Singleton Bypass Concept Design Flood Assessment

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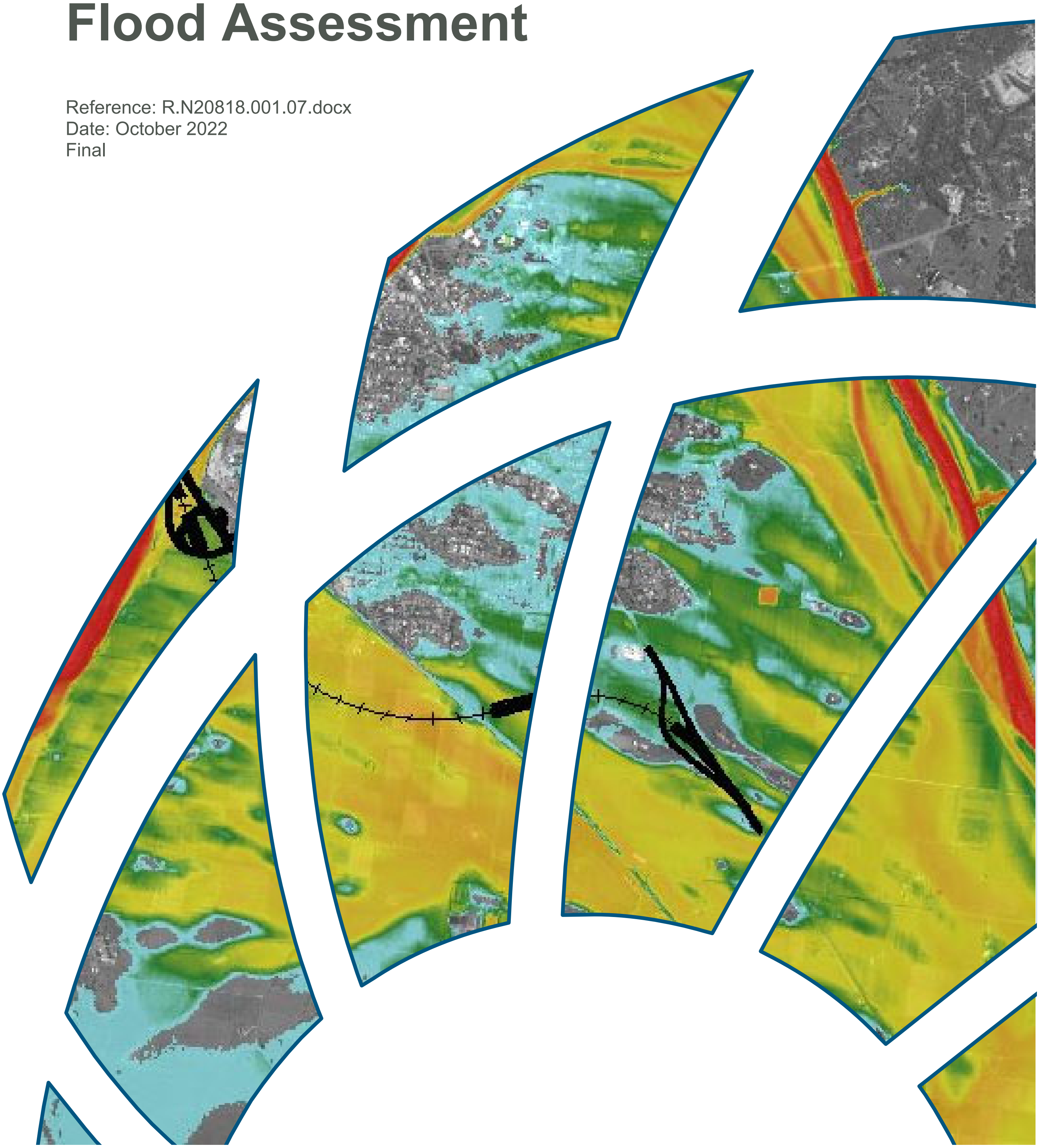

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Synopsis: **This document outlines a flood risk and impact assessment in relation to the concept design of the proposed Singleton Bypass.**

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1 Introduction

1.1 Background

BMT (formerly WBM) completed the Singleton Flood Study on behalf of Singleton Council in 2003. The flood study and subsequent flood risk assessments show that the Singleton township has a relatively high exposure to flood risk. The existing levee system has a finite level of protection with significant parts of the township expected to be inundated in major floods such as the 1% Annual Exceedance Probability (AEP) event. The 1955 Hunter River flood saw extensive flooding in Singleton and serves as an important reference event for potential flooding impact.

Since completion of the flood study, numerous flood risk assessments for development proposals in the study area, including rail infrastructure through Doughboy Hollow have been completed. Those additional studies assessed the flood risk of various development proposals and their potential impacts on flooding in the Singleton township and surrounding area.

Transport for New South Wales (TfNSW) is currently undertaking the Concept Design for a proposed Singleton bypass. This report documents the flood assessment of this Concept Design, referred to as the REF Addendum Design.

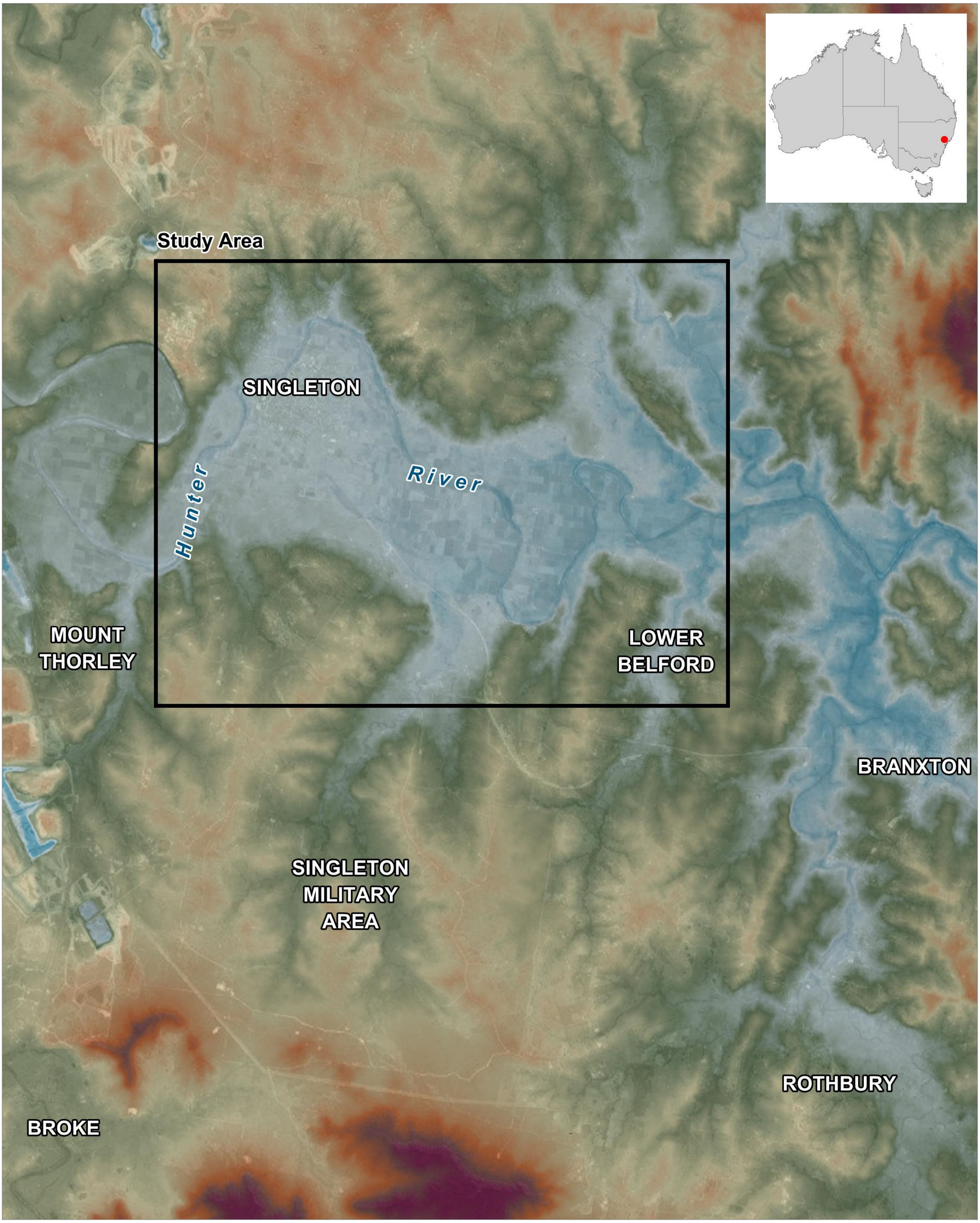
1.2 Study Area

The main study area includes the township of Singleton and the floodplain of the Hunter River between Hambledon Hill to the west and Lower Belford and Glendon to the east. The floodplain is defined by steep terrain to the north and the Golden Highway to the south. A Digital Elevation Model (DEM) of the study region based on Shuttle Radar Topography Mission (SRTM) 'bare earth' models (Gallant *et al*., 2011) and key localities is shown in Figure 1-1. The study area considered by the flood risk assessment of the proposed Singleton bypass is shown in Figure 1-2.

Land use in the study area includes the urban centre of Singleton which comprises residential, commercial and some industrial development. The dominant land use surrounding the Singleton township is agricultural land and pasture which primarily occupies the Hunter River and Doughboy Hollow floodplains. Numerous rural properties are also located throughout the study area.

Notable ground controls in the study area include the New England Highway and the Main North Railway Line, which traverse the floodplain between Whittingham and Singleton. The existing levee system on the north-western side of Singleton township, which joins with the Main North Rail Line embankment at Glenridding also affects flood behaviour in the area. Natural ground controls include Doughboy Hollow which becomes active during floods such as the 10% AEP event and greater.

Several flow constrictions are also present which include major bridge crossings provided along the Main North railway line, the New England Highway, Dunolly Road and Queen Street. Numerous other drainage / flow control structures are provided beneath the Main North railway line and New England Highway to convey flood flows across the floodplain during major flood events.



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Study Locality

Figure: 1-1

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Approx. Scale

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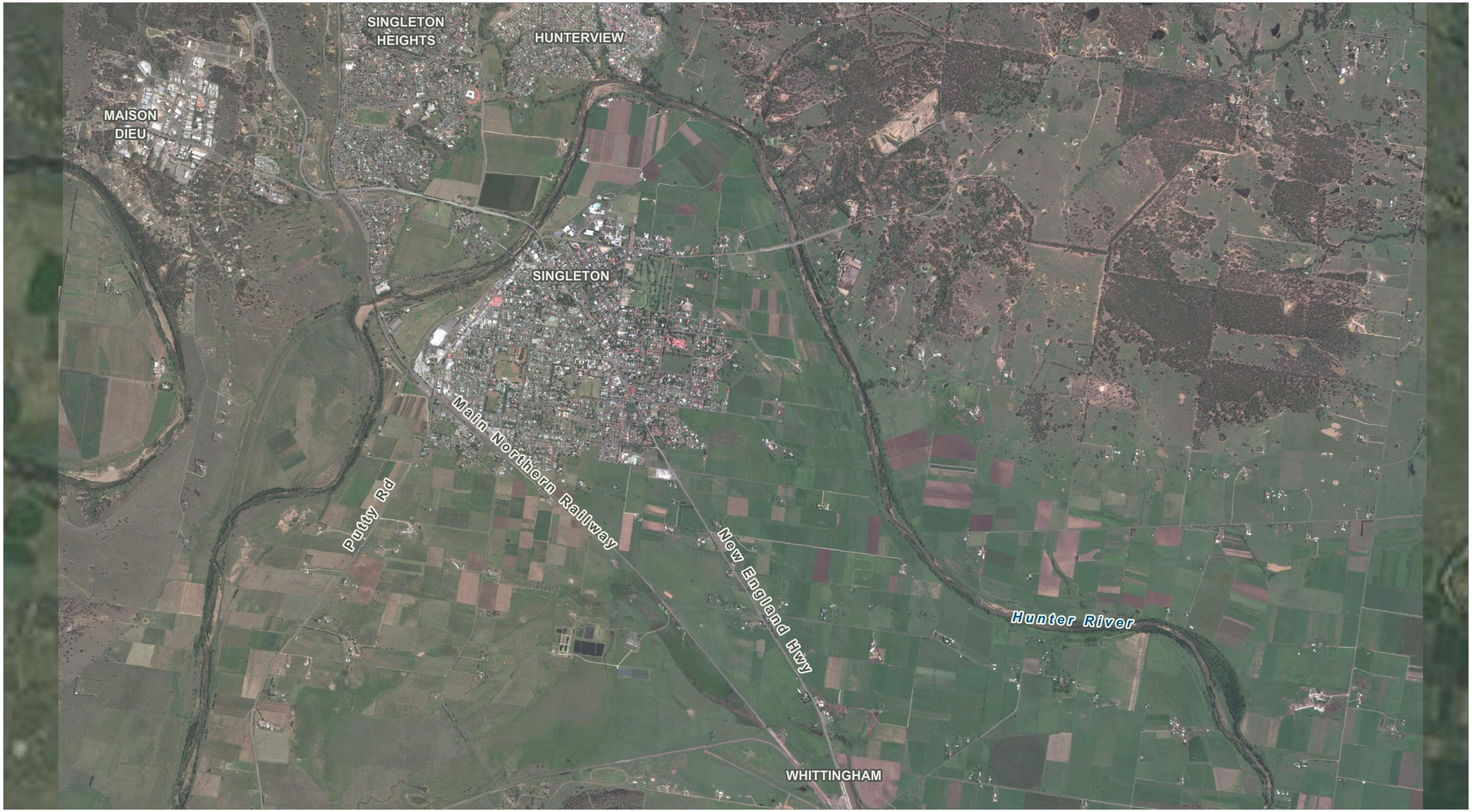

LEGEND

Title:
Singleton Bypass Study Area

Figure: 1-2

Rev: A

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1.3 Report Purpose

This report documents the flood impact assessment in relation to the REF Addendum Design for the proposed Singleton bypass. The flooding assessment incudes consideration of the following:

- existing design flood conditions (to be used as the baseline for impact assessment);
- the proposed bypass route alignments and its service/performance requirements;
- design flood simulations for a range of return period events;
- estimation of pre- and post- design flood conditions and the impacts of the concept design;
- assess the scour potential at bridge structures; and
- potential flood mitigation and design modifications that may be required to minimise flood impacts.

2 Development of the Singleton Flood Model

2.1 Model Background

Since the completion of the 20% concept design in May 2018, BMT has been undertaking the Singleton Floodplain Risk Management Study and Plan (FRMSP) for Singleton Council. The study includes a more comprehensive model calibration than had previously been undertaken for that utilised for the 20% concept design. Whilst the extents, topography and resolution are consistent with the 20% concept design model, the adopted Manning's 'n' roughness and Hunter River inflow conditions have changed to provide consistency with the Singleton Floodplain Risk Management Study model.

2.2 Design Flood Estimation

2.2.1 Flood Frequency Analysis

Following completion of the model calibration process for the Singleton Floodplain Risk Management Study, the historic peak flood level record at Singleton (Dunolly) was assessed to derive a Flood Frequency Analysis (FFA).

Despite the considerable limitations of the Dunolly Bridge gauging site for the estimation of peak flood flows, this site was selected as it has the longest period of record of any gauge in the area (over 100 years, compared to just under 50 years for the next longest record at Greta) and is the only one to have recorded the 1955 event.

A series of annual maxima water level records was extracted from the gauge records. A set of three rating curves were then derived to convert these records to a best estimate of peak flows. The rating curves were based on the actual Water NSW ratings for flood levels under 41 m AHD, transitioning to the modelled rating curves for flood levels above 41 m AHD. Two rating curves were based on the historic conditions with limited riparian vegetation – one pre-levee and one post-levee construction, i.e. pre-1963 and post-1963. The third rating curve was based on the recent conditions with extensive riparian vegetation and was considered for events from 1998 onwards.

An annual maxima flow series consisting of 106 records from 1913 to 2019 was analysed using the FLIKE FFA software. A Bayesian inference method was adopted with a Log Pearson III probability model. The 1893 historic event was incorporated into the analysis as a censored threshold exceedance value. The ten largest flood events recorded at Singleton and their corresponding peak flow estimates are presented in Table 2-1. The resultant fitted distribution is presented in Figure 2-1 together with the plotting positions of the annual maxima, determined using the Cunnane formula.

2.2.2 Very Rare to Extreme Flood Events

The estimation of very rare and extreme flood events requires extrapolation beyond those typically derived from an FFA. Appropriate peak design flows for the 0.05% AEP and Extreme events were therefore assessed using the information presented in Figure 2-2.

Table 2-1 Ten Largest Flood Events Recorded at Singleton

Event Year	Estimated Peak Flow Rate (m^3/s)
1955	10 500
1893	*>6500*
1913	6500
1971	4800
1930	4150
1952	4050
1949	3750
2007	3700
1977	3400
1976	2840

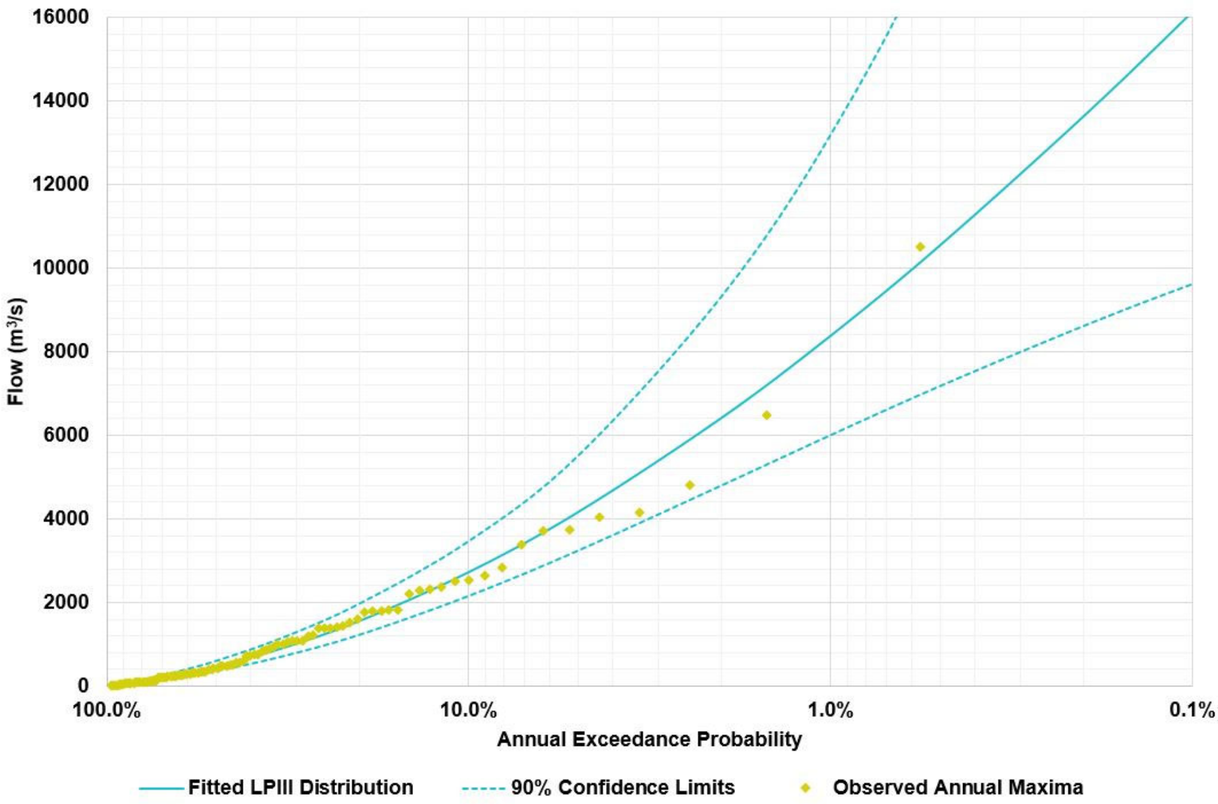


Figure 2-1 Singleton Flood Frequency Analysis

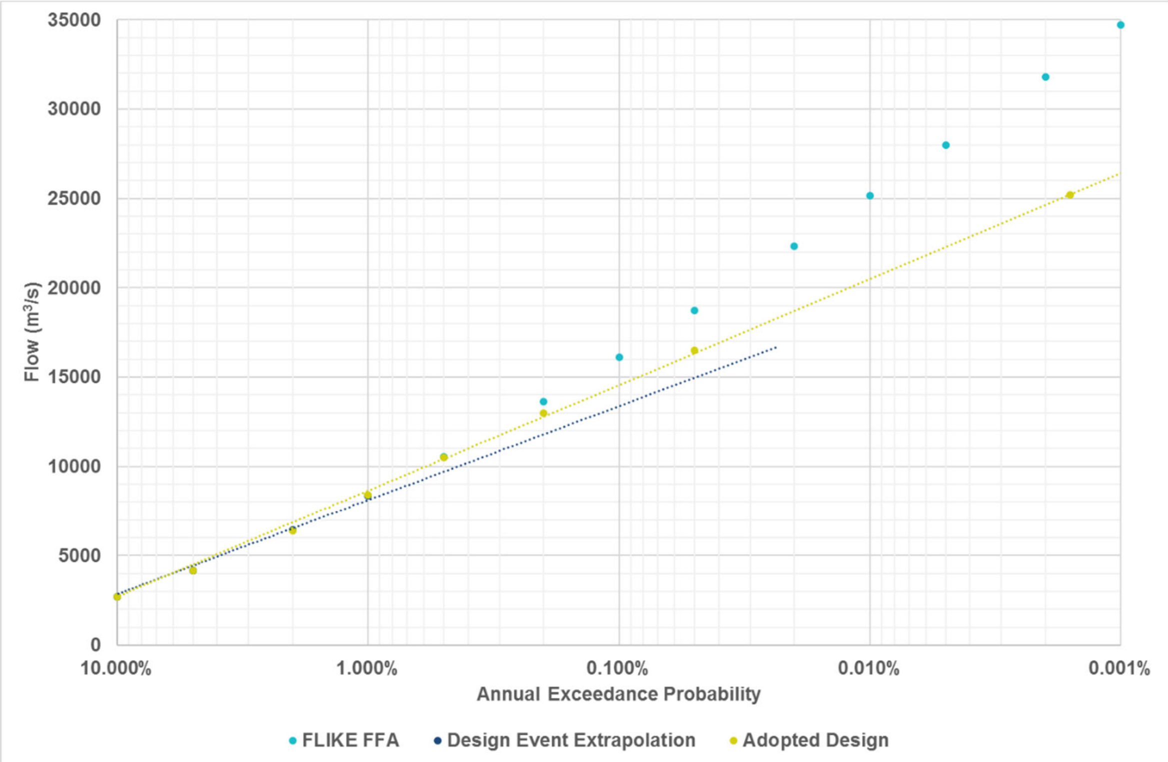


Figure 2-2 Estimation of Very Rare to Extreme Events

From guidance provided in ARR 2019, the expected AEP of the Probable Maximum Flood (PMF) event for a catchment area of the Hunter River at Singleton is approximately 0.0016% (or a 62,500-year ARI). The estimated peak flow for an event of this rarity from the FLIKE FFA is around 32,000 m^3/s. The estimation of the PMF event for large catchments is highly uncertain. However, extreme event magnitudes for large river catchments are often represented through the adoption of a peak flow of three times the 1% AEP event, which is around 25,200 m^3/s.

For the Singleton bypass concept design assessment an Extreme Flood event condition with a peak flow of 25,200 m^3/s has been adopted, with a peak flow of 16,500 m^3/s being adopted for the 0.05% AEP condition.

2.2.3 Design Flood Conditions

Having established appropriate estimates of design flood flows, the TUFLOW model was simulated to derive the baseline design flood conditions for the study area. The model configuration adopted the recent riparian vegetation conditions used to calibrate the June 2007 event. The design inflow hydrographs were based on the June 2007 flood hydrograph shape and scaled to match the peak flows from the FFA. A similar approach using the recorded February 1955 event hydrograph produced an almost identical hydrograph shape to that of June 2007.

The resultant peak flood levels modelled at Singleton (Dunolly Bridge) from the design simulations are presented in Table 2-2. These are compared to the three significant historic flood event levels. The design flood levels appear to be inconsistent with those recorded for the 1913 and 1955 events. However, the Singleton levee scheme has been constructed since these events and the flood levels for a given flow at Dunolly Bridge have increased as a result.

Table 2-2 Comparison of Design and Historic Flood Levels

Flood Event	Study (m AHD)
20% AEP	39.5
10% AEP	41.5
2007	*41.8*
1913	*41.8*
5% AEP	41.8
2% AEP	42.2
1955	*42.2*
1% AEP	42.4
0.05% AEP	43.0
Extreme	43.7

The design flood conditions for the study area are presented in Appendix A and formed the baseline for the subsequent flood impact assessment of the Singleton bypass REF Addendum Design.

3 Existing Conditions and Constraints

3.1 Existing Conditions

The establishment of existing design flood conditions provides for description of the:

- General flood behaviour throughout the study area;
- Existing flooding conditions based on design flood events; and
- Constraints and limitations along potential routes with respect to flooding regimes.

Design flood modelling results are shown for the 20% AEP, 10% AEP, 5%, AEP, 2% AEP, 1% AEP, 0.05% AEP and Extreme flood events in Appendix A, and are used as a baseline for the assessment of the concept design in Section 4. Table 3-1 summarises the peak flood levels for those events (the reporting locations are noted on Figure 3-1).

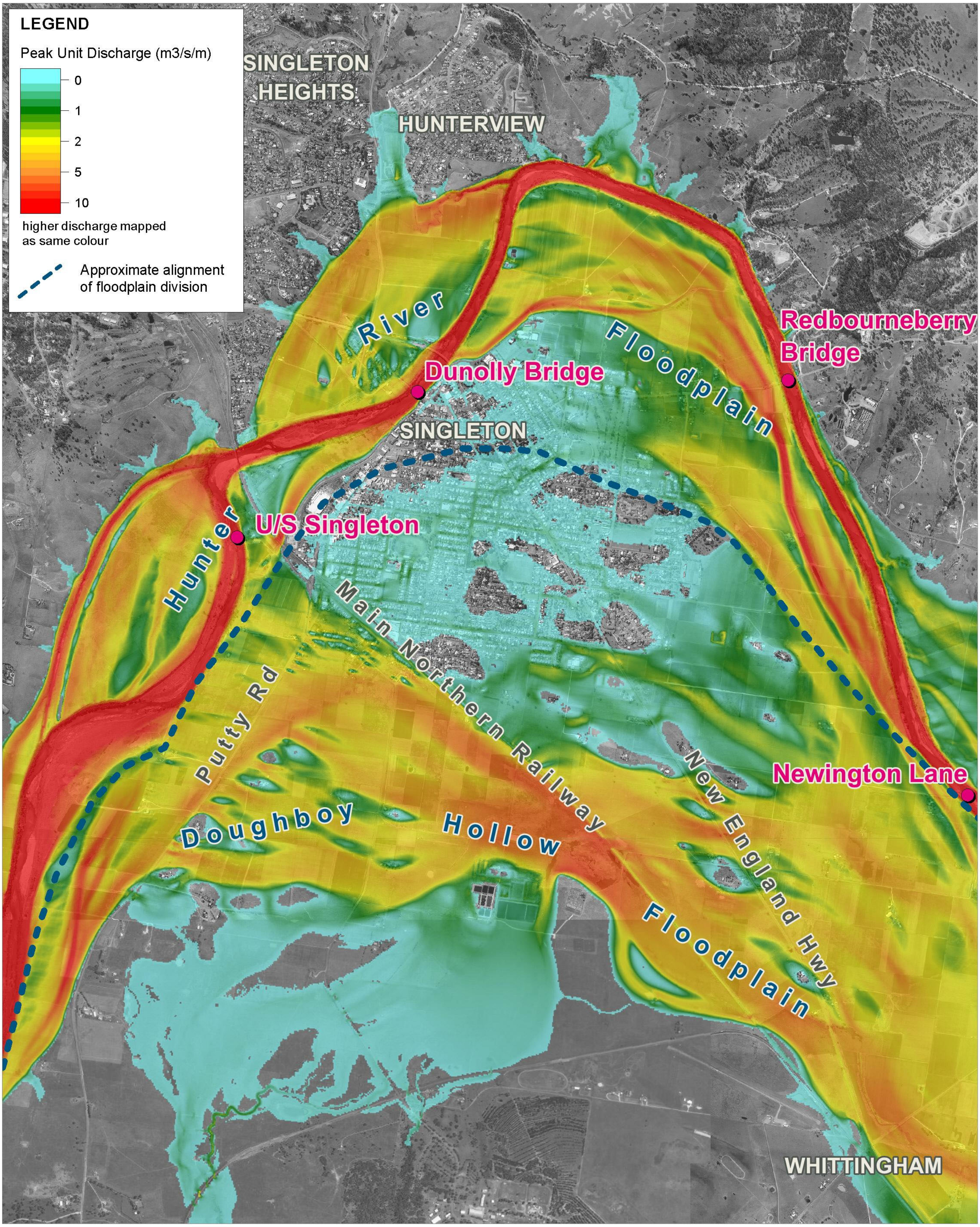
Table 3-1 Peak Design Flood Levels at Selected Locations

Design Flood Event	Peak Flood Level (m AHD)			
	U/S Singleton Gauge	Dunolly Bridge	Redbourneberry Bridge	Newington Lane
20% AEP	40.1	39.5	37.6	36.0
10% AEP	42.1	41.5	39.2	37.6
5% AEP	42.8	41.8	39.7	37.9
2% AEP	43.3	42.2	40.0	38.2
1%AEP	43.8	42.4	40.3	38.5
0.05% AEP	45.0	43.0	41.5	39.8
Extreme	46.0	43.7	42.7	41.6

Peak flood velocities of between 2 m/s and 4 m/s are typical in the Hunter River while floodplain flows (e.g. through Doughboy Hollow) of between 0.5 m/s and 1.5 m/s are typical.

3.2 Flooding Constraints

The Main North railway line and New England Highway bisect the natural path of major flood flows conveyed through Glenridding and Doughboy Hollow floodplains. The Singleton flood levee along the riverbank, which was constructed initially in 1963 and extended in 1982-1983 and again in 1987, is not overtopped by floods up to and including the 1% AEP event. This is expected, as the levee was built to withhold flooding similar to that experienced in 1955.



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Singleton 1% AEP Flood Flow Distribution

Figure: 3-1

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However, the model results indicate that flooding by the 1% AEP event would overtop the Main North railway line in the vicinity of John Street South and the railway station, resulting in extensive inundation of residential properties. Also, there is a significant damming effect by the railway embankment and a small ridge adjacent to the Wastewater Treatment Works that results in deep flooding in the Doughboy Hollow floodplain. This increases the likelihood of overtopping of the Main North railway line and subsequent flooding of the township.

Across the broader floodplain area, the New England Highway currently experiences a level of flood immunity somewhere between the 10% AEP and 5% AEP.

An overview of the baseline flood behaviour is presented in Figure 3-1, which provides mapping of the spatial concentration of flood flows. It indicates the two main flow path alignments:

- the Hunter River channel and adjacent floodplain flowing around the northern side of Singleton; and
- the Doughboy Hollow floodplain, which breaks away from the Hunter River at Glenridding and flows around the southern side of Singleton, before combining with the Hunter River floodplain again at Whittingham.

4 Assessment of the Singleton Bypass Concept Design

The construction of a road embankment across a floodplain can potentially increase flood levels, re-distribute flows, increase inundation times and increase velocities. These impacts need to be minimised, especially in populated areas and in areas of agricultural or environmental significance. It is also important that an economically viable solution is achieved.

Flood mitigation and/or design modifications that may be required to achieve the selected design criteria are summarised Section 4.1. The flood impacts and performance of the potential bypass route options is presented in Section 4.2.

4.1 Flood Mitigation and Design Modification

The bypass design has been assessed for flood impacts at the 20% and 80% concept design stages. As the design progressed, the design was adjusted to minimise flood impacts. The principal design modifications to assist with flood mitigation include the inclusion 1,800 m raised viaduct across the Doughboy Hollow floodplain and a further 600 m long viaduct near the southern connection of the bypass. The viaducts and other bridges associated with the bypass seek to minimise any obstruction to floodplain flow which the bypass would otherwise cause.

4.2 Potential Impacts

4.2.1 Overview

The concept design model was simulated for the 20% AEP to 1% AEP design flood event range (the results of which are presented in Appendix B) and compared to simulations of existing conditions, providing for a relative assessment of the potential impacts and performance of the bypass design. Potential impacts that can be quantified through the modelling include:

- Changes in peak flood level within the study area;
- Increases in velocity and scour potential;
- Increase in flood hazard; and
- Identification of adjacent property that may be adversely impacted by changed flooding behaviour.

The performance of the concept design can also be considered in terms of:

- Flood immunity level;
- Relative timing of overtopping; and
- Duration of inundation.

4.2.2 Changes in Peak Flood Level

Appendix C contains flood impact mapping in terms of change in peak flood level from existing conditions to the modelled REF Addendum concept design. Seven design flood magnitudes – the 20% AEP, 10% AEP, 5% AEP, 2% AEP and 1% AEP design events are presented.

At the 20% AEP event there are no notable impacts on the modelled peak flood levels due to the minimal extent of out-of-bank flooding and the bridging of the Hunter River. At the 10% AEP event there are some increases in peak flood level within lower lying parts of Doughboy Hollow. These increases are associated with the proposed Putty Road connection as it forms a partial obstruction to flow and results in a slight redistribution of that flow. The impacts occur to flowpaths that are active in the existing case and the increases in peak flood level are generally in the range of 0.02 m to 0.05 m with increases of up to 0.07 m in a localised area against the railway. Other highly localised differences in peak flood levels are apparent within the immediate vicinity of the Putty Road connection with increases of up to 0.12 m and decreases of up to 0.20 m.

At the 5% AEP event, there are increases in peak flood level of around 0.03 m within the Hunter River upstream (west) of the proposed bypass. Peak flood level increases of up 0.03 m also occur within the Doughboy Hollow floodplain although these are now less extensive when compared to the 10% AEP event. Highly localised increases of a higher magnitude occur immediately adjacent to the Putty Road connection. No dwellings appear to be impacted by more than a 0.02 m increase.

At the 2% AEP event the peak flood level increases within the Hunter River extend further upstream but remain within 0.02 m to 0.05 m. There is a significant flow through Doughboy Hollow but this is not impacted by the proposed bypass. There is a reduction in peak flood level to multiple properties south and south-east of the Putty Road connection. These decreases are up to 0.08 m and are associated with the redistribution of flow due to the Putty Road Connection. The floodplain near the southern connection is now active and the proposed design results in some minor increases and decreases in peak flood level. However, the impacts are localised and limited to rural property, with no impacts to any existing dwellings.

At the 1% AEP event the flood impacts near the Putty Road connection and the southern connection generally increase in extent and magnitude. Much of the land local to the connections is likely to be acquired by TfNSW for the construction and operation of the Singleton bypass. Therefore, depending on the extent of land acquisition, much of the localised impact may not result in any adverse effects to property. The modelled peak flood level impacts at dwelling locations remote from the bypass are up to a 0.04 m increase. There are reduced peak flood levels across large urban areas of Singleton, up to around a 0.04 m decrease.

4.2.3 Changes in Peak Flood Velocity and Scour Potential

Appendix D presents simulated changes in peak flood velocity distribution associated with the concept design for the range of modelled design events. In general, the mapping shows that changes in floodplain velocity distribution is relatively localised for all design events considered. These impacts are largely associated with the local redistribution of flows around the Putty Road connection and the southern connection.

At the 20% AEP event there are no significant impacts on the modelled peak flood velocities due to the minimal extent of out-of-bank flooding and the bridging of the Hunter River. At the 10% AEP event some minor impacts on the modelled peak flood velocities have been identified at the proposed Putty Road connection. The impacts are typically reduced velocities due to the presence of the bypass embankments. However, peak velocities are locally increased where flood waters along the Rose Point floodway overtop the Putty Road connections to the bypass.

At the 5% AEP event the proposed Putty Road connection has resulted in a minor local redistribution of flood flows. This results in localised changes to the modelled peak flood velocities, most notably along the Rose Point floodway alignment. Within the Rose Point floodway upstream of the railway, peak velocities are increased locally by approximately 0.7 m/s to 1.0 m/s. There is a reduction in peak velocity through the floodway rail culverts from around 1.6 m/s to 1.2 m/s and in the floodway downstream of the railway from around 0.9 m/s to 0.7 m/s.

At the 2% AEP event the peak velocity impacts are generally consistent with those of the 5% AEP event, albeit to a larger magnitude. Within the Rose Point floodway upstream of the railway, peak velocities are increased from around 0.8 m/s to 1.3 m/s. There is a reduction in peak velocity in the floodway downstream of the railway from around 0.8 m/s to 0.5 m/s extending for around 800 m downstream of the bypass. Peak flood velocities adjacent to the north bound connection from Putty Road increase by up to 0.5 m/s where the Putty Road connection redistributes floodwater within the floodplain. There are some minor peak velocity increases of up to 0.15 m/s adjacent to the southern abutment of the Hunter River railway bridge.

At the 1% AEP event the peak velocity impacts are generally consistent with those of the 2% AEP event, albeit to a larger magnitude. Within the Rose Point floodway upstream of the railway, peak velocities are increased from around 0.8 m/s to 1.3 m/s. There is a reduction in peak in the floodway downstream of the railway from around 0.8 m/s to 0.5 m/s. Peak flood velocities adjacent to the north bound connection from Putty Road increase by up to 0.8 m/s where the Putty Road connection redistributes floodwater within the floodplain. There are some minor peak velocity increases of up to 0.3 m/s adjacent to the southern abutment of the Hunter River railway bridge. Modelled velocities here are in excess of 2 m/s in both the existing and post-construction scenarios. There are also reduced peak velocities in areas that become partially sheltered by the bypass embankment.

At the 1% AEP event the embankment between the two large floodplain viaducts creates minor localised increases in peak flood velocity due to a slight concentration in flow as water passes alongside and around the embankment. The maximum increase is 0.7 m/s. There are also reduced peak velocities in areas that become partially sheltered by the bypass embankment.

4.2.4 Other Impacts

This flood impact assessment has considered mainstream flooding of the Hunter River. At other locations where the proposed bypass alignment traverse creeks and gully lines, local cross-drainage has been sized by the AECOM drainage design team.

Currently the duration of flooding varies from event to event. Given the extensive contributing catchment to the Hunter River at Singleton, major flood events typically last for a few days. Whilst potentially not directly impacted by on-site floodwater, evacuation of the Singleton CBD area under major flood conditions may require closure of the centre for a few days until peak floodwaters subside. Presently access routes are expected to be closed for a few days in major flood events. The bypass design does not impact the overall duration of flood inundation, but potentially changes localised drainage following the recession of a flood. The bypass can benefit the community by providing additional flood evacuation routes and local accessibility during a flood event.

4.3 Hydraulic Assessment

This section details the hydraulic assessment at the bridge structures, to assist with the bridge design process. Flood levels are reported at locations approximately one bridge length upstream and downstream of the structure. Velocities have been extracted at the bridge structure. Ranges are provided where there is significant variation.

Estimation of scour at abutments presents significant challenges and uncertainty. Ettema et al (2010) developed design curves to determine a scour amplification factor, based on the ratio of flow through the main channel upstream of and through the bridge section. This factor is then applied to the general contraction scour, as per the Laursen equations, which form the basis of the empirical equations developed by Froehlich and HIRE (QLD TMR, 2013). Abutment scour has been calculated following this approach. The local pier scour has been calculated as recommended within HEC-18, which is based on the equations developed by the Colorado State University. No allowance has been made in the scour calculations for potential debris loading.

4.3.1 Bridge at southern connection (BR011)

Flood flows through the 600 m long bridge at the southern connection occur from around the 2% AEP event, as an existing flood flow path within the broader Doughboy Hollow floodplain becomes activated. Modelled peak flow rates through the bridge structure are around 16 m^3/s at the 1% AEP event and 170 m^3/s at the 0.05% AEP event.

The modelled peak flood levels and velocities along the length of the bridge structure are summarised in Figure 4-1 and Figure 4-2, respectively. The velocities represent the peak depth-averaged velocities. Peak surface velocities can be approximated as being 1.143 times the depth-averaged.

The bridge does not function with a significant hydraulic contraction. This limits the effectiveness of abutment scour assessment calculations, which are a function of the general contraction scour. Therefore, only pier scour calculations have been undertaken, with the assumption that these are also reasonable to represent potential abutment scour at either end of the structure. The local pier scour results are summarised in Figure 4-3. Typical scour depths at the pier locations along the bridge structure are 1.5 m for the 1% AEP event and 2.75 m for the 0.05% AEP event.

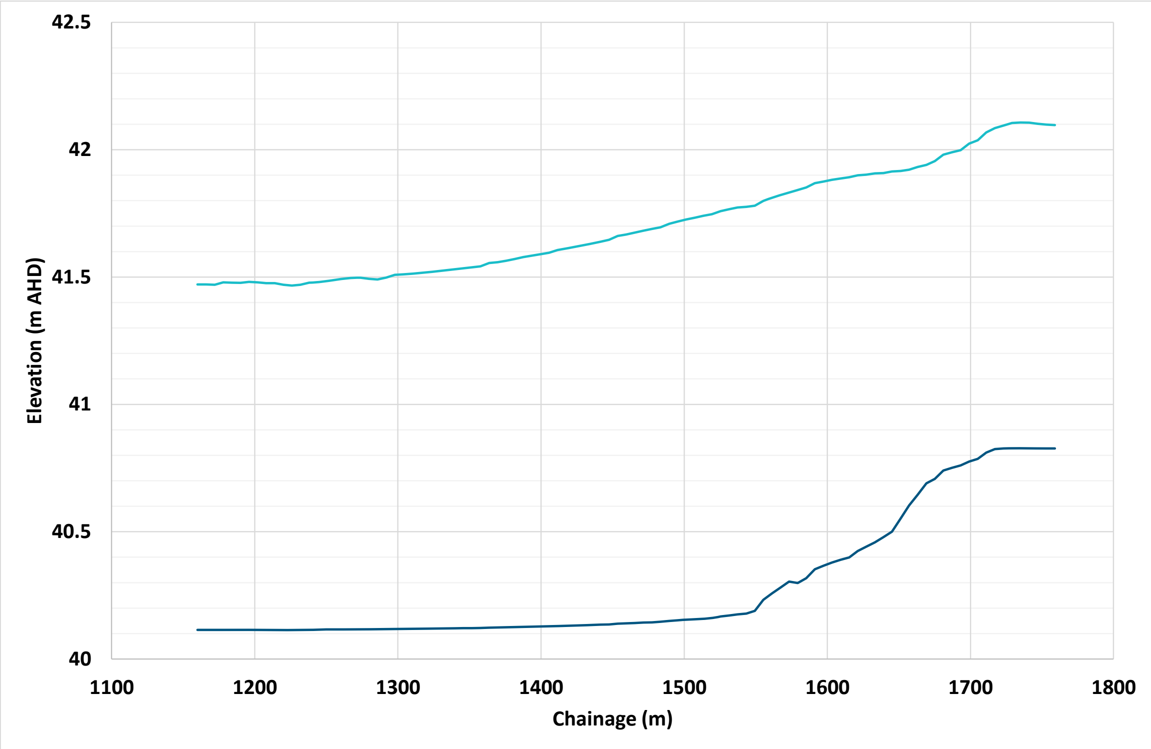

Figure 4-1 Modelled Peak Flood Levels at BR011

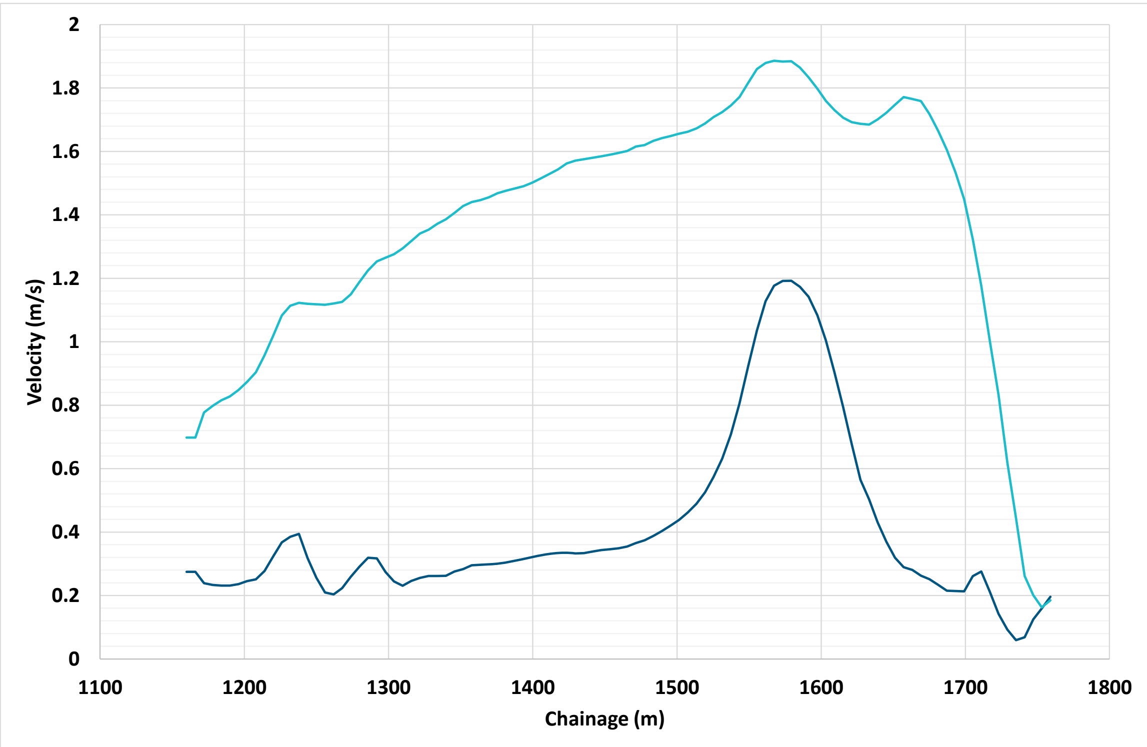

Figure 4-2 Modelled Peak Velocities at BR011

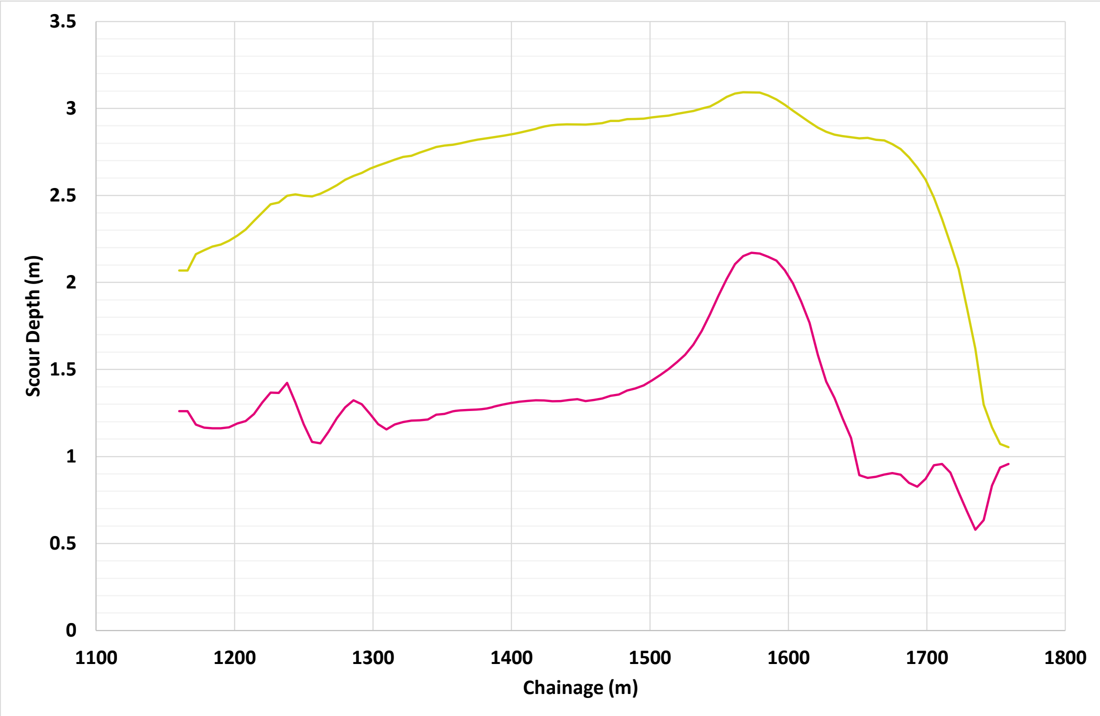

Figure 4-3 Estimated Scour Depth at BR011

4.3.2 Bridge over floodplain (BR021)

Flood flows through the bridge over floodplain occur from around the 10% AEP event, with the activation of the Doughboy Hollow floodplain. Modelled peak flow rates through the bridge structure are around 1100 m^3/s at the 1% AEP event and 2200 m^3/s at the 0.05% AEP event.

The modelled peak flood levels and velocities along the length of the bridge structure are summarised in Figure 4-4 and Figure 4-5, respectively.

As for BR011, the bridge does not function with a significant hydraulic contraction. Therefore, only pier scour calculations have been undertaken. The local pier scour results are summarised in Figure 4-6. Typical scour depths at the pier locations along the bridge structure are 2.75 m for the 1% AEP event and 3.25 m for the 0.05% AEP event. However, from around ch.3500 the shallow depth of resistant clays limits the effective depth of scour. The blade piers at the crossing of the Main North Railway are very wide in relation to the modelled flow depths, which presents significant uncertainty when estimating potential scour depths. The typical estimates of 2.75 m for the 1% AEP event and 3.25 m for the 0.05% AEP event are likely appropriate, but this may warrant further investigation during future design stages.

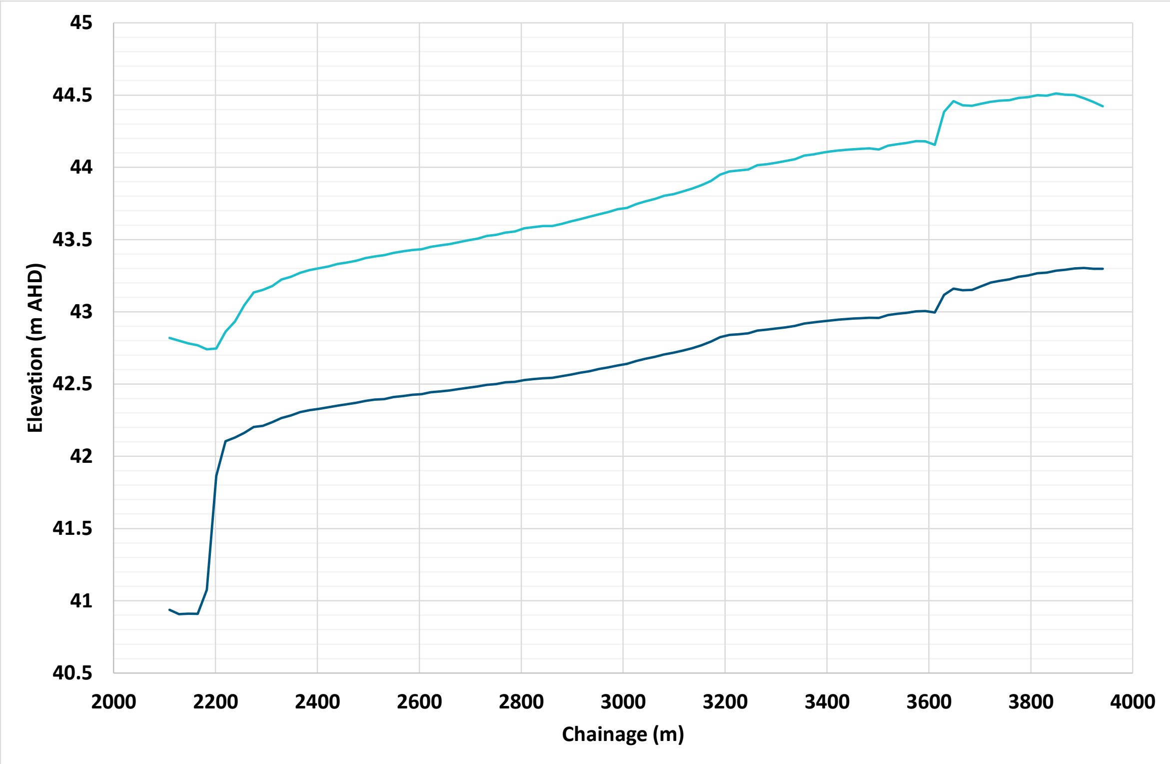

Figure 4-4 Modelled Peak Flood Levels at BR021

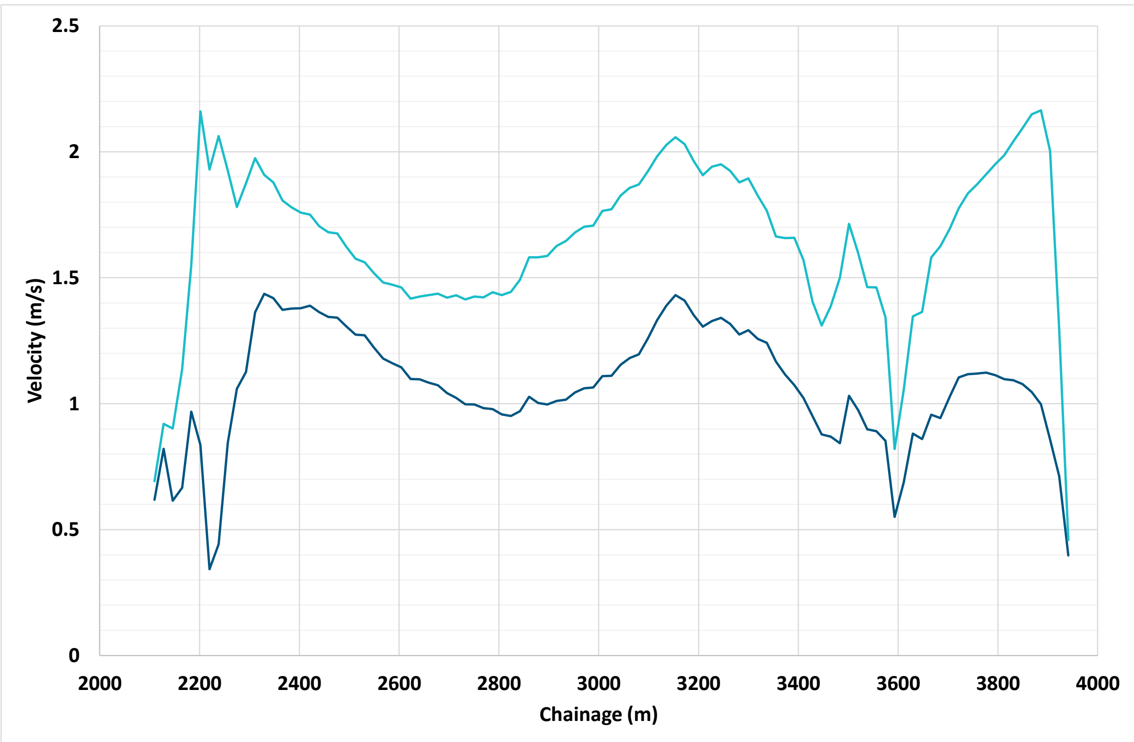

Figure 4-5 Modelled Peak Velocities at BR021

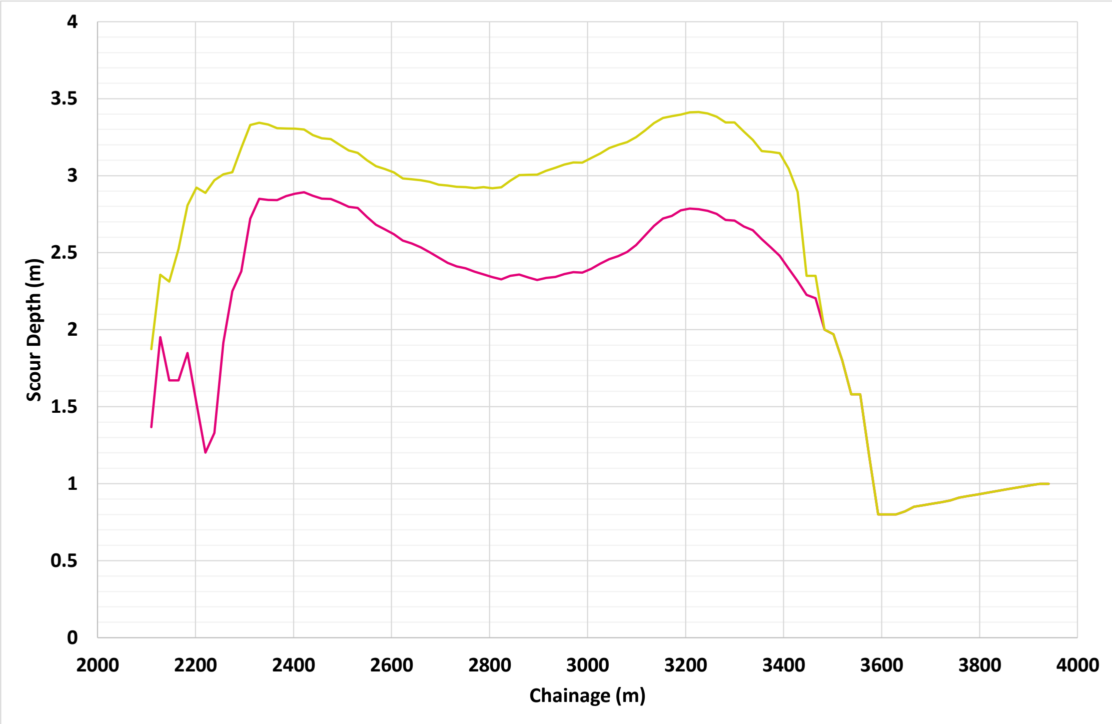

Figure 4-6 Estimated Scour Depth at BR021

4.3.3 Bridge over Rose Point floodway (BR023)

The bridge over Rose Point floodway spans approximately 100 m and includes two equally spaced circular piers. The piers have a 2 m diameter and the structure has sloping abutments. Flood flows occur from around the 10% AEP event, with the activation of the Doughboy Hollow floodplain. Modelled peak flow rates through the bridge structure are around 260 m^3/s at the 1% AEP event and 740 m^3/s at the 0.05% AEP event.

The modelled peak flood levels and velocities at the bridge structure are summarised in Table 4-1 and Table 4-2, respectively.

The depth of potential scour at the structure is effectively limited by the resistant clays, which based on the nearby bore samples from the Geotechnical Investigation Factual Report (Douglas Partners, 2019) are around 1.5 m below the surface (1.9 m ~250 m to the north and 1.0 m ~250 m to the south). The estimated scour depth across the structure is presented in Figure 4-7.

Table 4-1 Modelled Peak Flood Levels at BR023

Design Event	Upstream Level (m AHD)	Downstream Level (m AHD)
1% AEP	43.8	43.4
0.05% AEP	45.5	44.6

Table 4-2 Modelled Peak Velocities at BR023

Location	Depth-averaged (m/s)		Surface[1] (m/s)	
	1% AEP	0.05% AEP	1% AEP	0.05% AEP
Span 1 (south)	1.1-1.3	1.8-2.4	1.3-1.5	2.0-2.7
Pier 1	1.3	2.4	1.5	2.7
Span 2	1.2-1.3	2.3	1.4-1.5	2.6-2.7
Pier 2	1.2	2.3	1.4	2.7
Span 3 (north)	0.6-1.2	1.4-2.3	0.7-1.4	1.6-2.7

1 Surface velocity is estimated as 1.143 times the depth-averaged velocity (CIRIA, 2002)

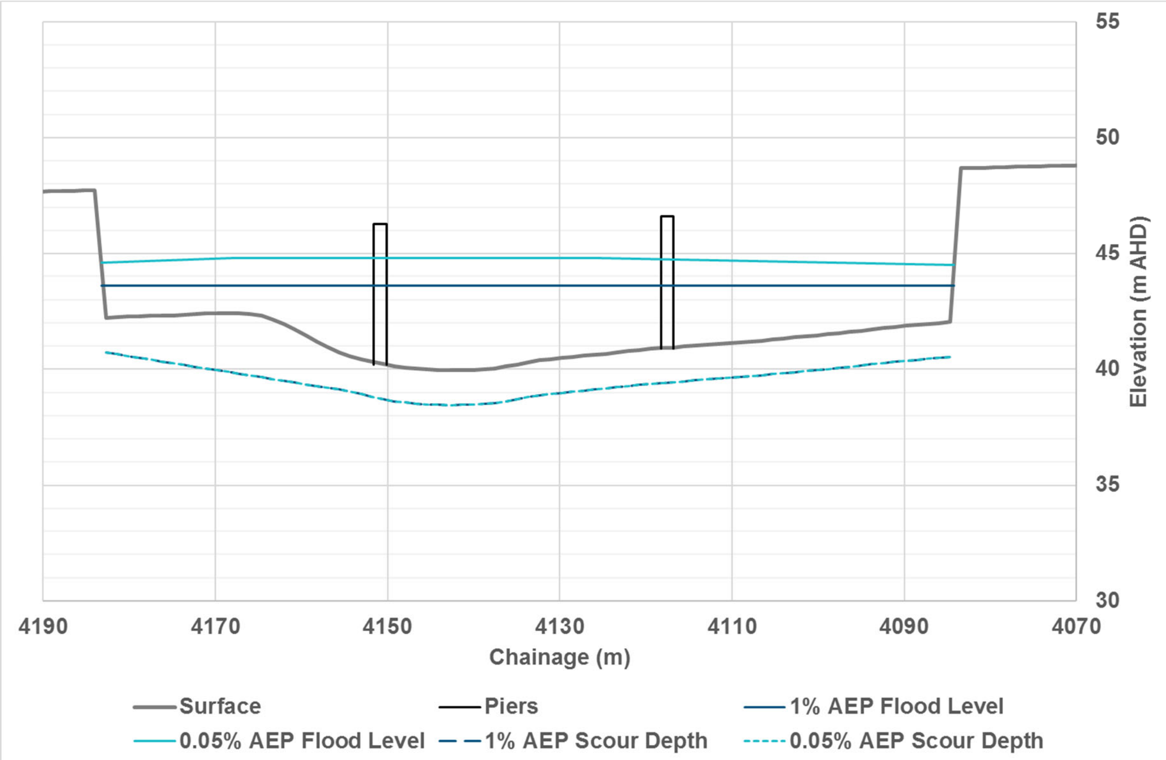

Figure 4-7 Bridge Section at BR023

4.3.4 Bridge over Hunter River (BR030)

The bridge over the Hunter River spans 204 m and includes five circular piers of 2 m diameter and has sloping abutments. It is shown schematically in Figure 4-8. Being a crossing of the mainstream channel, flood flows occur through the bridge for all modelled events. Modelled peak flow rates through the bridge structure are around 4800 m^3/s at the 1% AEP event and 6600 m^3/s at the 0.05% AEP event.

The modelled peak flood levels and velocities at the bridge structure are summarised in Table 4-3 and Table 4-4, respectively. It should be noted that the significant head loss reported across the bridge is largely attributed to a combination of existing contraction through the railway bridge.

Also, of note is that the velocities are highest around the inside of the bend rather than the outside. Although at bank-full capacity the highest velocities are concentrated at the outside of the bend, once out-of-bank flooding is initiated the overall velocity distribution changes and is governed by broader scale floodplain topography. This is principally related to the contraction and expansion of the left floodplain flows through the bridge structures.

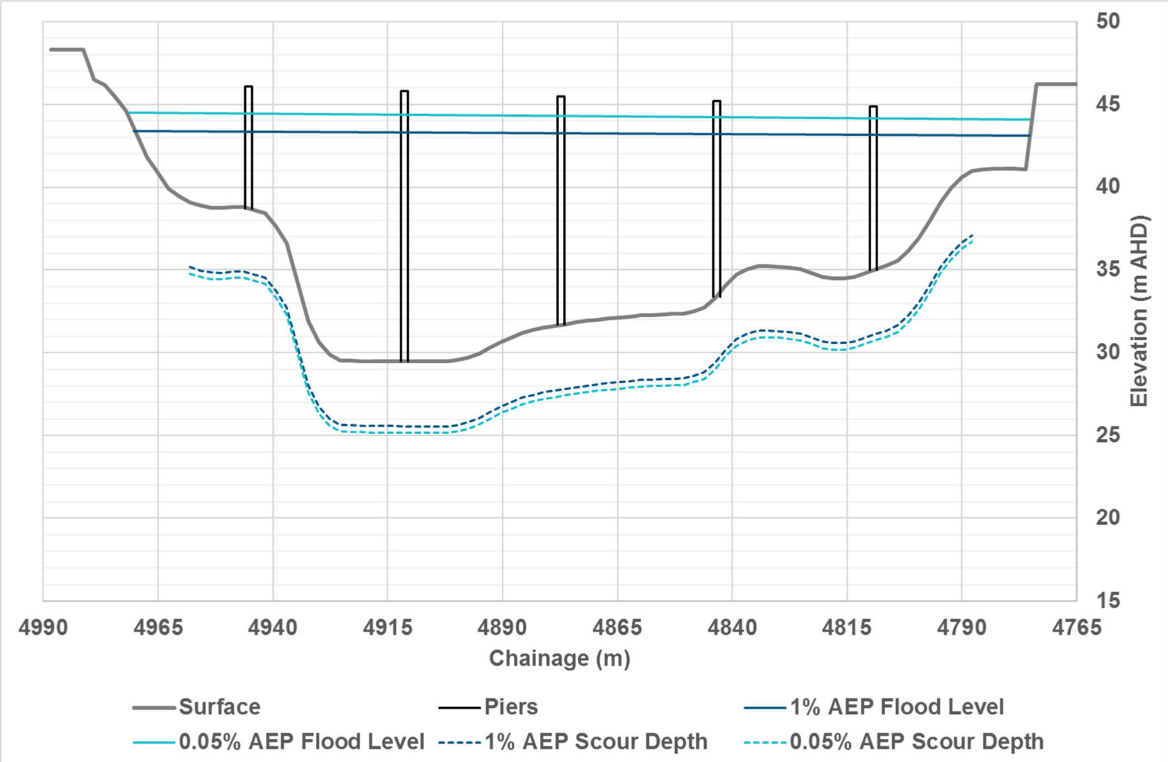

Figure 4-8 Bridge Section at BR030

Table 4-3 Modelled Peak Flood Levels at BR030

Design Event	Upstream Level (m AHD)	Downstream Level (m AHD)
1% AEP	43.7	42.8
0.05% AEP	45.0	43.7

Table 4-4 Modelled Peak Velocities at BR030

Location	Depth-averaged (m/s)		Surface[1] (m/s)	
	1% AEP	0.05% AEP	1% AEP	0.05% AEP
Span 1 (south)	1.5-3.0	2.0-3.8	1.7-3.4	2.2-4.3
Pier 1	3.0	3.8	3.4	4.3
Span 2	3.0-3.3	3.8-4.0	3.4-3.7	4.3-4.6
Pier 2	3.1	3.8	3.6	4.3

Location	Depth-averaged (m/s)		Surface[1] (m/s)	
	1% AEP	0.05% AEP	1% AEP	0.05% AEP
Span 3	2.9-3.1	3.5-3.8	3.3-3.6	4.0-4.4
Pier 3	2.9	3.5	3.3	4.0
Span 4	2.7-2.9	3.4-3.6	3.1-3.3	3.9-4.1
Pier 4	2.7	3.4	3.1	3.8
Span 5	2.5-2.7	3.2-3.4	2.9-3.1	3.6-3.9
Pier 5	2.5	3.2	2.9	3.6
Span 6 (north)	2.0-2.5	3.2-1.3	2.3-2.9	3.6-1.4

1 Surface velocity is estimated as 1.143 times the depth-averaged velocity (CIRIA, 2002)

The local scour calculations for the deepest point at pier 4 provide a scour depth estimate of 3.9 m for the 1% AEP event and 4.3 m for the 0.05% AEP event. The bridge has complex approach flow conditions and as such the calculation of general contraction (and hence abutment scour depths) is highly sensitive to the selection of the representative approach conditions. Therefore, abutment scour calculations are not presented. The bridge channel section and pier scour depth estimates are presented in Figure 4-8.

It should be noted that there is currently no detailed geotechnical information available at the bridge location and so the estimated scour depths may be limited by the underlying soil or rock layers. Further assessment of the local scour conditions should be undertaken during future design stages, when such information is available.

4.3.5 Hydraulic Assessment Flood Level Summary

Table 4-5 provides a summary of bridge details along with design flood levels for the 1% AEP and 0.05% AEP events. It can be seen that for all four bridges, the bridge decks are elevated above the 0.05% AEP (1 in 2000 AEP).

Table 4-5 Summary of Flood Levels at Bridges*

Bridge ID	Bridge Description	Soffit Elevation (mAHD)	Deck Thickness (m)	Peak Flood Level (mAHD)	
				1%	0.05%
BR011	Bridge at southern connection	44.4	1.8	40.8	42.1
BR021	Bridge over floodplain	48.1	1.8	43.3	44.5
BR023	Bridge over Rose Point floodway	46.1	1.8	43.6	44.8
BR030	Bridge over Hunter River	44.5	1.8	43.2	44.3

**For reporting purposes, the maximum flood level and the minimum soffit along the length of the bridge has been used. Bridge and flood elevations may vary from quoted levels along the alignment*

4.4 Scour Protection Works

The design of specific scour protection works has not been considered for this assessment. It is recommended that the depth of bridge abutments and piers exceed the potential scour depths and are not reliant upon scour protection measures.

5 Conclusion

The Singleton Bypass Concept Design (REF Addendum Design) Flood Assessment Report documents the existing flooding conditions in the study area and the likely flood impacts of the proposed bypass. The assessment represents a concept design level assessment of the proposed Singleton bypass in terms of potential impact on existing Hunter River flood conditions and bridge structure requirements to minimise adverse flood impact.

The existing design flood conditions for a range of flood event magnitudes are presented in Appendix A through a flood mapping series, incorporating peak flood extents, levels, depth and velocity distribution. The design flood conditions post-bypass construction is presented in Appendix B. The impact of the proposed bypass alignment and adopted bridge structure configuration was presented in terms of relative change from the existing peak flood level and velocity distribution, as presented in Appendix C and Appendix D respectively.

A hydraulic assessment at the bridge structures has been undertaken, providing information of flood velocities and estimated pier scour depths to assist with the bridge design process.

6 References

Austroads, 2019. *Guide to Bridge Technology Part 8: Hydraulic Design of Waterway Structures*

BMT, 2018. *Singleton Bypass Concept Design (20%) Flood Assessment*, May 2018.

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Ettema, R., Nakato, T. and Muste, M. (2010) *Estimation of Scour Depth at Bridge Abutments NCHRP 24-20*

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QLD TMR, (2019) *Bridge Scour Manual*

WBM, 2003. *Singleton Flood Study, Final Draft Report prepared for Singleton Shire Council*, May 2003.

Appendix A Existing Design Flood Mapping

LEGEND

Peak Flood Depth (m)

- 0.5 lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 higher depths mapped as same colour

Peak Flood Velocity (m/s)

Scale: 1mm = 0.5m/s @A3

- 0.5
- 1.0
- 2.0
- 3.0

20 Peak Flood Level Contours (m AHD)

Title:

Singleton Bypass Concept Design Flood Assessment Existing - 20% AEP Modelled Peak Flood Conditions

Figure: A-1

Rev: A

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

N

0 0.5 1km

Approx. Scale

BMT

www.bmt.org

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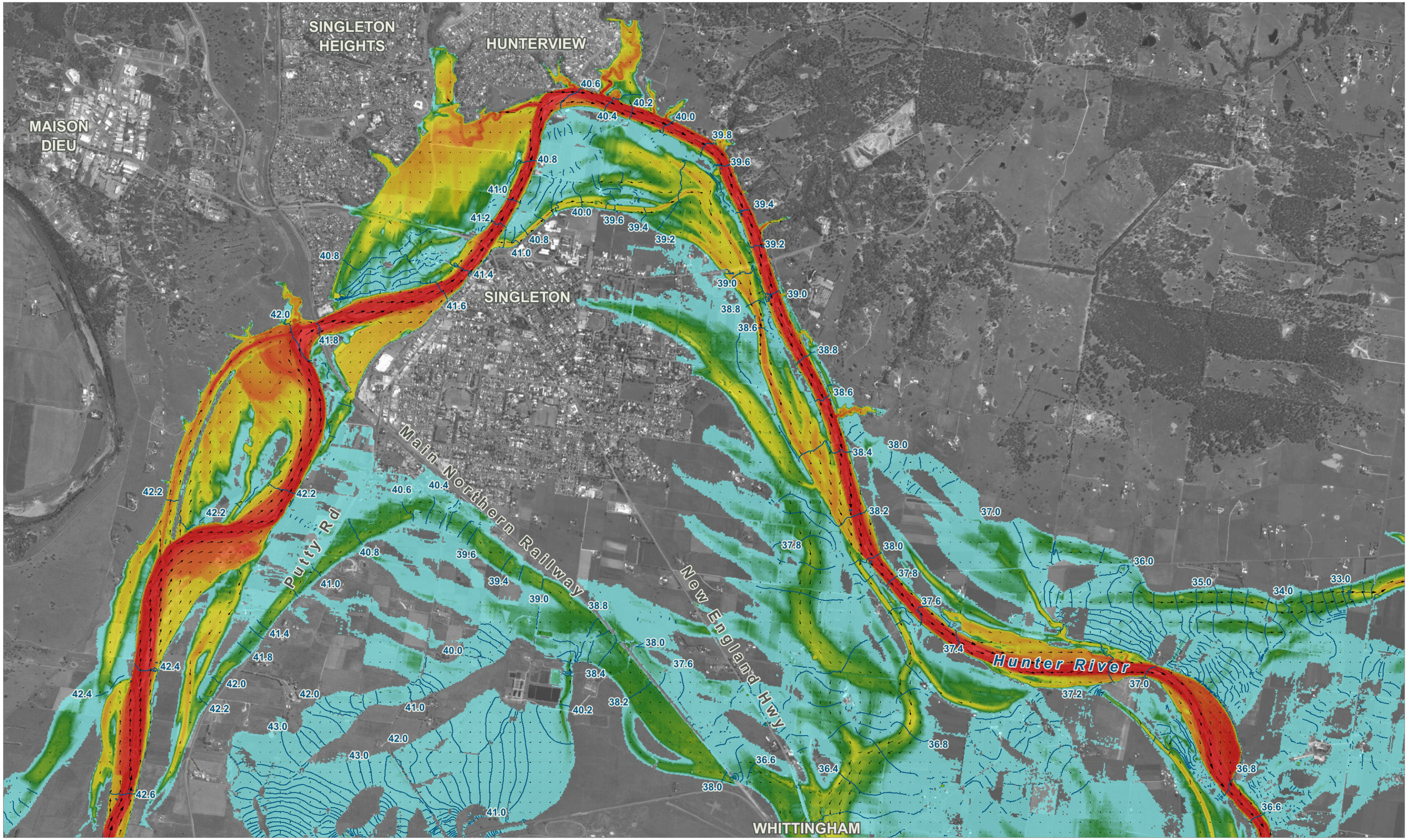

LEGEND

Peak Flood Depth (m)
- 0.5 lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 higher depths mapped as same colour

Peak Flood Velocity (m/s)
Scale: 1mm = 0.5m/s @A3
- 0.5
- 1.0
- 2.0
- 3.0

20 Peak Flood Level Contours (m AHD)

Title:
Singleton Bypass Concept Design Flood Assessment Existing - 10% AEP Modelled Peak Flood Conditions

Figure: A-2

Rev: A

N

0 0.5 1km
Approx. Scale

BMT
www.bmt.org

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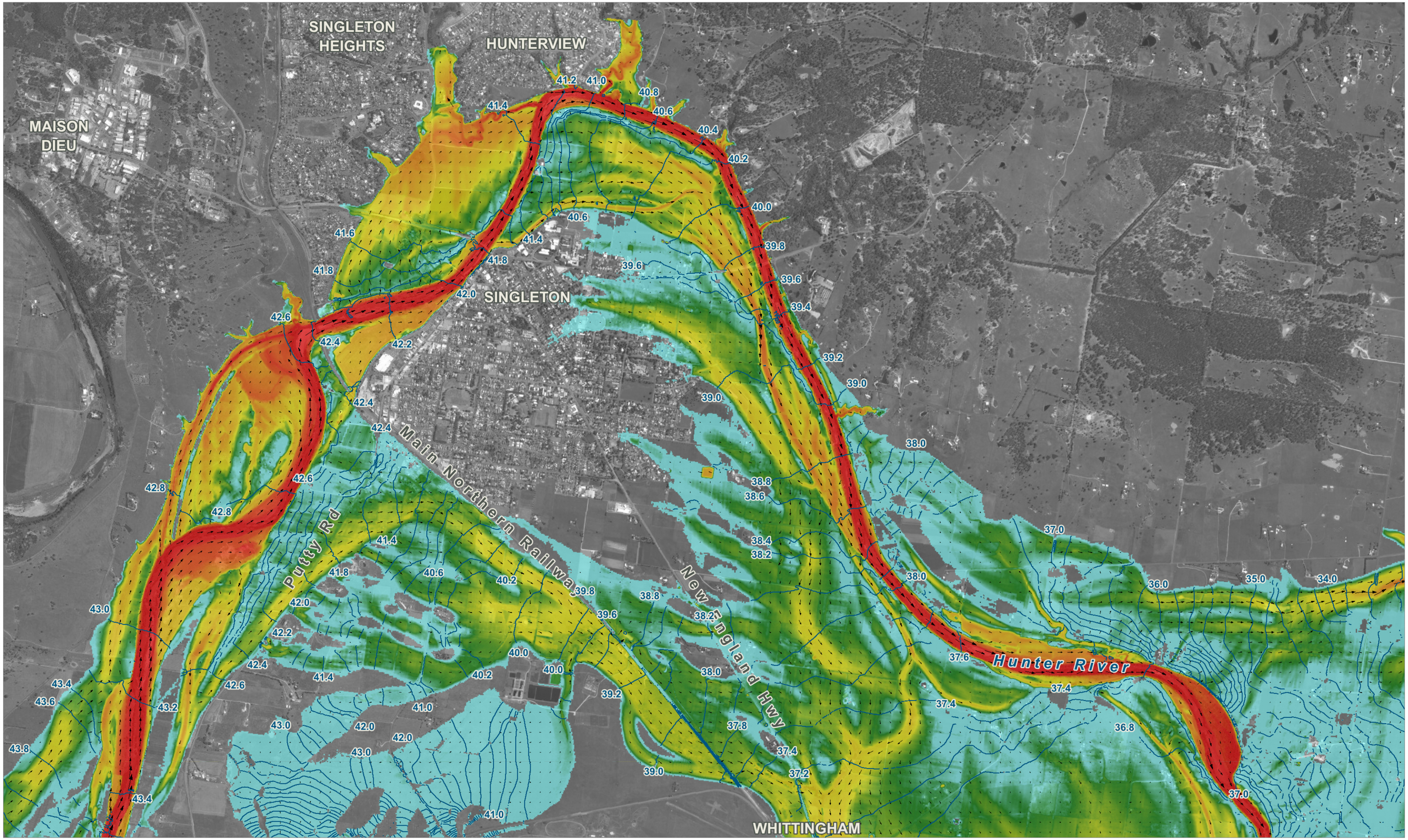

LEGEND

Peak Flood Depth (m)

- 0.5 — lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 — higher depths mapped as same colour

Peak Flood Velocity (m/s)

Scale: 1mm = 0.5m/s @A3

- 0.5
- 1.0
- 2.0
- 3.0

20 — Peak Flood Level Contours (m AHD)

Title:

Singleton Bypass Concept Design Flood Assessment
Existing - 5% AEP Modelled Peak Flood Conditions

Figure: A-3

Rev: A

N

0 0.5 1km

Approx. Scale

BMT
www.bmt.org

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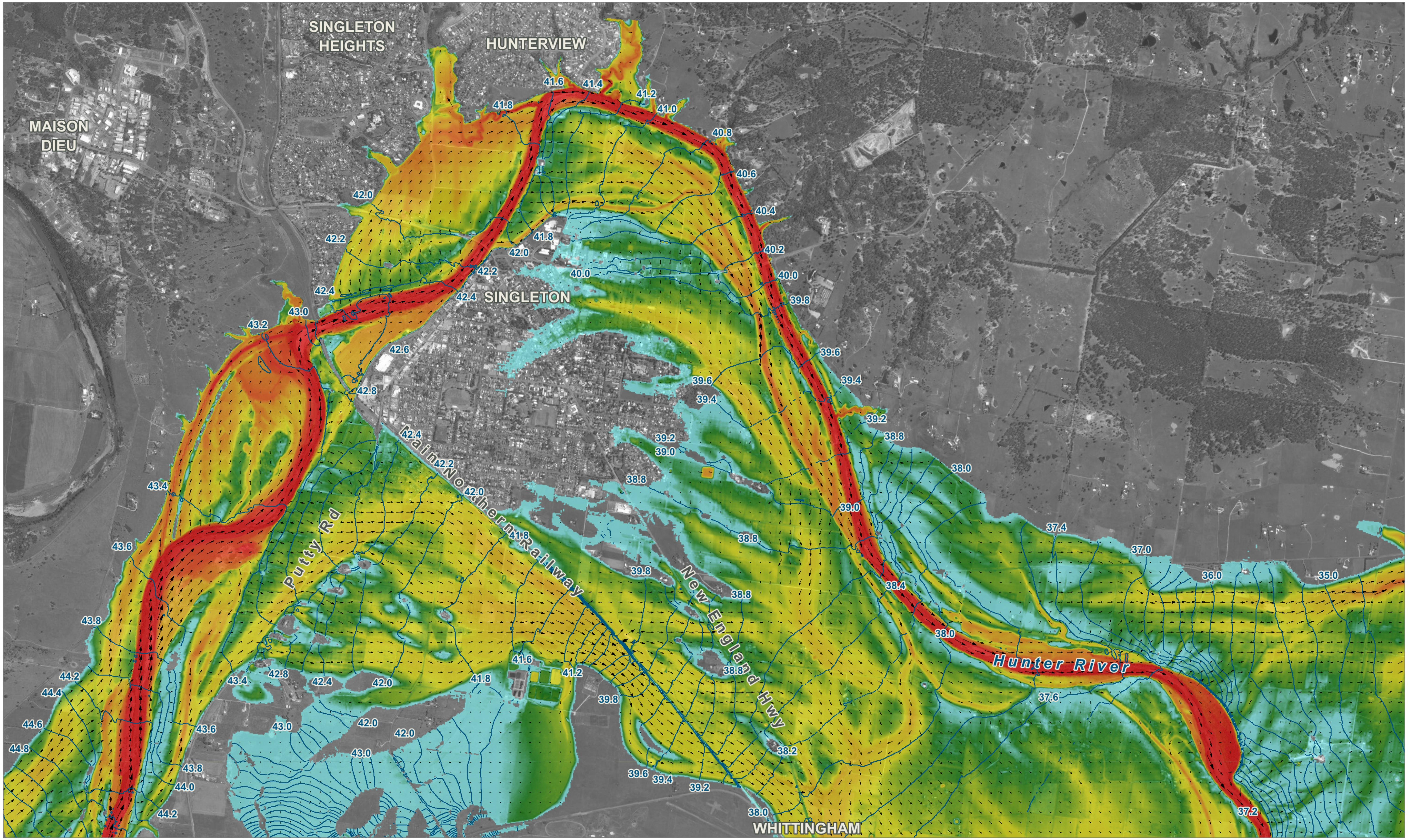

LEGEND

Peak Flood Depth (m)

0.5 lower depths mapped as same colour
1.0
2.0
5.0
10 higher depths mapped as same colour

Peak Flood Velocity (m/s)

Scale: 1mm = 0.5m/s @A3

0.5
1.0
2.0
3.0

20 Peak Flood Level Contours (m AHD)

Title:

Singleton Bypass Concept Design Flood Assessment
Existing - 2% AEP Modelled Peak Flood Conditions

N

0 0.5 1km
Approx. Scale

Figure: A-4

Rev: A

BMT
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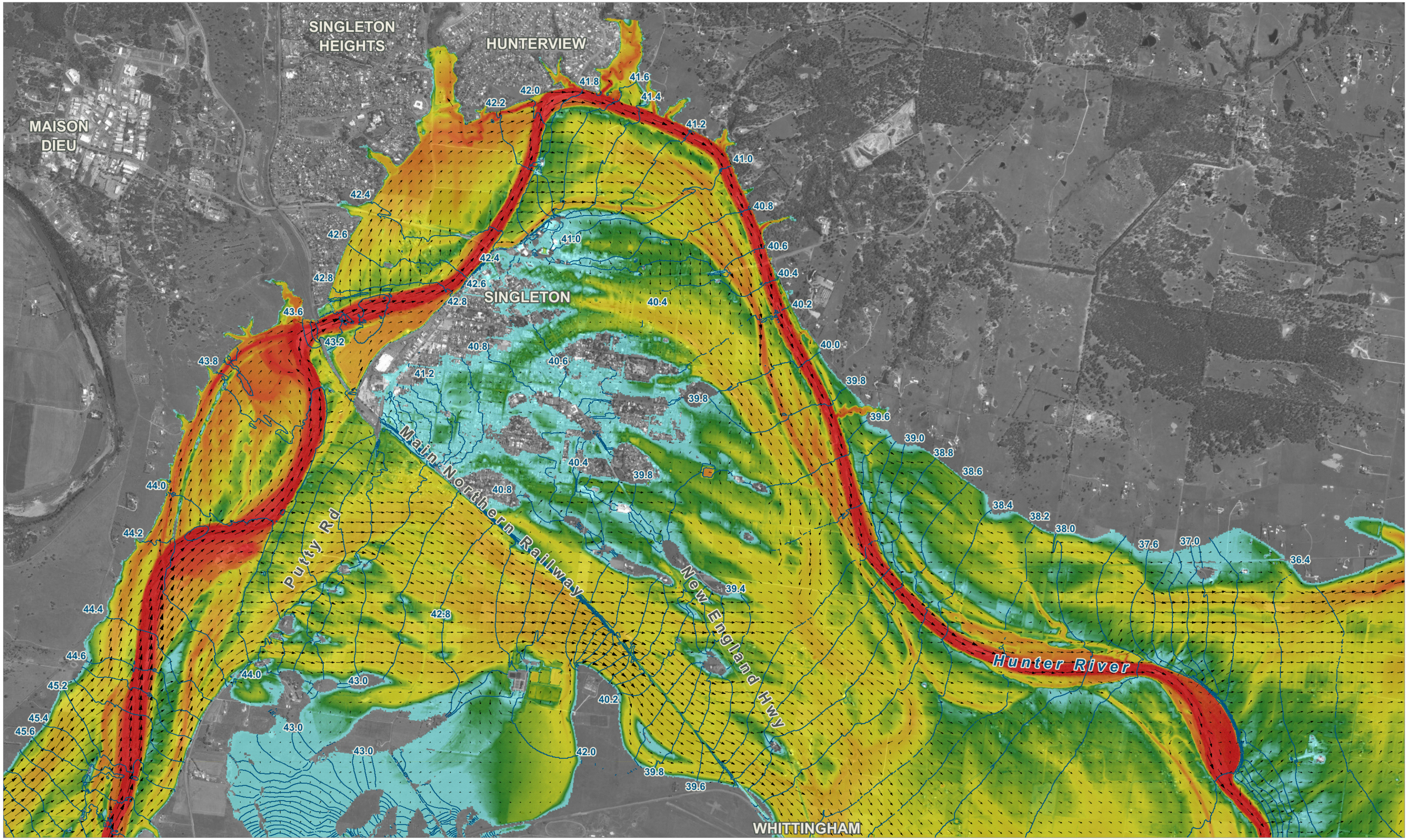

LEGEND

Peak Flood Depth (m)

- 0.5 lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 higher depths mapped as same colour

Peak Flood Velocity (m/s)

Scale: 1mm = 0.5m/s @A3

- 0.5
- 1.0
- 2.0
- 3.0

20 Peak Flood Level Contours (m AHD)

Title:

Singleton Bypass Concept Design Flood Assessment
Existing - 1% AEP Modelled Peak Flood Conditions

Figure: A-5

Rev: A

N

0 0.5 1km

Approx. Scale

BMT

www.bmt.org

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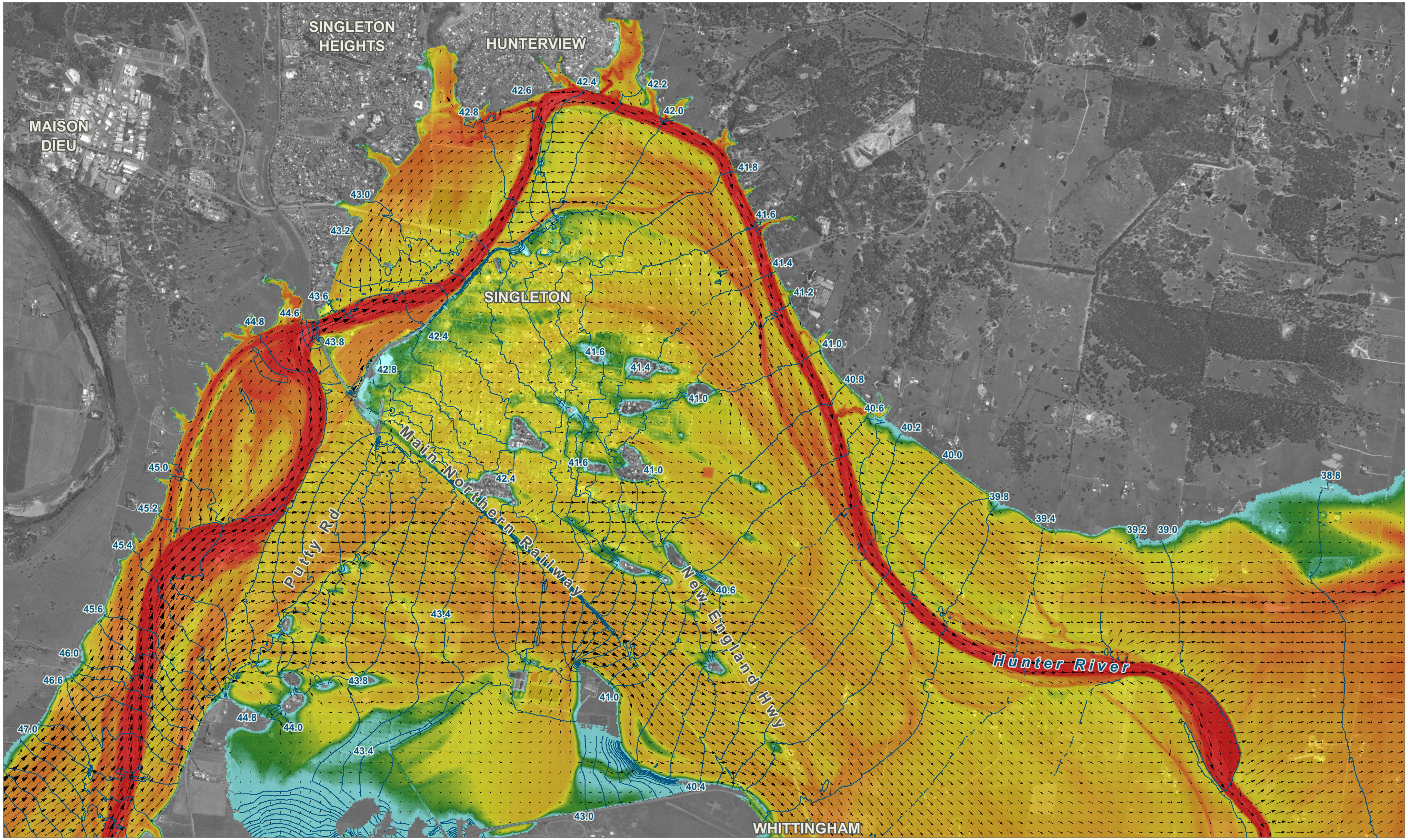

LEGEND

Peak Flood Depth (m)

- 0.5 lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 higher depths mapped as same colour

Peak Flood Velocity (m/s)

Scale: 1mm = 0.5m/s @A3

- 0.5
- 1.0
- 2.0
- 3.0

20 Peak Flood Level Contours (m AHD)

Title:

Singleton Bypass Concept Design Flood Assessment
Existing - 0.05% AEP Modelled Peak Flood Conditions

Figure: A-6

Rev: A

N

0 0.5 1km

Approx. Scale

BMT
www.bmt.org

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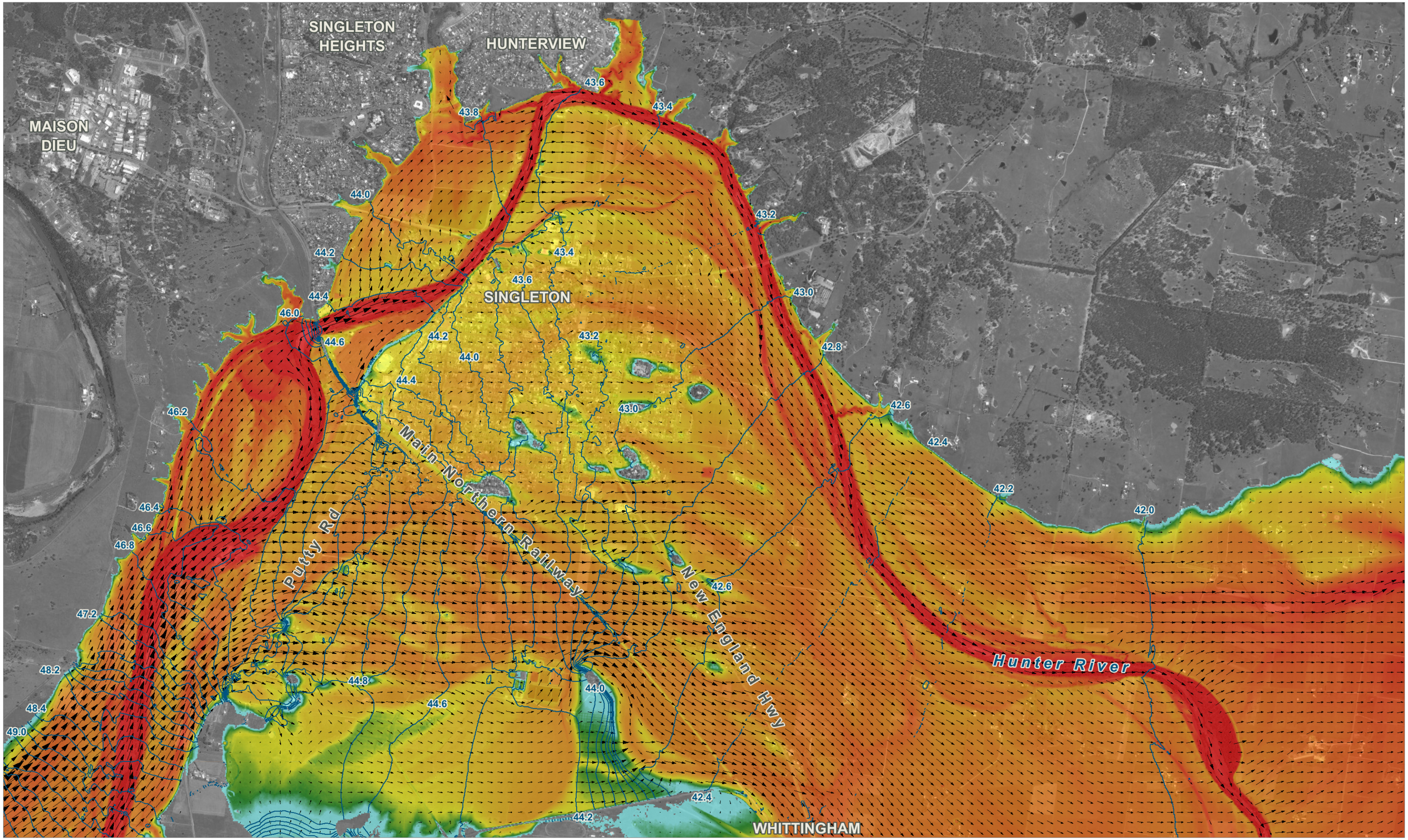

LEGEND

Peak Flood Depth (m)

- 0.5 lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 higher depths mapped as same colour

Peak Flood Velocity (m/s)

Scale: 1mm = 0.5m/s @A3

- 0.5
- 1.0
- 2.0
- 3.0

20 Peak Flood Level Contours (m AHD)

Title:

Singleton Bypass Concept Design Flood Assessment Existing - Extreme Event Modelled Peak Flood Conditions

Figure: A-7

Rev: A

N

0 0.5 1km

Approx. Scale

www.bmt.org

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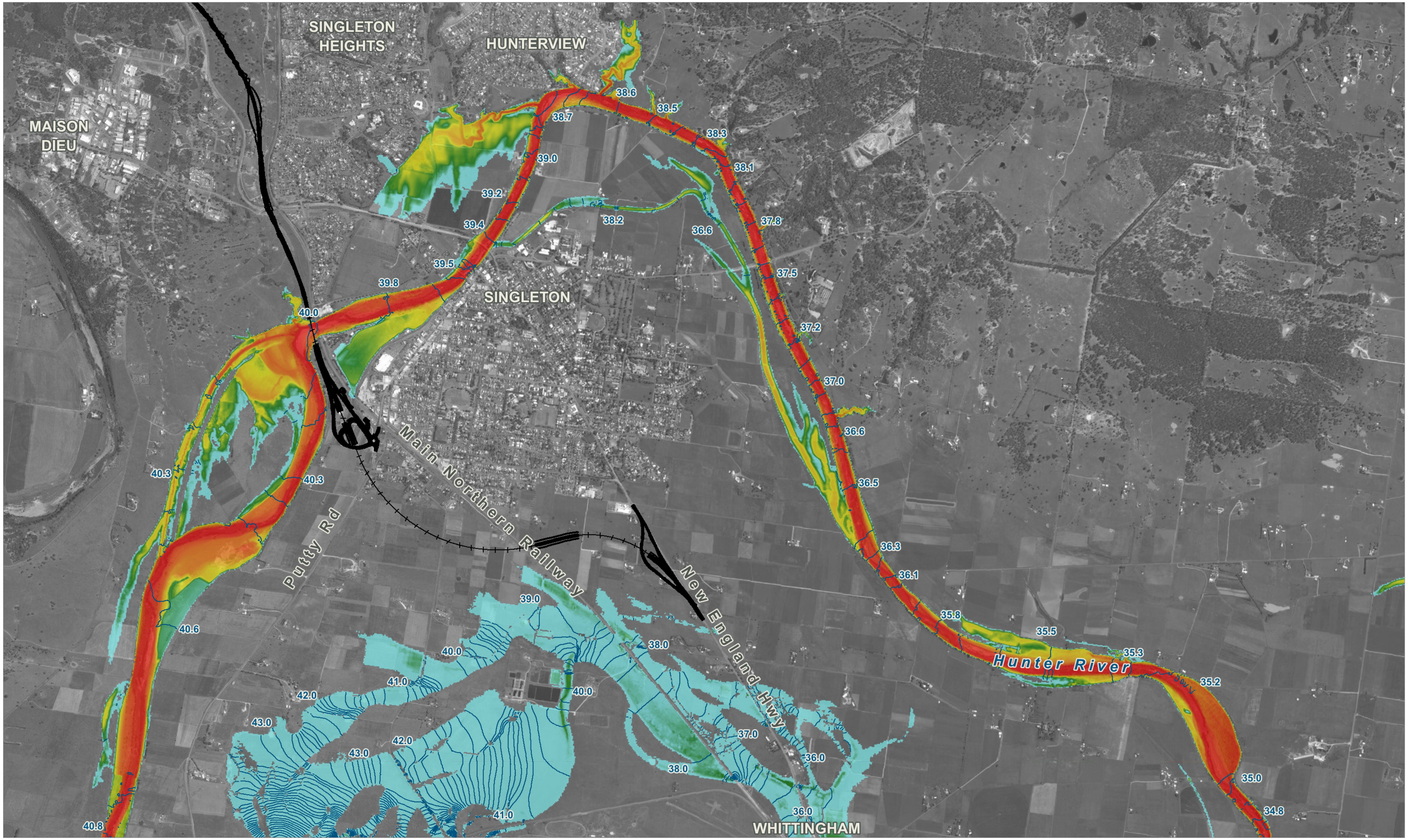
Appendix B Concept Design Flood Mapping



LEGEND

Peak Flood Depth (m)

- 0.5 lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 higher depths mapped as same colour

Peak Flood Velocity (m/s)

Scale: 1mm = 0.5m/s @A3

- 0.5
- 1.0
- 2.0
- 3.0

20 Peak Flood Level Contours (m AHD)

Bypass Alignment

Bridge Structure

Title:

Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 20% AEP Modelled Peak Flood Conditions

Figure: B-1

Rev: A

N

0 0.5 1km

Approx. Scale

BMT
www.bmt.org

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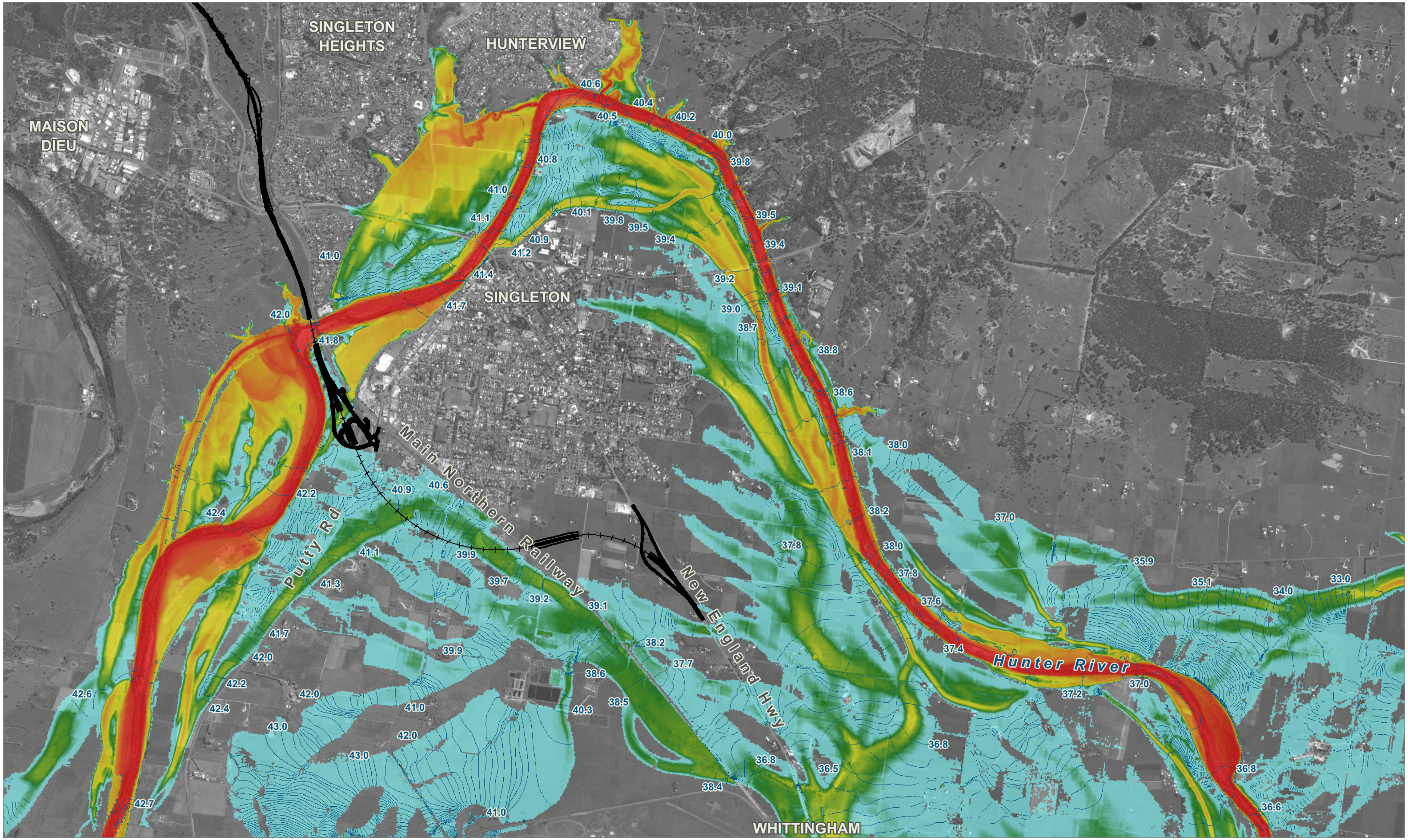

LEGEND

Peak Flood Depth (m)
- 0.5 lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 higher depths mapped as same colour

Peak Flood Velocity (m/s)
Scale: 1mm = 0.5m/s @A3
- 0.5
- 1.0
- 2.0
- 3.0

- 20 Peak Flood Level Contours (m AHD)
- Bypass Alignment
- Bridge Structure

Title:
Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 10% AEP Modelled Peak Flood Conditions

Figure: **B-2**

Rev: **A**

N

0 0.5 1km
Approx. Scale

BMT
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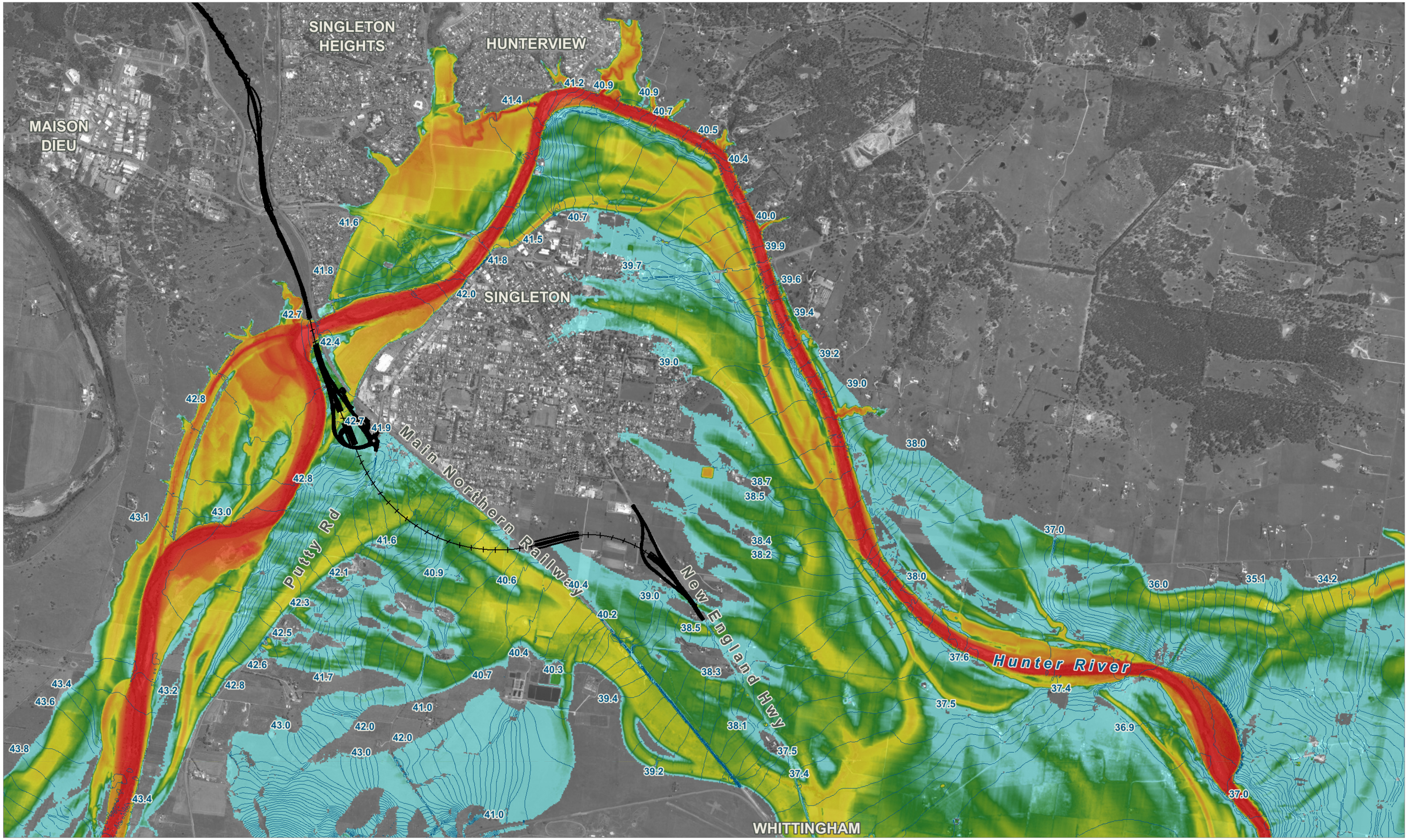

LEGEND

Peak Flood Depth (m)

- 0.5 lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 higher depths mapped as same colour

Peak Flood Velocity (m/s)

Scale: 1mm = 0.5m/s @A3

- 0.5
- 1.0
- 2.0
- 3.0

20 Peak Flood Level Contours (m AHD)

Bypass Alignment

Bridge Structure

Title:

Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 5% AEP Modelled Peak Flood Conditions

Figure: B-3

Rev: A

N

0 0.5 1km

Approx. Scale

BMT

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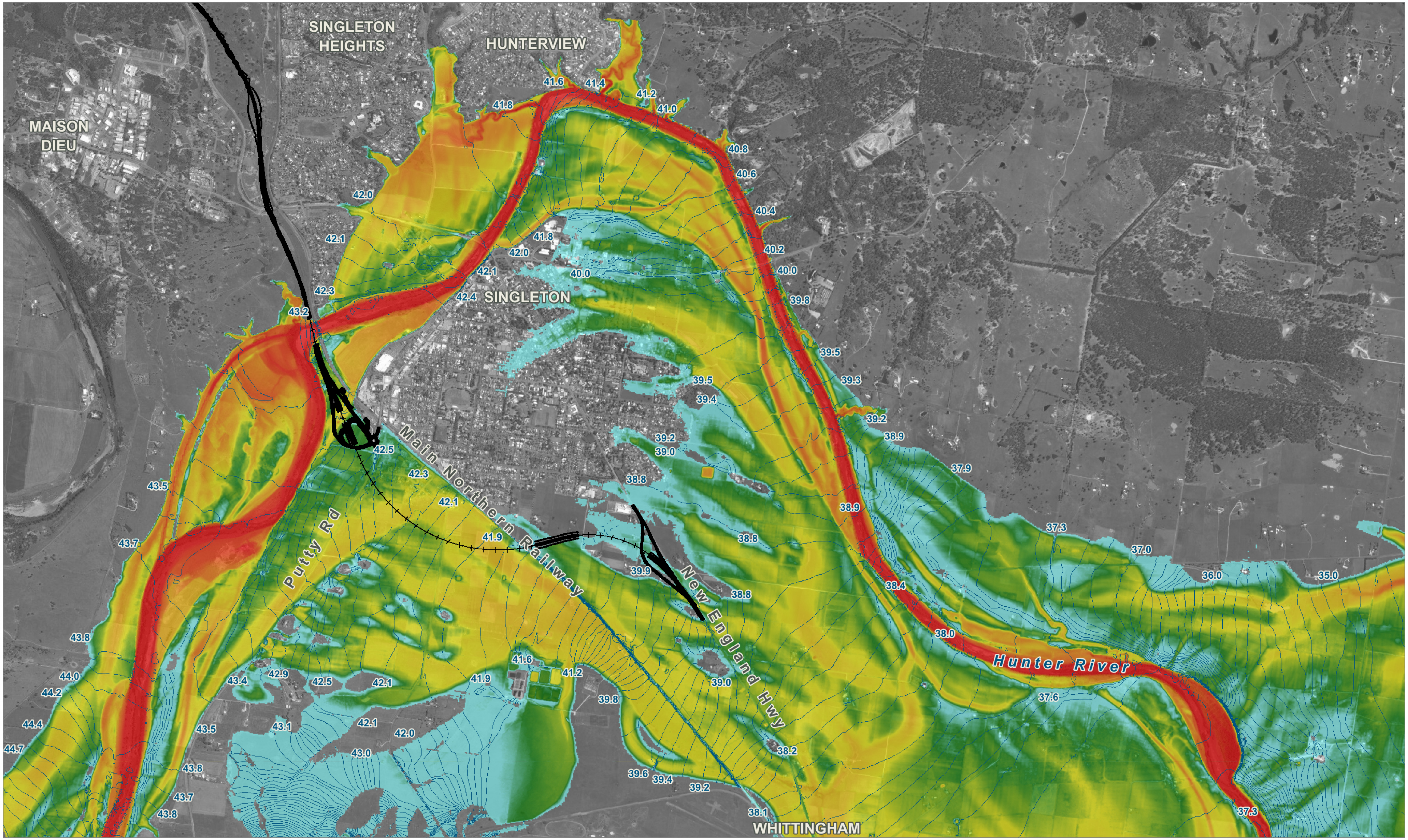

LEGEND

Peak Flood Depth (m)
- 0.5 — lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 — higher depths mapped as same colour

Peak Flood Velocity (m/s)
Scale: 1mm = 0.5m/s @A3
- 0.5
- 1.0
- 2.0
- 3.0

20 Peak Flood Level Contours (m AHD)

Bypass Alignment

Bridge Structure

Title:
Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 2% AEP Modelled Peak Flood Conditions

Figure: B-4

Rev: A

N

0 0.5 1km
Approx. Scale

BMT
www.bmt.org

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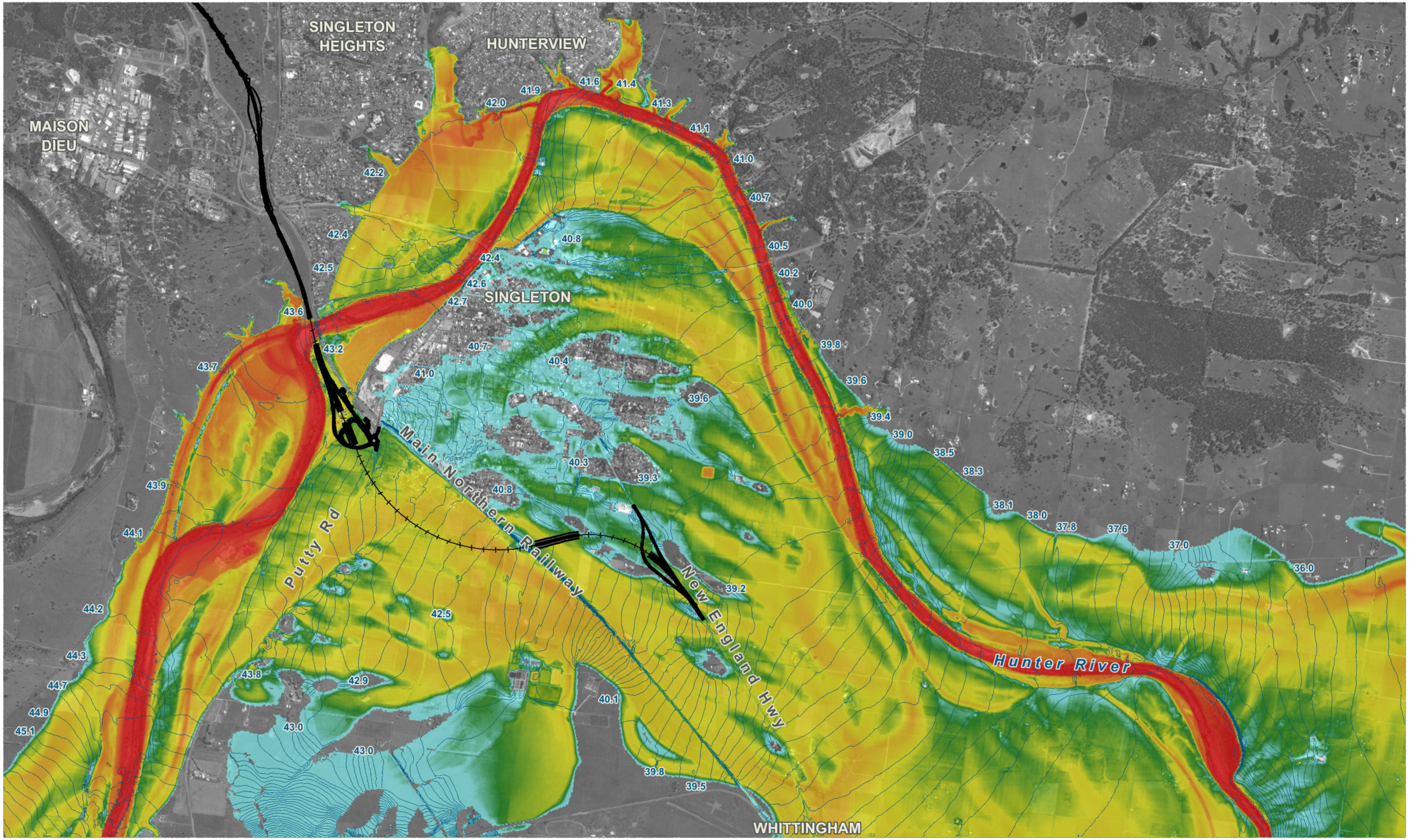


LEGEND

Peak Flood Depth (m)
- 0.5 — lower depths mapped as same colour
- 1.0
- 2.0
- 5.0
- 10 — higher depths mapped as same colour

Peak Flood Velocity (m/s)
Scale: 1mm = 0.5m/s @A3
- 0.5
- 1.0
- 2.0
- 3.0

20 — Peak Flood Level Contours (m AHD)

Bypass Alignment

Bridge Structure

Title:
Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 1% AEP Modelled Peak Flood Conditions

Figure: B-5

Rev: A

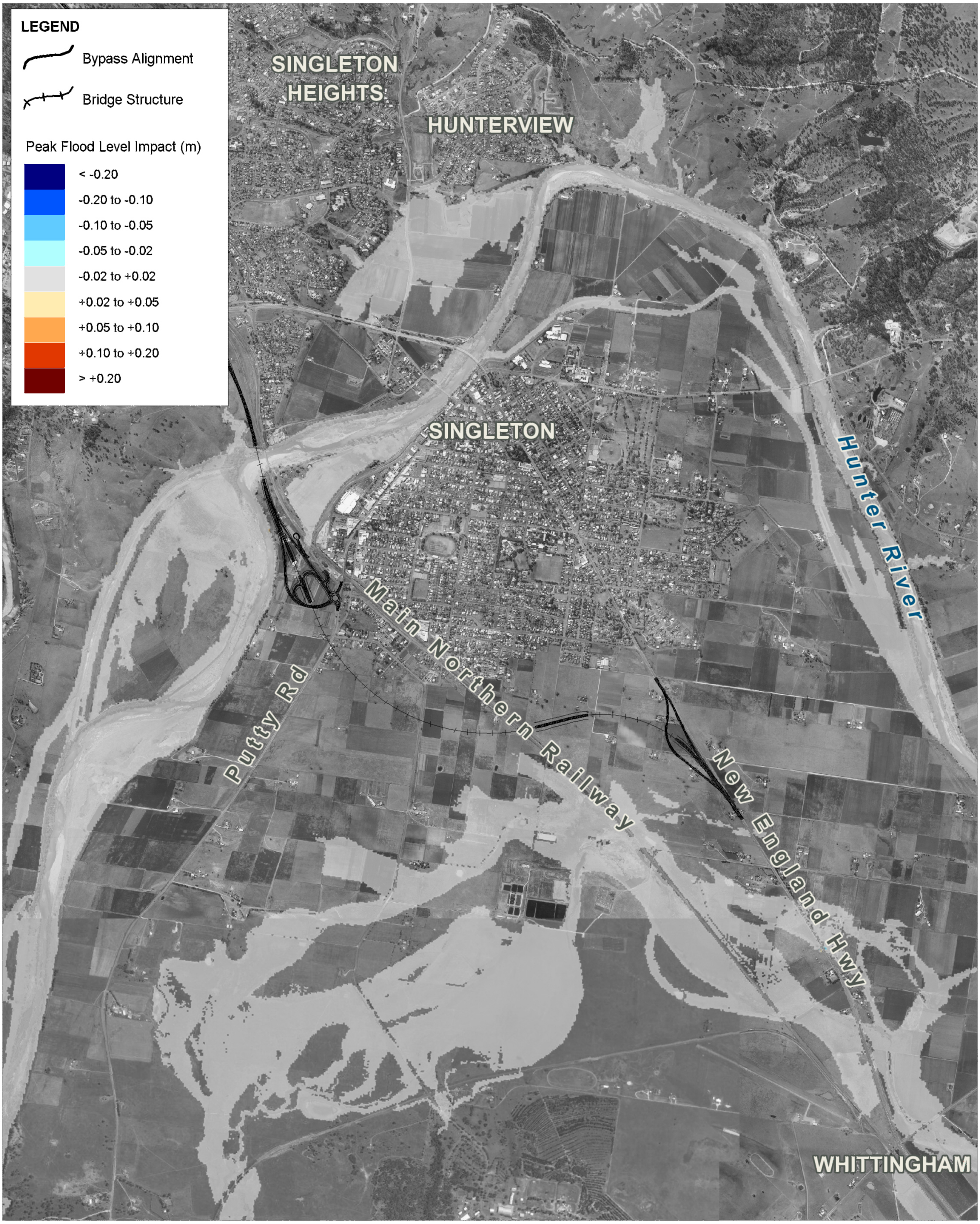
N

0 0.5 1km
Approx. Scale

BMT
www.bmt.org

Filepath: "K:\N20818.k.br_Singleton_Bypass\Mapinfo\Workspaces\REF_Addendum_Final\DRG_205_221018_1%AEP_DSN.wor"

Appendix C Concept Design Flood Level Impact Mapping



Title:

Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 20% AEP Peak Flood Level Impact

Figure: C1

Rev: A

N

0 0.75 1.5km

Approx. Scale

BMT
www.bmt.org

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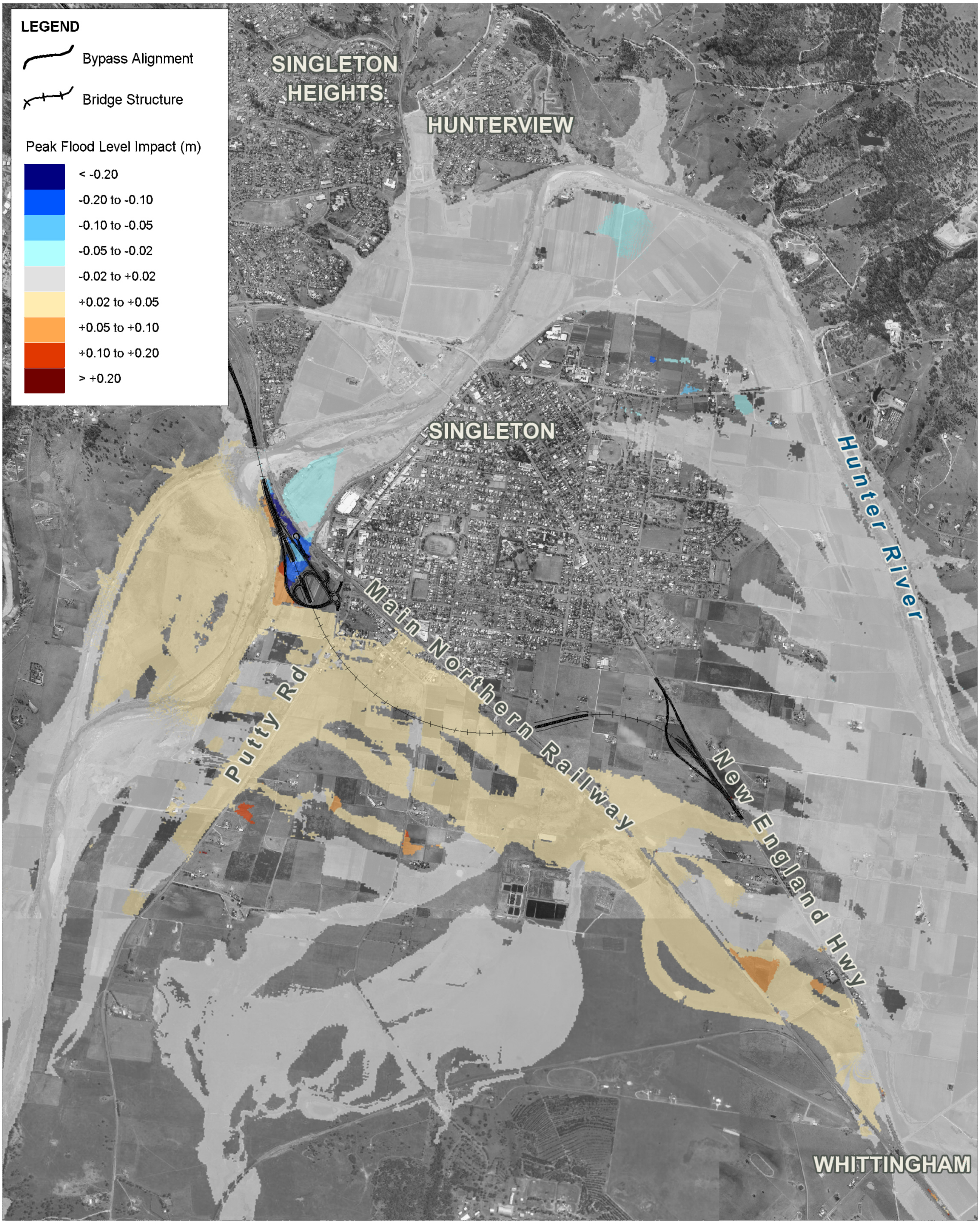

Title:

Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 10% AEP Peak Flood Level Impact

Figure: **C2**

Rev: **A**

N

0 0.75 1.5km

Approx. Scale

BMT
www.bmt.org

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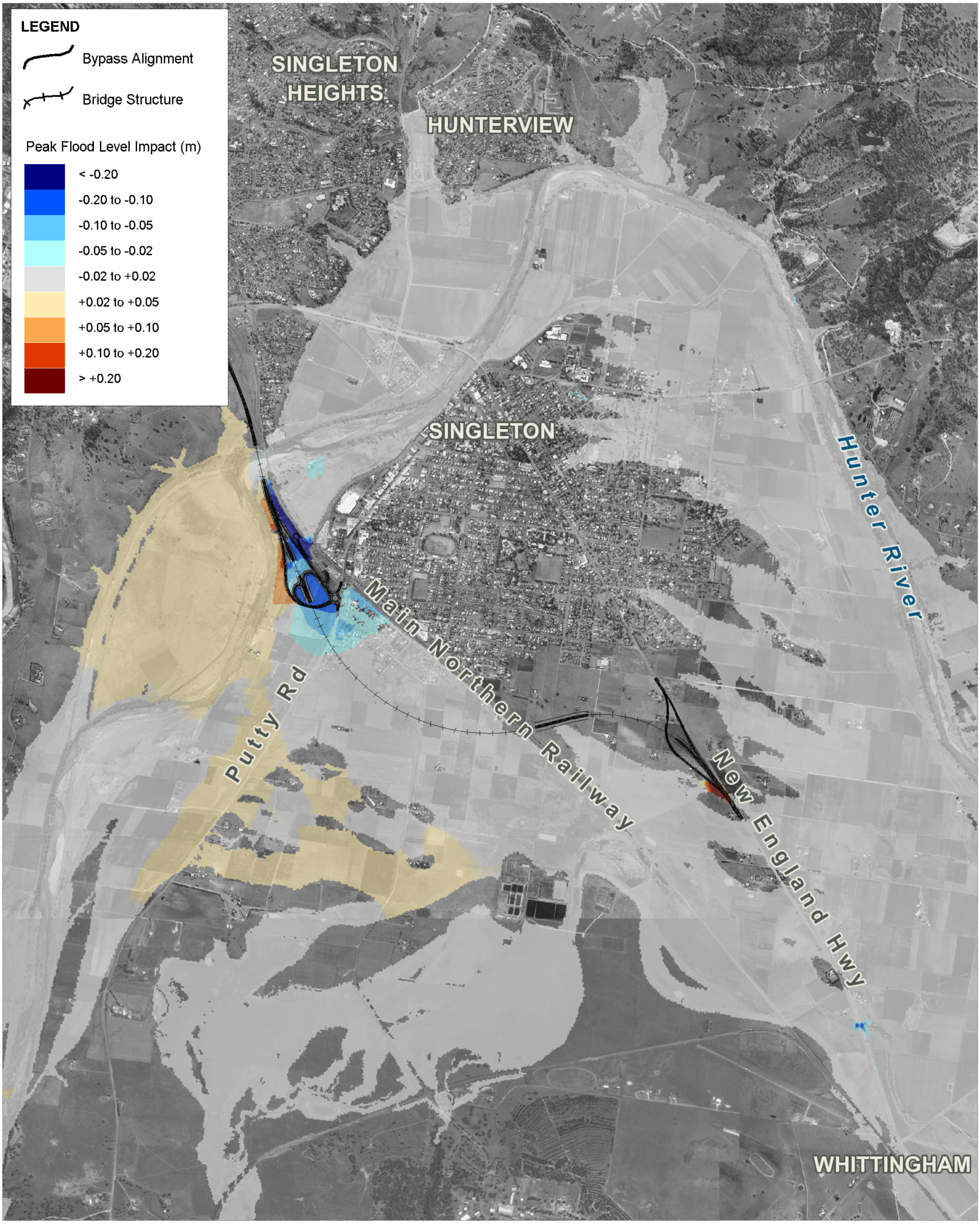

Title:
Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 5% AEP Peak Flood Level Impact

Figure: C3

Rev: A

N

0 0.75 1.5km

Approx. Scale

BMT
www.bmt.org

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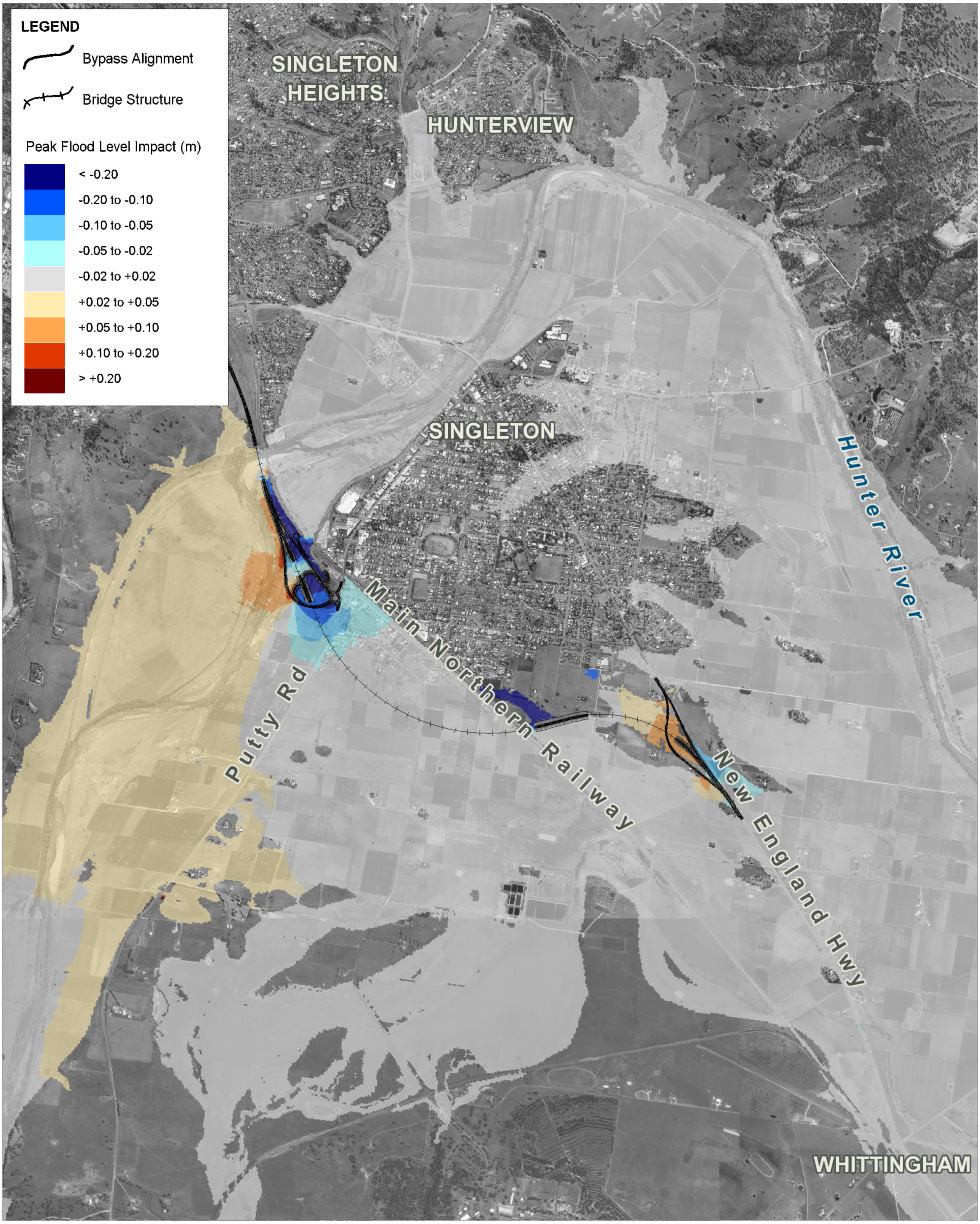

Title:

Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 2% AEP Peak Flood Level Impact

Figure: C4

Rev: A

N

0 0.75 1.5km

Approx. Scale

BMT
www.bmt.org

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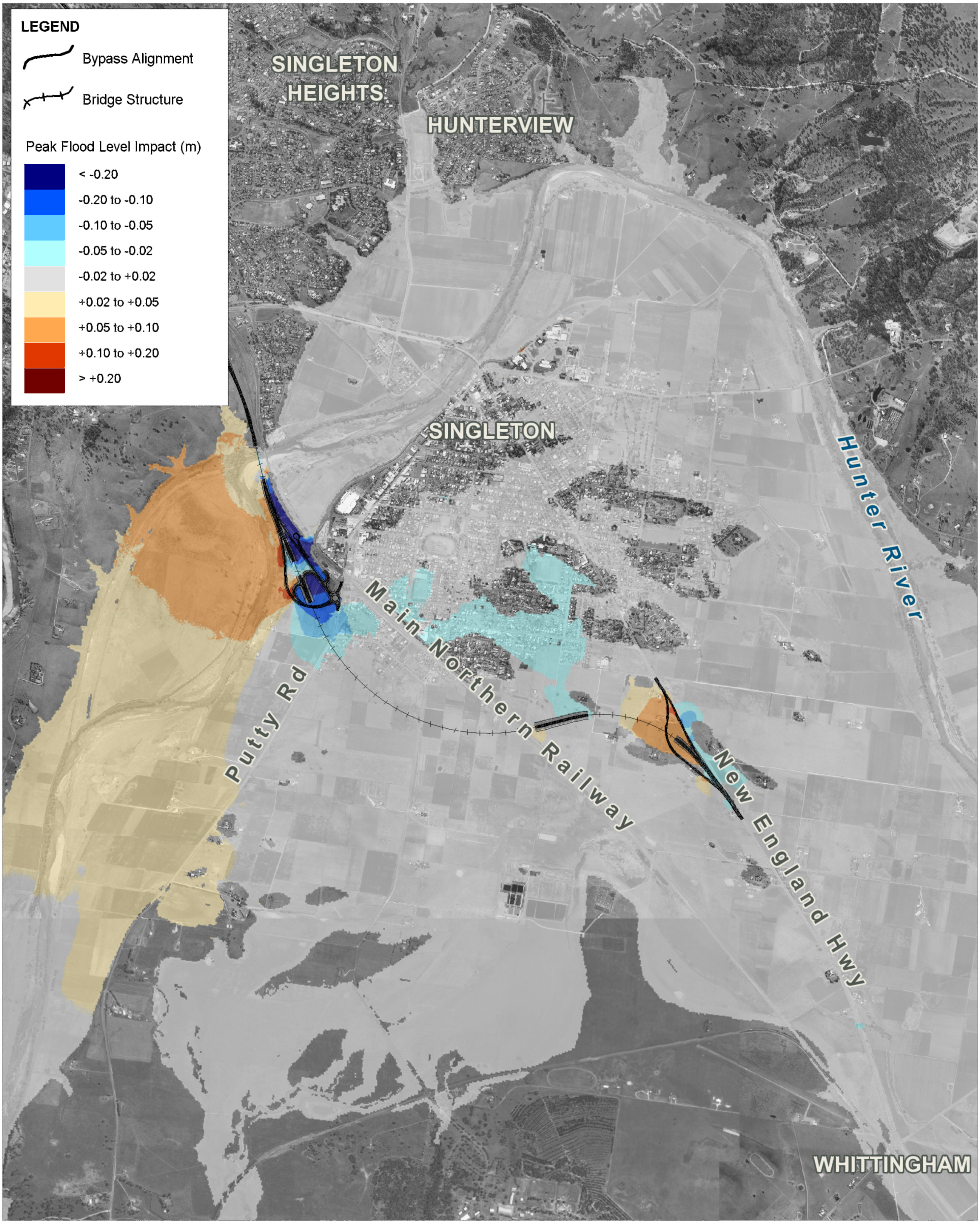


Title:

Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 1% AEP Peak Flood Level Impact

Figure: C5

Rev: A

N

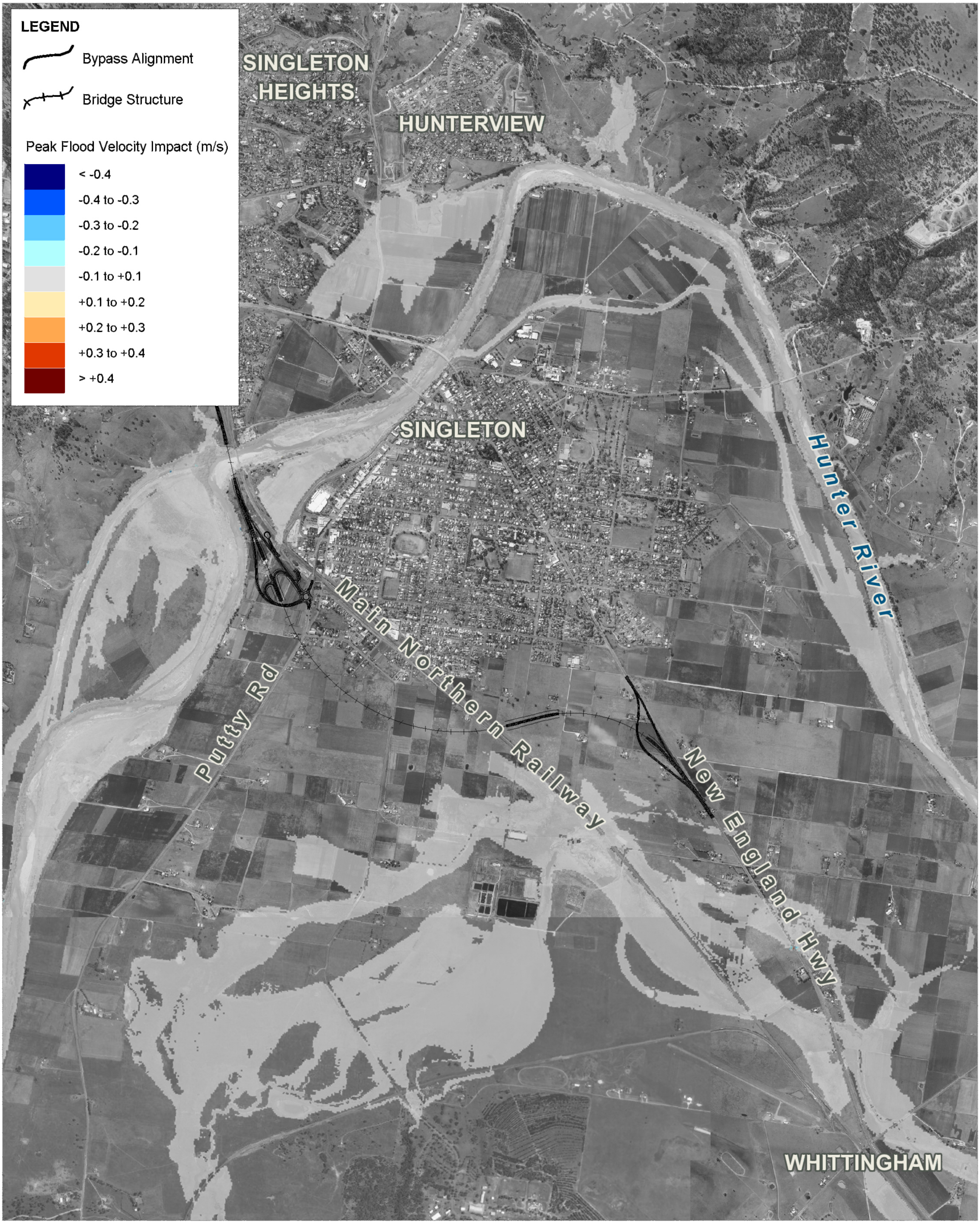
0 0.75 1.5km

Approx. Scale

BMT
www.bmt.org

Filepath: "K:\N20818.k.br_Singleton_Bypass\Mapinfo\Workspaces\REF_Addendum_Final\DRG_305_221018_1%AEP_h_impact.wor"

Appendix D Concept Design Flood Velocity Impact Mapping



Title:

Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 20% AEP Peak Flood Velocity Impact

Figure: D-1

Rev: A

N

0 0.75 1.5km

Approx. Scale

BMT

www.bmt.org

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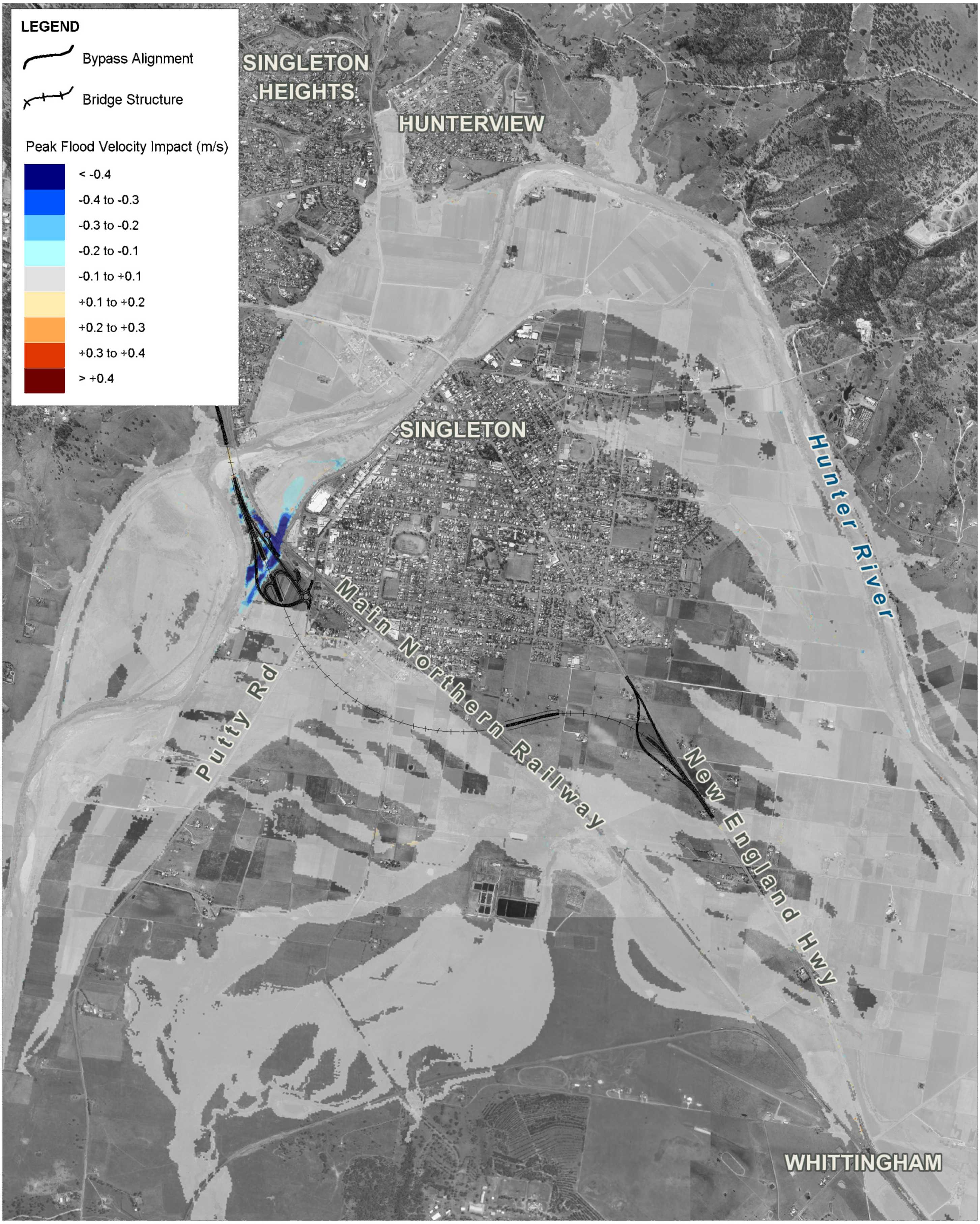

Title:

Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 10% AEP Peak Flood Velocity Impact

Figure: D-2

Rev: A

N

0 0.75 1.5km

Approx. Scale

BMT
www.bmt.org

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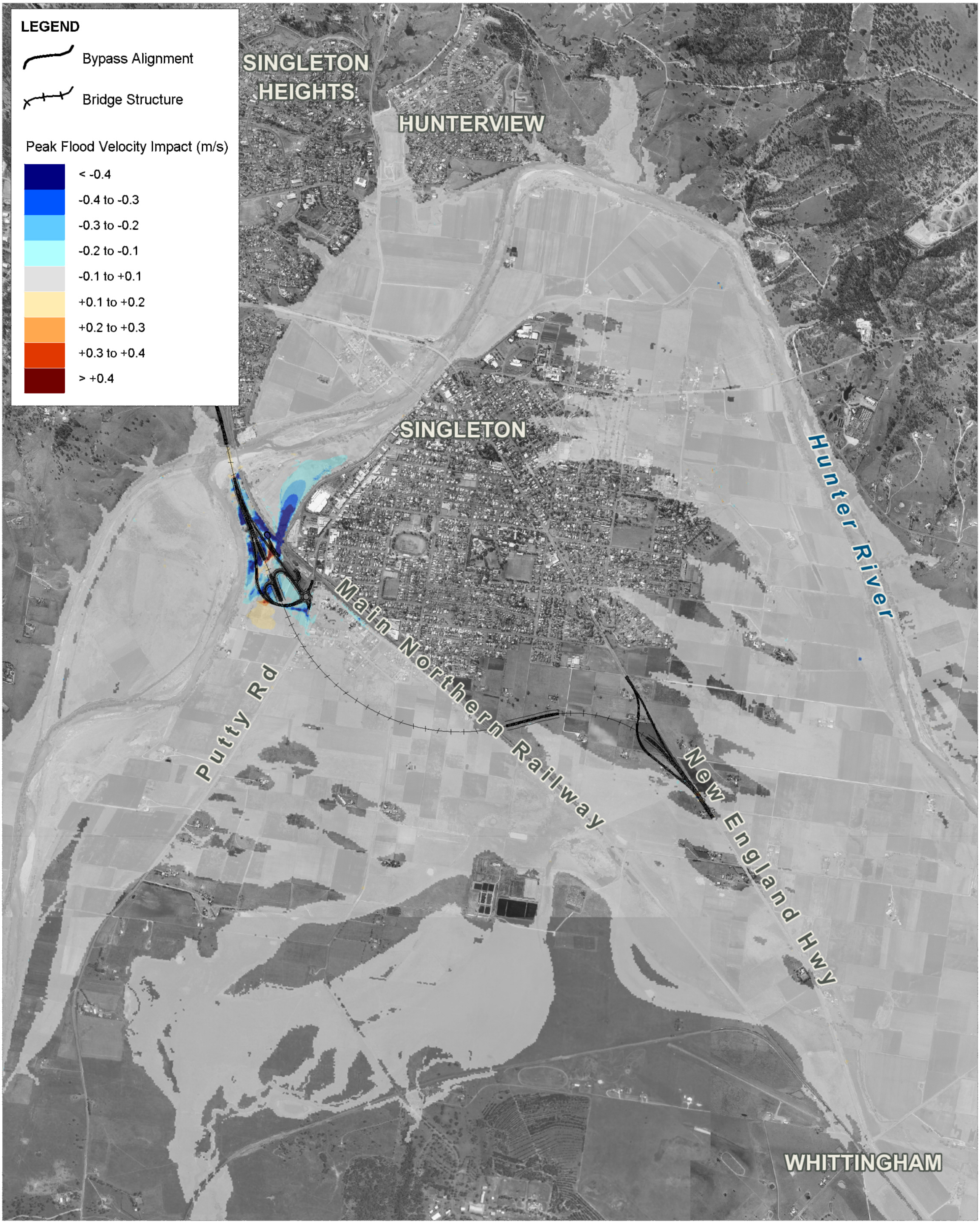

Title:

Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 5% AEP Peak Flood Velocity Impact

Figure: **D-3**

Rev: **A**

N

0 0.75 1.5km
Approx. Scale

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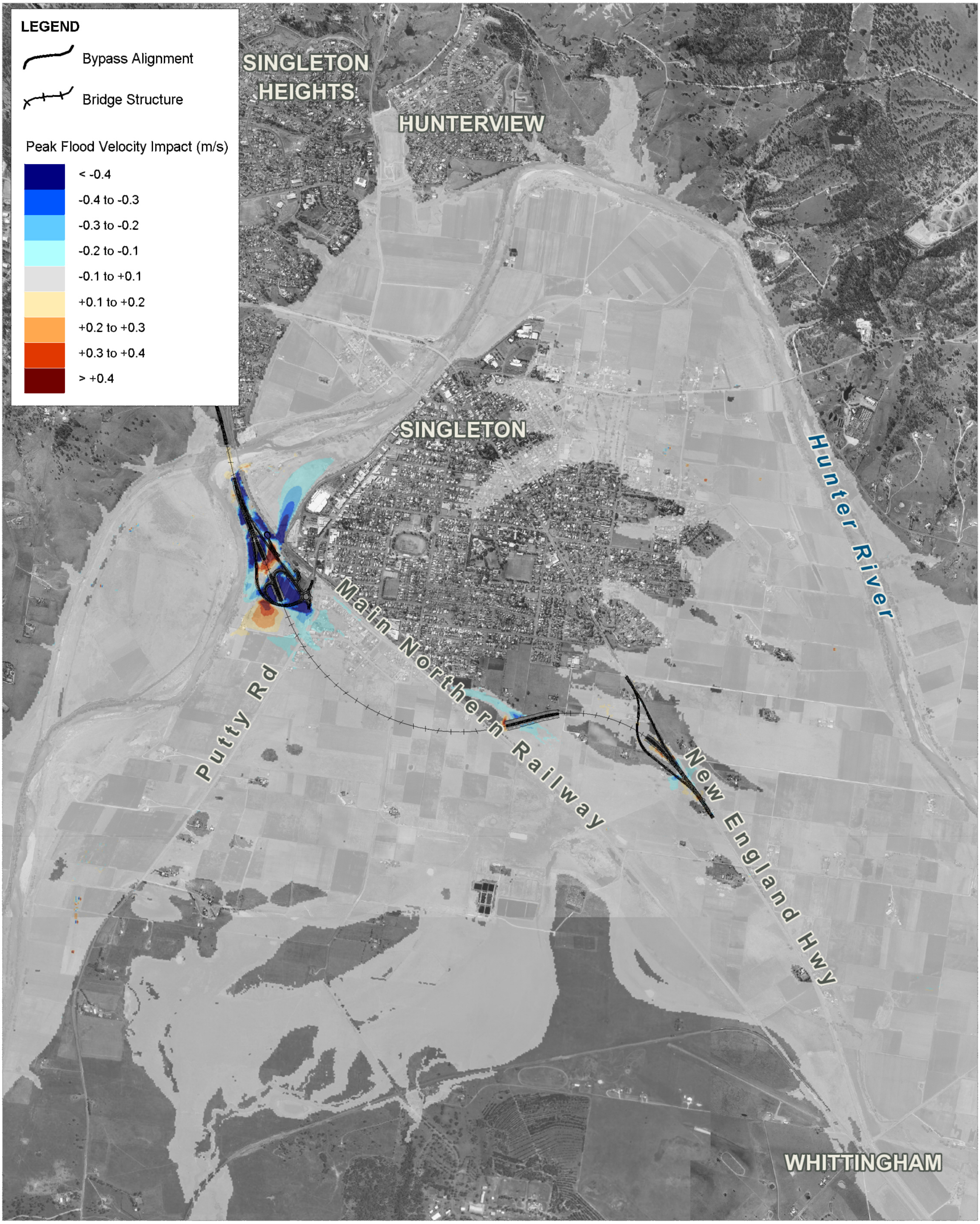
Filepath: "K:\N20818.k.br_Singleton_Bypass\Mapinfo\Workspaces\REF_Addendum_Final\DRG_403_221018_5%AEP_v_impact.wor"



Title:
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REF Addendum Design - 2% AEP Peak Flood Velocity Impact

Figure: **D-4**

Rev: **A**

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N

0 0.75 1.5km

Approx. Scale

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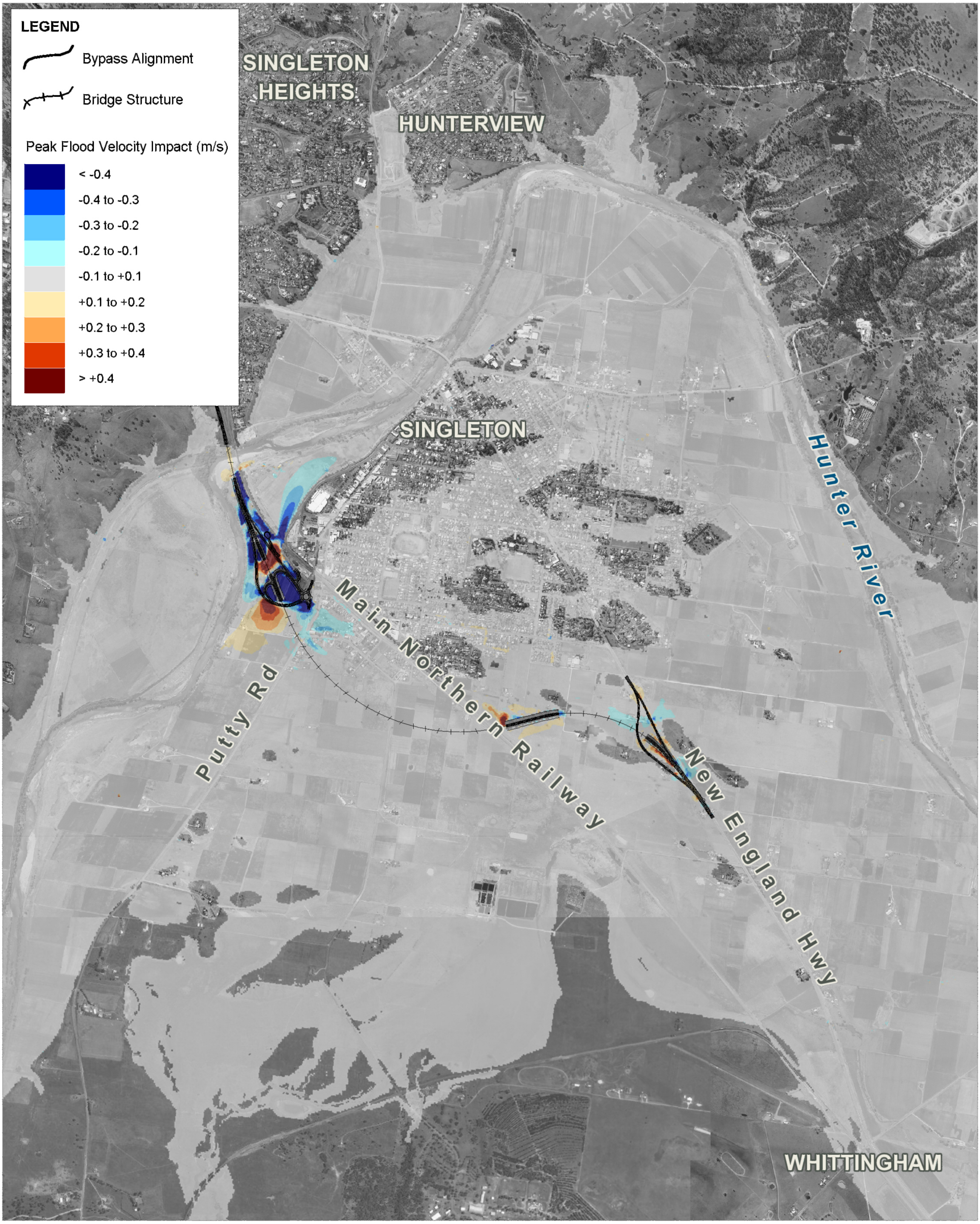
Filepath: "K:\N20818.k.br_Singleton_Bypass\Mapinfo\Workspaces\REF_Addendum_Final\DRG_404_221018_2%AEP_v_impact.wor"



Title:

Singleton Bypass Concept Design Flood Assessment
REF Addendum Design - 1% AEP Peak Flood Velocity Impact

Figure: **D-5**

Rev: **A**

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N

0 0.75 1.5km

Approx. Scale

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BMT has a proven record in addressing today's engineering and environmental issues.

Our dedication to developing innovative approaches and solutions enhances our ability to meet our client's most challenging needs.

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