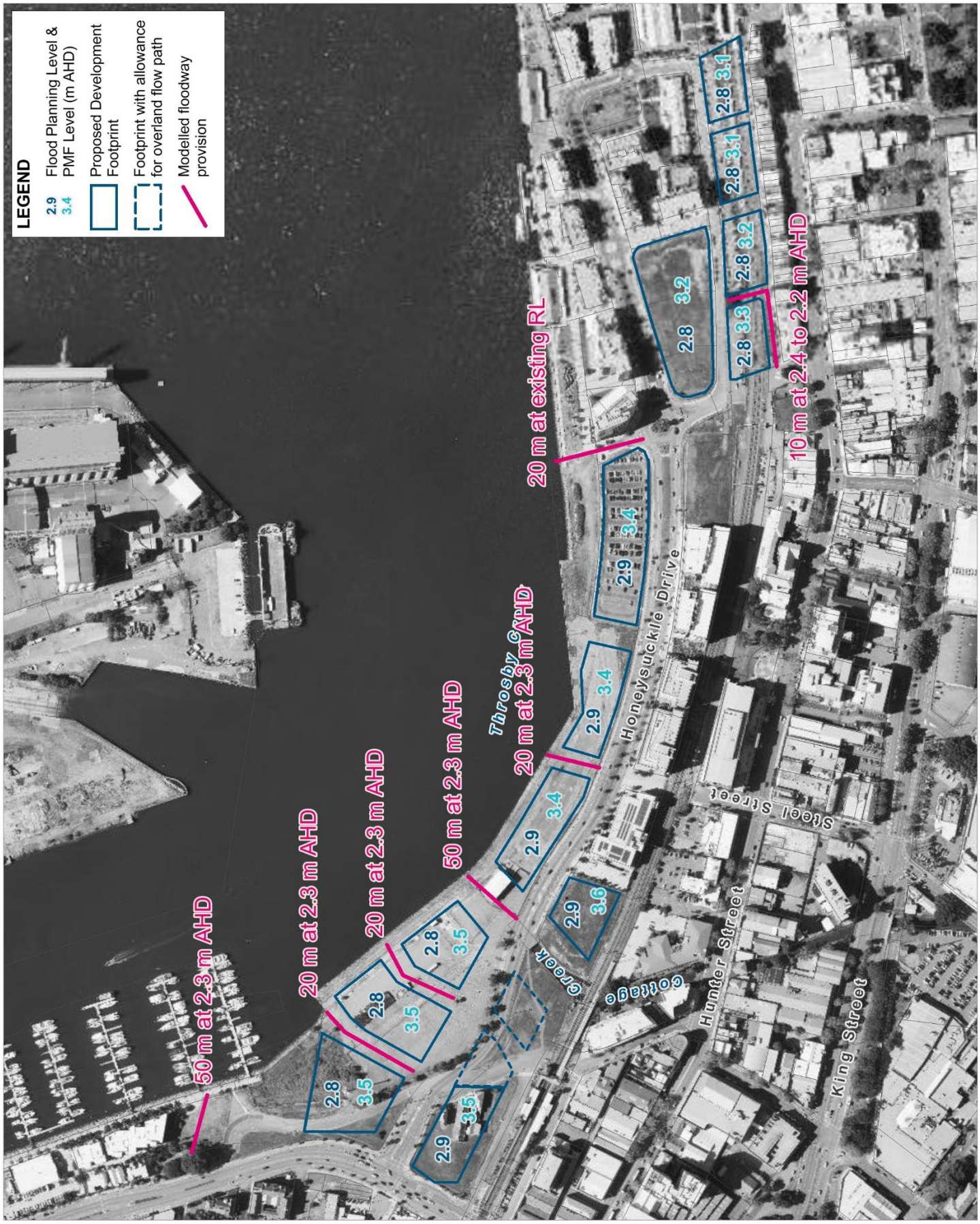
The Flood Planning Level (FPL) is used to manage the risk to property presented by the flood hazards. It is defined by the Newcastle Development Control Plan (DCP) 2012 as being the 1% AEP flood level plus a 0.5 m freeboard, for all occupiable rooms of all buildings.

Table 6-5 presents the range of modelled peak flood levels for the various post-development design events considered. Following discussions with Council it was agreed that due to the significant impact of potential structure blockage within some locations of the study area it was prudent to incorporate structure blockages into the process for defining appropriate FPLs. Therefore, the FPLs for the development sites across Honeysuckle have been defined using a freeboard of 0.4 m above the 1% AEP design event with structure blockages. However, where the FPL from local catchment flooding was found to be lower than 2.8 m AHD, the ocean flooding condition becomes critical, setting the required FPL at 2.8 m AHD. The FPL and PMF level for each development site is presented in Figure 6-2.

Table 6-5 Range of Modelled Design Post-Development Flood Levels

Scenarios (HDC preliminary layout)	Location 1 – western end of Honeysuckle Drive	Location 2 – overland flow path west of Cottage Creek	Location 3- midway along Honeysuckle Drive	Location 4 – eastern end of Honeysuckle Drive
1% AEP Design Event	2.31	2.30	1.89	1.77
1% AEP Design Event with Blockages	2.47	2.37	2.50	1.77
0.5% AEP Design Event	2.47	2.39	2.56	1.87
0.5% AEP Design Event with Blockages	2.54	2.41	2.68	2.00
0.2% AEP Design Event	2.76	2.74	2.78	2.12
0.2% AEP Design Event with Blockages	2.76	2.73	2.84	2.25
PMF Event	3.48	3.41	3.41	2.82

*See Figure 4-1 for reporting locations



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Flood Planning Levels

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When adopting this FPL condition, the freeboards presented in Table 6-6 are provided. The adopted FPLs provide for a relatively good standard of protection against even larger flood events such as the 0.5% and 0.2% AEP.

Table 6-6 Range of Post-Development FPL Freeboard

Scenarios (HDC preliminary layout)	Location 1 – western end of Honeysuckle Drive	Location 2 – overland flow path west of Cottage Creek	Location 3- midway along Honeysuckle Drive	Location 4 – eastern end of Honeysuckle Drive
1% AEP Design Event	0.56	0.47	1.01	0.40
1% AEP Design Event with Blockages	0.40	0.40	0.40	0.40
0.5% AEP Design Event	0.40	0.38	0.34	0.30
0.5% AEP Design Event with Blockages	0.33	0.36	0.22	0.17
0.2% AEP Design Event	0.11	0.03	0.12	0.05
0.2% AEP Design Event with Blockages	0.11	0.04	0.06	-0.08
PMF Event	-0.61	-0.64	-0.51	-0.65

6.6 Floodway Provisions

In defining the FPLs and limiting potential flood impacts of the Honeysuckle Development Area to the broader urban centre of Newcastle, several floodways have been provided within the TUFLOW model to maintain the free passage of overland flows from the upstream Cottage Creek catchment through to the Throsby Basin. The locations of these floodways are presented in Figure 6-2 and are summarised below:

- A 50 m wide corridor at the northern end of Fig Tree Park
- Two 20 m wide floodways in the Throsby Precinct between Honeysuckle Drive and Throsby Basin at a level of 2.3 m AHD
- An allowance for overland flood flows to be conveyed through the ground floor level of the indicated buildings within the Throsby Precinct
- A 50 m wide corridor between buildings along the alignment of Cottage Creek
- A 20 m wide floodway in the Cottage Creek Precinct between Honeysuckle Drive and Throsby Basin at a level of 2.3 m AHD (the Steel Street floodway)
- A 20 m wide corridor between buildings along the existing Worth Place floodway alignment
- A 10 m wide floodway in the Honeysuckle Central Precinct to allow an overland flow path to be maintained between Worth Place / Steel Street and Wright Lane.

The existing flood behaviour through the Honeysuckle Development Area is typically well defined by upstream hydraulic controls, with the conveyance of overland flows being restricted to roadways and

other open space between buildings. However, within the Throsby Precinct to the west of Cottage Creek there is a concentration of converging overland flow paths that require additional space to transition to their intended downstream floodway alignments through to the Throsby Basin. There are development footprints intended to be developed within this location (as per the dashed outlines in Figure 6-2) with the potential to impact (albeit to relatively minor degree) the design flood levels in Wickham.

The performance of the floodways requires that they provide sufficient conveyance of the expected overland flood flows. As such, they should be relatively clear of obstructions, as per the existing Steel Street floodway configuration on the southern side of Honeysuckle Drive. Street landscaping and furniture items such as trees, seating and minor encroachment of steps should be acceptable as they are not expected to significantly impact the floodway capacity. However, the floodways should be kept clear of major obstructions that might adversely impact the conveyance of overland flows. Specific design details of the floodway areas should be assessed within the flood impact assessment at the DA stage.

Even small increases in upstream flood levels result in additional runoff volumes being conveyed along the Light Rail corridor, across Hannell Street and into Wickham. The current solution adopted within the development concept is to retain ground levels within this area at the required 2.3 m AHD. This could comprise ground level car parking provision with first floor residential and/or commercial development being raised on piers. However, there are alternative mitigation solutions to accommodate flooding whilst addressing the broader needs of the development. This could include compensatory conveyance of overland flows through sub-surface drainage infrastructure and/or additional capacity through re-grading of the adjacent floodways.

The floodplain risk management options for this area will require further assessment when the nature of the proposed developments is more advanced, to ensure that any associated flood impacts do not exceed those determined within this conceptual configuration.

Most floodways have been modelled as a flat level of 2.3 m AHD, which is consistent with the intended seawall promenade. The promenade then typically acts as the hydraulic control on upstream flood levels. The exceptions to this are the floodway linking Worth Place and Wright Lane in Honeysuckle Central, which was modelled as grading from 2.4 m AHD at the western end, down to 2.2 m AHD at the eastern end, and the Worth Place floodway, which was modelled as per its existing condition. The HWC floodway was modelled at a level above the PMF.

Figure 6-3 to Figure 6-5 present the modelled conditions for the Steel Street, HWC and Worth Place floodway alignments. They demonstrate the relatively minor activation within the adopted 1% AEP design flood condition, contrasting with the significant conveyance of overland flows at the PMF event. The adopted floodway configurations essentially limit upstream flood impacts to downstream of the Light Rail alignment, which is a significant hydraulic control (evident in the floodway profile figures) buffering potential impacts further upstream. Raising the floodway levels above 2.3 m AHD was found to influence modelled peak flood levels outside of the Honeysuckle Development Area.

The principal design constraint for the floodways is that they provide sufficient conveyance of the expected overland flood flows. As such, they should be relatively clear of obstructions, as per the existing Steel Street floodway configuration on the southern side of Honeysuckle Drive. With regards

to flood risk within the floodways, it is relatively low (H1) for major flood events such as the 1% AEP, becoming substantial (L4) under extreme flood conditions such as the PMF. This is consistent with the existing road alignments between National Park and the Throsby Basin. The Risk to Life within the floodways is expected to be managed through taking refuge within the adjoining developments, as discussed in Section 6.7.

It may be possible to provide minor grading of finished surface levels within the floodways, if required for the management of local surface runoff for example. The ultimate details of each floodway will be dependent on the individual development proposals and their requirements and as such will require confirmation of their suitability during the DA stages. However, in principal they will need to be in close consistency to those modelled in the concept configuration to prevent adverse flood impacts.

The HWC floodway has been modelled as inactive for all flood events. However, it is likely that the finished surface levels of the developed case will be at the required FPL of the adjacent buildings, which is 2.9 m AHD. This will provide the conveyance of around 0.4 m depth of overland flow during a PMF event, as indicated in Figure 6-4.

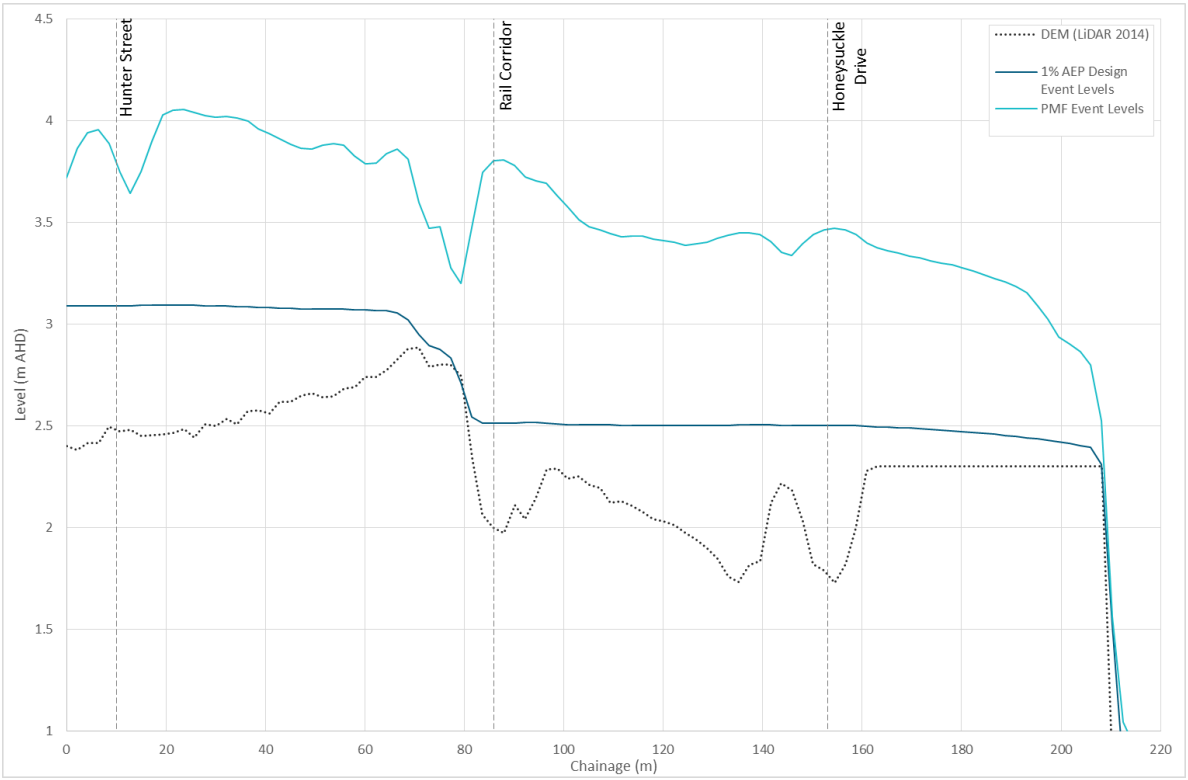


Figure 6-3 Steel Street Modelled Floodway Profile

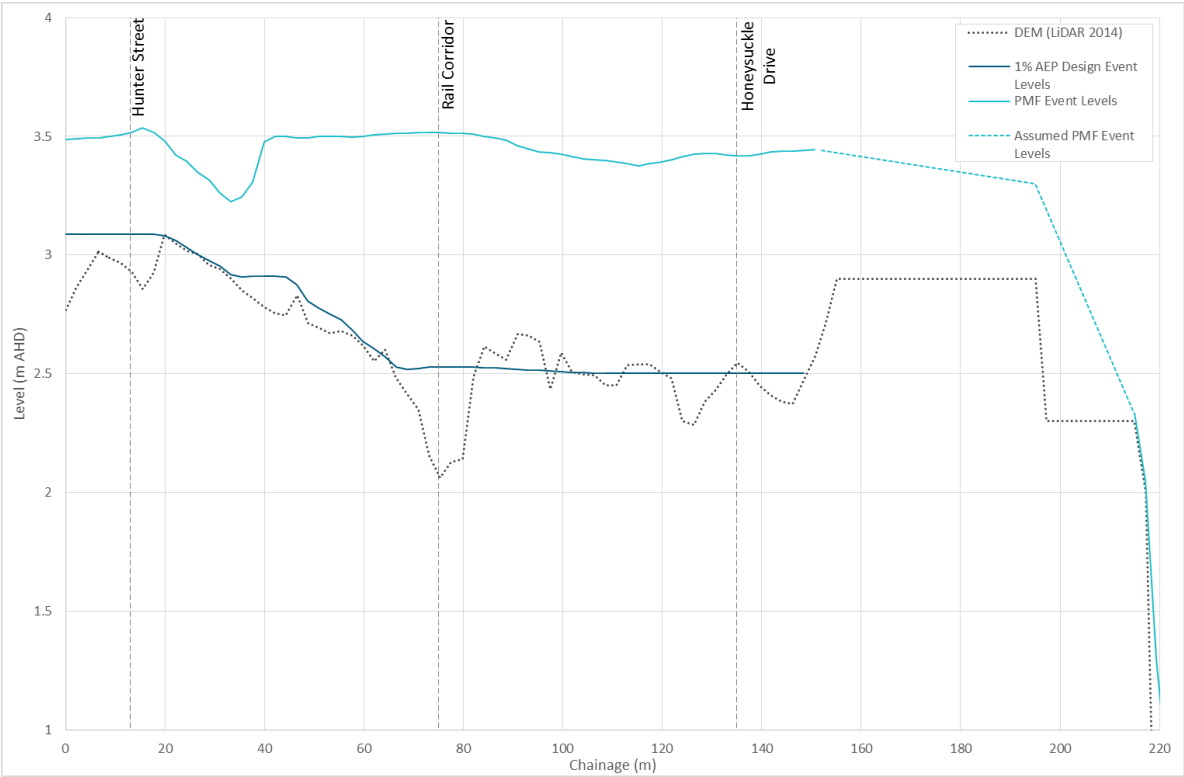


Figure 6-4 HWC Modelled Floodway Profile

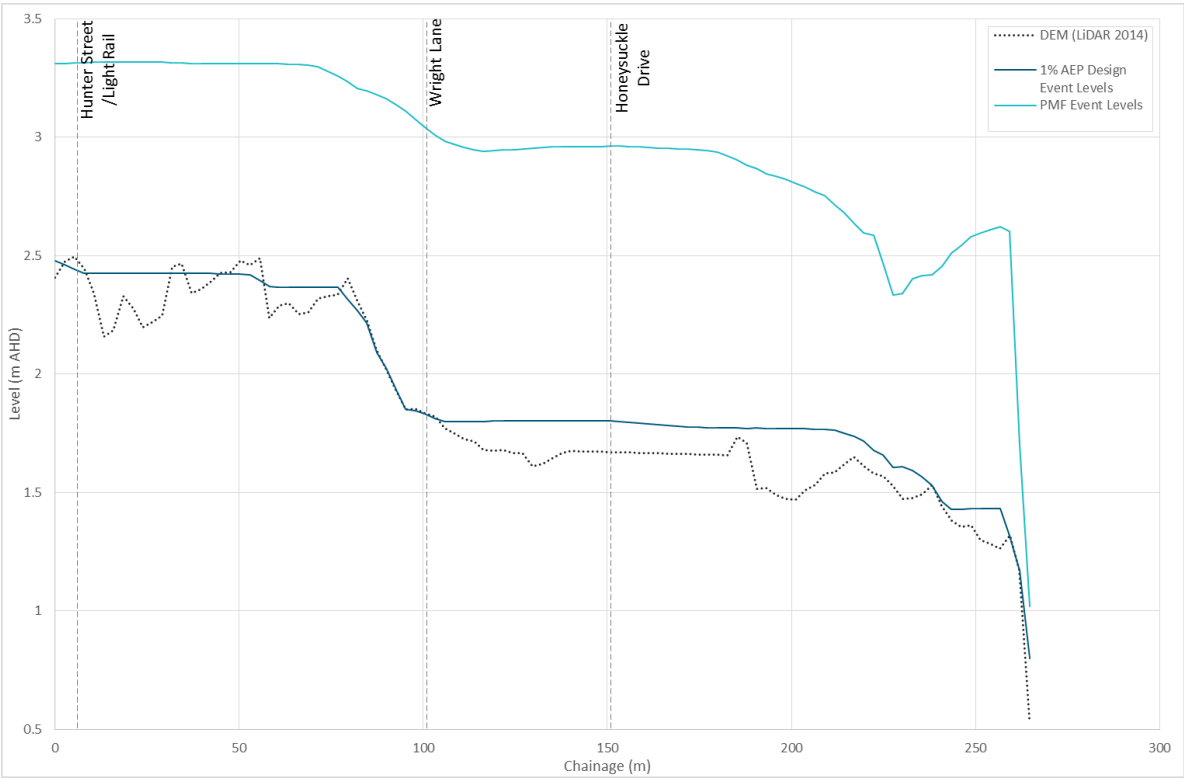


Figure 6-5 Worth Place Modelled Floodway Profile

6.7 Flood Emergency Response

The nature of flooding within the Honeysuckle Development Area is of a relatively low hazard, even for rare flood events such as the 1% AEP. However, for very rare and extreme events there is an increasing risk to people within the overland flow conveyance corridors of the existing roadways and floodway alignments. Due to the short duration, high intensity rainfall events that cause such flooding, there would be little advance flood warning to initiate evacuation of the area. This is consistent with the existing risk throughout much of the Newcastle CBD.

To manage the Risk to Life during a potential extreme flood event such as the PMF, an appropriate Flood Emergency Response Plan is required. The FPL requirements for future development in the area will provide relatively safe refuge adjacent to the areas of high hazard. Furthermore, the multi-storey construction of future development will also provide on-site flood-free refuge above the PMF level. Each proposed development will be required to produce a Flood Emergency Response Plan specific to its building design. These Plans will provide details regarding the flood risk specific to the site and to the most suitable flood egress routes to access flood-free refuge areas.

As identified within the Newcastle City-wide Floodplain Risk Management Study, roadways present the most hazardous conditions for people during a major overland flood event and the provision of more potential flood-free refuge areas in the CBD will help manage and reduce this risk.

6.8 Summary of Flood Planning Information for HDC Sites

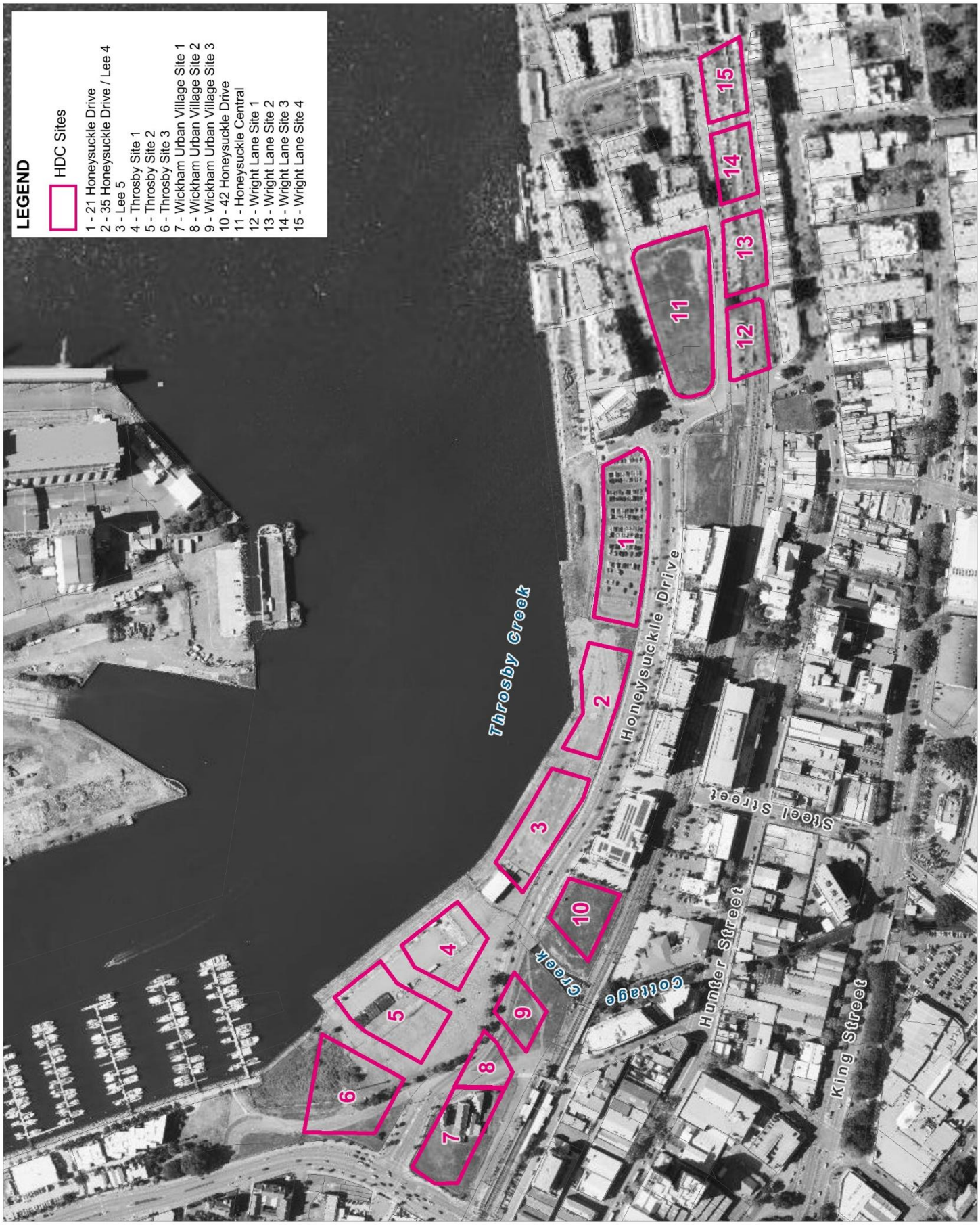
A summary of the key information for flood planning requirements at each of the HDC site locations is provided within Table 6-7, with the location of each site presented in Figure 6-6. This information includes site specific details such as:

- local catchment 1% AEP flood level
- local catchment PMF level
- Flood Planning Level
- Flood classification
- Risk to Property
- Risk to Life
- Modelled peak velocities

Table 6-7 Flood Planning Information for HDC Development Sites

Site Location	1% AEP with ARR 2016 Blockage Post-Development Levels (m AHD)	PMF Level (m AHD)	FPL[1] (m AHD)	Post-Development Flood Classification		Risk to Property	Risk to Life	Velocity (m/s)			
				1% AEP	PMF			1% AEP	0.5% AEP	0.2% AEP	PMF
21 Honeysuckle Drive	2.50	3.44	2.90	Fringe	Floodway	P1	L4	0.8	1.4	1.6	2.2
35 Honeysuckle Drive / Lee 4	2.50	3.43	2.90	Storage	Floodway	P2	L4	0.7	1.1	1.7	3.0
Lee 5	2.50	3.38	2.90	Storage	Floodway	P2	L4	0.7	1.0	1.5	3.3
Throsby – Site 1	2.40	3.50	2.80	Fringe	Floodway	P1	L4	0.3	0.6	1.3	2.8
Throsby – Site 2	2.40	3.50	2.80	Fringe	Floodway	P1	L4	0.2	0.4	1.0	2.9
Throsby – Site 3	2.37	3.47	2.80	Fringe	Floodway	P1	L4	0.1	0.4	1.0	2.5
Wickham Urban Village – Site 1	2.48	3.49	2.90	Fringe	Storage	P2	L4	0.4	0.5	0.7	1.1
Wickham Urban Village – Site 2	2.46	3.49	2.90	Fringe	Floodway	P2	L4	0.3	0.5	0.7	1.3
Wickham Urban Village – Site 3	2.45	3.49	2.90	Fringe	Floodway	P1	L4	0.3	0.5	0.7	1.9
42 Honeysuckle Drive	2.49	3.62	2.90	Fringe	Floodway	P2	L4	0.7	1.0	1.3	1.8
Honeysuckle Central	1.86	3.29	2.80	Fringe	Floodway	P1	L5	0.1	2.0	2.1	2.9
Wright Lane – Site 1	2.42	3.31	2.80	Fringe	Floodway	P1	L4	0.3	1.4	2.4	2.6
Wright Lane – Site 2	2.43	3.19	2.80	Fringe	Floodway	P1	L4	0.2	1.3	1.4	2.0
Wright Lane – Site 3	2.34	3.05	2.80	Fringe	Floodway	P1	L4	-	0.1	0.4	2.0
Wright Lane – Site 4	2.34	3.05	2.80	Fringe	Fringe	P1	L4	-	0.0	0.5	1.1

[1] Note that where the 1% AEP post-development level + 0.4 m freeboard is less than 2.8 m AHD, a FPL of 2.8 m has been adopted in accordance with Council's ocean planning level of 2.8 m AHD. FPLs have been rounded to 1 decimal place.



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HDC Sites

Figure: **6-6**

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7 Conclusions

This study has provided an update to the original Lawson & Treloar flood risk information derived in 1999 and seeks to provide an up-to-date platform from which to assess current flood risk in the Honeysuckle Redevelopment Area and potential flood impacts associated with the proposed development. As such, improvements have been made to the original study to bring it into line with current best practice floodplain risk management, including:

- Representation of overland flood flows within a 2D modelling scheme
- Updating of the baseline model floodplain topography using recent (2014) LiDAR data
- Calibration of the model to the June 2017 flood event
- Modification of the model topography to account for recent developments, such as the Newcastle Light Rail
- Application of the recently release ARR 2016 guidelines to provide updated design flood conditions and assessment of the potential blockage of hydraulic structure

The study has found that the baseline design flood conditions of the 1% AEP event are significantly different to those derived in the original Lawson & Treloar study. These are likely attributable to the significant attenuation of flood flows within National Park.

A flood impact assessment was undertaken based on a preliminary development layout provided by HDC. This found that flood impacts associated with the proposed development are largely restricted to the existing Honeysuckle development downstream of the light rail corridor.

The peak flood levels derived from local catchment flooding are often lower than those of the ocean flooding. As such, the design ocean flood level of 2.3 m AHD is the critical flood condition throughout much of Honeysuckle and Council's existing Flood Planning Level of 2.8 m AHD has been applied. However, for some sites close to Cottage Creek or Steel Street, local catchment flood conditions are critical and the FPL has been set slightly higher at 2.9 m AHD.

The assessment of post-development flood conditions provides significant differences to those derived by the original Lawson & Treloar study. Modelling the significant attenuation of flood flows within National Park becomes even more critical when representing the post-development flood conditions. This results in the significance of the HWC and Steel Street floodways identified by the Lawson & Treloar study being diminished within the current study, the former of which is not required to be maintained.

Flood planning requirements are provided for each development site within the study area to help inform the future DA processes.

8 References

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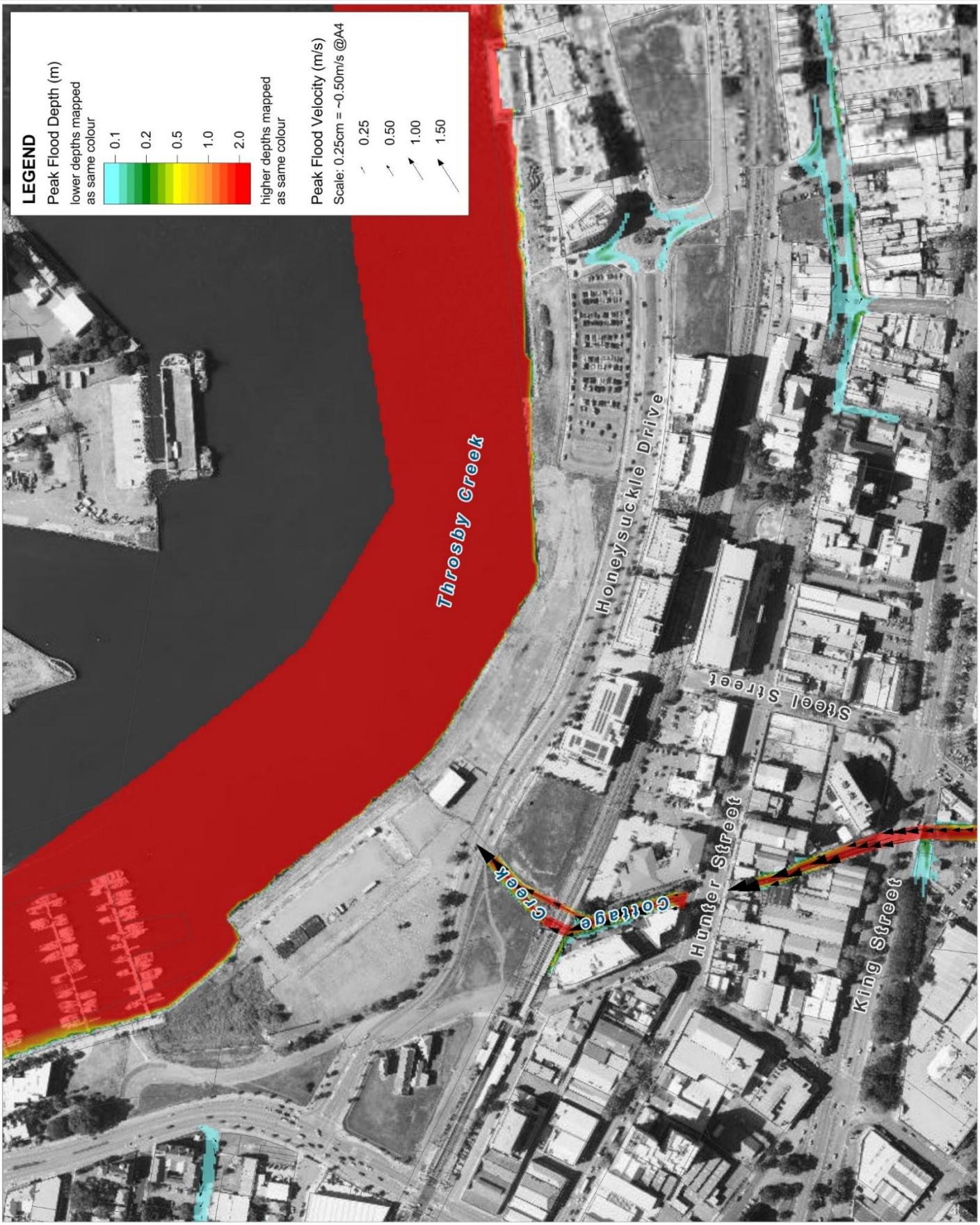
Appendix A Existing Design Flood Mapping



Title:

Existing Flood Condition for the 10% AEP Design Event

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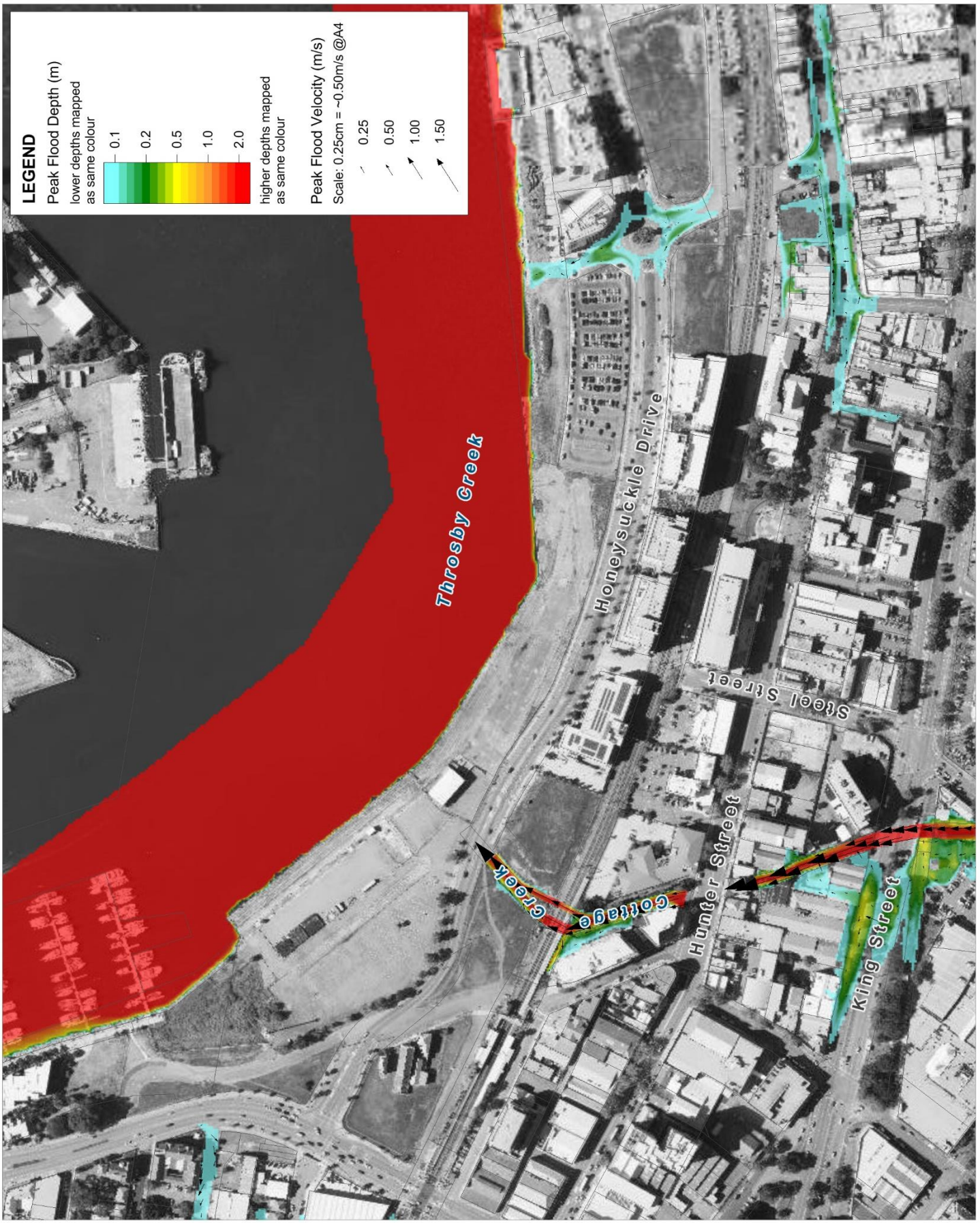

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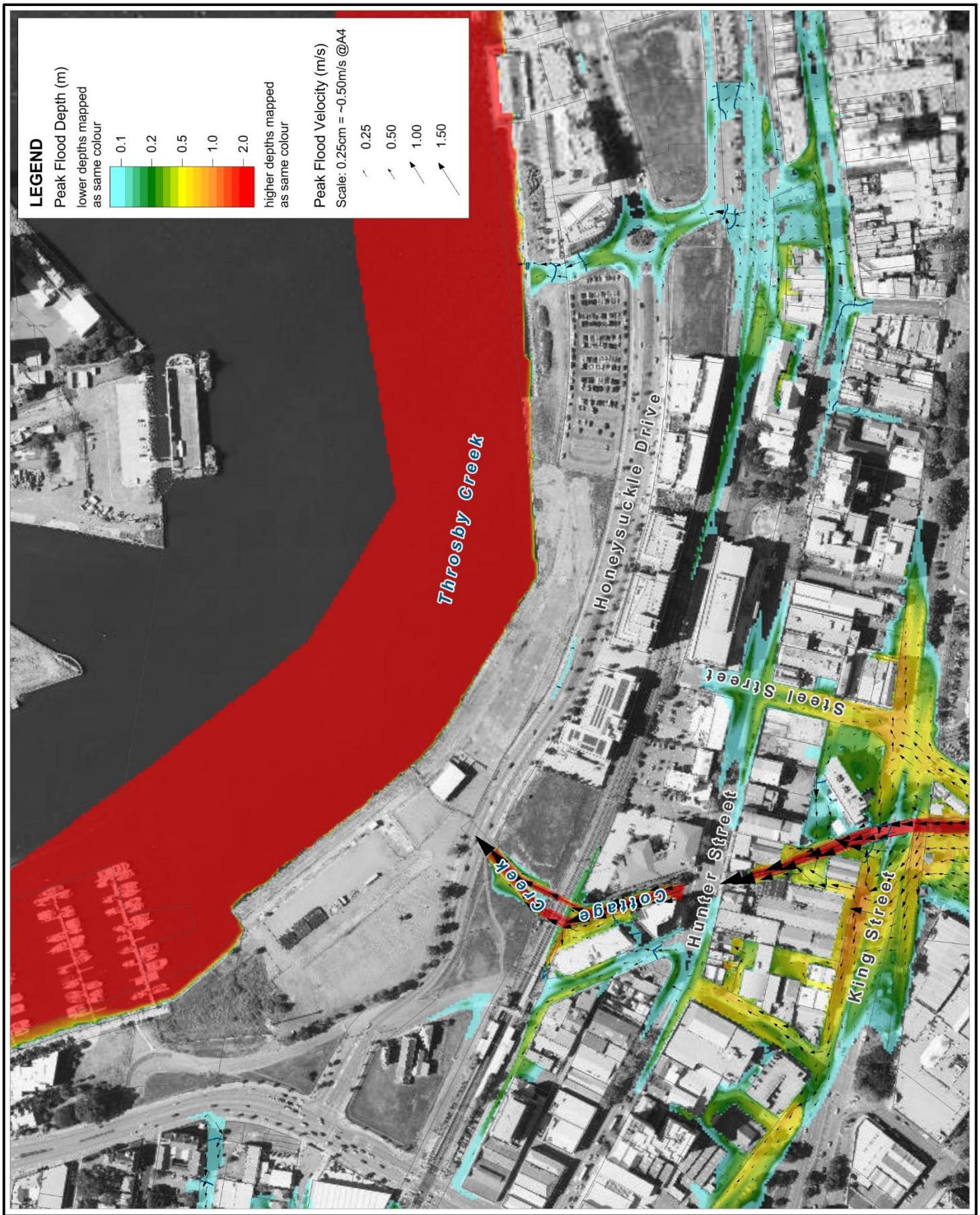

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Existing Flood Condition for the 1% AEP Design Event

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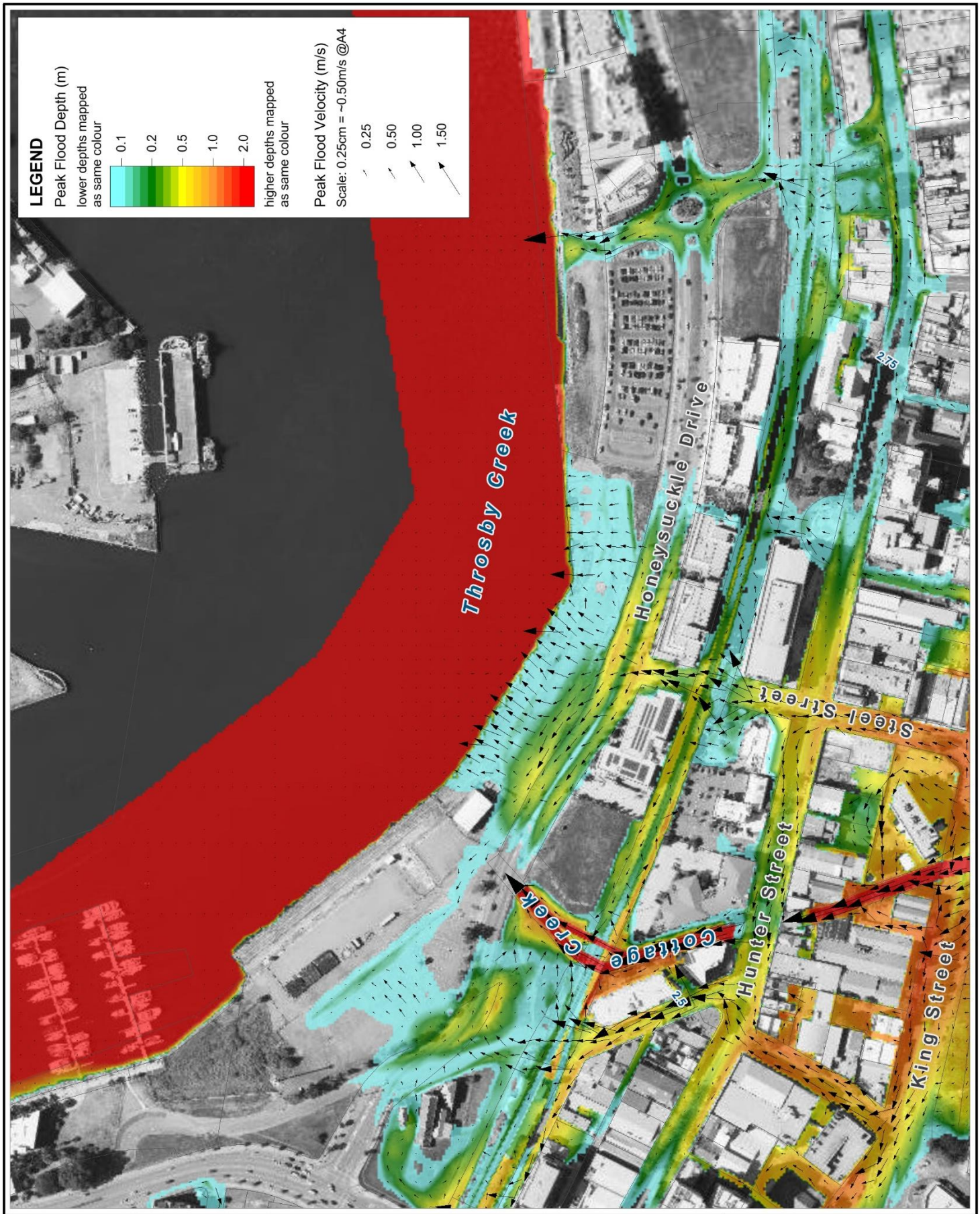

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Existing Flood Condition for the 0.5% AEP Design Event

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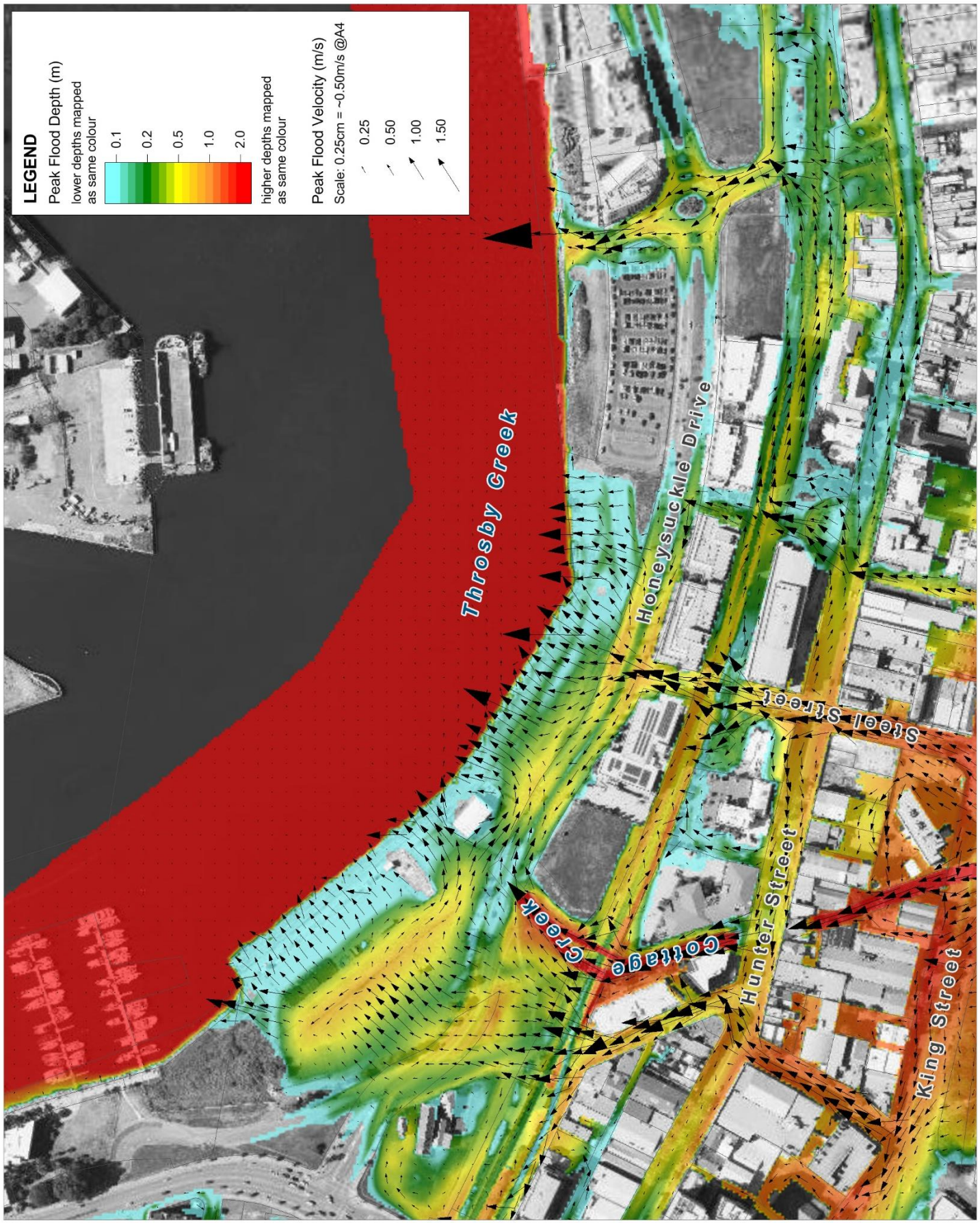

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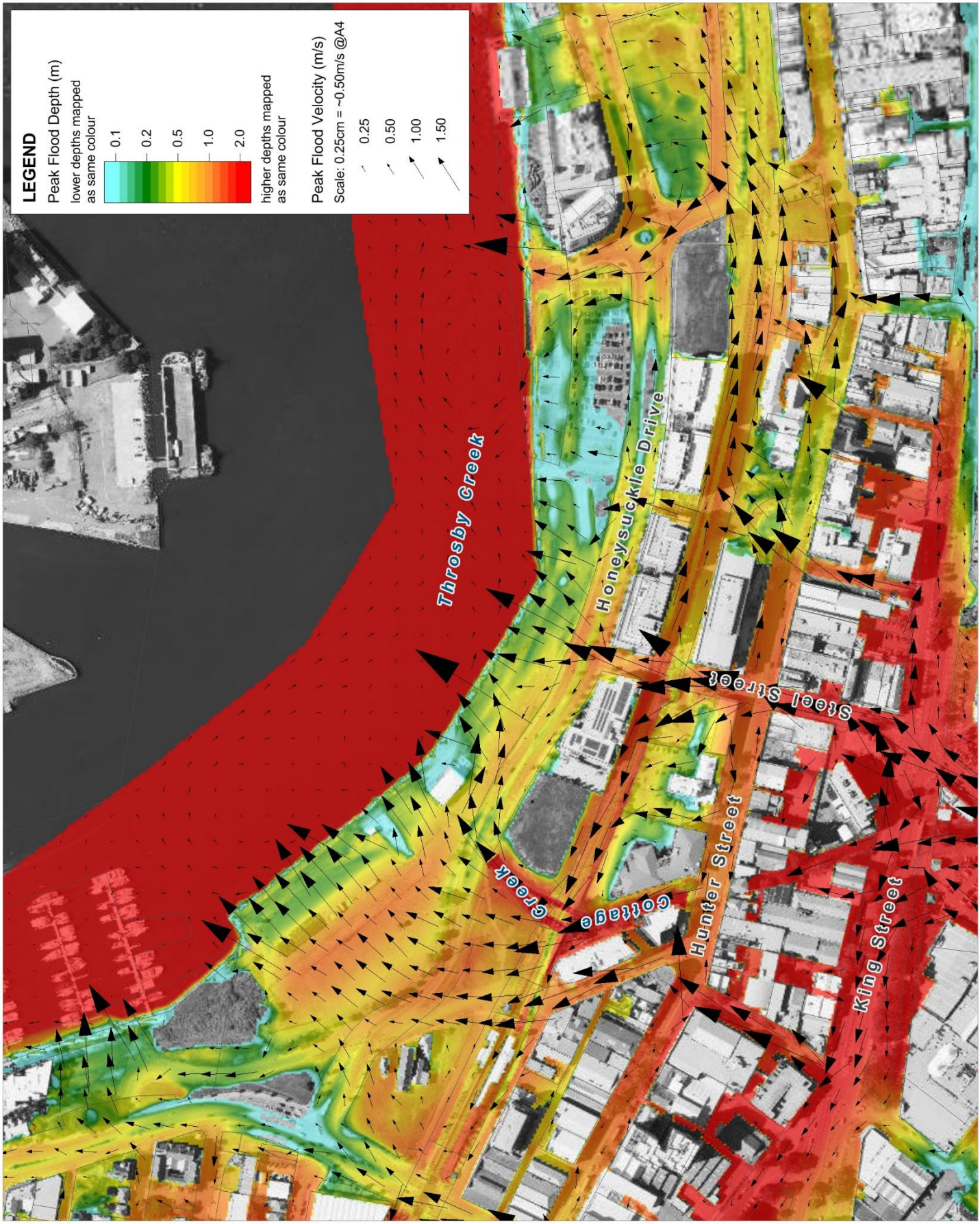

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Existing Flood Condition for the PMF Event

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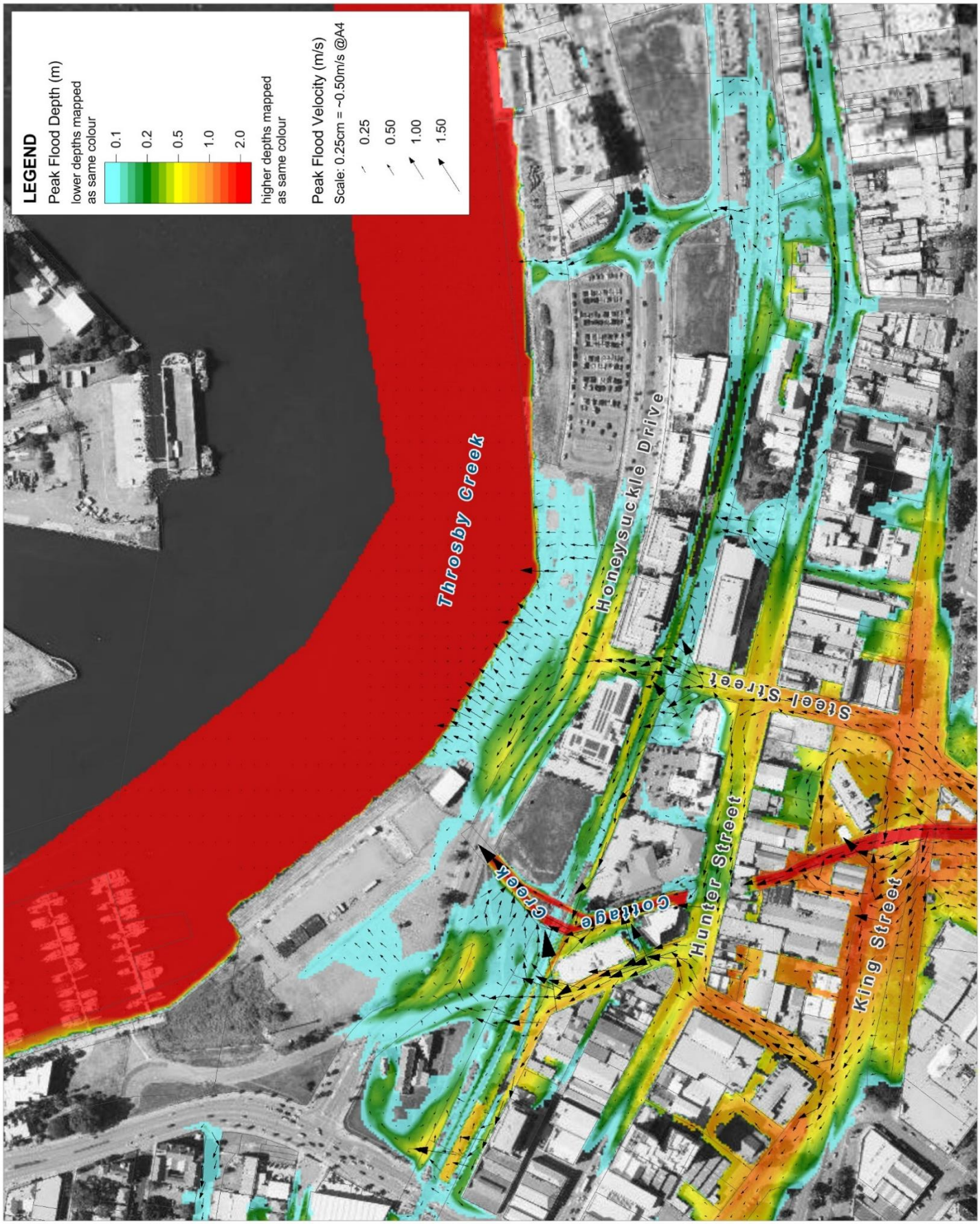
Appendix B Structure Blockages Flood Mapping



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Existing Flood Condition for the 1% AEP Design Event ARR 2016 Blockages

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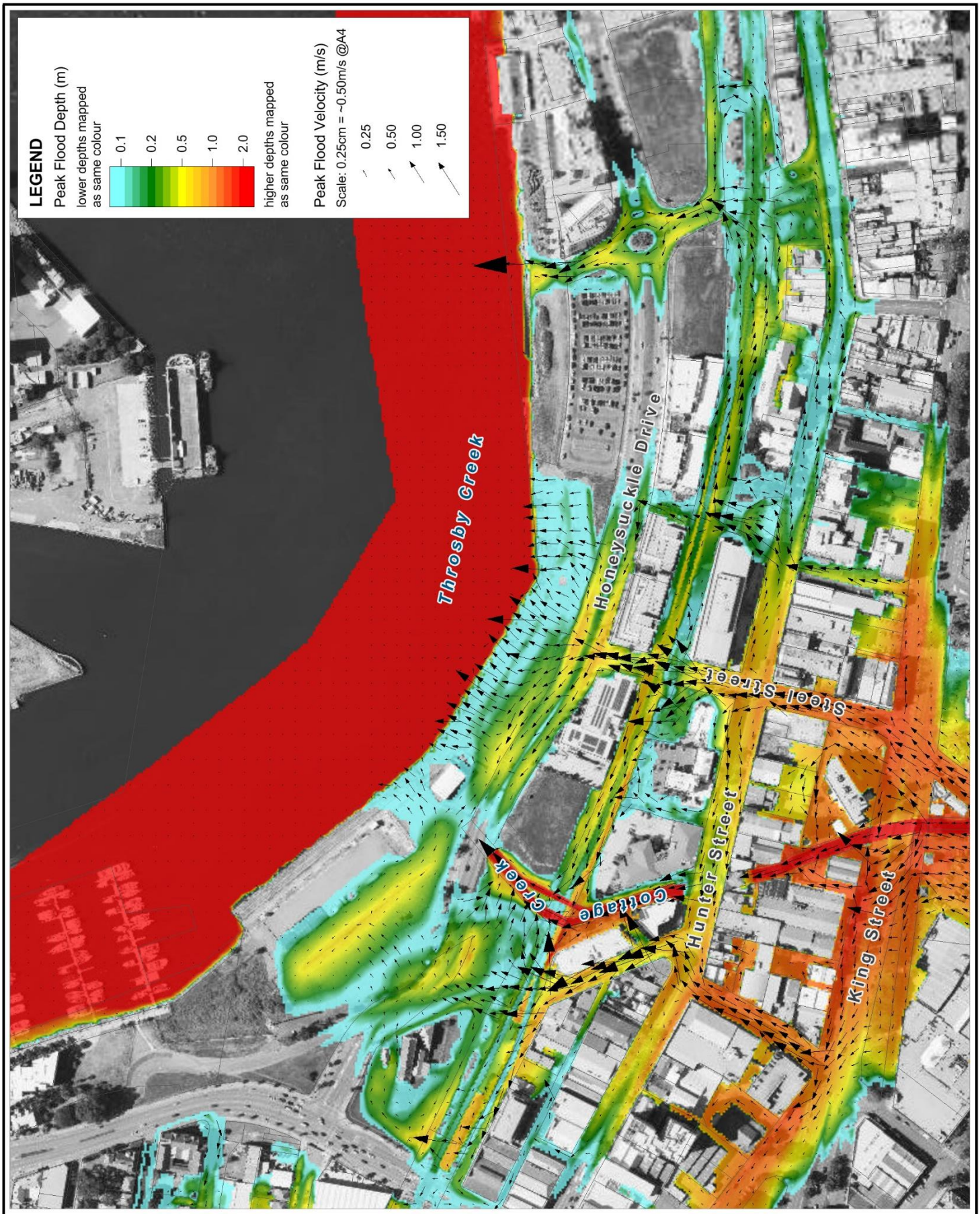

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Existing Flood Condition for the 0.5% AEP Design Event ARR 2016 Blockages

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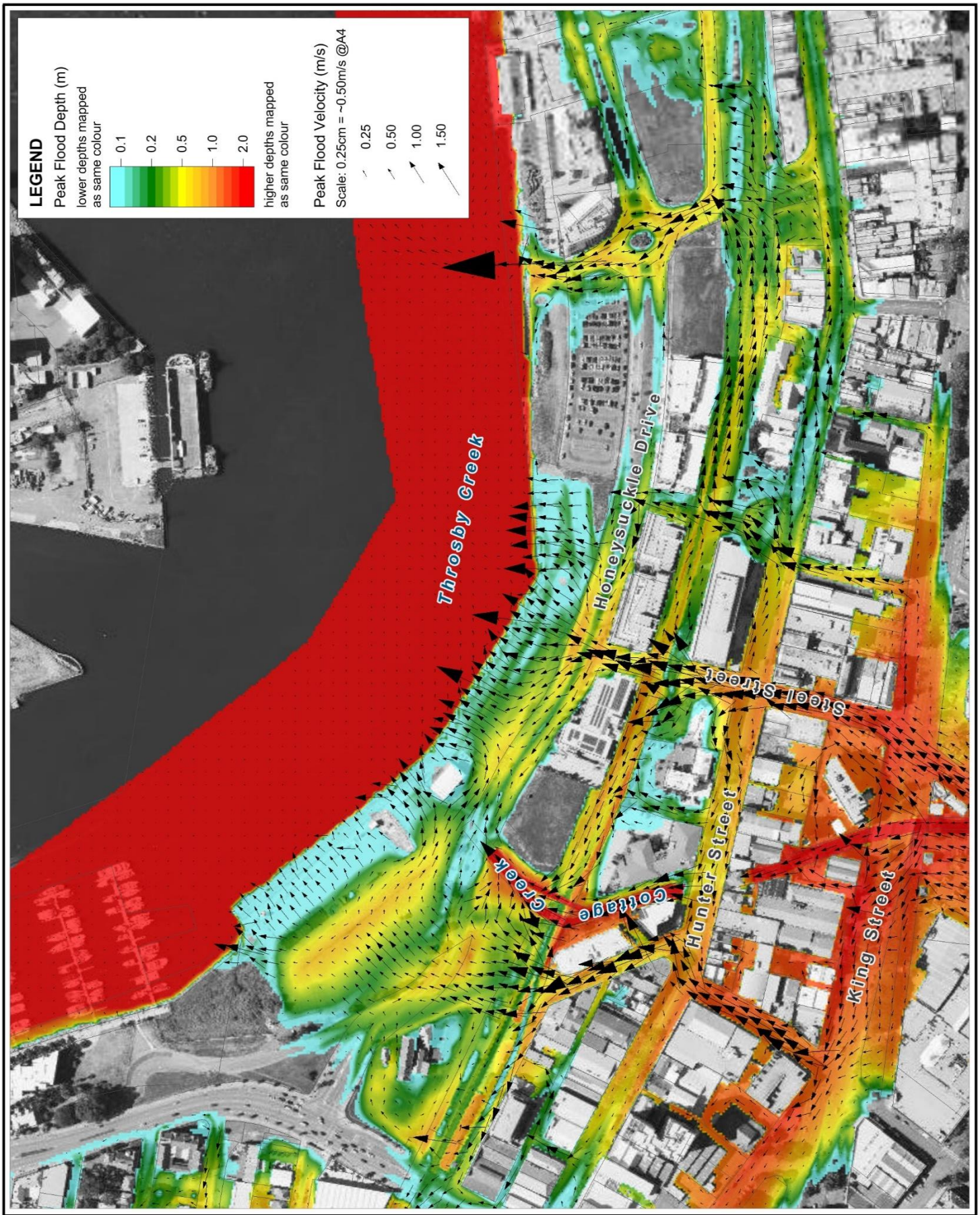

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Existing Flood Condition for the 0.2% AEP Design Event ARR 2016 Blockages

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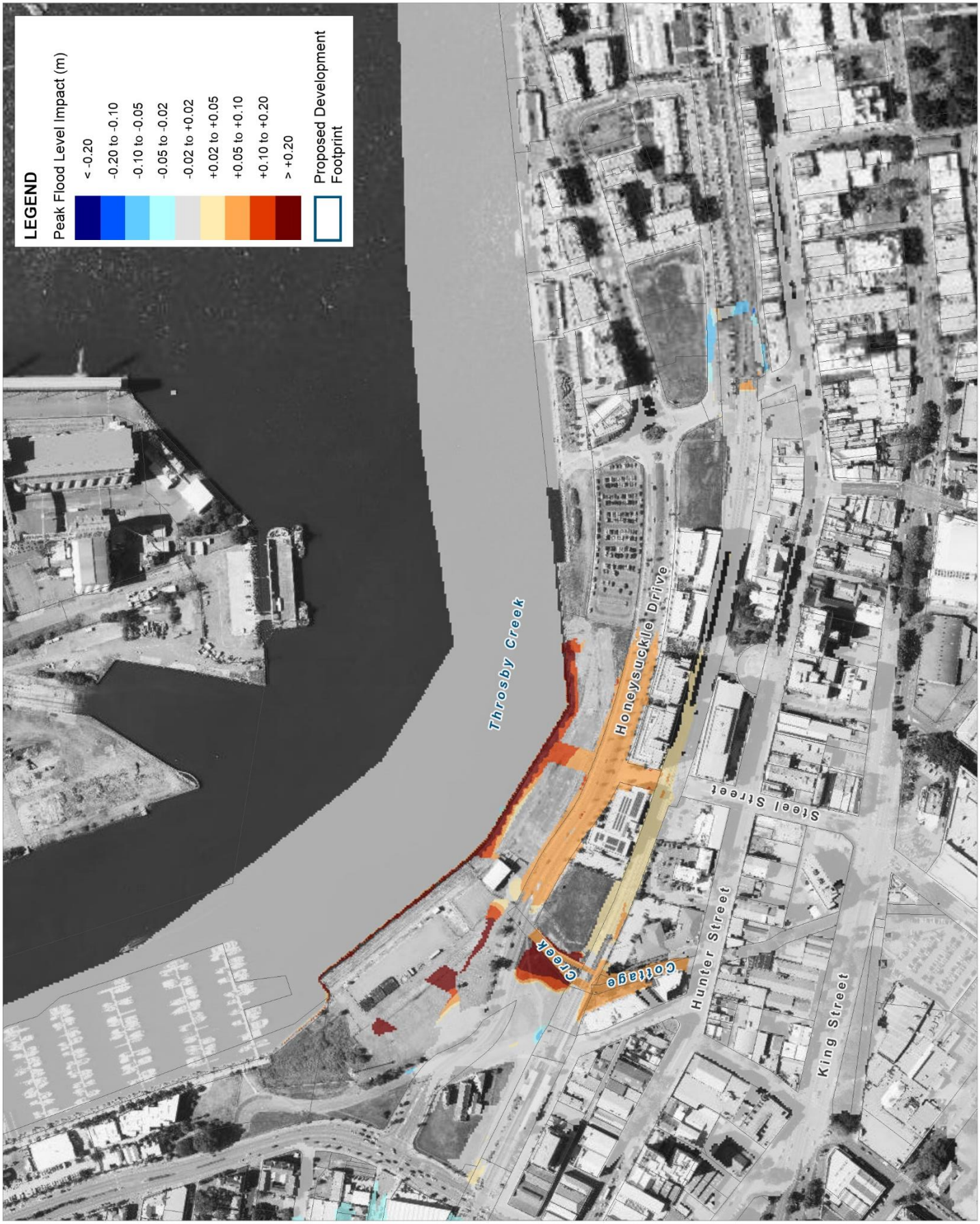
Appendix C Impacts of Development



Title:

Peak Flood Level Impacts for the 1% AEP Event HDC Preliminary Layout

Figure: **C-1**

Rev: **A**

N

0 50 100m
Approx. Scale

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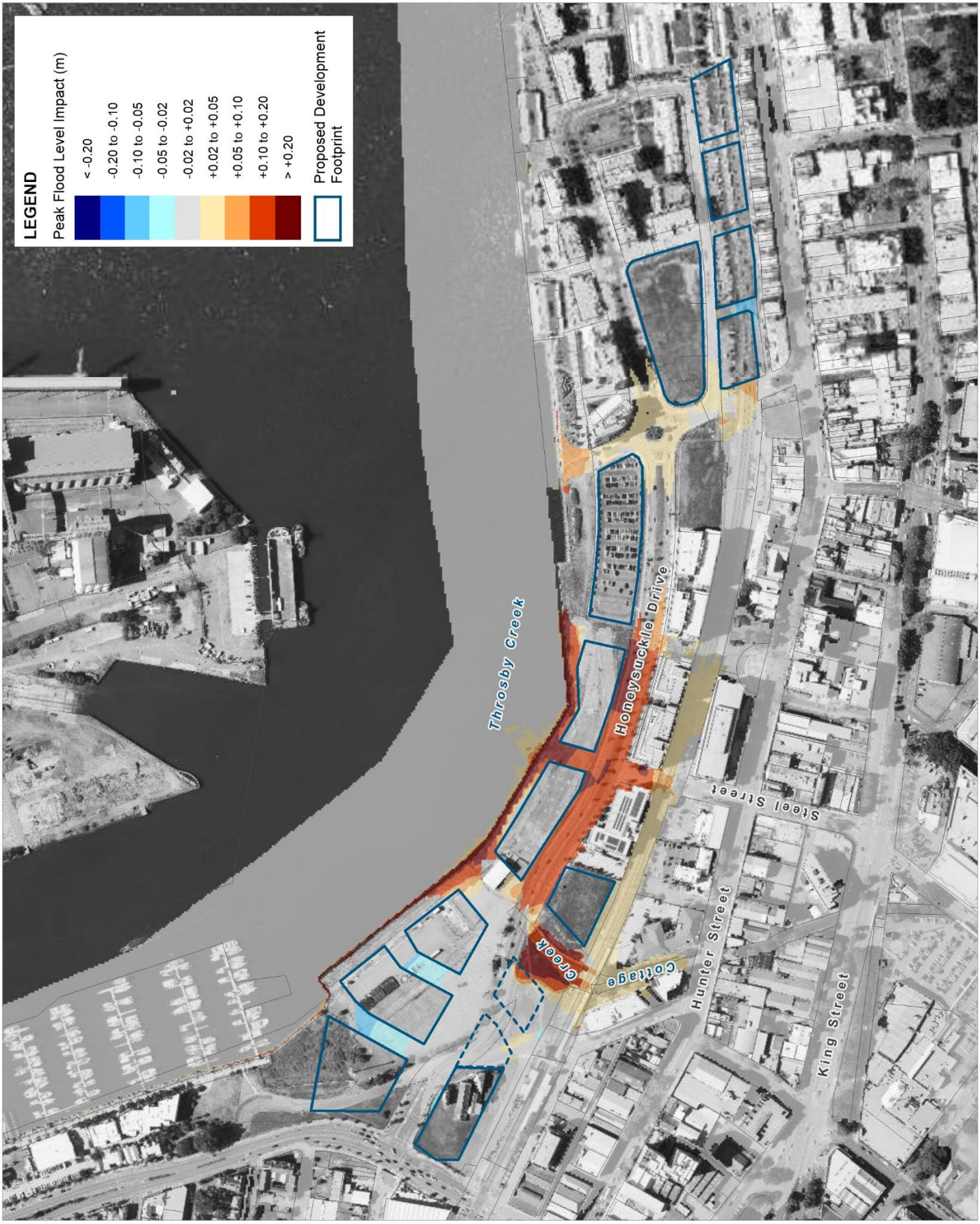

Title:

Peak Flood Level Impacts for the 0.5% AEP Event HDC Preliminary Layout

Figure: C-2

Rev: A

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0 50 100m
Approx. Scale

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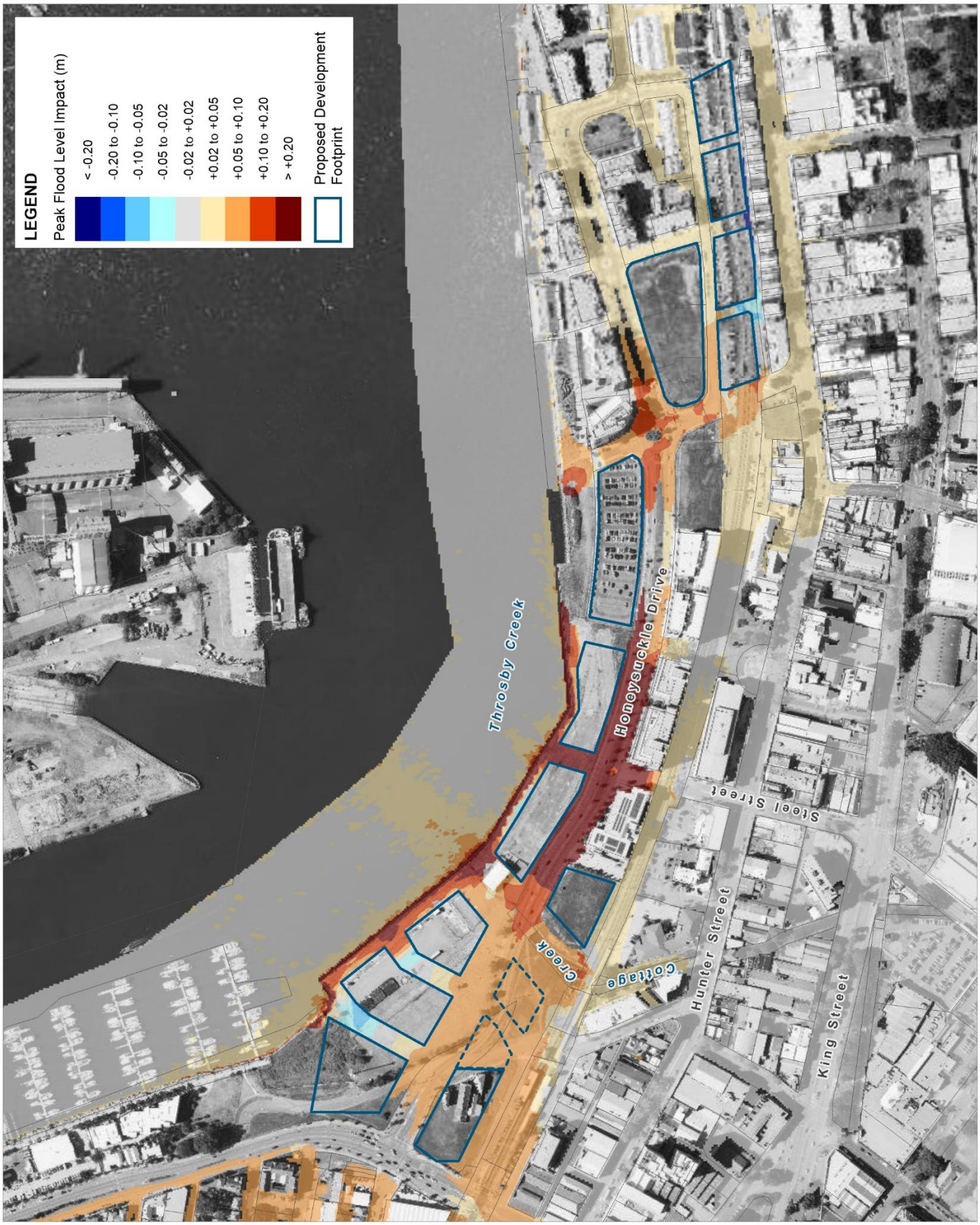

Title:

Peak Flood Level Impacts for the 0.2% AEP Event HDC Preliminary Layout

Figure: **C-3**

Rev: **A**

N

0 50 100m
Approx. Scale

BMT WBM
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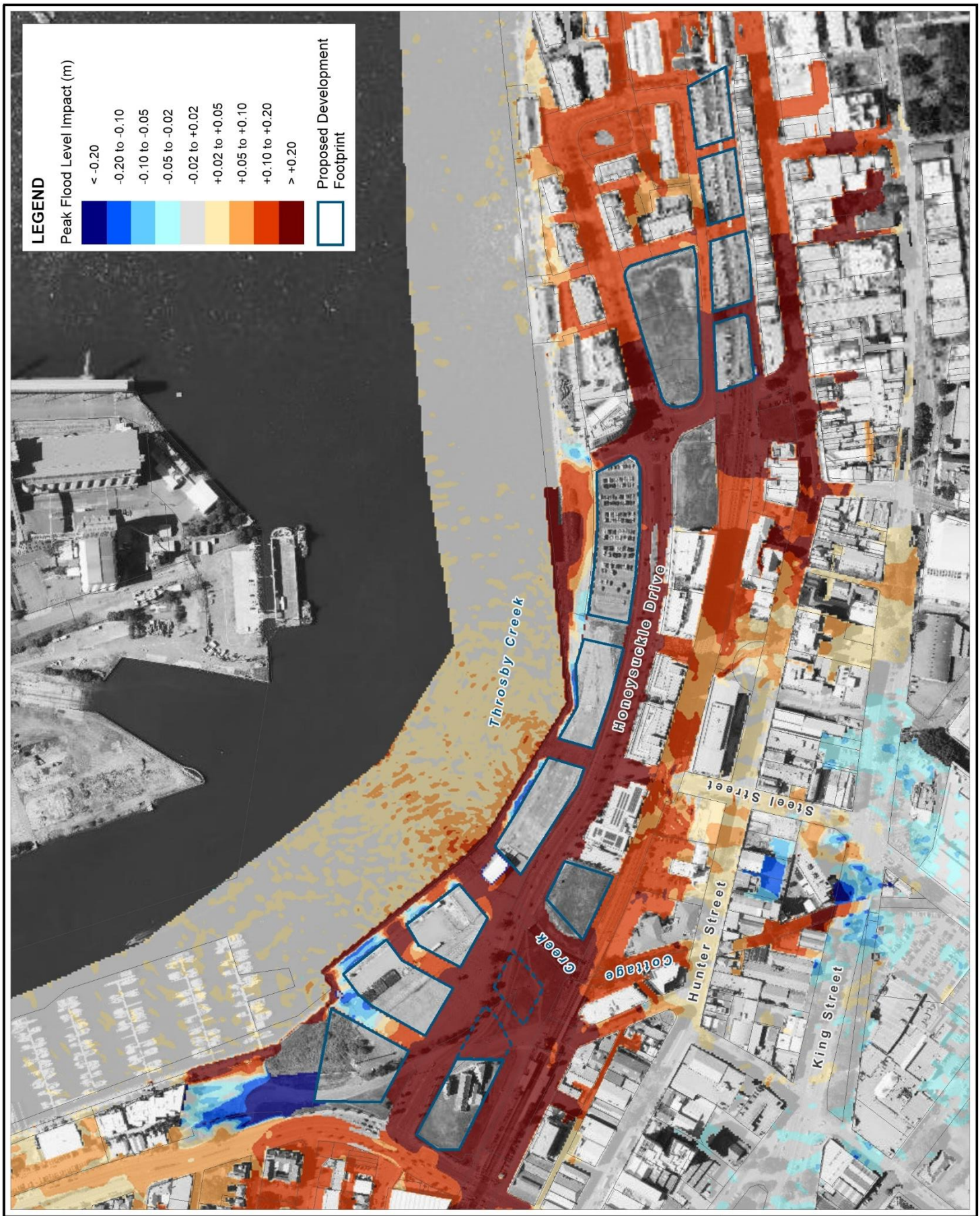

Title:

Peak Flood Level Impacts for the PMF Event HDC Preliminary Layout

Figure: **C-4**

Rev: **A**

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0 50 100m
Approx. Scale

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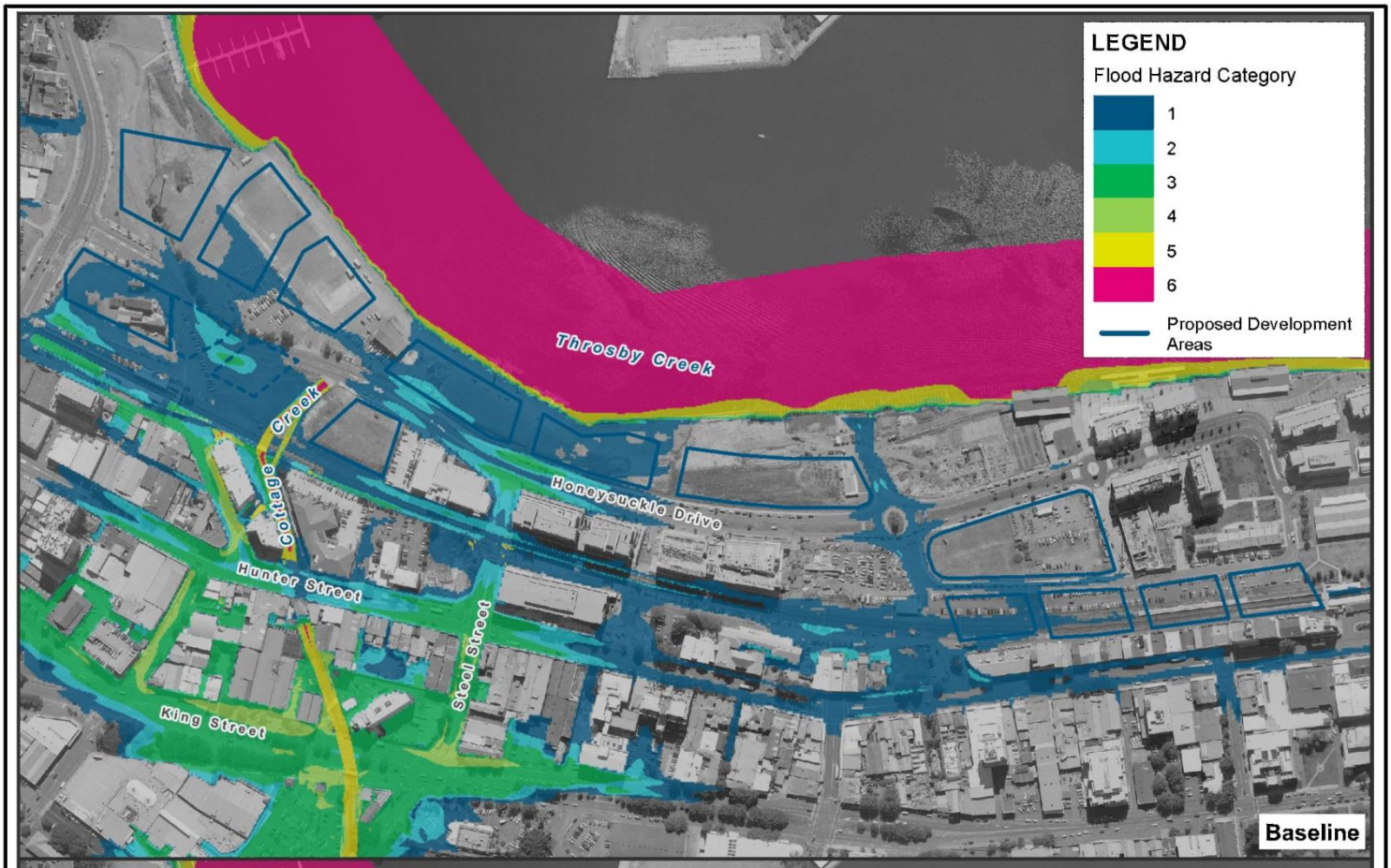

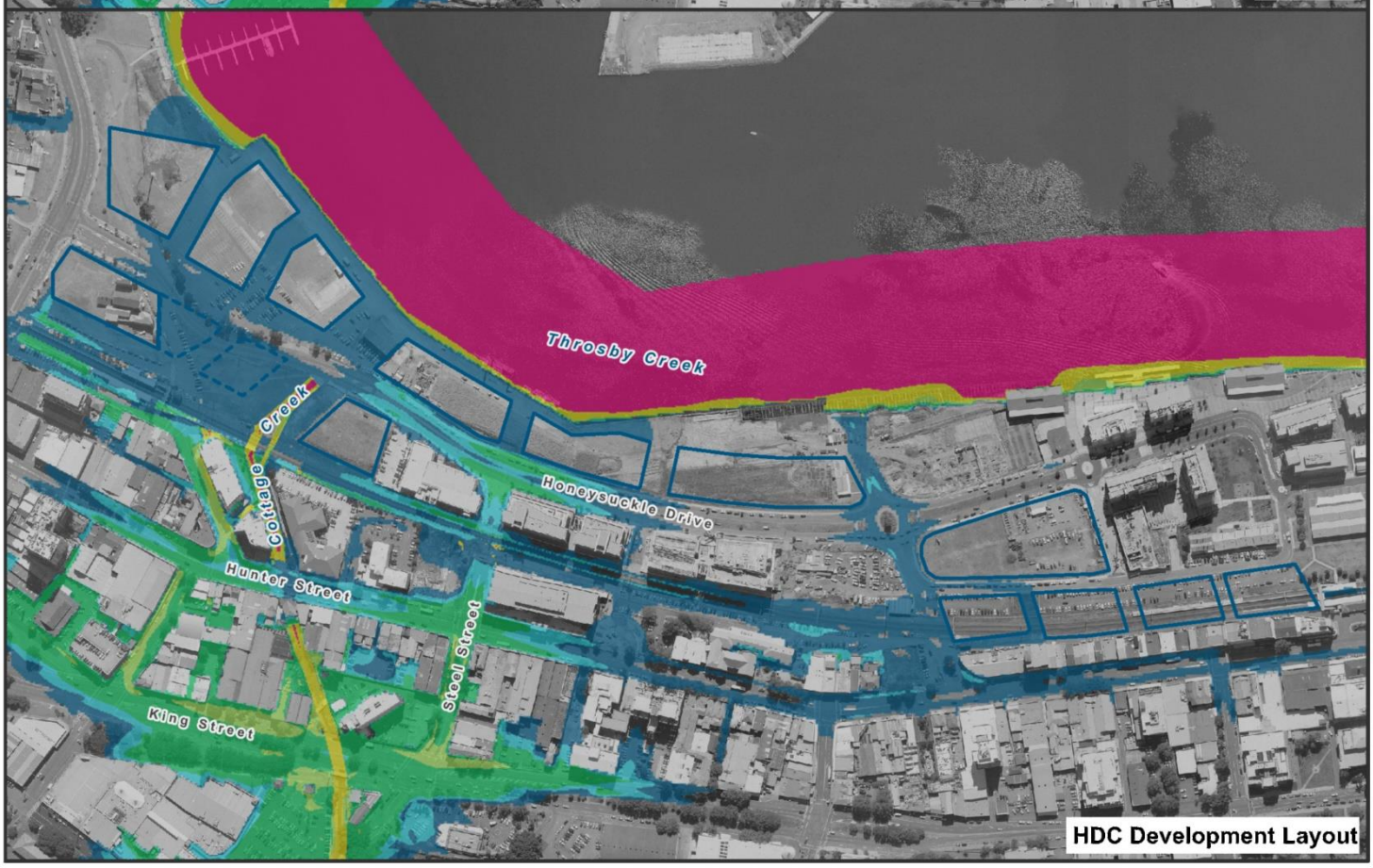

Title:

Best Practice Flood Hazards - 1% AEP Design Event HDC Preliminary Layout

Figure: C-5

Rev: A

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Approx. Scale

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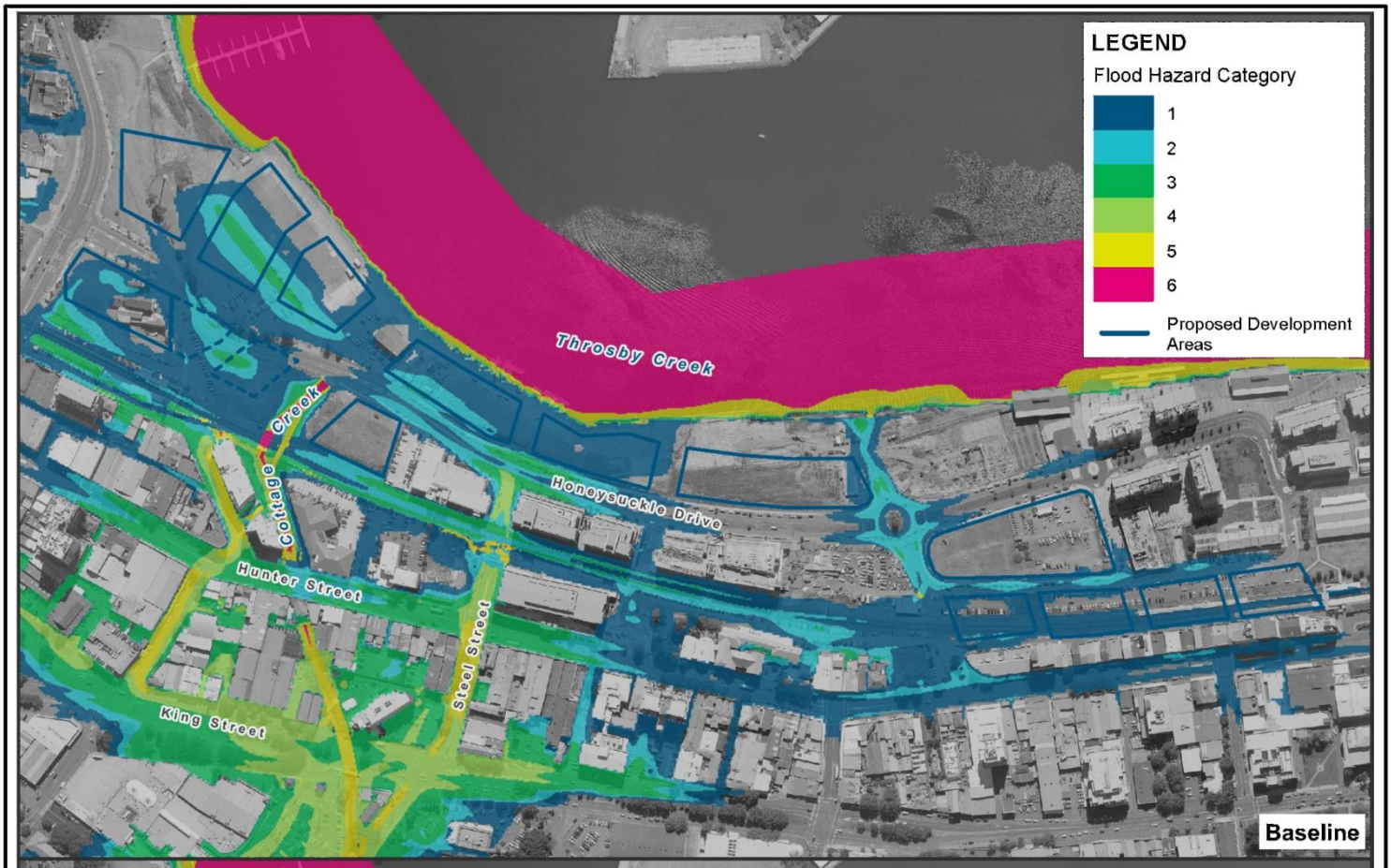

Title:

Best Practice Flood Hazards - 0.5% AEP Design Event HDC Preliminary Layout

Figure: C-6

Rev: A

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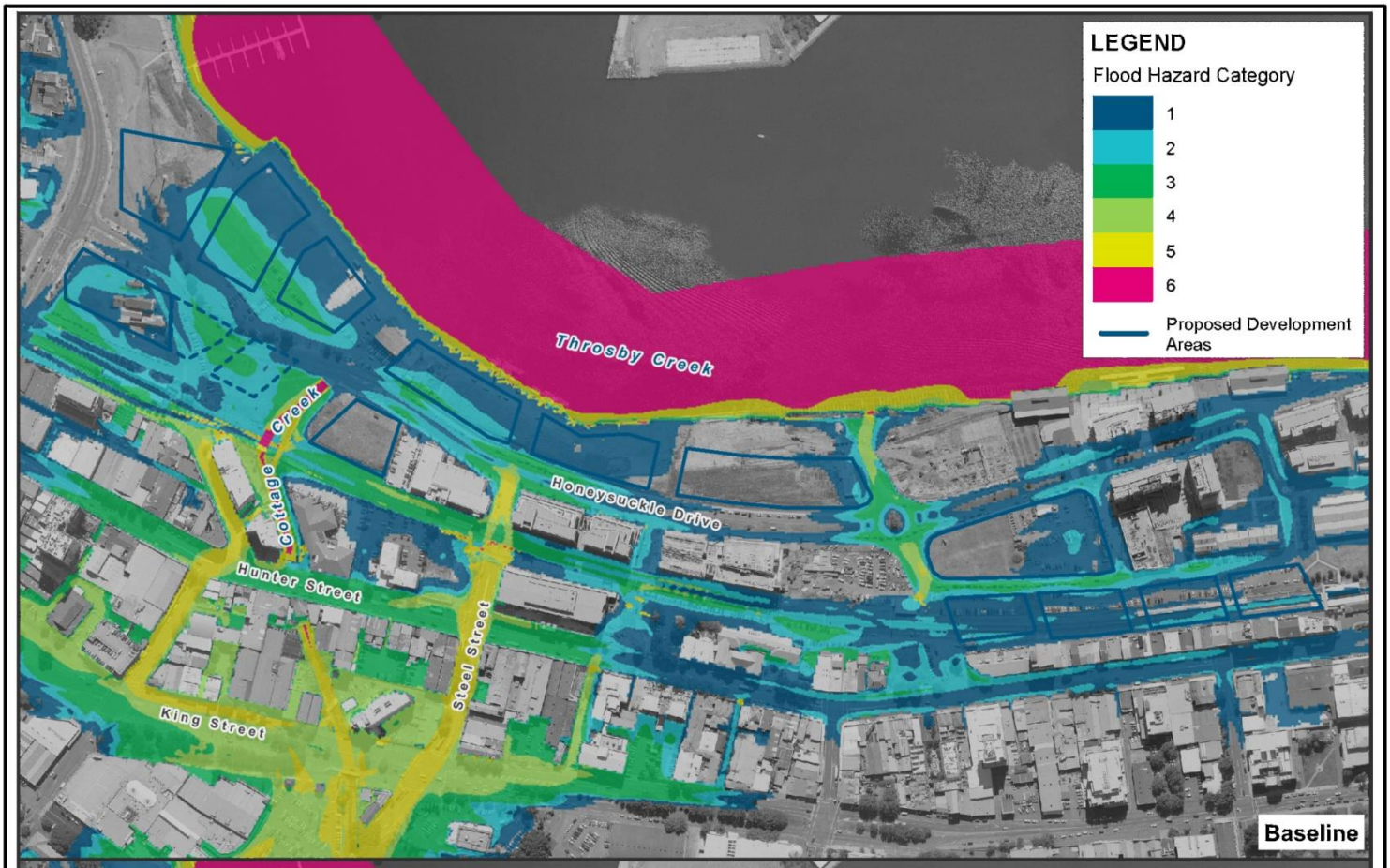

Title:

Best Practice Flood Hazards - 0.2% AEP Design Event HDC Preliminary Layout

Figure: C-7

Rev: A

N

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Approx. Scale

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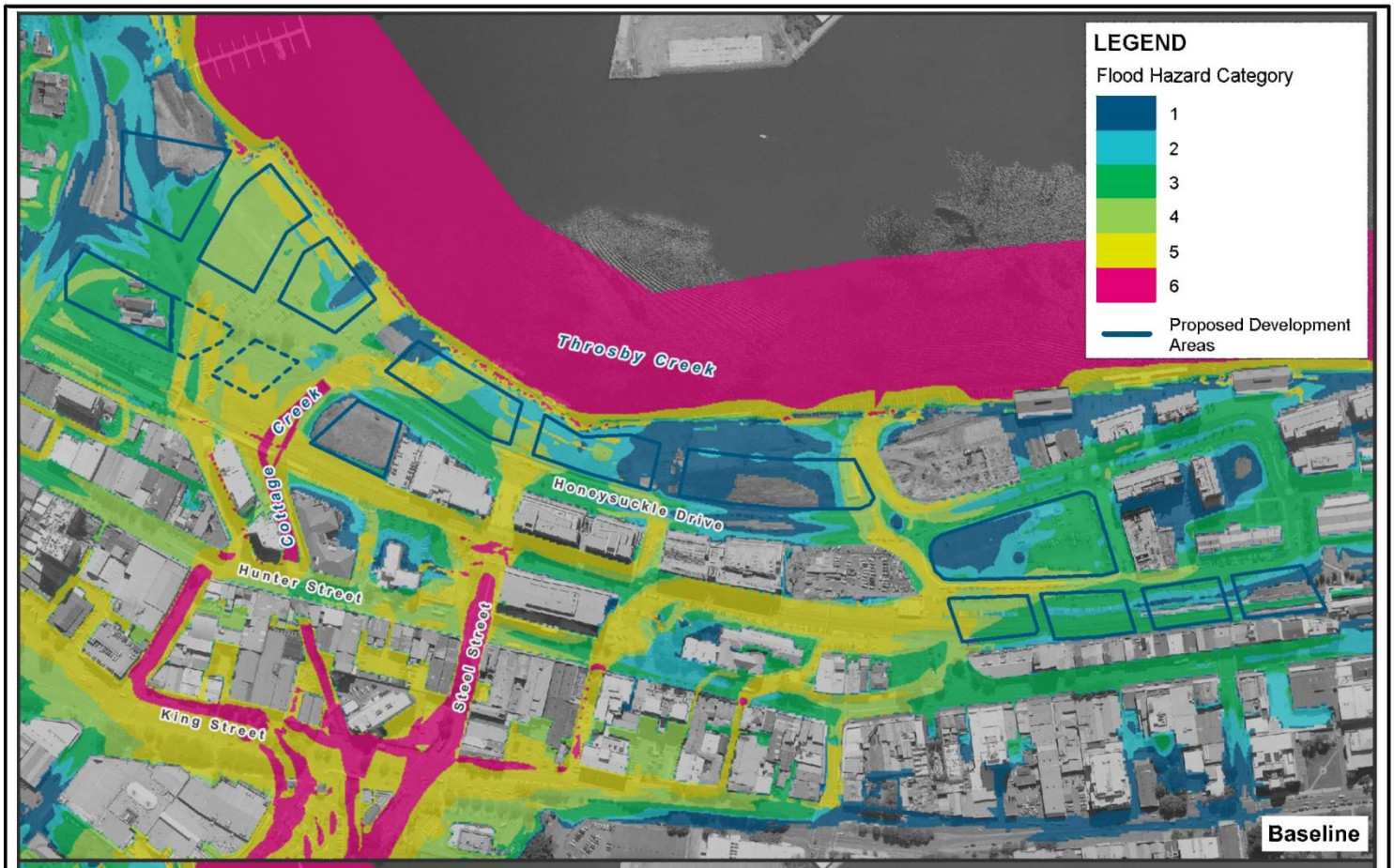

Title:

Best Practice Flood Hazards - PMF Event
HDC Preliminary Layout

Figure: **C-8**

Rev: **A**

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Approx. Scale

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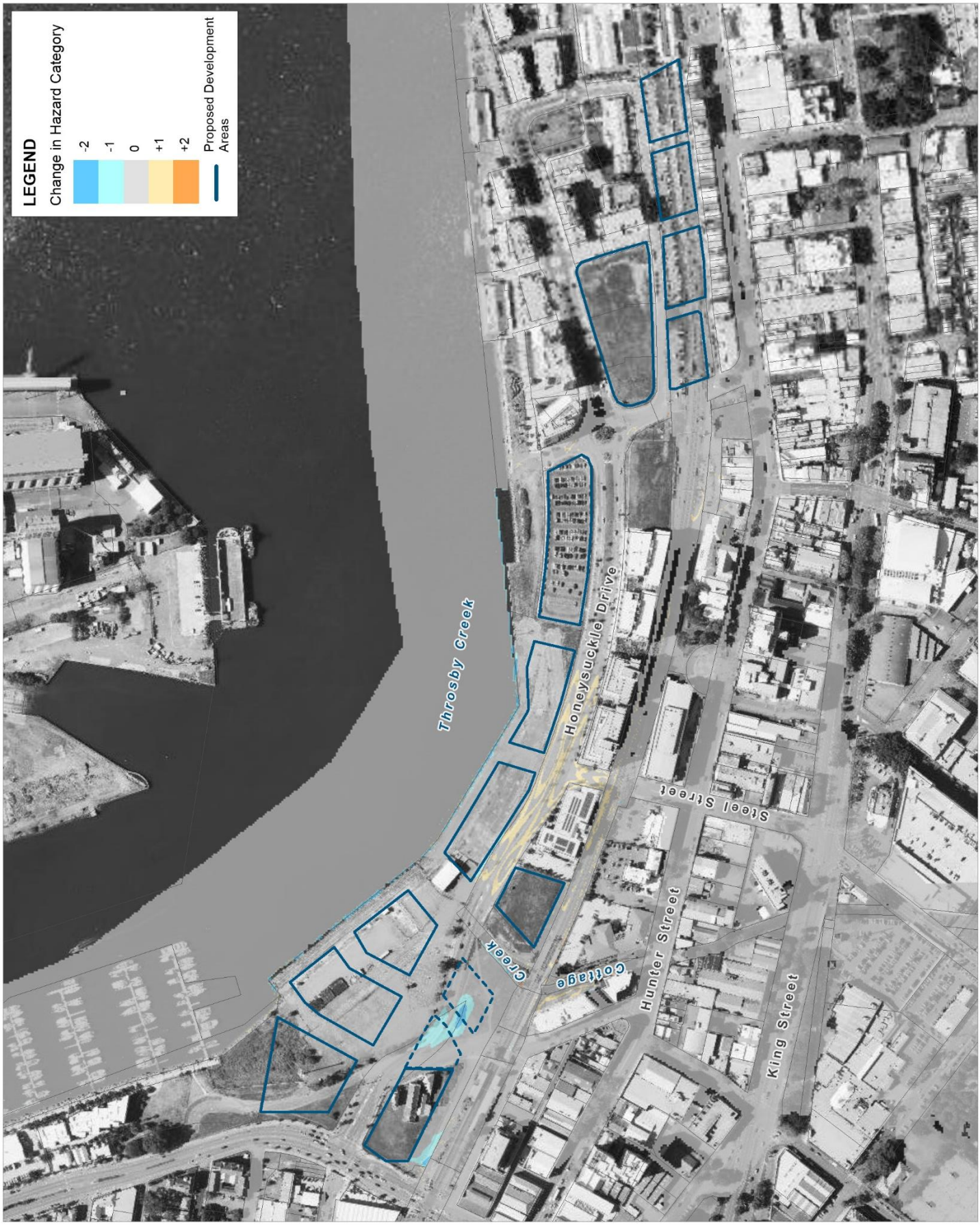

Title:

Change in Best Practice Flood Hazards - 1% AEP Design Event
HDC Preliminary Layout

Figure: **C-9**

Rev: **A**

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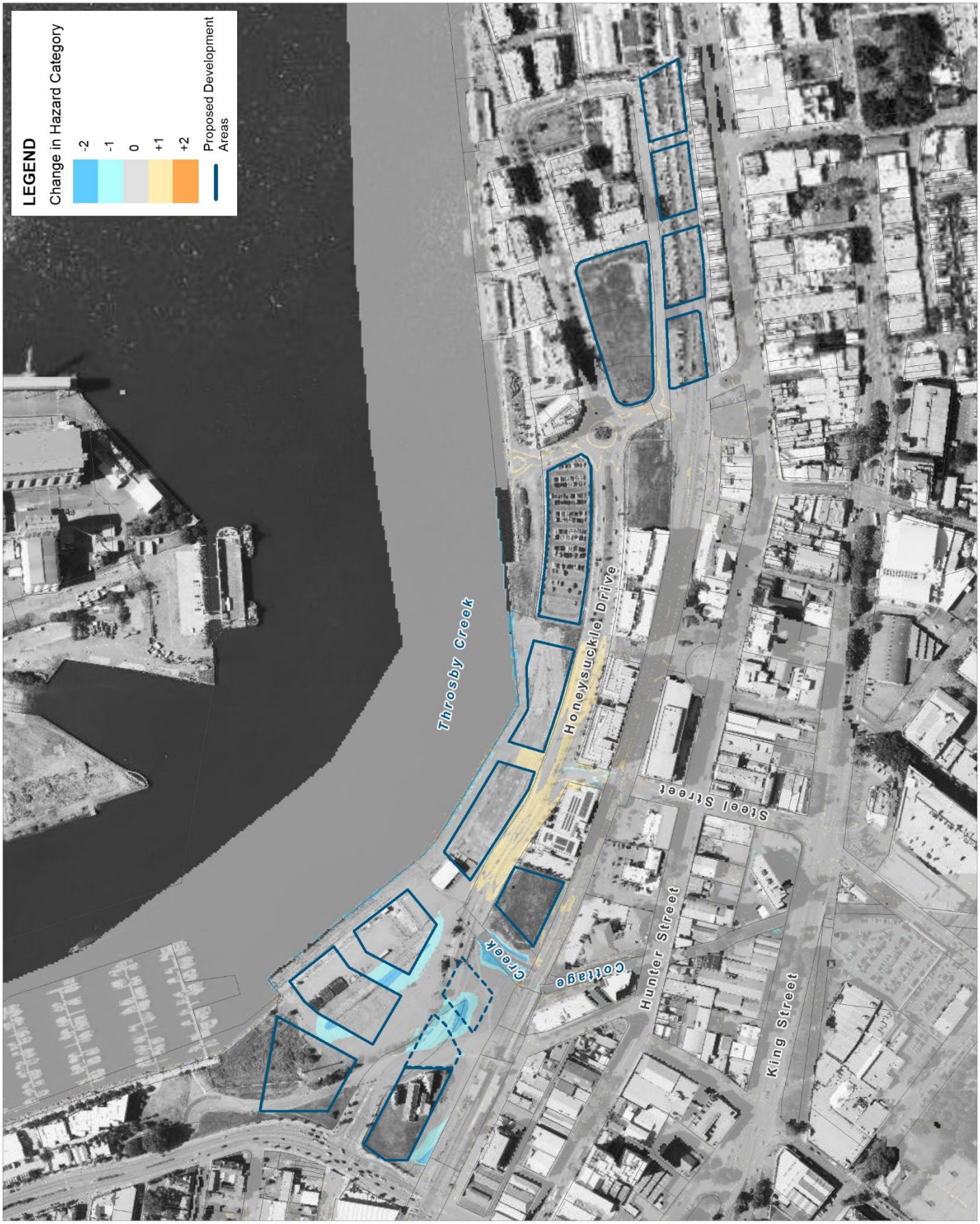
Filepath K:\N20778_Honeysuckle_Development_FIA\MI\Workspaces\Figures\DRG_100_100y_DEV028_Hazard_Afflux_001.WOR



Title:

Change in Best Practice Flood Hazards - 0.5% AEP Design Event HDC Preliminary Layout

Figure: **C-10**

Rev: **A**

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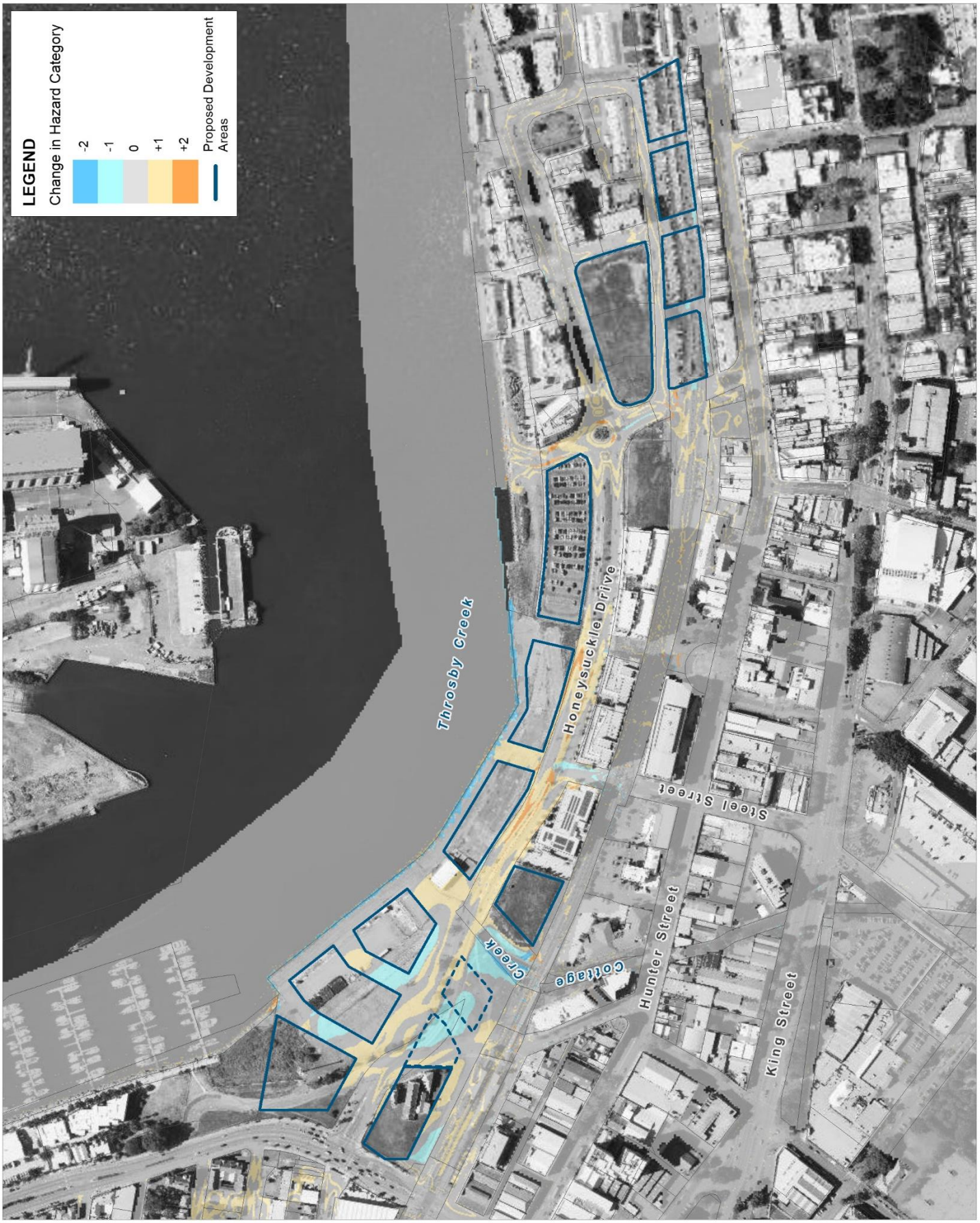

Title:

Change in Best Practice Flood Hazards - 0.2% AEP Design Event
HDC Preliminary Layout

Figure: **C-11**

Rev: **A**

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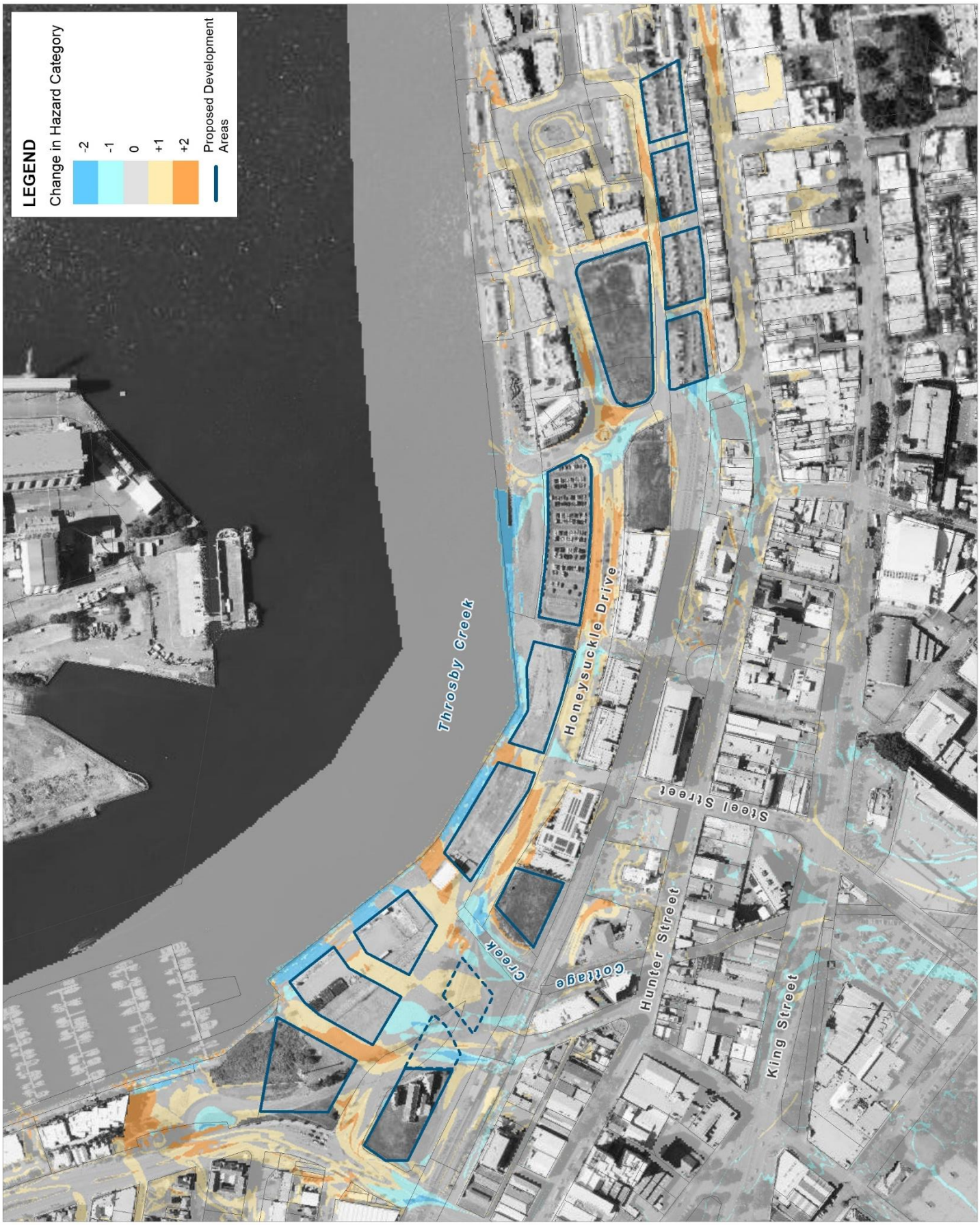
Filepath K:\N20778_Honeysuckle_Development_FIA\MI\Workspaces\Figures\DRG_102_500y_DEV028_Hazard_Afflux_001.WOR



Title:

Change in Best Practice Flood Hazards - PMF Design Event
HDC Preliminary Layout

Figure: **C-12**

Rev: **A**

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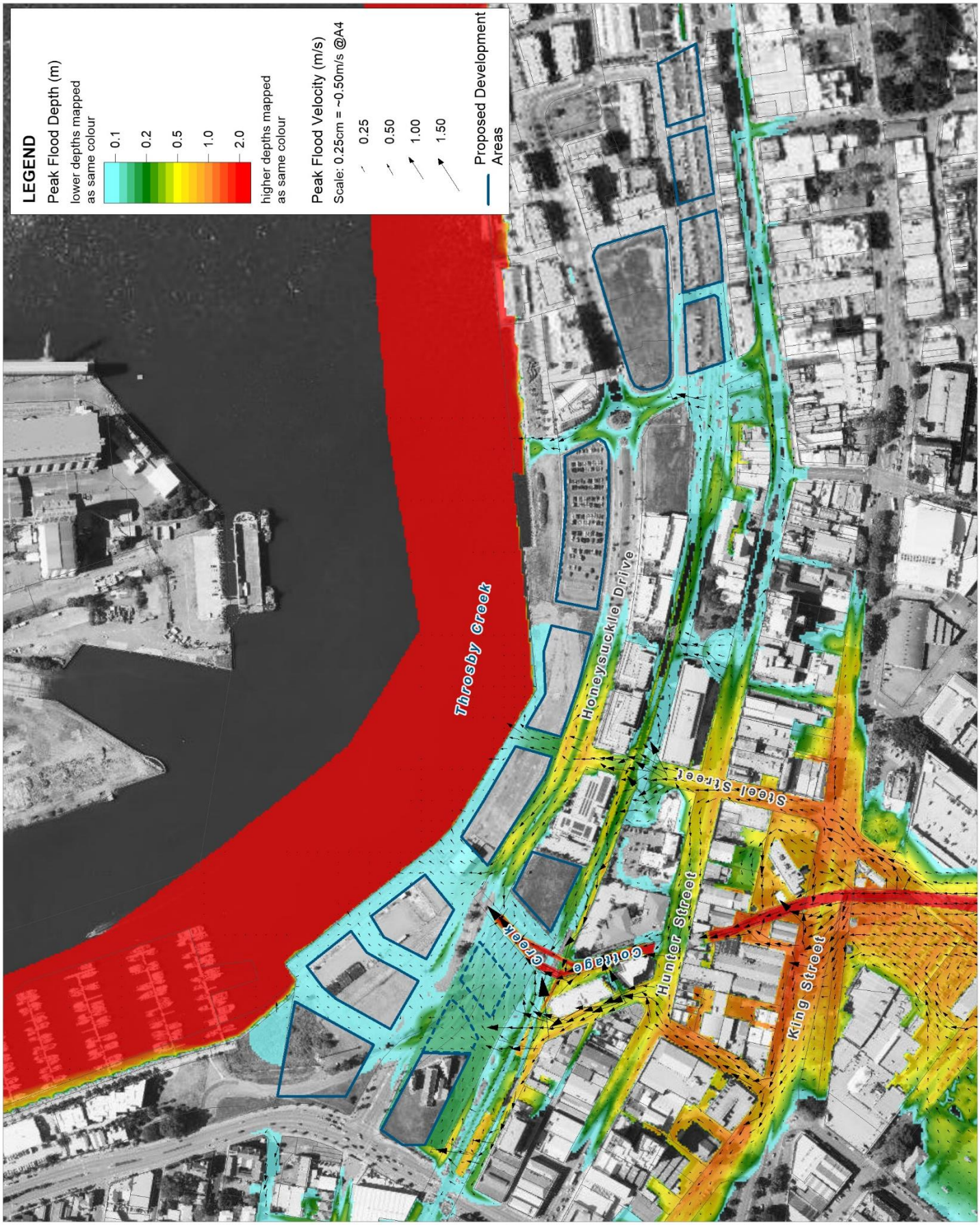
Appendix D Flood Planning Mapping



Title:

Flood Condition for the 1% AEP Design Event
HDC Preliminary Layout

Figure: **D-1**

Rev: **A**

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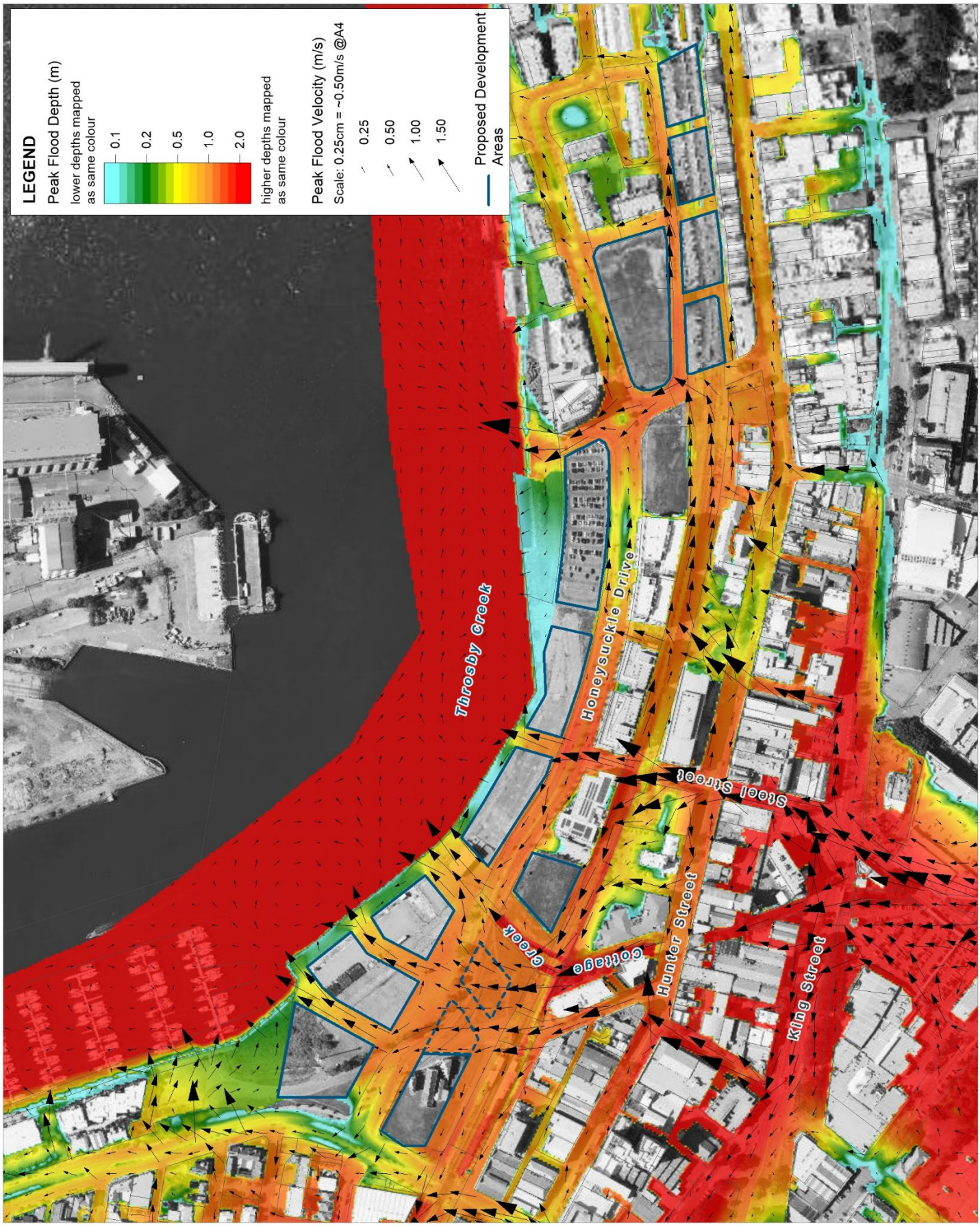

Title:

Flood Condition for the PMF Event
HDC Preliminary Layout + HWC Floodway Blocked

Figure: **D-2**

Rev: **A**

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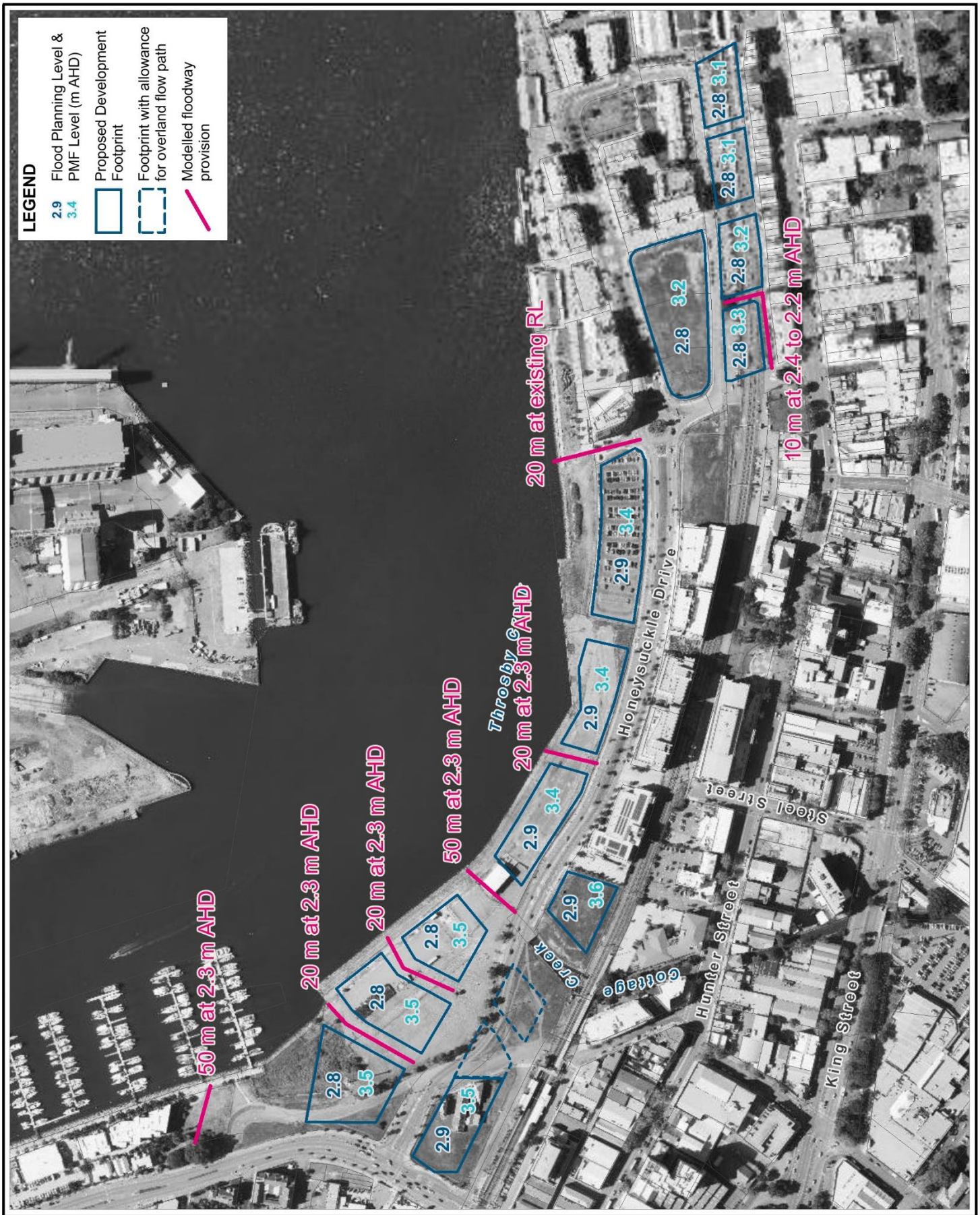
Filepath K:\N20778_Honeysuckle_Development_FIA\MI\Workspaces\Figures\DRG_085_PMF_DEV028_Depth_001.WOR



Title:

Flood Planning Levels

Figure: **D-3**

Rev: **A**

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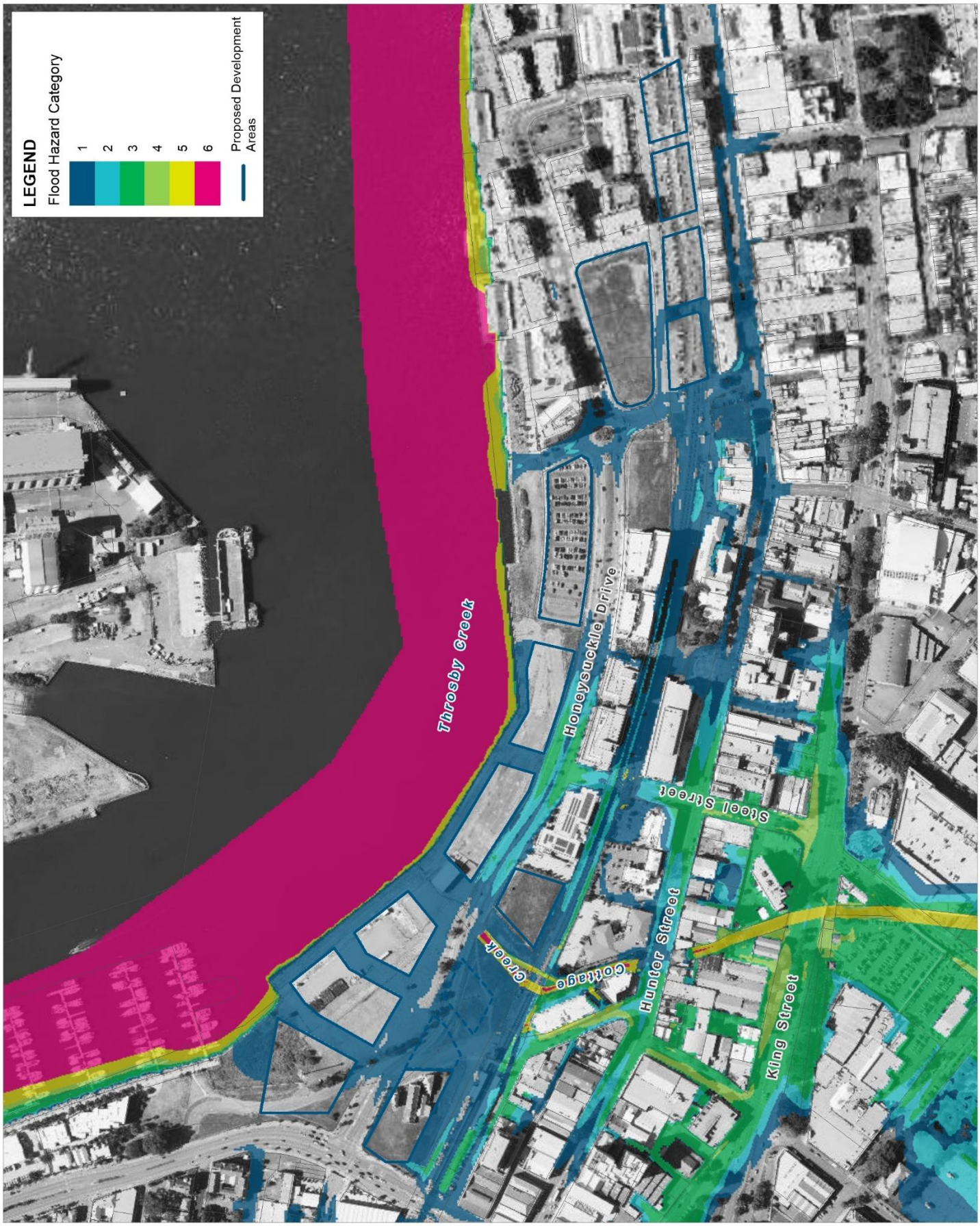

Title:

Best Practice Flood Hazards - 1% AEP Design Event HDC Preliminary Layout

Figure: **D-4**

Rev: **A**

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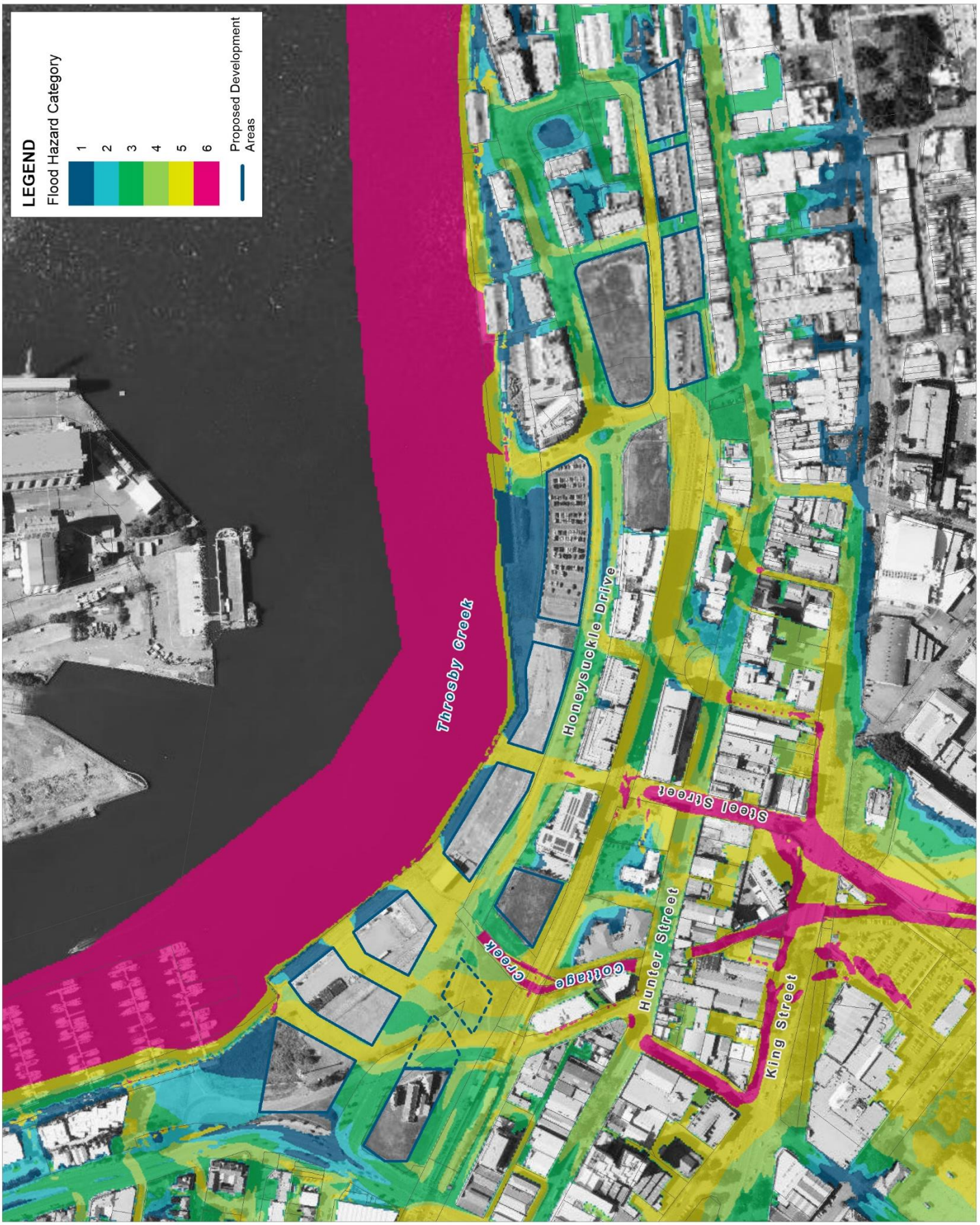
Filepath :K:\N20778_Honeysuckle_Development_FIA\MI\Workspaces\Figures\DRG_086_100y_DEV028_BPFHHazard_001.WOR



Title:

Best Practice Flood Hazards - PMF Event
HDC Preliminary Layout

Figure: **D-5**

Rev: **A**

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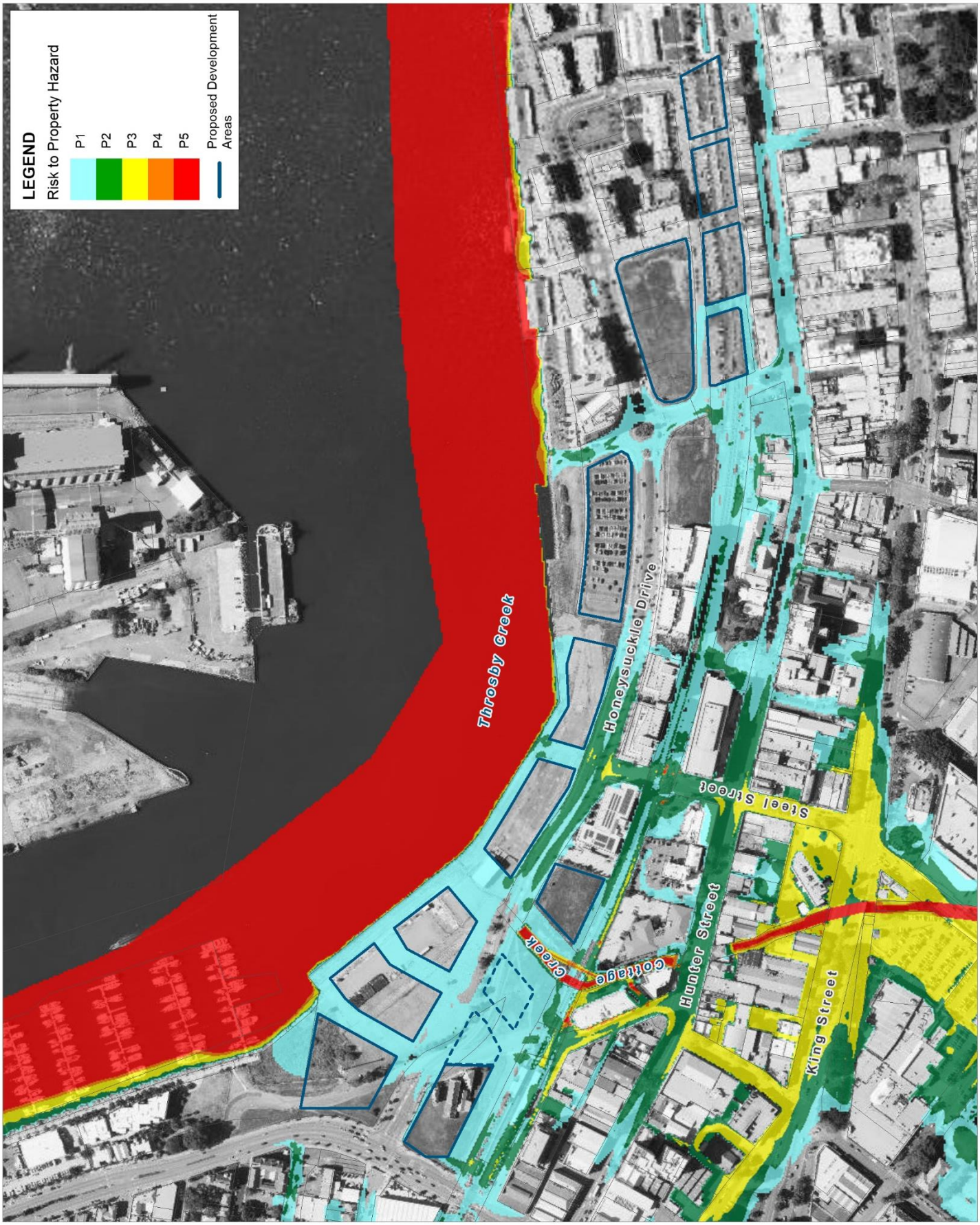

Title:

Risk to Property Hazard
HDC Preliminary Layout

Figure: **D-6**

Rev: **A**

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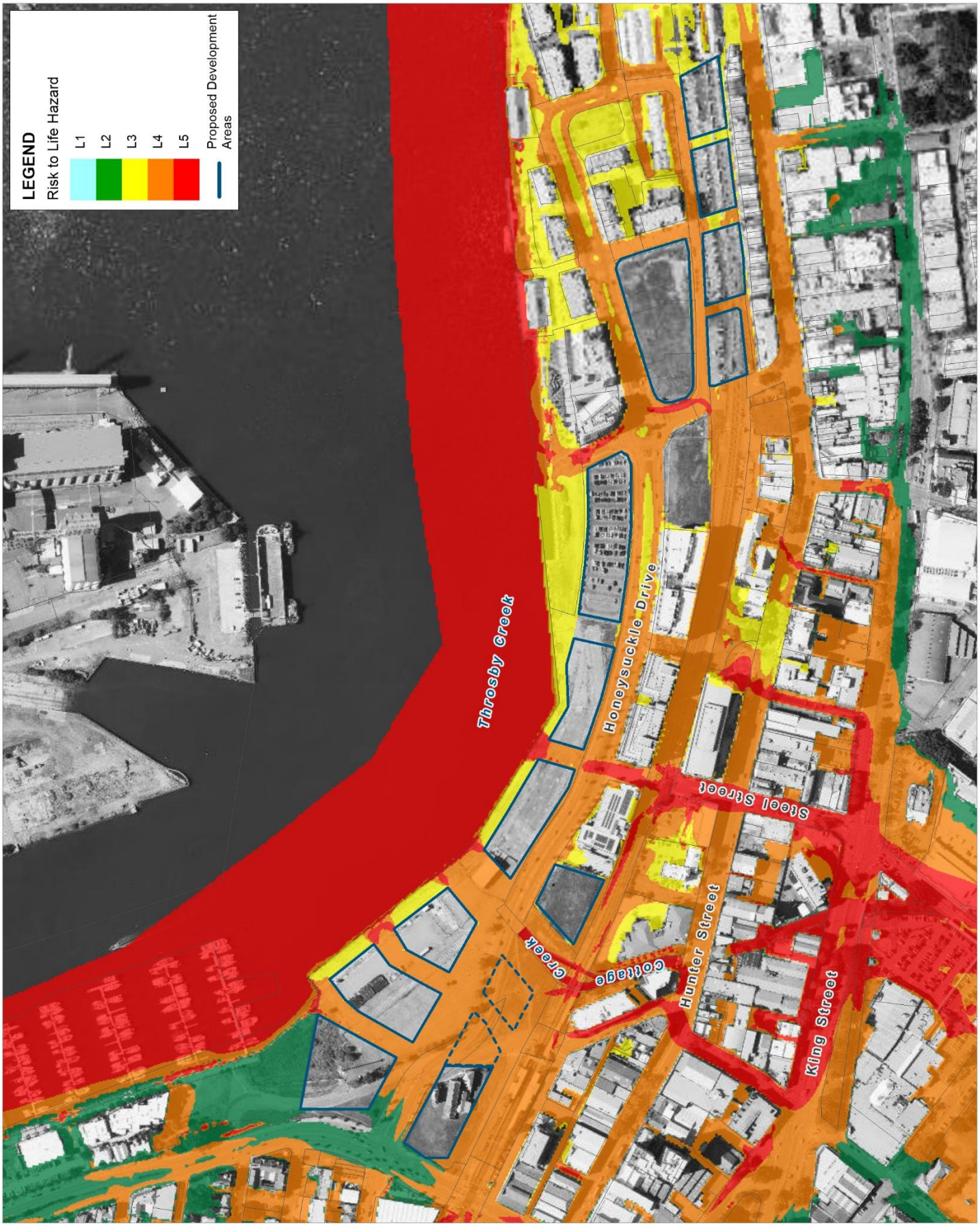

Title:

Risk to Life Hazard
HDC Preliminary Layout + HWC Floodway Blocked

Figure: **D-7**

Rev: **A**

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Title:

Hydraulic Categorisation - 1% AEP Design Event
HDC Preliminary Layout

Figure: **D-8**

Rev: **A**

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Filepath :K:\N20778_Honeysuckle_Development_FIA\MI\Workspaces\Figures\DRG_104_100y_DEV028_HydCat.WOR

Title:

Hydraulic Categorisation - PMF Event
HDC Preliminary Layout

Figure: **D-9**

Rev: **A**

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