Mr Wayne Grout
Design and Approvals Manager – Stage 2 Infrastructure
MACH Energy Australia Pty Ltd
Via email: wayne.grout@machenergyaustralia.com.au

05/08/2020

Dear Mr Grout

Mount Pleasant Open Cut Coal Mine - Modification 4 Rail Infrastructure (DA 92/97)
Flood Impact Assessment and Independent Review

I refer to the following documentation that was submitted by MACH Energy Australia Pty Ltd (MACH Energy) in accordance with Conditions 44C and 44D of Schedule 3 of the consent for the Mount Pleasant Open Cut Coal Mine (DA 92/97):

- Letter requesting the Planning Secretary's approval of the final report detailing the independent review outcomes for the Mount Pleasant Operation (DA 92/97) MOD 4 rail infrastructure final design, dated 23 July 2020;
- Mount Pleasant Rail Loop Stage 2 - Rail Modification Flood Impact Assessment prepared by WRM Water and Environment, dated 29 May 2020;
- Rail Spur Design Flood Impact Assessment Review prepared by Haskoning Australia Pty Ltd, dated 1 June 2020;
- Addendum No. 1 (to the Rail Modification Flood Impact Assessment) prepared by WRM Water and Environment Pty Ltd, dated 26 June 2020; and
- Biodiversity Conservation Division letter regarding the Mt Pleasant Coal (DA92/97-PA-2 MOD 4) - Review of flood studies for new rail infrastructure, dated 24 June 2020.

I wish to advise that the Department is satisfied with the documentation provided, the outcomes of the assessment and considers that the final design of the MOD 4 rail infrastructure and independent review meets the criteria outlined in Conditions 44C and 44D of Schedule 3 of the development consent.

Accordingly, the Planning Secretary has approved the final report in accordance with condition 44D of Schedule 3, subject to the conditions outlined below:

Unless otherwise agreed by the Planning Secretary, MACH Energy must:

- *provide relevant flood modelling results to the Logues Lane residents and provide these residents with a clear understanding of the potential flood risks, the need to monitor flood conditions and respond to warnings and evacuate advice early in a flood event, by the* ***31st August 2020****; and*
- *provide final design drawings for the MOD 4 rail infrastructure to the Planning Secretary which have been endorsed by a suitably qualified and experienced engineer, certifying that the infrastructure, including any associated hydraulic structures:*
  - *has been designed to withstand a 1% Annual Exceedance Probability flood event; and*
  - *do not pose a significant risk to public safety during such a flood event,*

by no later than ***30th September 2020****; and*

Mach Energy may not undertake any construction works that would increase flood risks at property 23 until such time as the purchase of this property from Jabetin Pty Ltd has been finalised and MACH Energy has provided notification of settlement to the Planning Secretary.

For the sake of clarity, I wish to confirm that construction of the MOD 4 rail infrastructure may commence from the date of this letter, subject to compliance with the above conditions.

The Department notes that if MACH Energy wishes to make any further adjustments or changes to the final design of the MOD 4 rail infrastructure, including any associated hydraulic structures, these changes may require further review and approval of the Planning Secretary.

It is requested that MACH Energy place the MOD 4 Rail Infrastructure Flood Impact Assessment and Independent Review is placed on the project website at your earliest convenience.

If you have any questions, please contact Tegan Cole via email at Tegan.Cole@planning.nsw.gov.au.

Yours sincerely

Matthew Sprott
Director
Resource Assessments (Coal & Quarries)
as nominee of the Planning Secretary

MACHEnergy

Mount Pleasant Operation

Rail Modification Flood Impact Assessment (MOD 4)

Mount Pleasant Rail Loop Stage 2

Rail Modification Flood Impact Assessment

MACH Energy Australia Pty Ltd

0744-01-K4, 29 May 2020

Report Title	Mount Pleasant Operation - Rail Modification Flood Impact Assessment
Client	MACH Energy Australia Pty Ltd
Report Number	0744-01-K4

Revision Number	Report Date	Report Author	Reviewer
1_DRAFT	7 May 2020	AN/SU	DN
2_DRAFT	8 May 2020	AN/SU	DN
3	21 May 2020	AN/SU	DN
4	29 May 2020	AN/SU	DN

For and on behalf of WRM Water & Environment Pty Ltd
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PO Box 10703 Brisbane Adelaide St Qld 4000
Tel 07 3225 0200

David Newton
Director

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1 Introduction

1.1 PROJECT OVERVIEW

The Mount Pleasant Operation Development Consent DA 92/97 was granted on 22 December 1999. The Mount Pleasant Operation was also approved under the *Environment Protection and Biodiversity Conservation Act, 1999* (EPBC Act) in 2012 (EPBC 2011/5795).

MACH Energy Australia Pty Ltd (MACH Energy) acquired the Mount Pleasant Operation from Coal and Allied Operations Pty Ltd (Coal & Allied) on 4 August 2016. MACH Energy commenced construction activities at the Mount Pleasant Operation in November 2016 and commenced mining operations in October 2017, in accordance with Development Consent DA 92/97 and EPBC 2011/5795.

The approved Mount Pleasant Operation includes the construction and operation of an open cut coal mine and associated rail spur and product coal loading infrastructure located approximately three kilometres (km) north-west of Muswellbrook in the Upper Hunter Valley of New South Wales (NSW) (Figure 1-1).

The mine is approved to produce up to 10.5 million tonnes per annum (Mtpa) of run-of-mine (ROM) coal. Up to approximately nine trains per day of thermal coal products from the Mount Pleasant Operation will be transported by rail to the port of Newcastle for export or to domestic customers for use in electricity generation.

1.2 APPROVED RAIL SPUR

The ultimate extent of the approved Bengalla Mine open cut intersects the approved Mount Pleasant Operation rail spur.

While the intersection of the Bengalla Mine open cut with the approved Mount Pleasant Operation rail infrastructure is still some years away, MACH Energy sought and obtained approval for a modification to DA 92/97 (MOD 4) for a new rail spur and train load out facility to ensure continuity of future product transport to manage this interaction.

The approved MOD4 rail infrastructure comprises:

- duplication of the approved rail spur, rail loop, conveyor and rail load-out facility and associated services;
- duplication of the Hunter River water supply pump station, water pipeline and associated electricity supply that currently follows the rail spur alignment; and
- demolition and removal of the redundant approved infrastructure within the extent of the Bengalla Mine, once the new rail, product loading and water supply infrastructure has been commissioned and is fully operational.

The alignment of the approved MOD4 rail infrastructure is shown in Figure 1-2.

The MOD4 project involves construction of a new rail spur embankment across part of the floodplain of the Hunter River. The rail spur design includes a major viaduct to accommodate floodplain flows, and smaller culvert structures that will align with existing culverts along the existing ARTC-owned railway embankment.

The MOD4 rail infrastructure also includes the construction of a water supply pump station and associated water pipeline however these are not considered to have any material effect on flooding given the water supply pipeline would be buried within the Hunter River floodplain and therefore would not impede overland flow during a flood event.

1.3 SCOPE OF FLOOD ASSESSMENT

MACH Energy previously engaged WRM Water & Environment Pty Ltd (WRM) to complete a flood assessment for the Mount Pleasant Operations Rail Modification (MOD4) Environmental Assessment in 2017. This impact assessment (WRM, 2017) was based upon the project Reference Design (Hatch, 2017).

MACH Energy has engaged AECOM Australia Pty Ltd (AECOM) to carry out further site investigation and detailed design work for the approved rail spur. Following approval of MOD4, design work has been progressing, and has included (but not limited to) refining the rail alignment, earthworks, and viaduct arrangement.

AECOM requested WRM to review and undertake hydrologic and hydraulic modelling to assess the flood impacts of the approved rail spur on private properties and public infrastructure. This flood impact assessment is intended to confirm that the detailed design is consistent with the relevant MOD4 Statement of Commitments and MOD4 DA 92/97 Conditions of Consent.

This report presents the methodology and results of the flood impact assessment.

1.4 REPORT STRUCTURE

This report is structured as follows:

- Section 2 describes the drainage characteristics of catchments in the vicinity of the study area.
- Section 3 outlines available data including stream gauge data and previous relevant studies.
- Section 4 describes the development and verification of the hydrologic model and the estimation of design flood discharges.
- Section 5 describes the development and verification of the hydraulic model.
- Section 6 provides the results of the flood assessment.
- Section 7 presents the conclusions of the study.
- Section 8 is a list of references.

Figure 1-1 – Locality map, Mount Pleasant Operation

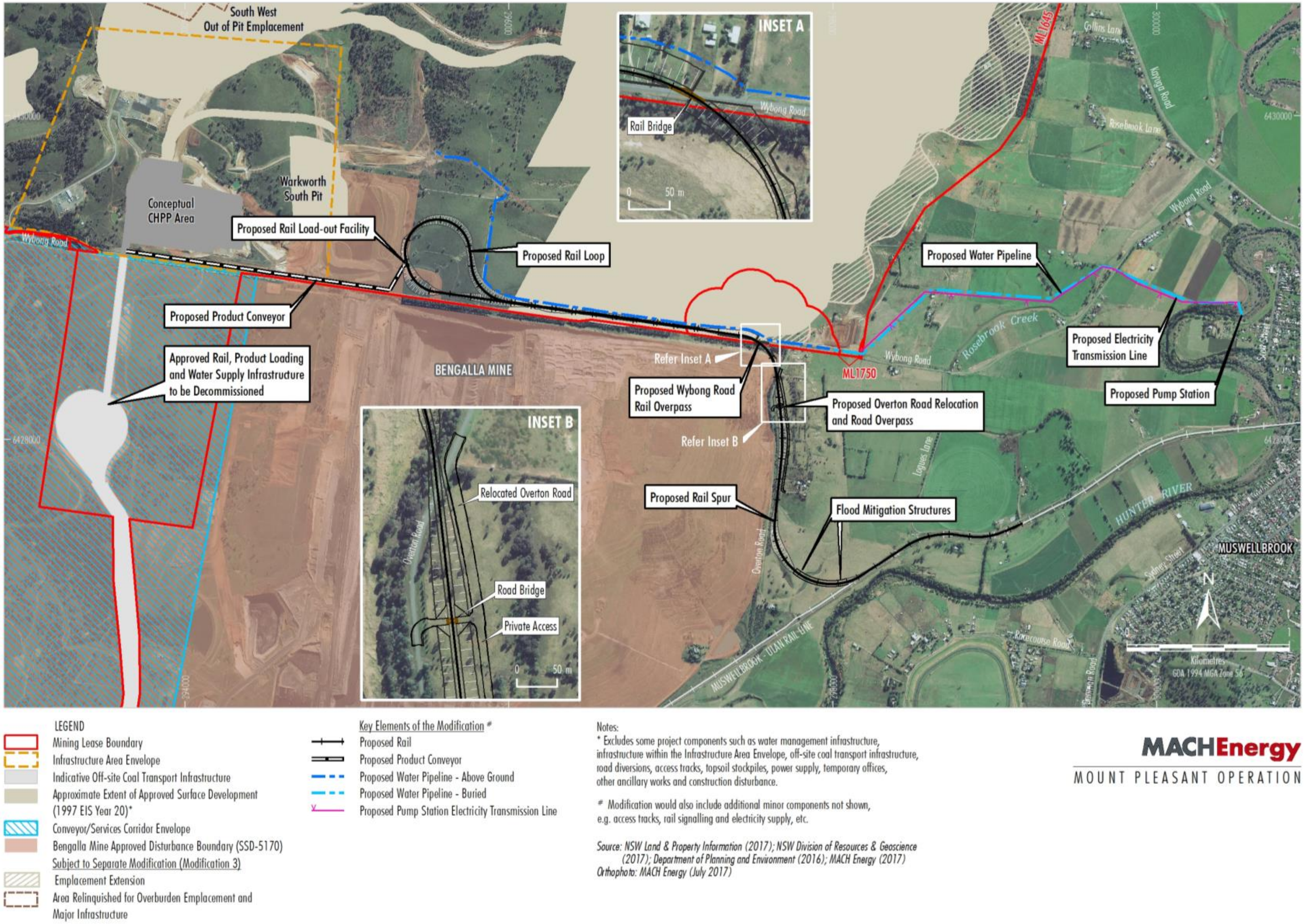


Figure 1-2 - Alignment of approved rail spur

2 Existing drainage network

2.1 CATCHMENT AND FLOODPLAIN CONFIGURATION

The approved rail spur is located on the northern floodplain of the Hunter River. The Hunter River has a catchment area of 4,220 square kilometres (km^2) upstream of Muswellbrook.

The Hunter River floodplain in the vicinity of Muswellbrook consists of a wide, flat floodplain with a width of about 2 km. An incised main channel approximately 10 metres (m) deep meanders across the floodplain. The floodplain is drained by a number of meandering floodplain drainage channels which collect local runoff from the floodplain and local catchment inflows. These floodplain channels also convey breakout flows from the Hunter River main channel during flood events.

Figure 2-1 shows a cross-section of the Hunter River floodplain near the approved rail spur location. The existing Muswellbrook-Ulan Rail Line is located on an existing embankment across the floodplain.

The existing ARTC-owned rail and public road embankments crossing the floodplain incorporate various cross-drainage structures, including bridges and culverts, to convey in-bank and floodplain flows. The existing rail embankment overtops under certain flooding conditions. The MOD4 rail infrastructure rail spur remains at the same elevation as the existing Muswellbrook–Ulan Rail Line for approximately 1 km from the turnout location before it begins rising toward the foothills adjacent to the Bengalla Mine waste emplacement.

2.2 GLENBAWN DAM

Glenbawn Dam is a major water supply dam located on the Hunter River upstream of Muswellbrook. The structure is an ungated, rock embankment dam, utilising both a chute spillway and fuse plugs for water level control.

The original dam was completed in 1958, however the dam was raised with a three-fold increase in capacity in 1987. Relevant details of Glenbawn Dam are as follows[a]:

- Catchment area = 1,300 km^2
- Surface area at Full Supply Level (FSL) = 26.1 km^2
- Main wall height = 100 m
- Spillway crest level = 280.6 metres above Australian Height Datum (mAHD)
- FSL = 276.2 mAHD
- Storage capacity at FSL = 750,000 megalitres (ML)
- Spillway length = 190 m

[a] Source = NSW Office of Water website

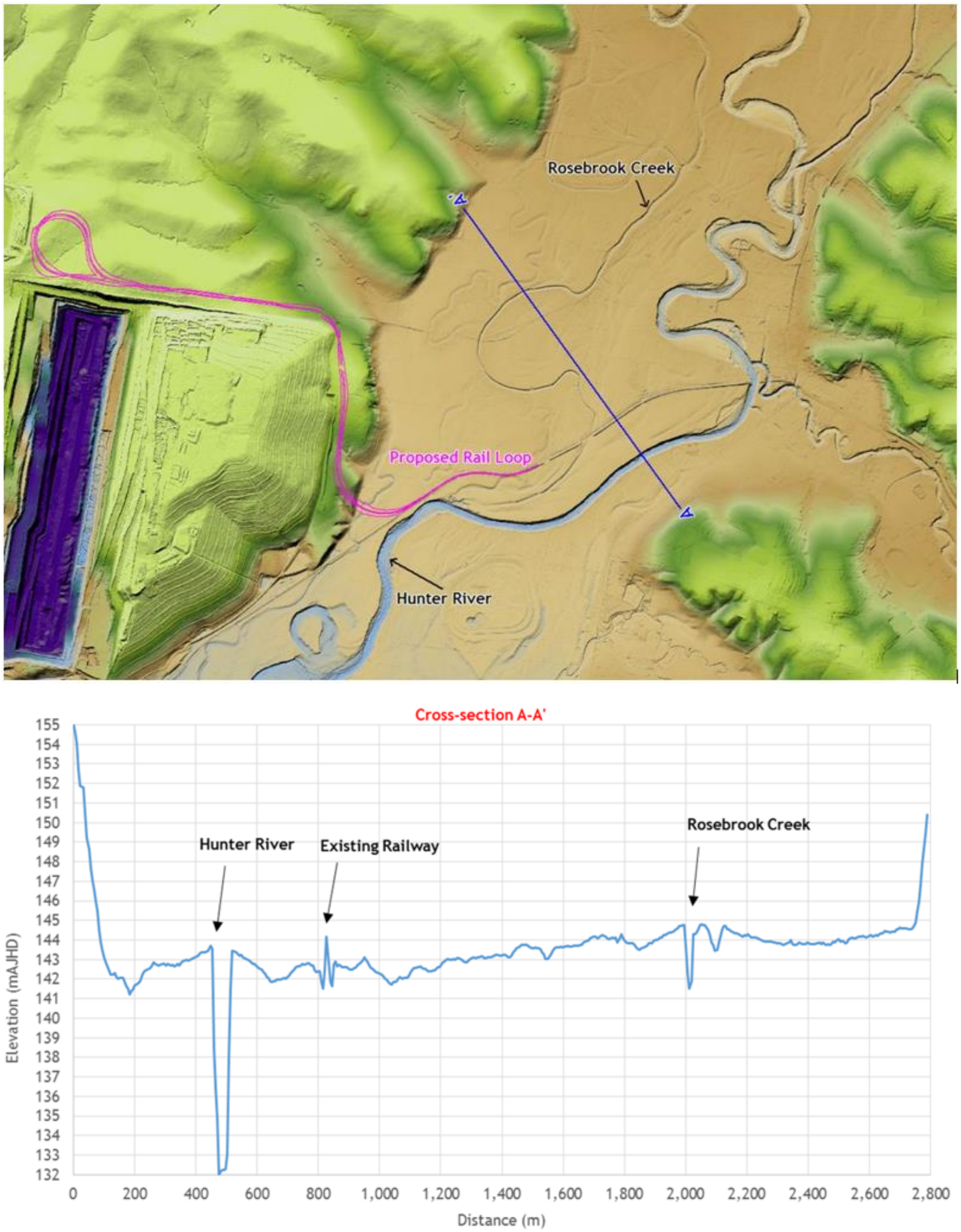


Figure 2-1 - Hunter River floodplain cross-section

3 Available data

3.1 STREAMFLOW DATA

Recorded streamflow data is available at a number of stream gauges within the Hunter River catchment (shown in Table 3.1). Figure 3-1 shows the locations of these streamflow gauges. The most relevant stream gauge is Hunter River at Muswellbrook Bridge gauge, which is only 3 km north-east of the approved rail spur.

The Hunter River at Muswellbrook Bridge gauge has recorded streamflow data since 1913, but significant data was missing prior to 1961. The data recorded since 1961 was used to undertake the flood frequency analysis (FFA) for the study.

Table 3.1 - Stream gauges within the study area

Station Name	Station Number	Catchment area (km^2)	Latitude Longitude	Period of Available Data
Hunter River at downstream Glenbawn Dam	210015	1,295	-32.11 150.99	Aug 1940 - Oct 2017
Hunter River at Aberdeen	210056	3,090	-32.16 150.88	Mar 1959 – Oct 2017
Hunter River at Muswellbrook Bridge	210002	4,220	-32.26 150.89	Jan 1913 – Oct 2017
Hunter River at Denman	210055	4,530	-32.38	Feb 1959 – Oct 2017

3.2 PREVIOUS STUDIES

3.2.1 Worley Parsons (2004)

A detailed flood study for the Hunter River (Muswellbrook to Denman) was undertaken by WorleyParsons Services Pty Ltd (Worley Parsons) for Muswellbrook Shire Council in 2014. RAFTS hydrologic and TUFLOW hydraulic models were developed for the Hunter River and calibrated to the 1998, 2000 and 2007 historical flood events. Worley Parsons used the calibrated RAFTS model and TUFLOW model to estimate design flood discharges and design flood levels for a range of design events.

The detailed model configuration and parameters of the Hunter River RAFTS model were provided in the 2014 Hunter River flood study report (WorleyParsons, 2014). This includes detailed RAFTS node and link parameters, design rainfall intensities and design rainfall losses.

The design discharges in the 2014 Hunter River flood study (WorleyParsons, 2014) were estimated using standard procedures outlined in 'Australian Rainfall and Runoff – A Guide to Flood Estimation' (1987) (ARR 1987) (Pilgrim, 1987). This includes the Intensity-Frequency-Duration data, temporal patterns and areal reduction factor methodology from the ARR 1987 documentation.

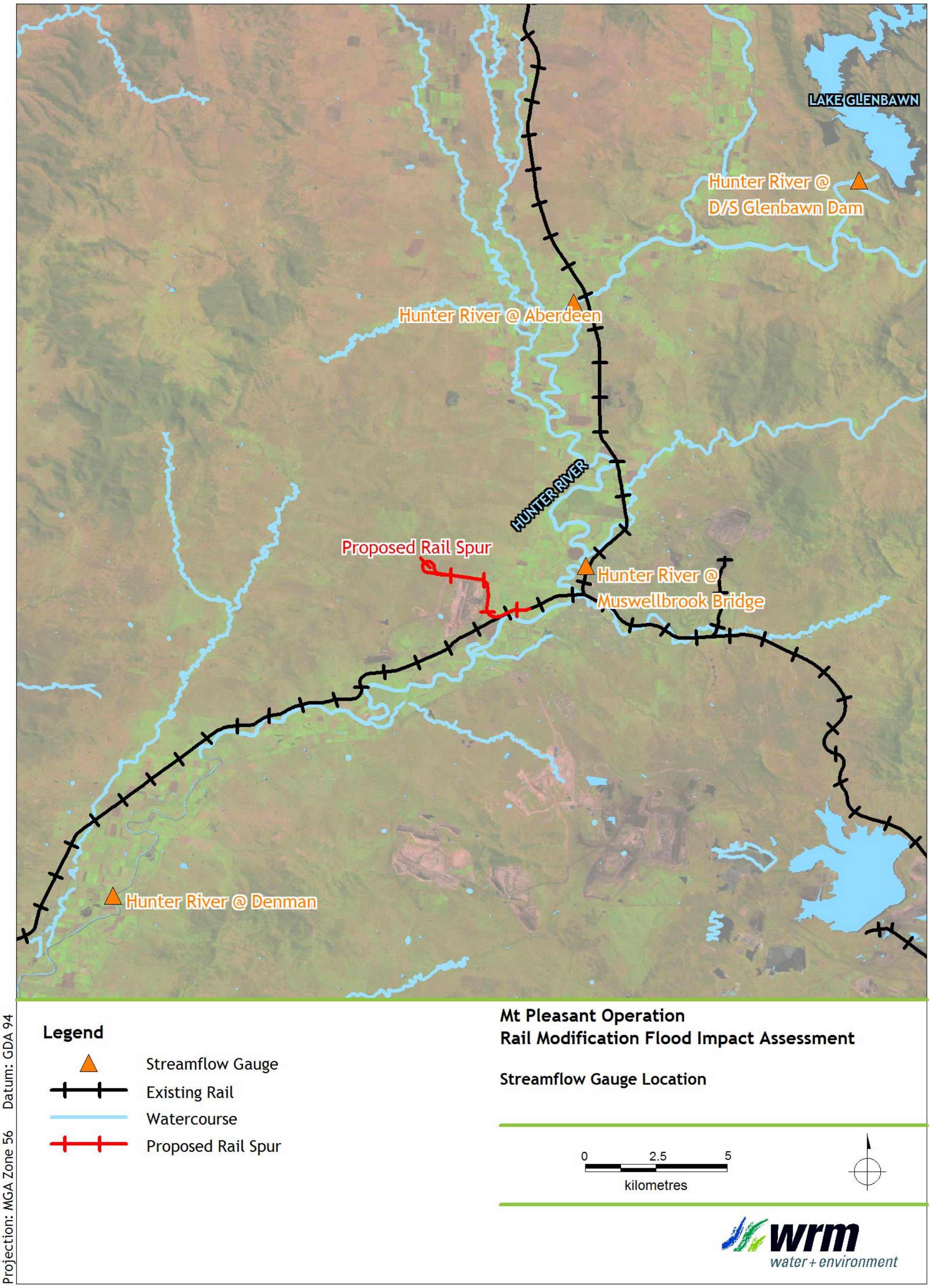


Figure 3-1 - Location of streamflow gauges

3.2.2 WRM (2017)

WRM completed a flood assessment for the Mount Pleasant Operation Rail Modification (MOD 4) Environmental Assessment (EA Phase) in December 2017.

The calibrated Hunter River RAFTS model developed by WorleyParsons (2014) was reproduced using the detailed configuration and parameters reported in the 2014 Hunter River flood study report (WorleyParsons, 2014) and was used for the WRM (2017) flood assessment.

The design discharge hydrographs were determined in accordance with the methodology recommended in Australian Rainfall and Runoff (ARR) 2019 (Ball et al., 2019), replacing ARR 1987 (Pilgrim, 1987). The major changes between ARR 2016 and ARR 1987 include:

- the use of new rainfall Intensity-Frequency-Duration (2016 IFDs), which are based on a more extensive rainfall database, with more than 30 years of additional rainfall data and data from extra rainfall stations;
- the use of an ensemble of 10 temporal patterns to derive the design discharges (the temporal pattern that gives the peak discharge closest to the mean is used), compared to using a single temporal pattern as in ARR 1987; and
- modified areal reduction factors.

WRM completed additional hydraulic modelling on behalf of AECOM for the approved rail spur as part of the Mount Pleasant Early Contractor Involvement (ECI) phase in 2019 (the ECI Phase).

3.3 TOPOGRAPHIC DATA

The following topographic data (supplied by AECOM) was available for this study:

- LiDAR survey data provided by MACH energy for the 2017 (EA phase) flood assessment;
- The following data provided by AECOM on 31 May 2019 (obtained from file *MACH-MOD-00-0000-SV-20190529.12da*):
    - Additional LiDAR survey data for the area in the vicinity of the rail spur (AECOM LiDAR data); and
    - Ground survey data for the area in the vicinity of the approved rail spur.

The above three sets of data were incorporated into the 2019 (ECI phase) hydraulic model to undertake the current assessment.

4 Estimation of discharges

4.1 METHODOLOGY

The calibrated Hunter River RAFTS model used for the WRM (2017) study was used derive design discharges in the Hunter River for the 5% (1 in 20), 2% (1 in 50) and 1% (1 in 100) Annual Exceedance Probability (AEP) events.

4.2 FLOOD FREQUENCY ANALYSIS

4.2.1 Selection of period for flood frequency analysis

A flood frequency analysis (FFA) was undertaken on the Hunter River at Muswellbrook Bridge gauge (Station No. 210002). The catchment area to Muswellbrook Bridge gauge is 4,220 km^2 and includes Glenbawn Dam. The catchment area of Glenbawn Dam is 1,300 km^2. Glenbawn Dam provides some 120,000 ML of flood storage between the full supply level and the spillway level. The available flood storage volume has a significant impact on the downstream discharges. Hence, hydrology of the Hunter River at Muswellbrook would be expected to be different after the upgrade of Glenbawn Dam in 1987.

Muswellbrook Bridge gauge has recorded streamflow data from 1913 to present. However, significant data was missing prior to 1961. A FFA reflecting post-dam hydrology would use data from 1987 onwards. However, this would only provide 30 years of data.

An additional 26 years of data is available if the full record from 1961 is adopted. However, it is noted that this period includes data prior to the dam upgrade in 1987. Hence, a FFA based on data since 1961 is likely to slightly overestimate design discharges at Muswellbrook Bridge gauge. This provides a conservative estimate of design discharges suitable for use in impact assessment. The model results will not be used to set design flood levels for the approved rail spur which are determined by the existing rail embankment levels.

4.2.2 FFA results

The peak annual discharges recorded at Muswellbrook Bridge gauge between 1961 and 2016 shown in Table 4.1 were used in the FFA. The FFA was undertaken using the Bayesian inference methodology recommended in ARR 2019 using the FLIKE software. The FFA results are given in Table 4.1, and represented graphically in Figure 4-1. There is a 90% likelihood that the design discharge is within the 90% confidence limits shown in Figure 4-1. The 5%, 2% and 1% AEP design peak discharges are 1,732 cubic metres per second (m^3/s), 2,754 m^3/s and 3,721 m^3/s, respectively.

Table 4.1 - Peak annual discharges at Hunter River at Muswellbrook Bridge gauge

Year	Peak Annual Discharge (m^3/s)	Year	Peak Annual Discharge (m^3/s)
1961	93	1989	546
1962	874	1990	808
1963	385	1991	107
1964	542	1992	2,144
1965	28	1993	217
1966	28	1994	72
1967	394	1995	321
1968	701	1996	999
1969	383	1997	120
1970	313	1998	1,502
1971	3,207	1999	227
1972	232	2000	1,598
1973	117	2001	237
1974	327	2002	87
1975	136	2003	117
1976	2,109	2004	182
1977	679	2005	52
1978	865	2006	12
1979	255	2007	256
1980	8	2008	245
1981	86	2009	77
1982	77	2010	197
1983	165	2011	424
1984	1,153	2012	195
1985	237	2013	259
1986	57	2014	20
1987	183	2015	83
1988	139	2016	183

Table 4.2 - Flood frequency analysis results for Muswellbrook Bridge gauge

AEP	Design Discharge (m^3/s)
5%	1,732
2%	2,754
1%	3,721
0.5%	4,872
0.2%	6,705
0.1%	8,348

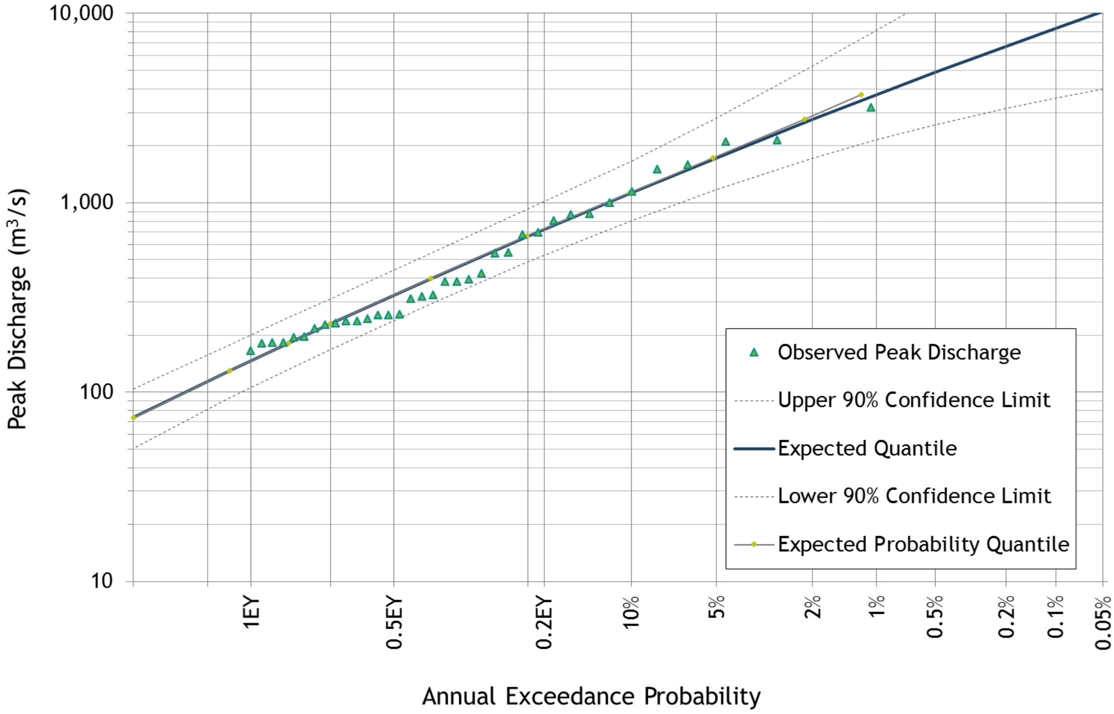


Figure 4-1 - LPIII distribution of recorded flows, Muswellbrook Bridge gauge

4.3 HYDROLOGIC MODEL CONFIGURATION

The model configuration and parameters of the calibrated Hunter River RAFTS model developed by WorleyParsons (2014) are generally unchanged. The adopted Glenbawn Dam configuration is provided in Section 4.3.4.

4.3.1 Design rainfalls

Design rainfall depths were obtained from the Commonwealth Bureau of Meteorology (BOM) for a range of design AEPs and storm durations, as shown in Table 4.3.

Table 4.3 - Design rainfall depths

Storm Duration (Hours)	Rainfall Depths (millimetres [mm])			
	10% AEP	5% AEP	2% AEP	1% AEP
12	74	86	102	115
18	87	101	121	137
24	97	113	136	154
36	113	133	160	182
48	125	147	178	203
72	141	166	201	229

4.3.2 Areal reduction factor

Table 4.4 shows the adopted areal reduction factors for the Hunter River catchment to Muswellbrook. The areal reduction factors were estimated in accordance with recommendations of Chapter 4 in ARR 2019. The Hunter River catchment is within the South-East Coast zone.

Table 4.4 - Areal reduction factors for Hunter River to Muswellbrook

Storm Duration (Hours)	Areal Reduction Factor			
	10% AEP	5% AEP	2% AEP	1% AEP
12	0.768	0.758	0.745	0.735
18	0.818	0.810	0.800	0.792
24	0.868	0.863	0.855	0.850
30	0.876	0.871	0.864	0.858
36	0.882	0.877	0.870	0.864
48	0.892	0.886	0.879	0.874
72	0.903	0.898	0.891	0.885

4.3.3 Temporal patterns

The temporal patterns define the variability of rainfall during an event. The ensemble event approach described in ARR 2019 has been used for this analysis. This approach uses an 'ensemble' of 10 temporal patterns for each storm duration to derive a range of estimated flood peaks for each AEP up to the 1% AEP event.

The temporal patterns of relevance to the Hunter River (South-East Coast temporal patterns) were obtained from the ARR 2019 Data Hub.

4.3.4 Glenbawn Dam

Glenbawn Dam was included in the RAFTS model to account for the effect of available flood storage from the dam. Dam data including the storage curve, full supply level and spillway level were obtained from the NSW Office of Water website. The full supply level was adopted as the initial water level in the dam for all design events.

4.3.5 Rainfall losses

The rainfall losses were adjusted so that the RAFTS peak design discharges matched the results of the FFA. Table 4.5 shows the adopted rainfall losses for the 5%, 2% and 1% AEP design events. The adopted rainfall losses are comparable to the recommended rainfall losses from ARR 2019.

Table 4.5 - Adopted rainfall losses

Design Event (AEP)	Initial Loss (mm)	Continuing Loss (mm/hr)
5%	47	1.7
2%	41	1.6
1%	38	1.5

4.4 ADOPTED PEAK DESIGN DISCHARGES

Table 4.6 shows the 5%, 2% and 1% AEP RAFTS design discharges and comparison to the FFA results at Hunter River at Muswellbrook Bridge gauge. The RAFTS predicted design discharges match reasonably well to FFA (within about 3%) and hence the RAFTS design discharges were adopted in the hydraulic model to estimate design flood levels and velocities. The adopted 5%, 2% and 1% AEP peak design discharges are 1,776 m^3/s, 2,760 m^3/s and 3,841 m^3/s, respectively.

Table 4.6 - Comparison of RAFTS predicted design discharges and FFA at Muswellbrook Bridge gauge

Design Event (AEP)	FFA (m^3/s)	RAFTS (m^3/s)	Difference (RAFTS minus FFA)
5%	1,731	1,776	+2.6%
2%	2,754	2,760	+0.2%
1%	3,721	3,841	+3.2%

5 Hydraulic modelling

5.1 OVERVIEW

The TUFLOW two-dimensional unsteady flow model (BMT WBM, 2016) was used to estimate flood levels and flood velocities along the channel and floodplain of the Hunter River in the vicinity of the Project.

TUFLOW estimates flood levels and velocities on a fixed grid pattern by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. It also incorporates a one-dimensional or quasi two-dimensional modelling system (ESTRY).

The following two models were developed:

- **Existing conditions** – This model represents current conditions, with the ARTC rail embankment in place but without the approved rail spur and viaduct; and
- **Developed conditions** – This model represents future (developed) conditions, with the approved rail spur and viaduct in place.

5.2 EXISTING CONDITIONS TUFLOW MODEL CONFIGURATION

5.2.1 Spatial configuration

Figure 5-1 shows the extent of the hydraulic model and the locations of the inflow and outflow boundaries. The model extends approximately 6 km upstream and 13 km downstream of Muswellbrook and covers an area of some 70 km^2 including Sandy Creek. The model also includes Rosebrook Creek on the northern floodplain of the Hunter River.

The hydraulic model developed for the MOD 4 rail infrastructure covers a smaller area than the model developed by WorleyParsons for the Hunter River (Muswellbrook to Denman) Flood Study (2014). The WorleyParsons hydraulic model was developed to define the characteristics of flooding around the townships of Muswellbrook and Denman to inform the preparation of a Floodplain Risk Management Study and Plan. The smaller spatial extent of the hydraulic model developed for this study is suitable for identifying the potential impacts of the MOD4 rail infrastructure at a finer scale.

5.2.2 Topographic data

LiDAR survey data was provided by MACH Energy covering an area of 560 km^2. Several data sources were combined to develop the existing conditions topography in the TUFLOW model, as described in Section 3.3. A 5 m grid size was adopted for the model. The existing ARTC railway embankment was configured using LiDAR data supplemented with the ECI design surface along a 545 m section of the existing rail, noting that the ECI design surface is intended to match the existing ARTC rail elevation over this section.

5.2.3 Manning's roughness

The TUFLOW model uses Manning's 'n' values to represent hydraulic resistance. Discrete regions of continuous vegetation types and land uses were mapped using aerial photography, and an appropriate roughness value assigned to each region. The adopted Manning's 'n' values are shown in Table 5.1. The Manning's 'n' values were refined during model verification and were applied to all design event modelling.

5.2.4 Inflow and outflow boundaries

Figure 5-1 shows the locations of two inflow boundaries, the Hunter River and Sandy Creek, for the hydraulic model. The discharge hydrographs adopted as inflows to these boundaries were obtained from the RAFTS model.

A single normal depth outflow boundary with 0.1% slope was adopted for the Hunter River model. The outflow boundary of this model is located approximately 13 km downstream of Muswellbrook and will not have an impact on flood levels in the vicinity of the approved rail spur.

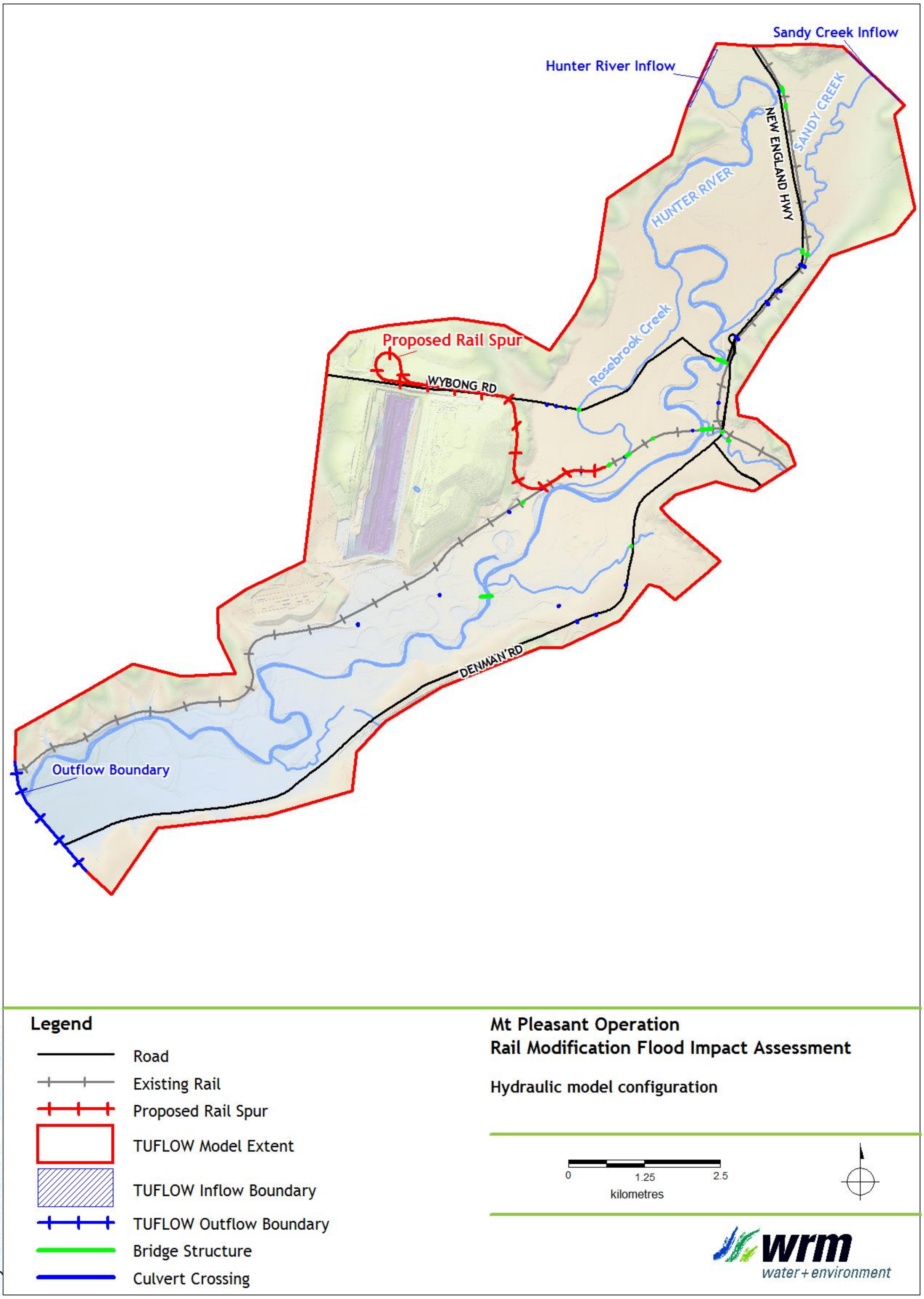


Figure 5-1 - Existing conditions TUFLOW model configuration

Table 5.1 – Adopted Manning's roughness for different land use types

Land use	Manning's 'n'
Pasture / Overbank	0.040
Channel	0.030
Dense vegetation	0.065
Road	0.020
Rail	0.035
Urban area	0.100

5.2.5 Existing hydraulic structures

Survey information on the existing hydraulic structures including culvert crossings and bridges were provided by FYFE (surveyors) dated 15 November 2017. A total of 26 culvert structures and 16 bridge structures were included in the hydraulic model based on the survey information. Figure 5-1 shows the locations of the modelled culvert and bridge structures.

A number of the modelled culvert and bridge structures shown on Figure 5.1 were not included in the WorleyParsons model, which focused on larger structures that had a greater potential to affect flooding at a regional scale.

5.3 HYDRAULIC MODEL VERIFICATION

5.3.1 Overview

The hydraulic model described in Section 5.2 was validated to the August 1998 and November 2000 historical events. These are the largest flood events in the last 24 years.

The recorded flow hydrographs for the Hunter River at Muswellbrook Bridge gauge for the two historical events were obtained from NSW Department of Primary Industries Office of Water (DPI Water) website and adopted as inflows to the hydraulic model. The recorded flow hydrographs were shifted by about 1.5 hours earlier to account for the model inflow boundary being about 10 km (channel length) upstream of the Muswellbrook Bridge gauge. The model predicted flow and level hydrographs were then compared to the recorded hydrographs to validate the hydraulic model.

5.3.2 Model verification results

Figure 5-2 to Figure 5-5 show the recorded and predicted flow and water level hydrographs at Hunter River at Muswellbrook Bridge gauge for the August 1998 and November 2000 flood events. Table 5.2 shows the comparison of recorded and predicted peak flood levels at Muswellbrook Bridge gauge for the two historical flood events. The following is of note:

- Using the recorded flow hydrographs, the model predicted discharges at Muswellbrook Bridge gauge match the recorded discharges well for the historical flood events. This indicates there is little channel storage or attenuation from the model inflow boundary to the gauge.
- The model predicted water levels at Muswellbrook Bridge gauge match the recorded water levels well for the historical flood events. The predicted peak flood levels at the gauge are within 0.1 m of the recorded peak flood levels.
- Figure 5-6 shows the comparison of model results and a historical photograph at New England Highway near Muscle Creek (WorleyParsons, 2014) for the November 2000 flood event. The model predicted depths at this location are comparable to the historical photo.
- Overall, a good validation has been achieved for the August 1998 and November 2000 flood events, indicating that the model is suitable for determining design flood levels and assessing impacts across the study area.

Table 5.2 - Comparison of recorded and predicted peak flood levels at Hunter River at Muswellbrook Bridge gauge

Event	Peak Flood Level at Muswellbrook Bridge (mAHD)		
	Recorded	Predicted	Difference (m)
August 1998	146.29	146.43	+0.15
November 2000	146.61	146.61	0.00

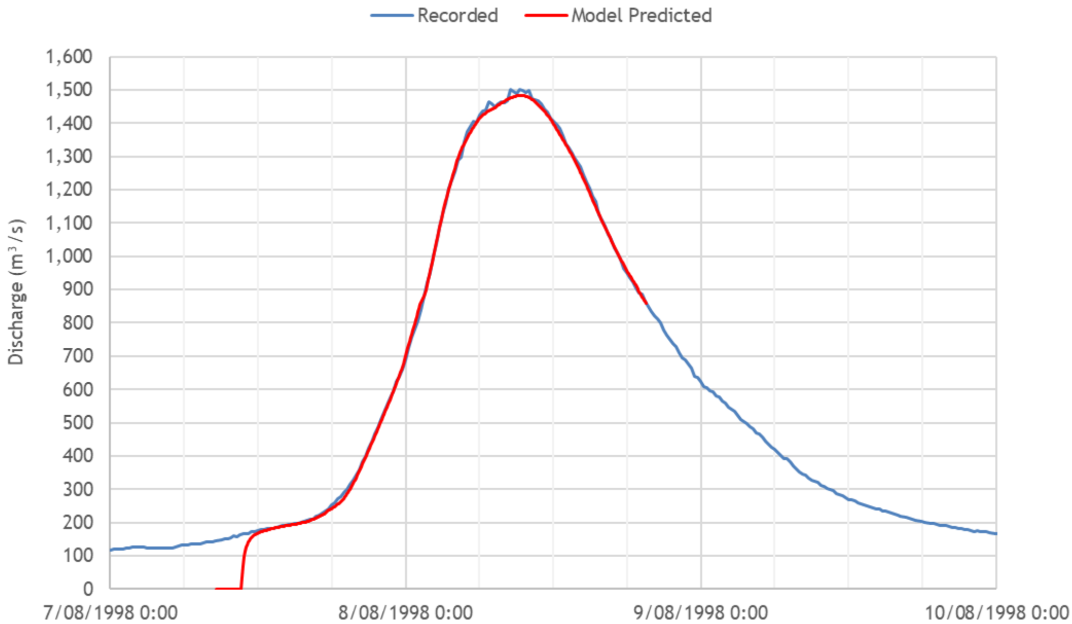


Figure 5-2 - Comparison of recorded and predicted flow hydrographs, Hunter River at Muswellbrook Bridge, August 1998 flood event

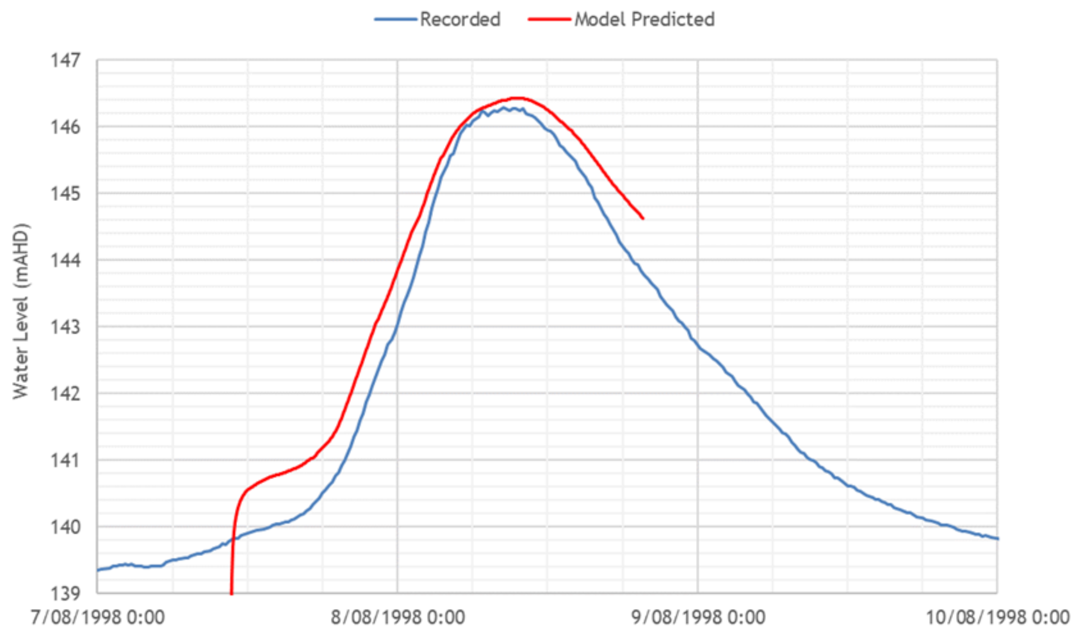


Figure 5-3 - Comparison of recorded and predicted water level hydrographs, Hunter River at Muswellbrook Bridge, August 1998 flood event

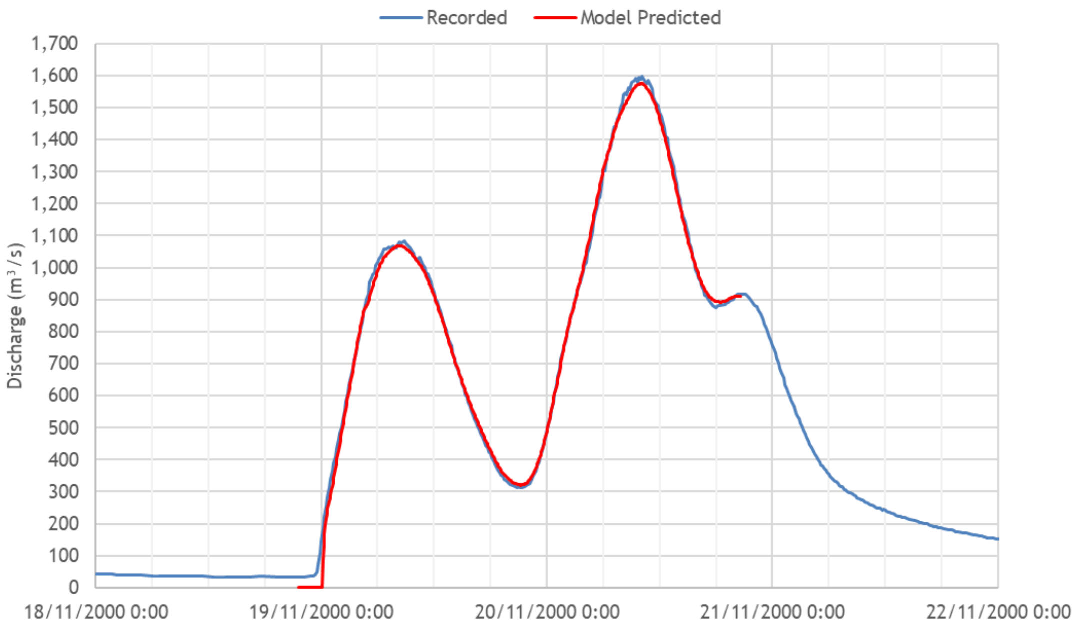


Figure 5-4 - Comparison of recorded and predicted flow hydrographs, Hunter River at Muswellbrook Bridge, November 2000 flood event

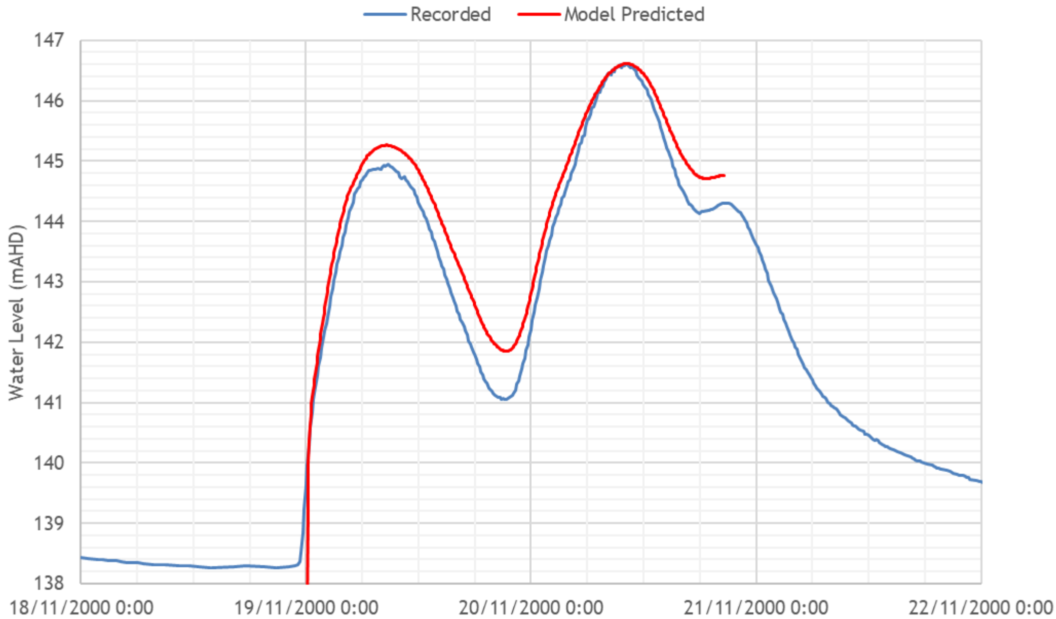
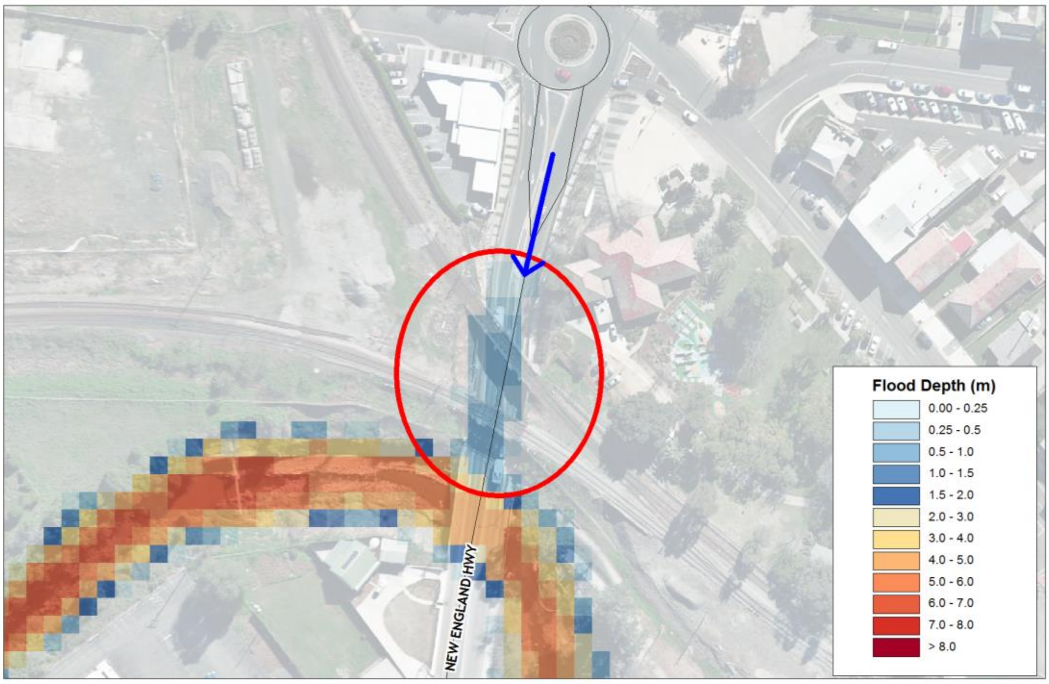


Figure 5-5 - Comparison of recorded and predicted water level hydrographs, Hunter River at Muswellbrook Bridge, November 2000 flood event



NOVEMBER 2000 – MUSWELLBROOK

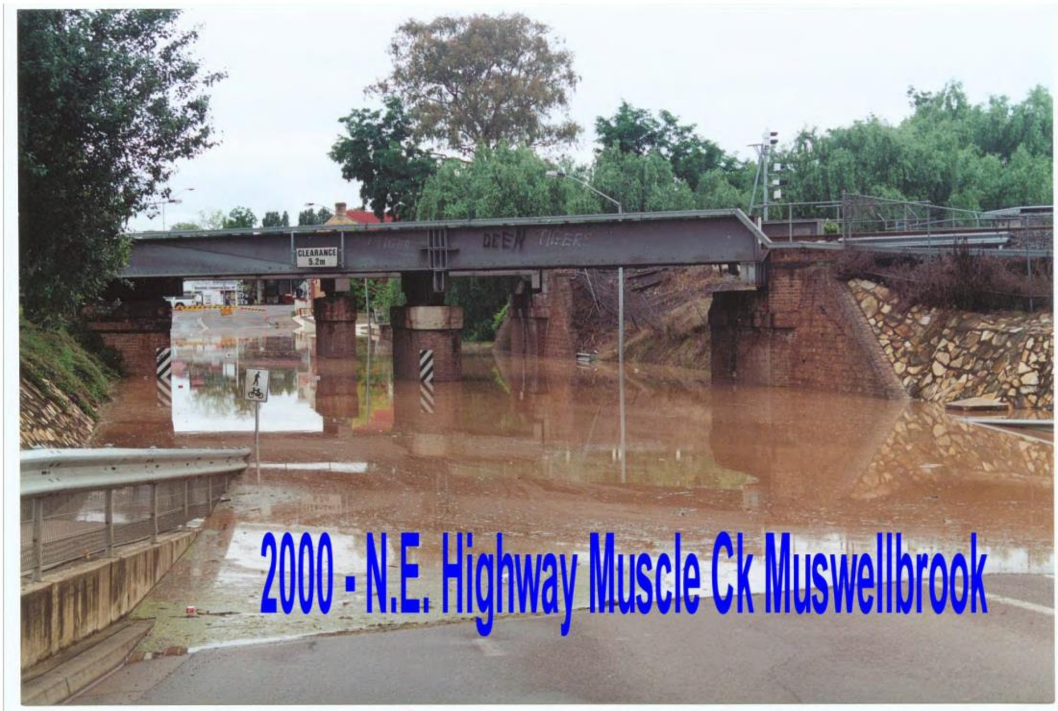


Figure 5-6 - Comparison of model results and historical photographs, November 2000 flood event

5.4 DEVELOPED CONDITIONS TUFLOW MODEL CONFIGURATION

5.4.1 Overview

The existing conditions TUFLOW model was modified to include the approved rail spur. Apart from inclusion of the rail spur, all other details of the model were unchanged.

5.4.2 Approved rail spur design

AECOM supplied an earthworks model of the approved rail spur (the ECI design) on 31 May 2019 (file "MACH-MOD-00-1000-CI-20190529.12da"). The earthworks model was supplied in GDA94/MGA Zone 56 projection.

AECOM also supplied information ("design in progress" sketches) on the viaduct and culverts on 6 June 2019 in the following PDF files:

- General layout of the approved rail spur:

  "60601930_0001_WTR_SKT_0101 A.pdf";
- Viaduct:

  "60601930_0019_STR_SKT_0001-0024.pdf"; and
- Culverts:

  "60601930_0021_STR_SKT_0001-0009_A.pdf"

The above files provided by AECOM were used as the basis for configuring the rail spur in the TUFLOW model. Updated excerpts from the design drawings for the 7-span design were supplied by AECOM on 13 May 2020 in the following PDF files and are shown in Figure 5-7 and Figure 5-8:

- Underbridge at floodplain, flood study sketch - plan:

  "60620355-SKT-BDG-200-701004-A.pdf"; and
- Underbridge at floodplain, flood study sketch - elevation:

  "60620355-SKT-BDG-200-701005-A.pdf".

AECOM advised that the embankment crest levels in the supplied earthworks model (the ECI design) represent the top of formation level (excluding the ballast). For this flood impact assessment, the crest level of the approved rail embankment was represented as the top of formation level plus 400 mm (i.e. the ECI design formation level was raised by 400 mm) to represent the top of ballast. The ballast was assumed to be impervious.

Figure 5-9 shows a longitudinal plot comparing existing ground levels (red line), the ECI design formation level (green line) and the adjusted formation level (black line) (ECI formation level plus 400 mm). The ECI formation level plus 400 mm (black line) was adopted to represent the approved rail spur in the hydraulic model.

5.4.3 Floodplain viaduct configuration

The initial ECI design for the floodplain viaduct comprised a 9-span bridge spanning a total of 257 m.

Following initial assessment, the viaduct design was refined by extending the eastern abutment to the west by two bridge spans (each span 28.5 m), resulting in a shorter viaduct length of 7 bridge spans (see Figure 5-7 and Figure 5-8). This configuration was able to meet the MOD4 design criteria for flood impacts.

Individual bridge piers were represented in the hydraulic model as partial blockages within individual grid cells, using "layered flow constrictions". For the adopted 7-span design, there is a total of six bridge piers.

5.4.4 Floodplain culverts

In addition to the viaduct, the rail spur will include the following culvert structures (refer to Figure 5-9 for chainage reference):

- CH-425: Extension of the existing 3 cells of reinforced concrete box culverts (RCBCs) with internal dimensions of 0.9 m (W) x 0.6 m (H); and
- CH-640: Construction of new 10 cells of RCBCs with internal dimensions of 1.8 m (W) x 1.0 m (H) beneath the new rail spur.

At CH-425, the existing culverts at CH-425 will be extended along their existing alignment in the hydraulic model.

At CH-640, the new culverts were assumed to be perpendicular to the rail embankment.

5.4.5 Potential for blockage of bridge opening

The potential blockage due to debris at the bridge piers was assessed using guidelines in Book 6 – Chapter 6 of AR&R 2019. The assessment considered the dimensions of the bridge openings as well as the potential debris sizes from the catchment upstream of the bridge. It was determined that the debris potential at the bridge is “Low”, with a likely blockage level of 0%. Therefore, for this assessment, no additional blockage factor was added for debris blockage for the design case. However, a sensitivity assessment was undertaken which included blockage of a portion of the viaduct (see Section 6.7).

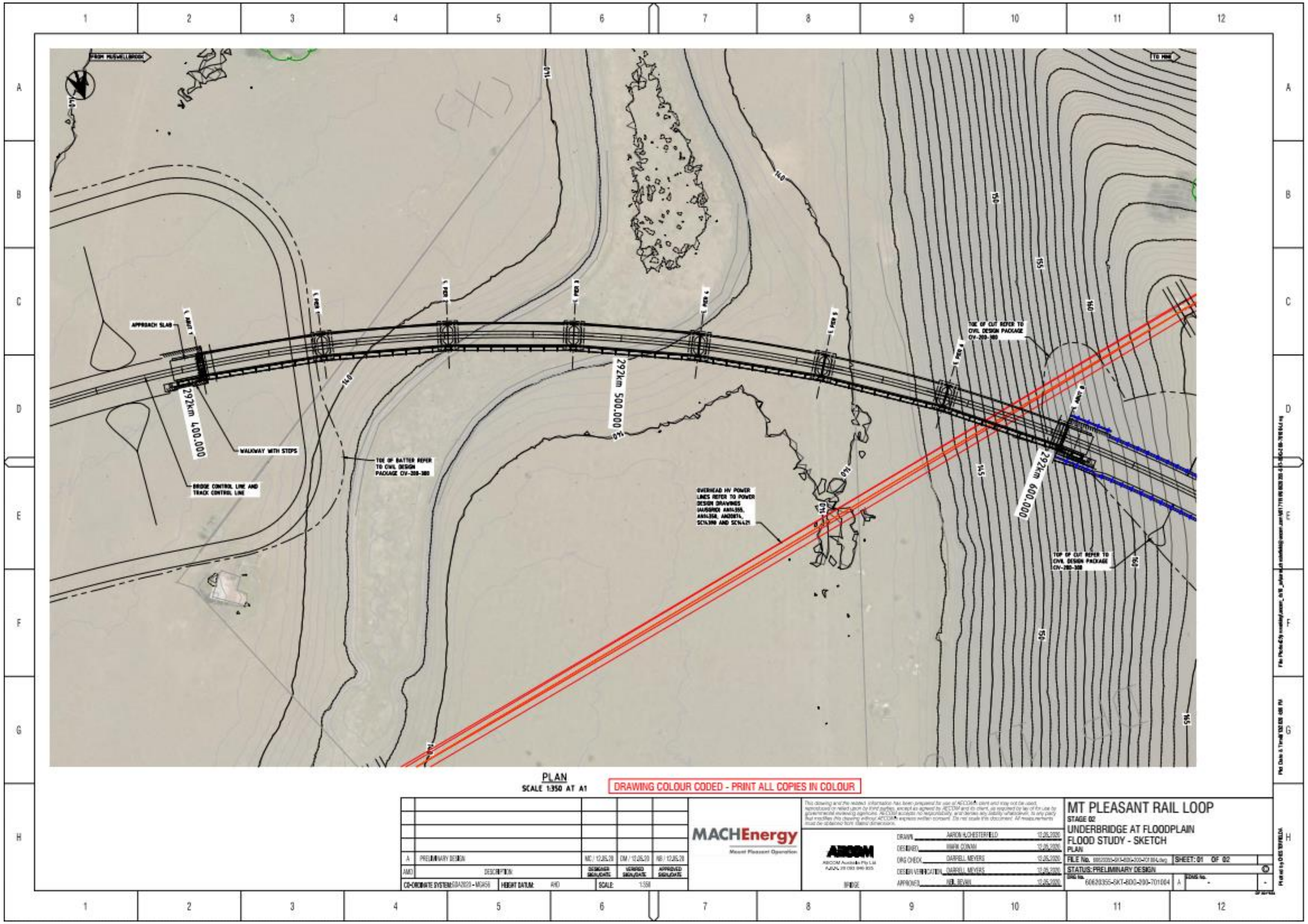


Figure 5-7 - General arrangement of the floodplain viaduct (plan) – 7 span design

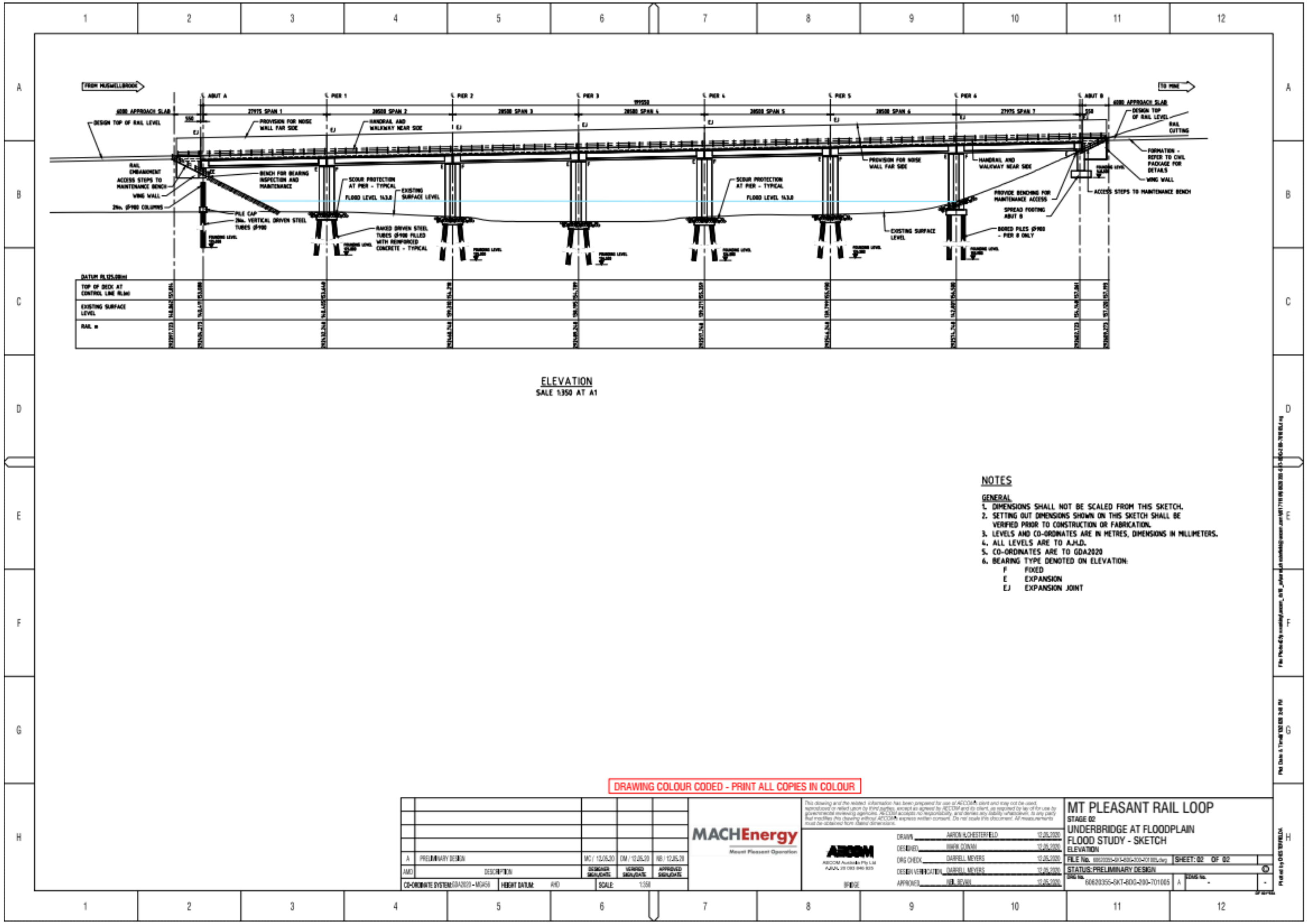
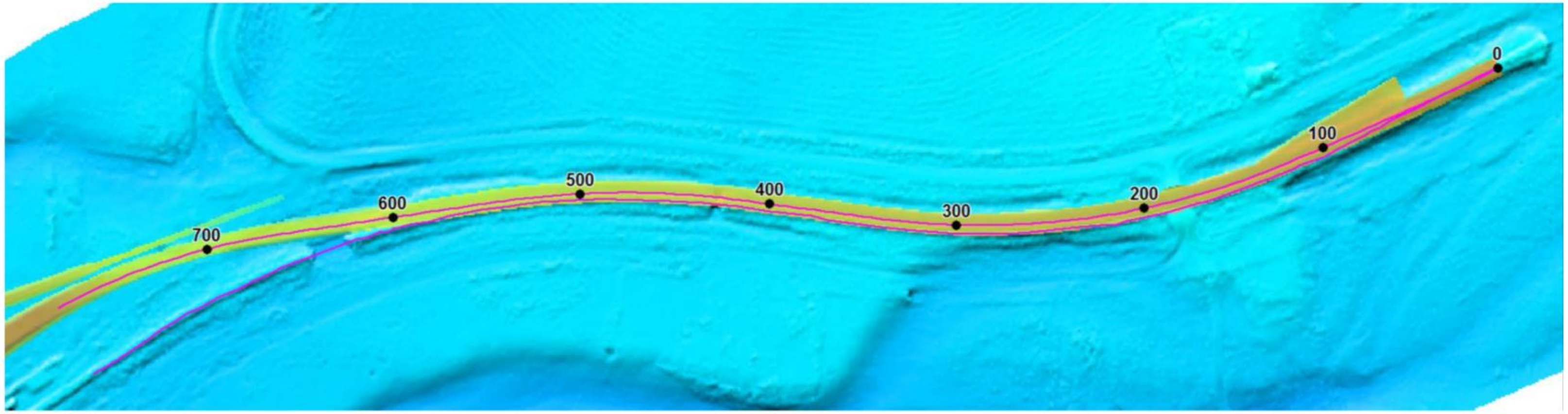


Figure 5-8 - General arrangement of the floodplain viaduct (elevation) - 7 span design



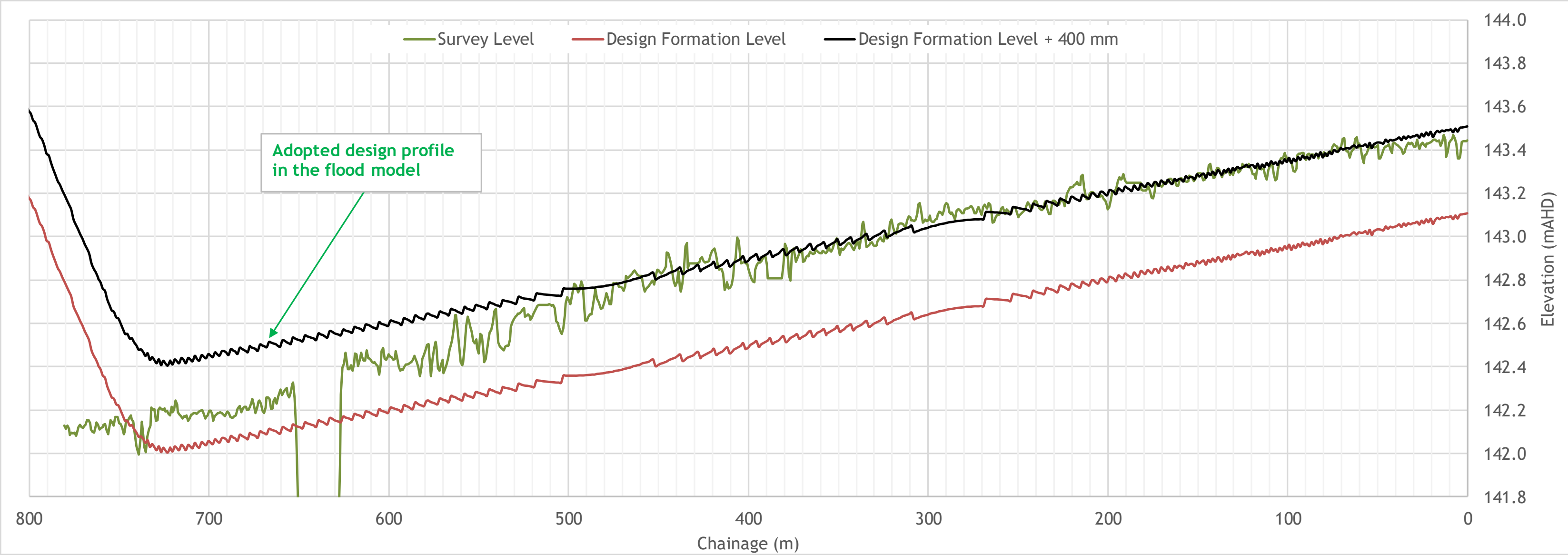


Figure 5-9 - Longitudinal section along first 800m of the rail spur

6 Flood impact assessment

6.1 OVERVIEW

The flood impacts of the approved rail spur were investigated by comparing the TUFLOW model results with and without the approved rail spur for the 5%, 2% and 1% AEP design events.

6.2 MOD 4 DESIGN CRITERIA

The flood impact criteria for the approved rail spur from the MOD 4 consent conditions (44C) for the 1% AEP flood event are:

- no more than 0.1 m increase in flood levels on any privately-owned land;
- no more than 0.01 m increase in flood levels at any privately-owned residence or commercial spaces
- no more than 0.01 m increase in flood levels at any public roads servicing privately-owned properties
- no more than 0.1 m per second increase in flood velocities at privately-owned residences or commercial spaces.

These criteria have been adopted for the assessment of hydraulic impacts of the rail spur.

6.3 FLOOD MODEL RESULTS

Figure 6-1 and Figure 6-2 show predicted peak flood levels and depths for the 1% AEP event in the vicinity of the approved rail spur under existing and developed conditions respectively. Results for the 2% and 5% AEP events are shown in Appendix A. Figure 6-3 and Figure 6-4 show the 1% AEP peak flood velocities for existing and developed conditions. Velocity results for the 2% and 5% AEP events are shown in Appendix A.

The model results for the study area indicate the following:

- Extensive overbank flows would occur along the northern Hunter River floodplain and along Rosebrook Creek for the 5%, 2% and 1% AEP events.
- The southern Hunter River floodplain would be generally unaffected by Hunter River flooding for the 5% AEP event, but extensive overbank flows would occur along the southern floodplain of the river for events equal to or greater than 2% AEP.
- Wybong Road and Logues Lane (to the north of the existing railway) would be inundated for the 5%, 2% and 1% AEP events.

6.4 PREDICTED FLOOD IMPACTS

Impacts of the rail spur on peak flood levels and velocities for the 1% AEP event are shown in Figure 6-5 and Figure 6-6 respectively. Figures showing flood impact for the 2% and 5% AEP events are provided in Appendix A. The results indicate the following:

- There are no predicted increases in peak flood levels greater than 0.01 m at privately owned land, including private lots south of the Hunter River, for all modelled events. This satisfies the MOD4 design criteria.

- There are no increases in peak flood levels greater than 0.01 m along the centreline of existing roads that service private properties including Wybong Road, for all modelled events, which satisfies the MOD4 design criteria. The impacts on peak flood levels along Wybong Road are described in more detail in Section 6.5.
- There are predicted increases in peak flood levels exceeding 0.01 m along a section of Logues Lane for the 5%, 2% and 1% AEP events. However, all properties along Logues Lane are mine-owned and the road does not currently service any private properties. On this basis, the MOD4 criteria is achieved.
- There are no predicted increases in peak velocities greater than 0.1 m/s at privately owned land, including private lots south of the Hunter River, for all modelled events. Predicted increases in velocities are highest beneath the proposed viaduct due to the constriction formed by the viaduct and rail spur embankment. However, these velocity impacts dissipate to less than 0.1 m/s within 500 m of the viaduct and hence do not extend to privately owned properties in the area.

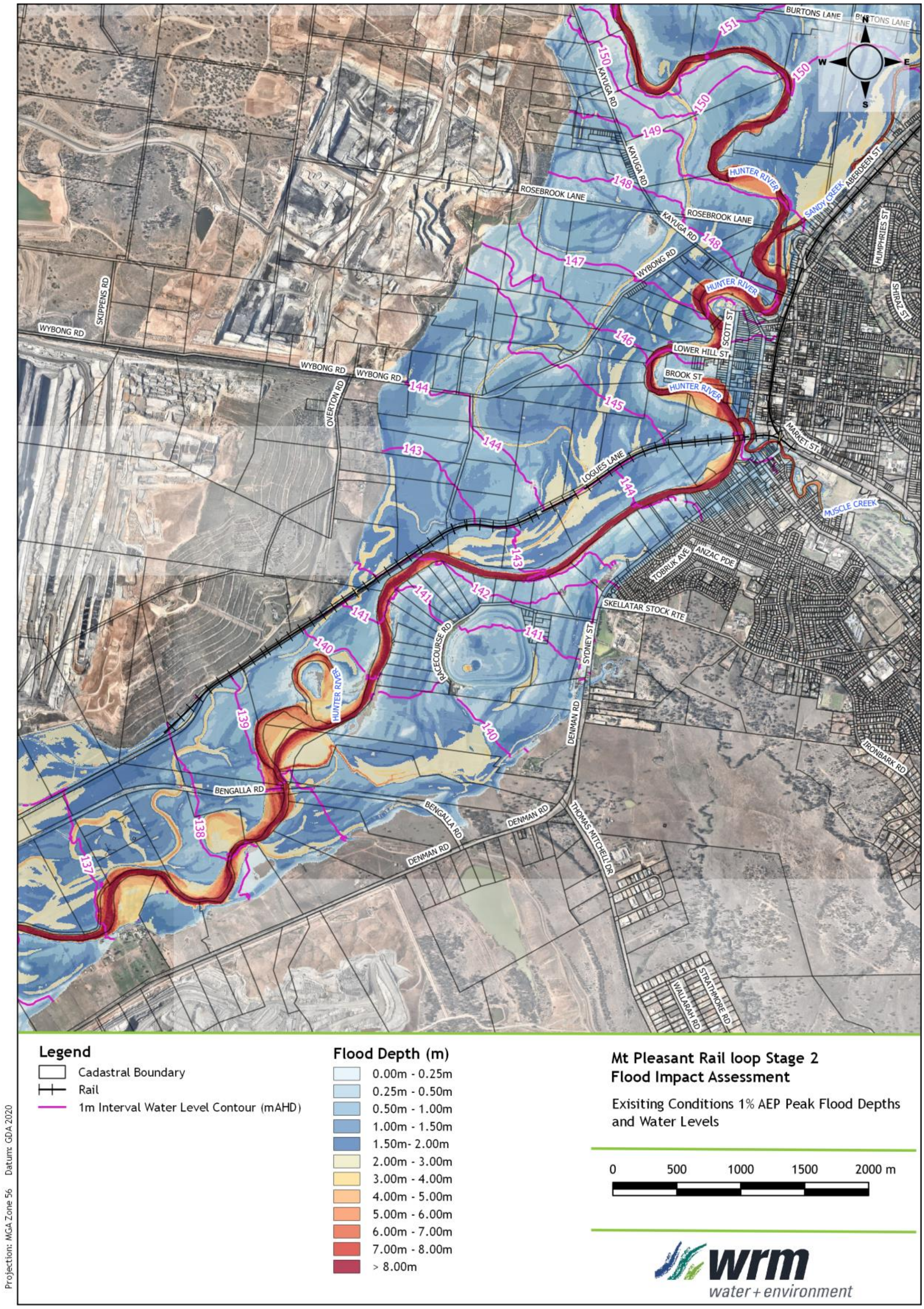


Figure 6-1 - Existing conditions 1% AEP flood level and depth

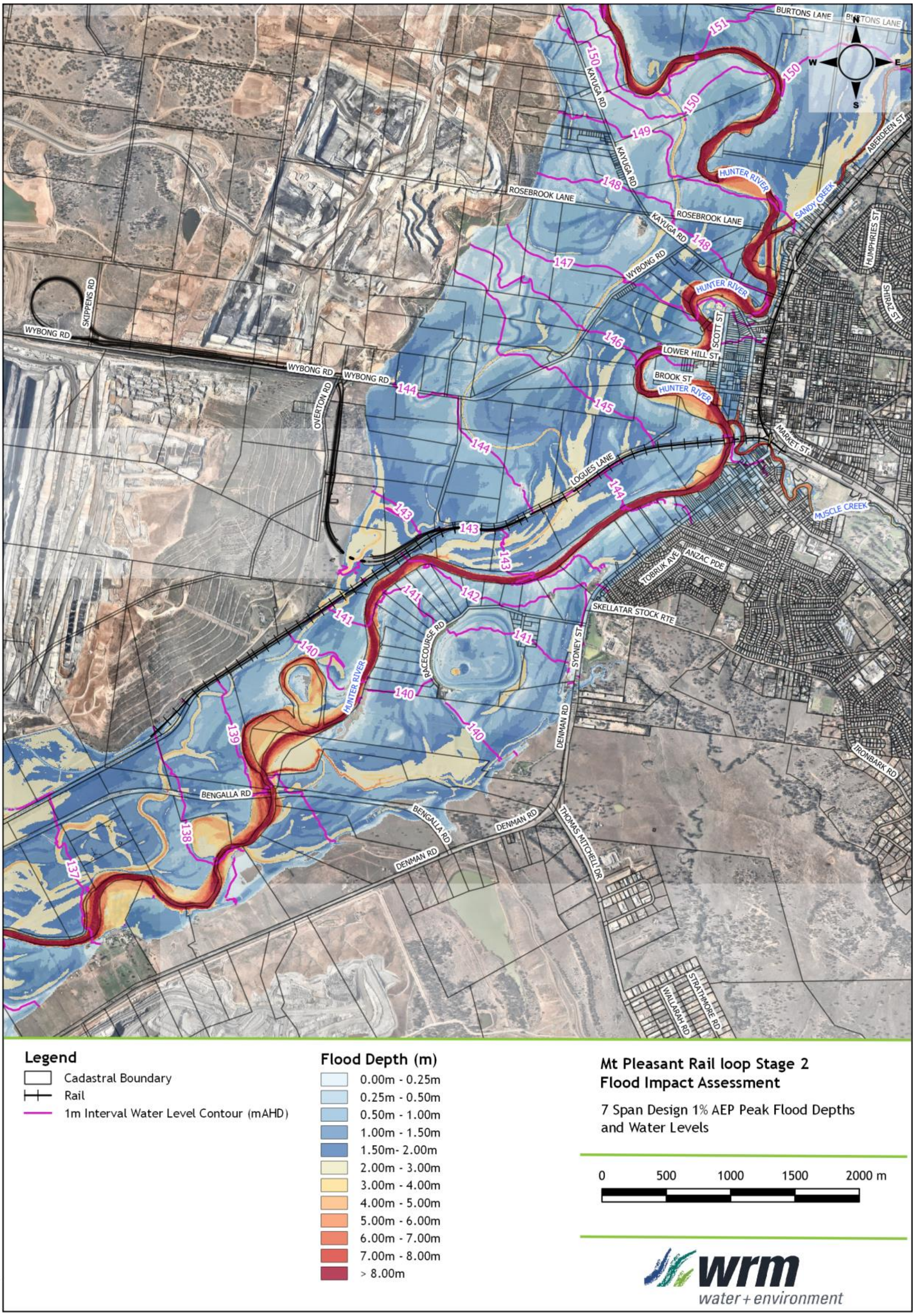


Figure 6-2 - Developed conditions 1% AEP flood level and depth

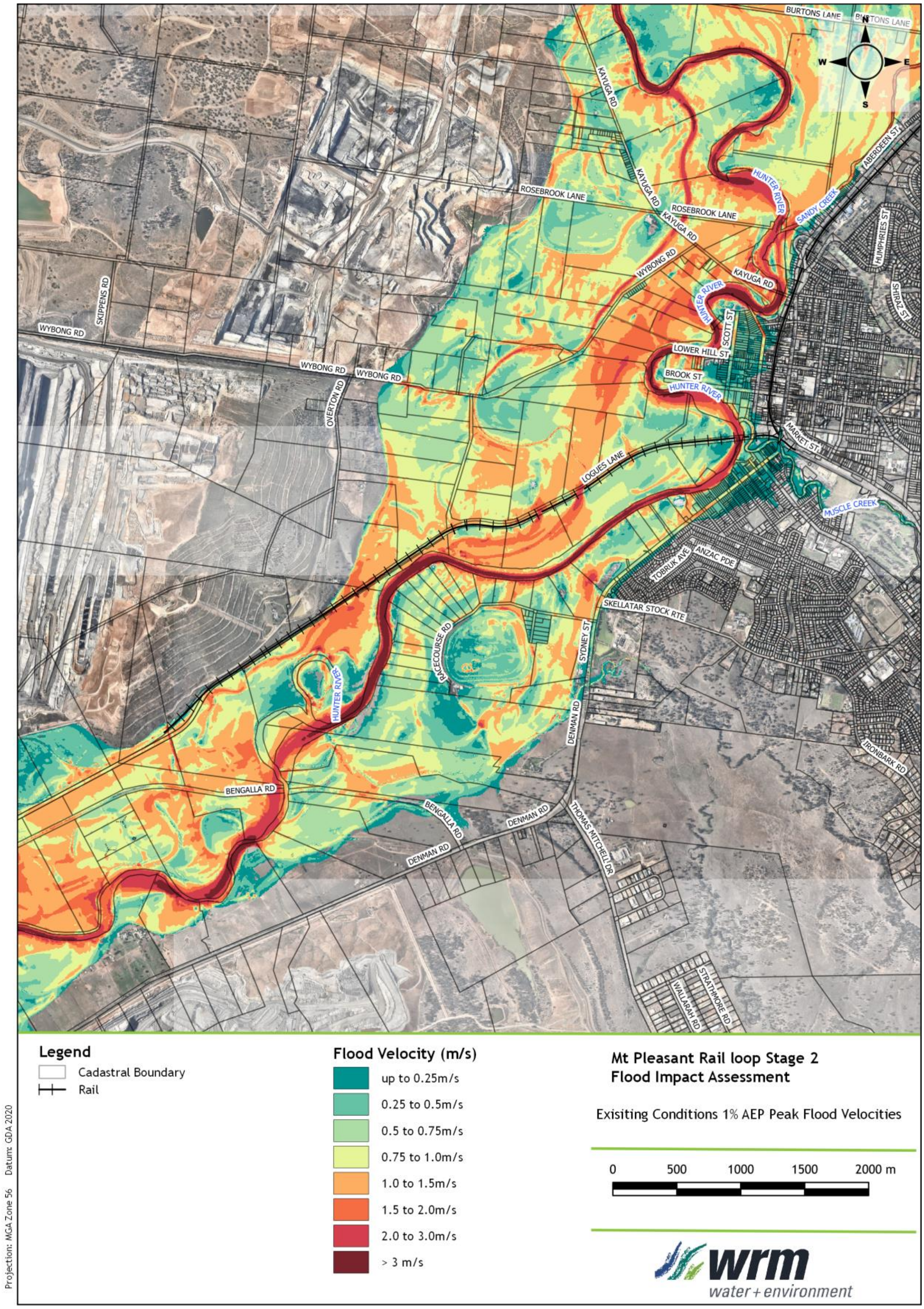


Figure 6-3 - Existing conditions 1% AEP flood velocity

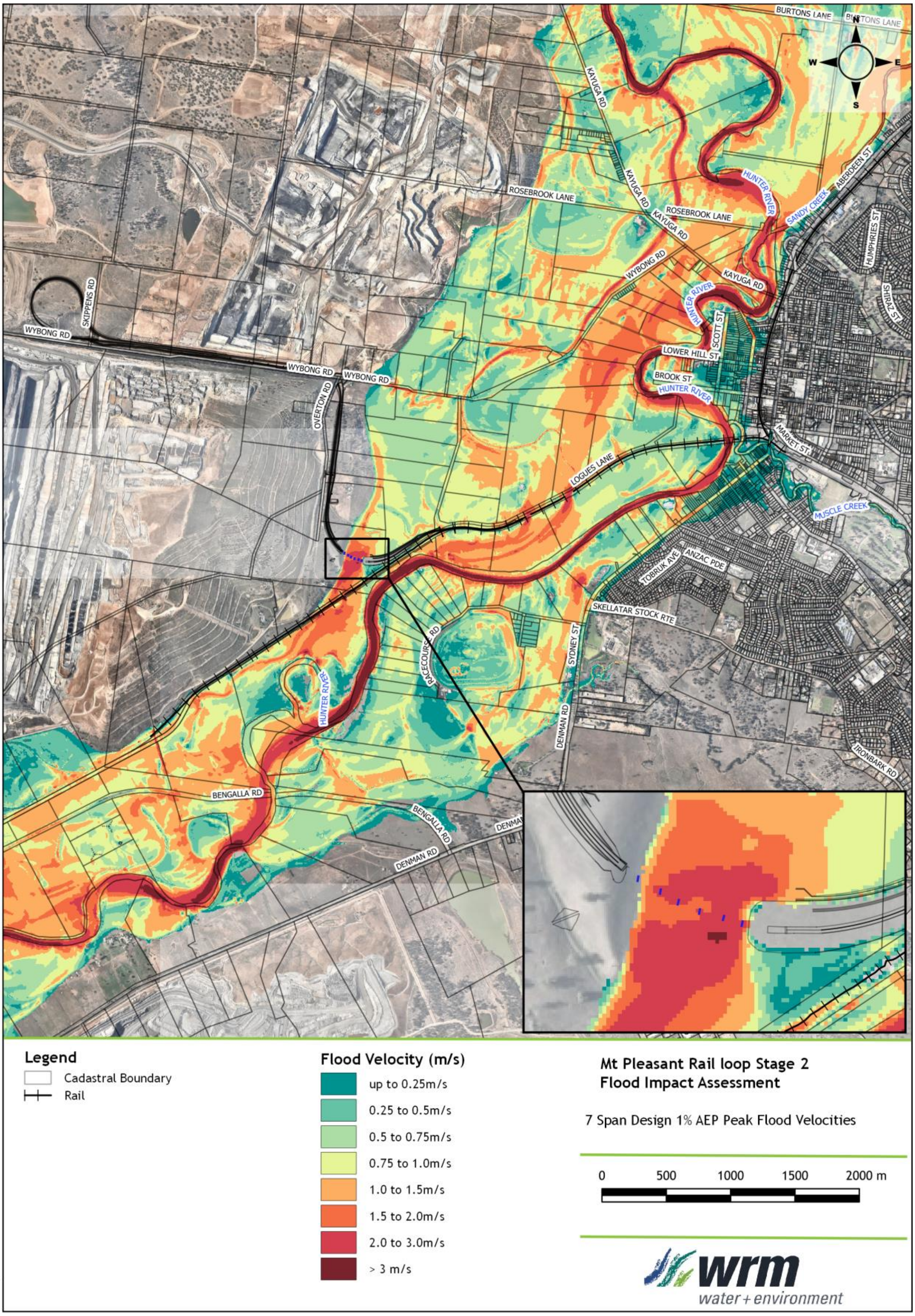


Figure 6-4 - Developed conditions 1% AEP flood velocity

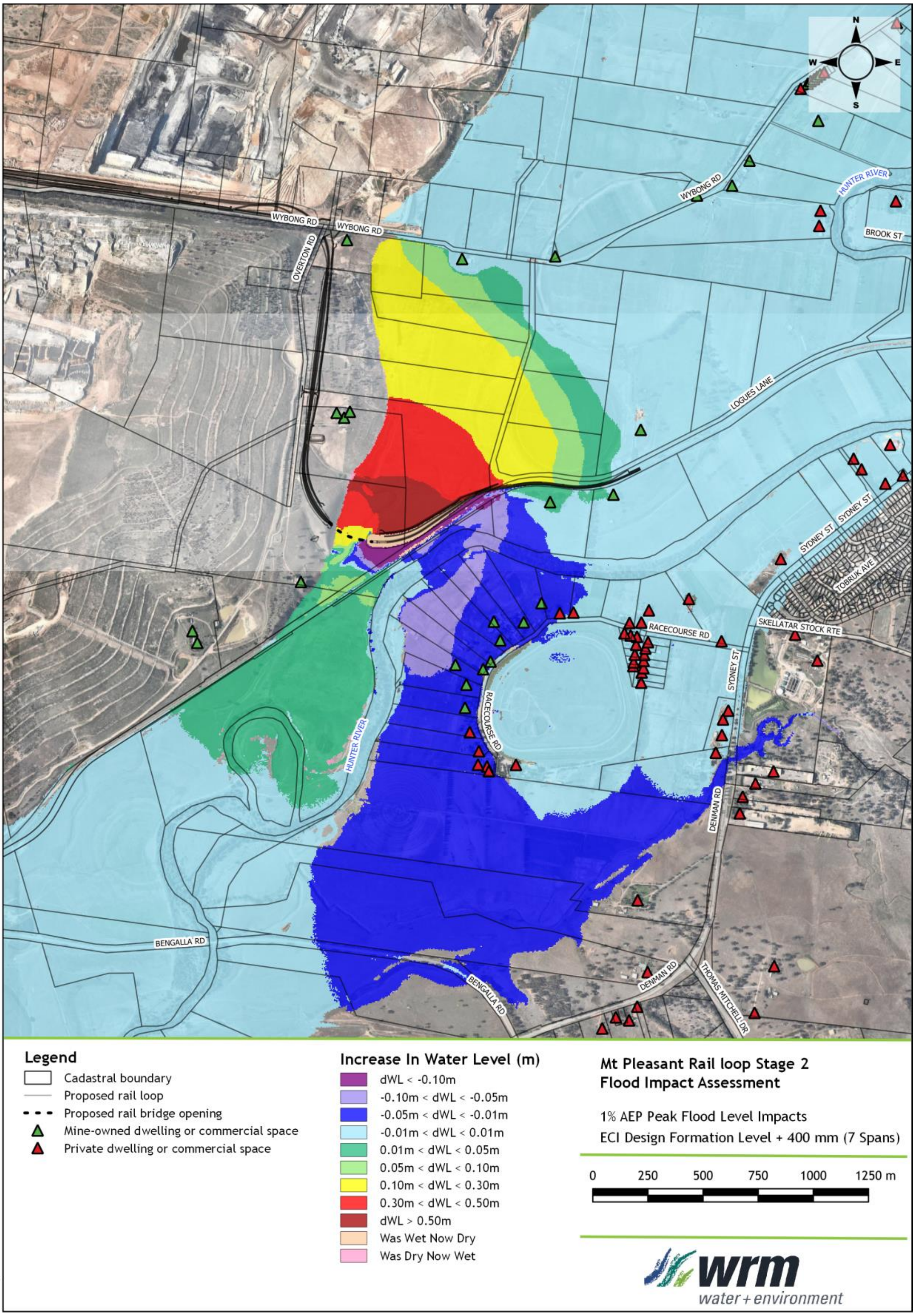


Figure 6-5 - Flood level impacts of rail spur, 1% AEP

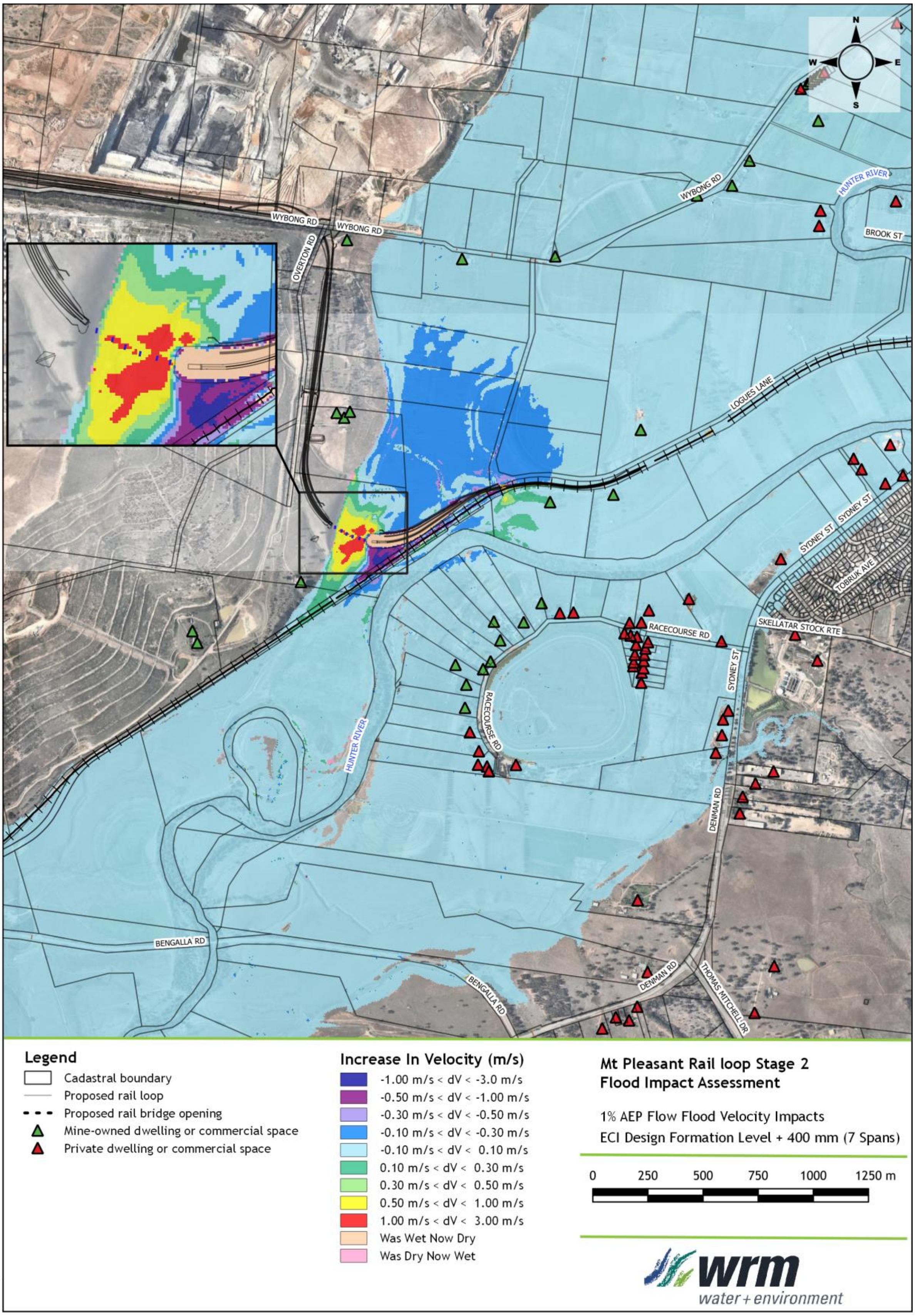


Figure 6-6 - Flood velocity impacts of rail spur, 1% AEP

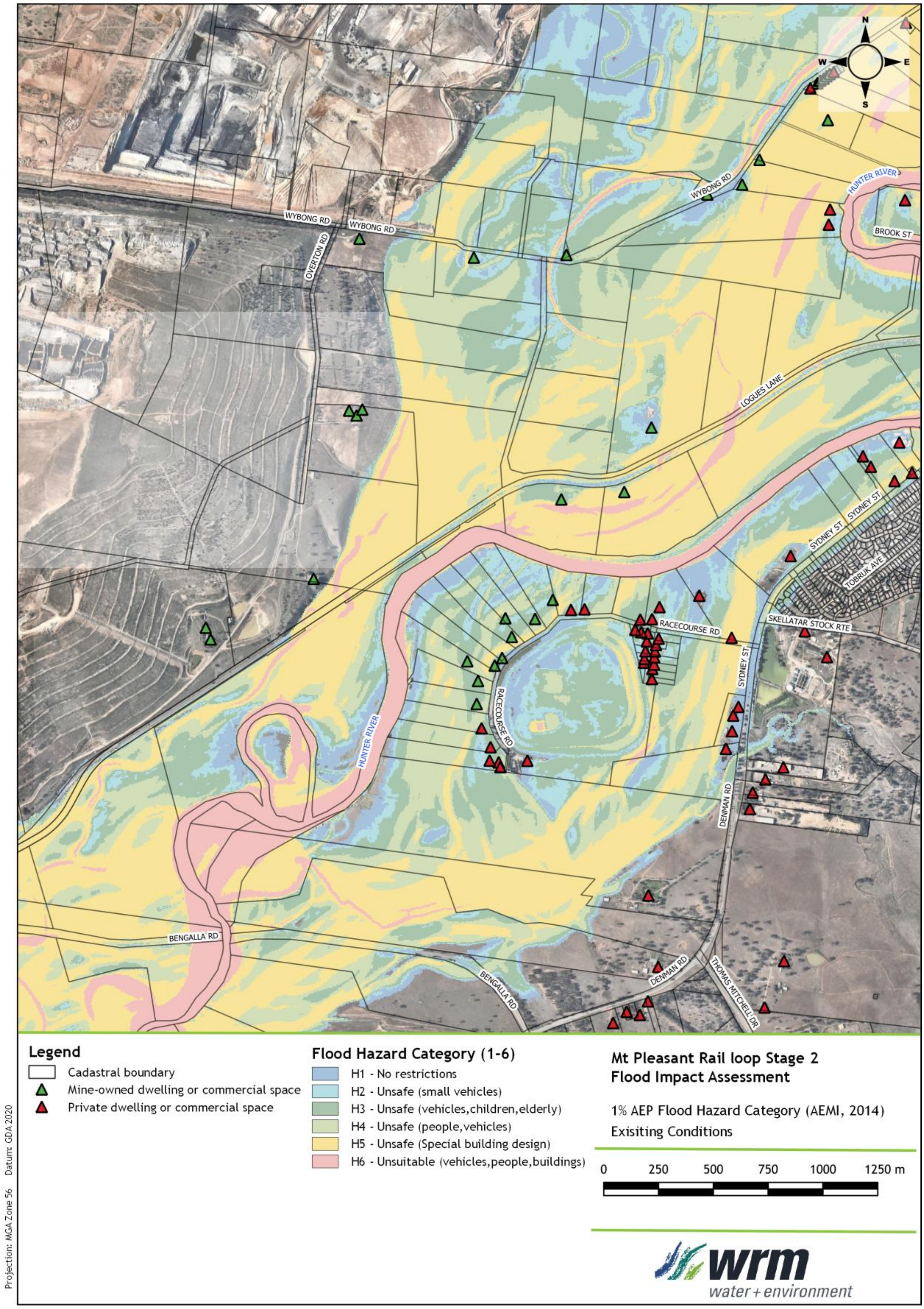


Figure 6-7 - Flood hazard 1% AEP, Existing conditions

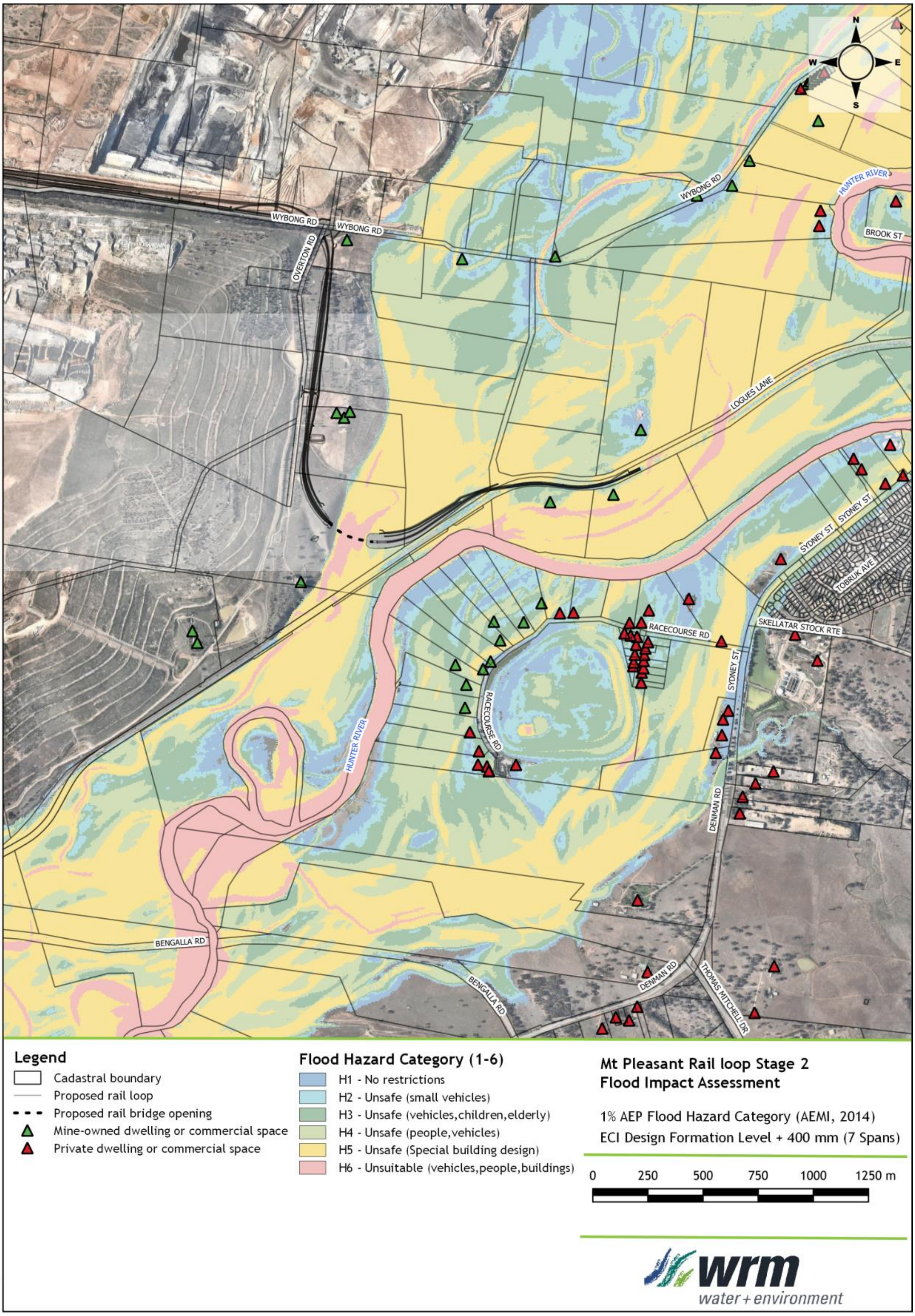


Figure 6-8 - Flood hazard 1% AEP, Developed conditions

6.5 IMPACT ON WYBONG ROAD

The 1% AEP model results show impacts from the rail spur extending upstream to Wybong Road near the western limit of the flood extent. Close inspection of ground level information in this area shows that Wybong Road is elevated and forms a hydraulic control, which means that any impact on the downstream side of Wybong Road does not propagate upstream (Figure 6-9).

Figure 6-11 shows the modelled 1% AEP flood level and road level along the centreline of Wybong Road. Reference chainages are shown in Figure 6-10. Wybong Road is flooded over a length of about 500 m, to a maximum depth of about 0.7 m for the 1% AEP event.

Figure 6-12 shows 1% AEP flood level impacts along the Wybong Road centreline. The maximum impact is 0.004 m, which is less than the MOD4 design criteria of 0.010 m.

6.6 FLOOD HAZARD

Figure 6-7 and Figure 6-8 show flood hazard for the 1% AEP event for existing and developed conditions based on the six hazard categories outlined in the Australian Emergency Management Handbook 7, *Managing the floodplain: Best practice in flood risk management in Australia* (AEMI, 2013).

The hazard mapping results show that the western portion of Wybong Road is affected by the H5 hazard category for both existing and developed conditions. Hence, the rail spur will not increase the 1% AEP flood hazard along Wybong Road which would be untrafficable under existing and developed conditions.

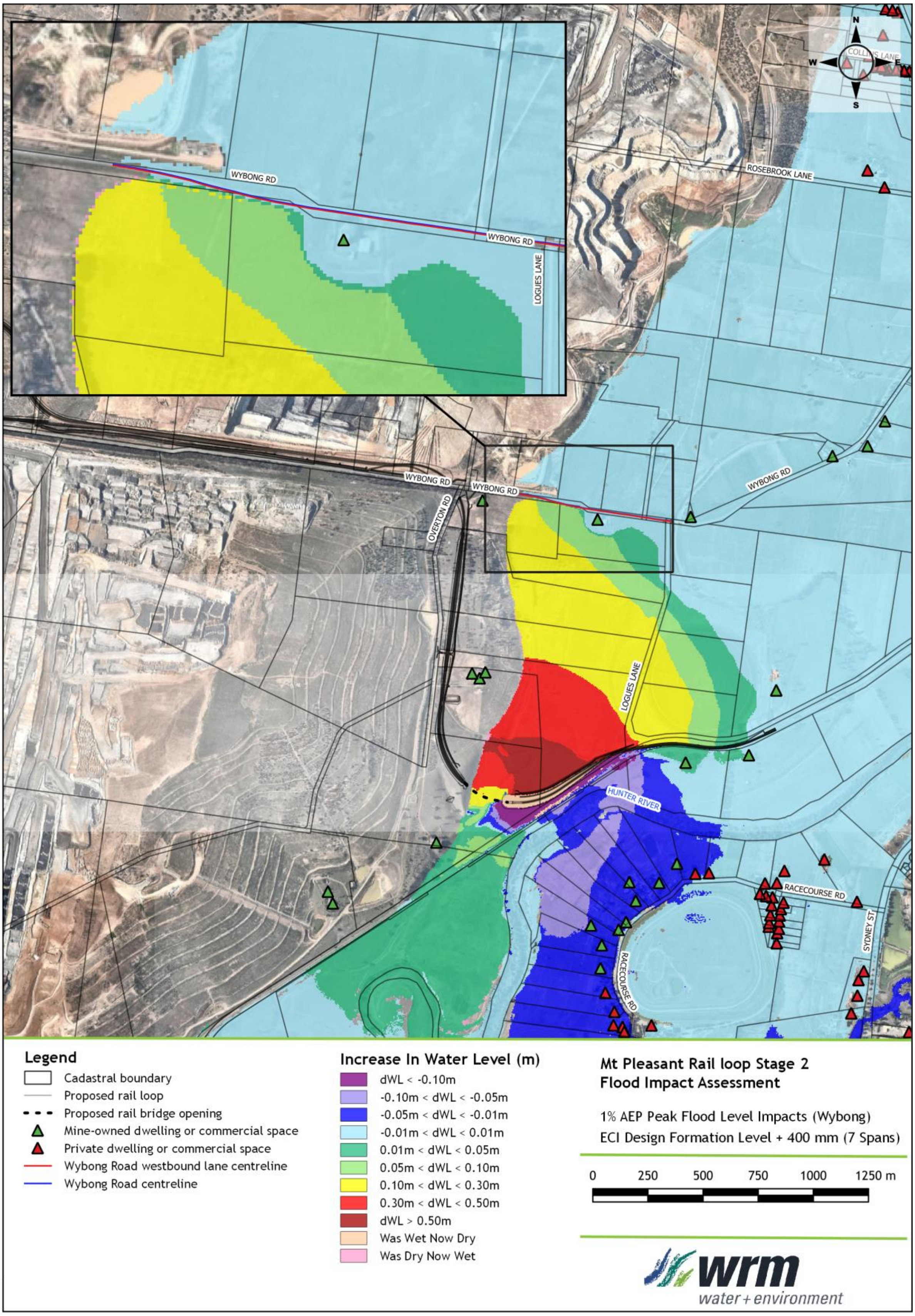


Figure 6-9 - Flood level impacts of rail spur, 1% AEP event

Figure 6-10 - Reference chainage along Wybong Road

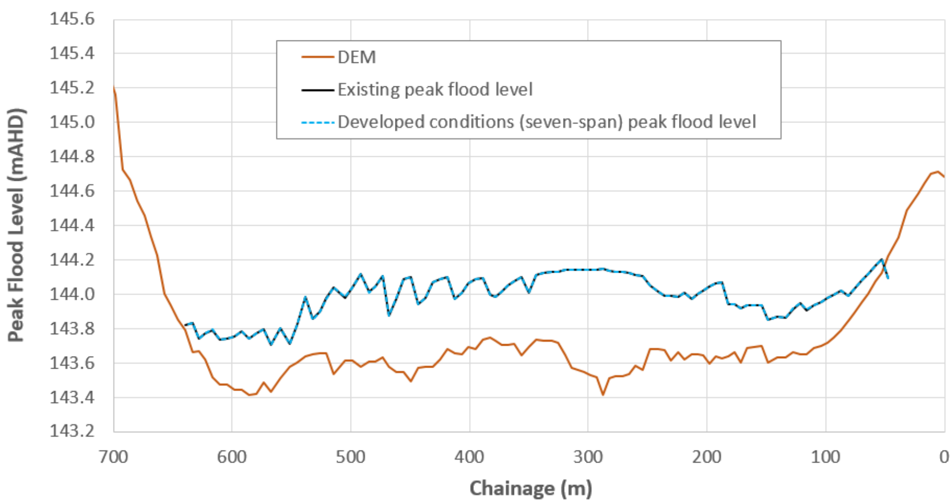


Figure 6-11 - 1% AEP inundation depth along Wybong Road

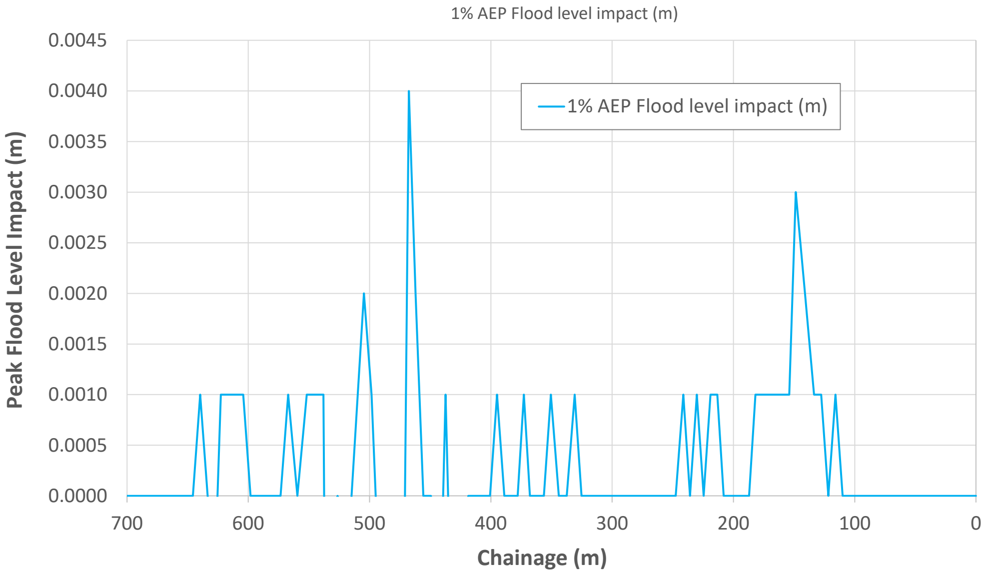


Figure 6-12 - 1% AEP flood level impact at Wybong Road centreline

6.7 SENSITIVITY ANALYSIS

A sensitivity analysis was undertaken to assess the sensitivity of the modelled rail spur impacts to flow rate and roughness (Manning's n) for the 1% AEP event. Sensitivity to flow rate was assessed by varying flow rate by +/- 10% from the calibrated model. Sensitivity to roughness was assessed by varying Mannings n by +/- 20% from the calibrated model. For each sensitivity case, the model was run for existing and developed conditions with the adjusted flow rate or roughness. A summary of the modelled sensitivity cases is shown in Table 6.1.

In addition to the flow and roughness sensitivity cases, an additional run was undertaken with a 20 m wide blockage in the viaduct to determine the additional flood level impact that such a blockage would cause.

Impacts for the sensitivity cases were assessed as follows:

- The impact of the rail spur with higher flow was assessed by comparing sensitivity Run 5 with Run 1.
- The impact of the rail spur with lower flow was assessed by comparing sensitivity Run 6 with Run 2.
- The impact of the rail spur with higher roughness was assessed by comparing sensitivity Run 7 with Run 3.
- The impact of the rail spur with lower roughness was assessed by comparing sensitivity Run 8 with Run 4.
- The impact of blockage of the viaduct was assessed by comparing sensitivity Run 9 with the unblocked developed case. Hence, this sensitivity case shows the additional impact of the blockage, compared to the case with the viaduct unblocked.

The results of the sensitivity cases are shown in Figure 6-13 to Figure 6-17. In summary, the sensitivity cases do not show substantially different impacts to the developed case, which provides confidence that the actual impacts are likely to be similar to the modelled impacts.

Table 6.1 – Summary of sensitivity model runs

Run	Description	Viaduct	1% AEP Discharge	Manning's n	Viaduct blockage
1	Exist - High flow	None	+10%	Calibrated	None
2	Exist - Low flow	None	-10%	Calibrated	None
3	Exist - High n	None	Calibrated	+20%	None
4	Exist - Low n	None	Calibrated	-20%	None
5	Design - High flow	7-span	+10%	Calibrated	None
6	Design – Low flow	7-span	-10%	Calibrated	None
7	Design - High n	7-span	Calibrated	+20%	None
8	Design – Low n	7-span	Calibrated	-20%	None
9	Design with blockage	7-span	Calibrated	Calibrated	20m wide, full depth blockage centred on 1st pier from east abutment

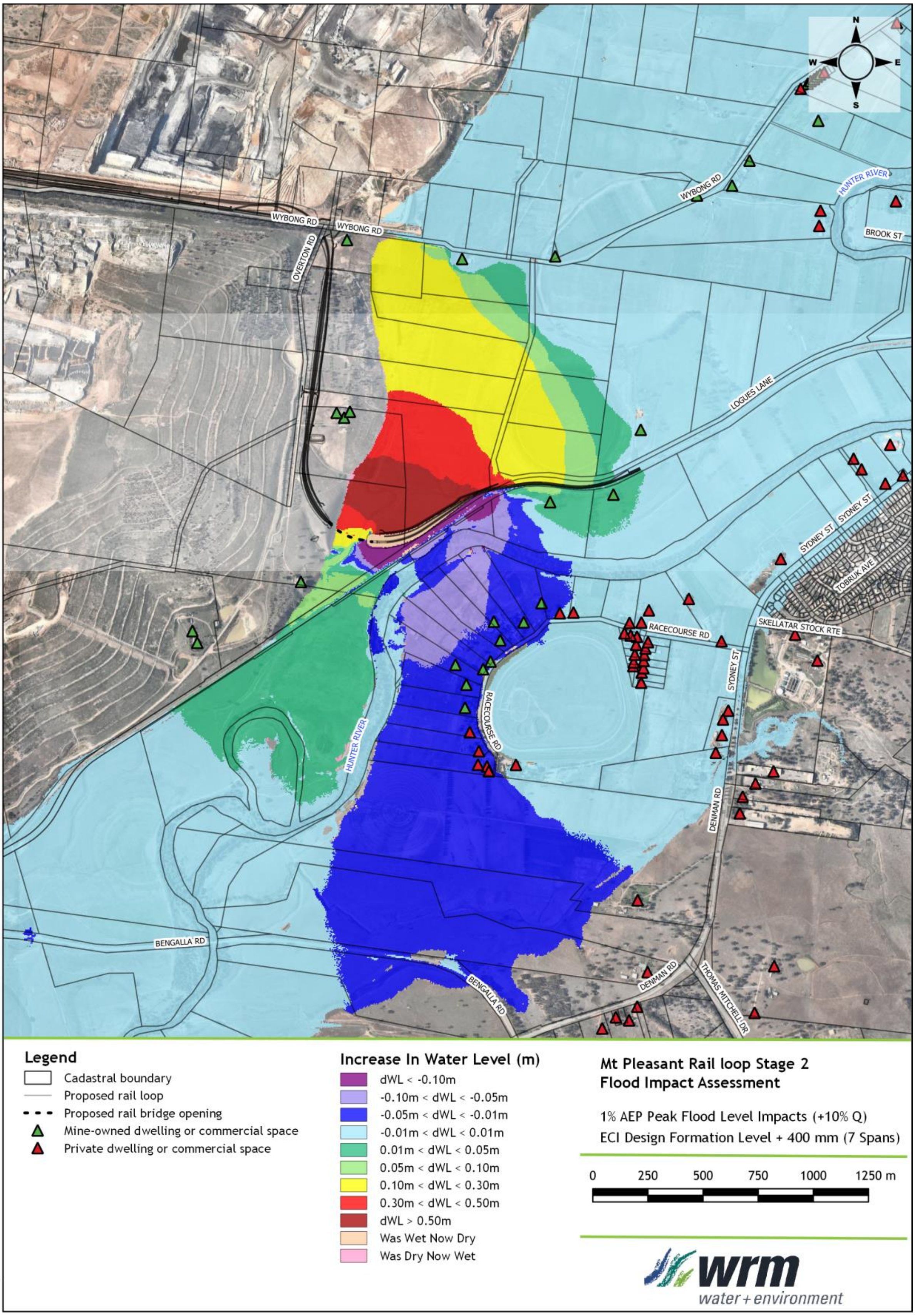


Figure 6-13 - Sensitivity case, 1% AEP flood level impacts, Flow + 10%

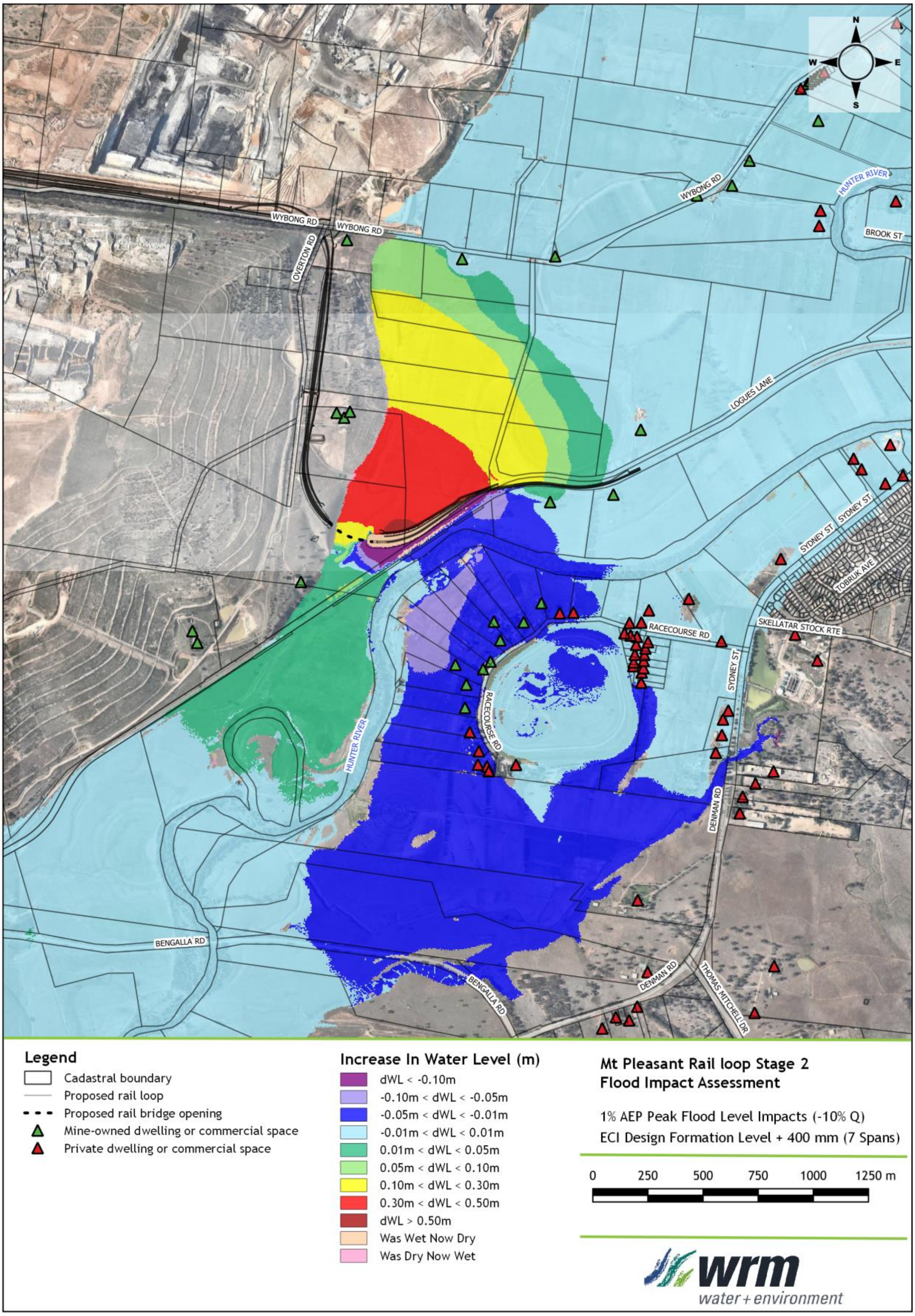


Figure 6-14 - Sensitivity case, 1% AEP flood level impacts, Flow - 10%

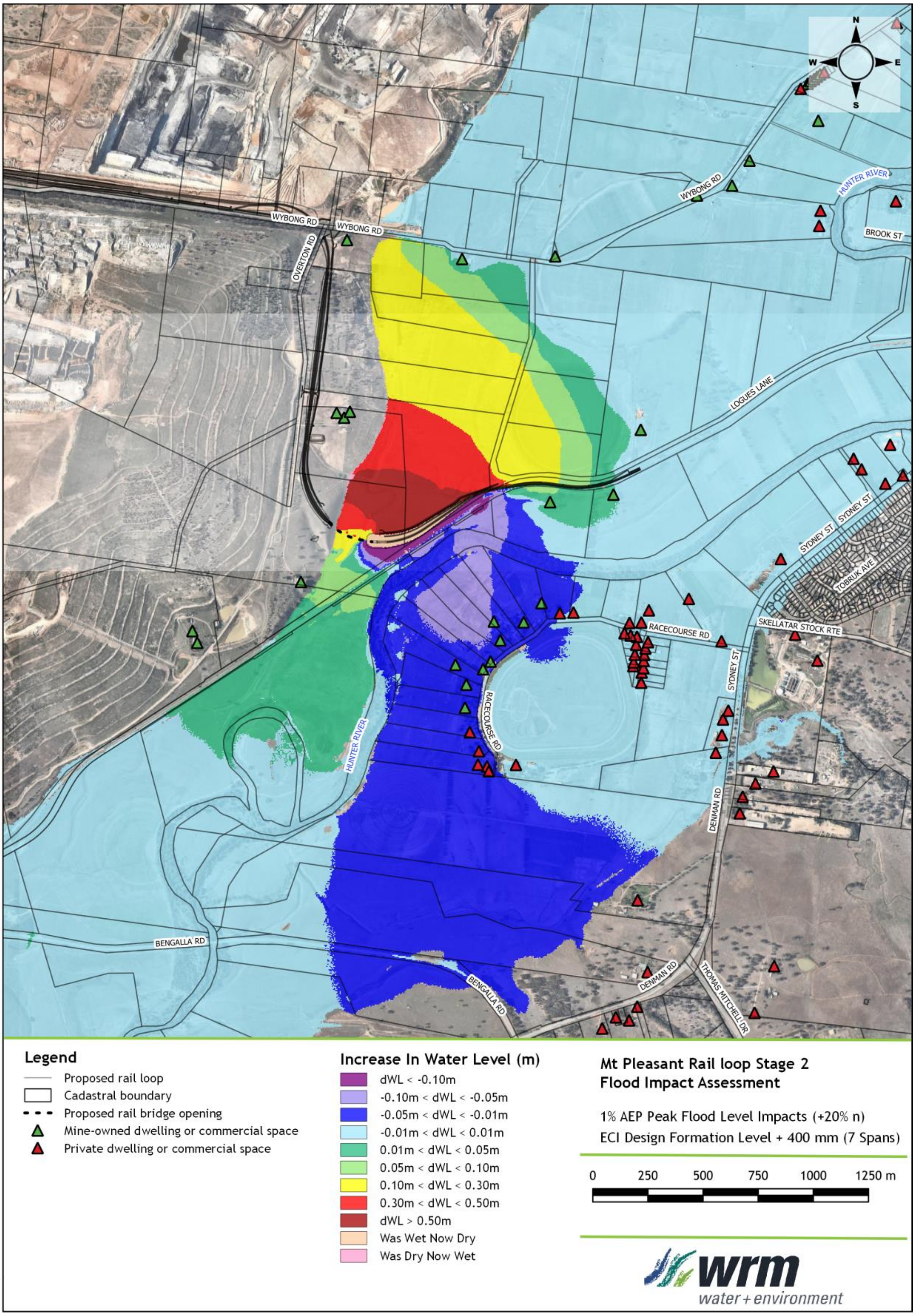


Figure 6-15 - Sensitivity case, 1% AEP flood level impacts, Manning's n + 20%

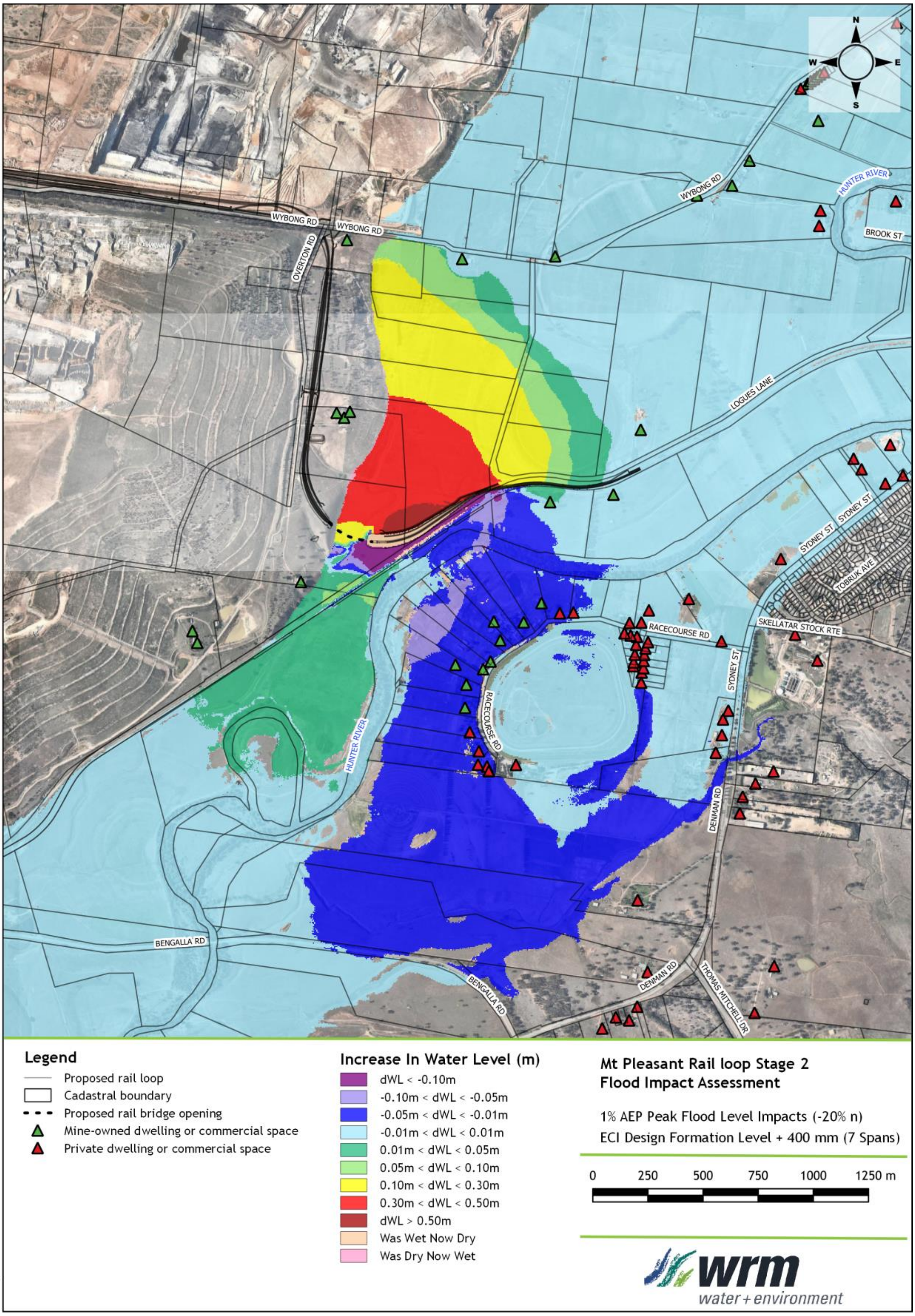


Figure 6-16 - Sensitivity case, 1% AEP flood level impacts, Manning's n - 20%

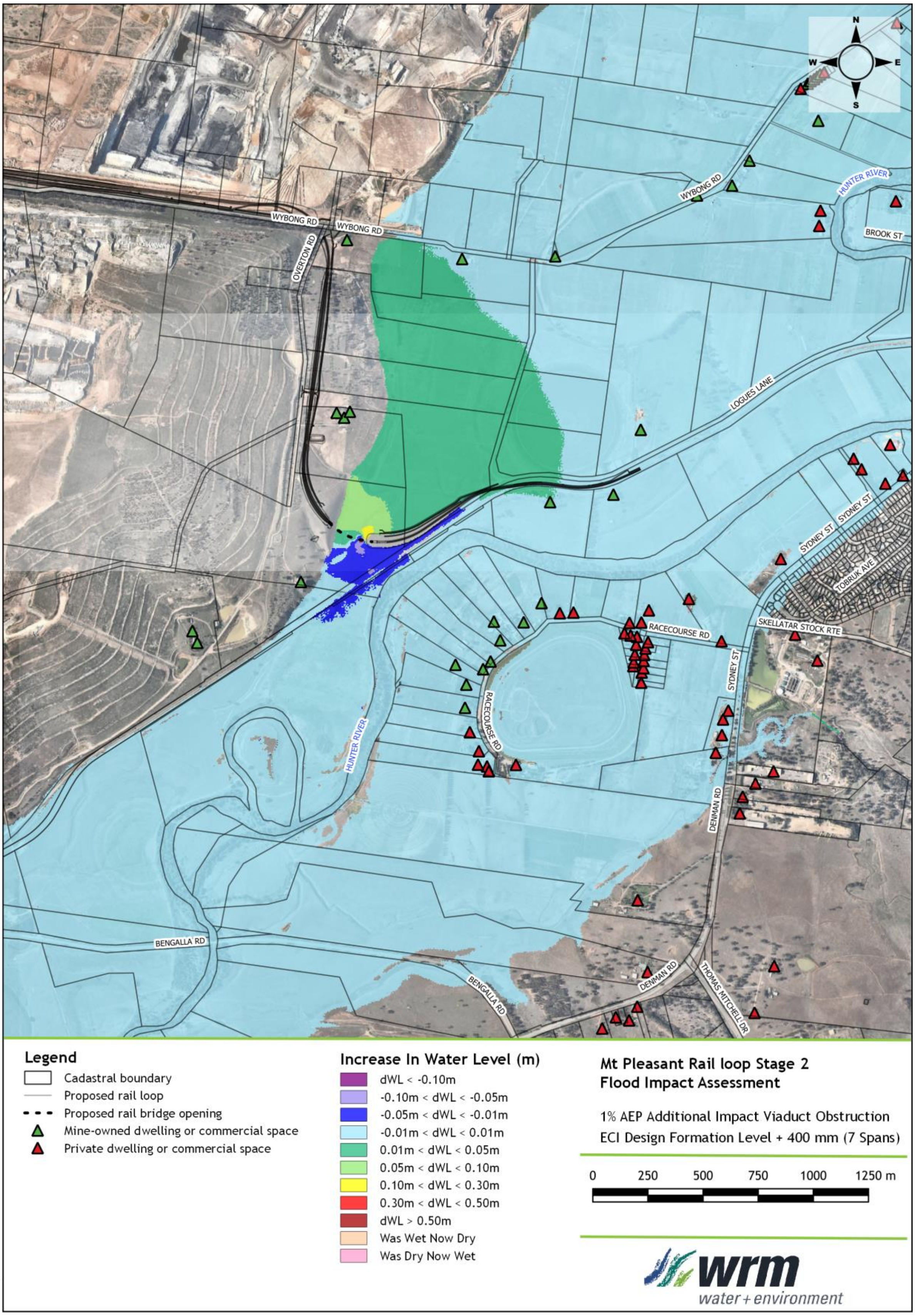


Figure 6-17 - Sensitivity case, 1% AEP, additional flood level impacts due to blockage

7 Summary of findings

Detailed hydrologic and hydraulic modelling of the Hunter River floodplain in the area of interest was undertaken to assess the impacts of the approved rail spur on flood levels and velocities. The models were validated against the August 1998 and November 2000 historical events. These are the largest flood events in the last 24 years.

The model results show that:

- There are no predicted increases in peak flood levels greater than 0.01 m at privately owned land, including private lots south of the Hunter River, for all modelled events. This satisfies the MOD4 design criteria.
- There are no increases in peak flood levels greater than 0.01 m along the centrelines of existing roads that service private properties including Wybong Road, for all modelled events, which satisfies the MOD4 design criteria. The impacts on peak flood levels along Wybong Road are described in more detail in Section 6.5.
- There are predicted increases in peak flood levels exceeding 0.01 m along a section of Logues Lane for the 5%, 2% and 1% AEP events. However, all properties along Logues Lane are mine-owned and the road does not currently service any private properties. On this basis, the MOD4 criteria is achieved.
- There are no predicted increases in peak velocities greater than 0.1 m/s at privately owned land, including private lots south of the Hunter River, for all modelled events. Predicted increases in velocities are highest beneath the proposed viaduct due to the constriction formed by the viaduct and rail spur embankment. However, these impacts do not propagate to privately owned properties in the area.
- The maximum predicted flood level impact along the centreline of Wybong Road is 0.004 m, which is less than the MOD4 design criteria of 0.01 m.
- The hazard mapping results show that the western portion of Wybong Road is affected by the H5 hazard category for both existing and developed conditions. Hence, the rail spur will not increase the 1% AEP flood hazard along Wybong Road, which would be untrafficable under existing and developed conditions.
- Sensitivity testing was undertaken of the modelled rail spur impacts to flow rate and roughness (Manning's n) as well as blockage beneath the viaduct for the 1% AEP event. The sensitivity cases do not show substantially different impacts to the developed case, which provides confidence that the actual impacts are likely to be similar to the modelled impacts.

8 References

Ball et al., 2016	*'Australian Rainfall and Runoff – A Guide to Flood Estimation'*, Ball J, Babister M, Nathan R, Weeks W, Weinmann E, Retallick M, Testoni I, (Editors), © Commonwealth of Australia (Geoscience Australia), 2016.
BMT WBM, 2016	*'TUFLOW User Manual Build 2016-03-AA'*, BMT WBM Pty Ltd, 2016.
Geoscience Australia, 2016	*ARR Data Hub, http://data.arr-software.org/*
Pilgrim, 1987	*'Australian Rainfall and Runoff – A Guide to Flood Estimation'*, Pilgrim DH (Editor), Institution of Engineers, Australia, Barton, Australian Capital Territory, 1987.
WorleyParsons, 2014	*'Hunter River Flood Study (Muswellbrook To Denman)'*, Report prepared for Muswellbrook Shire Council by WorleyParsons Services Pty Ltd, 8 September 2014. *'XP-RAFTS User Manual'*, XP Software, Australia, 2013.
WRM, 2017	*'Mount Pleasant Operation, Rail Modification Flood Assessment'*, Report ref. 0744-09-B3 prepared by WRM Water & Environment Pty Ltd for Mach Energy Australia Pty Ltd, 19 December 2017.
XP Software, 2013	*'XP-RAFTS User Manual'*, XP Software, Australia, 2013.

Appendix A Flood mapping

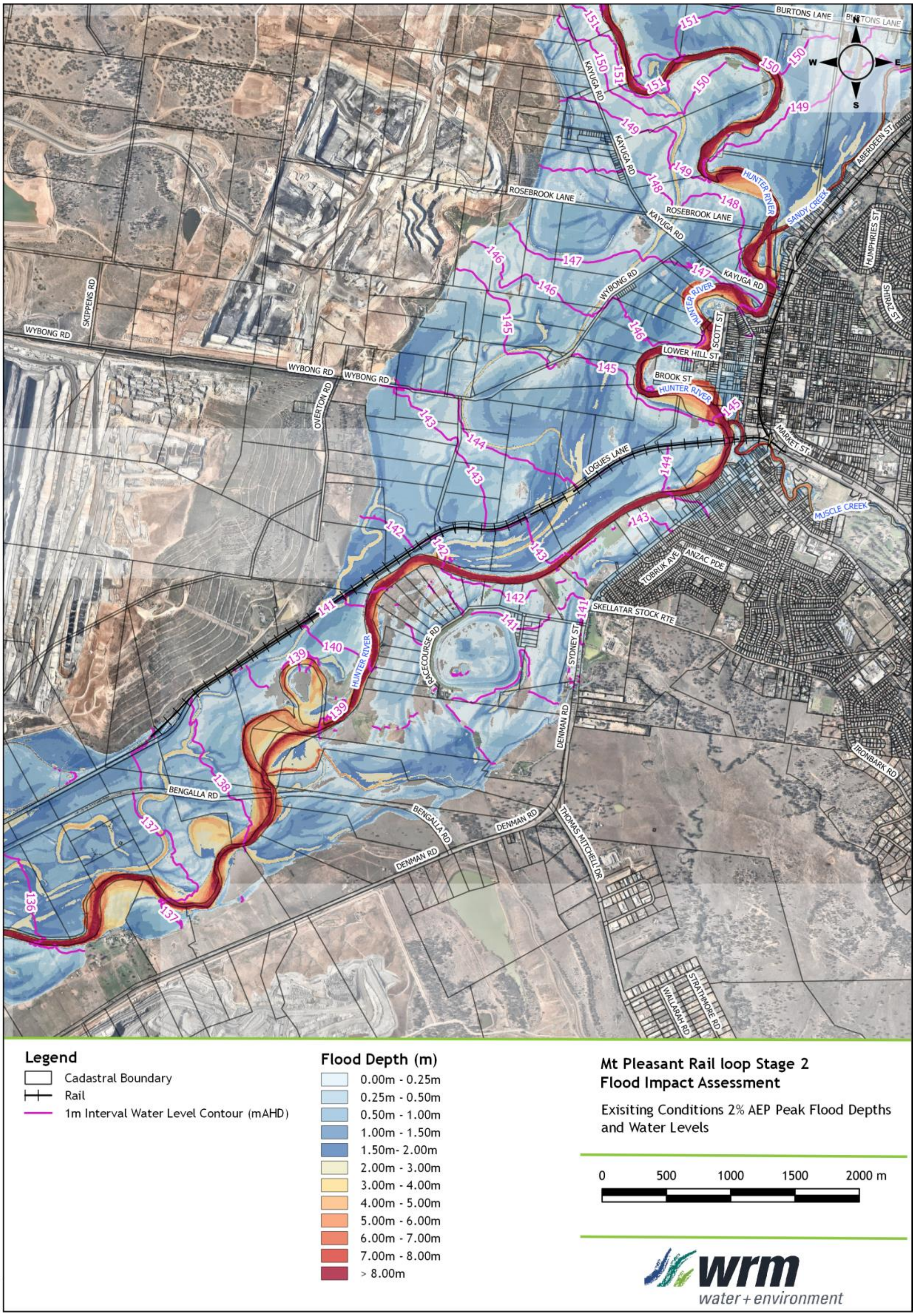


Figure A.1 - Existing conditions 2% AEP flood level and depth

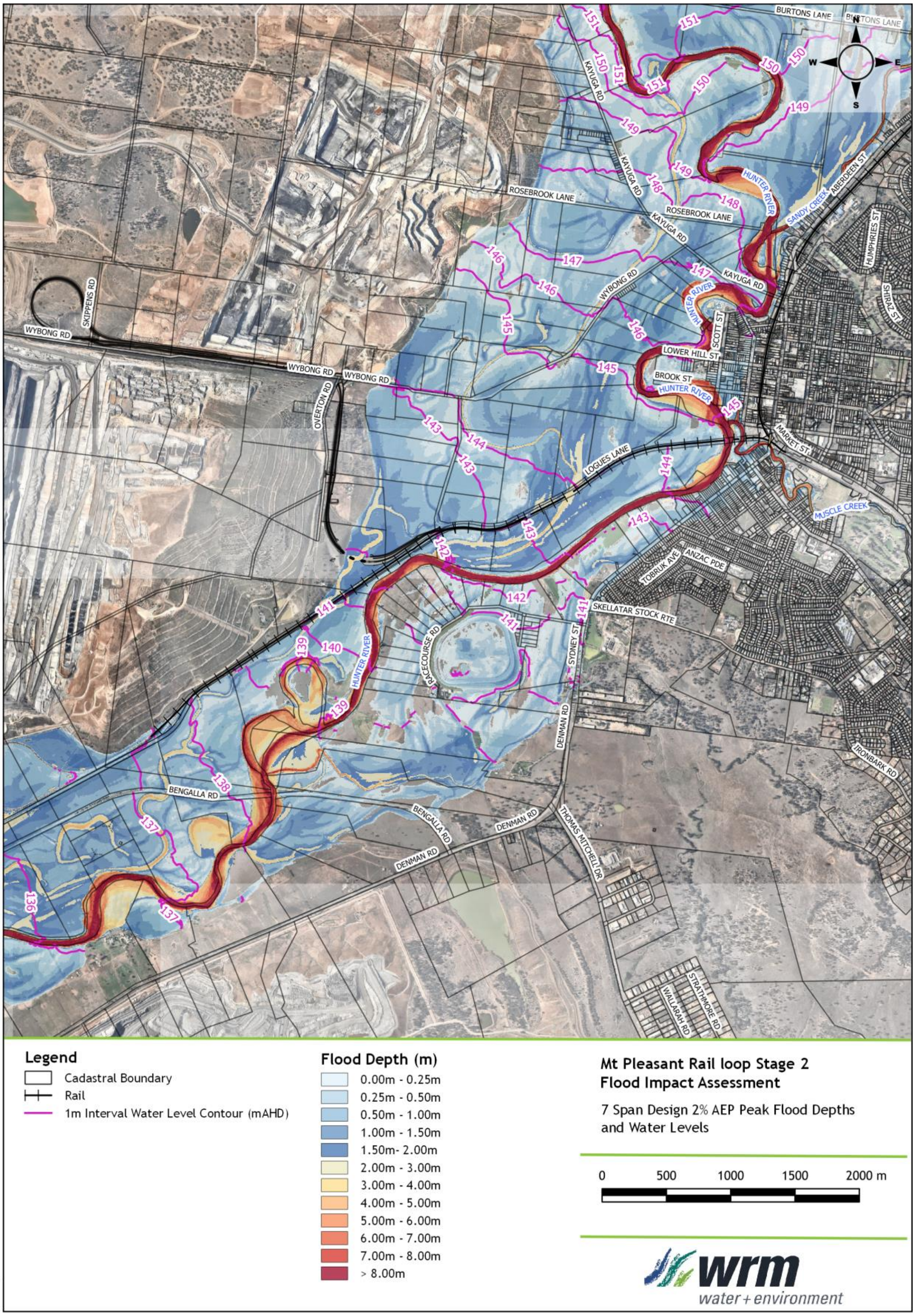


Figure A.2 - Developed conditions 2% AEP flood level and depth

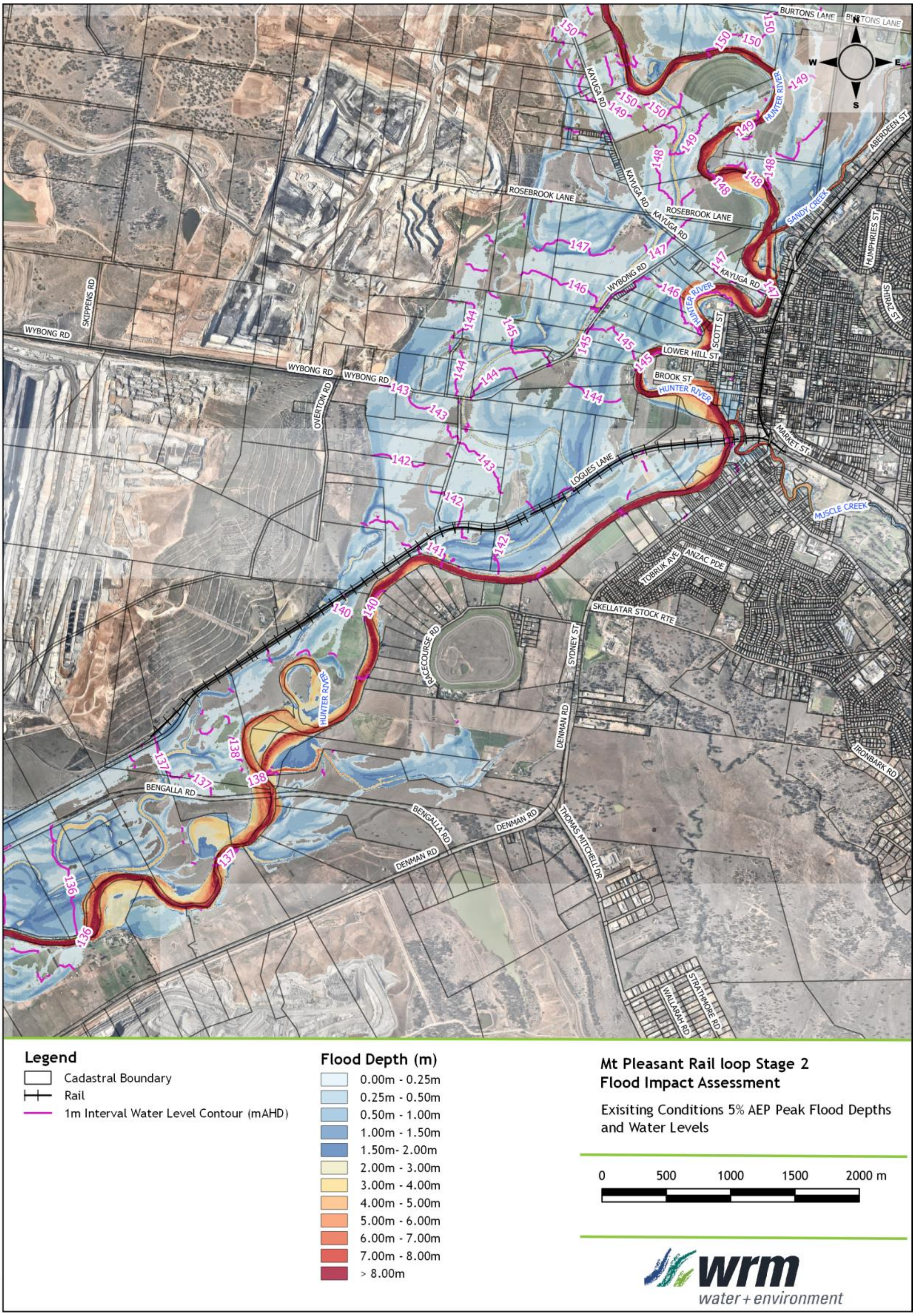


Figure A.3 - Existing conditions 5% AEP flood level and depth

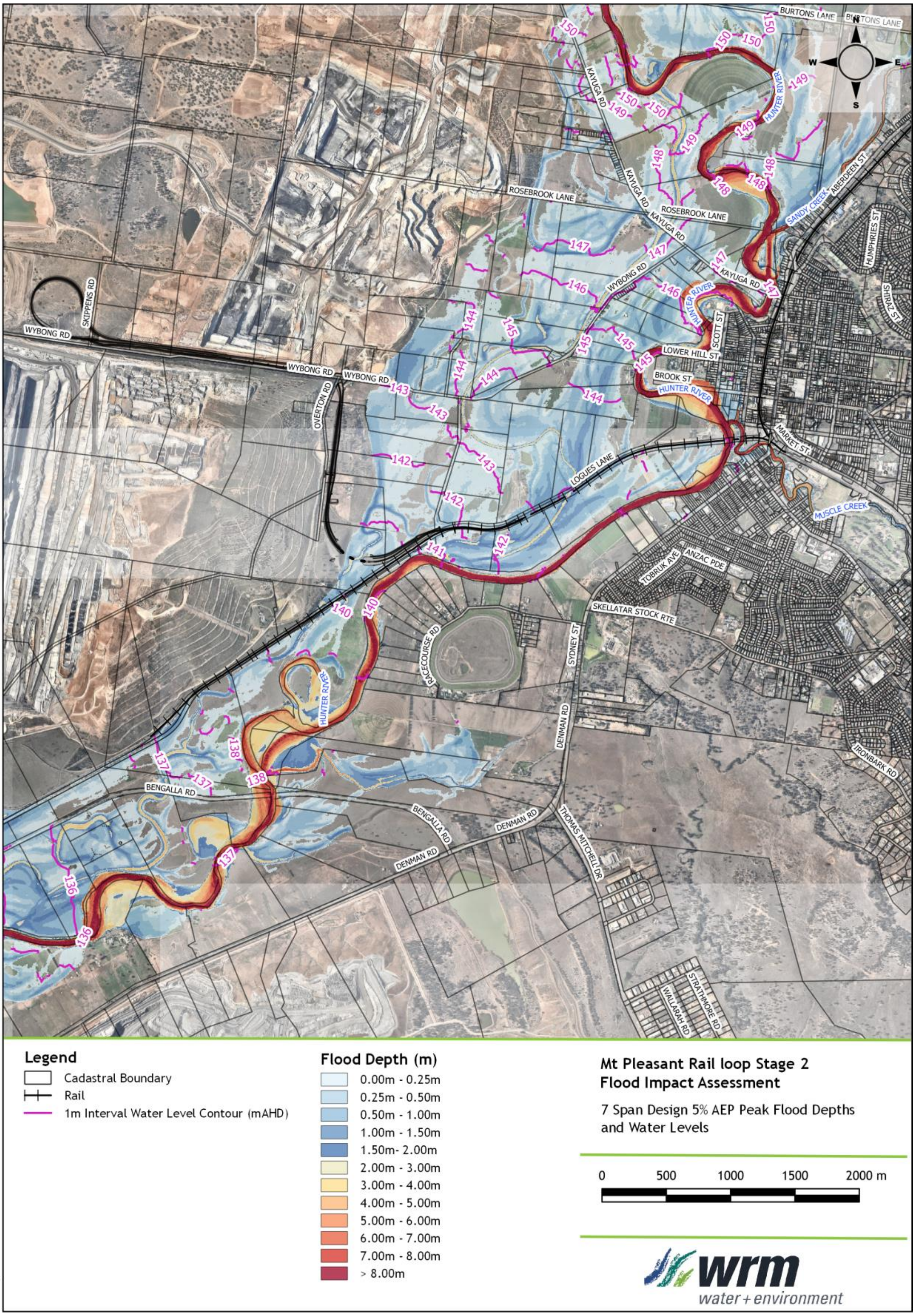


Figure A.4 - Developed conditions 5% AEP flood level and depth

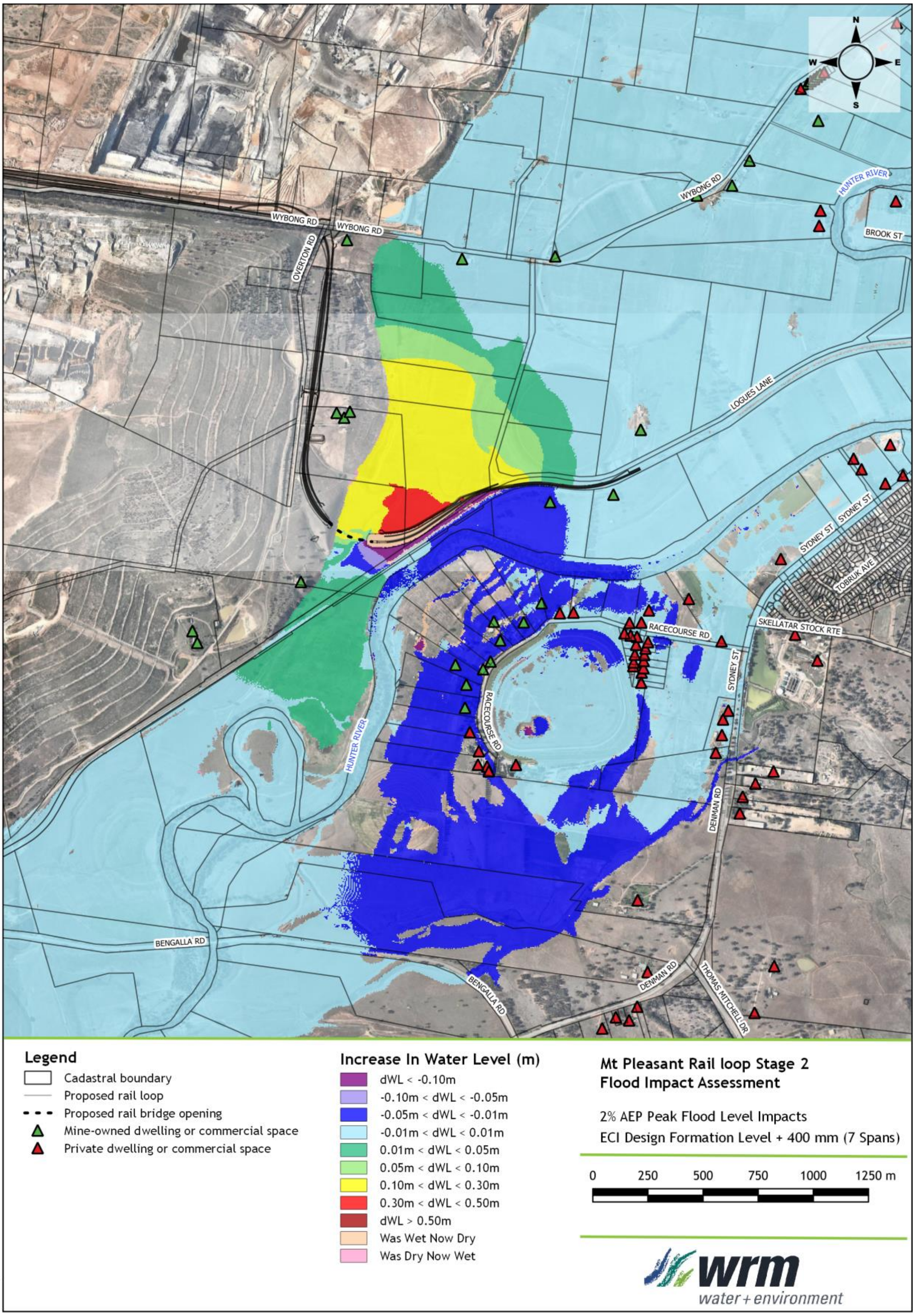


Figure A.5 -Flood level impacts of rail spur, 2% AEP

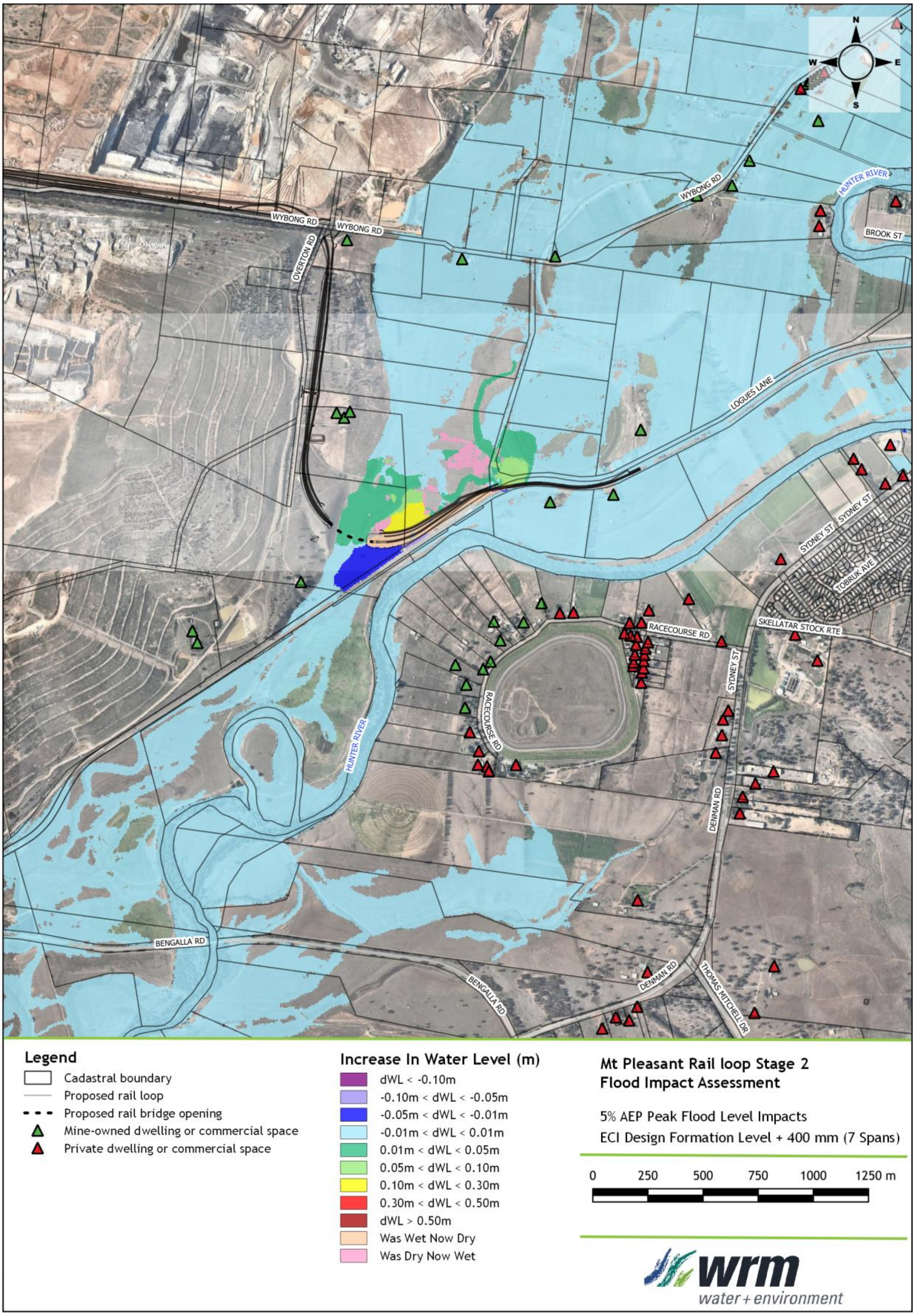
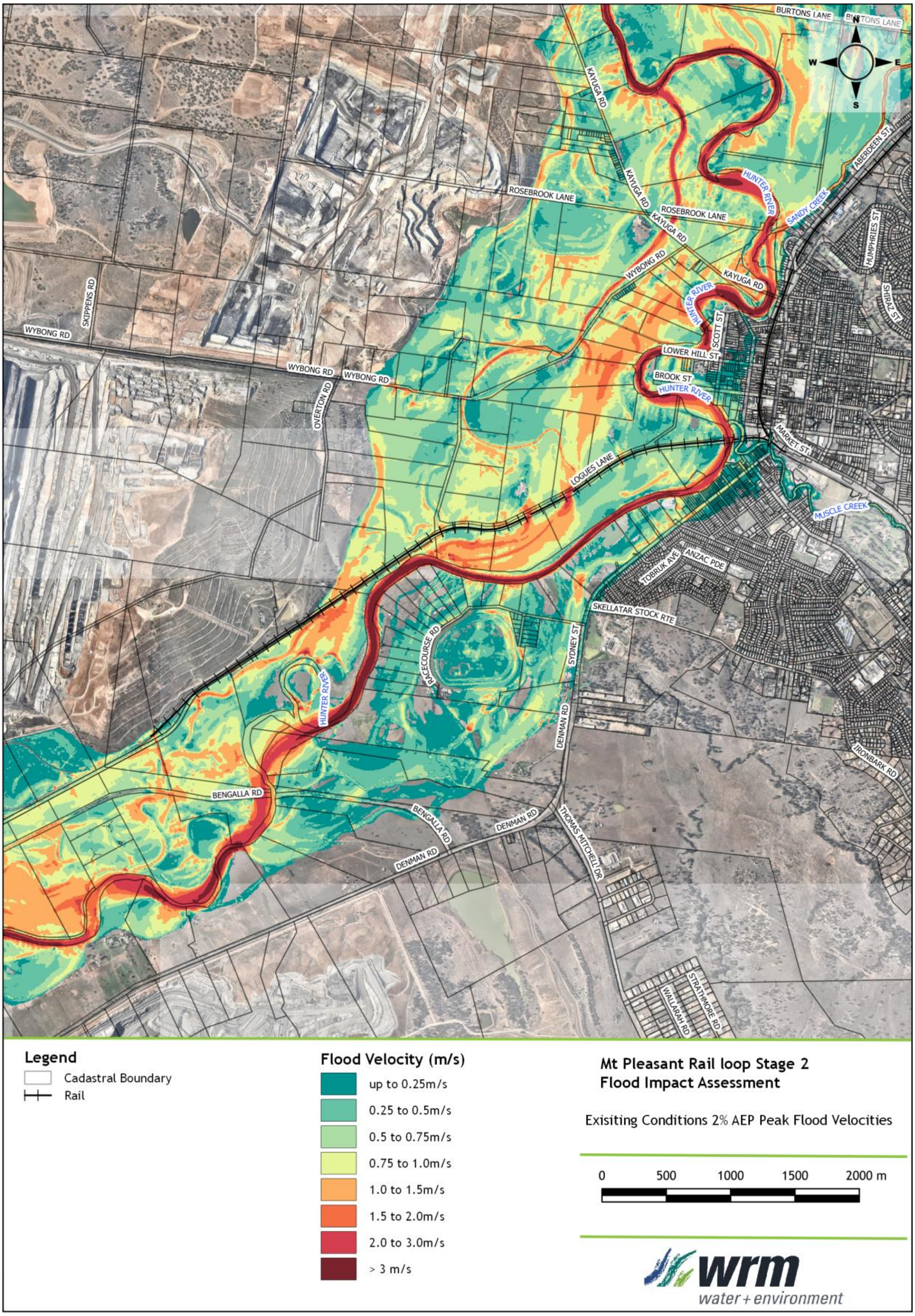


Figure A.6 -Flood level impacts of rail spur, 5% AEP



Projection: MGA Zone 56 Datum: GDA 2020

Figure A.7 - Existing conditions 2% AEP flood velocity

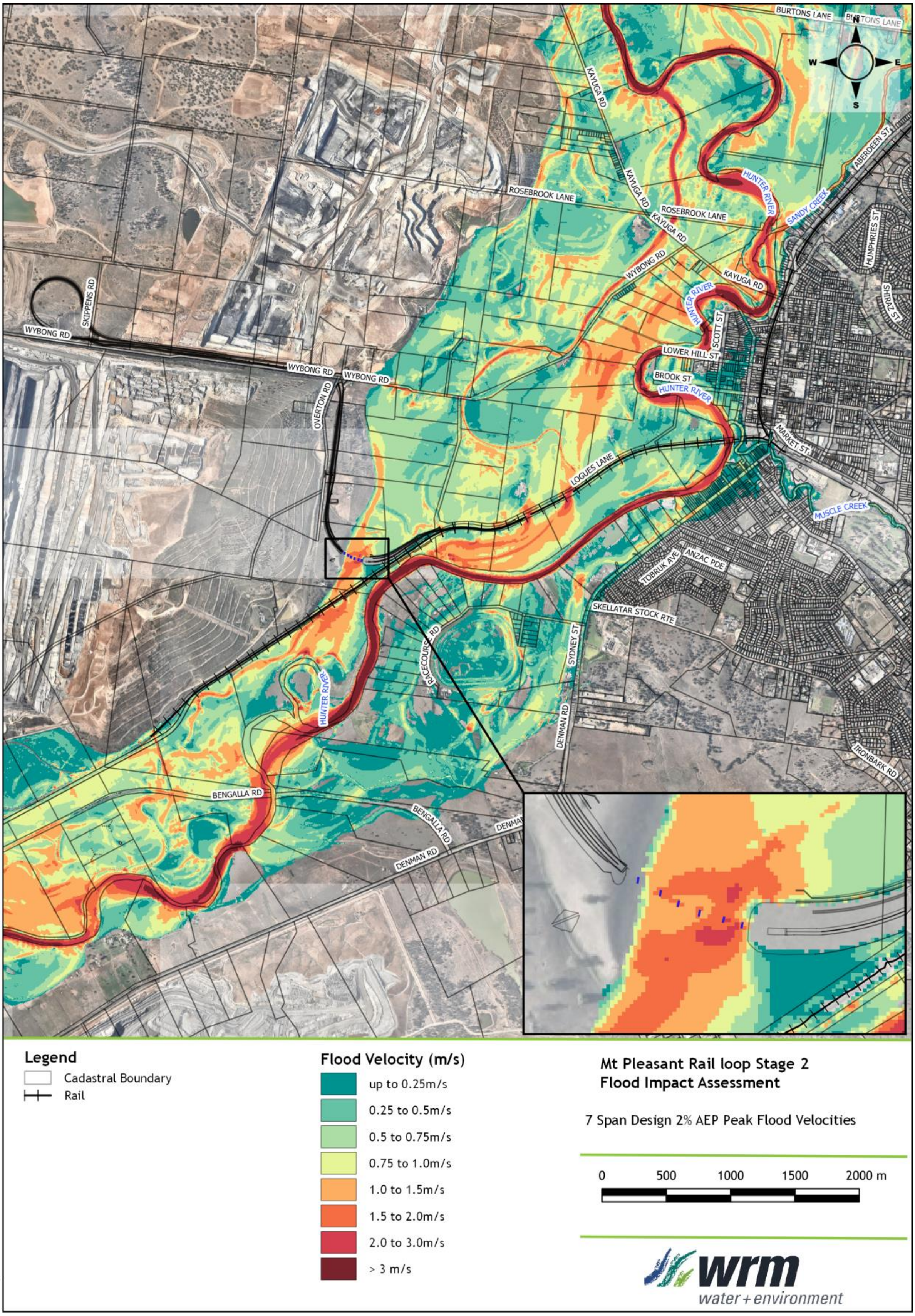


Figure A.8 - Developed conditions 2% AEP flood velocity impact

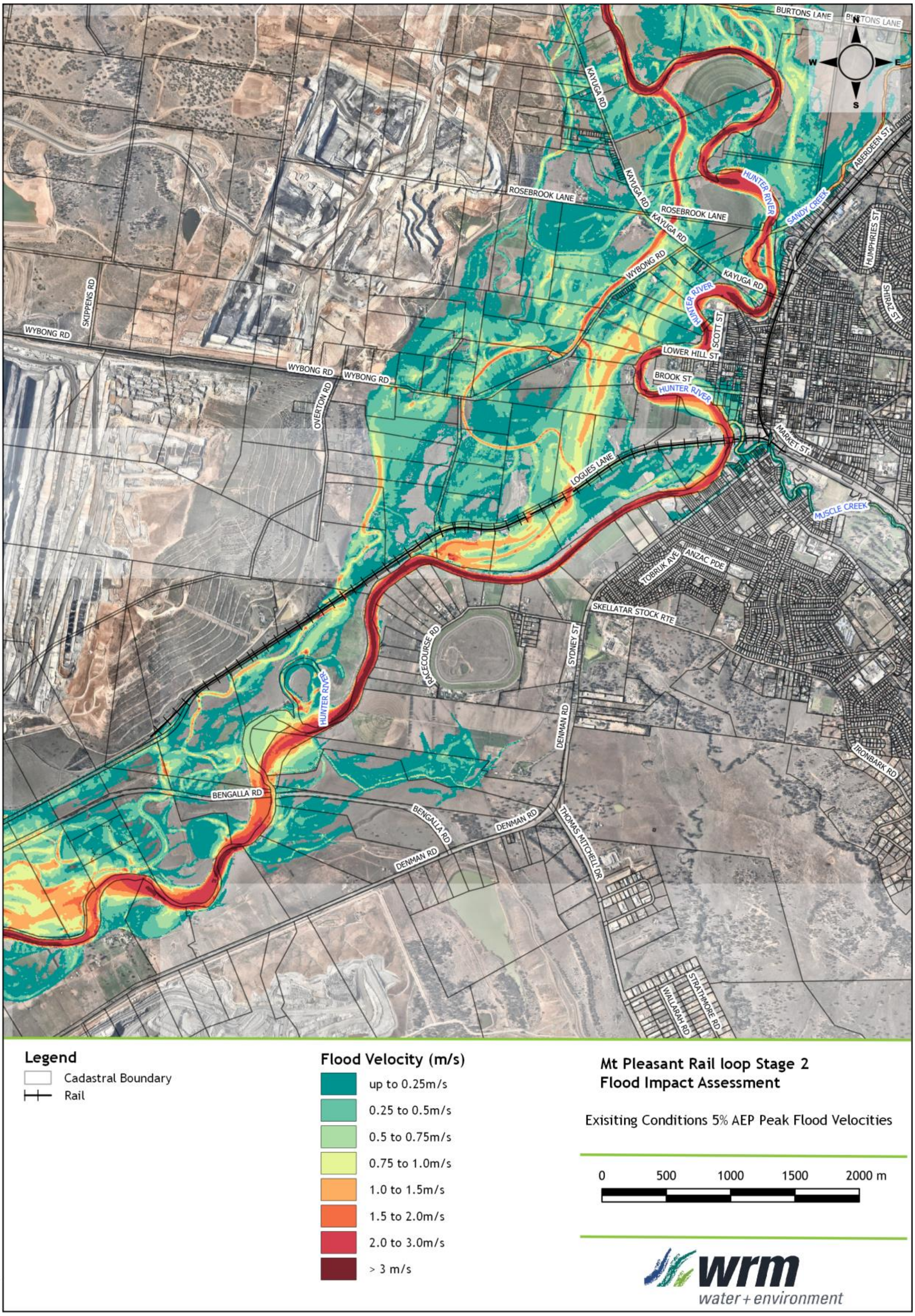


Figure A.9 - Existing conditions 5% AEP flood velocity

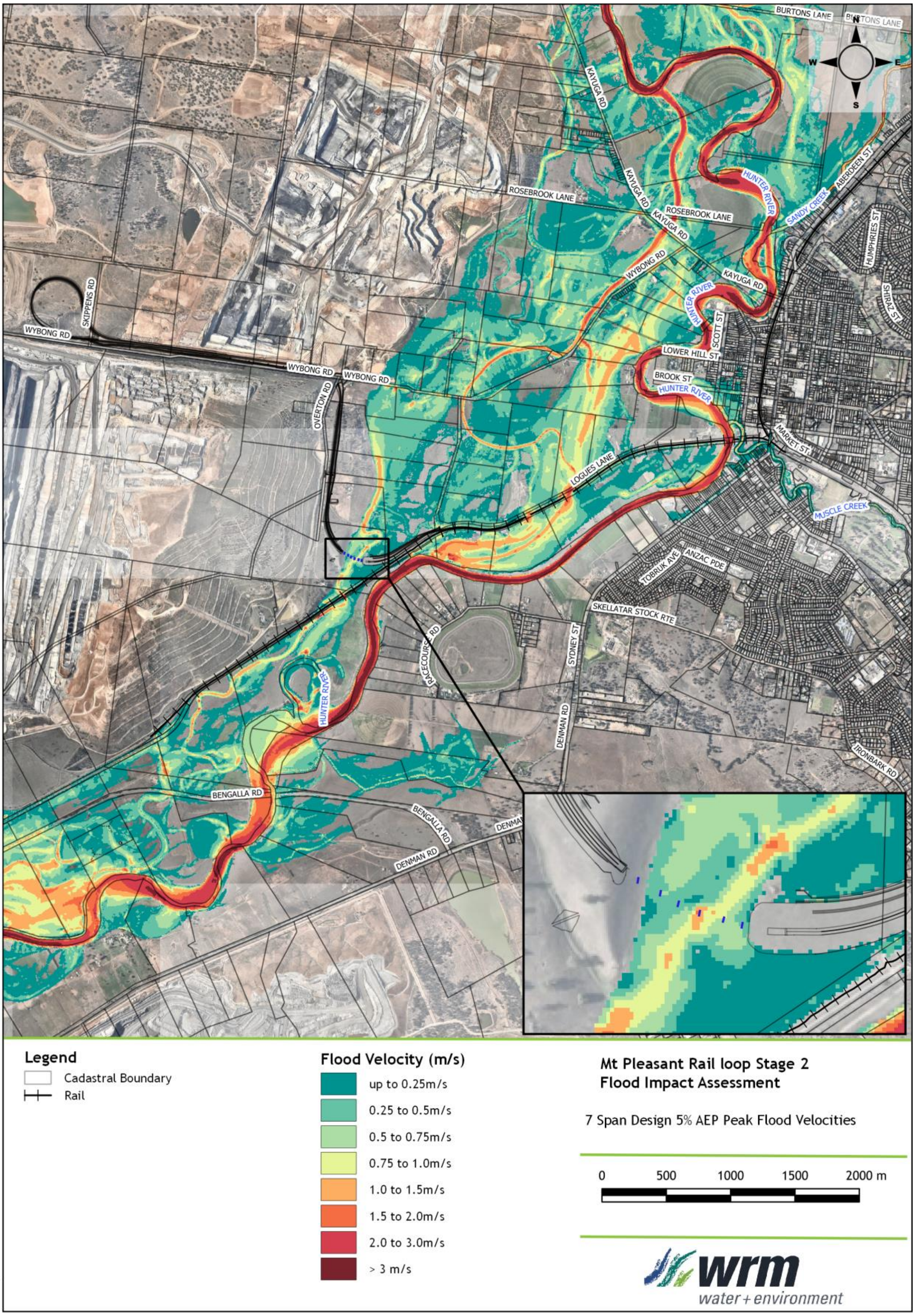


Figure A.10 - Developed conditions 5% AEP flood velocity impact

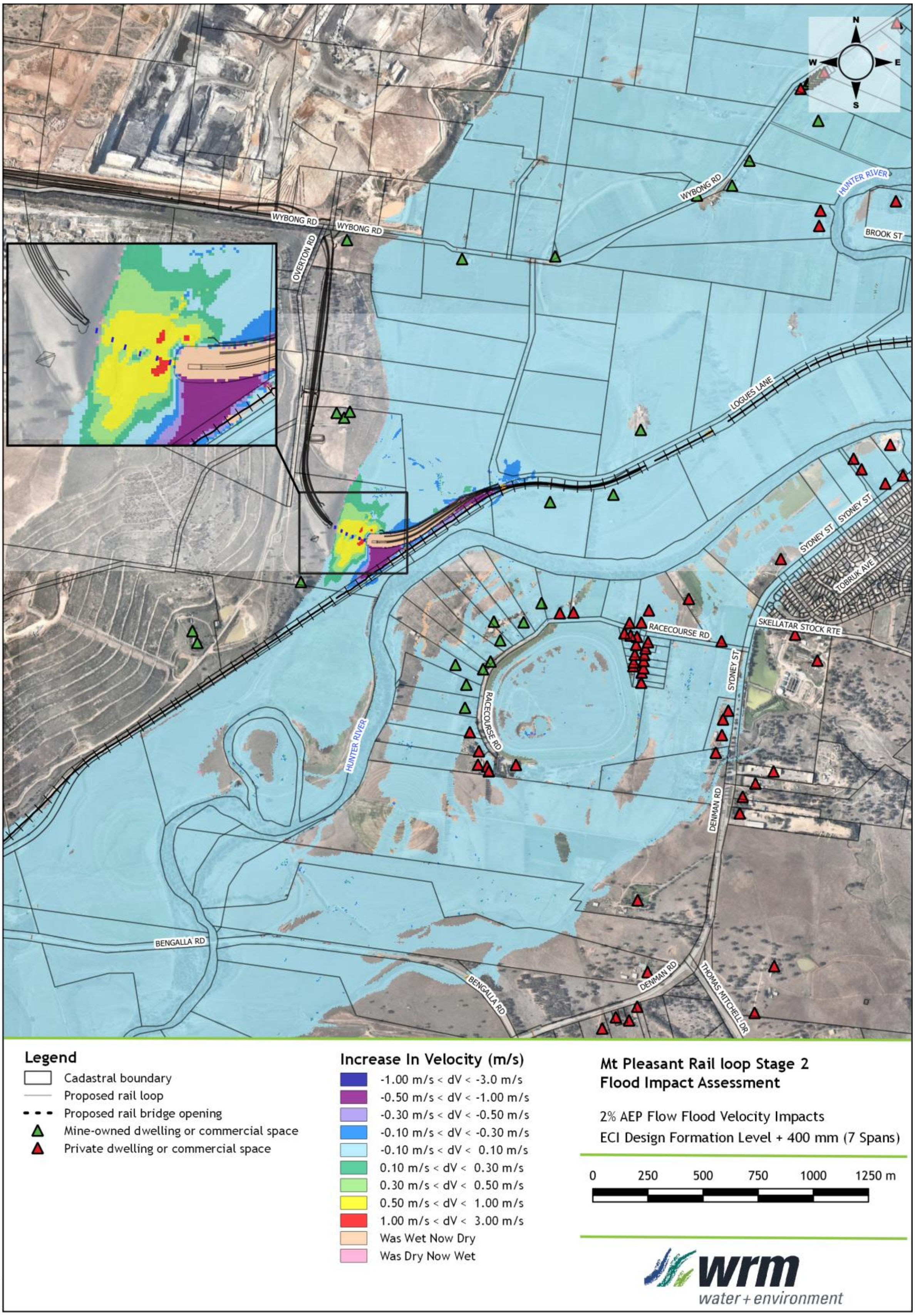


Figure A.11 -Flood velocity impacts of rail spur, 2% AEP

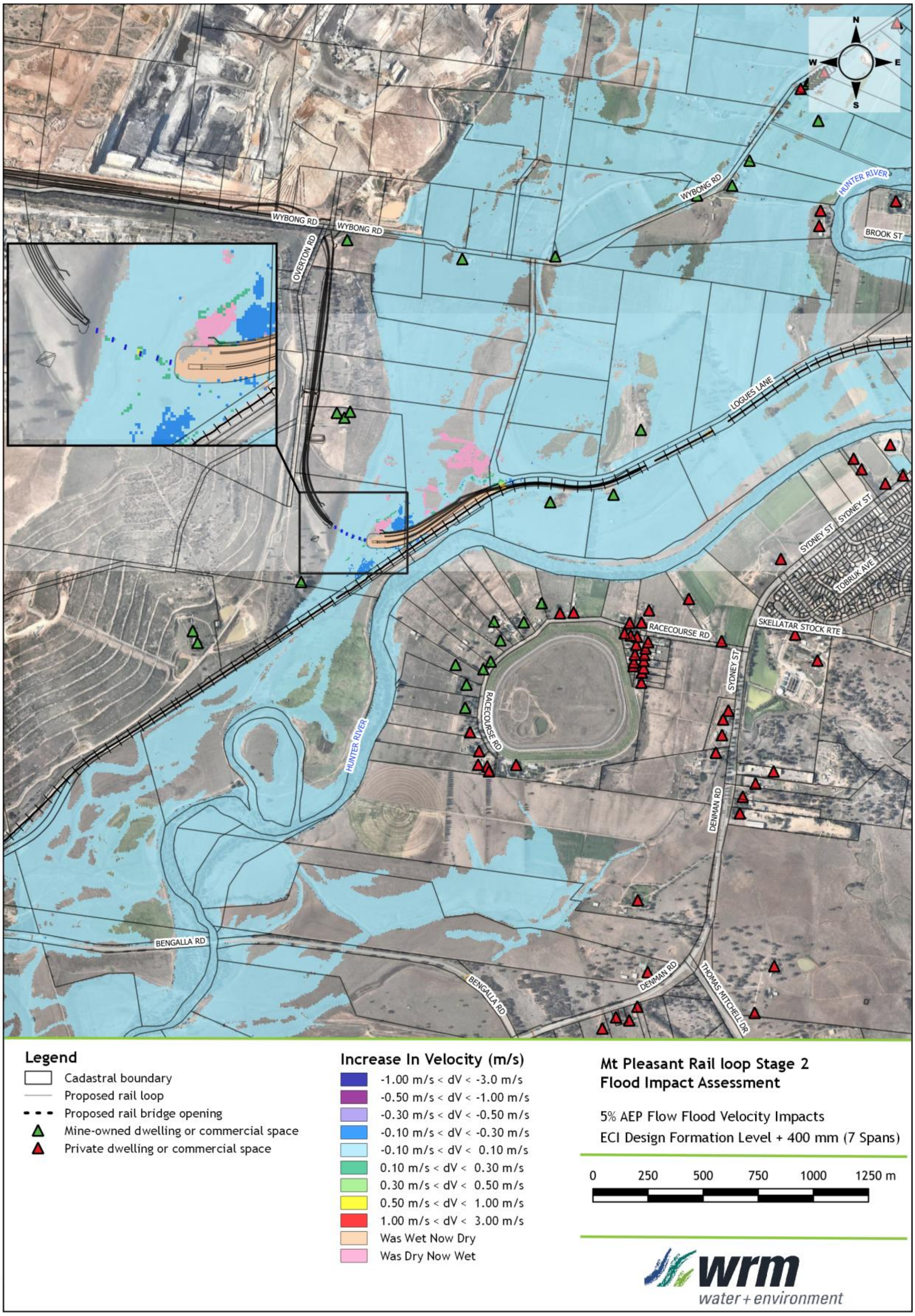


Figure A.12 -Flood velocity impacts of rail spur, 5% AEP

Mount Pleasant Operation

Addendum 1 to the Rail Modification Flood Impact Assessment (MOD 4)

Addendum No.1

Date	26 June 2020	Pages	9
Job No.	0744-11-Q2		
Subject	Mt Pleasant Rail Loop Stage 2 - Logues Lane Flood Depth		

Introduction

MACH has consulted with OEH (DPIE). Through the consultation process, OEH (DPIE) has requested information on the flood impact on Logues Lane resulting from the developed condition.

OEH (DPIE) has requested that the flood event that results in Logues Lane being inundated by 200 mm be identified. This is to apply to both the existing and developed conditions. Information on the impact of the 7-span viaduct and rail spur on Logues Lane is included in this addendum.

We have undertaken an assessment of flood depths along Logues Lane, which is located on the northern side of the approved Mount Pleasant Rail Loop.

The assessment has been undertaken using the TUFLOW hydraulic model developed for the *Mount Pleasant Rail Loop Stage 2 Rail Modification Flood Impact Assessment* (WRM, 2020). Full details of the model are documented in the WRM (2020) report.

Flood depths along Logues Lane have been assessed for existing conditions, and developed conditions with the rail spur in place. Results are presented for the 20% annual exceedance probability (AEP) event and the 10% AEP event, which are smaller events than documented in the flood impact assessment report (WRM, 2020) which considered events of 5% AEP and larger.

Estimation of discharges for the 20% and 10% AEP events

The flood impact assessment (WRM, 2020) used a RAFTS hydrologic model of the Hunter River catchment to estimate design discharges at Muswellbrook. The RAFTS model was calibrated to produce peak discharges consistent with the results of a flood frequency analysis (FFA) of recorded streamflow data at the Muswellbrook Bridge gauge (Station No. 210002).

For the assessment of the smaller flood events, the 5% AEP boundary inflows to the TUFLOW model were scaled down by the ratio of peak discharges at Muswellbrook from the FFA. This provides a simplified method of estimating TUFLOW boundary inflows for the smaller events which is expected to produce peak discharges that would be very close to values derived from a hydrologic model of the smaller flood events.

The peak discharges from the FFA are shown in Table 1. Table 2 shows the adopted scaling factors used to convert the 5% AEP hydraulic model inflows (from the RAFTS model) to the 10% and 20% AEP inflows.

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Table 1 - Flood frequency analysis results for Muswellbrook Bridge gauge

AEP	Design Discharge (m^3/s)
20%	666
10%	1132
5%	1,732
2%	2,754
1%	3,721

Table 2 - Hydraulic model inflow scaling for 20% and 10% AEP events

Design Event (AEP)	FFA (m^3/s)	RAFTS (m^3/s)	Scale Factor
20%	666	-	0.375
10%	1132	-	0.637
5%	1,732	1,776	-

Flood model results for Logues Lane (20% AEP and 10% AEP events)

The model results show that:

- Logues Lane is not predicted to be overtopped during a 20% (1 in 5) AEP event for existing or developed conditions. Logues Lane will not be inundated for this design event as there is no breakout from the Hunter River onto the floodplain (Figure 1 and Figure 2).
- For the 10% (1 in 10) AEP event, there are predicted peak flood depths of up to 0.435 m for both existing and developed conditions along the Logues Lane centreline, immediately to the north of the rail spur where Logues Lane starts heading east alongside the existing ARTC rail line (Figure 3 and Figure 4).
- For the 10% (1 in 10) AEP event, there are predicted increases in peak flood levels of up to 0.015 m for developed conditions along the Logues Lane centreline immediately to the north of the rail spur where Logues Lane starts heading east alongside the existing ARTC rail line (Figure 5 and Figure 6).
- The (maximum) increase of 0.015m is near chainage 1100 m where the flood depth under existing conditions is about 0.10 m. The developed conditions have no impact on the peak flood level across Logues Lane at chainage 1050 m where there is a precited peak flood depth of 0.435 m. This would make Logues Lane un-trafficable for both the existing and developed conditions for the 10% AEP event.
- The design event that will result in an inundation of at least 0.20 m will be between the 10% AEP and 20% AEP events.

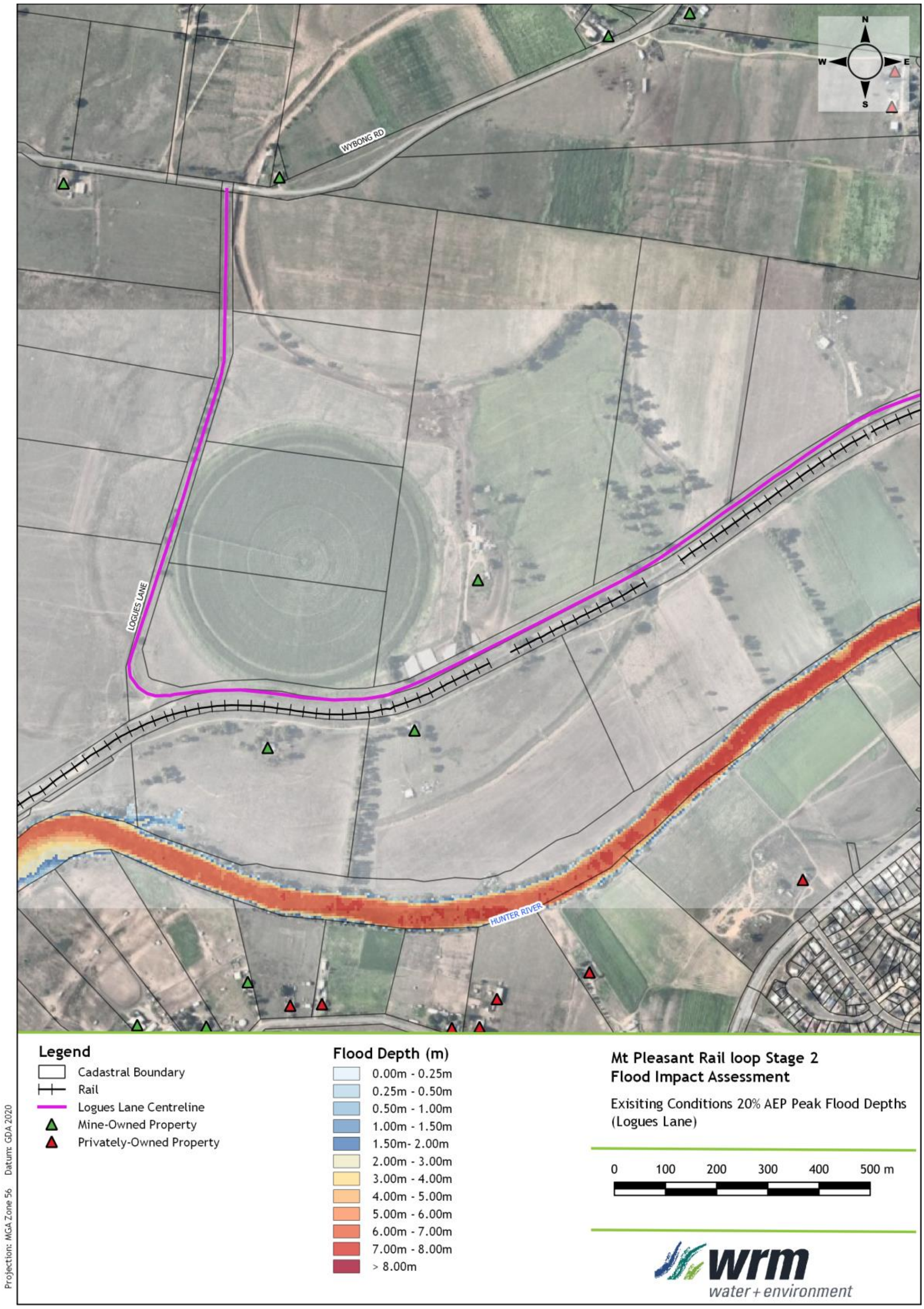


Figure 1 - Existing conditions 20% AEP peak flood depth

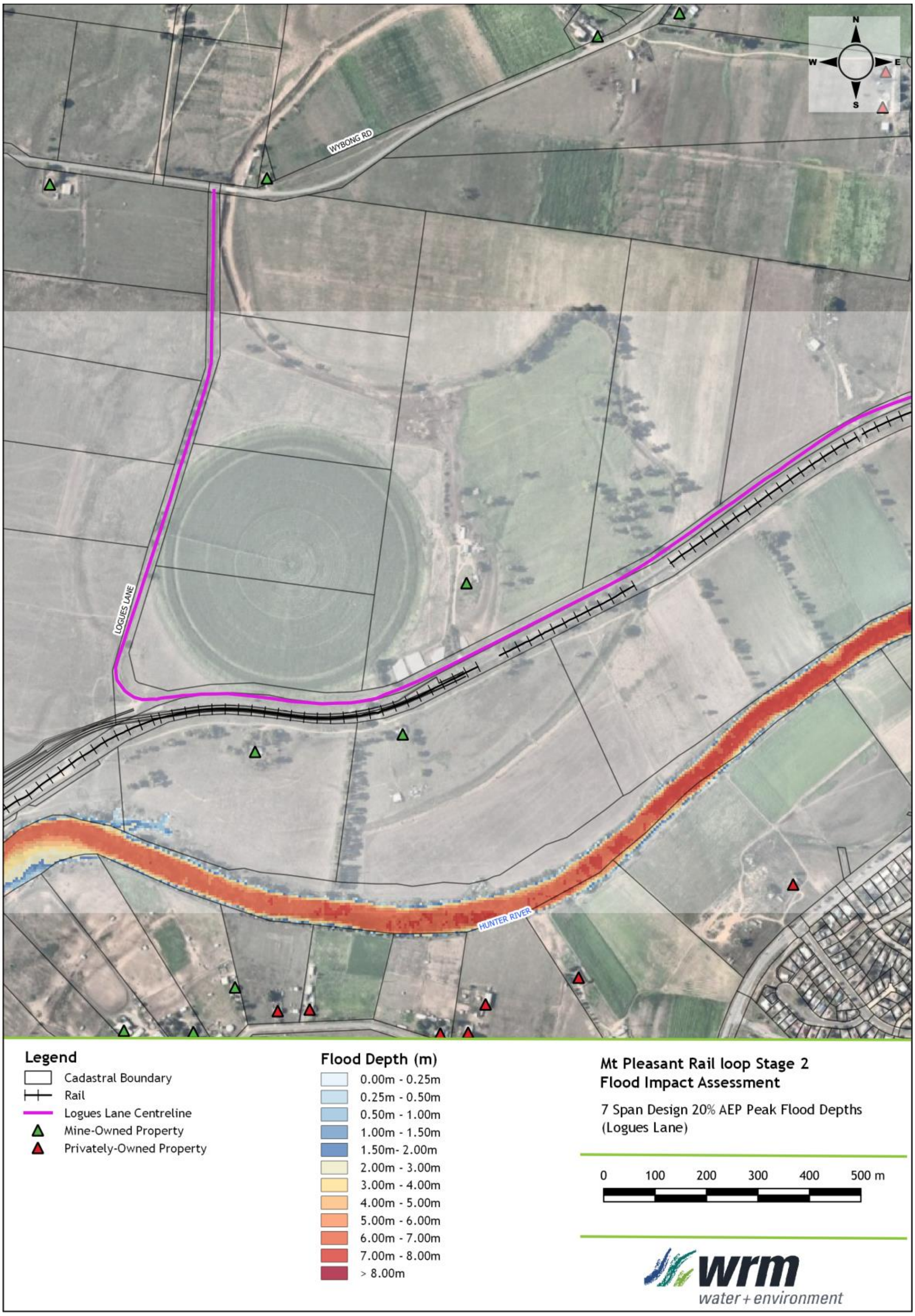


Figure 2 - Developed conditions 20% AEP peak flood depth

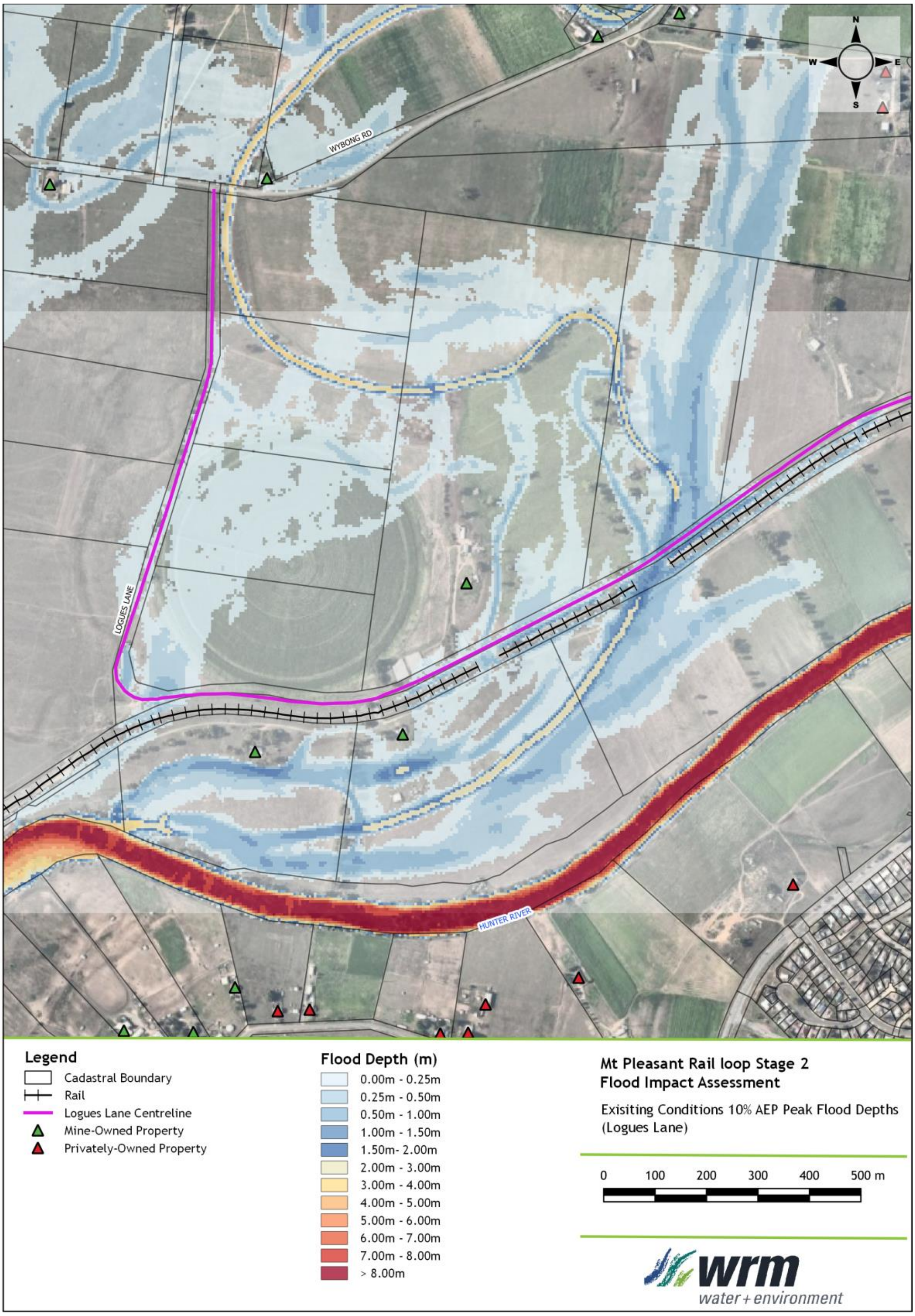


Figure 3 - Existing conditions 10% AEP peak flood depth

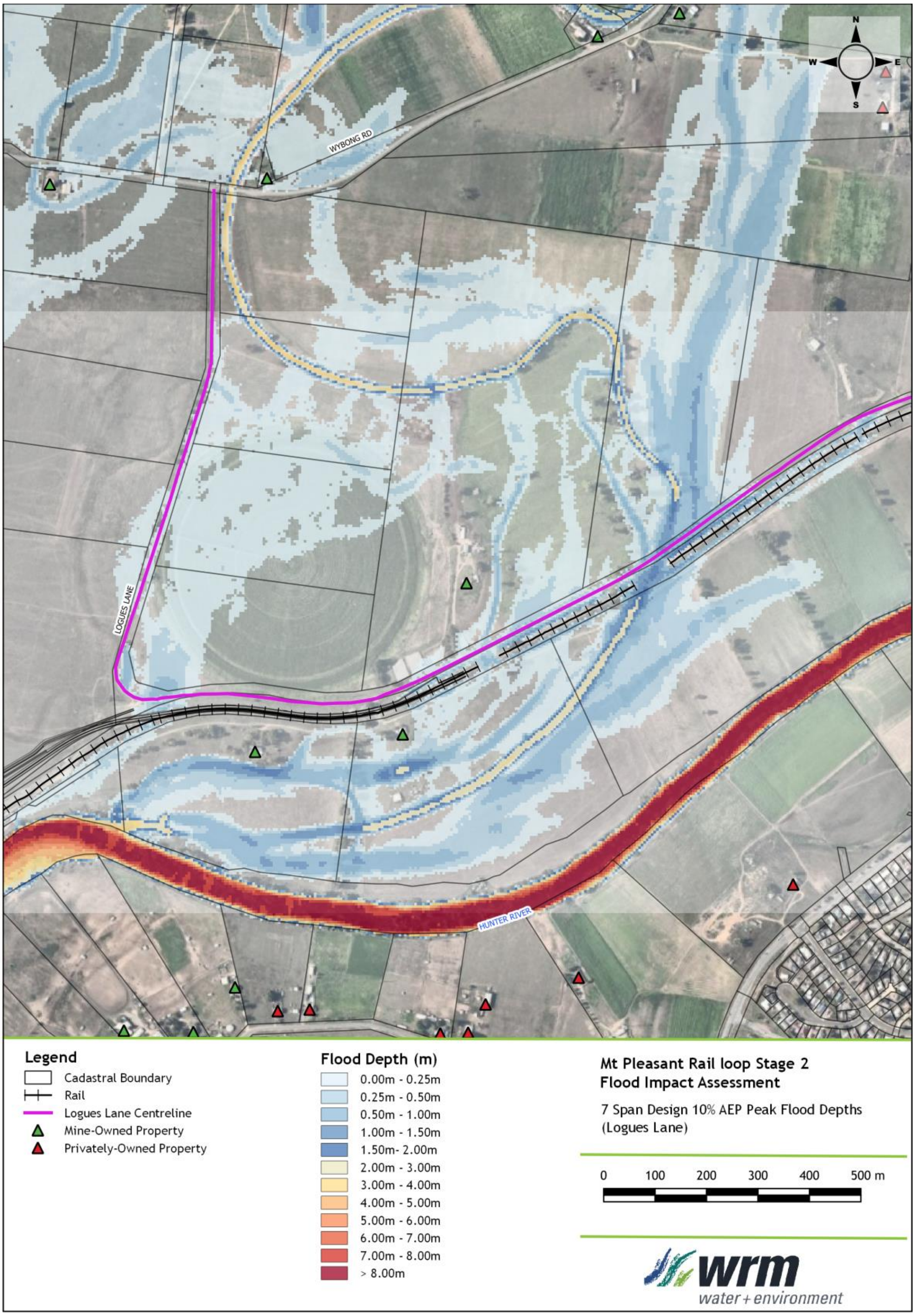


Figure 4 - Developed conditions 10% AEP peak flood depth

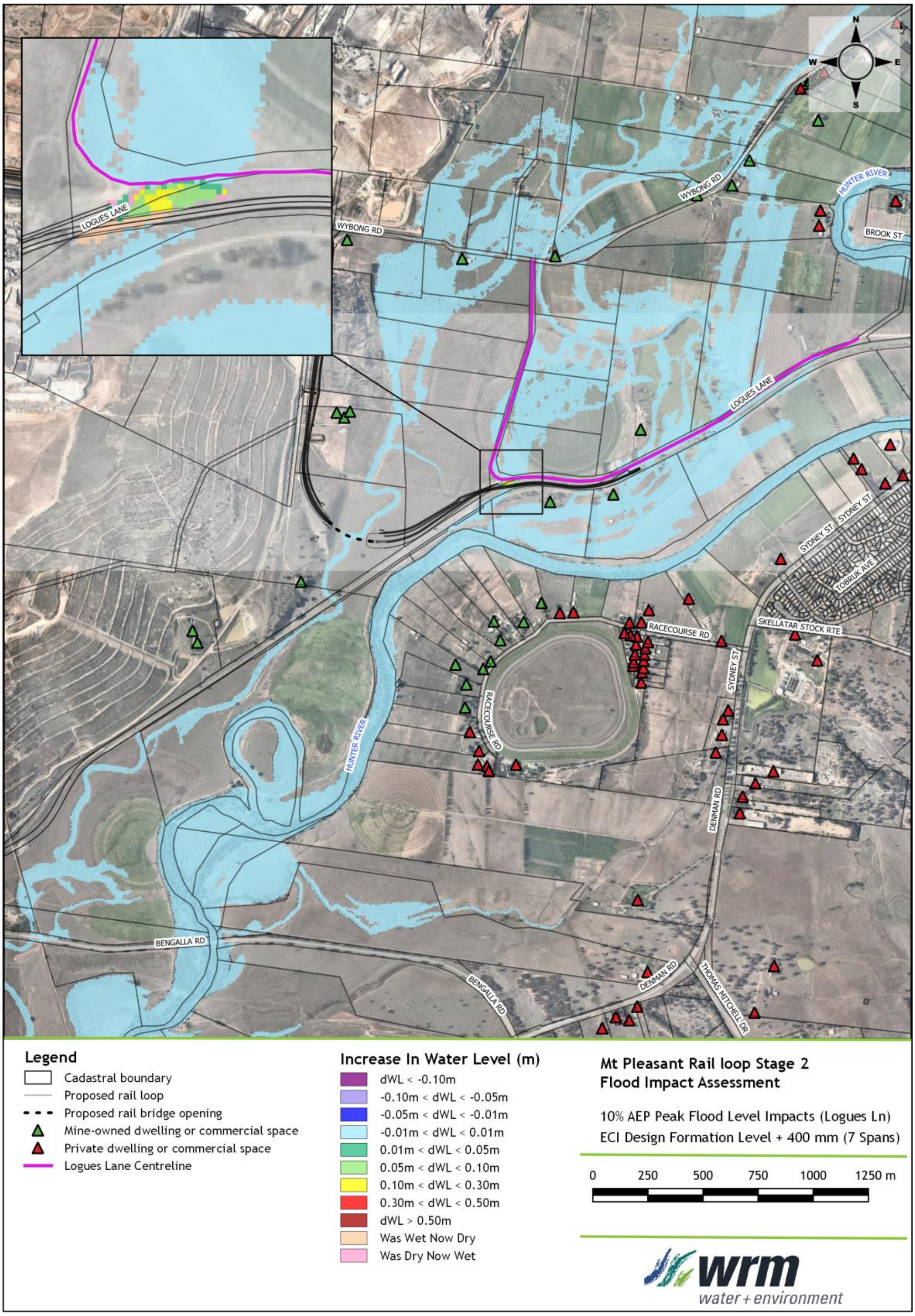
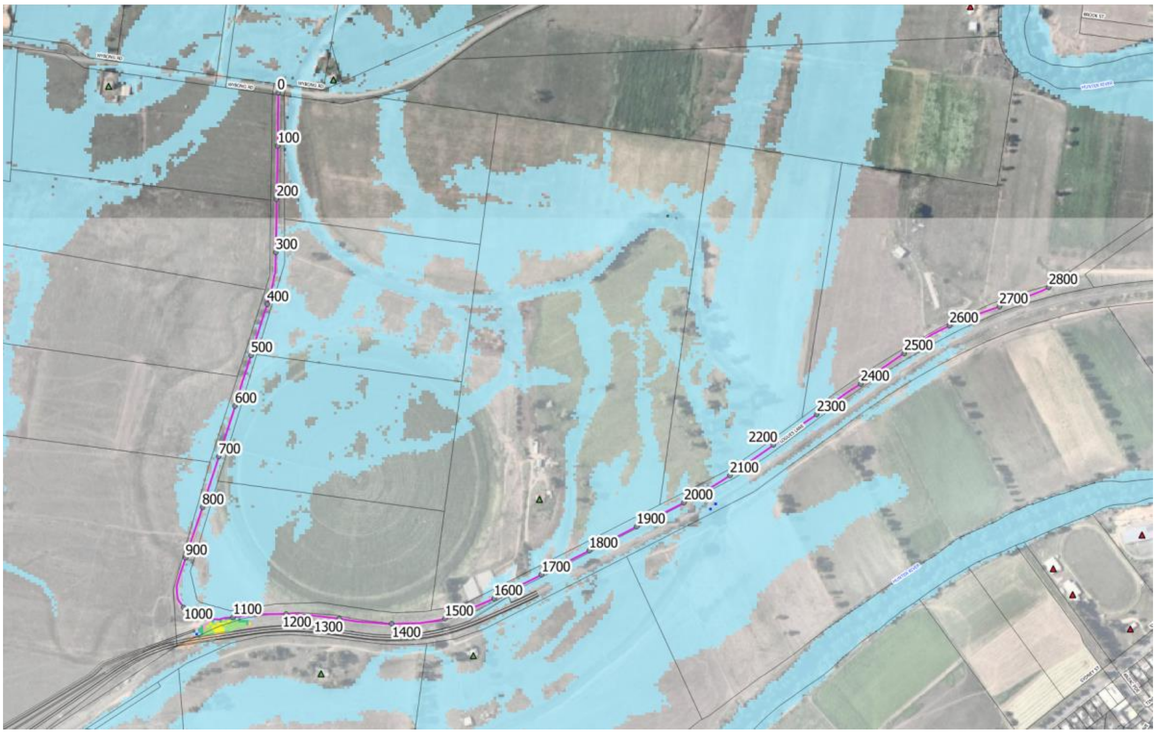


Figure 5 - Flood level impacts of rail spur, 10% AEP



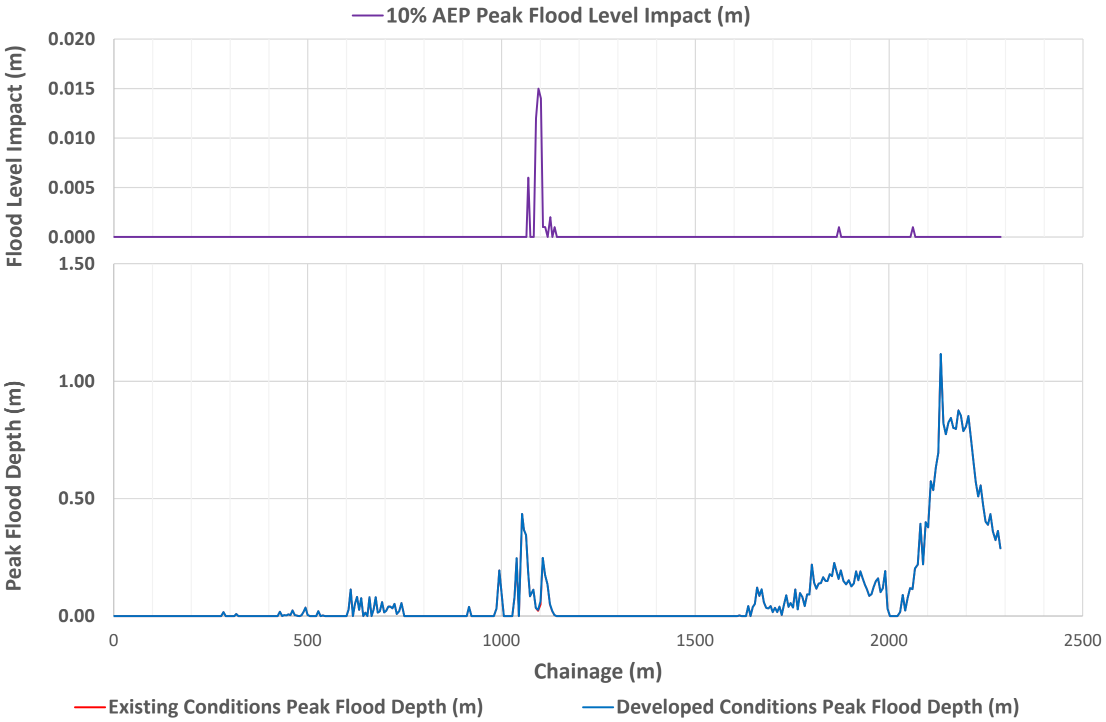


Figure 6 - 10% AEP flood level impact along the centreline of Logues Lane

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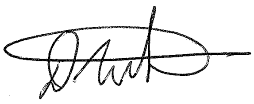
Summary

- Logues Lane is not flooded by the Hunter River for the 20% AEP flood event under existing or developed conditions.
- The 10% AEP river flood event will inundate the low point near the southwest corner of Logues Lane to a maximum depth of about 0.43 m. The maximum impact of the rail spur on flood depths along Logues Lane for this event is about 0.015 m.

Please do not hesitate to contact me if you require further information.

For and on behalf of

WRM Water & Environment Pty Ltd



David Newton

Director

References:

WRM, 2020 — *'Mount Pleasant Rail Loop Stage 2, Rail Modification Flood Impact Assessment'*, Report ref. 0744-11-K4 prepared by WRM Water & Environment Pty Ltd for Mach Energy Australia Pty Ltd, 29 May 2020.

MACHEnergy

Mount Pleasant Operation

Independent Review – Rail Spur Design Flood Impact Assessment (MOD 4)

Rail Spur Design Flood Impact Assessment Review

Client: MACH Energy

Reference: PA2390 Mount Pleasant – Rail Design Flood Assessment Review

Status: 03/Final

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Royal HaskoningDHV

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1 Introduction

MACH Energy has commissioned Royal HaskoningDHV (RHDHV) to undertake an independent review of the Mount Pleasant Rail Loop Stage 2 – Rail Modification Flood Impact Assessment Report (WRM, 2020). This independent review of the final design is a requirement of condition 44D of DA92/97 MOD 4 consent.

The proposed Rail Spur is located on the Hunter River floodplain between Muswellbrook and Denman. Details of the proposed rail spur are presented in Figure 1-1. The proposed rail spur has the potential to cause an impact on flood levels on the Hunter River floodplain.

The proposed rail modification involves construction of a new rail spur across part of the floodplain of the Hunter River. The rail modification also includes the construction of a water supply pump station and associated water pipeline, however, these are not considered to have any material effect on flooding given the water supply pipeline would be buried within the Hunter River floodplain and therefore would not impede overland flow during a flood event. Further details of the proposed rail modification are provided in the Flood Impact Assessment Report (WRM, 2020) and should be referred to as necessary.

The aim of this report is to provide an independent desktop review of the WRM Report 0744-01-K4, dated 29 May 2020 and titled: Pleasant Rail Loop Stage 2 – Rail Modification Flood Impact Assessment Report. The aim of the Flood Impact Assessment Report (WRM, 2020) was to assess the potential impacts of the proposed rail spur on Hunter River and to determine if the final design meets the performance criteria specified in condition 44C of the MOD4 consent. The WRM (2020) flood impact assessment report includes detailed hydrologic and hydraulic modelling of the Hunter River floodplain in the area of interest, which is used to assess the potential impacts of the proposed rail spur on flood levels and velocities.

The main aim of this report is to review the technical adequacy of the WRM 2020 flood impact assessment and to verify whether the design meets the required performance criteria specified in condition 44C of DA92/97 MOD 4 consent. The review also provides a comparison to design flows and peak water levels calculated as part of the Hunter River (Muswellbrook to Denman) Floodplain Risk Management Study and Plan (FRMS&P) undertaken by Royal HaskoningDHV on behalf of Muswellbrook Council. The focus of this report includes a review of the:

- Adopted hydrology (i.e. estimates of design (i.e. 1% AEP or 100-year Average Recurrence Interval (ARI))) river/catchment discharge)
- Parameterisation of the hydraulic (flood) model, including a review of adopted:
    - model setup
    - elevation data
    - roughness assumptions
    - structure parameterisation
    - achieved model calibration and verification
    - parameterisation of the proposed developed condition scenario.
- Validity of the conclusions regarding the impact of the rail modification project and evaluation of whether the final design meets the performance criteria specified in condition 44C of DA92/97 MOD 4 consent.

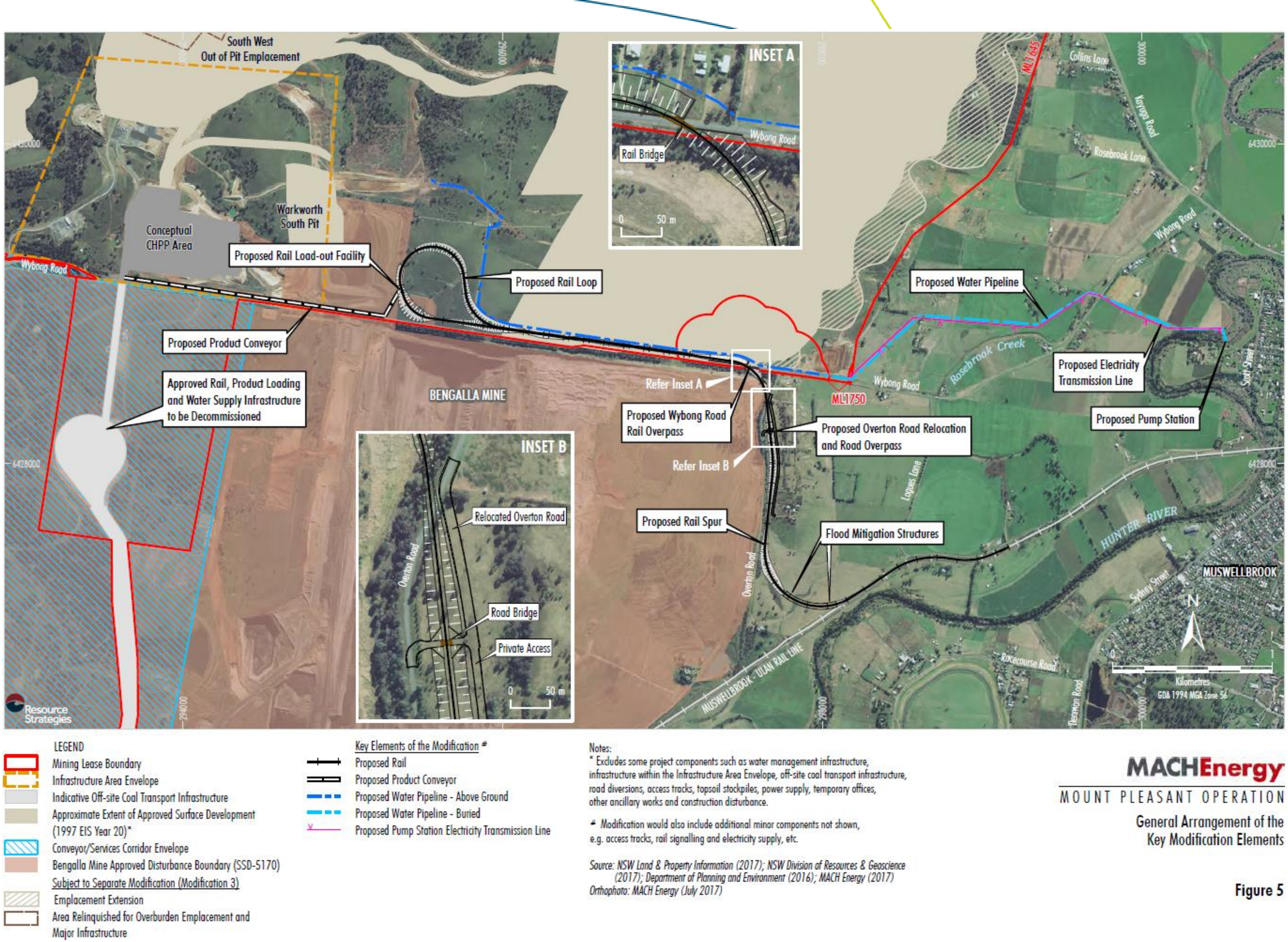

Figure 1-1: Alignment of Proposed Rail Spur (Fig 1.2 (WRM, 2020))

1.1 Background to Hunter River Model Revision Study

Background to Hunter River Model Revision Study (Royal HaskoningDHV (RHDHV), 2017) is provided as this is the work the WRM (2020) model is being compared to, in order to ensure consistency with outcomes with the Hunter River FRMS&P (RHDHV, 2020), which uses the hydrological estimates and TUFLOW model developed during the Model Revision Study (RHDHV, 2017).

Muswellbrook Shire Council (Council) commissioned Royal HaskoningDHV (RHDHV) to produce the Hunter River (Muswellbrook to Denman) Floodplain Risk Management Study (FRMS) on behalf of Council and The NSW Office of Environment and Heritage (OEH). The FRMS builds on the Hunter River Flood Study (Muswellbrook to Denman) that was prepared by WorleyParsons in 2014.

One of the initial tasks of the FRMS was to undertake a technical adequacy review of the 2014 flood study. That review was prepared by RHDHV in March 2016 and identified a number of issues regarding the reliability of the Hunter River Flood Models that were developed as part of the 2014 study.

Subsequent to that review being completed, OEH were made aware that rating curves for many of the Upper Hunter stream gauges had been recently revised by NSW Office of Water (NOW). The revised rating curves substantially reduce the estimated flow rate for a given stage height at the gauging location. The revisions are due to the increase in vegetation densities both within the channel and on the channel banks over the last two decades (see Figure 3-4).

A meeting was held on 29 October 2016 to discuss the need to recalibrate and verify the Hunter River Flood Models that were developed by Worley Parsons in 2014 as part of the Flood Study. It was decided that the Hunter River model calibration and design event verification needed to be revisited to ensure confidence in the outcomes of the FRMS and potential future uses of the model.

The model revision process also provided an opportunity to update the models to be consistent with the recently formalised Australian Rainfall and Runoff 2016 (Commonwealth of Australia) guidelines. The 2014 flood study applied the methods documented in the Australian Rainfall and Runoff 1987 (IEAust) guideline.

The following scope for the model revision process was established by RHDHV in consultation with OEH and Council:

- Review and analysis of recent changes to stream gauge rating curves.
- Modification to the Hunter River hydraulic model to more reliably represent the current floodplain characteristics.
- Recalibration of the Hunter River hydrologic and hydraulic models using stream gauging data for flood events that occurred in 1988 and 2000.
- Flood frequency analysis using data from the Muswellbrook stream gauge.
- Establishment of revised design event conditions for a full range of Annual Exceedance Probability (AEP) flood events based on the outcomes from the model calibration and verification process and the Australian Rainfall and Runoff 2016 methods.
- Verification of the revised design model outcomes using available data from the 1955 and 1971 events.

An example of the review and modelling of rating curve changes in RHDHV (2017) is presented in Figure 3-4.

1.2 Details of Independent Review Qualification and Required Consultation

The purpose of this report is to detail the independent review undertaken to verify that the final rail spur design is able to meet the performance criteria specified in condition 44C of the MOD4 consent (refer Section 3.3).

To meet condition 44D of the MOD 4 consent, details of the reviewer and consultation with OEH (now dPIE) are provided.

This review has been undertaken by Rohan Hudson (BE (Environmental), UNSW & M.Eng.Sci (Coastal), UNSW) who works for the independent engineering consultancy Haskoning Australia Pty Ltd (a company of Royal HaskoningDHV). Rohan has over 20 years' experience as a numerical modeller and floodplain risk manager both in NSW and the UK. He was involved in RHDHV (2017) as described above (Section 1.1) and was the lead author of the Muswellbrook FRMS&P (RHDHV, 2020). Rohan has presented a number of papers at the floodplain management association (FMA) conference and was called as a witness to the Coronial Inquiry into the deaths of three Dungog residents that occurred in April 2015.

As part of the review the relevant staff at dPIE (NSW department of Planning Industry Environment (dPIE), formerly OEH) were emailed on the 7th April 2020. A number of issues were discussed on the 8th April 2020. These issues are detailed in Section 3.4 of this report.

2 Review of Flood Discharge Estimates

2.1 Design Discharge Estimation Techniques

Estimates of design discharge for a given annual exceedance probability (AEP) can either be based on:

- **Flood Frequency Analysis (FFA):** If a sufficient duration (normally > 50 years) of river discharge data is available, extreme value analysis can be used to estimate design discharges. The use of FFA is preferable as it removes uncertainty between the amount of rainfall and resulting river discharge that is inherent in hydrological modelling. However, FFA depends on the availability of a sufficient length of good quality discharge data. Issues with rating curves (used to determine river discharge based on the measurement of water levels) can reduce the accuracy of design discharge based on FFA.

- **Hydrological modelling (using design rainfall data):** if no (or insufficient) river discharge data is available (i.e. the catchment or site is not "gauged"), then hydrological modelling is the most accurate method of determining design discharge. A hydrological (or catchment) model uses a parameterisation of the catchment to calculate the rate of river discharge from a given rainfall event. Typical hydrological models used in Australia include: XP-RAFTS, RORB, WBNM and ILSAX.

2.2 WRM (2020) Flood Frequency Analysis

2.2.1 Introduction and Review of Method

WRM (2020) reports that: *an FFA was undertaken on the Hunter River at Muswellbrook Bridge gauge (Station No. 210002). The catchment area to Muswellbrook Bridge gauge is 4,220 km² and includes Glenbawn Dam. The catchment area of Glenbawn Dam is 1,300 km². Glenbawn Dam provides some 120,000 ML of flood storage between the full supply level and the spillway level. The available flood storage volume has a significant impact on the downstream discharge. Hence, hydrology of the Hunter River at Muswellbrook would be expected to be different after the upgrade of Glenbawn Dam in 1987.*

Muswellbrook Bridge gauge has recorded streamflow data from 1913 to present. However, significant data was missing prior to 1961. A FFA reflecting post-dam hydrology would use data from 1987 onwards. However, this would only provide 30 years of data.

An additional 26 years of data is available if the full record from 1961 is adopted. However, it is noted that this period includes data prior to the dam upgrade in 1987. Hence, a FFA based on data since 1961 is likely to slightly overestimate design discharges at Muswellbrook Bridge gauge. This is considered acceptable because it is a conservative approach for estimation of design discharges and also acceptable for a flood assessment. The model results will not be used to set design flood levels for the proposed rail spur which are determined by the existing rail embankment levels.

Royal HaskoningDHV (2017) notes that the Muswellbrook Flood Study (1986) examined a study performed by Hayes (1982) which analysed the impact of Glenbawn Dam on floods at Muswellbrook. **The study found that the original and upgraded dams have effectively the same mitigation effect**. The upgraded dam was increased in capacity; however, the available flood mitigation storage was reduced leading to a negligible net difference in flood mitigation properties. The RHDHV (2017) study sought to investigate this hypothesis via statistical analysis.

Statistical analysis using the t-test and the Mann-Whitney U-test was undertaken on the post-dam and post upgrade data sets. The t-test and the Mann-Whitney U-test analyse the mean and median of each of these data sets. The results of these tests showed that the impact of the dam on the two data sets is not statistically significant ($p>0.05$).

This analysis verified that the Post Glenbawn Dam and Post Glenbawn Dam Upgrades were statistically similar. Accordingly, it was considered appropriate to merge the two data sets to form a single post dam annual series for the 1956 to 2016 period.

A comparison of the annual maxima series adopted between WRM (2020) and RHDHV (2017) indicates that 5 more years of data could have been used by WRM (2020). Also, RHDHV (2017) undertook a complex Bayesian Methods to incorporate Pre-Glenbawn Dam data and historical flood events into the post dam FFA to further extend the available annual maxima series.

2.2.2 WRM (2020) FFA Results and Comparison to Royal HaskoningDHV (2017)

The WRM (2020) FFA was undertaken using the Bayesian inference methodology recommended in the ARR 2016 using the FLIKE software. The FFA results are given in Table 2.1, and represented graphically in Figure 2.1. There is a 90% likelihood that the design discharge is within the 90% confidence limits shown in Figure 2.1. The 5 percent (%) Annual Exceedance Probability (AEP) and 1% AEP design peak discharges are 1,732 cubic metres per second (m^3/s) and 3,721 m^3/s, respectively.

A comparison of the WRM (2020) to RHDHV (2017) FFA results is presented in Table 2-2. It shows that the WRM (2020) design discharge estimates are between 1.1 and 6.3% higher (i.e. are considered conservative) than those reported in RHDHV (2017) for AEP events ranging from 5% to 0.2% AEP (i.e. 20-year to 500-year ARI). While the RHDHV (2017) is likely to be more accurate (i.e. more of the historical stream gauge record was used) there is good agreement between the estimates of design discharges adopted by the two studies.

Table 2-1: WRM (2020) Flood frequency analysis results for Muswellbrook Bridge gauge

Source: WRM (2020) Table 4.2

AEP	Design Discharge (m^3/s)
5%	1,732
2%	2,754
1%	3,721
0.5%	4,872
0.2%	6,705
0.1%	8,348

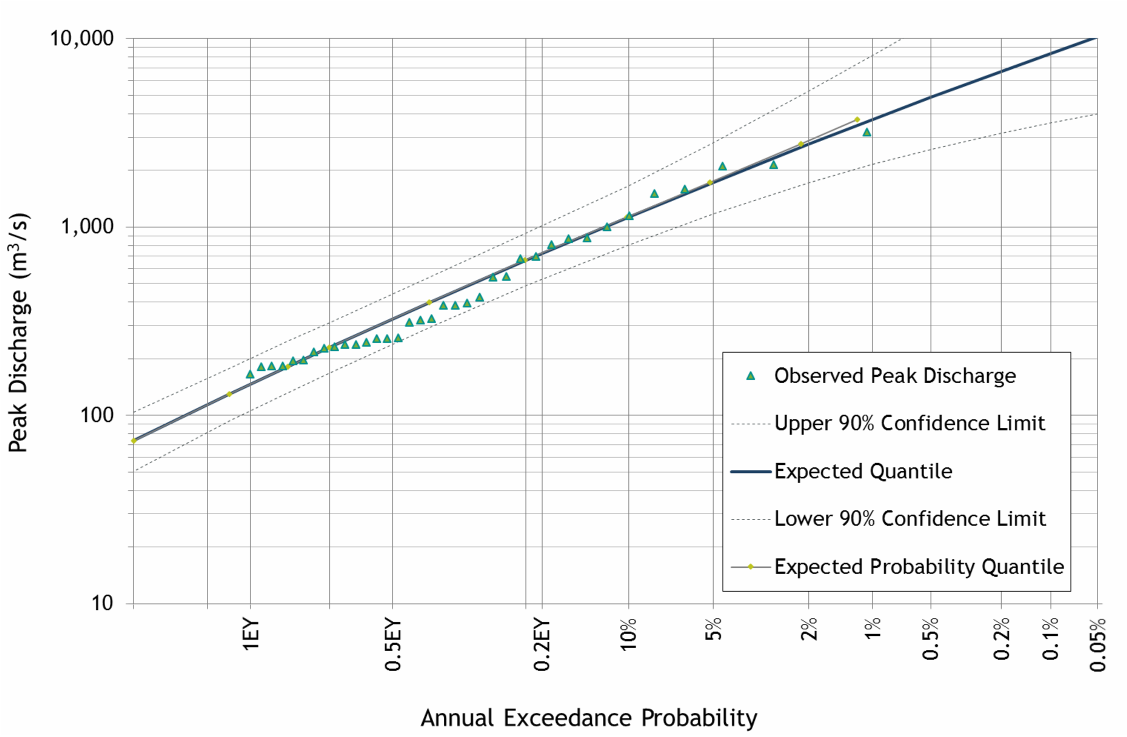

Figure 2-1: **FFA for the Muswellbrook Bridge gauge**

Source: WRM (2020) Figure 4.1

Table 2-2: Flood Frequency Analysis: Design Flows at the Muswellbrook Gauge (Comparison)

Event (AEP)	WRM (2020) FFA Flow (m³/s)	FRMS&P FFA Flow (m³/s)	90% Confidence Limits		% Difference to FRMS&P
			Lower Flow (m³/s)	Upper Flow (m³/s)	
5%	1,732	**1714**	1297	2295	1.1%
2%	2,754	**2682**	1954	3861	2.7%
1%	3,721	**3583**	2493	5571	3.9%
0.5%	4,872	**4643**	3056	7884	4.9%
0.2%	6,705	**6308**	3825	12106	6.3%

2.3 WRM (2020) Hydrological Modelling

2.3.1 Introduction and Review of Method (WRM (2020) XP-RAFTS Model)

WRM (2020) also calculated design flood discharges for the Hunter River using XP-RAFTS hydrological software (XP Software, 2013). The XP-RAFTs model configuration and parameters of the calibrated Hunter River RAFTS model developed by WorleyParsons (2014) were generally unchanged, however, the IFD data, losses, ARF and temporal pattern were updated to ARR 2019.

It is important to note that the WorleyParsons (2014) supplied two XP-RAFTS models:

- **Calibration model** – with standard catchment lags that were defined during the model calibration exercise.
- **Design model** – with increased catchment lags (i.e. uncalibrated) though no reason for this was provided in WorleyParsons (2014).

It is assumed that WRM (2020) used the calibration XP-RAFTS model with calibrated catchment lags.

Catchment modelling using XP-RAFTS is an appropriate technique to determine discharges for the study. A review of the important elements of the catchment modelling is provided in Table 2-3. Overall the assumptions and methodology are appropriate and the design discharges as presented in Table 4.7 of WRM (2020) (and reproduced in Table 2-4 of this report) are appropriate for the study. The adoption of ARR2019 techniques is considered appropriate as it produced design discharge that were in good agreement (i.e. to within 2-3%) with FFA (refer Table 2-4).

Table 2-3 – Review of XP-RAFTS Catchment Modelling

Review Element	Comment
Model Origin	WRM (2020) used the model configuration and parameters of the calibrated Hunter River RAFTS model developed by WorleyParsons (2014).
Initial and Continuing Losses	For the WRM (2020) study, the rainfall losses were adjusted so that the XP-RAFTS peak design discharges matched the results of the FFA. The WRM (2020) losses are in reasonable agreement to that adopted in RHDHV (2017) and appear to be appropriate.
IFD Data	Design rainfall depths were obtained from the Commonwealth Bureau of Meteorology (BoM) for a range of design AEP events and storm durations and are assumed to be correct.
Temporal Pattern	Temporal patterns define the variability of rainfall during an event. The ensemble event approach described in ARR 2019 has been used for this analysis. This approach uses an 'ensemble' of 10 temporal patterns for each storm duration to derive a range of estimated flood peaks for each AEP up to the 1% AEP event. It is assumed that WRM (2020) selected the 6th highest discharge to adopt for the design events which is recommended in ARR 2019 guidance. The temporal patterns of relevance to the Hunter River (South-East Coast temporal patterns) were obtained from the ARR Data Hub (Geoscience Australia, 2016) and hence are assumed to be appropriate.
Critical Duration	No information on the resulting critical duration is specified in the WRM (2020) report, however from Figure 2-2 it is apparent that the 36 hour duration was used for the 1% and 0.5% AEP, while the 24 hour event was used for the 0.2% AEP. RHDHV (2017) found that the 24 hour rainfall event was the critical duration. This may is due to difference in the XP-RAFTS model, most likely the use of a different Bx factor (refer Section 2.3.2). The slightly longer duration (and hence higher volume) hydrograph may produce a slightly higher flood level estimate in the WRM (2020) assessment.
Extreme Event / PMF	No information on the PMP/PMF is provided in the WRM (2020) report. It is assumed to be the same used in Worley Parsons (2014) and if so, is considered appropriate. The adopted PMF hydrograph is presented in Figure 2-2.

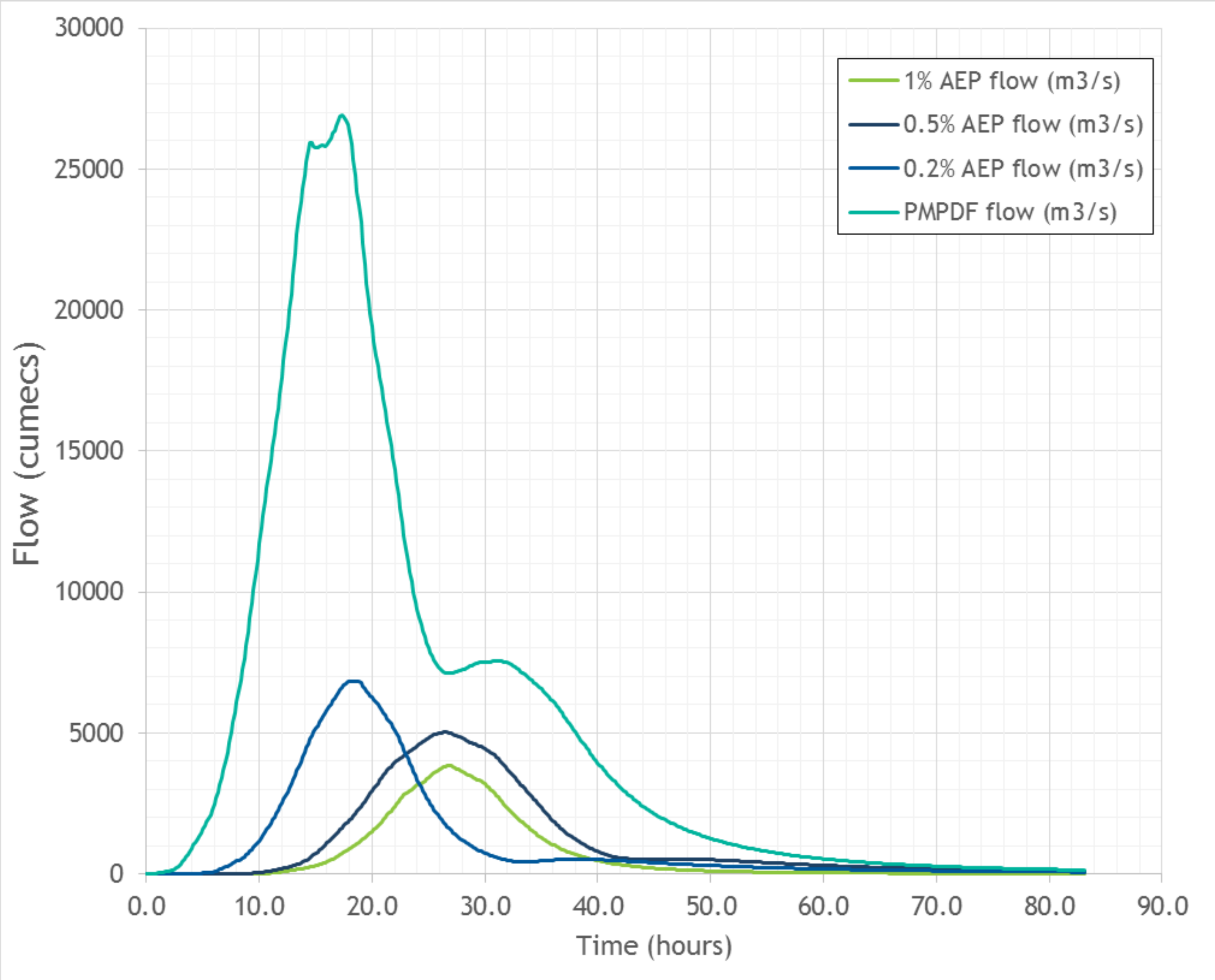

Figure 2-2: Hydrographs at Muswellbrook (WRM, 2020)

2.3.2 Difference to RHDHV (2017) XP-RAFTS Model

Due to errors with the gauge rating data, RHDHV undertook a complete hydrological and hydraulic model calibration exercise as part of the Model Revision Study (RHDHV, 2017). The following adjustments were made to model parameters to improve the overall calibration outcome:

- The Storage Coefficient Multiplication Factor (Bx) was adjusted from 1.0 to 1.2. This moderately increases the attenuation of runoff hydrographs from the model's sub catchments, reducing peak flows.
- Initial and continuing loss (IL & CL) rates were simplified. The 2014 model calibration included six different IL and CL zones which ranged from IL 5mm and CL 1 mm/hr to IL 15 mm and CL 2.5 mm/hr. The following loss rates were adopted for all Upper Hunter River Catchments in the revised calibration:
    - **Initial Loss Rate**: 15 mm (1998 event, i.e. wetter antecedent conditions) and 30 mm (2000 event, i.e. drier antecedent conditions)
    - **Continuing Loss Rate**: 1.5 mm/hr (both events).

2.3.3 WRM (2020) Hydrological Modelling Results and Comparison to RHDHV (2017)

A comparison of WRM (2020) FFA and hydrologic model flows to the RHDHV (2017) equivalent is presented in Table 2-4. The WRM hydrologic flows (adopted for use in the hydraulic model) are up to 8.6% higher for events up to the 1% AEP when compared to hydrologic design flows presented in RHDHV (2017). The use of slightly higher design discharge, means that, provided appropriate roughness values are adopted in the hydraulic model, there should be a degree of conservatism in the WRM (2020) assessment.

Differences between the larger 0.2% AEP and 0.5% AEP events (of between 20 to 30%) are likely to be due to the use of a different Bx factor (partly because the Worley Parsons model was calibrated to incorrectly rated gauge data) used in the XP-RAFTS models. It may also be that WRM (2020) adopted even lower loss parameters in these rarer events so that there is better agreement to FFA design discharges. While this is appropriate for smaller events where there is good confidence in the FFA, for rarer/larger events, there is less confidence in the FFA (i.e. where there is a divergence of the 90% confidence limits away from the expected quantile) and hence standard losses should be used.

Table 2-4: Comparison of Design Flows Estimates at the Muswellbrook Gauge

Event (AEP)	WRM (2020) FFA Flow (m^3/s)	WRM (2020) Hydrologic Model Flows (m3/s)	% Difference to FFA	FRMS&P FFA Flow (m^3/s)	FRMS&P Hydrologic Model Flows (m^3/s)	% Difference to FRMS&P
5%	1,732	**1,776**	2.5%	1714	**1650**	7.1%
2%	2,754	**-**	-	2682	**2900**	**-**
1%	3,721	**3,841**	3.1%	3583	**3510**	8.6%
0.5%	4,872	**5,022**	3.0%	4643	**4070**	19.0%
0.2%	6,705	**6,835**	1.9%	6308	**4860**	28.9%

2.3.4 Conclusions Regarding the Review of Hunter River Design Discharge

A review of the method and magnitude of the Hunter River design discharges provided in the WRM (2020) indicate that they are appropriate for the Mount Pleasant Rail Flood Impact Assessment. Both the design discharge estimates from the FFA and hydrological model are in good agreement with the more sophisticated (but necessary) analysis undertaken in RHDHV (2017) that form the basis of the Muswellbrook FRMS&P.

3 Review of Flood (Hydraulic) Model Predictions

Hydraulic (flood) models are a representation of the channel and floodplain and are used to calculate flood depths and velocity for a given river discharge. One-dimensional (1D) hydraulic models, (i.e. MIKE11, Estry) use cross-sections (X and Z coordinates) to represent the conveyance of the main channel and floodplain, while two-dimensional (2D) models, (i.e. TUFLOW, MIKE21) represent the channel and floodplain using small “cells” with a given elevation and allow water to flow in two (X and Y) directions improving the definition of floodplain storage, and allowing for complex flow behaviours to be modelled rather than applying assumptions or simplification on flow conditions to be made. 2D models are far more computationally intensive than 1D, however, given modern increases in computing power this is now less of an issue.

Software selection: The use of TUFLOW as the hydraulic model for the study is considered appropriate. TUFLOW (BMT WBM) estimates flood levels and velocities on a fixed grid pattern by solving the full two-dimensional depth averaged momentum and continuity equations for free surface flow. It also incorporates a one-dimensional or quasi two-dimensional modelling system (ESTRY). The one-dimensional (ESTRY) and two-dimensional (TUFLOW) schemes are solved independently, but are dynamically linked at the boundary to ensure continuity (mass) is conserved. The hydraulic modelling by WRM (2020) was undertaken using TUFLOW HPC solver with GPU hardware (version 2017-09-AC) which is the same as used by RHDHV (2017).

3.1 Review of Hunter River (WRM, 2020) Model

3.1.1 Model Overview

Full details of the Hunter River model are presented in WRM (2020). The model extends approximately 6 km upstream and 13 km downstream of the Project and covers an area of some 70 km^2 including Sandy Creek. The model features and extents are provided in Figure 3-1. The model was used to assess:

A summary of hydraulic model configuration includes:

- 5 metre by 5 metre grid TUFLOW model
- Hydrology for the Hunter from XP-RAFTS hydrologic model using ARR 2019 methods and data (as reviewed in Section 2.3)
- Ground elevation data based on LiDAR flown in August 2016
- 1D structure representation of road and rail infrastructure including: 26 culvert structures and 16 bridge structures
- Calibrated/validated to the 1998 and 2000 flood events.

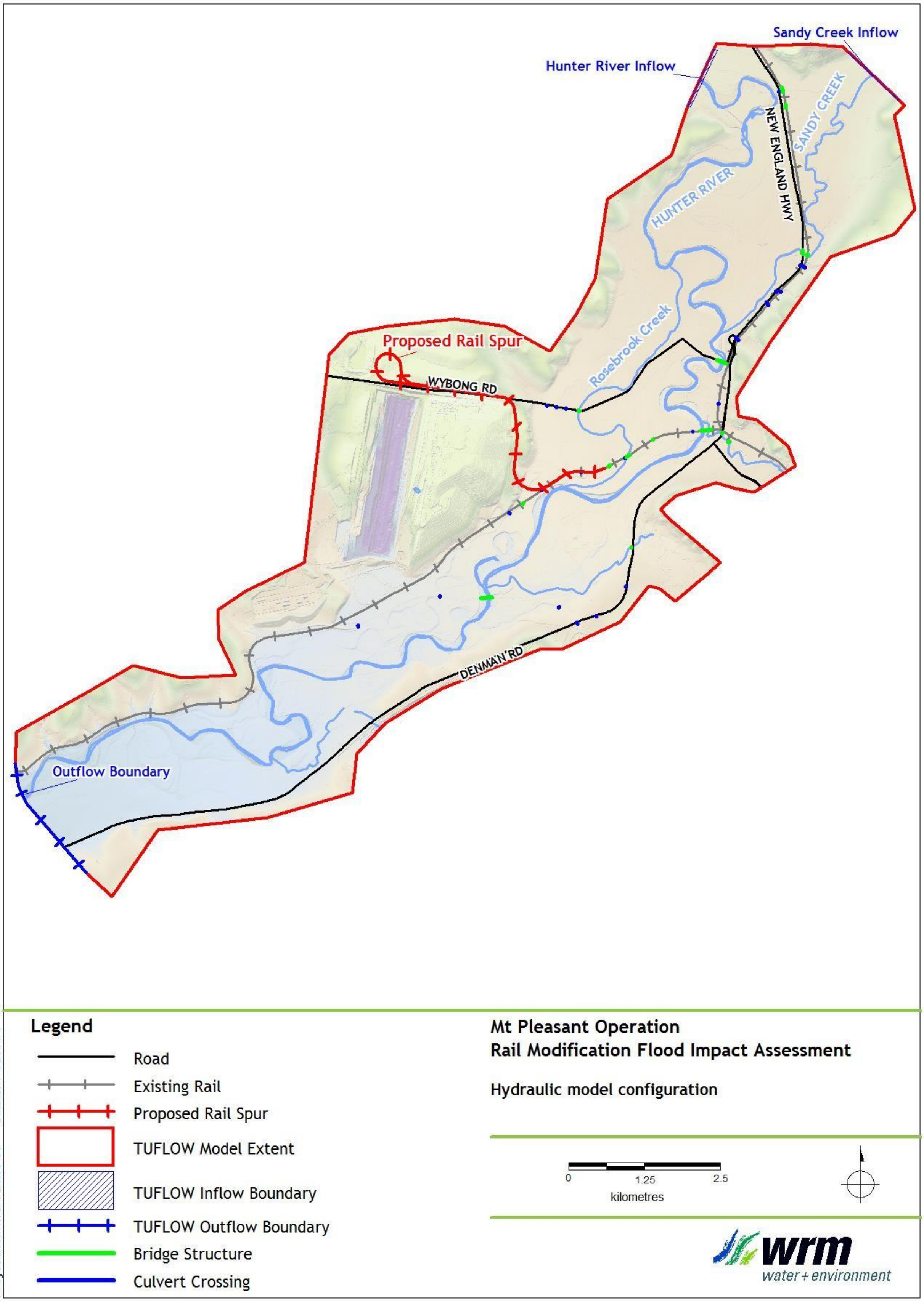

Figure 3-1: Hunter River TUFLOW model configuration (Fig 5.1 WRM (2020))

3.1.2 Detailed Hunter River Model Review

A review of the important elements of the Hunter River TUFLOW modelling is provided in Table 3-1. Overall the assumptions and methodology, and the assessment of the existing conditions appear to be appropriate.

Table 3-1 – Review of Hunter River TUFLOW Model

Review Element	Comment
Model Extents	The model extents are considered appropriate for the study area although are slightly smaller than that used in RHDHV (2017).
Model Resolution	A 5 metre grid resolution is considered appropriate for the study area and provides sufficient spatial resolution for the modelling assessment.
Inflow Boundary	Design inflows for the Hunter River were reviewed in Chapter 2 and appear appropriate. Calibration and validation event inflow are based on observed discharges so are assumed to be correct.
Downstream Boundary	A single normal depth outflow boundary was adopted for the Hunter River model. The outflow boundary of this model is located approximately 13 km downstream of the Rail Spur and as such would not impact on peak flood levels at the Project area. This is considered appropriate.
Elevation Data	Topographic data for the hydraulic model used elevation data based on LiDAR flown in August 2016. It is assumed this data is correct and appropriate. However, it is important to note that the LiDAR may not be able to accurately represent the channel bathymetry of deeper channel pools where standing water is present. RHDHV (2017) lowered pools by up to 2 metres to better represent observed channel stage-discharge characteristics.
Surface Roughness	A detailed discussion of the adopted hydraulic roughness (Manning's 'n') is presented in Section 3.1.3 of this report. Overall the range of values are considered appropriate.
Structures	Adopted hydraulic structures used in the hydraulic model are discussed in Section 5.2.5 of WRM (2020). Survey information on the existing hydraulic structures including culvert crossings and bridges were provided by FYFE (surveyors) dated 15 November 2017. A total of 26 culvert structures and 16 bridge structures were included in the hydraulic model based on the survey information. Figure 3-1 shows the locations of the modelled culvert and bridge structures.
Calibration/ validation	The Hunter River hydraulic model was calibrated/validated to the available observed data for the 1998 and 2000 flood event. Observed flows were applied to the model with a 1.5 hour lag used to account for shift in location to the model boundary. The expected good match between observed and model flows is presented in Figure 3-2. The TUFLOW model was able to reproduce observed peak flood levels (see Figure 3-3) to within between 0.1metres for both events. However, away from the flood peak, differences in water levels of greater than 0.5 metres indicate issues with the WRM (2020) model channel stage-discharge characteristics. This may be due to the LiDAR based elevation data not accurately defining the channel bed in channel pool areas (noted above) and also slight overestimation of bank vegetation channel roughness (for

Review Element	Comment
	pre 2000 conditions). While a good match to peak water levels was achieved it is important to recognise that changes to near bank channel vegetation mean that the channel stage-discharge characteristics have changed between 2000 and 2015 (RHDHV, 2017). This is further discussed in Section 3.1.3 of this report.
Proposed Conditions Model Updates	Section 6.1 to Section 6.3 of WRM (2020) provides some detail of the updates to the model required to represent the proposed conditions which included: • incorporation of an earthworks (i.e. elevation data) model into the hydraulic model, and • incorporation of conceptual mitigation measure into the model which included: the extension of two existing railway culvert crossings and two bridge openings of 105 metres and 90 metres with assumed 15 metre span lengths. Provided the structures were incorporated using appropriate loss parameters the schematisation of the concept rail spur it is considered a suitable tool for quantifying the potential impact. If the final design is different from the concept it should be re-assessed in the model.

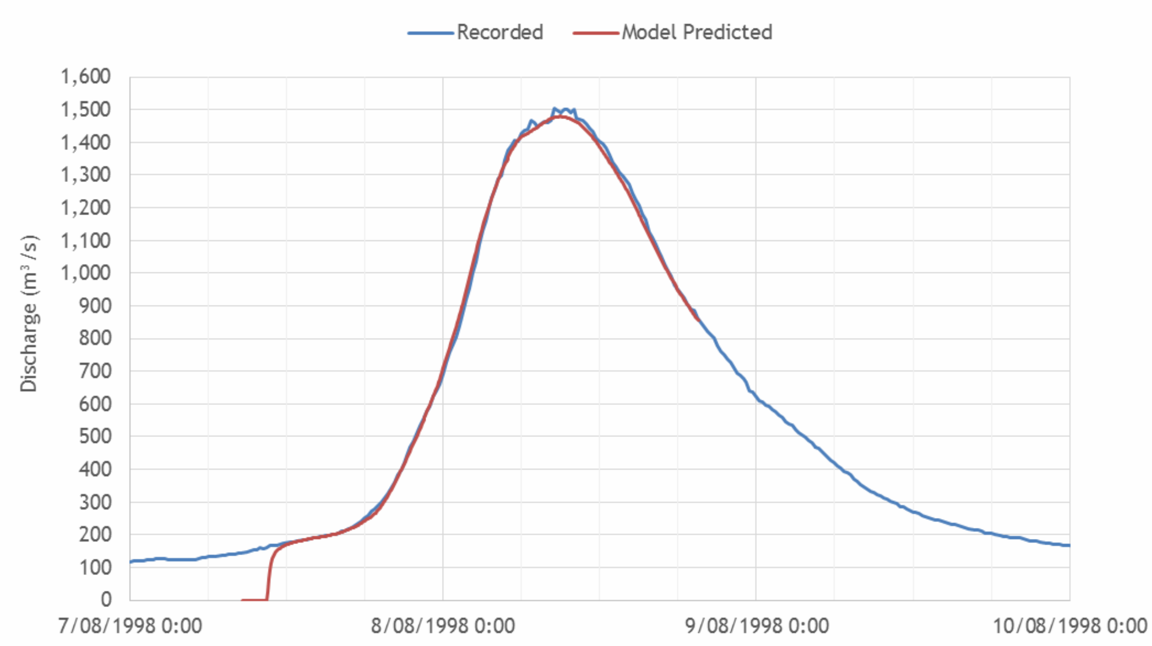

Figure 3-2: **Comparison of recorded and predicted flow hydrographs, Hunter River at Muswellbrook Bridge, August 1998 flood event**

Source: WRM (2020) Figure 5.2

Royal HaskoningDHV

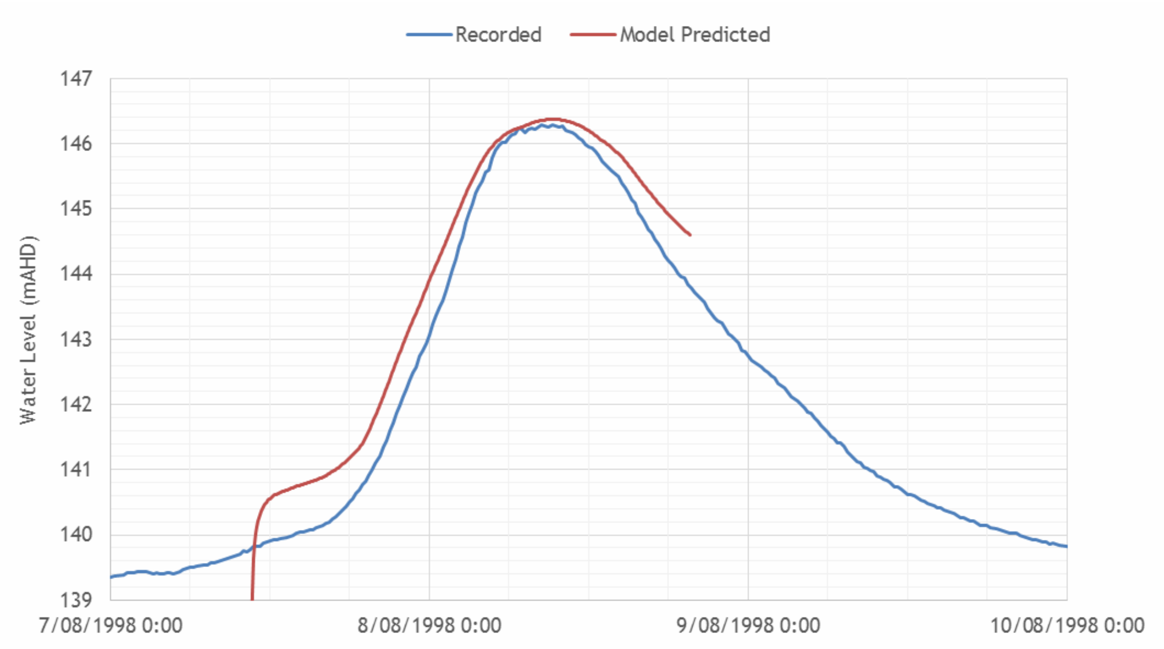

Figure 3-3: **Comparison of recorded and predicted water level hydrographs, Hunter River at Muswellbrook Bridge, August 1998 flood event**

Source: WRM (2020) Figure 5.3

3.1.3 Detailed Review or WRM (2020) vs RHDHV (2017) Roughness Parameterisation

A comparison of the adopted roughness values used in the three recent flood studies (i.e. WRM (2020), WorleyParsons (2014) and RHDHV (2017)) is presented in Table 3-2. The spatial distribution of material roughness (land uses and surface types) is presented in Figure 3-5. It appears consistent with that adopted in RHDHV (2017) and includes a representation of bank channel vegetation that was omitted from Worley Parsons (2017) model.

The main differences between the roughness values adopted in WRM (2020) and RHDHV (2017) are:

- WRM (2020) adopted a slightly higher pasture/overbank roughness. This will slightly increase predicted flood levels, especially for the larger design events.
- WRM (2020) did not account for increasing roughness of dense channel bank vegetation that has significantly reduced the in-bank channel capacity of the Hunter River over the past 30 years. This will tend to reduce predicted flood levels, especially for the smaller (i.e. 20% AEP and below) design events. However, this will not influence the models ability to predict the impact of the rail spur impact for the 1% AEP event which is the basis of the MOD4 performance criteria.

Table 3-2 – Comparison of Adopted Roughness Values

Land use	WRM (2020)	WorleyParsons (2014)	R3* (Pre 2001)	R4* (Intermediate)	R5* (Post 2010)
Pasture / Overbank	0.040	0.035	0.035	0.035	0.035
Channel	0.030	0.035	0.03	0.035	0.035
Dense channel bank vegetation	**0.065**	n/a	0.06	0.1	**0.15**
Dense vegetation	0.065	0.065	0.06	0.06	0.06
Road	0.020	0.02	0.02	0.02	0.02
Urban area	0.100	0.08	0.08	0.08	0.08

Note: * R3, R4 and R5 are different roughness parameterisation used in RHDHV (2017) to represent the changes to observed channel ratings from 1990 to now (refer Figure 3-4).

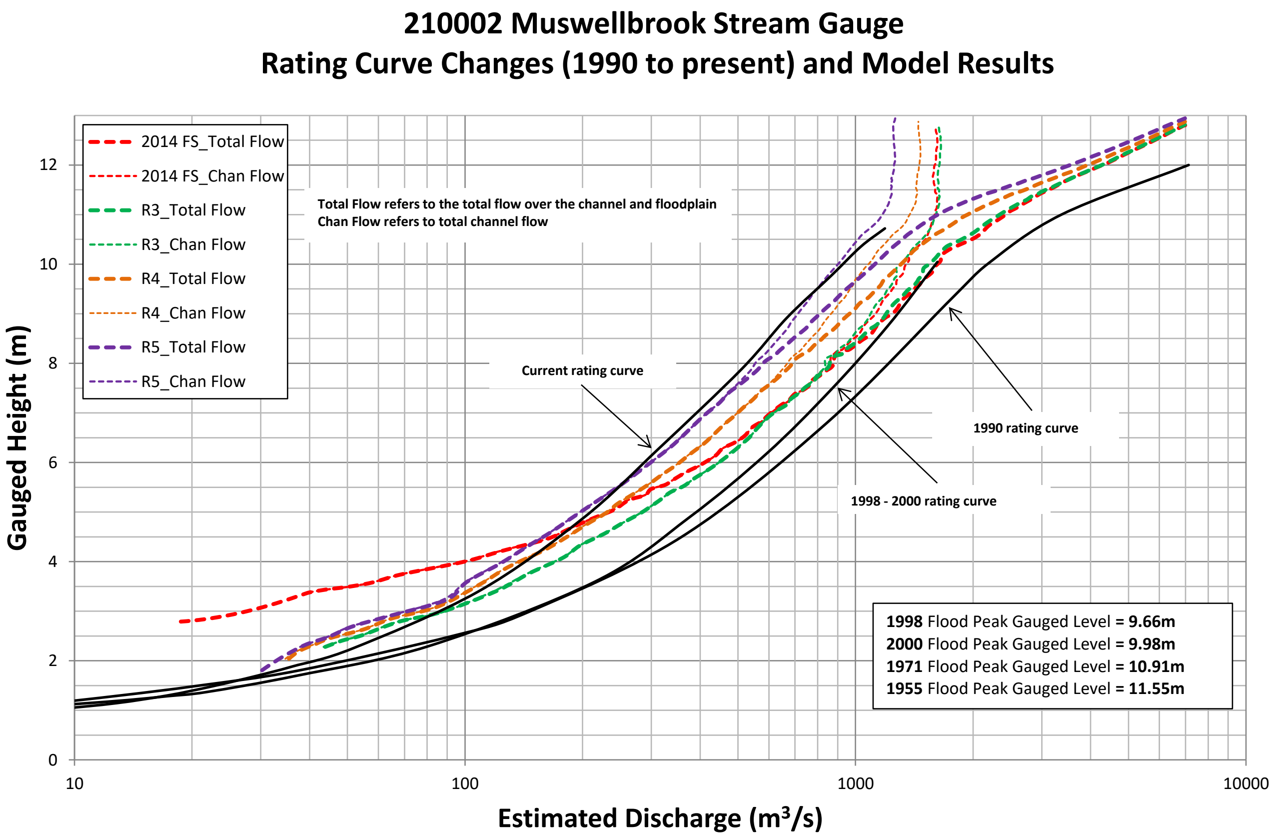

Figure 3-4: **Rating Curve data and RHDHV (2017) Model Results (Muswellbrook Gauge: 21002)**

Source: RHDHV (2017) Figure 5

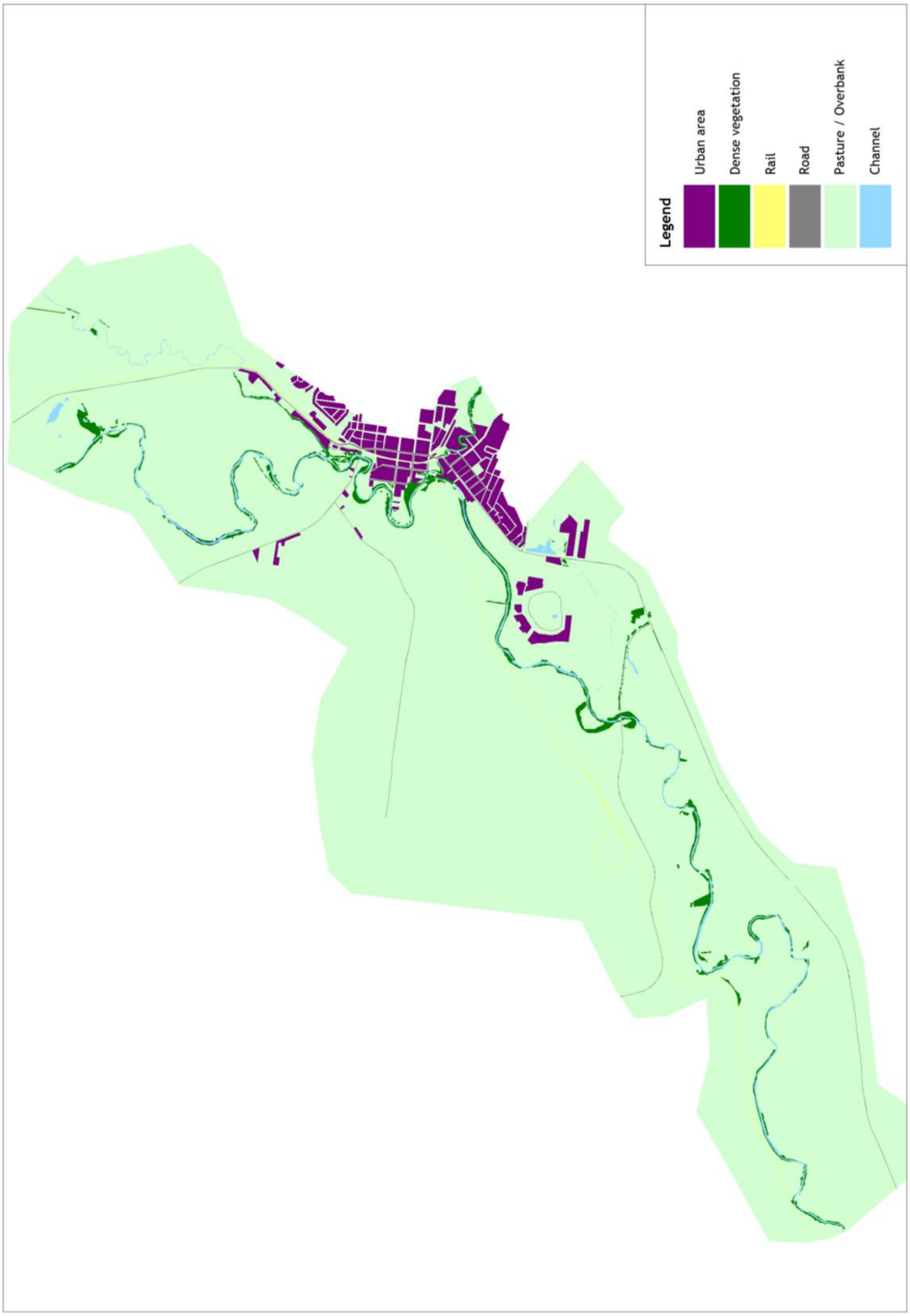

Figure 3-5: Hunter River TUFLOW model Roughness Distribution (WRM (2020))

3.2 Review of Existing Condition Model Results and Comparison to RHDHV (2017)

Figure 6.1, Figure A.1 and Figure A.3 of WRM (2020) show the predicted peak flood depths and extents along the Hunter River floodplain for the 1% AEP, 2% AEP and 5% AEP discharge design events respectively. The presentation of results is considered appropriate to evaluate the project and are in-line with expectations of flood behaviour for a large floodplain. The inclusion of contours of peak flood level assists the interpretation of results.

For the purpose of this review, gridded model results were also provided by WRM for comparison to the equivalent RHDHV (2017) model results. A map showing the difference in 1% AEP (i.e. 100-year ARI) peak water levels between the two models is presented in Figure 3-6 while a graph presenting the statistical difference in water level predictions between the two models is presented in Figure 3-7. In both figures, a positive value is where the WRM (2020) modelled water level is higher than the RHDHV (2017) modelled water level.

From an examination of the statistical difference in water level predictions (Figure 3-7) there is good overall agreement between the two models with virtually no bias in results present. The analysis shows that approximately 65% of the modelled area lies within ±0.1m of the RHDHV (2017) model 1% AEP results and that 80% of the modelled area sits within the range -0.15 to 0.12m of the RHDHV (2017) model 1% AEP result. Less than 5% of the modelled area is associated with water level differences ± 0.3m.

The spatial variation in 1% AEP (i.e. 100-year ARI) water level difference also shows negligible identifiable patterns indicating a key control or source contributing to the modelled difference.

It is interesting to see that while the WRM (2020) discharge was 8.6% higher than that used in RHDHV (2017), because lower channel roughness values were used, there was no systematic increase in predicted water levels for the 1% AEP design event.

Overall it is considered that the WRM (2020) model is suitable for determining the impact of the proposed rail spur and that the results are in good agreement with that presented in the Muswellbrook FRMS&P (RHDHV, 2017).

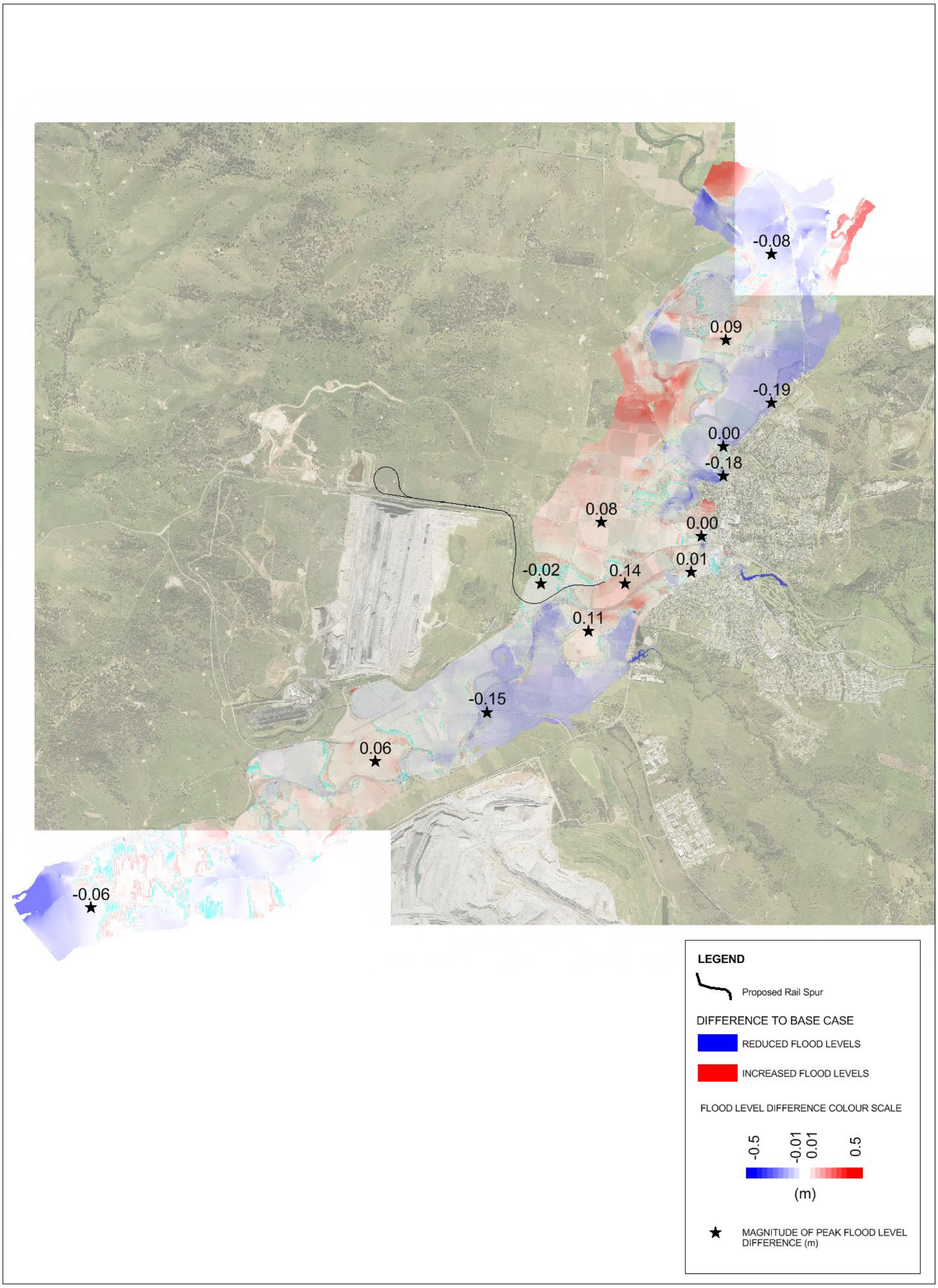

Figure 3-6: Comparison of WRM (2020) 1% AEP Design Flood Level to RHDHV (2017)

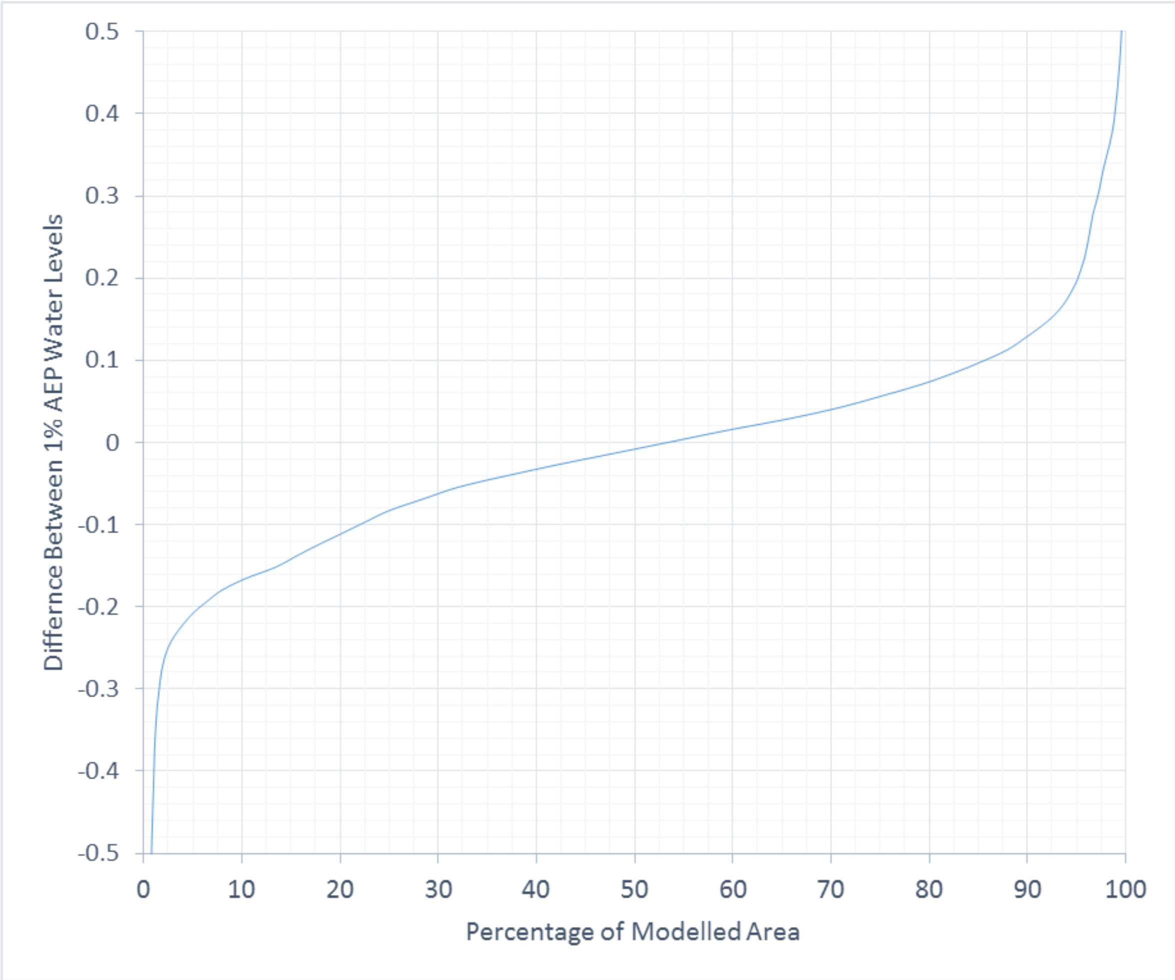

Figure 3-7: Statistical Comparison of WRM (2020) 1% AEP Design Flood Level to RHDHV (2017)

3.3 Review of Proposed Condition Model Results and Impact Assessment

The final design of the proposed rail spur was modelled by WRM (2020) to consider potential impacts of the Rail Modification on flooding. The final detailed design of the proposed rail spur (and associated hydraulic structures) was designed to meet the following (MOD 4 consent conditions (Clause 44C)) criteria for potential flooding impacts for a 1% AEP flood event:

- no more than 0.1 metre increase in flood levels on any privately owned land
- no more than 0.01 metre (1 cm) increase in flood levels at any privately owned dwellings or commercial spaces
- no more than 0.01 m increase in flood levels at any public roads servicing privately owned properties
- no more than 0.1 metres per second (m/s) increase in flood velocities on privately owned dwellings or commercial spaces.

Proposed mitigation measures were included in the modelled design to confirm that the proposed rail spur can be designed to meet the criteria above. The modelled mitigation measures include extension of two existing railway culvert crossings and a seven span bridge in the rail embankment. Details of the proposed mitigation measures are presented in Section 5.4 of WRM (2020). The 7 span bridge consists of 28.5m spans resulting in a waterway opening of 199.5 m. The six bridge piers were represented in the hydraulic model using “layered flow constriction cell” which is considered appropriate.

Figure 3-8 show the predicted flood level impacts while Figure 3-9 shows the predicted velocity impact for the 1% AEP design event. The resulting afflux appears consistent with the partial blockage of the floodplain, while the increase in velocity is associated with accelerated flow through the proposed bridge openings. The results show that the concept design meets the specified MOD4 design criteria which are clearly detailed in Section 6.4 of WRM (2020).

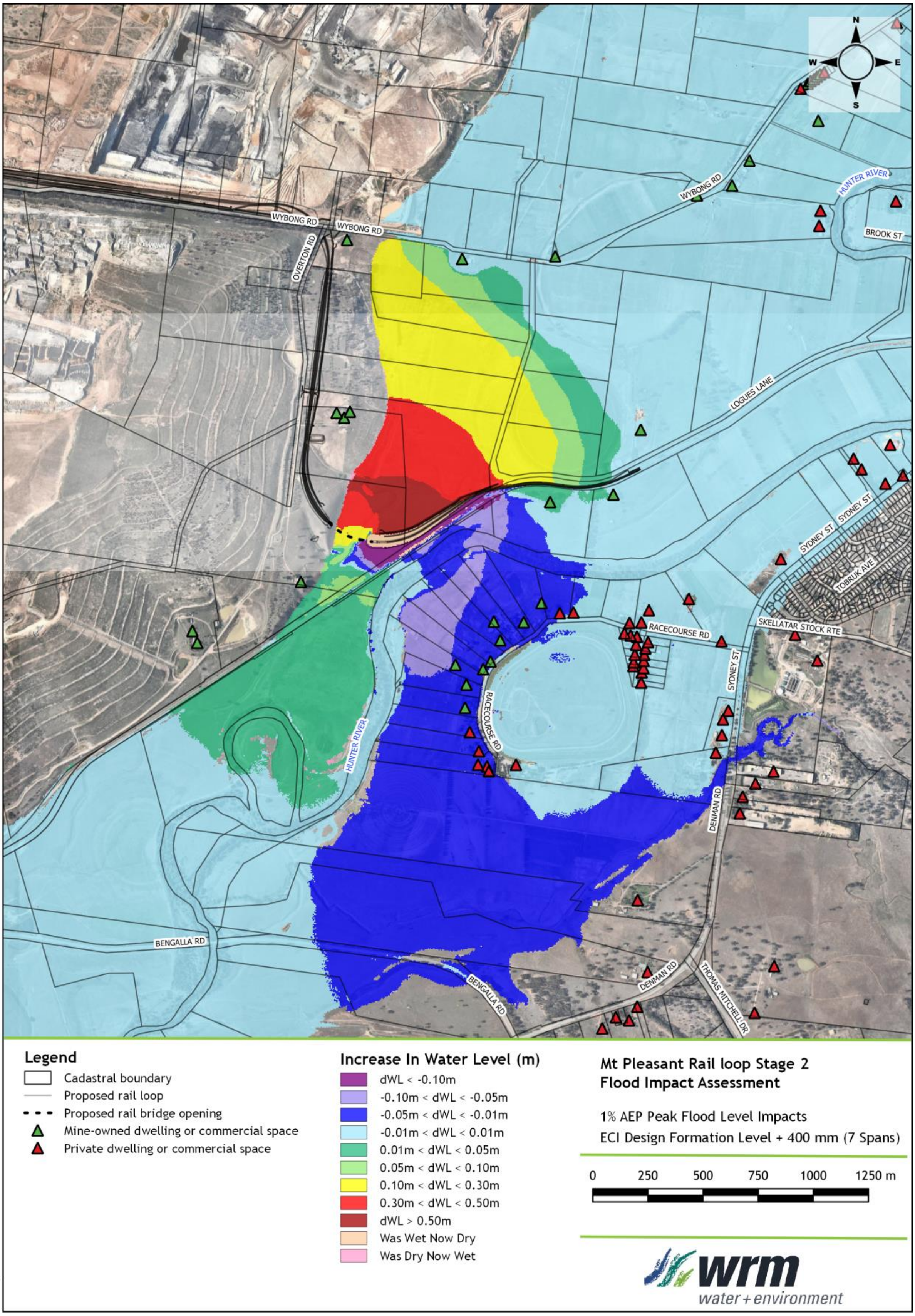

Figure 3-8: Peak flood level impacts, 1% AEP design event (Fig 6.5 WRM (2020))

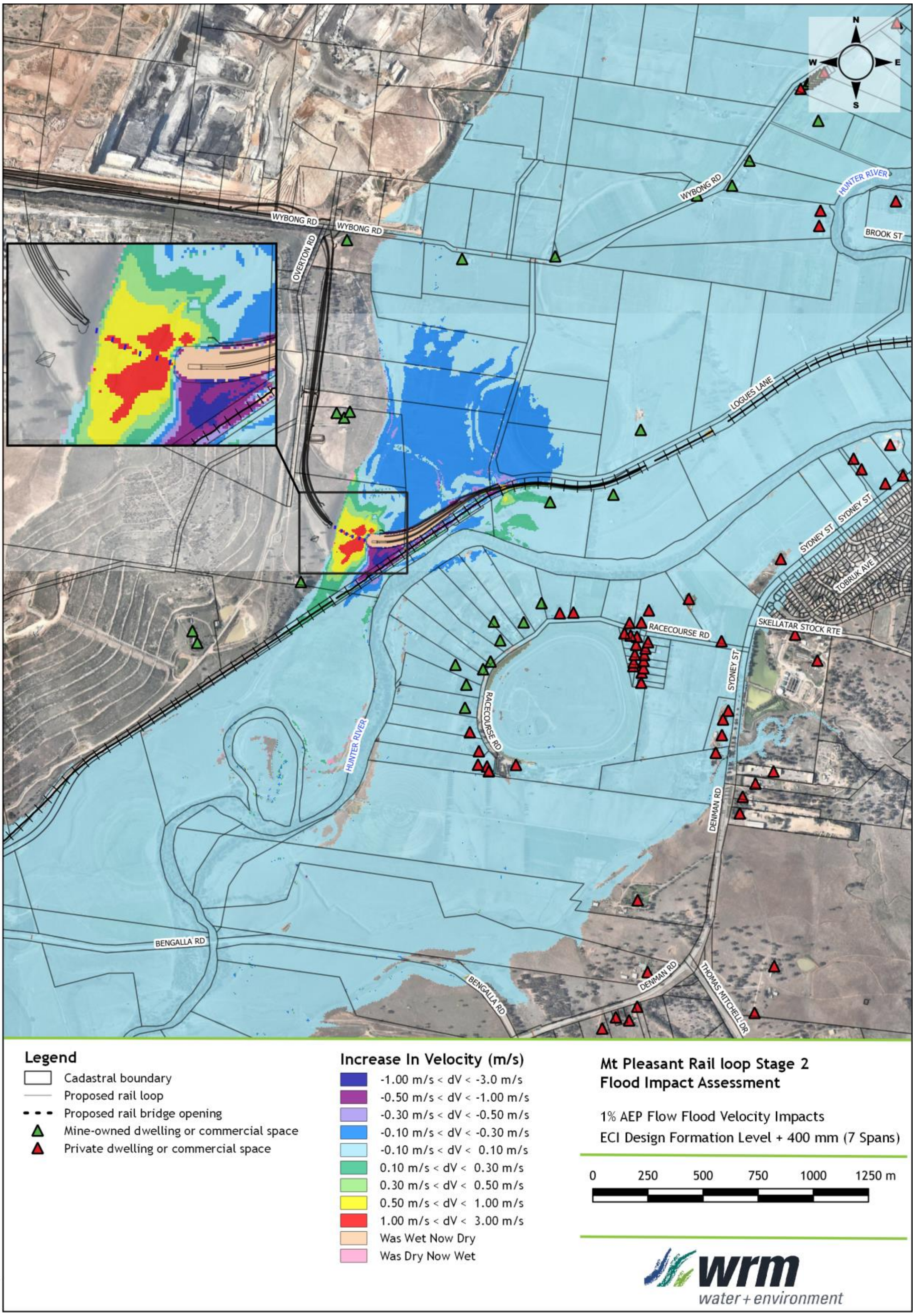

Figure 3-9: Flood velocity impacts, 1% AEP design event (Fig 6.6 WRM (2020))

3.4 Consultation with dPIE and Additional Checks

Consultation with the NSW department of Planning Industry Environment (dPIE), who assess flood risk in NSW and provided the original MOD4 consent criteria, was undertaken to ensure the flood impact was appropriately assessed. dPIE staff indicated that, in addition to the four consent conditions, it would be useful to provide additional information including:

a) The potential for change in flood hazard definition along Wybong Road.

b) If there is a change in when Wybong Road is first flooded.

c) How sensitive is flood impact to model parameters including discharge (+/- 10%) and Mannings / roughness (+/- 20%).

3.4.1 Wybong Road Flood Hazard

Maps of peak flood hazard (using the H1-H6 categorisation) are presented in Figures 6.7 and 6.8 of WRM (2020) for the existing and development conditions for the 1% AEP event. A comparison of the figures shows that there is no discernible change in flood hazard at Wybong Road (which is expected given the change in water level is less than 1cm). The figures also show that there are significant sections of road with an H5 hazard category which means that in the 1% AEP event the road would not be safe for vehicles and would not be considered trafficable in the existing or developed scenario.

3.4.2 Wybong Road Flood Immunity

Section 6.5 of WRM (2020) explains that Wybong Road acts as a hydraulic control which means, provided an extensive backwater does not occur due to the proposed rail loop, any impact on the downstream of Wybong Road will not propagate upstream of the road. Figure 6-12 shows that at the road centre-line, the maximum 1% AEP increase in flood level is 4 mm. Considering that during the 1% AEP event much of the road is covered to a depth of 600 mm, this minor increase is considered insignificant, and is just on the upstream limit of where the proposed development would impact flood levels. The modelled flood impact for smaller events such as the 5% and 2% AEP (20 and 50 year ARI) is presented in Figures A5 and A6 of WRM (2020). The figures show that in these smaller events, the flood impact does not propagate as far upstream as Wybong Road, so there would be no change in when the road is first flooded.

3.4.3 Sensitivity Testing of Flood Impact (discharge and roughness)

WRM (2020) undertook sensitivity testing to provide further confidence that the proposed rail design will meet the MOD4 performance criteria for a range of conditions. While model calibration already allows a high degree of confidence to be associated with the model results, the additional sensitivity testing helps further reduce uncertainty that could still exist.

Additional runs were undertaken for the 1% AEP event for the existing and design conditions to test how sensitive the flood impact is to variations in model parameters: including discharge (+/- 10%) and Mannings / roughness (+/- 20%).

A comparison of WRM (2020) Figure 6.13 to Figure 6.5 shows that a 10% increase in river/floodplain discharge would slightly increase the resulting impact of the proposed rail spur. However, the results show that even with a 10% increase in river discharge, the impact on Wybong Road is still less than 1 cm and hence meets the required MOD4 performance criteria. Likewise, while a 20% increase in roughness slightly increases the modelled flood impact, it is less than 1cm at Wybong Road. Both the reduce flow and roughness scenarios results in less flood impact.

3.4.4 Sensitivity Testing of Flood Impact (structure blockage)

WRM provided an overview of the initial ARR 2019 blockage assessment in WRM (2020) Section 5.4.5 (as presented below in italics). It appears appropriate given the large size of the openings and the location of the proposed bridging elements on shallow areas of the floodplain located a significant distance from the main Hunter River channel. The inclusion of a 20 m wide pier blockage in WRM (2020) Section 6.7, allows the impact of a large blockage to be assessed. Figure 3-10 show the predicted additional flood level impact of 20m pier blockage. It should be noted that the total flood impact is the sum of the impacts presented in Figure 3-8 and Figure 3-10. It shows that while an additional flood impact of up to 5cm is modelled for approximately 1 km upstream of the proposed viaduct, the additional impact at Wybong Road is less than 1 cm, which shows that the MOD4 consent conditions would still be met, even if pier blockage occurred.

The potential blockage due to debris at the bridge piers was assessed using guidelines in Book 6 – Chapter 6 of AR&R 2019. The assessment considered the dimensions of the bridge openings as well as the potential debris sizes from the catchment upstream of the bridge. It was determined that the debris potential at the bridge is “Low”, with a likely blockage level of 0%. Therefore, for this assessment, no additional blockage factor was added for debris blockage for the design case. However, a sensitivity assessment was undertaken which included blockage of a portion of the viaduct (see Section 6.7).

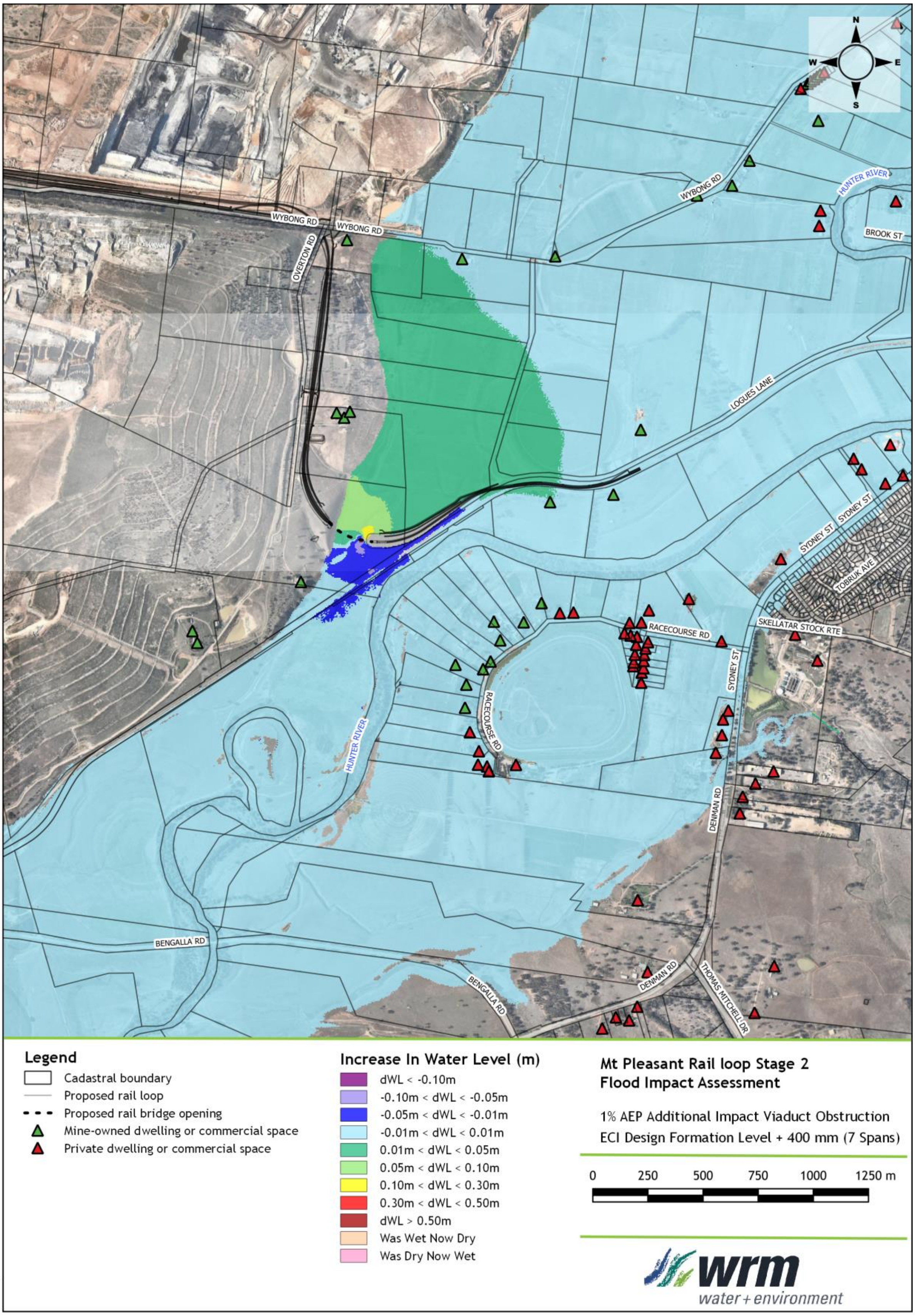

Figure 3-10: 1% AEP additional flood impact due to blockage (Fig 6.17 WRM (2020))

4 Summary and Conclusions

This report provides the required evidence to satisfy condition 44D of the MOD4 conditions to DA 92/97. This independent review has been conducted by Rohan Hudson who (as described in Section 1.2) is suitably qualified and experienced to undertake the review.

A summary of the independent review of the Mount Pleasant Rail Loop Stage 2 – Rail Modification Flood Impact Assessment Report (WRM, 2020) includes:

Hunter River Design Flood Discharge Estimates

A review of the method and magnitude (compared to RHDHV (2017)) of the Hunter River design discharges provided in the WRM (2020) indicate that they are appropriate.

A comparison of the WRM (2020) to RHDHV (2017) FFA shows that the WRM (2020) values are between 1.1 and 6.3% higher (i.e. conservative, more liberal estimate) than those reported in RHDHV (2017) for AEP events ranging from 5% to 0.2% AEP (i.e. 20-year to 500-year ARI). While the RHDHV (2017) estimate is likely to be more accurate (i.e. more data was used) there is good agreement between the two estimates of design discharges between the two studies.

A comparison of WRM (2020) hydrologic model (XP-RAFTS) flows to the RHDV (2017) equivalent shows that the WRM hydrologic flows (adopted for use in the hydraulic model) are up to 8.6% higher for events up to the 1% AEP when compared to hydrologic design flows adopted in RHDHV (2017). The main difference in flows is likely to be attributed to the additional model calibration (required due to correction of gauge rating tables) undertaken in the RHDHV study that resulted in the adoption of a higher Bx (catchment storage) parameter.

A review of the method and magnitude of the Hunter River design discharges provided in the WRM (2020) indicate that they are appropriate for the Mount Pleasant Rail Loop Stage 2 Flood Impact Assessment. Both the design discharge estimates from the FFA and hydrological model are in good agreement with the more sophisticated analysis undertaken in RHDHV (2017) that forms the basis of the Muswellbrook FRMS&P.

The use of slightly higher design discharge means that, provided appropriate roughness values are adopted in the hydraulic model, there should be a degree of conservatism in the WRM (2020) assessment.

Hunter River Model Review

A review of the important elements of the Hunter River TUFLOW model is provided in Table 3-1. Overall the assumptions and methodology appear appropriate and the assessment of the existing conditions appears to be appropriate.

The main difference between the WRM (2020) and RHDHV (2017) are in the selection of roughness values and the representation of deeper (channel pool) sections of the Hunter River. While WRM (2020) adopted a slightly higher pasture/overbank roughness (which will tend to increase flood levels in larger events), the use of lower roughness of dense channel bank vegetation (that has significantly reduced the in bank channel capacity of the Hunter River over the past 30 years) will tend to reduce predicted flood levels, especially for the smaller design events.

A comparison of the WRM (2020) to the RHDHV (2017) model 1% AEP result shows that a majority (i.e > 80%) of the modelled area lies within the water level difference range of ±0.15 metres of the RHDHV (2017) model 1% AEP result. This indicates that while the WRM (2020) discharge was 8.6% higher than that used in RHDHV (2017), because lower channel roughness values were used, there was no substantial overall increase in predicted water levels for the 1% AEP design event.

Overall it is considered that the WRM (2020) model is suitable for determining the impact of the proposed rail spur and that the results are in good agreement with that presented in the Muswellbrook FRMS&P (RHDHV, 2017).

Review of Impact Assessment

Proposed mitigation measures were included in the modelled design to confirm that the proposed rail spur has been designed to meet the specified criteria. The modelled mitigation measures included extension of two existing railway culvert crossings and a seven span bridge in the rail embankment.

Figure 3-8 showed the predicted flood level impacts while Figure 3-9 showed the predicted velocity impact for the 1% AEP design event. The resulting afflux appears consistent with the partial blockage of the floodplain, while the increase in velocity is associated with accelerated flow through the proposed bridge openings. **The results indicate that the proposed design satisfies the specified MOD4 impact criteria defined in condition 44C.**

A review of the flood hazard for Wybong Road and potential changes to the level of flood immunity of the road have also been presented and show the proposed design does not alter the usability of the road. Additional sensitivity testing of key model parameters (including discharge and roughness), show that the specified MOD4 impact criteria are still met under more severe conditions. A 20m pier blockage was also included and also showed that even under blockage conditions, the MOD4 impact criteria are still met.

Conclusion

This report provides the finding of an independent review required under condition 44D of the MOD4 consent and shows that the WRM (2020) Mount Pleasant – Rail Loop Stage 2 Flood Impact Assessment Report demonstrates that the final design of the rail spur is able to meet the specified performance criteria defined in condition 44C of the MOD4 consent.

5 References

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2. Royal HaskoningDHV, 2017, ***Hunter River Flood Study (Muswellbrook to Denman): Model Revisions Report**,* Royal HaskoningDHV (on behalf Muswellbrook Shire Council), dated 19 October 2017.
3. Royal HaskoningDHV (2019), **Muswellbrook FRMS&P**, Prepared by Royal HaskoningDHV on behalf Muswellbrook Shire Council, 8th April 2019
4. WorleyParsons, 2014 '***Hunter River Flood Study (Muswellbrook To Denman)***', Report prepared for Muswellbrook Shire Council by WorleyParsons Services Pty Ltd, 8 September 2014.
5. WRM, 2017, ***Mount Pleasant Operation - Rail Modification Flood Assessment***, Report No 0744-09-B3, dated 19 December 2017
6. WRM, 2020, ***Mount Pleasant Rail Loop Stage 2 - Rail Modification Flood Impact Assessment***, Report No 0744-01-K43, dated 29 May 2020