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Flood Impact Assessment for Ivanhoe Estate Master Plan

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FINAL

Flood Impact Assessment for Ivanhoe Estate Master Plan

Prepared for:	Frasers Property Australia
Prepared by:	BMT WBM Pty Ltd (Member of the BMT group of companies)

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Executive Summary

Introduction

BMT WBM was commissioned by Frasers Property Ivanhoe Pty Ltd to undertake a flood impact assessment for the proposed Ivanhoe Estate Master Plan, Macquarie Park to satisfy the Environmental Impact Statement (EIS) conditions of the Secretary's environmental assessment requirements (SEARs).

The aim of the flood impact assessment has been to assess the impacts of the proposed Master Plan on flooding, primarily within Shrimptons Creek. Ancillary impacts giving consideration to localised overland flooding have also been considered.

The flood impact assessment is reflective of the Ivanhoe Estate Master Plan received on the 25th of November 2017, and utilises the AR&R 2001 method for estimating rainfall intensities. It is understood that future design iterations will provide further detail and analysis of the potential impacts of climate change, specifically:

- potential increase in rainfall intensity.

Furthermore, it is understood that additional analysis will be undertaken at a later stage on:

- mitigation measures for buildings near existing flood risk areas; and
- water-sensitive urban design opportunities for more flood-resilient public domain.

Catchment Description

The Ivanhoe Estate is located north-west of Sydney within the City of Ryde's Local Government Area (LGA). The estate is currently owned by the Land and Housing Corporation (LAHC) and comprises 259 social housing dwellings totalling 8.3 ha in size. The area surrounding the study site is typified by low to medium density residential development to the south and commercial developments to the north interspersed with parks and recreational areas.

The Ivanhoe Estate is located within the Shrimptons Creek catchment which has a contributing upstream area of approximately 600 ha. The Shrimptons creek catchment includes the suburbs of Ryde, North Ryde, Marsfield and Macquarie Park.

Data Collection and Review

The Shrimptons Creek catchment has previously been modelled during investigations into catchment flooding. Flood studies, floodplain risk management studies and historic flood event analysis have all been undertaken for the Shrimptons Creek catchment.

The Shrimptons Creek TUFLOW model developed by Bewsher in 2010 was created as a part of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). The Macquarie Park catchment was broken up into several smaller catchments, constituting the tributary creeks of Lane Cover River, one of which is Shrimptons Creek.

The Shrimptons Creek TUFLOW model was provided by the City of Ryde Council to be used for the sole purpose of satisfying the Secretary's Environmental Assessment Requirements (SEARs).

Flood Model Development

The existing Shrimptons Creek TUFLOW model utilised runoff-routing software DRAINS to generate sub-catchment flow hydrographs. With the exception of Ivanhoe Estate, the existing DRAINS model hydrographs were maintained within the revised TUFLOW model. Within Ivanhoe estate, the DRAINS sub-catchment hydrographs were replaced with ‘rainfall on grid’, which applies design rainfall directly onto the individual cells of the TUFLOW model.

Additional updates were made to the TUFLOW model as follows:

(1) The underlying Digital Elevation Model (DEM) was updated to include recent ground elevation data including; 2013 LPI LiDAR and ground elevation survey provided by ADW Johnson Pty Ltd (drawing ref: 300001-DET-001-A).

(2) The existing drainage network was updated to include the details of survey undertaken by ADW Johnson Pty Ltd including; pipe diameter, invert levels and additional drainage network.

Design Event Modelling and Output

The developed hydrological and hydraulic models have been applied to derive design flood conditions within the Ivanhoe Estate study area. Design rainfall depth is based on the generation of intensity-frequency-duration (IFD) design rainfall curves based on IFD data and utilising the procedures outlined in AR&R (2001). For simplicity, this study has adopted the temporal patterns and initial and continuing loss guidance in accordance with ARR (2001) to ensure consistency with the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010).

The design events considered in this study include the 20 year ARI, 100 year ARI and Probable Maximum Flood (PMF) events. The model results for the design events considered have been presented in Appendix B. Maps have been produced showing flood depth, flood velocity, flood velocity-depth product, provisional flood hazard, provisional hydraulic category and flood risk mapping.

Flood Impact Assessment

In order to assess the proposed Ivanhoe Estate Master Plan, modelling was undertaken to represent the development within the TUFLOW hydraulic model (proposed scenario model). The proposed scenario TUFLOW model was updated to incorporate revisions to land use, model topography, drainage network and building layout at the site to represent the proposed Master Plan. Appendix C presents the results of the proposed Ivanhoe Estate Master Plan and Appendix D presents the change in design flood conditions due to the proposed development.

The results of the flood modelling indicated that the proposed Ivanhoe estate Master Plan caused minimal impacts when considering the 20 year ARI and 100 year ARI Shrimptons Creek flood events. No notable changes in water level or velocity were observed in the 20 year ARI event. In the 100 year ARI event, minor increases at the location of building ‘Lot B3’ were present due to the buildings encroachment into the 100 year ARI flood extent.

The magnitude of impacts for the PMF event are larger. Increases in peak water levels are present upstream of the site with significant decreases in water levels downstream from the site. However, the PMF event is typically used for emergency planning purposes only, rather than the assessment of absolute changes to modelled flood levels and velocities.

Conclusion

The flood impact assessment for the proposed Ivanhoe Estate Master Plan found negligible differences in design flood conditions and hence impacts on; emergency planning and evacuation, social and economic cost to the community and erosion, siltation, riparian vegetation and bank stability have not been altered due to the proposed Ivanhoe Estate development.

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1 Background

1.1 Introduction

BMT WBM was commissioned by Frasers Property Ivanhoe Pty Ltd to undertake a flood impact assessment for the proposed Ivanhoe Estate Master Plan, Macquarie Park to satisfy the Environmental Impact Statement (EIS) conditions of the Secretary's environmental assessment requirements (SEARs). The proposed Master Plan includes:

- residential flat buildings comprising private, social and affordable housing;
- seniors house comprising residential care facilities and self-contained dwellings;
- a new high school;
- child care centres;
- public open space and roads;
- minor retail development; and
- community uses.

The aim of this flood impact assessment has been to assess the impacts of the proposed Master Plan on flooding, primarily within Shrimptons Creek. Ancillary impacts giving consideration to localised overland flooding have also been considered.

The flood impact assessment has been undertaken using a modified version of the TUFLOW hydraulic model developed for Shrimptons Creek as a part of the City of Ryde's Macquarie Park Floodplain Risk Management Study and Plan (Bewsher, 2010). The model was provided by the City of Ryde Council to be used for the sole purpose of satisfying the Secretary's Environmental Assessment Requirements (SEARs).

In order to assess the impacts of the proposed Master Plan, the following TUFLOW hydraulic models have been developed:

- Current scenario model (refer Section 2) – the Shrimptons Creek TUFLOW model modified to include the latest aerial survey, drainage conduit survey and detailed survey of Shrimptons Creek.
- Proposed development scenario model (refer to Section 5) - builds on the current scenario model, incorporating revisions to the land uses, drainage network and building layout at the site to represent the proposed Master Plan.

The hydraulic models for the current and proposed scenarios were simulated using the 20 year Average Recurrence Interval (ARI), 100 year ARI and Probable Maximum Flood (PMF) design flood events for the critical storm duration, for both blocked and unblocked scenarios, as described in Section 3.3.

The flood impact assessment is reflective of the Ivanhoe Estate Master Plan received on the 25th of November 2017, and utilises the AR&R 2001 method for estimating rainfall intensities. It is understood that future design iterations will provide further detail and analysis of the potential impacts of climate change, specifically:

- Potential increase in rainfall intensity;

Furthermore, it is understood that additional analysis will be undertaken on:

- Mitigation measures for buildings near existing flood risk areas;
- Water-sensitive urban design opportunities for more flood-resilient public domain.

1.2 Study Area and Catchment Topography

The locality of Ivanhoe Estate is shown in Figure 1-1. The site is located north-west of Sydney within the City of Ryde's Local Government Area (LGA). The Ivanhoe Estate is currently owned by the Land and Housing Corporation (LAHC) and comprises 259 social housing dwellings totalling 8.3 ha in size. The area surrounding the study site is typified by low to medium density residential development to the south and commercial developments to the north interspersed with parks and recreational areas.

The Ivanhoe Estate is located within the Shrimptons Creek catchment which has a contributing upstream area of approximately 600 ha. The Shrimptons creek catchment includes the suburbs of Ryde, North Ryde, Marsfield and Macquarie Park.

1.3 Local Council Development Controls

A summary of potential site constraints, in relation to the proposed Master Plan and in accordance with the City of Ryde's Development Control Plan 2014 is given below. This list is not exhaustive, and where necessary, reference should be made to Councils *Part: 8.2 Stormwater Management Technical Manual* to ensure compliance with development controls.

(1) For Commercial and Recreational developments floor levels of habitable and non-habitable areas must comply with the freeboard requirements as stated in Table 2.1 of the Stormwater Technical Manual, reproduced below in Table 1-1. If these levels cannot be practically achieved for the entire floor area (E.g. for reasons of accessibility from a public space) then a lesser level may be considered subject to consideration of the extent or scale of property damage and risk to public safety

(2) Sensitive Uses and Facilities, defined as; Development accommodating services or facilities which are essential to evacuation during periods of flooding or if affected would unreasonable affect the ability of the community to return to normal activities after flood events. Examples of this include educational establishments, residential care facilities, fuel stations, public utility buildings, etc.
For Sensitive Uses and Facilities developments all floor levels must be no lower than the PMF level. Exemption from this may be considered, subject to consideration of the extent or scale of impact to the community that would occur in the event the structure is inundated.

(3) Critical Uses and Facilities, defined as; Emergency services facilities, administration building or public administration building that may provide an important contribution to the notification or evacuation of the community during flood events.

Title:
Site Locality

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(4) Basement parking or parking at levels below the adjacent flood levels, a bunded crest at the estimated PMF (probable maximum flood) level prior to descent into the parking area, must be provided such that inundation of the area is prevented.

Table 1-1 Freeboard Requirements

Drainage System/ Overland Flow	Residential			Industrial/Commercial	
	Land Level	Habitable Floor Level	Non-Habitable Floor Level	Land Level	Floor Level
Surface Drainage/ Adjoining Ground Level	-	0.15	-	-	0.15
Public Drainage Infrastructure, Creeks and Open Channels	0.5	0.5	0.1	0.3	0.3
Flooding and Overland Flow (Overland Flow Precincts and Low Risk)	N/A	0.3	0.14	N/A	0.3
Flooding and Overland Flow (Medium Risk and greater)	N/A	0.5	0.3	N/A	-
Onsite Detention	N/A	0.2	0.1	N/A	0.2
Road Drainage Minor Systems (Gutter and Pipe Flow)		0.15 below top of grate			
Road Drainage		Refer to Figure 2-1 of *Part: 8.2 Stormwater Management Technical Manual*			
Detention Basins		The top water level shall be designed to be 0.5 below the top of embankment (100 year ARI)			

1.4 Shrimptons Creek Model Review, Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010)

The Shrimptons Creek TUFLOW model developed by Bewsher in 2010 was created as a part of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). The Macquarie Park catchment was broken up into several smaller catchments, constituting the tributary creeks of Lane Cover River, one of which is Shrimptons Creek.

The initial stages of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010) involved the Macquarie Park Flood Study, which defined flood behaviour within the catchment, including the analysis of flows within the underground pipe drainage network and surface runoff. The flood study modelled a range of design flood events, from relatively frequent events to more extreme floods.

A numerical computer model was developed for the catchment to simulate flood behaviour, utilising the 2D surface water modelling software TUFLOW. TUFLOW has the capability to simulate the dynamic interaction of in-bank flows in open channels, major underground drainage systems, and overland flows through complex overland flow paths using a linked 1D/2D flood modelling approach.

The stormwater pit and pipe network and in-bank creek areas were modelled utilising one-dimensional elements linked dynamically with the 2D grid. The adopted grid size for this study is 3m, providing an appropriate level of resolution and detail across the catchment, while keeping model simulation times reasonable.

2 Flood Model Development – Current Scenario

2.1 Introduction

The purpose of the flood modelling for the flood impact assessment is to investigate the flood behaviour within the vicinity of the proposed Ivanhoe Estate Master Plan and the impacts of the proposed development on this flood behaviour. This includes the consideration of:

- Stormwater runoff within the vicinity of and across the Ivanhoe site (overland flow);
- Flows within the underground pipe drainage network; and
- Flows within the Shrimptons Creek at the south-eastern boundary of the site (mainstream flow).

Whilst consideration has been given to all flooding mechanisms at the proposed development site, the primary flood consideration is those within Shrimptons Creek, which constitute mainstream flooding.

The following Section details the updates which were made to the existing Shrimptons Creek flood model, such that the design flood conditions could be re-established for use in the flood impact assessment.

2.2 Hydrologic Model

The hydrologic model predicts the amount of runoff from rainfall and the attenuation of the flood wave as it travels down the catchment. This process is dependent on catchment area, slope and vegetation; variation in distribution, intensity and amount of rainfall; and antecedent conditions of the catchment.

The existing Shrimptons Creek model utilised runoff-routing software DRAINS to generate sub-catchment flow hydrographs for inclusion into the hydraulic model. With the exception of Ivanhoe Estate, the existing DRAINS model hydrographs were maintained within the current scenario model.

Within Ivanhoe estate, the DRAINS sub-catchment hydrographs were replaced with ‘rainfall on grid’, which applies design rainfall directly onto the individual cells of the TUFLOW model. This is particularly useful for studies where model results are desired in areas with small contributing catchments.

For design events, rainfall depths are usually determined by the estimation of intensity-frequency-duration (IFD) design rainfall curves for the catchment. Standard procedures for derivation of these curves are defined in ARR (2001). Table 2-1 shows design rainfall intensities utilised within the Ivanhoe estate.

Table 2-1 Design Rainfall Intensities (mm/h)

Duration (h)	Design Event	
	2 yr ARI	50 yr ARI
1	27.5	74.2
12	8.38	18.5
72	2.72	6.11

The recently released ARR update (2016) revised the recommended application of temporal patterns for use in design flood estimation. For simplicity, this study has adopted the temporal patterns and initial and continuing loss guidance in accordance with ARR (2001) to ensure consistency with the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). Similarly, a critical storm duration of 120 minutes for 20 year ARI and 100 year ARI events was maintained for this study as well as a 15-minute duration for the PMF event.

2.3 Hydraulic Model

BMT WBM has updated the existing Shrimptons Creek TUFLOW model. TUFLOW has the capability to simulate the dynamic interaction of in-bank flows in open channels, major underground drainage systems, and overland flows through complex overland flow paths using a linked 1D/2D flood modelling approach

The updates made to the existing Shrimptons Creek TUFLOW model are discussed in further detail below.

2.3.1 2D Model Domain and Topography

The 2D model cell size of 3 m utilised in the existing Shrimptons Creek model was maintained for this study. A cell size of 3 m was determined to be accurate to define the floodplain, including local topographical controls (e.g. perched channel banks, underpasses and road embankments) at and around the site. TUFLOW samples elevation points at the cell centres, mid sides and corners, so a 3 m cell size results in DEM elevations being sampled every 1.5 m.

The underlying DEM in the areas immediately surrounding the Ivanhoe site were updated utilising the latest available LiDAR (Light Detection and Ranging) survey, captured by the NSW Government's Land and Property Information (LPI) in 2013.

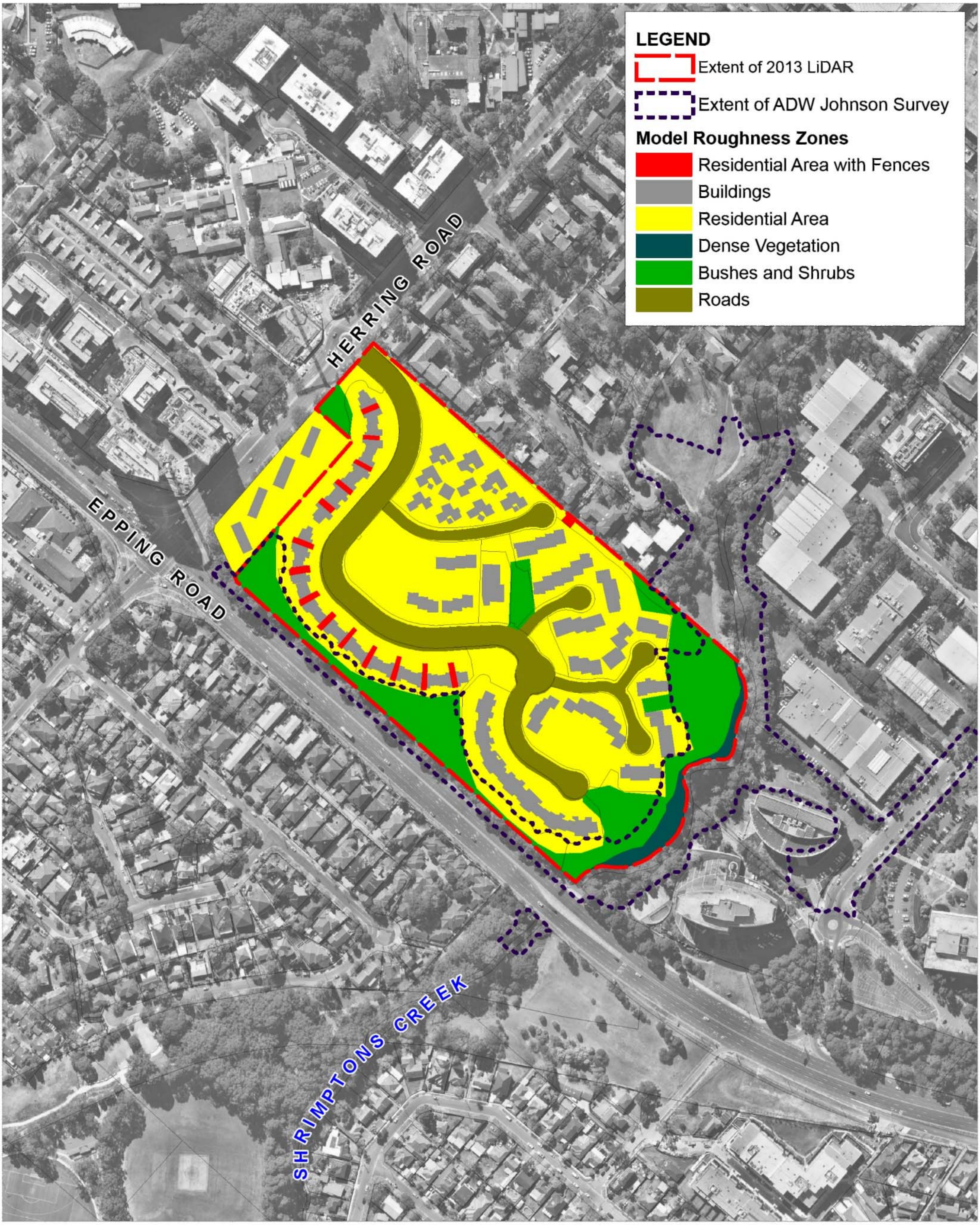
Additional survey of Shrimptons Creek was provided by ADW Johnson Pty Ltd (drawing ref: 300001-DET-001-A). The survey was conducted the 5th of July 2017, and represents the most accurate definition of Shrimptons Creek available at the time of modelling.

Figure 2-1 shows the different sources of underlying topography, in addition to the model roughness zones discussed further below.

Hydraulic Roughness (Manning's 'n')

Another input required in the development of the TUFLOW model is the assignment of different hydraulic roughness zones to represent the variation in flow resistance. These zones (e.g. creek channel, cleared land or vegetated areas) were maintained from the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). Manning's 'n' roughness values were determined by using the adopted values from the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010).

The Manning's 'n' roughness values are listed in Table 2-2. The spatial distribution of materials roughness zones representing variations in hydraulic roughness is presented in Figure 2-1.



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2D Model Domain

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Table 2-2 Adopted Model Roughness Values (Manning's n)

Material Description	Model Roughness (Manning's 'n')
Urban Properties (with Fencing)	0.100
Urban Properties	0.025
Water Body	0.020
Roads	0.020
Short Grass / Bare Earth	0.030
Forest	0.100
Buildings	20.000

Buildings

The influence of buildings and other obstacles to the passage of flow in urban floodplains is an important issue in the context of urban floodplain management (Engineers Australia, 2012). In a typical urban floodplain, some buildings will be elevated on fill and totally obstruct the passage of floodwater, others may be inundated with floodwater ponding inside the building, whilst others may be elevated on piers allowing flow under the building.

The buildings of the existing Shrimptons Creek model were modelled by elevating 0.2 m above the underlying DEM with an increased roughness (n = 20) to represent the energy dissipation of water flowing through and around buildings. The methodology utilised in the existing Shrimptons Creek model was maintained for this study.

Drainage Network

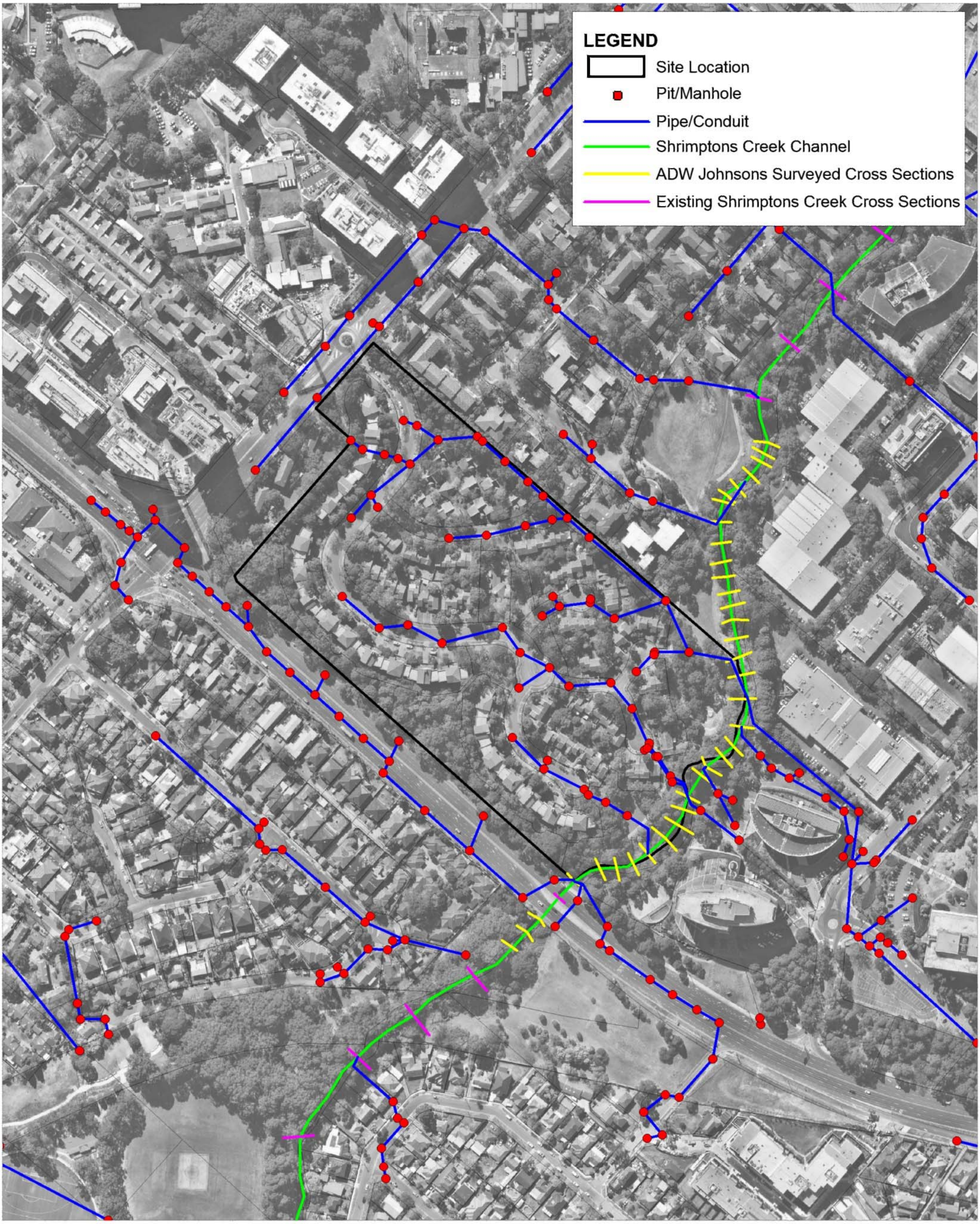
The existing Shrimptons Creek TUFLOW model utilised 1D cross-sections to model the in-bank flows of Shrimptons Creek. Cross-sections were placed at approximate 100 m intervals, and were '*directly extracted from specifically commissioned supplementary field measurements undertaken by registered surveyors*' (Bewsher 2010).

To provide greater definition of flooding within the section of Shrimptons Creek immediately adjacent to Ivanhoe Estate, 1D cross-sections were spaced at 20m intervals and updated utilising the survey data provided by ADW Johnson Pty Ltd (drawing ref: 300001-DET-001-A).

Pipe and Pit drainage networks from the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010) were updated with Survey Data by ADW Johnson Pty Ltd (drawing ref: 300001-DET-001-A). Updates included;

- Updating pipe diameters with survey information;
- Updating drainage pipe and pit network to match surveyed invert levels;
- The inclusion of local stormwater drainage which had not previously been included.

Figure 2-2 illustrates the 1D model elements included within the current scenario model for this study.



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2.3.3 Rainfall on Grid

As discussed in Section 2.2, the DRAINS sub-catchment hydrographs located within Ivanhoe Estate were replaced with ‘rainfall on grid’, which applies design rainfall directly onto the individual cells of the TUFLOW model.

The losses applied to the Ivanhoe Estate rainfall on grid were maintained from the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010), utilising an initial loss of 5 mm and 1 mm for pervious and impervious areas respectively with no continuing losses. Design temporal pattern Zone 1 was utilised as is recommended for catchments located in eastern NSW.

A comparison between the original model results and the current scenario model is shown in Section 4.2 to validate the use of rainfall on grid.

3 Design Flood Conditions

3.1 Introduction

Design storm events are hypothetical events that are used to estimate design flood conditions. They are based on a probability of occurrence, usually specified as an ARI or as an Annual Exceedance Probability (AEP). Chapter 5 of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010) describes the design storm conditions which have been utilised in this study. The 20 year ARI, 100 year ARI and PMF events have been assessed as part of this study. Table 3-1 lists the variables assessed for each design event. Further discussion on each of these variables is in the following report sections.

Table 3-1 Design Flood Combinations

Design Flood Condition	Design Rainfall	Blockage Scenario
20 Year ARI	20 Year ARI, 2 Hour Storm	Unblocked
		Blocked
100 Year ARI	20 Year ARI, 2 Hour Storm	Unblocked
		Blocked
Probable Maximum Flood (PMF)	PMF, 15 Minute Storm	Unblocked

3.2 Design Rainfall

The Australian Rainfall and Runoff (AR&R, 2001) method has been used to estimate design rainfall intensities and depth for the 20 year and 100 year ARI design storm events and the Bureau of Meteorology's Generalised Short-Duration Method has been used to estimate the probable maximum flood event.

A critical duration of 2 hours for the 20 year and 100 year ARI design storm events, and 15 minutes for the PMF was utilised for this assessment based on the modelling previously undertaken for the Shrimptons Creek catchment.

3.3 Drainage Blockage

The blockage of drainage conduits for this study utilises the same methodology documented in the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). The blockage factors applied for the blocked design condition in both the current and proposed scenario models is given below:

- A blockage factor of 25% was applied to culverts/bridges whose diagonal dimension exceeds 6m;
- A blockage factor of 35% was applied to culverts/bridges whose diagonal dimension is between 2m and 6m;
- A blockage factor of 50% was applied to culverts whose diagonal dimension is less than two meters.

Peak flood depth, velocity, velocity depth product, provisional flood hazard, provisional hydraulic categorisation and impacts have been determined from the combined ‘maximum envelope’ of both the blocked and unblocked conditions.

4 Model Results

4.1 Introduction

The following results for the current scenario are presented in Appendix B:

- Peak flood depth maps for each of the modelled design flood events;
- Peak flood velocity maps for each of the modelled design flood events;
- Peak flood velocity depth product maps for each of the modelled design flood events;
- Provisional hazard category map for the 100 year ARI and PMF events;
- Provisional hydraulic categorisation map for the 100 year ARI and PMF events; and
- Provisional Flood Risk Precinct mapping.

Flood mapping has been undertaken using the combined 'maximum envelope' of both the blocked and unblocked drainage scenarios for the critical 120-minute storm event for the 20 year and 100 year ARI events and 15-minute storm for the PMF. Flood mapping is shown for predicted peak water depths higher than 0.1m, consistent with that of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010).

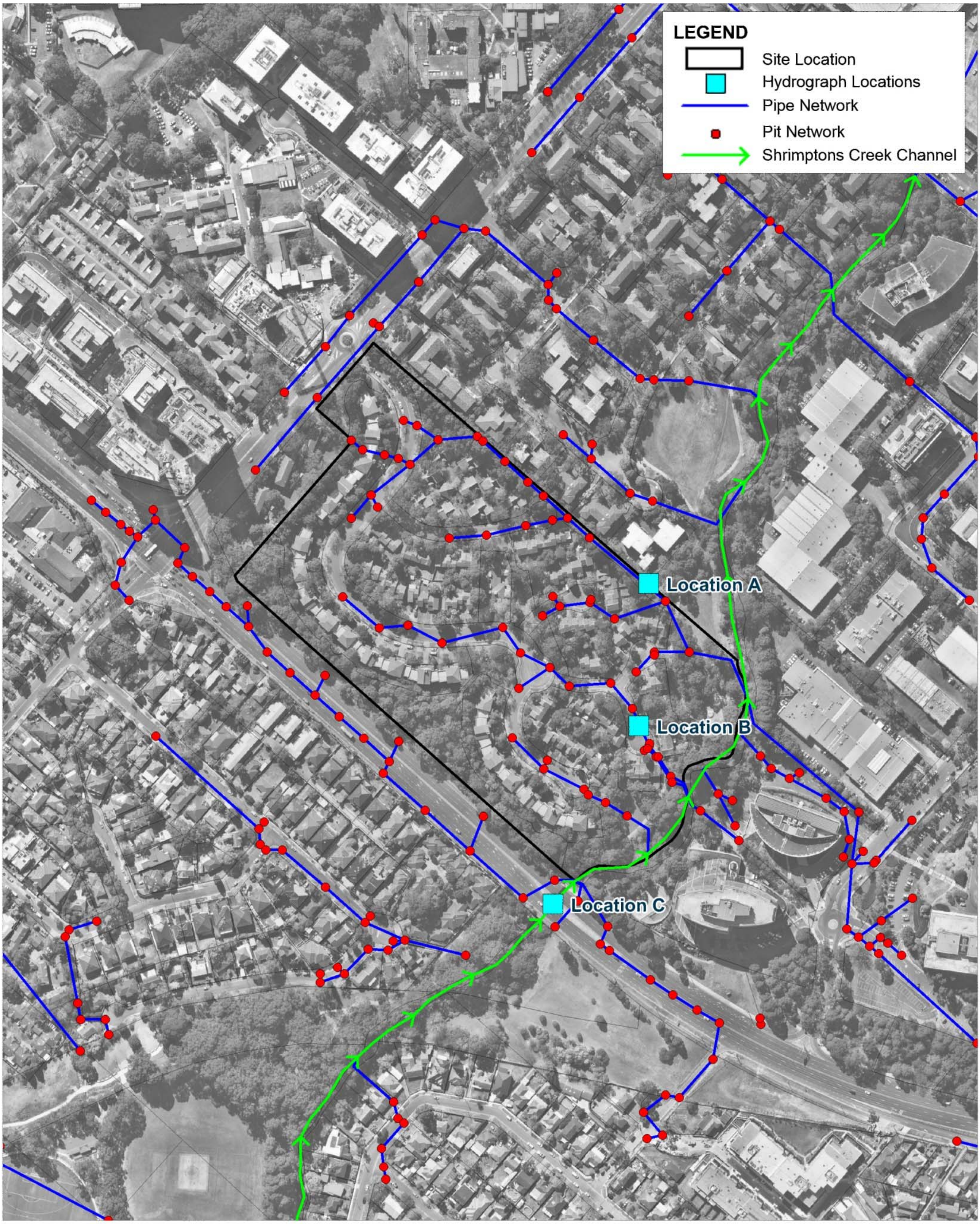
4.2 Comparison of Peak Flows with Existing Shrimptons Creek Model

To ensure conformance with the existing Shrimptons Creek model, peak flows at a number of drainage conduits (pipe and channels) were compared with the current scenario model. The comparison was undertaken primarily to validate the use of rainfall on grid within the Ivanhoe estate, and ensure conformance with the existing Shrimptons Creek model which utilised DRAINS sub-catchment inflows.

Figure 4-1 shows the locations where flood hydrographs were compared between the current scenario model, discussed in Section 2, and the TUFLOW model used in Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010). Figure 4-2 shows the design event hydrographs for each location.

In general, the current scenario model conformed well with the Shrimptons creek model; with locations A and C recording peak flows within 3%. Furthermore, the rate of rise and fall of the hydrograph limbs generally matched.

Location B indicated some differences in peak flow, most notably in the 20 year ARI. This is due to the difference in routing between the DRAINS model and TUFLOW rainfall on grid. DRAINS models internally route the excess run-off utilising the 'time-area' method which combines the rainfall hyetograph of 3 separate sub-areas (paved, supplementary and grassed) into a single hydrograph utilising separate parameters for each sub-area. The resulting hydrograph is injected directly into the 1D TUFLOW elements (pits and pipes). The rainfall on grid approach does not apply rainfall directly onto the 1D TUFLOW elements, but rather on the entire 2D mesh. The TUFLOW model routes the excess run-off via the underlying DEM, accounting for model roughness and slope to determine the run-off route across the 2D mesh. The TUFLOW parameters are represented spatially in GIS, and are typically of greater definition and detail than can be accounted for in a DRAINS model.



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Hydrograph Locations

Figure: **4-1**

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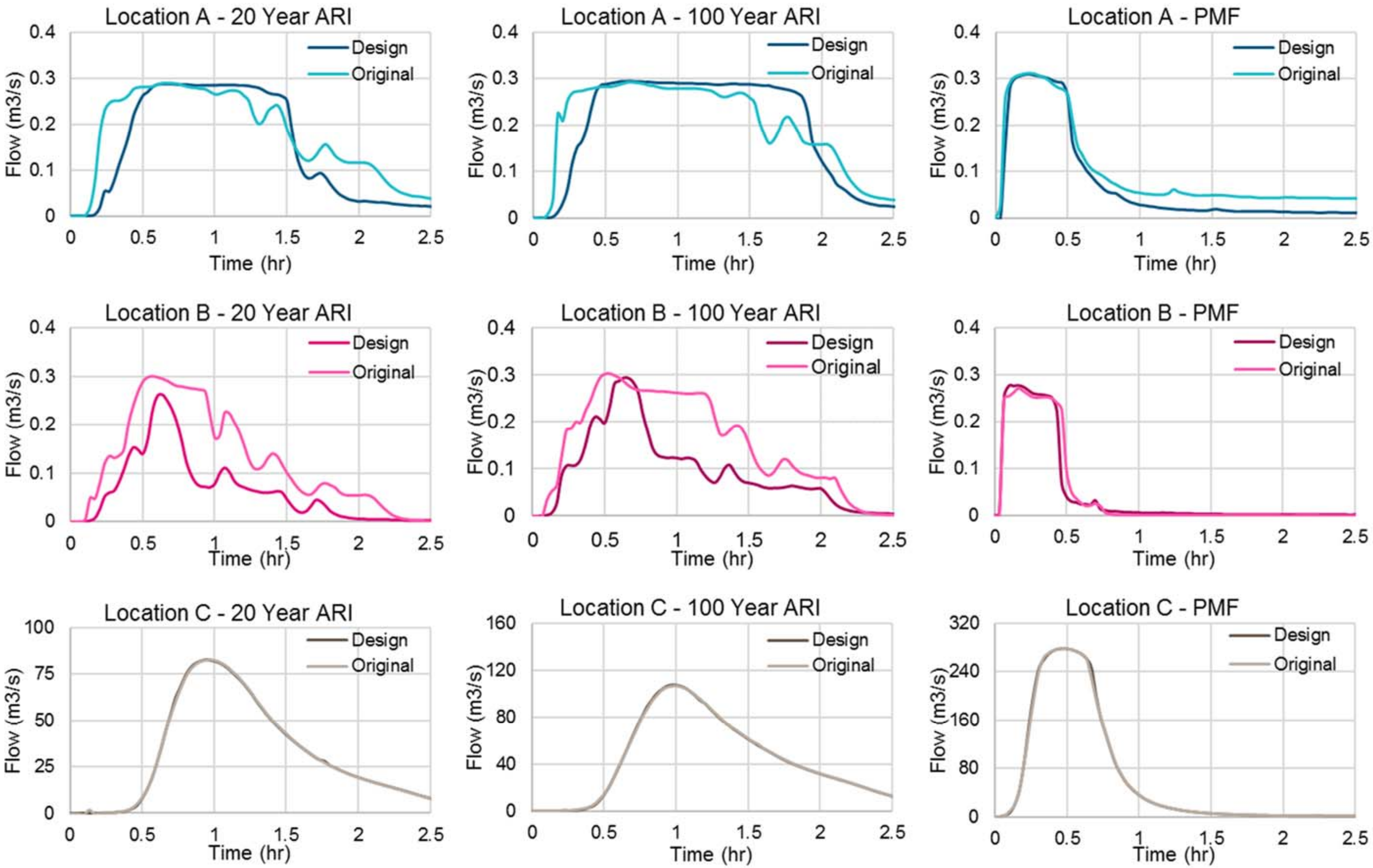


Figure 4-2 Hydrographs at Location A, Location B and Location C

4.3 Description of Flood Behaviour under Current Conditions

Design flood simulations were undertaken for the 20 year ARI, 100 year ARI and PMF design events. Figure 4-3 shows the peak flood depth at the site for the 100 year ARI event, all other results are presented in Appendix B.

In all design events, local drainage flows are conveyed across the site in a south-easterly direction. These flows are typified by shallow inundation (low depths), and minor velocities (<0.2m/s). These areas are referred to as 'Local Drainage' under the Floodplain Development Manual, and as such are omitted from further analysis (i.e. not considered within the Flood Impact Assessment, refer Section 5).

As shown in Figure 4-3, mainstream flood inundation within Ivanhoe Estate is largely confined to the distinct left and right bank of Shrimptons Creek. In the 100 year flood, Shrimptons creek is elevated approximately 2 m above the typical low-flow depth, causing the left bank of Shrimptons Creek to encroach onto Ivanhoe Estate by approximately 30 m. In the PMF event, this increases to 45 m.

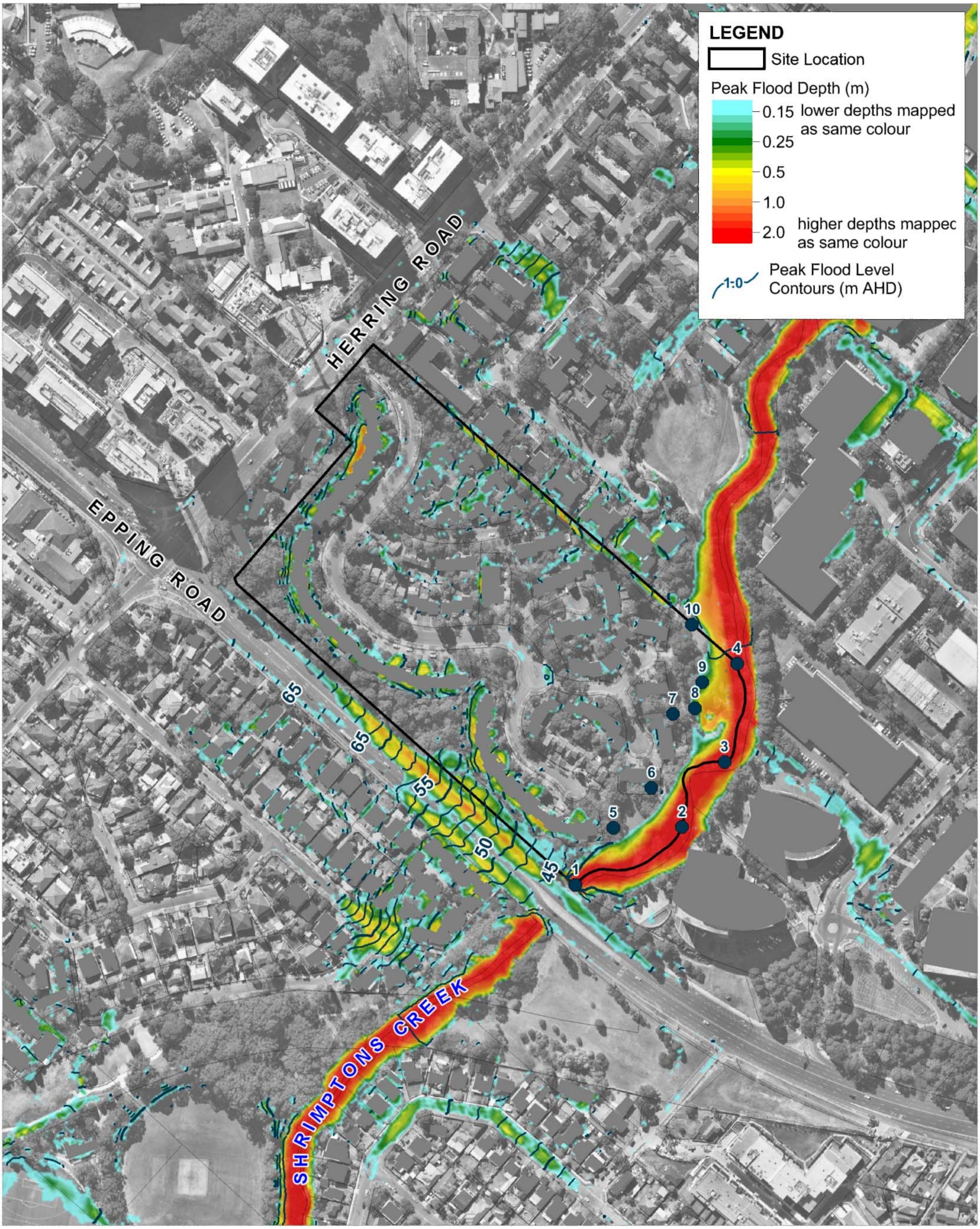
Flood depths in Shrimptons Creek range from 0 m at the bank sides, to depths of greater than 2 metres at the creek centreline. Shrimptons Creek velocities exceed 2 m/s at the creek centreline falling to 0-0.5m/s at the bank sides.

Peak flood levels within Shrimptons Creek for each modelled design event have been tabulated below in Table 4-1.

Table 4-1 Design Peak Flood Levels (m AHD) at Ivanhoe Estate

Location (refer Figure 4-3)	X co-ordinate	Y co-ordinate	Design Event		
			20 yr ARI	100 yr ARI	PMF
1	325659.3097	6260198.446	44.74	44.99	46.71
2	325742.8566	6260243.747	44.37	44.64	46.27
3	325776.3017	6260294.816	44.14	44.40	45.96
4	325786.1555	6260371.621	43.76	44.04	45.75
5	325688.8216	6260243.167	NFI	NFI	46.58
6	325718.8612	6260274.38	NFI	NFI	46.18
7	325735.5343	6260332.289	NFI	NFI	45.77
8	325753.0237	6260336.808	NFI	NFI	45.79
9	325758.8288	6260357.134	NFI	44.18	45.78
10	325750.6654	6260402.184	NFI	NFI	45.61

*NFI = No Flooding Indicated



Title:

Peak Flood Depth 100 yr ARI

Figure: 4-3

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0 75 150m

Approx. Scale

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4.4 Provisional Hazard Classification

The Updating National Guidance on Best Practice Flood Risk Management (NFRAG, 2014) considers a holistic approach to consider flood hazards to people, vehicles and structures. It recommends a composite six-tiered hazard classification, reproduced in Figure 4-4. The six hazard classifications are summarised in Table 4-2.

The key factors influencing flood hazard or risk are:

- Size of the Flood
- Rate of Rise - Effective Warning Time
- Community Awareness
- Flood Depth and Velocity
- Duration of Inundation
- Obstructions to Flow
- Access and Evacuation

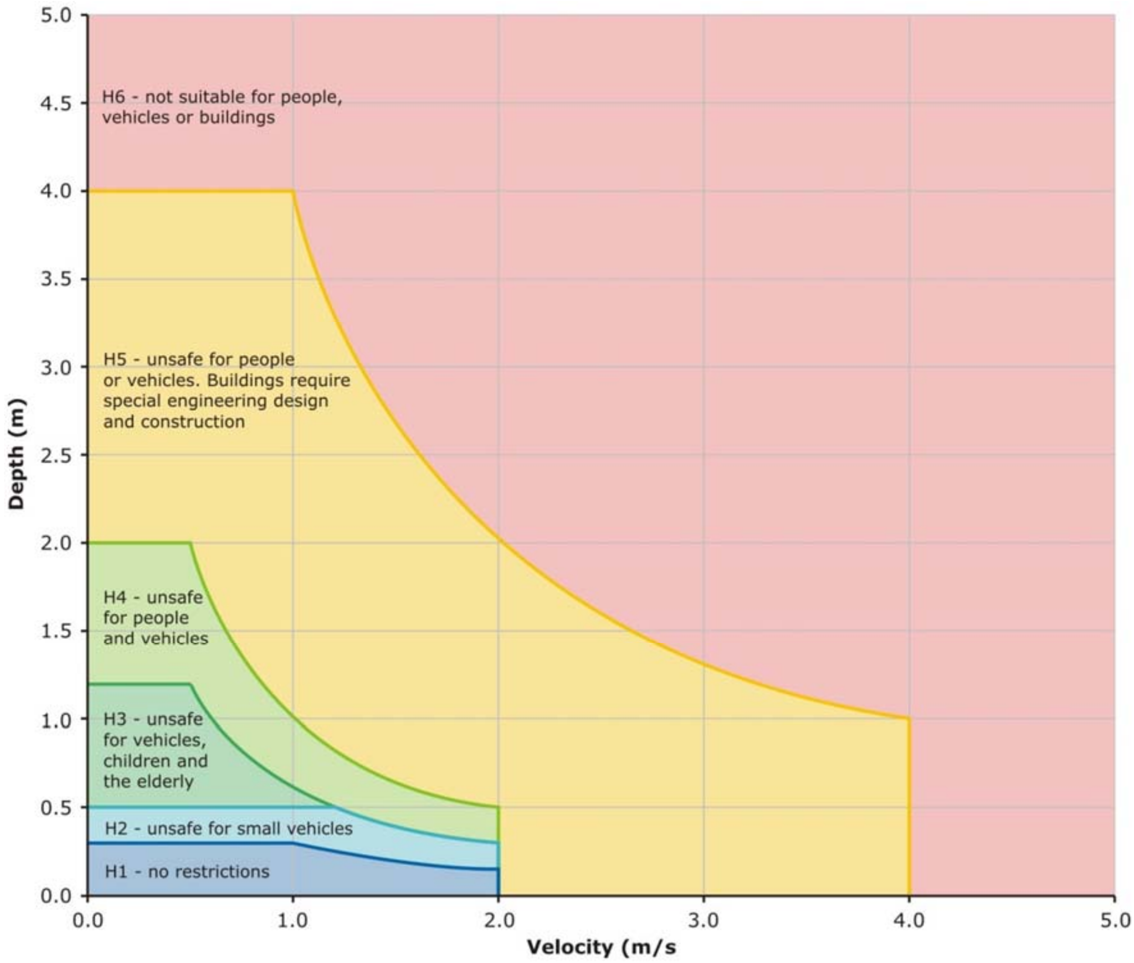


Figure 4-4 Combined Flood Hazard Curves

Table 4-2 Combined Flood Hazard Curves – Vulnerability 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 all vehicles. Buildings require special engineering design and construction.
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure.

The provisional flood hazard level is often determined on the basis of the predicted flood depth and velocity. This is conveniently done through the analysis of flood model results. A high flood depth will cause a hazardous situation while a low depth may only cause an inconvenience. High flood velocities are dangerous and may cause structural damage while low velocities generally do not.

Provisional hazard category mapping in the vicinity of the proposed development is included in Appendix B, and is presented for the 100 year ARI and PMF events.

4.5 Hydraulic Categorisation

Hydraulic categorisation is one of the tools used to identify flood behaviour and risk. Outcomes of the categorisation are primarily used to inform future land use planning. The categorisation is not used to assess individual developments, but rather to give a catchment-scale overview of which areas may be appropriate for various types of land use.

There are no prescriptive methods for determining what parts of the floodplain constitute floodways, flood storages and flood fringes. Descriptions of these terms within the Floodplain Development Manual (DIPNR, 2005) are essentially qualitative in nature. Of particular difficulty is the fact that a definition of flood behaviour and associated impacts is likely to vary from one floodplain to another depending on the circumstances and nature of flooding within the catchment.

The hydraulic 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%.
- 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.

Hydraulic categorisation was not undertaken for the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010), however Council's DCP gives reference to flood storage areas (refer Appendix A). Consequently, BMT WBM have undertaken a provisional hydraulic categorisation, utilising the approach defined by the criteria proposed by Howells et al, 2003:

Floodway is defined as areas where:

- Velocity x depth greater than 0.25 m^2/s and velocity greater than 0.25 m/s; or
- Velocity greater than 1 m/s.

Flood storage areas were identified as those areas which do not operate as floodways but where the depth of inundation exceeded 1 m.

Flood fringe is the remaining area of land affected by flooding, after floodway and flood storage areas have been defined.

Provisional hydraulic category mapping in the vicinity of the proposed development is included in Appendix B, and is presented for the 100 year ARI and PMF events.

5 Flood Impact Assessment

5.1 Introduction

In order to assess the proposed Ivanhoe Estate Master Plan, modelling was undertaken to represent the development within the TUFLOW hydraulic model (proposed scenario model). The Master Plan development includes:

- residential flat buildings comprising private, social and affordable housing;
- seniors house comprising residential care facilities and self-contained dwellings;
- a new high school;
- child care centres;
- public open space and roads;
- minor retail development; and
- community uses.

The resultant change in flood conditions have been assessed against the current scenario model (refer Section 2), and are presented in the following section.

5.2 Flood Model Development – Master Plan

5.2.1 Hydraulic Model

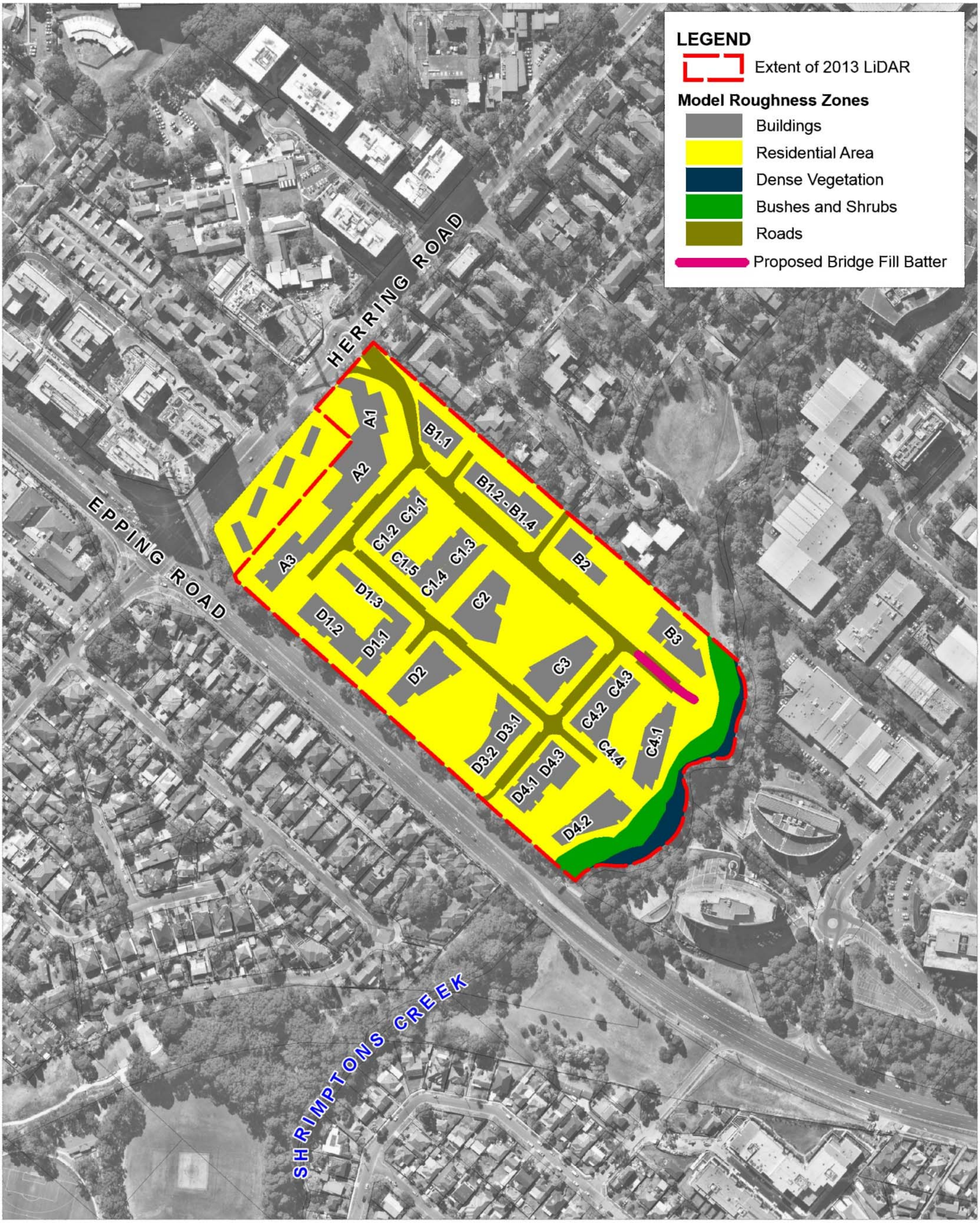
Details of the proposed Ivanhoe Estate Master Plan were provided by Bates Smart Pty Ltd (drawing ref: DA02.MP.101(G).pdf). The following Section details the updates which were made to the 'current scenario' Shrimptons Creek flood model; incorporating revisions to land use, drainage network and building layout at the site to represent the proposed Master Plan ('proposed development scenario').

Hydraulic Roughness (Manning's 'n')

Model Roughness zones representing land-use at the site, were revised to incorporate the Master Plan building footprints, roads, residential areas and green areas. The Manning's 'n' roughness values are listed in Table 2-2. The spatial distribution of materials roughness zones representing variations in hydraulic roughness is presented in Figure 5-1.

Buildings

The proposed building ground floor levels provided by Bates Smart (drawing ref: DA02.MP.101(G).pdf). have been represented in the TUFLOW model using a z-shape to set the finished ground floor level. Above the finished floor level, buildings have been represented utilising an increased Manning's roughness (n = 20) to represent the energy dissipation of water flowing through and around buildings. This methodology is consistent with the flood models developed as part of the Macquarie Park Floodplain Risk Management Study and Plan (Bewsher 2010).



Title:

2D Model Domain Developed Scenario

Figure: 5-1

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Approx. Scale

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Concept Bridge Design

Preliminary longitudinal sections were provided by ADW Johnson (drawing ref: 300001-ESK-074-A-2017-10-06_ Bridge.pdf) for the proposed bridge spanning Shrimptons Creek. The proposed bridge is to provide vehicle access between Ivanhoe Estate on the north-western side of Shrimptons Creek, and Lyonpark Road to the south-east.

The bridge design has been included within the TUFLOW hydraulic model by modelling the fill batter on the north-western side of Shrimptons Creek. The batter on the eastern side of Shrimptons Creek was not modelled, as it was sufficiently above the PMF flood level at the proposed location. The proposed bridge soffit levels are above the current PMF level for the site, and hence have not been modelled. No provision has been made for the modelling of piers within Shrimptons Creek, as it is expected that this will be undertaken during detailed design.

The location of the bridge fill batter is shown in Figure 5-1.

Drainage Network

The network of pits and pipes contained within Ivanhoe Estate have been removed from the 'proposed development scenario' model. Details of the proposed drainage network for the Ivanhoe Estate Master Plan were not available at the time of modelling, however as discussed earlier in Section 4.3, the areas outside of the main channel of Shrimptons Creek are considered 'Local Drainage' under the Floodplain Development Manual, and hence will have no major impact on the mainstream flood levels.

Figure 5-2 illustrates the 1D model elements included within the proposed development scenario model.

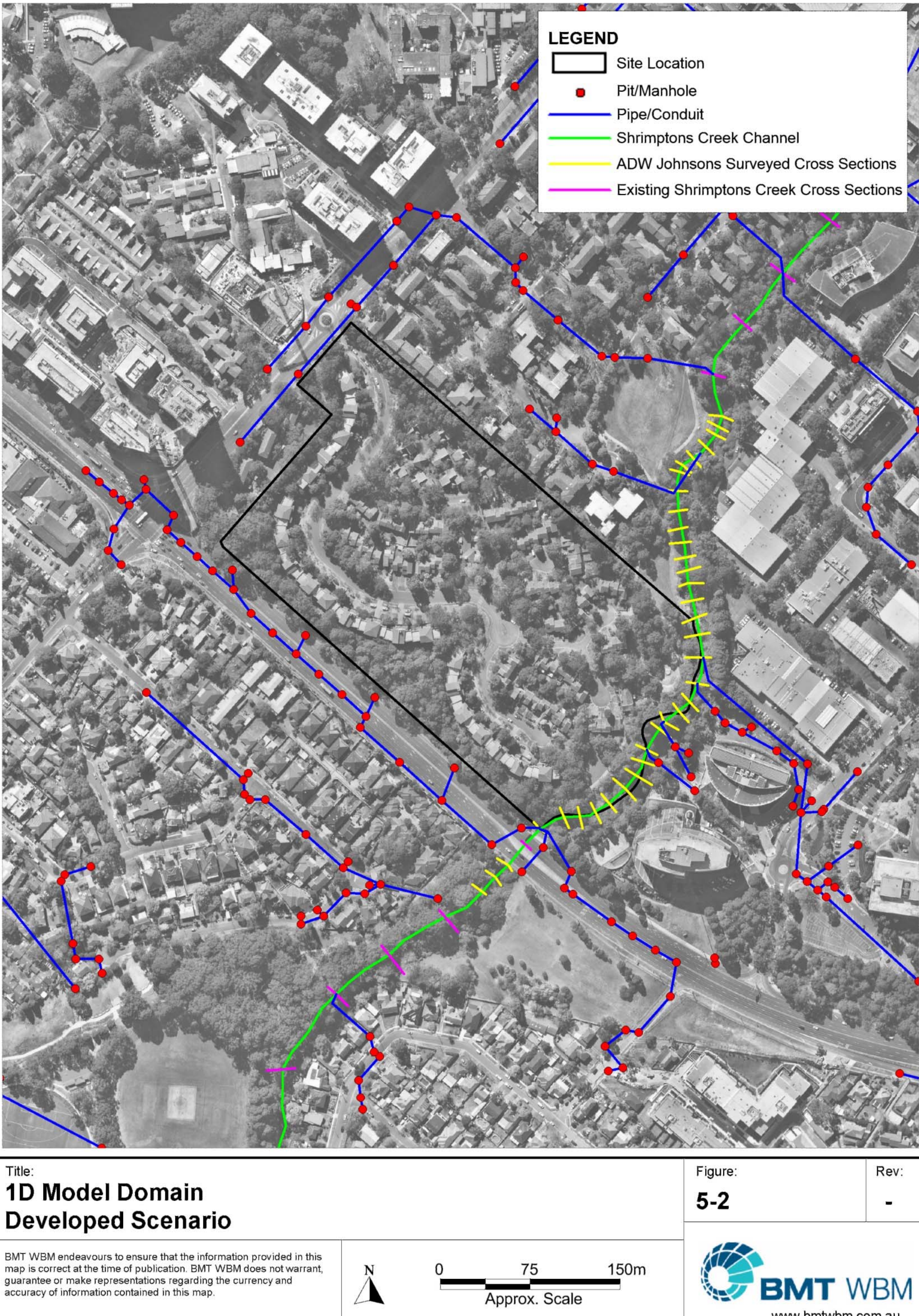
5.3 Flood Impacts

The "proposed development scenario" TUFLOW hydraulic model has been used to derive the peak flood conditions for the 20 year ARI, 100 year ARI and the PMF (Probable Maximum Flood) design events. Appendix C presents the results of the 'proposed development scenario' and includes; peak flood depth, peak flood velocity, peak velocity-depth product, provisional hazard, hydraulic categorisation and provisional flood risk precinct mapping.

Afflux diagrams are presented in Appendix D for peak flood level and peak flood velocity for the design events simulated. These diagrams show the afflux (increase) between flood conditions resulting from the proposed development and the existing baseline flood conditions. They are useful for presenting the magnitude and extent of potential flood impacts associated with development of the site. The following impact results are presented below:

- Figure 5-3 – Prospect Creek 100 year ARI Peak Water Level Afflux
- Figure 5-4 – Prospect Creek 100 year ARI Peak Velocity Afflux

Peak water levels and depths have been extracted from a number of point locations around the study area boundary and within the proposed development site for the "current" and "proposed development" scenarios (please refer to Table 5-1 and Table 5-2). Figure 5-3 shows the locations reported in these tables.



Title:

1D Model Domain Developed Scenario

Figure: 5-2

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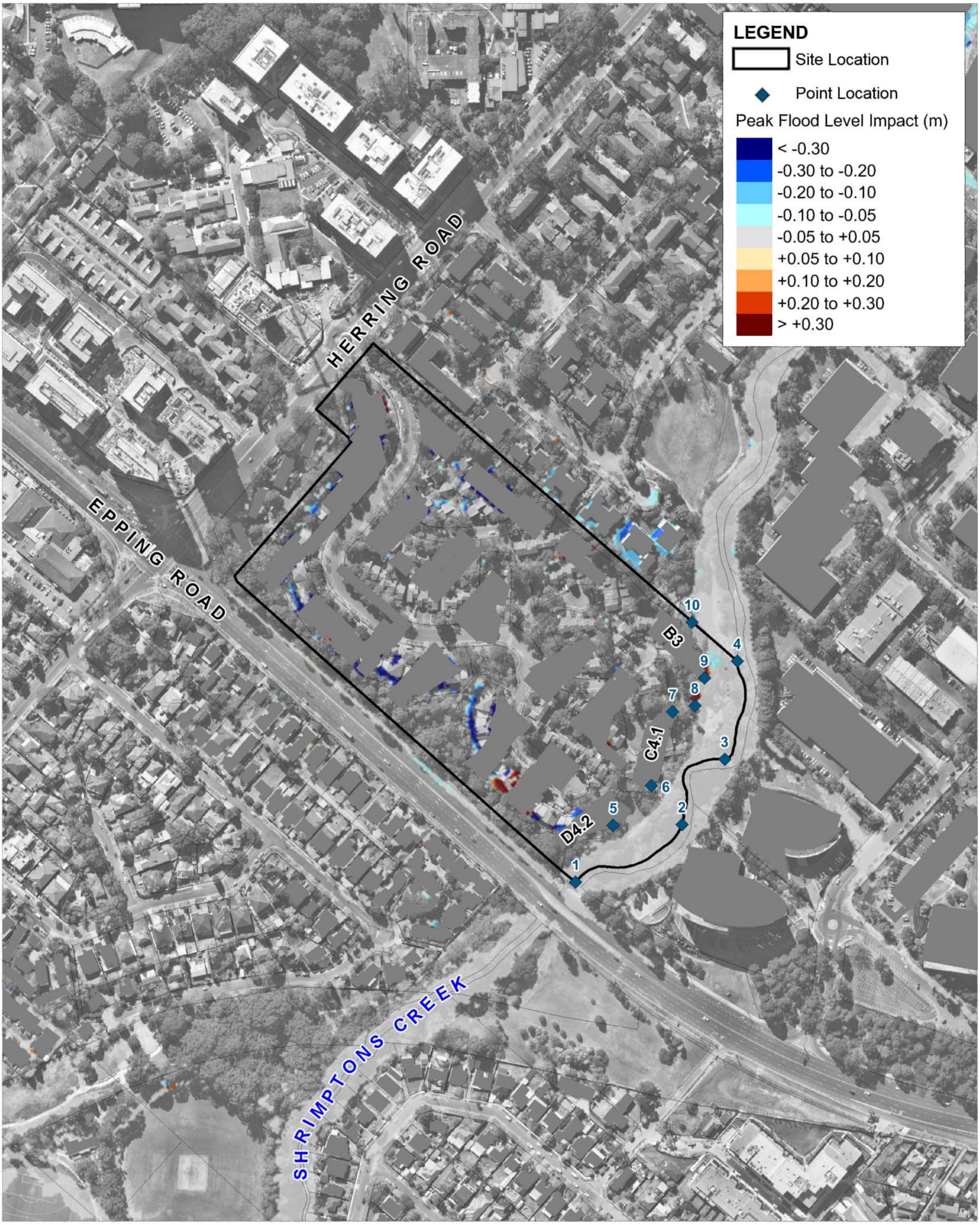

Title:

Peak Flood Level Impact 100 yr ARI

Figure: 5-3

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Approx. Scale

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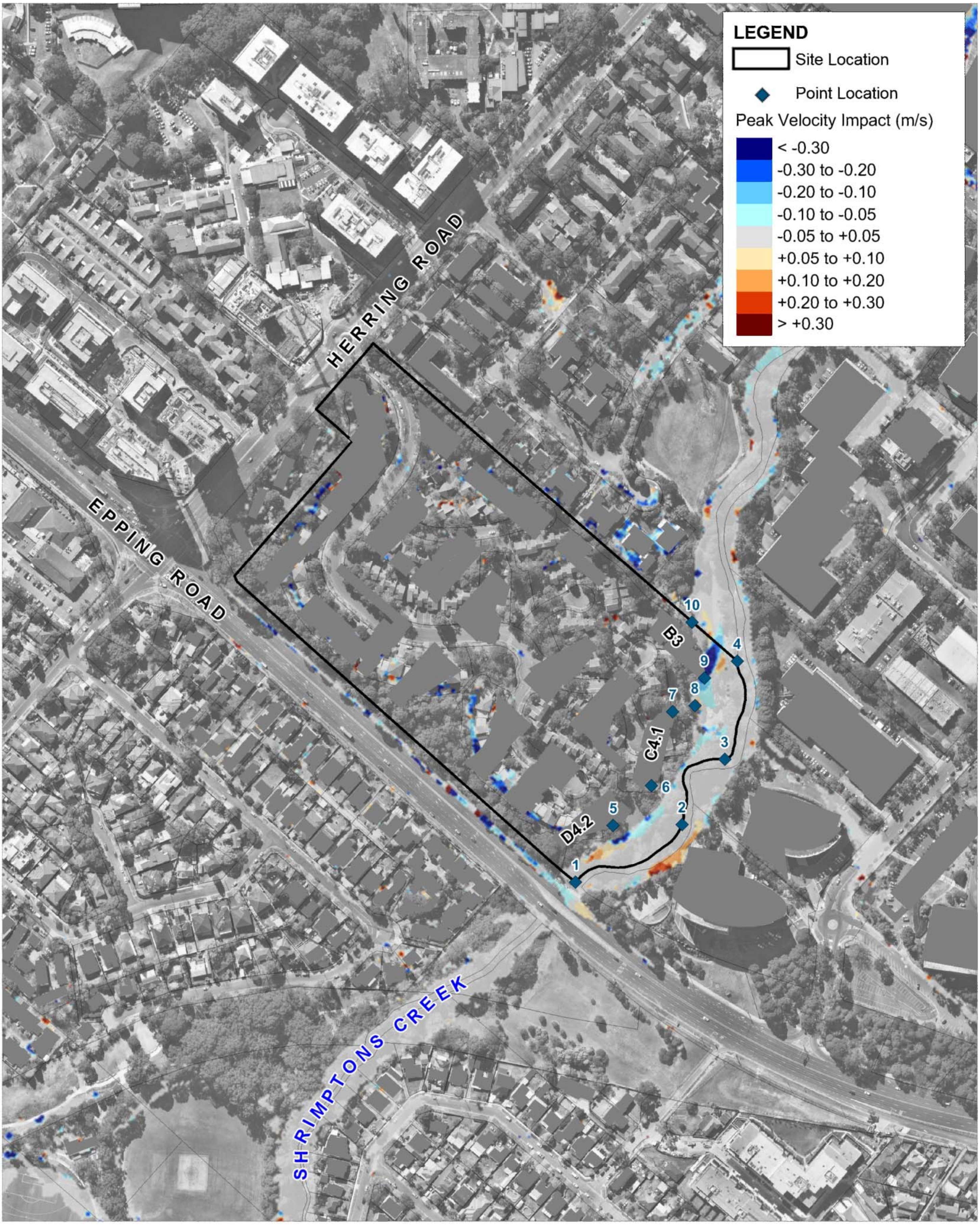

Title:

Peak Velocity Impact
100 yr ARI

Figure: **5-4**

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Approx. Scale

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Table 5-1 Peak Flood Level Results

Location (Refer to Figure 5-3)	Current Scenario (m AHD)			Proposed Development Scenario (m AHD)			Difference in Peak Flood Levels (m)		
	20yr ARI	100yr ARI	PMF	20yr ARI	100yr ARI	PMF	20yr ARI	100yr ARI	PMF
1	1	44.74	44.99	46.71	44.74	44.98	46.72	0.00	-0.01
2	2	44.37	44.64	46.27	44.37	44.63	46.28	0.00	-0.01
3	3	44.14	44.40	45.96	44.13	44.39	45.98	0.00	-0.01
4	4	43.76	44.04	45.75	43.75	44.03	45.77	0.00	-0.01
5	5	NFI	NFI	46.58	NFI	NFI	NFI	NFI	NFI
6	6	NFI	NFI	46.18	NFI	NFI	46.98	NFI	NFI
7	7	NFI	NFI	45.77	NFI	NFI	NFI	NFI	NFI
8	8	NFI	NFI	45.79	NFI	NFI	45.95	NFI	NFI
9	9	NFI	44.18	45.78	NFI	44.42	45.94	NFI	0.24
10	10	NFI	NFI	45.61	NFI	NFI	45.61	NFI	NFI

*NFI No Flooding Indicated

Table 5-2 Peak Flood Velocity Results

Location (Refer to Figure 5-4)	Current Scenario (m/s)			Proposed Development Scenario (m/s)			Difference in Peak Flood Velocity (m/s)		
	20yr ARI	100yr ARI	PMF	20yr ARI	100yr ARI	PMF	20yr ARI	100yr ARI	PMF
1	2.65	3.04	5.62	2.65	3.05	5.60	0.00	0.01	-0.02
2	0.98	1.10	1.80	0.99	1.09	1.78	0.00	0.00	-0.01
3	1.49	1.66	2.15	1.49	1.66	2.09	0.00	0.00	-0.06
4	1.43	1.53	2.10	1.42	1.54	2.47	0.00	0.01	0.36
5	NFI	NFI	NFI	NFI	NFI	NFI	NFI	NFI	NFI
6	NFI	NFI	0.25	NFI	NFI	0.07	NFI	NFI	-0.18
7	NFI	NFI	0.18	NFI	NFI	NFI	NFI	NFI	NFI
8	NFI	NFI	1.71	NFI	NFI	0.97	NFI	NFI	-0.74
9	NFI	0.72	1.93	NFI	0.22	0.79	NFI	-0.50	-1.14
10	NFI	NFI	1.13	NFI	NFI	NFI	NFI	NFI	NFI

*NFI No Flooding Indicated

As shown in Figure 5-3, the proposed Ivanhoe estate Master Plan development results in minimal impacts when considering the 20 year ARI and 100 year ARI Shrimptons Creek flood events. No notable changes in water level or velocity were observed in the 20 year ARI event. In the 100 year ARI event, minor increases at the location of building 'Lot B3' were present due to the buildings encroachment into the 100 year flood extent. These impacts are in the order of 0.00 to 0.25 m. A resultant reduction in velocity in the order of 0.50 m/s is present at building 'Lot B3'.

The magnitude of impacts for the PMF event are larger. Increases in peak water levels are present upstream of the site with significant decreases in water levels downstream from the site due to the proposed bridge obstructing the active PMF flow path. Peak flood levels from mainstream flooding for Shrimptons Creek at buildings 'Lot B3', 'Lot C4.1' and 'Lot D4.2' are 45.65 mAHD, 46.40 mAHD and 46.75 mAHD respectively.

Changes in velocity during the PMF event are relatively localised to the proposed development footprint with some effects upstream and downstream. Increases in velocity within Shrimptons Creek are observed due to shifting in flow paths around the development. The PMF event is usually used for emergency planning purposes only, rather than the assessment of absolute changes to modelled flood levels and velocities. Further discussion is provided in the following section.

5.3.1 Emergency Planning and Evacuation Considerations

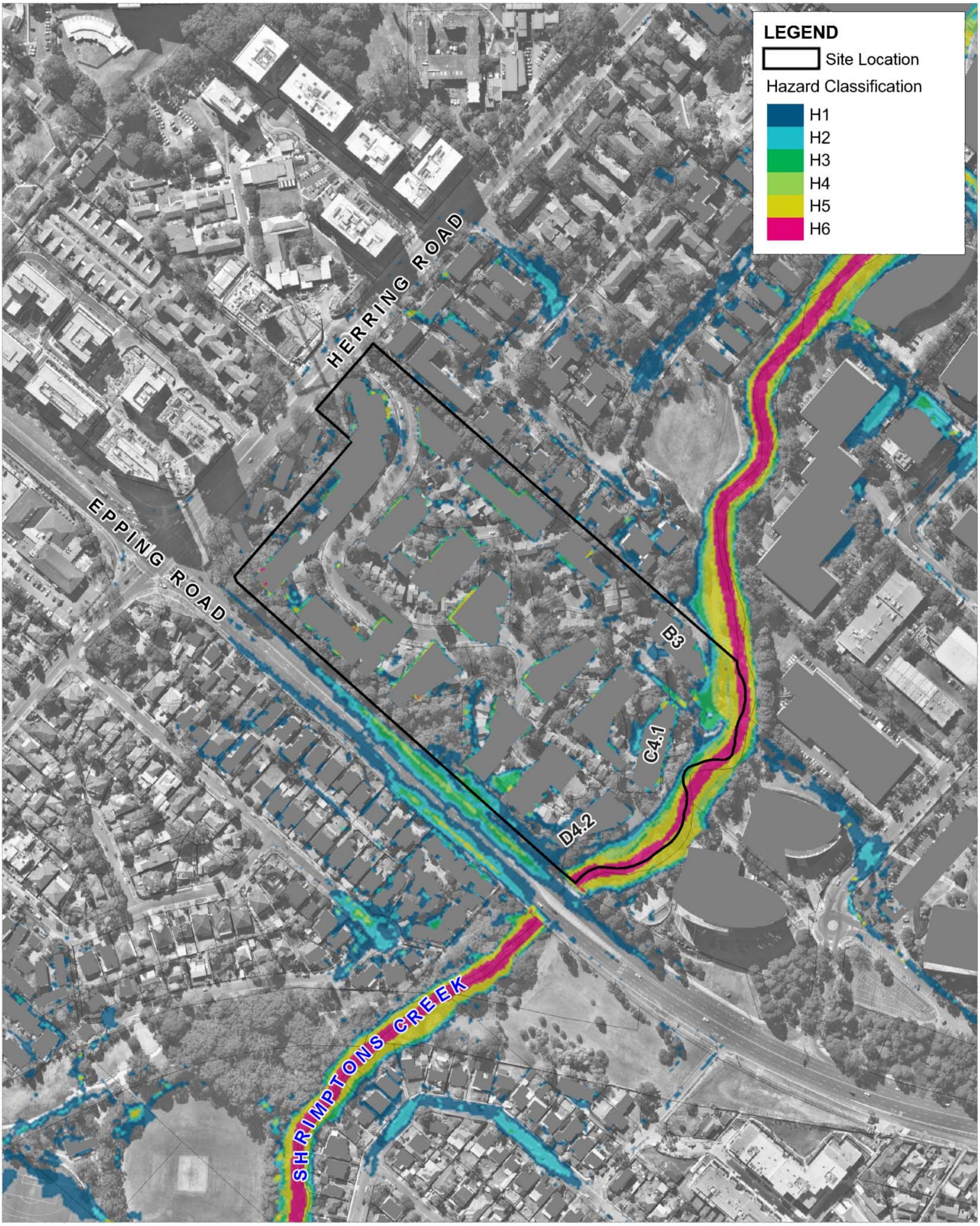
To consider potential impacts on risk to life and structural stability during extreme flood events, preliminary hazard classification has been considered. The Hazard Classification thresholds detailed in *Updating National Guidance on Best Practice Flood Risk Management* (D. McLuckie et. al., 2014) have been adopted for this assessment. Descriptions of each hazard threshold have been reproduced in Table 5-3.

Table 5-3 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 all vehicles.
H5	Unsafe for all people and all vehicles. Buildings require special engineering design and construction.
H6	Unconditionally dangerous. Not suitable for any type of development or evacuation access. All building types considered vulnerable to failure.

Hazard classification mapping has been included within Appendix B and Appendix C for the 'current' and 'proposed development' scenarios respectively. Figure 5-5 shows the provisional hazard classification for the 100 year ARI under the proposed development scenario.

As shown in Figure 5-5, all buildings with the exception of 'Lot B3' are located outside of the 1% AEP extent of Shrimptons Creek, and hence outside of the hazard classification thresholds given in Table 5-3. The eastern side of building 'Lot B3' is located partly within the H1-H2 hazard classifications, limiting evacuation opportunities east. However, as rising road access is available to the west of the property, and Shrimptons Creek lies to the east, an eastern evacuation route would not be a viable option. The finished floor level of 'Lot B3' is 46 mAHD, which is above the 100yr ARI peak flood level (44.35 mAHD) and the PMF peak flood level (45.65 mAHD).



Title:
Flood Hazard Classification - Developed Scenario 100 yr ARI

Figure: **5-5**

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Approx. Scale

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The most significant hazard at the site occurs during the Shrimptons Creek PMF event (refer Appendix C, Figure C-11). Buildings denoted 'Lot C4.1' and 'Lot D4.2' are all located on the fringe of Hazard classification zones H1-H4. A small segment of Building 'Lot B3' is located within the H5 zone of the PMF.

During the PMF event, all proposed Ivanhoe Estate Master Plan buildings floor levels are above the Shrimptons Creek PMF mainstream flood level, providing flood-free-refuge for all events up to the PMF. In addition, rising road access from Shrimptons Creek is available up to Herring Road for all modelled design events. Construction on buildings 'Lot B3', 'Lot C4.1' and 'Lot D4.2' would be required to be specially designed to structurally withstand the expected high depth and velocity condition of floodwaters during an extreme event.

In conclusion, the Ivanhoe Estate Master Plan does not change the current emergency planning and evacuation considerations for the site. There is no considerable risk to life, due to the availability of rising road access to Herring Road in the event of flood. Furthermore, buildings 'Lot B3', 'Lot C4.1' and 'Lot D4.2' provide flood-free-refuge for all events up to the PMF. All other buildings are subject to 'local drainage' conditions only, and do not pose a significant hazard.

5.3.2 Impacts of Social and Economic Cost to the Community

As discussed above, there are no tangible flood impacts due to the proposed development for the modelled 20 year ARI and 100 year ARI flood events. Increases in peak flood level are of greater magnitude in the PMF event, however these remain local to the development. There are no impacts upstream or downstream of the proposed Ivanhoe Estate development in all modelled design events, hence there is no potential the Ivanhoe Estate development to cause an increase in flood frequency, or flood inundation which may cause social or economic costs to the community.

5.3.3 Impacts on Erosion, Siltation, Riparian Vegetation and Bank Stability

As discussed in Section 5.2, the modelling of the Ivanhoe Estate Master Plan considered revisions to land use, drainage network, building layout and proposed bridge location. Due to the preliminary nature of the planning process, this modelling did not consider any changes to the Shrimpton Creek corridor, which may potentially include;

- land-forming;
- change in vegetation; and
- landscape features.

The results of the proposed scenario model, did not indicate any substantial change in flood level, or changes to in-channel flood velocity. Changes in in-channel flood velocity, especially those in greater frequency flood events (i.e. less than the 20 year ARI), have the potential to cause erosion which may reduce bank stability. If velocities are substantially decreased, then there is potential for siltation, which may cause issues to the growth of riparian vegetation. However, given there are no flood impacts in the modelled design events up to the 100 year ARI, there is limited potential for there to be any changes to erosion, siltation or bank stability due to the modelled conditions of the Ivanhoe Estate development.

We trust the above provides a suitable description of the existing flood behaviour at the site and the potential flood impacts associated with the proposed development. Please feel free to contact the undersigned to discuss further as required.

Yours Faithfully,
BMT WBM

Sebastian Froude
Engineer

6 References

NSW Department of Infrastructure, Planning and Natural Resources (DIPNR) (2005), *Floodplain Development Manual*.

Howells, L., McLuckie, D., Collings, G., Lawson, N. (2003). *Defining the Floodway – Can One Size Fit All?* Floodplain Management Authorities of NSW 43rd Annual Conference, Forbes

McLuckie, D., Babister, M., Smith, G., Thomson, R., (2014). *Updating National Guidance on Best Practice Flood Risk Management*, Floodplain Management Association Conference, Deniliquin, May 2014

Pilgrim, DH (editor) (2001), *Australian Rainfall and Runoff – A Guide to Flood Estimation*. Institution of Engineers, Australia.

Appendix A Summary of DCP Controls

Summary of Relevant City of Ryde Development Controls Regarding Flooding at Ivanhoe Estate Redevelopment

Definitions and understandings for the development controls according to City of Ryde's Development Control Plan 2014.

- **In accordance with the NSW Floodplain Development Manual, flood levels are determined from the 100yr ARI (Annual Recurrence Interval) storm event.**
- The level of flood risk is basically a product of flood depth and the velocity of flow and can be categorised as follows.
    - High Flood Risk – Areas where there is a potentially catastrophic damage to property, risk to life, evacuation problems or where development would significantly or adversely alter flood behaviour. Most development is restricted in these locations.
    - Medium Flood Risk – Areas whereby there would be potential flood damage or public safety is a concern but could be addressed by the application using appropriate measures.
    - Low Flood Risk – Land within the floodplain (i.e. within the extent of the probable maximum flood) but not identified as either High Flood Risk, Medium Flood Risk Precinct or as an Overland Flow Precinct.
    - Overland Flood Risk – Areas identified as Overland Flow Precincts are distant from watercourses where shallow inundation (relative to major flooding) occurs following heavy rain. Typically, the depth of inundation will be less than 0.3 m to 0.5 m but more than 0.1 m to 0.2 m in a 100 year ARI event.
- Minor overland flow depths may typically be around 50mm to 100mm and, whilst they do not present great risk to development, must meet the minimum development control requirements to ensure there is adequate protection from any stormwater inundation.
- **Freeboard – An additional level difference applied above the flood level**
- **Habitable – Floor areas which are furnished or provide dry storage of goods. Inundation of these areas would result in a great loss of amenity and property damage to the development.**
- **Non-Habitable – Enclosed or partially open floor area which is not habitable.**

Development and Land Use Categories likely to be present in the redevelopment:

- Residential Development
- Retail, Commercial & Industrial Development
- Recreation and Non-Urban Development
- Landform Development
- Carparking Areas
- **Sensitive Uses and Facilities, defined as; Development accommodating services or facilities which are essential to evacuation during periods of flooding or if effected would**

unreasonable affect the ability of the community to return to normal activities after flood events. Examples of this include educational establishments, residential care facilities, fuel stations, public utility buildings, etc.

- **Critical Uses and Facilities, defined as; Emergency services facilities, administration building or public administration building that may provide an important contribution to the notification or evacuation of the community during flood events.**

Corresponding to the likely Development and Land Use Categories the following controls must be adhered according to City of Ryde's Development Control Plan 2014:

1. A Flood Impact Statement is to be prepared in accordance with Section 2.2 of the Stormwater and Floodplain Management Technical Manual and is required to address the various controls related to the following development types.
2. To minimise property damage, the following finished surface levels must be attained for new parking areas;
    a. For open parking areas, no less than the 100yr ARI flood level.
    b. For enclosed parking areas, the parking area must be no less than the 100yr ARI flood level plus 150mm freeboard.
    c. Basement parking or parking at levels below the adjacent flood levels, a bunded crest at the estimated PMF (probable maximum flood) level prior to descent into the parking area, must be provided such that inundation of the area is prevented.
    d. For new parking areas associated with concessional development, parking areas are to be elevated to habitable floor level.
3. New parking areas must not divert overland flow or reduce flood storage such to adversely impact the surrounding area.
4. Large open parking areas (greater than 10 carspaces) must provide adequate restraints or barriers to prevent vehicles leaving the site up to the 100yr ARI flood event.
5. The utilisation of existing parking areas must not result in the increased risk to property damage or threat to public safety.
6. **For landform development exposed to Low Risk and above Flood Risk Category (or where this is not known, the indicative extent of inundation on Councils mapping system) the following must occur.**
    a. Fences are permeable, open or otherwise a frangible structure, such to permit the conveyance of floodwaters below the 100yr ARI flood event. In the event the flood level is unknown, 200mm above ground level is to be adopted.
    b. The face of retaining walls, pools or garden beds aligned towards overland flows are no greater than 200mm in height, unless it can be demonstrated such a structure will not have an adverse impact to the surrounding area by way of a Flood Impact Statement.

7. Residential development on land subject to flood risk categorised as high will not be permitted unless it can be clearly demonstrated that development under this section can be undertaken on the land without jeopardising public safety and access, property damage or adverse ramifications of the pre-developed flood regime by means of a Flood Impact Statement.

8. For Residential development floor levels of habitable and non-habitable areas must comply with the freeboard requirements as stated in Table 2.1 of the Stormwater Technical Manual, reproduced below.

<table>
<tr><th rowspan="2">Drainage System/ Overland Flow</th><th colspan="3">Residential</th><th colspan="2">Industrial/ Commercial</th></tr>
<tr><th>Land Level [(b)]</th><th>Habitable Floor Level</th><th>Non-Habitable Level [(c)]</th><th>Land Level [(b)]</th><th>Floor Level</th></tr>
<tr><td>Surface Drainage/ adjoining ground level [(a)]</td><td>-</td><td>.15m</td><td>-</td><td>-</td><td>.15m</td></tr>
<tr><td>Public drainage infrastructure, creeks and open channels</td><td>0.5m</td><td>0.5m</td><td>0.1m</td><td>0.3m</td><td>0.3m</td></tr>
<tr><td>Flooding and Overland Flow (Overland Flow Precincts and Low Risk)</td><td>N/A</td><td>0.3m</td><td>0.15m</td><td>N/A</td><td>0.3m</td></tr>
<tr><td>Flooding and Overland Flow (Medium Risk and greater)</td><td>N/A</td><td>0.5m</td><td>0.3m</td><td>N/A</td><td>-</td></tr>
<tr><td>Onsite Detention [(d)]</td><td>N/A</td><td>0.2m</td><td>0.1m</td><td>N/A</td><td>0.2m</td></tr>
<tr><td>Road Drainage

Minor Systems (Gutter and pipe flow)</td><td></td><td colspan="4">0.15m below top of grate</td></tr>
<tr><td>Road Drainage</td><td></td><td colspan="4">Refer to Figure 2-1.</td></tr>
<tr><td>Detention Basins [(4)]</td><td></td><td colspan="4">The top water level shall be designed to be 0.5m below top of embankment (100yr ARI)</td></tr>
</table>

Table 2.1 Freeboard requirements.

9. **For Residential, Commercial and Recreational developments, new structures subject to flooding and overland flow (excluding those sites located in Overland Flow Precincts) must be designed and constructed to withstand the anticipated hydrostatic forces. For all parts of the development potentially exposed to floodwater, below the minimum freeboard requirement, the development structure must:**
    a. **Be constructed of flood compatible building components in accordance with the Stormwater and Floodplain Management Technical Manual.**
    b. **A structural engineer must certify that the completed works are designed and capable of withstanding forces subject to forces of floodwater, debris, buoyancy forces anticipated by the 100yr ARI flood event.**
10. Residential, Commercial and Recreational developments must not divert major overland flows or reduce flood storage such to adversely impact the neighbouring property or surrounding area. It must be demonstrated the development does not;
    a. Reduce the pre-developed level of flood storage.
    b. Increase flood levels or velocities such to adversely impact adjoining dwellings.
11. If Residential and Commercial developments involve subdivision of the land, it must be demonstrated that any potential development of this newly created allotment can comply with the controls under this section.
12. For Residential and Commercial developments, a restrictive covenant must be placed on the title of the land to ensure there are no further significant works and alterations to the landform or development are undertaken without the approval of Council such to impact on flooding.
13. Commercial development on land subject to flood risk categorised as high will not be permitted unless it can be clearly demonstrated that development under this section can be undertaken on the land without jeopardising public safety and access, property damage or adverse ramifications of the pre-developed flood regime by means of a Flood Impact Statement.
14. **For Commercial and Recreational developments floor levels of habitable and non-habitable areas must comply with the freeboard requirements as stated in Table 2.1 of the Stormwater Technical Manual. If these levels cannot be practically achieved for the entire floor area (E.g. for reasons of accessibility from a public space) then a lesser level may be considered subject to consideration of the extent or scale of property damage and risk to public safety**
15. For Commercial and Recreational developments, all goods and materials must be stored at the minimum habitable floor level, complying with the freeboard requirements as stated in Table 2.1 of the Stormwater Technical Manual, unless the site is located in an Overland Flow Precinct in which case this may be reduced to 500mm above the adjoining ground level. Exemptions from this may be considered if it can be demonstrated in the Flood Impact Statement, that the materials will not adversely impact the surrounding environment or can be damaged if subject to stormwater inundation.
16. Recreational developments located on large lots subject to full inundation must demonstrate that adequate refuge is provided for all occupants above the PMF (probable maximum flood) event. This is to ensure that public safety is maintained.

17. **Development categorised as "Sensitive Uses and Facilities" as per Schedule 2 subject to flood risk categorised as MEDIUM or HIGH will not be permitted.**
18. **For Sensitive Uses and Facilities developments all floor levels must be no lower than the PMF level. Exemption from this may be considered, subject to consideration of the extent or scale of impact to the community that would occur in the event the structure is inundated.**
19. For Sensitive Uses and Facilities developments, new structures subject to flood waters and major overland flows must be designed and constructed to withstand the anticipated hydrostatic forces. For all parts of the development potentially exposed to floodwater up to the PMF event, the development structure must:
    a. be constructed of flood compatible building components in accordance with the Stormwater Technical Manual.
    b. A structural engineer must certify that the completed works are designed and capable of withstanding forces subject to forces of floodwater, debris, buoyancy forces anticipated by the PMF flood event.
20. Sensitive Uses and Facilities developments must not adversely impact the existing flood regime in terms of diverting major overland flows or reduce flood storage such to adversely impact the surrounding area. The submitted Flood Impact Statement must demonstrate the development does not;
    a. Reduce the pre-developed level of flood storage.
    b. Increase flood levels or velocities such to adversely impact adjoining dwellings.
21. Development categorised as "Critical Uses and Facilities" as per Schedule 2 will not be permitted on land subject to major overland flows and floodwaters, excluding lots identified as Overland Flow Precincts.

Appendix B Flood Mapping for Current Scenario