VICKERY EXTENSION PROJECT

ENVIRONMENTAL IMPACT STATEMENT

APPENDIX C

FLOOD ASSESSMENT

WHITEHAVEN COAL

Vickery Extension Project

Flood Assessment

Whitehaven Coal Limited

0800-02-G10, 10 August 2018

Report Title	Vickery Extension Project - Flood Assessment
Client	Whitehaven Coal Limited c/- Resource Strategies
Report Number	0800-02-G10

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1 Introduction

1.1 BACKGROUND

The former Vickery Coal Mine and the former Canyon Coal Mine are located approximately 25 kilometres (km) north of Gunnedah, in New South Wales (NSW). Open cut and underground mining activities were conducted at the former Vickery Coal Mine between 1986 and 1998. Open cut mining activities at the former Canyon Coal Mine ceased in 2009. The former Vickery and Canyon Coal Mines have been rehabilitated following closure.

The approved Vickery Coal Project (herein referred to as the Approved Mine) (Figure 1.1) is an approved, but yet to be constructed, open cut project involving the development of an open cut coal mine and associated infrastructure, and would facilitate a run-of-mine (ROM) coal production rate of up to approximately 4.5 million tonnes per annum (Mtpa) for a period of 30 years.

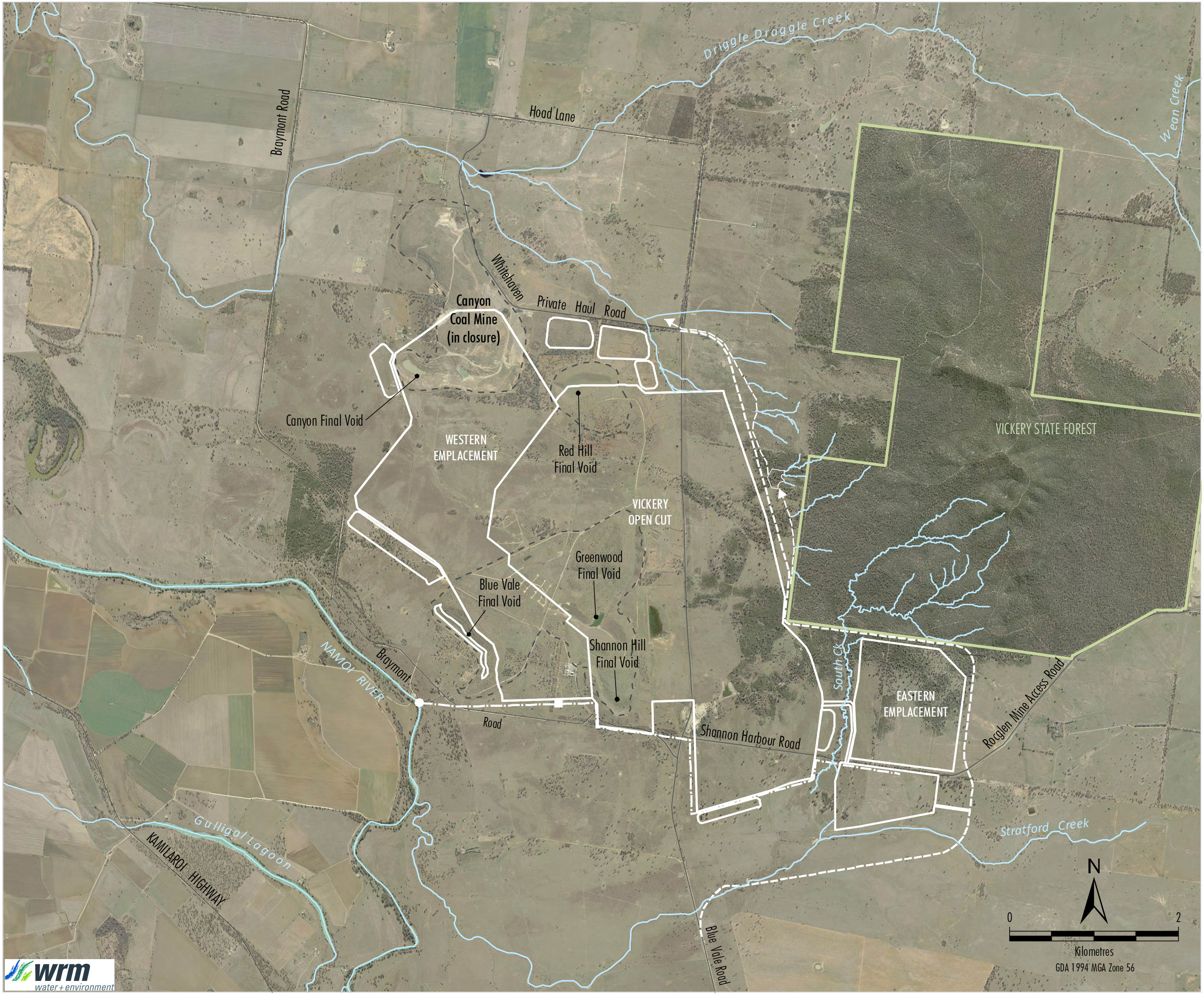
Whitehaven Coal Limited (Whitehaven) is seeking a new Development Consent for extension of open cut mining operations at the Approved Mine (herein referred to as the Vickery Extension Project [the Project]). This would include a physical extension to the Approved Mine footprint to gain access to additional ROM coal reserves, an increase in the footprint of waste rock emplacement areas, an increase in the approved ROM coal mining rate and construction and operation of the Project Coal Handling and Preparation Plant (CHPP), train load-out facility and rail spur (Figure 1.2). This infrastructure would be used for the handling, processing and transport of coal from the Project, as well as other Whitehaven mining operations.

Whitehaven is seeking Development Consent under Part 4 of the NSW *Environmental Planning and Assessment Act, 1979* (EP&A Act) for the Project.

Figure 1.2 illustrates the general arrangement of the Project. A detailed description of the Project is provided in Section 2 in the Main Report of the Environmental Impact Statement (EIS).

Figure 1.3 shows the location of the Project and the various watercourses in the vicinity of the Project. The Project mining area is located on the edge of the Namoi River floodplain and the secondary infrastructure area (Figure 1.2) would be constructed on and adjacent to the Stratford Creek floodplain, which is a tributary of the Namoi River. The Project rail spur crosses the Namoi River floodplain before connecting to the Werris Creek Mungindi Railway. The Project rail loop is located east of the confluence between the Namoi River and Stratford Creek.

This report presents the methodology and results of the hydrological and hydraulic modelling undertaken to address the flooding related requirements in the Secretary's Environmental Assessment Requirements (SEARs) and in particular determine flooding characteristics in the various watercourses located in the vicinity of the Project under existing conditions (pre-mine) and proposed conditions with the mine in place.



LEGEND

- State Forest
- Historic Mining Area
- Indicative Extent of Vickery Coal Project
- Road Realignment
- Up-catchment Diversion
- Pipeline and Powerline Corridor

Source: LPMA - Topographic Base (2010) and Orthophoto (Boggabri 2011); Department of Industry (2015)

WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

General Arrangement of the Approved Mine

Figure 1.1

wrm water + environment

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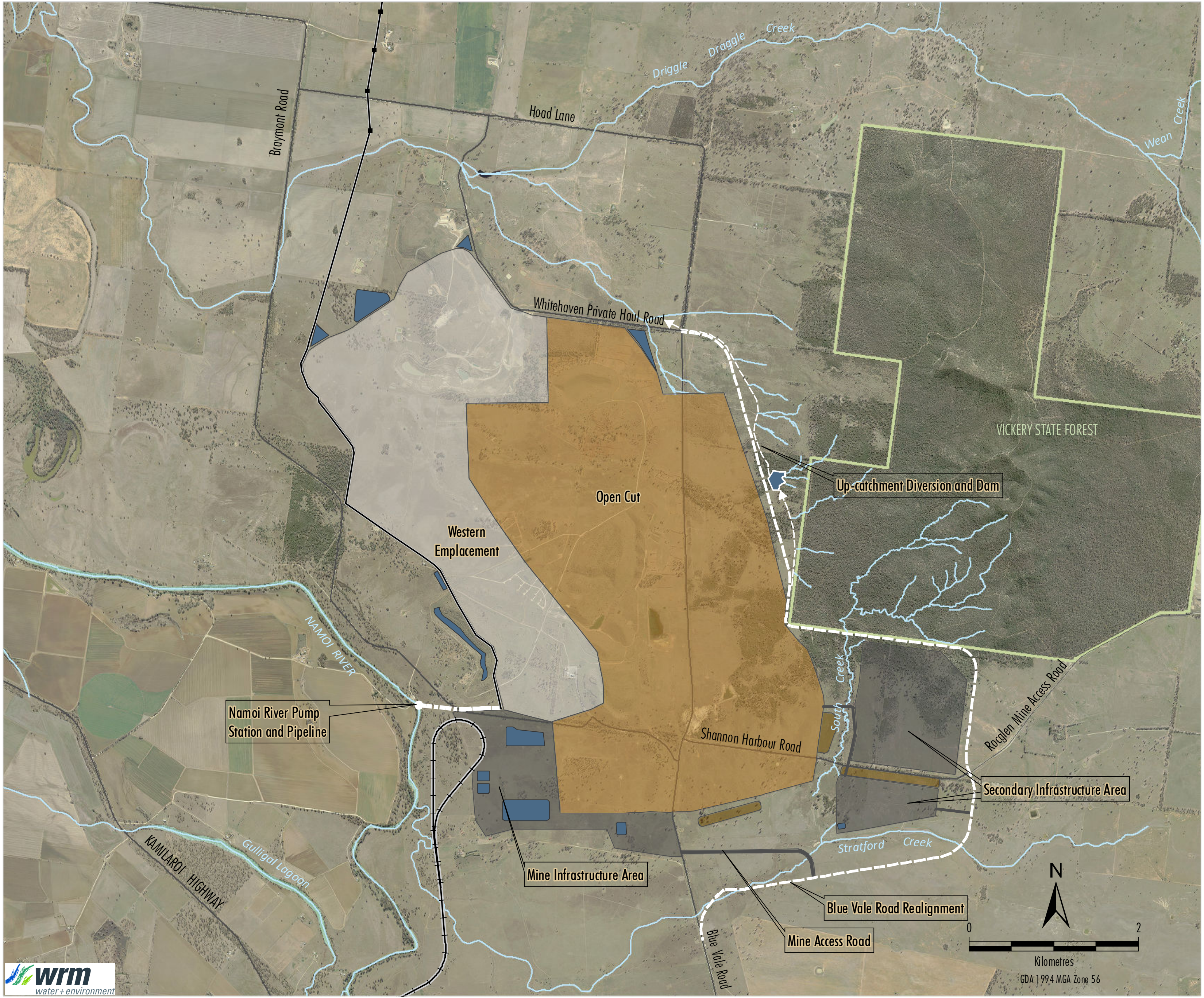

LEGEND

- State Forest

Project Components

- Indicative Extent of Open Cut
- Indicative Extent of Out of Pit Waste Rock Emplacement
- Indicative Extent of Infrastructure Area
- Indicative Extent of Soil Stockpile
- Indicative Extent of Water Storage
- Indicative Mine Access Road Alignment
- Indicative Namoi River Pump Station and Pipeline
- Indicative Road Realignment
- Indicative Up-catchment Diversion and Dam Location
- Indicative Rail Spur Alignment
- Indicative Location of Groundwater Bores and Pipeline

Source: Orthophoto - Department of Land and Property Information, Aerial Photography (July 2011); Department of Industry (2015); Essential Energy (2015)

WHITEHAVEN COAL

VICKERY EXTENSION PROJECT

General Arrangement of the Project

Figure 1.2

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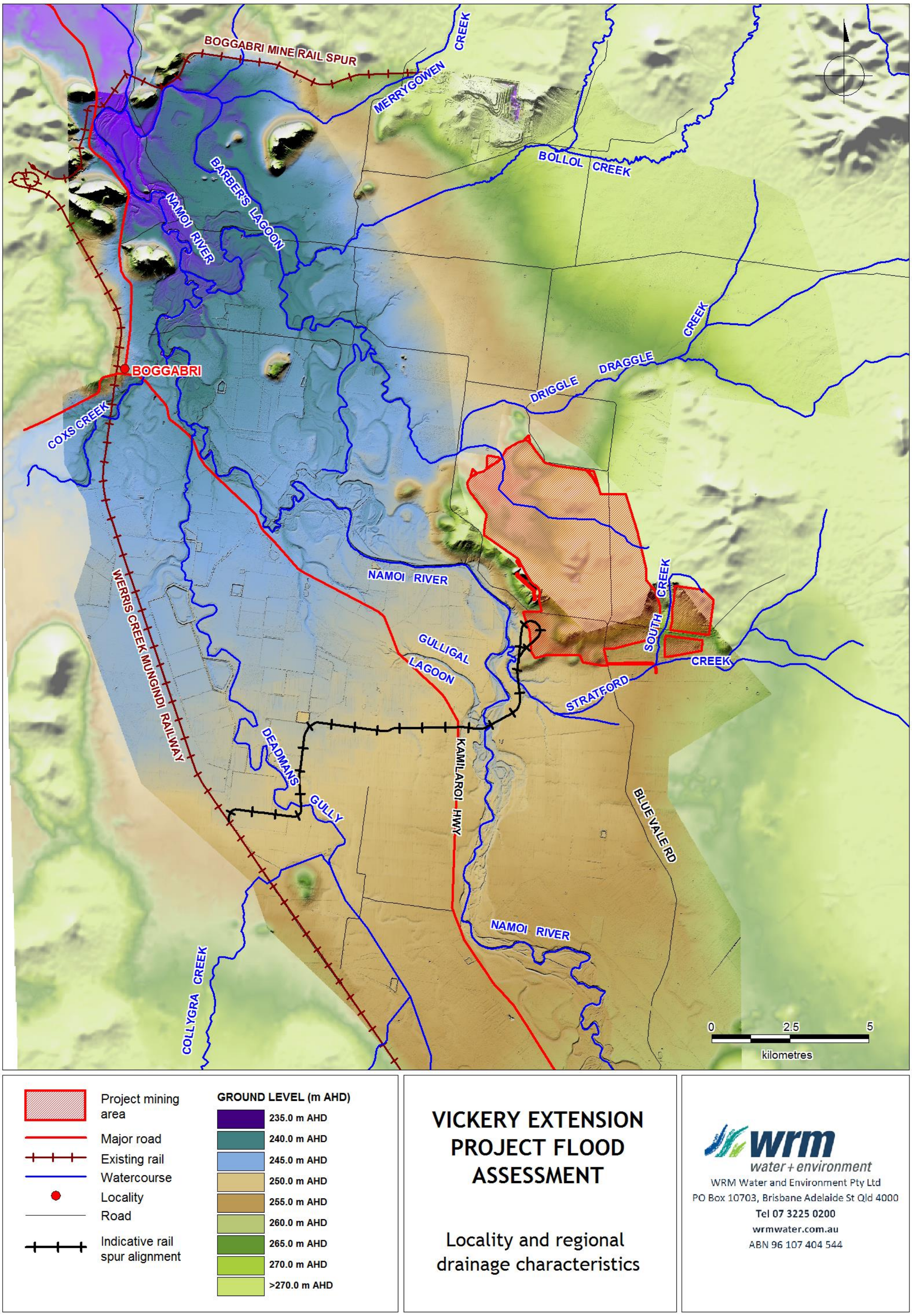


Figure 1.3 – Locality and regional drainage characteristics

1.2 REPORT STRUCTURE

This report is structured as follows:

- **Section 2** outlines the SEARs in relation to flooding and identifies where in the document each requirement has been addressed.
- **Section 3** describes the drainage characteristics in the vicinity of the Project.
- **Section 4** describes the methods adopted to estimate design discharges in the various watercourses in the vicinity of the Project. This section includes flood frequency analysis (FFA) results, a description of hydrological model development and validation, as well as estimated design discharges for various design events.
- **Section 5** describes the methodology and results of hydraulic modelling undertaken to estimate design flood levels in the vicinity of the Project.
- **Section 6** describes the impact of the Project and associated infrastructure on flood characteristics (including predicted changes to flood levels, velocities and flow distribution) based on the hydraulic model results described in Section 5.
- **Section 7** summarises the results of this assessment.

2 Assessment requirements and regulatory framework

2.1 SECRETARY'S ENVIRONMENTAL ASSESSMENT REQUIREMENTS

The SEARs for the Project were issued on 19 February 2016 and updated on 19 July 2018 (State Significant Development (SSD) 7480). This Flood Assessment report has been prepared to address the flooding related SEARs, as well as the various agencies' requirements and recommendations which supported the SEARs. Table 2.1 lists the SEARs for the Project (SSD_7480) that are relevant to this assessment. Table 2.2 lists the associated agency comments that are relevant to this assessment and the sections of this report in which they are addressed.

This report only addresses the flooding aspects of these SEARs and agency requirements.

Table 2.1 – Secretary's Environmental Assessment Requirements

SEARs	Where considered in this report
The EIS must address the following specific issues: • **Water** – including: - an assessment of the potential flooding impacts of the development.	This requirement has been addressed through the preparation of this flood assessment report.

Table 2.2 – Associated agency requirements and recommendations

Agency comment	Where considered in this report
<u>Comments by DPI Lands</u>:	
The proposed rail spur will intersect numerous formed public roads. The Environmental Assessment will need to detail how those impacts will be managed under the Roads Act, 1993, and the proposed treatments to ensure continued public access.	Section 6 - describes the potential impacts of the Project on flood levels and velocities along Kamilaroi Highway and Blue Vale Road.
The proposed rail spur will cross the Namoi River. The Environmental Assessment will need to address any issues associated with construction within the bed and bank of the river, and also give consideration to any native title rights and interests in this land.	Section 6.2 – describes the Project rail spur. Impacts to aquatic ecology are considered separately in the Aquatic Ecology Assessment (EcoLogical, 2018) (Appendix N of the EIS). Native Title is considered in other parts of the EIS.

Agency comment	Where considered in this report
Comments by DPI Fisheries:	
DPI Fisheries should be consulted with regards to the crossing methodology and site specific mitigation measures for construction of new culverts or bridges in watercourses that are considered to be Key Fish Habitat within the rail spur investigation corridors. The design and construction of bridges, culverts, and temporary access tracks across all waterways should be undertaken in accordance with the Department's Policy and Guidelines for Fish Habitat Conservation and Management (Update 2013). The EA should provide details on methods of dredging, duration and timing of works, and the proposed mitigation measures to protect riparian and aquatic habitat. DPI Fisheries should be consulted with regards to any temporary measures that will result in blocking fish passage. This includes coffer dams, temporary access tracks or redirecting flows whilst works are conducted in Key Fish Habitat.	Section 6 – describes the Project rail spur. Impacts to aquatic ecology are considered separately in the Aquatic Ecology Assessment (EcoLogical, 2018) (Appendix N of the EIS).
NSW OEH – Attachment A (Flooding and coastal erosion):	
The EIS must map the following features relevant to flooding as described in the Floodplain Development Manual (2005) (NSW Government 2005) including: • Flood prone land. • Flood planning area, the area below the flood planning level. • Hydraulic categorisation (floodways and flood storage areas).	Section 5.4 shows the extent of flood prone land defined by an extreme flood event. “Flood planning area” and “hydraulic categorisation” was not required to be mapped for the purposes of this impact assessment as the area is managed under the draft FMP (see Section 2.2).
The EIS must describe flood assessment and modelling undertaken in determining the design flood levels for events, including a minimum of the 1 in 10 year, 1 in 100 year flood levels and the probable maximum flood, or an equivalent extreme event.	Section 4 and 5 - describes the hydrology and hydraulic modelling to estimate peak flood levels for the 1 in 5, 1 in 20, and 1 in 100 annual exceedance probability (AEP) events in accordance with The Floodplain Development Manual (NSW Government, 2005) (the Manual). The 1 in 10 AEP event was not specifically reported in this assessment), however the estimated peak flood levels would be between the 1 in 5 (20%) and 1 in 20 (5%) AEP events which are included in this assessment. An extreme event equal to three times the 1 in 100 AEP flood event was included in this assessment as a representation of the probable maximum flood (PMF) for Namoi River. This assessment was done to assess the PMF flood level and extent in relation to the open cut mine area.

Agency comment	Where considered in this report
The EIS must model the effect of the proposed Vickery Extension Project (including fill) on the flood behaviour under the following scenarios: • Current flood behaviour for a range of design events as identified in 8) above. The 1 in 200 and 1 in 500 year flood events as proxies for assessing sensitivity to an increase in rainfall intensity of flood producing rainfall events due to climate change.	Section 6 - describes the effect of the Project on peak flood levels and extents. The effects of climate change are also addressed in this section.
Modelling in the EIS must consider and document: • The impact on existing flood behaviour for a full range of flood events including up to the probable maximum flood. • Impacts of the development on flood behaviour resulting in detrimental changes in potential flood affection of other development or land. This may include redirection of flow, flow velocities, flood levels, hazards and hydraulic categories. • Relevant provisions of the NSW Floodplain Development Manual 2005.	Section 6. Section 2.2.
The EIS must assess the impacts on the proposed Vickery Extension Project on flood behaviour, including: • Whether there will be detrimental increases in the potential flood affectation of other properties, assets and infrastructure. • Consistency with Council floodplain risk management plans. • Compatibility with the flood hazard of the land. • Compatibility with the hydraulic functions of flow conveyance in floodways and storage in flood storage areas of the land. • Whether there will be adverse effect to beneficial inundation of the floodplain environment, on adjacent or downstream of the site. • Whether there will be direct increase in erosion, siltation, destruction of riparian vegetation, destruction of riparian vegetation or a reduction in the stability of river banks or watercourses. • Any impacts the development may have upon existing community emergency management arrangements for flooding. These matters are to be discussed with the SES and Council. • Whether the proposal incorporates specific measures to manage risk to life from flood. • Emergency management, evacuation and access, and contingency measures for the development considering the full range of flood risk (based upon the probable maximum flood or an equivalent extreme flood event). These matters are to be discussed with and have support of Council and the SES. • Any impacts the development may have on the social and economic costs to community as consequence of flooding.	Section 6 and Attachment 5 of the EIS. Social and economic impacts are considered separately in the Socio-economic Assessment (AnalytEcon, 2018) (Appendix J of the EIS).

2.2 NSW GOVERNMENT'S FLOOD PRONE LAND POLICY

The Floodplain Development Manual (NSW Government, 2005) (the Manual) has been prepared to support the NSW Government's Flood Prone Land Policy. The primary objective of the policy is to develop sustainable strategies for managing human occupation and use of the floodplain using risk management principles. The Manual provides a framework for implementing the policy to achieve the policies primary objective. It also outlines processes for ensuring these needs are addressed through the development of Floodplain Management Plans (FMPs).

2.2.1 Namoi River flooding

The Office of Environment and Heritage (OEH) has prepared rural FMPs using the Manual that define the requirements for managing floodwaters within rural floodplains. These plans, developed in consultation with local farming communities, help to provide farmers with knowledge about their risk exposure and examine ways they can manage this risk while maintaining the flooding regimes to waterways and flood-dependent ecosystems.

Licensing of works and compliance functions under Part 8 of the *Water Act 1912* (currently being replaced by provisions within the *Water Management Act 2000)* are the responsibility of the NSW Department of Industry - Water (DI-Water). The statutory FMPs prepared under the *Water Act 1912* set out schemes for the management of floodwaters.

Part of the Project area, including the Project rail spur, is located within the gazetted Namoi River floodplain defined by the Carroll to Boggabri FMP (NSW DNR, 2006). The FMP identifies a set of rules that determine whether works on the Namoi River floodplain comply with the intent of the FMP. These rules are based on the 1984 historical flood, which is equivalent to 25% of the 1955 flood. Works outside the extent of this historical flood event are considered to comply with the requirements of the FMP.

OEH and Department of Primary Industries - Water (DPI Water) (now DI-Water) have developed a draft of a new Floodplain Management Plan for the Upper Namoi Valley Floodplain (draft FMP) in pursuance of Section 50 of the *Water Management Act 2000* to replace the now superseded part of the *Water Act 1912*. The draft FMP contains rules to coordinate the approval of new flood works or amendments to existing flood works in a similar manner to the existing FMP. However, rules have now been defined for a number of management zones that represent different hydraulic and ecological regions across the floodplain. The management zones have been defined in accordance with clause 41A of the *Water Management (General) Regulation 2011* (the Regulation). Descriptions of the management zones are given in Table 2.3. The locations of the zones are shown in Appendix A.

Notwithstanding the fact that the draft FMP has not been finalised or gazetted[1], the management rules given in the draft FMP have been used as the basis for assessing the infrastructure proposed as part of the Project. These rules and the management zones have been developed by assessing the flooding characteristics of a small flood represented by a 20% AEP design flood event or the 1992 historical flood and a number of large flood events represented by three historical floods (1998, 1971 and 1984) as well as the 5% AEP design flood event. For this assessment, the proposed works have been assessed against the 20% AEP (small flood), 5% AEP (large flood) as well as for 1% AEP design flood to satisfy the requirements of the SEARs.

[1] In addition, the Project would not require a flood work approval under Section 90 of the *Water Management Act 2000* as this requirement does not apply to State Significant Development with development consent as per Section 4.41 of the *Environmental Planning and Assessment Act 1979*.

Figure 2.1 shows that parts of the Project mining area are located within the Zone C (flood fringe) management zone. The Blue Vale Road realignment (approved for the Approved Mine) crosses the AID (ill-defined floodway) and BL (floodplain) management zones (Stratford Creek) and the Project rail spur crosses the AD (defined floodway), AID, BL, C and D management zones. The objectives given in the draft FMP for each management zone have been adopted for the assessment of the Project infrastructure (noting that the Project would not require a flood work approval under the *Water Management Act 2000* due to section 4.41 of the *Environmental Planning and Assessment Act 1979*), including:

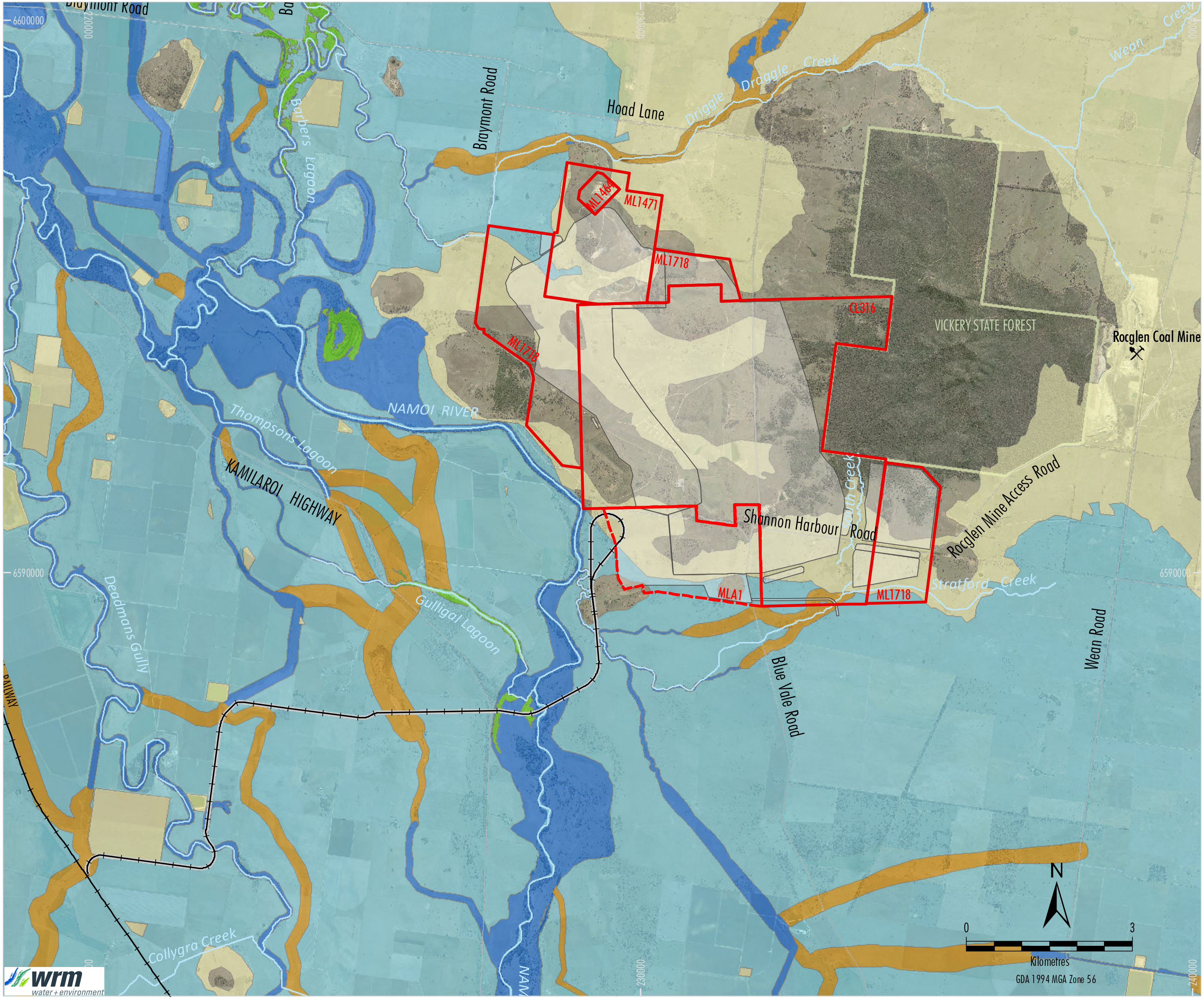
- flood levels should not increase by more than 20 cm on adjacent privately-owned landholdings;
- increases in flood level and velocity should not impact on high value infrastructure (houses);
- peak flood flow should not be redistributed more than 5% across the floodplain;
- velocity should not increase by more than 50%;
- flood connectivity to ecological and/or cultural assets and facilitate fish passage should be maintained;
- drainage time on adjacent land holdings within 24 hours of existing drainage times should be maintained;
- the cumulative impact that the proposed flood work and other existing works on the landholding may have on adjacent landholdings should be considered; and
- increases on flood level and velocity should not impact on heritage sites.

Table 2.3 - Upper Namoi River Management Zones, Draft FMP

Management Zone	Description
AD (defined floodways)	Includes defined floodways with major drainage lines and other areas where a significant discharge of floodwater occurs during all flood events. These areas are generally characterised by relatively high flood flow velocity and depth
AID (ill-defined floodways)	Includes ill-defined floodways that are major discharge areas without clear channels or banks
(BU/BL (floodplain)	Includes areas of the Upper/Lower Liverpool Plains Floodplain that are important for the conveyance of floodwater during large flood events and for the temporary pondage of floodwaters during the passage of a flood. Its outer boundary is defined by a slope of less than or equal to 0.5%
C (flood fringe)	Contains flood fringe and flood protected developed areas
CU (Urban)	Contains urban areas
D	Is a special protection zone for areas of ecological and/or cultural significance

2.2.2 Namoi River tributaries

The proposed mine secondary infrastructure is located adjacent to Stratford Creek and its tributary, South Creek, drains through the secondary infrastructure area (Figure 1.2). The north-western corner of the Project and the Project borefield and pipeline are located adjacent to and across the Driggle Draggle Creek floodplain. The impacts of these infrastructure have been assessed against a range of design flood events including the 20%, 5% and 1% AEP events.



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LEGEND

- Mining Tenement Boundary (ML & CL)
- Mining Lease Application (MLA)
- State Forest
- Railway
- Indicative Extent of Project Mining Area Components
- Indicative Rail Spur Alignment

Draft Upper Namoi Management Zones

- Zone AD – Defined Floodways
- Zone AID – Ill-defined Floodways
- Zone BL – Flood Storage and Secondary Flood Discharge – Upper Liverpool Plains
- Zone C – Flood Fringe and Flood Protected Developed Area
- Zone D – Special Protection Zone

Source: Orthophoto - Department of Land and Property Information, Aerial Photography (July 2011); Department of Industry (2015); Office of Environment and Heritage (2016)

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VICKERY EXTENSION PROJECT

Draft FMP Management Zones

Figure 2.1

3 Drainage characteristics

3.1 NAMOI RIVER

Figure 1.3 shows the drainage system within the area of interest between Gunnedah and Boggabri and the location of the Project mining area and Project rail spur.

The main drainage feature in the area of interest is the Namoi River, which drains in a northerly direction to the west of the Project mining area. The Namoi River catchment is bounded by the Great Dividing Range in the east, the Liverpool Ranges and Warrumbungle Ranges in the south, and the Nandewar Ranges and Mt. Kaputar to the north. Major tributaries of the Namoi River include Cox's Creek and the Mooki, Peel, Cockburn, Manilla, and Macdonald rivers, all of which join the Namoi upstream of Boggabri. The catchment area of the Namoi River to Boggabri is approximately 22,600 square kilometres (km^2).

The Namoi River adjacent to the proposed mine is characterised by a 50 metre (m) to 70 m wide main channel meandering along a lower terrace floodplain. The lower terrace contains several remnant river channels and is about 500 m to 1,200 m wide. The lower terrace floodplain cuts through the greater Namoi River floodplain that varies in width from 6 km to 11 km.

The Namoi River floodwater remains within the banks of the lower terrace floodplain in the vicinity of the Approved Mine for events up to about the 10% AEP flood. For larger events, floodwater overflows at several locations onto both the eastern and western floodplains.

Floodwater overflowing from the Namoi River onto the western floodplain drains in a westerly direction to Deadmans Gully. Deadmans Gully converges with Collygra Creek, which eventually drains to the Namoi River south of Boggabri.

Floodwater overflowing onto the eastern floodplain to the south of the Approved Mine drains in an unconfined manner until it drains into Stratford Creek. Stratford Creek drains into the Namoi River immediately to the south of the Project.

For events between the 5% and 2% AEP events, floodwater that overflows onto the eastern and western floodplains drains independently of the main river channel, with flood levels that are generally lower than the adjacent Namoi River flood levels. For larger events, the floodwaters converge and flow as one water body across the entire floodplain.

3.2 LOCAL DRAINAGE

Several minor tributaries drain into the Namoi River from the east including Stratford Creek, to the immediate south of the Approved Mine, Driggle Draggle and Bollol creeks to the north of the Approved Mine. The catchment areas of Stratford, Driggle Draggle and Bollol Creeks to the Namoi River are 105 km^2, 248 km^2 and 158 km^2 respectively.

The catchments of Stratford, Driggle Draggle, Bollol and Merrygowen Creeks generally drain independently of the Namoi River across broad and ill-defined flow paths, generally at shallow depths. Driggle Draggle Creek receives overflows from Bollol Creek during large flood events. They are all potentially affected by backwater flows from the Namoi River at their downstream ends.

A minor tributary of Stratford Creek, referred to as South Creek, drains from the Vickery State Forest in a southerly direction between the open cut and the secondary infrastructure area in a generally unconfined manner. The catchment area of South Creek to Stratford Creek confluence is 7 km^2.

A tributary of Driggle Draggle Creek crosses the Project mining area before draining around the northern side of the Project.

4 Estimation of flood discharges

4.1 METHODOLOGY

The methodology for estimating flood discharges in the various watercourses in the vicinity of the Project differs depending on catchment and available data.

Namoi River design discharges for the 20%, 5% and 1% AEP events were estimated by undertaking an annual series FFA of the recorded flows at the Gunnedah stream gauge (gauge no. 419001). An extreme event equal to three times the 1% AEP flood event was included in this assessment as a representation of the PMF.

To calibrate the Namoi River hydraulic model, historical Namoi River discharge flood hydrographs for the 1955 and 1998 events were obtained from the quasi-2D hydraulic model (MIKE 11) developed as part of the Carroll to Boggabri Flood Study (SMEC, 2003) and provided by OEH. This model extends upstream of Gunnedah and provides estimates of the distribution of flow between the river channel and the overbank floodplains.

Design flood discharges in the Namoi River tributaries, including Collygra Creek, Deadmans Gully, Stratford Creek, South Creek, Driggle Draggle and Bollol Creek were estimated using the XP-RAFTS hydrological software (XP Software, 2013) and validated against design discharges estimated using the Draft Australian Rainfall and Runoff (ARR) Regional Flood Frequency Estimation model (RFFE) (Ball J et al, 2016).

4.2 NAMOI RIVER DISCHARGES

4.2.1 Historical event flood discharges

SMEC (2003) developed a quasi-2D hydraulic model (MIKE 11) of the Namoi River and floodplain to determine peak flood levels for the 1998 and 1955 historical floods. These results form the basis of the Carroll to Boggabri FMP and were used to calibrate the Namoi River hydraulic model. The SMEC MIKE 11 model provided inflow discharge hydrographs at the following locations:

- Namoi River - main channel;
- Namoi River - eastern floodplain; and
- Deadmans Gully.

Figure 4.1 and Figure 4.2 present the MIKE 11 discharges for the 1998 and 1955 flood events respectively at each of the three upstream inflow locations. These flood discharge hydrographs were obtained directly from flow data embedded in the MIKE 11 model. The combined flow from these locations represent the total Namoi River flow as it passes Gunnedah, separated into the floodplain and river flows.

For the 1998 flood event, a higher proportion of the peak flood flow drains along the Namoi River main channel, whereas for the 1955 event (a significantly larger event) the majority of the peak flow drains into the area via the Namoi River eastern floodplain. Additionally, the floodplain flow peaks a little later than the Namoi River channel for the 1998 events, whereas the peak occurs concurrently for the 1955 event, indicating that the event was large enough for the three flow paths to combine.

4.2.2 Flood frequency analysis

An annual series FFA was undertaken of the 48 years (1968 to 2015) of recorded stream flow data at the Namoi River at Gunnedah stream gauge (gauge no. 419001) to estimate the 20%, 5% and 1% AEP design discharges. The estimated peak discharge for the 1955 flood event, which was the largest historical event on record, was also included in the FFA (shown as “historical data” on Figure 4.3).

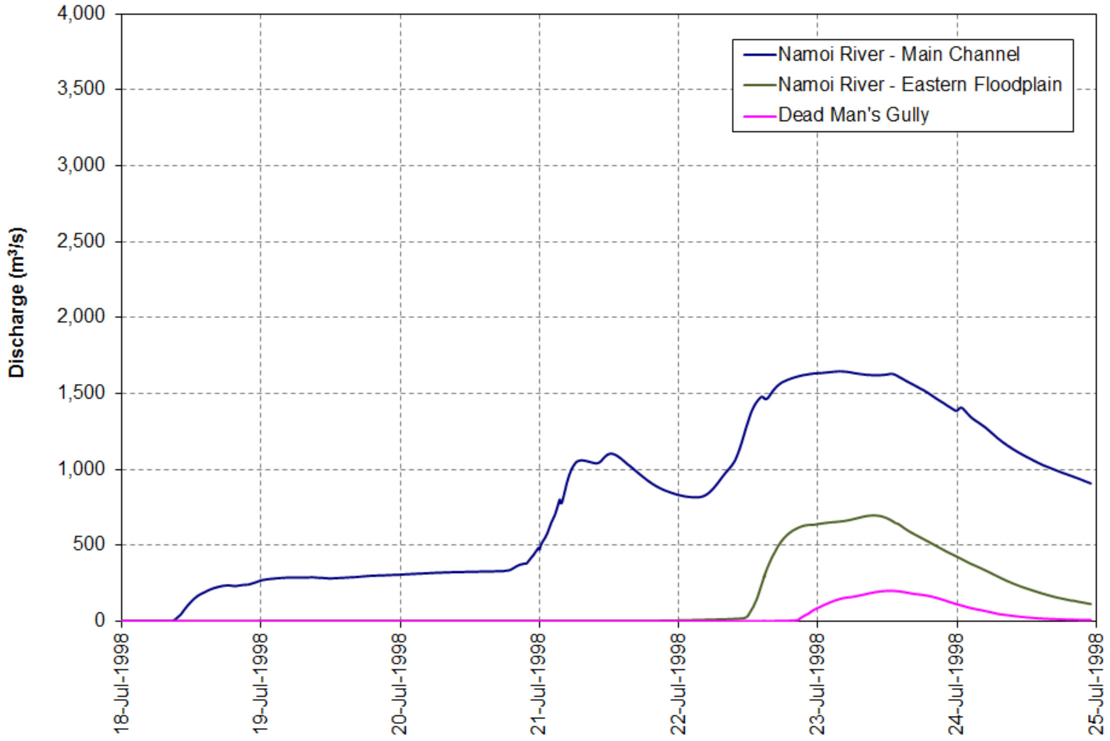


Figure 4.1 - MIKE 11 model flood discharges, 1998 event

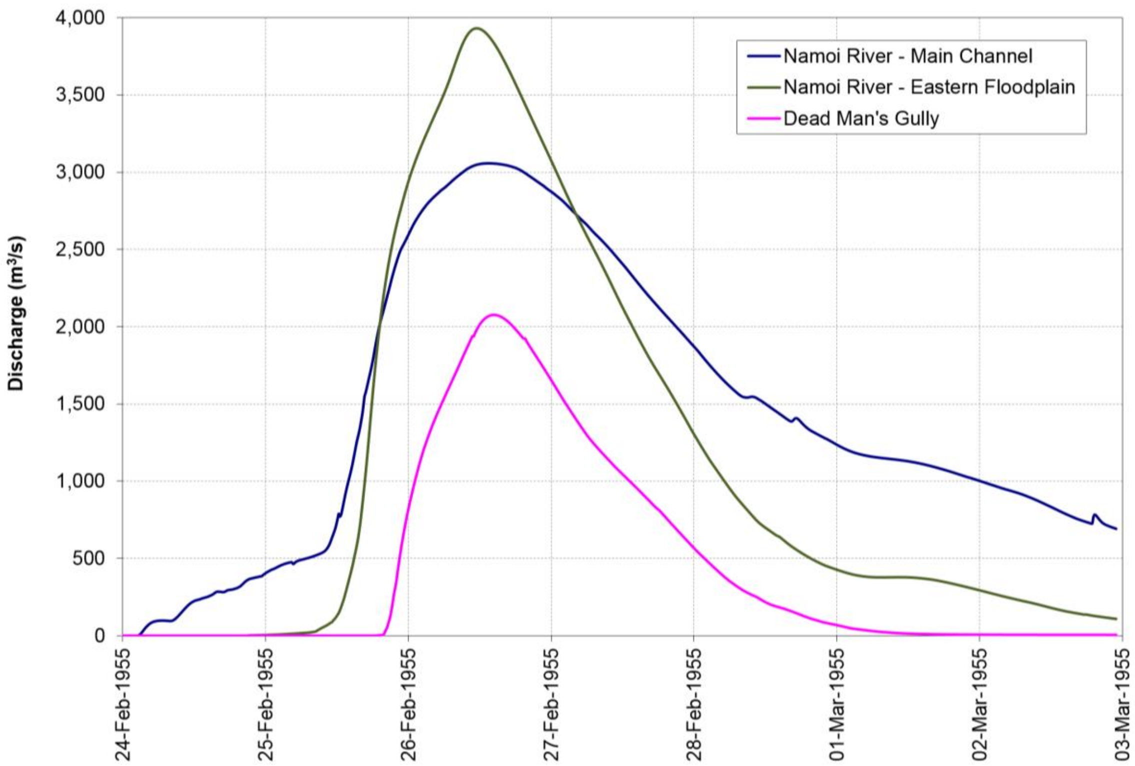


Figure 4.2 - MIKE 11 model flood discharges, 1955 event

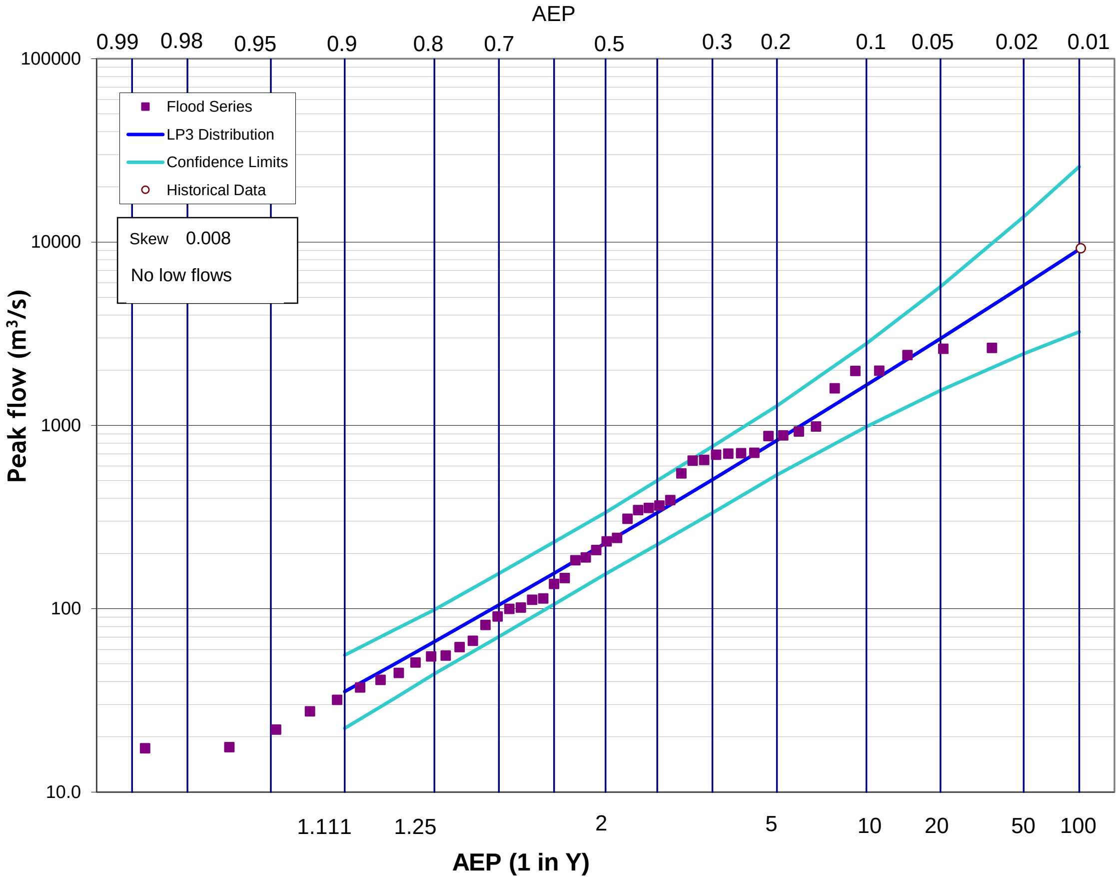


Figure 4.3 - FFA for the Namoi River at Gunnedah (gauge no. 419001)

The peak flow for the 1955 flood event was derived by converting the recorded peak water level to a stream discharge using the currently available rating curve for the gauge.

The Gunnedah stream gauge is located approximately 26 km upstream of the Approved Mine. Peak discharges at Gunnedah are considered representative of discharges at the Project site as the major tributaries to the Namoi River (the Manilla River, Macdonald River, Peel River and the Mooki River) join the Namoi River upstream of the Gunnedah stream gauge, with no other major tributaries joining the Namoi River between Gunnedah and the Project.

Figure 4.3 shows a FFA for the Namoi River at the Gunnedah stream gauge as a LPIII distribution fitted to the annual series. The 95% and 5% confidence limits of the estimate are also shown. Table 4.1 shows the predicted peak discharges for the 20%, 5% and 1% AEP design flood events including the peak discharges for three historical events from the LPIII distribution. The results suggest that the 1955 flood had an AEP of about 1% and the 1998 event had an AEP of about 7%.

Note that the “Flood Series” in Figure 4.3 refers to 1968 to 2015 recorded stream data at the Namoi River Gunnedah gauge station. “Historical Data” refers to the derived peak discharge for the 1955 flood event. Also, the *Gunnedah and Carroll Floodplain Management Study* adopted by Gunnedah Shire Council (SMEC, 1999) concluded that the 1955 flood event had an AEP of between 1.4% and 1.0% and the Carroll to Boggabri Flood Study (SMEC, 2003) concluded that that the 1955 flood event had an AEP of 1% at the Gunnedah stream gauge. The FFA results are consistent with previous studies and are suitable for this study.

Table 4.1 – Historical and peak design discharges, Namoi River at Gunnedah (gauge no. 419001), ordered by peak discharge magnitude

Event	Peak discharge in cubic metres per second (m^3/s)
20% AEP	828
1998 (approx. 7% AEP)	2,617
5% AEP	2,975
1% AEP	9,141
1955 (approx. 1% AEP)	9,260
Extreme (3 x 1% AEP)	27,423

4.2.3 Extreme flood

The extreme flood event was determined to define the extent of flood prone land from the Namoi River. It is not possible to estimate the PMF using the FFA methodology for the Namoi River because the PMF is beyond the credible limit of extrapolation from the 48 years of available data. Therefore, an estimate of a peak discharge for an 'extreme' flood has been made by using three times the 1% AEP discharge estimate.

4.3 NAMOI RIVER TRIBUTARIES DESIGN DISCHARGES

4.3.1 Overview

The XP-RAFTS hydrological model (XP Software, 2013) was used to estimate the 20%, 5%, 1% AEP and PMF design discharges in Collygra Creek, Deadmans Gully, Stratford Creek, South Creek, Driggle Draggle Creek and Bollol Creek.

In the absence of recorded stream flow data, the modelled 20%, 5% and 1% AEP XP-RAFTS design discharges were compared with those estimated using the RFFE. The RFFE is an automated web-based tool developed by ARR to estimate design peak discharges for ungauged catchments based on FFA results from nearby gauged catchments.

There is some uncertainty in peak discharge estimates generated by the RFFE for this region given the sparseness of stream gauges in the area that have been used to define the RFFE estimates. However, it is considered reasonable to use for validation purposes.

Design discharges were estimated using the rainfall intensities, losses and temporal patterns obtained from ARR (IEAust, 1987). Although design rainfall depths, losses and temporal patterns have recently been updated as part of the ARR update (Ball, J et al. 2016), they were in draft at the time of the assessment and have not been used. Given that there is no calibration data and the model results will be validated against RFFE estimates, the use of the ARR 1987 data remains appropriate for the impact assessment.

4.3.2 XP-RAFTS model spatial configuration

Figure 4.4 shows the XP-RAFTS model configuration for Collygra Creek, Deadmans Gully, Stratford Creek, Driggle Draggle and Bollol Creeks. The model consists of 37 subcatchments ranging in size from 2.2 km^2 to 43.5 km^2. This includes 10 subcatchments for Collygra Creek, 3 subcatchments for Deadmans Gully, 10 subcatchments for Stratford Creek, 8 subcatchments for Driggle Draggle creek and 6 subcatchments for Bollol Creek.

4.3.3 XP-RAFTS model parameters

Table 4.2 shows the adopted XP-RAFTS subcatchment areas, catchment slopes and PERN 'n' roughness coefficients. All subcatchments were assigned a fraction impervious of 0%. Channel routing was modelled using the Muskingum method with a storage exponent 'X' of 0.25. The subcatchment and routing link parameters were adjusted to obtain the best match between modelled discharges and those estimated using the RFFE.

Table 4.2 – XP-RAFTS model subcatchment parameters

XP-RAFTS subcatchment	Area (km^2)	Catchment slope (%)	PERN 'n'	XP-RAFTS subcatchment	Area (km^2)	Catchment slope (%)	PERN 'n'
Collygra Creek catchment				*Stratford Creek catchment continued*			
CC01	35.3	1.5	0.06	VC09	8.6	0.4	0.06
CC02	28.2	0.8	0.06	VC06	5.1	0.7	0.06
CC03	27.0	0.5	0.06	VC07	6.9	0.3	0.06
CC04	23.4	1.6	0.06	VC08	6.4	0.2	0.06
CC05	25.4	2.1	0.06	*Driggle Draggle Creek catchment*			
CC06	30.3	1	0.06	DD01	27.2	1.3	0.06
CC07	8.7	0.9	0.06	DD02	22.1	2.2	0.06
CC08	17.0	0.5	0.06	DD03	43.5	1.5	0.06
CC09	31.6	0.4	0.06	DD04	29.6	0.8	0.06
CC10	25.3	0.2	0.06	DD05	19.1	0.7	0.06
Deadmans Gully				DD06	36.2	0.6	0.06
DMG12	24.8	0.7	0.06	DD07	21.7	1	0.06
DMG13	35.3	0.2	0.06	DD08	18.3	0.3	0.06
DMG14	15.7	0.1	0.06	*Bollol Creek catchment*			
Stratford Creek catchment				BC01	26.7	1.6	0.08
VC01	25.5	1.7	0.06	BC02	36.0	1.7	0.08
VC02	19.5	1.2	0.06	BC03	22.2	0.9	0.06
VC03	21.9	0.5	0.06	BC04	32.5	0.6	0.06
VC04	5.2	0.4	0.06	BC05	26.9	0.4	0.06
VC05us	3.4	2	0.08	BC06	13.2	0.2	0.06
VC05ds	2.2	2	0.06				

4.3.4 Design rainfall intensities and rainfall losses

The 20%, 5% and 1% AEP rainfall intensities were obtained from Intensity-Frequency-Duration (IFD) data determined from ARR Volume 2 (IEAust, 1987). It is of note that the 2016 IFD rainfalls are some 10% to 20% lower than the 1987 IFD rainfalls. Notwithstanding this, the differences in rainfall intensities are not expected to affect the magnitude of the impacts of the Project. Therefore, for the purpose of an impact assessment, the 1987 IFD rainfalls remain appropriate.

For the PMF, design rainfall intensities were calculated according to the Generalised Short Duration method (BOM, 2003) and the Generalised Tropical Storm Method (BOM, 2005).

For regions in NSW east of the western slopes, the ARR (IEAust, 1987) recommends a design initial loss of between 10 millimetres (mm) and 35 mm and a design continuing loss rate of 2.5 mm/hour. For this study, an initial loss of 25 mm and continuing loss rate of 2.5 mm/hour were adopted for all design events up to 1% AEP. The adopted initial loss and continuing loss for the PMF event is 0 mm. The adopted initial losses were consistent with the range of losses given in the old ARR (IEAust, 1987) and the new ARR (Ball J et al, 2016) for the region.

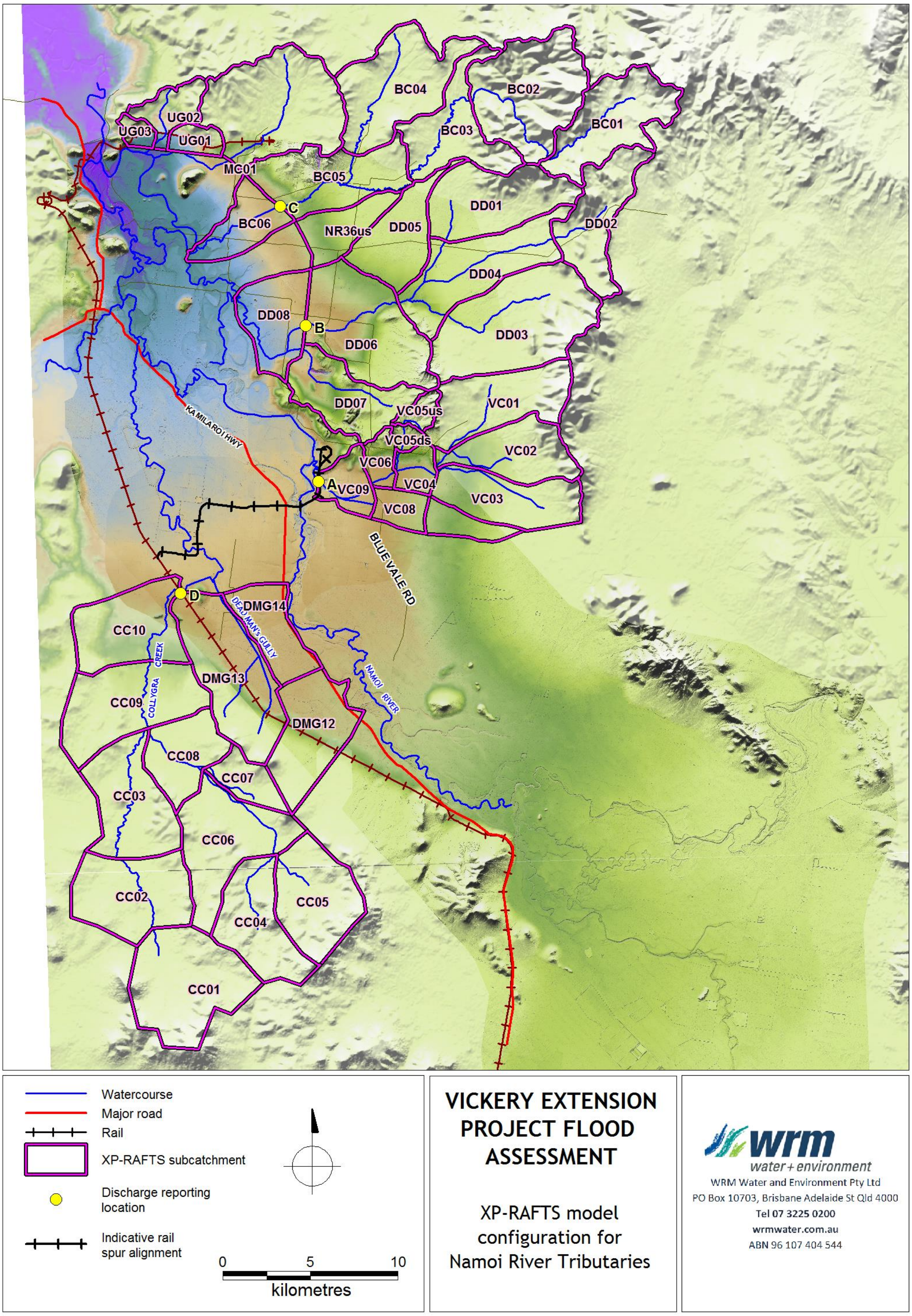


Figure 4.4 – XP-RAFTS model configuration for Namoi River Tributaries

4.3.5 XP-RAFTS model comparison to RFFE

Tables 4.3 to 4.6 show the comparison between XP-RAFTS design peak discharges and those estimated using the RFFE at four locations (A to D as shown on Figure 4.4). The results indicate that the XP-RAFTS predicted peak design discharges are generally in good agreement with the RFFE estimates (to within 14%). Given that the XP-RAFTS model has been based on the physical characteristics of the catchment, the predicted flood discharges from the XP-RAFTS model have been adopted for the study.

Table 4.3 - Comparison of XP-RAFTS design peak discharges with RFFE estimates at Location A

AEP (%)	RFFE design peak discharge (m^3/s)			XP-RAFTS design peak discharge (m^3/s)	% difference to expected RFFE discharge
	Expected	5^{th} %ile confidence limit	95^{th} %ile confidence limit		
20	43	18	104	46	7%
5	103	42	256	108	5%
1	221	84	585	206	-7%

Table 4.4 - Comparison of XP-RAFTS design peak discharges with RFFE estimates at Location B

AEP (%)	RFFE design peak discharge (m^3/s)			XP-RAFTS design peak discharge (m^3/s)	% difference to expected RFFE discharge
	Expected	5^{th} %ile confidence limit	95^{th} %ile confidence limit		
20	68	28	163	73	9%
5	162	66	402	168	3%
1	346	131	920	317	-9%

Table 4.5 - Comparison of XP-RAFTS design peak discharges with RFFE estimates at Location C

AEP (%)	RFFE design peak discharge (m^3/s)			XP-RAFTS design peak discharge (m^3/s)	% difference to expected RFFE discharge
	Expected	5^{th} %ile confidence limit	95^{th} %ile confidence limit		
20	45	19	110	52	14%
5	108	44	269	116	7%
1	231	88	615	218	-6%

Table 4.6 - Comparison of XP-RAFTS design peak discharges with RFFE estimates at Location D

AEP (%)	RFFE design peak discharge (m^3/s)			XP-RAFTS design peak discharge (m^3/s)	% difference to expected RFFE discharge
	Expected	5^{th} %ile confidence limit	95^{th} %ile confidence limit		
20	72	30	176	75	4%
5	171	69	423	189	10%
1	361	140	940	377	4%

4.3.6 Summary of XP-RAFTS design discharges in the Namoi River tributaries

Table 4.7 shows a summary of the predicted XP-RAFTS model design peak discharges at these locations.

Table 4.7 - Summary of XP-RAFTS design peak discharges

Location ID	Location description	XP-RAFTS design peak discharge (m^3/s)			
		20% AEP	5% AEP	1% AEP	PMF
A	Stratford Creek upstream of Namoi River confluence	46	108	206	1,466
B	Driggle Draggle Creek	73	168	317	2,036
C	Bollol Creek	52	116	218	1,270
D	Collygra Creek upstream of the Project rail spur	75	189	377	2,012

5 Hydraulic modelling

5.1 METHOD OF ANALYSIS

The TUFLOW two-dimensional unsteady flow model (BMT WBM, 2016) was used to estimate flood levels and flood velocities along the channel and floodplains of the Namoi River and its tributaries 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 one-dimensional (ESTRY) and two-dimensional (TUFLOW) schemes are solved independently, but are dynamically linked at the boundary to ensure continuity (mass) is conserved.

Preliminary hydraulic modelling results indicated that the peak flood levels across the Driggle Draggle Creek floodplain in the vicinity of the Project are not influenced by the Namoi River tailwater levels at the Project area. Therefore, two hydraulic models were developed for the study; Namoi River model and Namoi Tributaries model.

The models were developed to estimate design flood levels along the Namoi River and its floodplain for the 20%, 5% and 1% AEP events to assess the impact of the mine infrastructure on flood levels and flow distributions across the Namoi River, Driggle Draggle Creek, Stratford Creek and South Creek floodplains. Design flood levels and extents were also prepared for an extreme flood event to determine the extent of flood prone land.

The Namoi River model was calibrated to the available water level data for the historical 1998 Namoi River flood and then verified against available water level data for the 1955 flood events. The predicted TUFLOW water level results were also compared against the predicted water levels in the SMEC (2003) study. The Namoi Tributaries model were developed using the adopted parameters from the Namoi River model due to lack of available calibration data.

5.2 TUFLOW MODEL CONFIGURATION

5.2.1 Spatial configuration

Figure 5.1 shows the extent of the Namoi River model. Figure 5.1 also shows the locations of the 2D inflow and outflow boundaries and the locations of hydraulic structures, which are modelled in the 1D scheme. The model extends approximately 19 km upstream and 23 km downstream of the Project and covers an area of some 452 km^2 and includes Stratford Creek. The adopted study extent was selected to obtain the best representation of flow distributions between the channel and floodplain. A 15 m grid cell size was adopted for the Namoi River model.

Figure 5.2 shows the extent of the Namoi Tributaries model. Figure 5.2 also shows the locations of the 2D inflow and outflow boundaries. The model covers an area of approximately 537 km^2 across the Driggle Draggle Creek and Bollol Creek floodplain. To better represent the channel capacities of Driggle Draggle and Bollol Creeks, a finer 10 m grid cell size was adopted for the Namoi Tributaries model.

5.2.2 Topographic data

Topographic data for the hydraulic model was obtained from a number of sources. The underlying topographic data for the Namoi River model area between Gunnedah and Boggabri was provided by the NSW Department of Environment and Climate Change as Airborne Laser Survey (ALS), acquired during 2000. This is the same base data that was used in the Carroll to Boggabri Flood Study (SMEC, 2003).

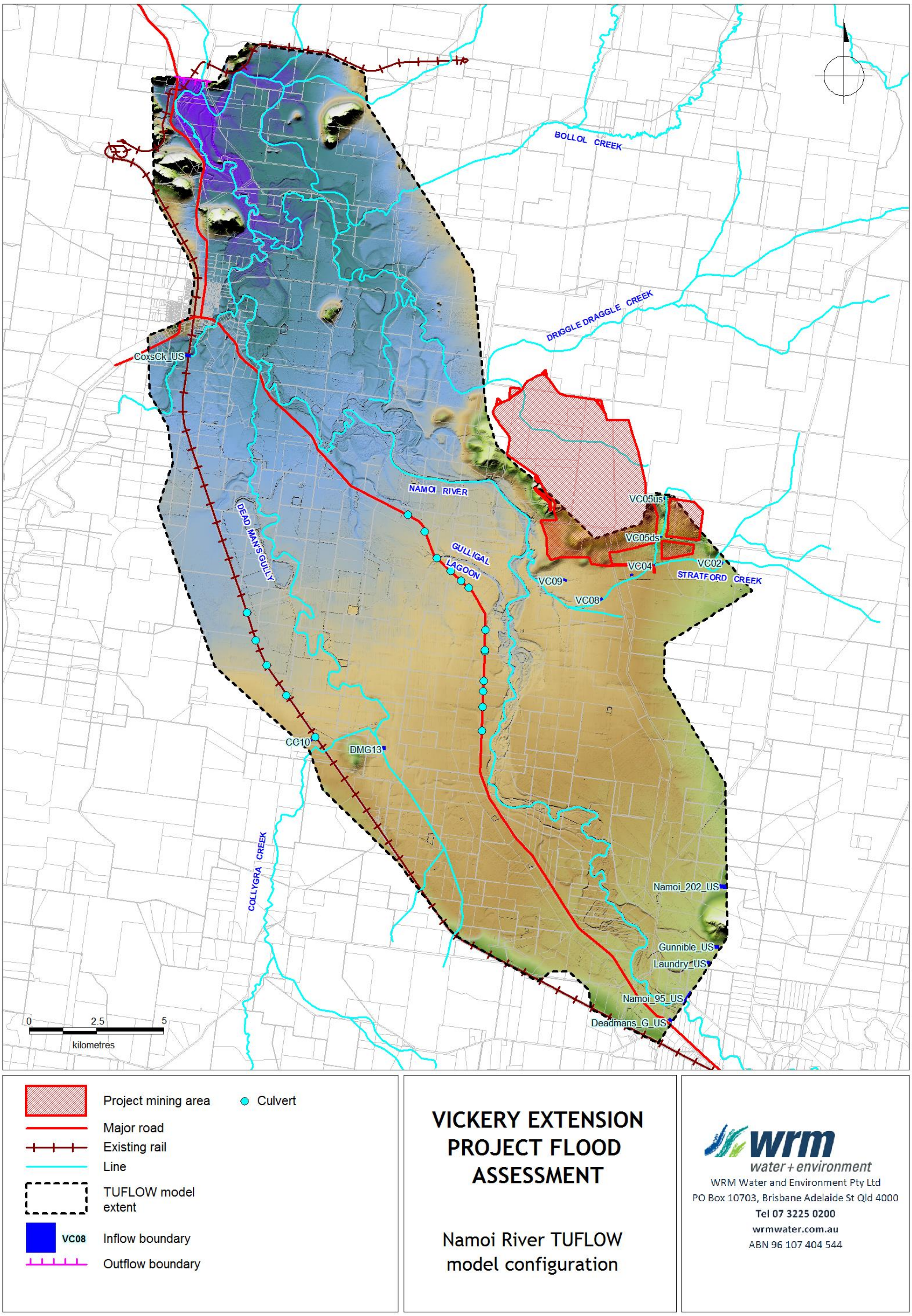


Figure 5.1 – Namoi River TUFLOW model configuration (existing conditions)

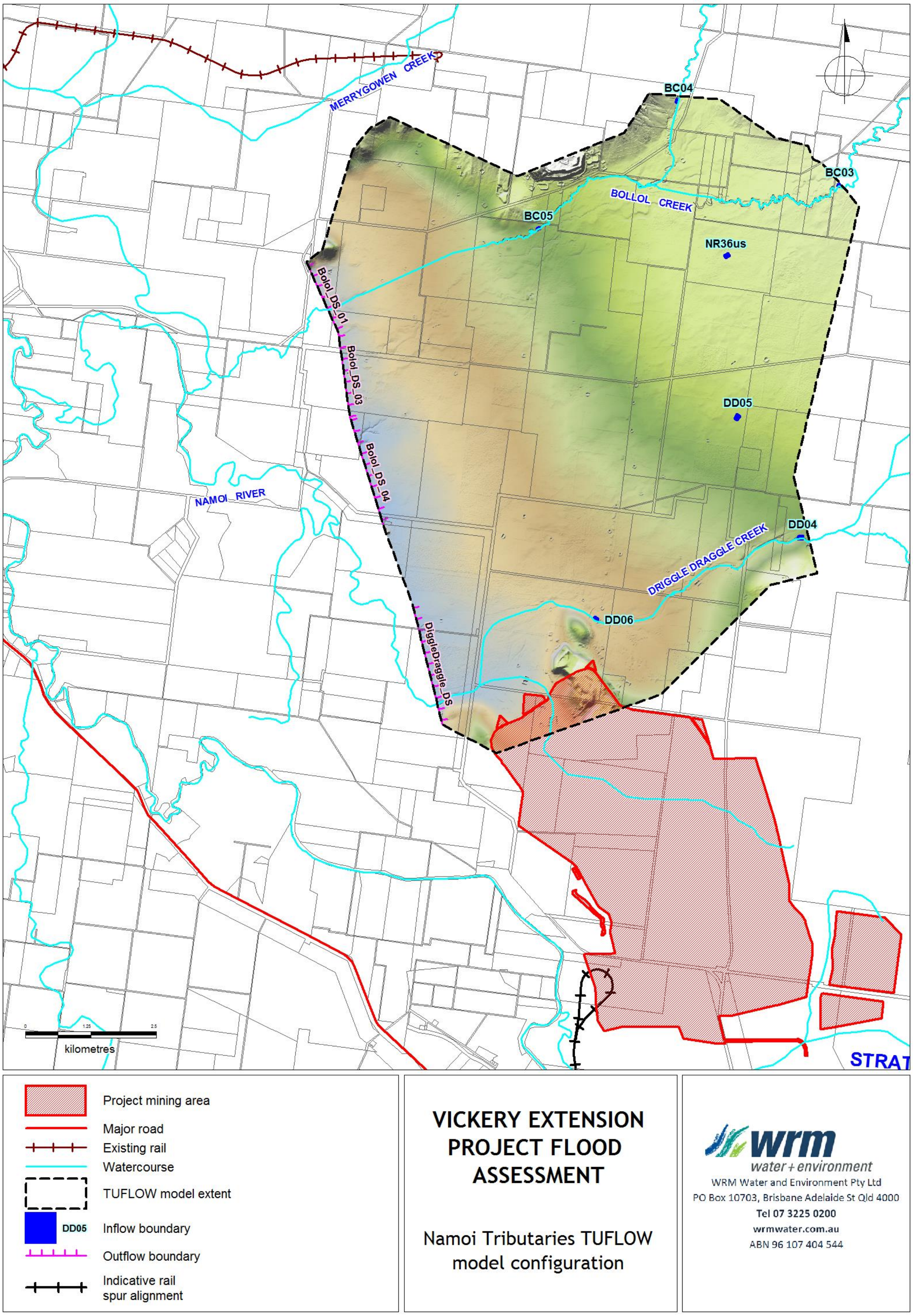


Figure 5.2 – Namoi Tributaries TUFLOW model configuration (existing conditions)

Verification of the ALS accuracy was carried out using 188 natural surface points surveyed by RTK GPS. The mean error of all comparisons (average error of all comparisons) was found to be 0.18 m with a standard deviation of 0.11 m. However, an inspection of the supplied data indicates that there is a minor 'tilt' across each aerial scan width that had not been corrected. The absolute error produced by this tilt at each location varies across the floodplain. Where available, the ALS data were supplemented with more detailed survey data, as described below.

- More detailed survey data in the vicinity of the Project area was provided by Coalworks Ltd (now Whitehaven) covering an 18 x 14 km area. The survey data was provided as ortho-photogrammetry points and breaklines of the landscape features (watercourses, infrastructure, levee banks etc.). Investigation of the accuracy of this data to the RTK GPS data found height variations of up to 0.3 m. Note that the day during which the survey was flown the Namoi River had a flow of approximately 22 m^3/s, which was taken into account by subtracting this value from the Namoi River main channel discharge.
- Additional LiDAR survey was provided by Whitehaven in the area where the Project rail spur is located. The survey data covers an area of 66 km^2. The LiDAR data was provided with a vertical accuracy of up to 0.15 m.
- More detailed survey data was also provided by Whitehaven for a 246 km^2 area which covers the floodplains of Driggle Draggle Creek and Bollol Creek as well as the adjacent Namoi River. The survey data, acquired during September 2015, was provided as regularised ground strike points (ALS) with a horizontal distance of 1 m between points. This data supersedes some areas covered by the ALS data provided by the NSW Department of Environment and Climate Change. Investigation of the accuracy of this data to the RTK GPS data showed height variations of up to 0.1 m.

Overall, the best available topographic data was used to assess the relative impacts of the Project infrastructure. It is likely that the predicted peak flood levels and depths at each location for the historical flood events (Section 5.3) would be commensurate with the accuracy of the adopted survey data.

5.2.3 Surface roughness

Table 5.1 presents the adopted hydraulic roughness (Manning's 'n') values in the study area. Manning's 'n' was used to calibrate the hydraulic model to the historical water level data. The higher the roughness number, the more the flow would be impeded. Note that floodwater flowing across a floodplain that is heavy in crop will behave differently to a floodplain that has been freshly tilled. The adopted crop roughness values represent conditions of relatively low vegetation cover. The hydraulic roughness (Manning's 'n') values shown in Table 5.1 were derived by iteratively adjusting the roughness coefficients until a reasonable match is obtained between the recorded and predicted peak flood levels.

Table 5.1 – Adopted hydraulic roughness Manning's 'n' values

Area	Manning's 'n'
Crops	0.035
Channel for Namoi River model	0.030
Channel for Namoi River Tributaries model	0.035
Overbank / grass	0.060
Riparian vegetation	0.150

5.2.4 Inflow and outflow boundaries

Figure 5.1 and Figure 5.2 show the locations of inflow boundaries to the Namoi River and Namoi Tributaries hydraulic model. The discharge hydrographs adopted as inflows to these models were obtained from various sources summarised in Table 5.2.

The 1984 flood event hydrograph shape (obtained from the SMEC (2003) Mike 11 model) was applied to the design peak discharges for the 20%, 5% and 1% AEP design events in the Namoi River model because the 1984 flood is the design flood event used to define the floodplain in the superseded FMP. The 1984 flood event hydrograph is a similar size and shape to the 1998 flood. The XP-RAFTS model inflows were used for Stratford Creek and Collygra Creek in the Namoi River model and for Driggle Draggle Creek and Bollol Creek in the Namoi Tributaries model.

For the Namoi River model, Collygra Creek enters at the western boundary of the modelled area while Stratford enters from the eastern boundary. The catchment areas of Collygra Creek and Stratford Creek are between 105 km^2 to 252 km^2, whereas the Namoi River catchment upstream of Gunnedah is 17,100 km^2 (i.e. more than 100 times greater). As such the timing of the flood events in the Namoi River are not expected to coincide with the tributaries. Therefore, the Stratford Creek design flood discharges, derived from the XP-RAFTS model, were assumed to have peaked and receded before the Namoi River flows arrive. That is, both the local catchment and regional events were run together offset in time to provide a single flood extent.

A single normal depth outflow boundary was adopted for the Namoi River model. The outflow boundary of this model is located approximately 23 km downstream of the Project and as such would not impact on peak flood levels at the Project area.

A total of four normal depth outflow boundaries were adopted for the Namoi Tributaries model. Preliminary model results showed that peak flood levels at the area of interest (the Project rail spur) are not affected by tailwater levels in the Namoi River.

Table 5.2 - Summary of adopted inflow hydrograph sources

TUFLOW model	Event	Inflow hydrograph source			
		Namoi River	Stratford Creek	Driggle Draggle Creek	Bollol Creek
Namoi River model	1998	MIKE 11[a]	[b]	[c]	[c]
	1955	MIKE 11[a]	[b]	[c]	[c]
	20% AEP	FFA[d]	XP-RAFTS[e]	[c]	[c]
	5% AEP	FFA[d]	XP-RAFTS[e]	[c]	[c]
	1% AEP	FFA[d]	XP-RAFTS[e]	[c]	[c]
	Extreme	FFA[f]	XP-RAFTS[e]	[c]	[c]
Namoi Tributaries model	20% AEP	[c]	[c]	XP-RAFTS[e]	XP-RAFTS[e]
	5% AEP	[c]	[c]	XP-RAFTS[e]	XP-RAFTS[e]
	1% AEP	[c]	[c]	XP-RAFTS[e]	XP-RAFTS[e]
	PMF			XP-RAFTS[e]	XP-RAFTS[e]

[a] - Inflow hydrographs obtained from the SMEC MIKE 11 hydraulic model (SMEC, 2003)

[b] - Zero inflow adopted

[c] - Outside of model extent

[d] -Obtained from the FFA (see Section 4.2.2) and adopting the 1984 hydrograph shape

[e] - Peak discharge hydrographs obtained from the XP-RAFTS model described in Section 4.3

[f] - A peak discharge equal to three times the FFA 1% AEP discharge was adopted

5.2.5 Existing hydraulic structures

Table 5.3 provides details of the existing major hydraulic structures within the Namoi River hydraulic model extent. The locations of the structures are shown in Figure 5.1. Details of these structures were obtained from Australian Rail Track Corporation and Gunnedah Shire Council. The existing hydraulic structures were modelled within the one-dimensional scheme (ESTRY) directly linked to the two-dimensional model as well as two-dimensional openings.

The earthen levees, drainage banks and dams located across the floodplain have been included in the model topography by explicitly defining the embankment alignment and crest levels from the available aerial survey data.

Table 5.3 – Existing hydraulic structures

ID	Location	Invert level (mAHD)		Culvert dimensions	Culvert cross-sectional area (m^2)
		Up-stream	Down-stream		
HW1	Kamilaroi Hwy	248.04	248.0	8x3.16(W)x1.83(H)	46.26
HW2	Kamilaroi Hwy	246	245.5	4x3.16(W)x1.83(H)	23.13
2430A	Kamilaroi Hwy	252.65	252.55	3x0.75(W)x0.45(H)	1.01
2435A	Kamilaroi Hwy	252.7	252.6	2x0.75(W)x0.45 (H)	0.68
2435B	Kamilaroi Hwy	252.52	252.5	2x0.75(W)x0.45(H)	0.68
2440A	Kamilaroi Hwy	251.18	251.12	3x0.75(W)x0.45(H)	1.01
2440B	Kamilaroi Hwy	251.73	251.42	1x0.75(W)x0.45(H)	0.34
2440C	Kamilaroi Hwy	251.73	251.42	1x1.22(W)x0.3(H)	0.37
2445	Kamilaroi Hwy	251.5	251.46	1x0.75(W)x0.45(H)	0.34
2450	Kamilaroi Hwy	250.0	249.8	2x0.75(W)x0.45(H)	0.68
2455A	Kamilaroi Hwy	250.13	249.98	1x0.75(W)x0.45(H)	0.34
2455B	Kamilaroi Hwy	249.8	249.6	2x0.75(W)x0.45(H)	0.68
2470A	Kamilaroi Hwy	248.62	248.53	2x0.75(W)x0.45(H)	0.68
CC1	Existing Rail	251.5	251.1	1x4.5(W)x2.2(H)	9.9
CC2	Existing Rail	249.4	249.0	1x4.5(W)x2.2(H)	9.9
CC3	Existing Rail	249.0	248.9	5x5(W)x2.2(H)	55.0
CC4	Existing Rail	248.5	248.2	1x4.5(W)x1.8(H)	8.1
CC5	Existing Rail	247.4	247.2	1x4.5(W)x1.8(H)	8.1
CC6	Existing Rail	247.7	247.5	1x6(W)x0.9(H)	5.4

5.3 HYDRAULIC MODEL CALIBRATION AND VERIFICATION

The Namoi River hydraulic model was calibrated to the available data for the 1998 and 1955 flood events. Data available for the 1998 flood consisted of aerial photography near the peak (see Appendix B) as well as post-flood survey peak flood levels at four locations for the 1998 event and six locations for the 1955 event. Given the available calibration data at the time is limited, the TUFLOW model was also compared against peak flood levels predicted by the SMEC (2003) MIKE 11 model for the same events.

The aerial photography in Appendix B (taken on 23 July 1998 near the peak of the event) shows the extent of flooding of the Namoi River between Gunnedah and Boggabri in the vicinity of the Vickery Coal Mine (e.g. Blue Vale, Greenwood and Shannon Hills Pits), flow paths between Namoi River and Deadmans Gully, as well as the confluence of Collygra

Creek and Deadmans Gully. These aerial photographs were stitched together to provide an observed flood extent for this event for use in model calibration.

Figure 5.3 shows the predicted flood extent and flood depths for the 1998 flood together with the estimated 1998 flood extent derived from the aerial photography. Figure 5.3 also shows the locations of four surveyed flood levels during this event. Table 5.4 compares recorded and predicted flood levels for the 1998 event at the four surveyed locations. The flood depths across the overbank (crop) areas for this event are generally up to 0.5 m. Peak Namoi River flood depths are up to 8.0 m.

The predicted 1998 flood extent in the over-bank areas is generally consistent with the observed extent of flooding as shown in the aerial photography (Appendix B), in particular the dry areas between the Namoi River and Deadmans Gully. In addition, the predicted flood levels near the Project area (survey points B, C and D) range between 0.1 m and 0.2 m of the post-flood survey peak levels for the July 1998 calibration event. The model does not predict the flood extent along the western side of Deadmans Gully. It appears that the flooding in this area was due to Collygra Creek, which has not been modelled.

Figure 5.4 shows the predicted flood extent and flood depths for the 1955 flood event as well as the locations of six surveyed flood levels during this event. Table 5.4 compares recorded and predicted flood levels for the 1955 event at the six surveyed locations.

For the 1955 flood, predicted peak flood levels closest to the Project area (survey points D and E) range between 0.24 m and 0.50 m higher than the surveyed flood levels. This would suggest that the model will provide conservative estimates of design flood levels close to the Project and therefore suitable for identifying key potential risk of the Project (i.e. the potential flood immunity of the open cut). The differences in recorded and predicted 1955 flood levels are up to 1.05 m at Point B, the closest survey point to the Project rail spur.

Table 5.4 also show comparisons of TUFLOW predicted flood levels and the MIKE 11 predicted flood levels (SMEC, 2003) are in good agreement. Both models over-estimate flood levels for the 1955 flood event by a similar magnitude.

Table 5.4 - Comparison between recorded and predicted peak flood levels for the 1998 and 1955 events

Surveyed point	Surveyed flood level (mAHD)	WRM (2018) TUFLOW model		SMEC MIKE 11 model (SMEC, 2003)	
		Predicted flood level (mAHD)	Diff. (m)	Predicted flood level (mAHD)	Diff. (m)
1998 flood event					
A	253.48	253.76	0.28	252.57	-0.91
B	250.43	250.54	0.11	251.25	0.82
C	248.90	249.10	0.20	- [a]	- [a]
D	245.77	245.92	0.15	- [a]	- [a]
1955 flood event					
A	253.46	253.35	-0.12	253.14	-0.32
B	248.54	249.59	1.05	249.44	0.90
C	249.96	250.27	0.31	- [a]	- [a]
D	250.92	251.16	0.24	252.03	1.11
E	249.64	250.14	0.50	249.76	0.12
F	246.32	247.10	0.78	246.66	0.34

[a] – No comparison between recorded and predicted flood levels is shown for this location in SMEC's flood study report (SMEC, 2003). The reason for this is unknown.

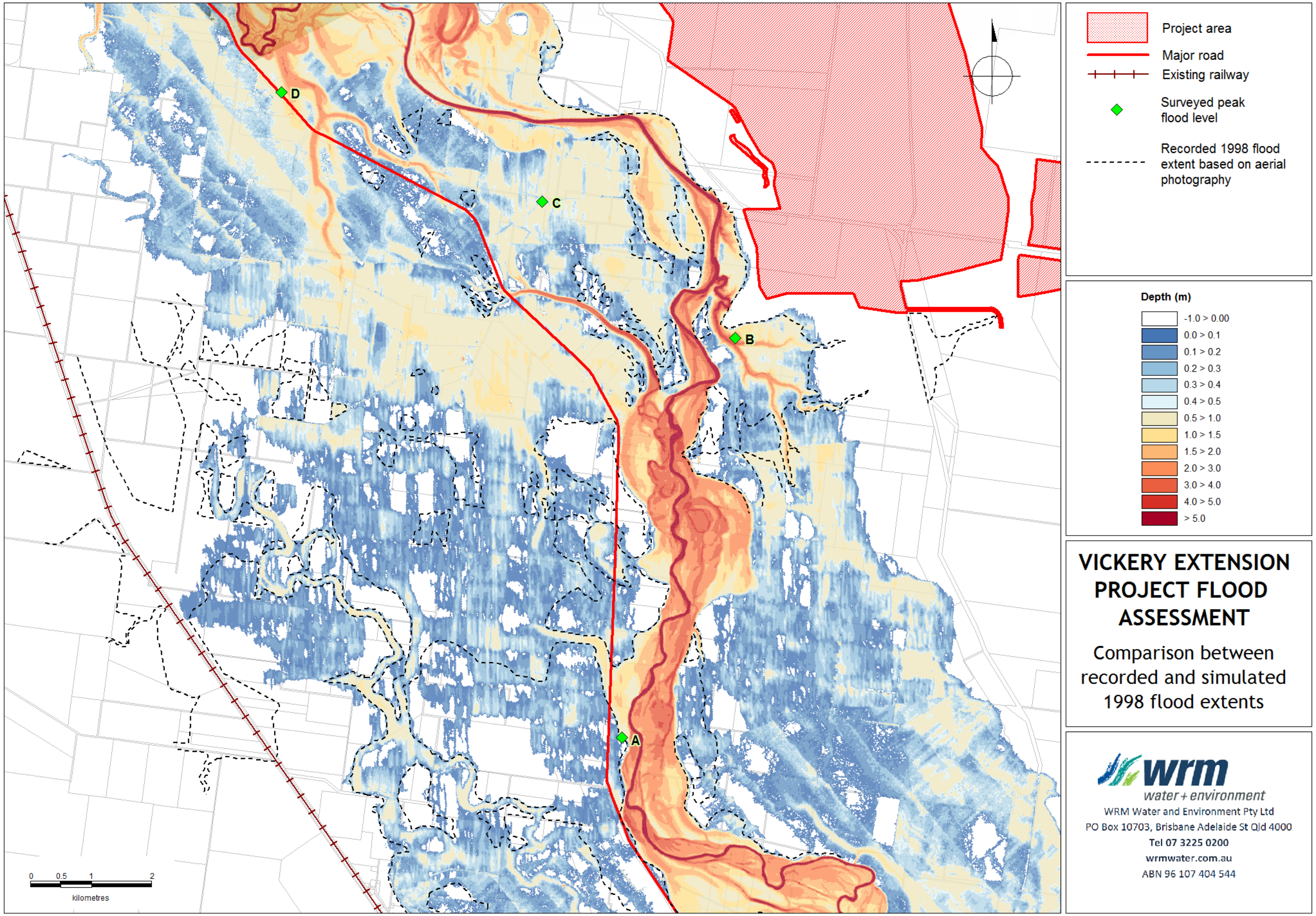


Figure 5.3 - Comparison of recorded and predicted 1998 flood depths, extents and locations of surveyed flood levels

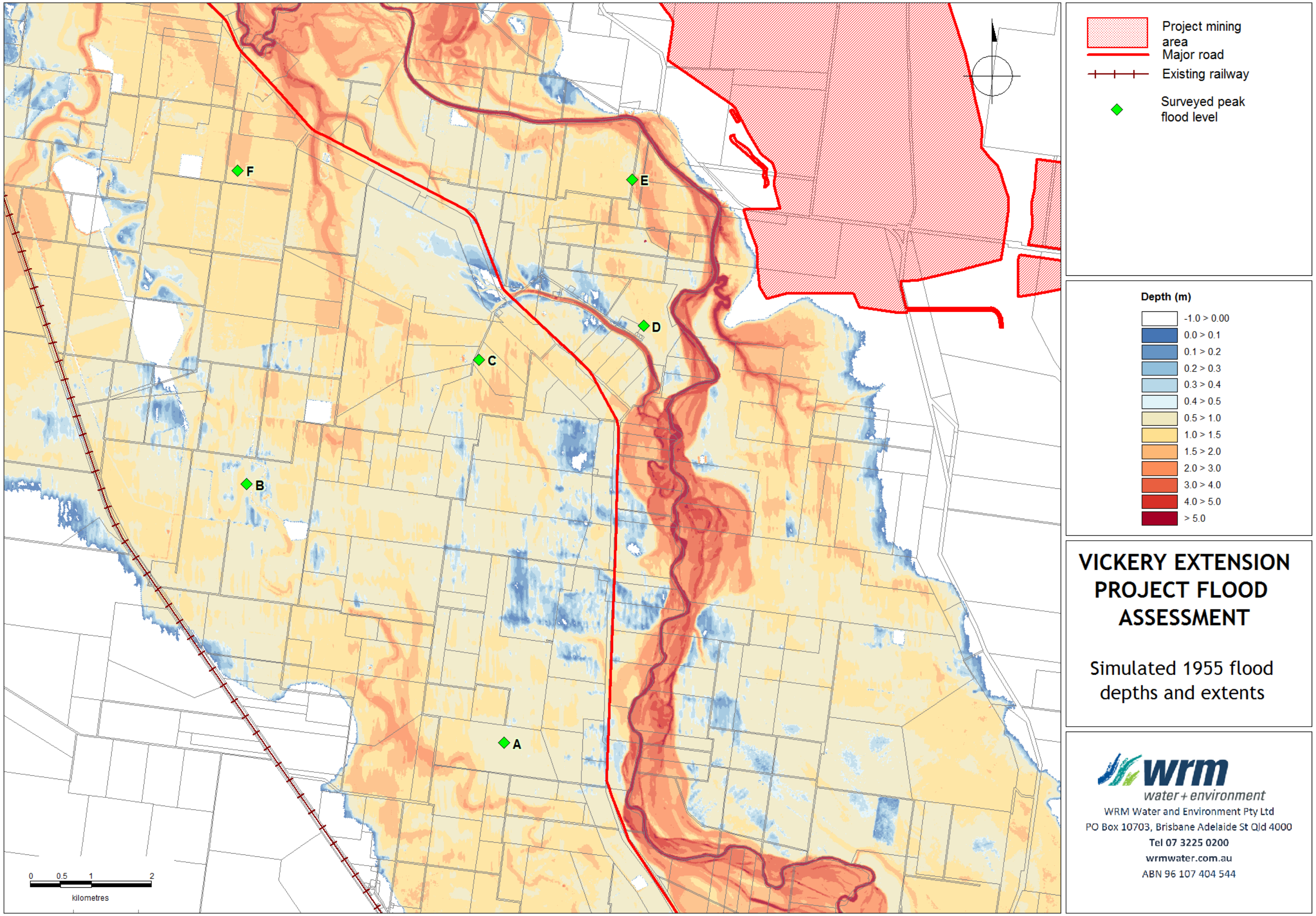


Figure 5.4 - Comparison of recorded and predicted 1955 flood depths, extents and locations of surveyed flood levels

Overall, the TUFLOW model is considered to be a good representation of the magnitude and pattern of flooding in the Namoi River in the model study area and potentially provides conservatively high estimates of design flood levels in the area of interest.

The modelling shows the Project mining area (with the exception of the Project rail spur) is outside the extent of the 1955 flood from the Namoi River. On this basis, further calibration of the model to reduce the predicted flood levels to match the recorded flood levels was not considered to be warranted.

It is noted that differences in recorded versus predicted flood depths for the 1955 may be due to:

- inaccuracies in flood depths at survey points (as these are based on people's recollection 50 years after the event);
- limits in the accuracy of the topographic survey data used for the simulations;
- earthworks/levees that may have been constructed since the 1955 event; and
- changes in vegetation type/height on the adjacent to the floodplain including seasonal changes in crop height.

5.4 MODEL RESULTS – EXISTING CONDITIONS FLOODING

Figure 5.5, Figure 5.6 and Figure 5.7 show the predicted peak flood depths and extents along the Namoi River, Driggle Draggle Creek, Stratford Creek and South Creek floodplains for the 20%, 5% and 1% AEP design events respectively. Figure 5.8 shows the peak flood depths and extent adjacent to the Project for the extreme event (PMF in the Namoi River Tributaries and three times 1% AEP in the Namoi River). This defines the extent of flood prone land adjacent to the Project.

Figure 5.9, Figure 5.10 and Figure 5.11 show the predicted peak flood velocities along the Namoi River, Stratford Creek, South Creek and Driggle Draggle Creek floodplains for the 20%, 5% and 1% AEP design events respectively.

The following is of note with regards to existing flooding characteristics along Namoi River, Stratford Creek, South Creek and Driggle Draggle Creek:

- With the exception of the Project rail spur, the Project is not located on the Namoi River floodplain or extent of Namoi River flood prone land. Therefore, Namoi River flood protection levees are not required to protect the final landform.
- The steeper upper reach of South Creek has sufficient channel capacity to convey the 1% AEP discharges. The South Creek channel loses definition near the south-western corner of the secondary infrastructure area. At this point, South Creek overflows and drains as shallow overland flows, inundating the location of the secondary infrastructure area. Predicted flood depths across the secondary infrastructure area are less than 1.6 m for events up to the PMF.
- The South Creek overland flows would potentially drain across the south-east corner of the open cut, and accordingly the Project would include a flood bund to protect the open cut (and final void) from South Creek inundation.
- Stratford Creek south of the Project mining area has a channel capacity of less than the 20% AEP discharge. Overbank flows drain across the Stratford Creek floodplain general at shallow depths.
- The southern boundary of the secondary infrastructure area is located on the edge of the Stratford Creek floodplain. Predicted flood depths in this area are up to 0.6 m for the 20% AEP event, up to 1.5 m for the 1% AEP event and up to 1.6 m for the PMF.
- The predicted overland flow velocities in the area affected by South Creek flooding are generally less than 0.8 and 2.2 metres per second (m/s) for events up to 1% AEP and for PMF, respectively. The predicted flood velocities along Stratford Creek south of the secondary infrastructure area are generally less than 1.3 and 2.9 m/s for events up to 1% AEP and for PMF, respectively.

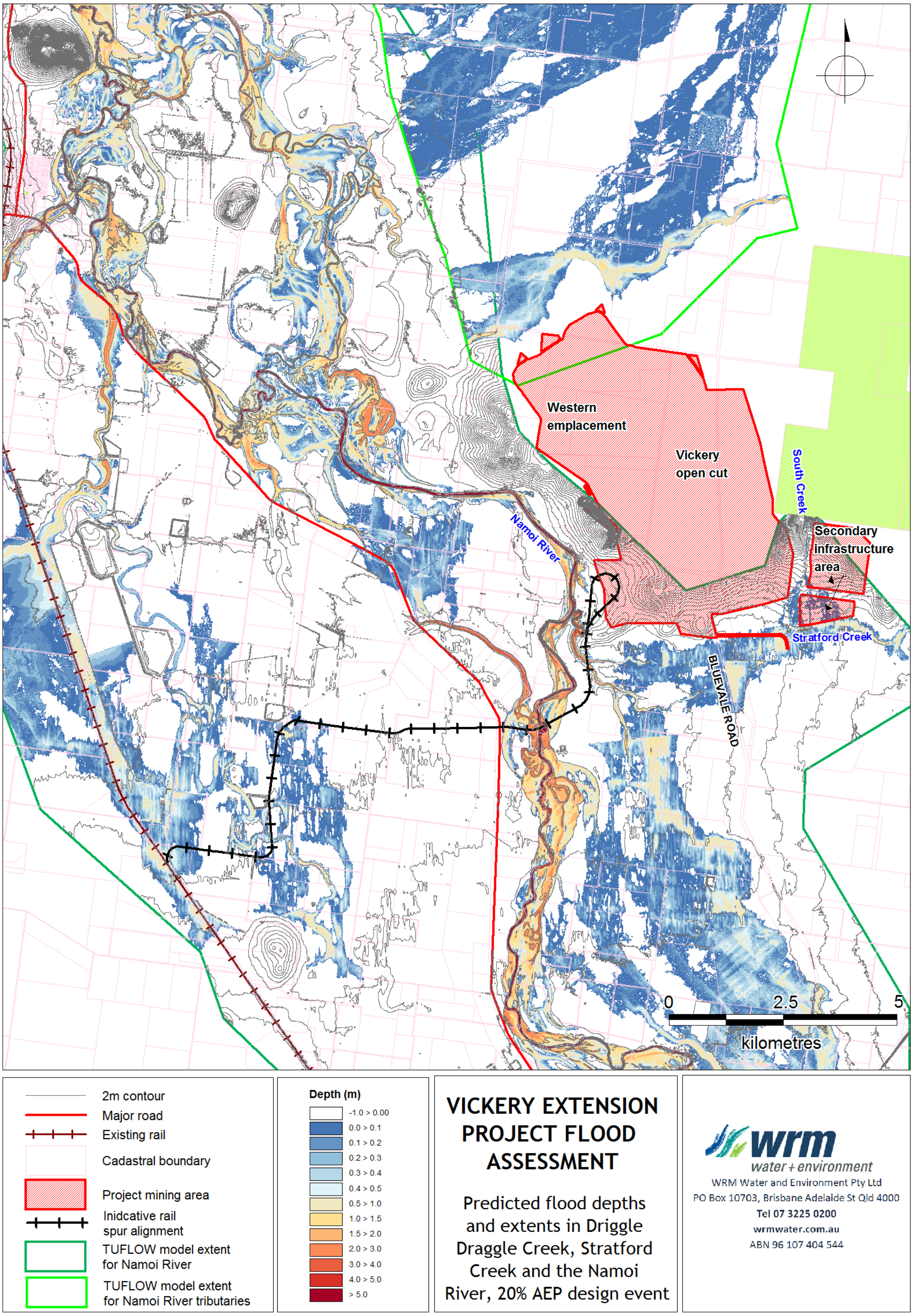


Figure 5.5 - Predicted flood depths and extents in Driggle Draggle Creek, Stratford Creek and the Namoi River, 20% AEP design event

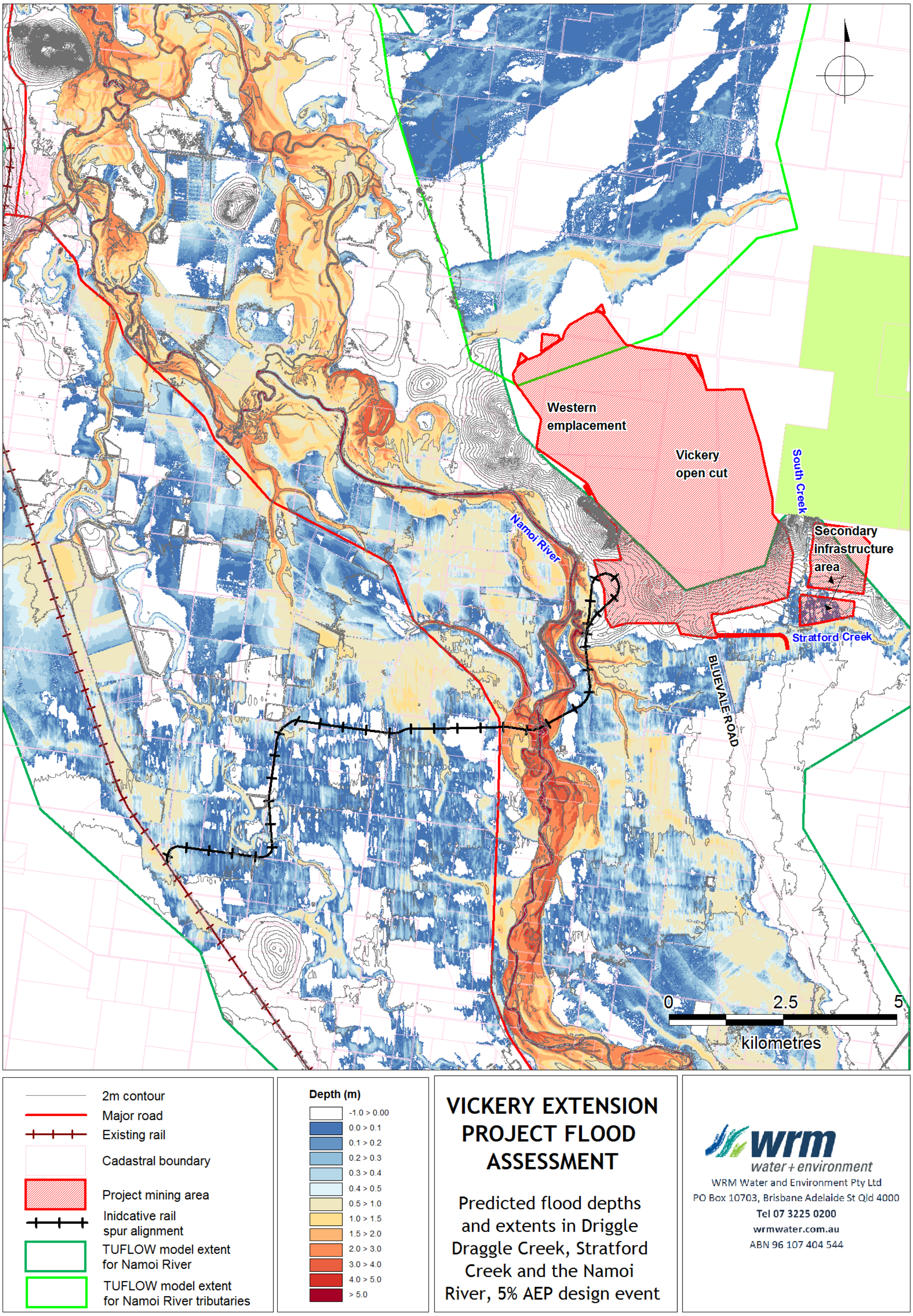


Figure 5.6- Predicted flood depths and extents in Driggle Draggle Creek, Stratford Creek and the Namoi River, 5% AEP design event

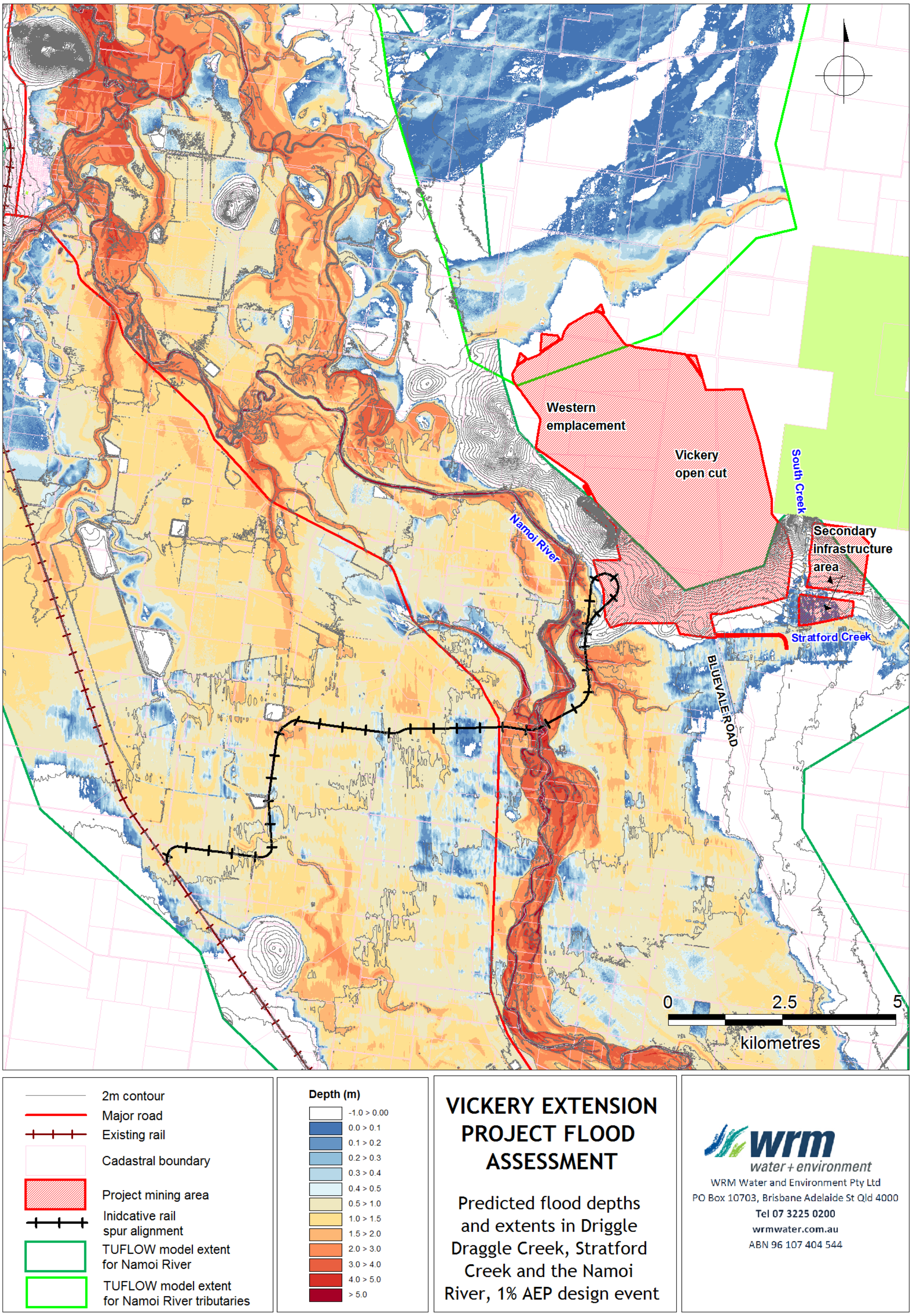


Figure 5.7 - Predicted flood depths and extents in Driggle Draggle Creek, Stratford Creek and the Namoi River, 1% AEP design event

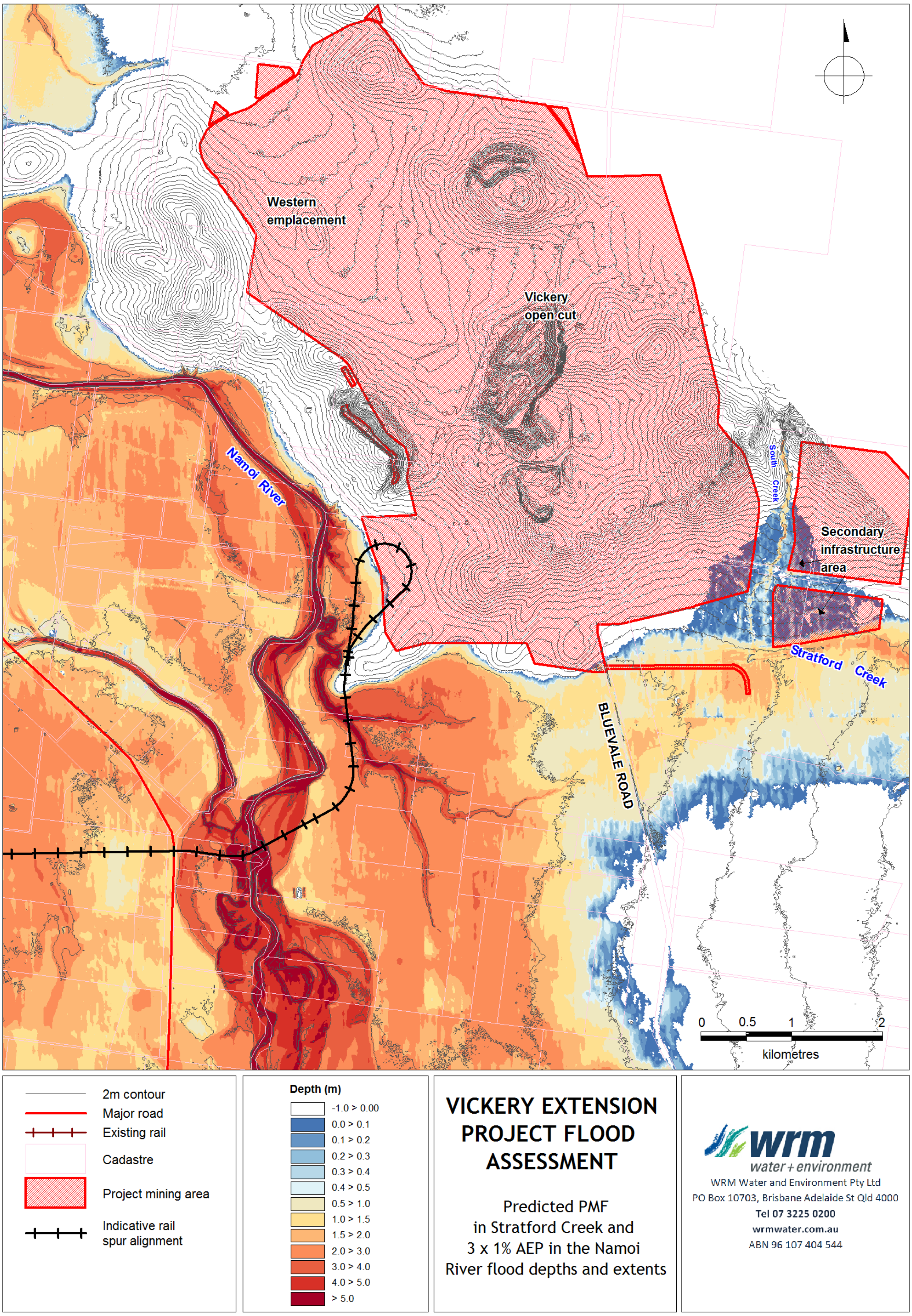


Figure 5.8 - Predicted extent of floodprone land adjacent to the project site

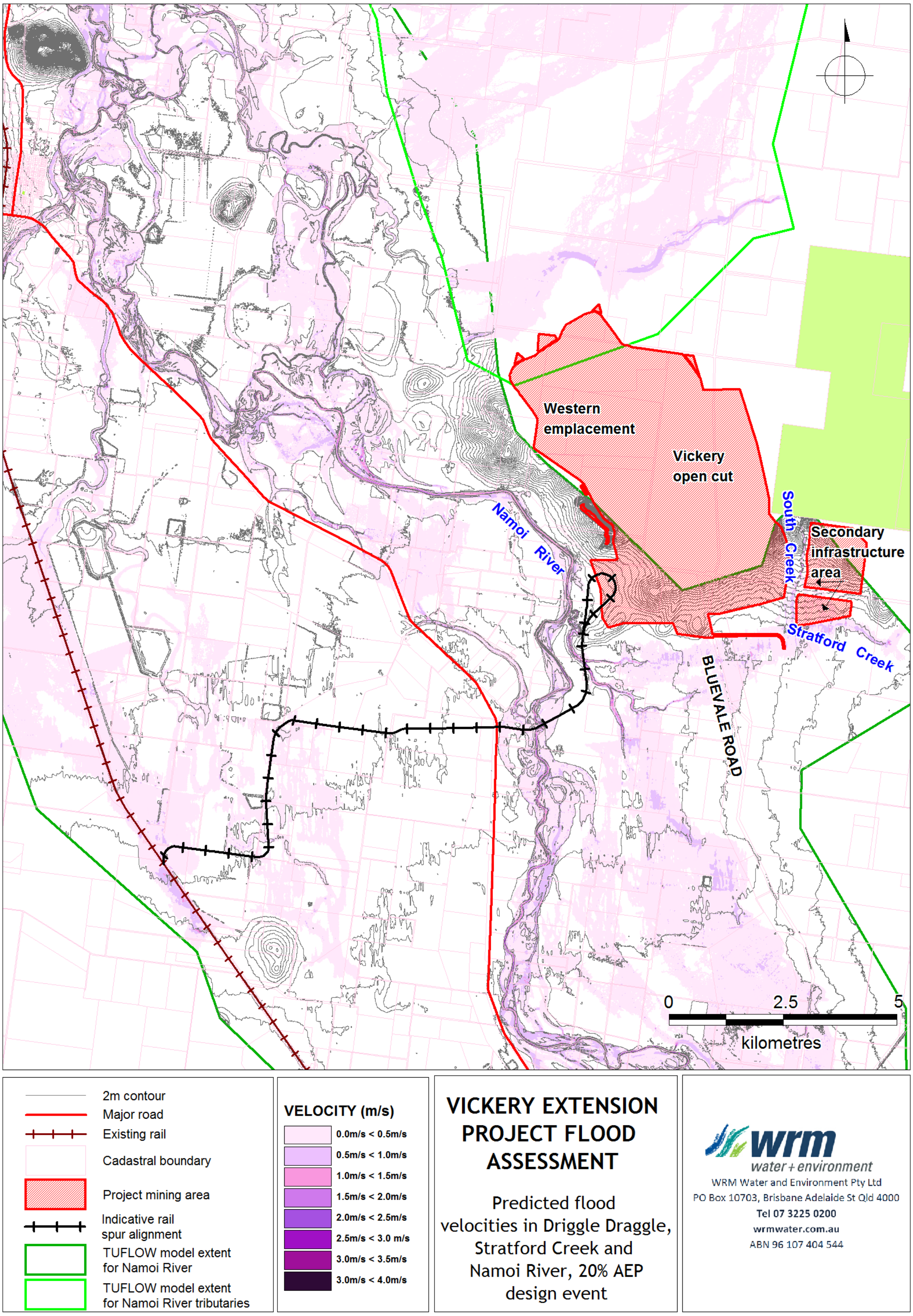


Figure 5.9 – Predicted flood velocities in Driggle Draggle Creek, Stratford Creek and the Namoi River, 20% AEP design event

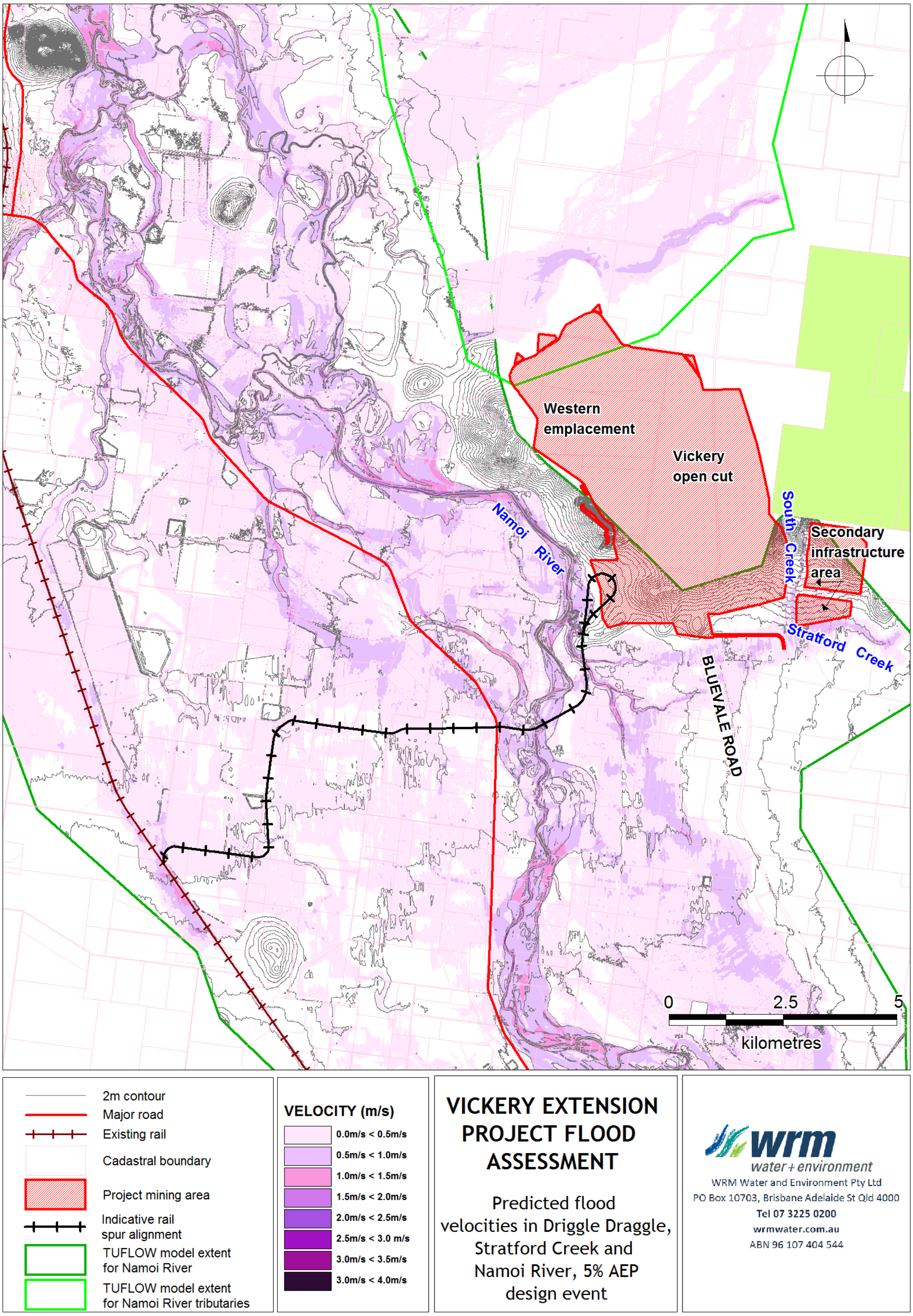


Figure 5.10 - Predicted flood velocities in Driggle Draggle Creek, Stratford Creek and the Namoi River, 5% AEP design event

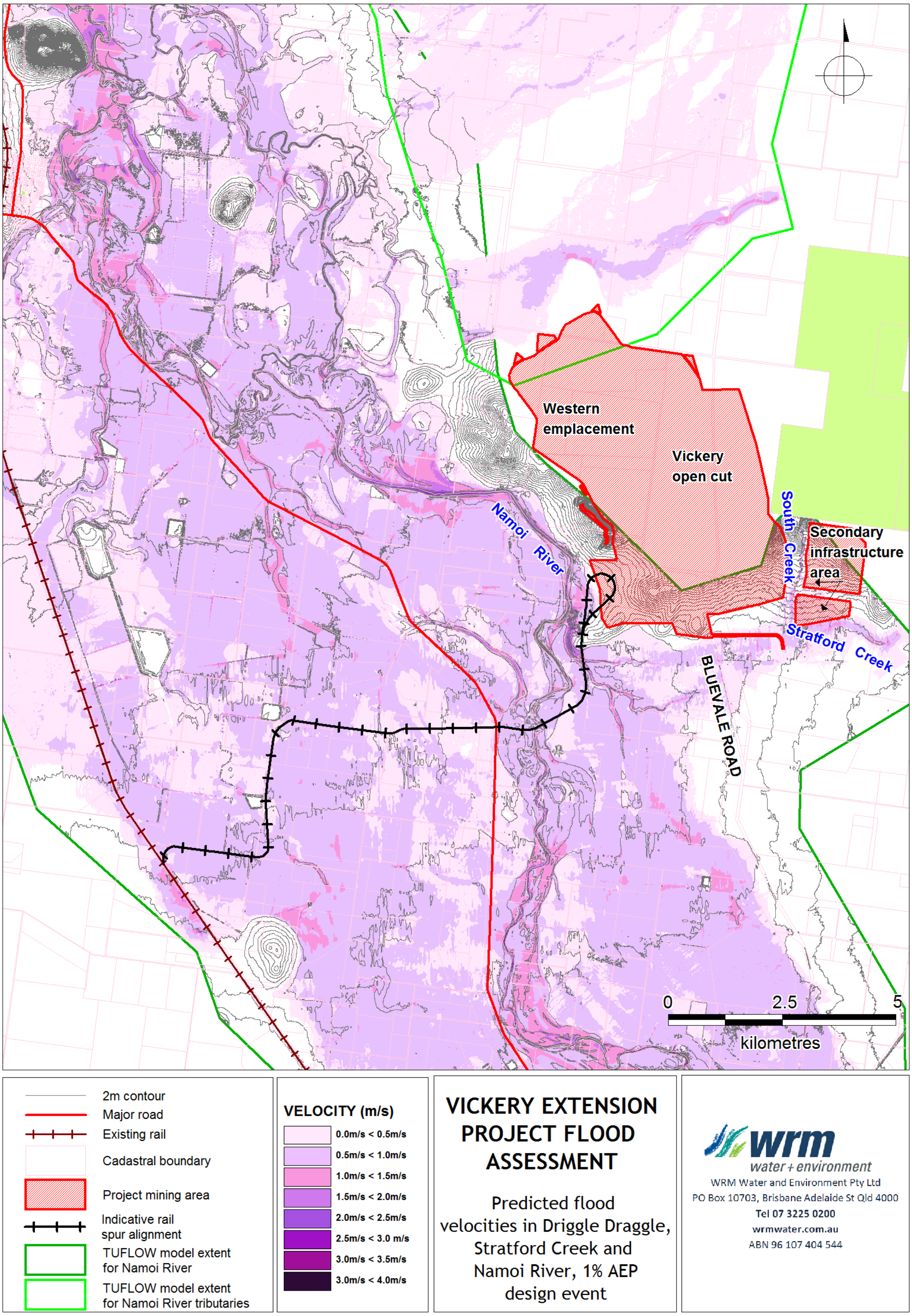


Figure 5.11 - Predicted flood velocities in Driggle Draggle Creek, Stratford Creek and the Namoi River, 1% AEP design event

6 Flood impact assessment

6.1 OVERVIEW

The Namoi River and Namoi River tributary TUFLOW models were used to estimate peak flood levels and velocities in the vicinity of the Project during mining by incorporating changes in topography due to the Project mining landforms and Project rail spur. The results were then used to assess the impact of the Project on peak flood levels and velocities when compared to existing conditions for the 20%, 5% and 1% AEP design events. The extents of the Namoi River and Namoi River Tributary TUFLOW models are given in Figure 6.1.

6.2 PROPOSED INFRASTRUCTURE

6.2.1 South Creek and Stratford Creek levees

The existing conditions hydraulic model results show that the secondary infrastructure area is affected by shallow depths of flooding from Stratford Creek and the south-western corner of the secondary infrastructure area and the south-eastern corner of the open cut are affected by shallow depths of flooding from South Creek. It is proposed to construct levees in these areas to prevent water from inundating these areas during the operational phase and following mine closure. The proposed levees are located within the Zone C of the draft FMP, even though they are not inundated by Namoi River extreme flood event. The existing conditions modelling shows that flood protection levees are not required for the Namoi River flooding.

Figure 6.1 shows the locations of the proposed levees. The levees will be designed to prevent inundation of the final void for the PMF. The existing conditions modelling shows that PMF flood depths along the proposed levees range between 0.3 m and 1.6 m. Final levee heights would be determined during detailed design in consideration of freeboard requirements.

6.2.2 Project rail spur

Figure 6.1 shows the alignment of the Project rail spur. The Project rail spur waterway openings will be designed to satisfy the conditions of the draft FMP (see Section 2.2.1). For the purposes of modelling impacts, it has been assumed that bridges will cross the Namoi River, Stratford Creek and Deadmans Gully (AD, D and AID zones, see Figure 2.1) with the superstructure located at the level required to maintain the distribution of flow and above 1% AEP flood level across the Kamilaroi Highway with appropriate road clearance. A range of openings (bridges and culverts) with embankments have been used across the BL and C zones to maintain the flow distribution across the floodplain. The final vertical alignment of the rail and sizing of the openings (bridges and culverts) will be determined during the detailed design stage.

6.2.3 Blue Vale Road realignment

Figure 6.1 shows the location of the proposed Blue Vale Road realignment. Detailed design of the realignment has not been undertaken at this stage. While the proposed road has not been included in the developed conditions model, the proposed Blue Vale Road realignment is proposed to have the same flood immunity as the existing road. Blue Vale Road is currently overtopped by the 20% AEP flood (see Figure 5.5).

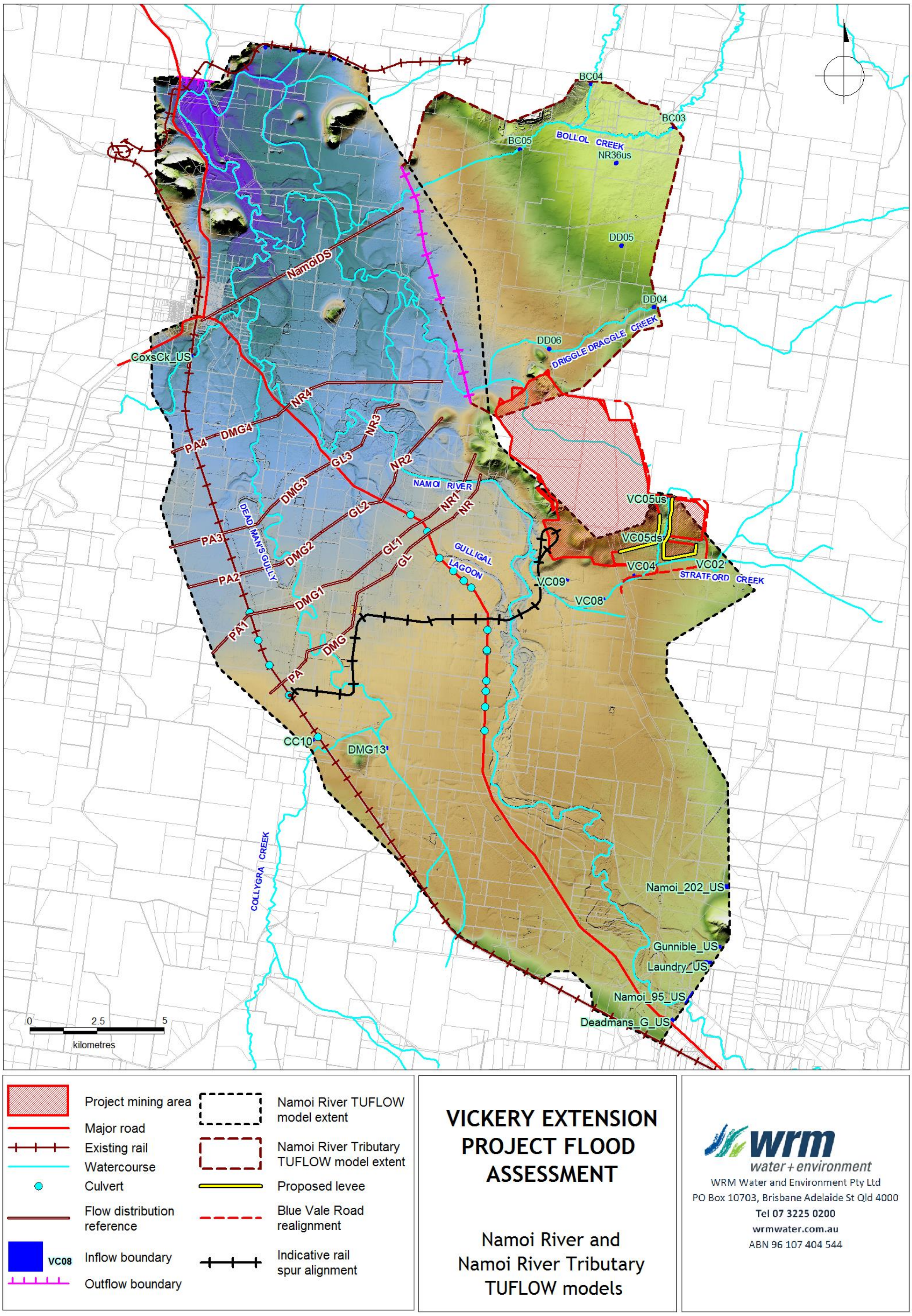


Figure 6.1 – Namoi River and Namoi River Tributary TUFLOW models

6.2.4 Project Borefield and Pipeline

The Project borefield and pipeline would be located to the north of the Project mining area (Figure 2.2) on land owned by Whitehaven. The pipeline would be predominantly above ground and would be <10 cm in diameter. Predicted flood levels associated with Driggle Draggle Creek are provided on Figure 5.5, 5.6 and 5.7 for the 20% AEP, 5% AEP and 1% AEP design events, respectively. An increase in flood levels associated with the Project borefield and pipeline would be minor (<10 cm) and there would be no change to flood levels, velocities or extents on privately owned land.

6.3 IMPACT OF SOUTH AND STRATFORD CREEK LEVEES

Figure 6.2, Figure 6.3 and Figure 6.4 show the predicted flood level impacts and Figure 6.5, Figure 6.6 and Figure 6.7 show the predicted changes in peak flood velocities along South and Stratford Creeks due to the proposed levees for the 20%, 5% and 1% AEP events respectively.

The predicted impact of the proposed levees on peak flood levels and velocities along South and Stratford Creeks is small (less than 0.05 m and 0.5 m/s, respectively) and are generally localised near the levees (within land owned by Whitehaven). There are no predicted increases in peak flood levels or velocities at existing privately-owned land and dwellings due to the proposed levees and therefore the proposed levees would satisfy the criteria of the draft FMP.

6.4 IMPACT OF THE PROJECT RAIL SPUR

The Project rail spur has been assessed against the criteria given in the draft FMP (see Section 2.2.1) using the 20% AEP design event as a representative small flood and the 5% AEP design event as the representative large flood. The impact of the Project rail spur on the 1% AEP design event has also been assessed.

6.4.1 Impact on flood levels

Figure 6.8, Figure 6.9 and Figure 6.10 show the predicted flood level impacts due to the Project rail spur for the 20%, 5% and 1% AEP events respectively. The impacts for the 20% (small event) and 5% AEP (large event) are generally confined to Whitehaven owned land. There are no flood level impacts at the Kamilaroi Highway or at dwellings for these events. No heritage sites or cultural values identified for the Aboriginal Cultural Heritage Assessment (Appendix G of the EIS) or the Historic Heritage Assessment (Appendix K of the EIS) are predicted to be impacted through the changes to flood levels. On this basis, and with the conservative model predictions (Section 5.3), the Project rail spur satisfies the draft FMP criteria that flood levels would increase by less than 20 cm on adjacent private landholdings and would not impact on high value infrastructure or historic sites and cultural values.

With respect to the 1% AEP event, the impacts on flood level dissipates to zero within 1.5 km upstream of the Project rail spur. The impact at the Project rail spur is up to 0.3 m for the 1% AEP event within the Whitehaven owned land and not in the close vicinity of the high infrastructure. Peak 1% AEP flood levels on the Kamilaroi Highway increase by up to 0.1 m. Kamilaroi Highway is already inundated by up to 1 m for this event and is therefore impassable.

Further work to optimise the locations of openings and bunds will be undertaken during detailed design to confirm the design objectives would be met.

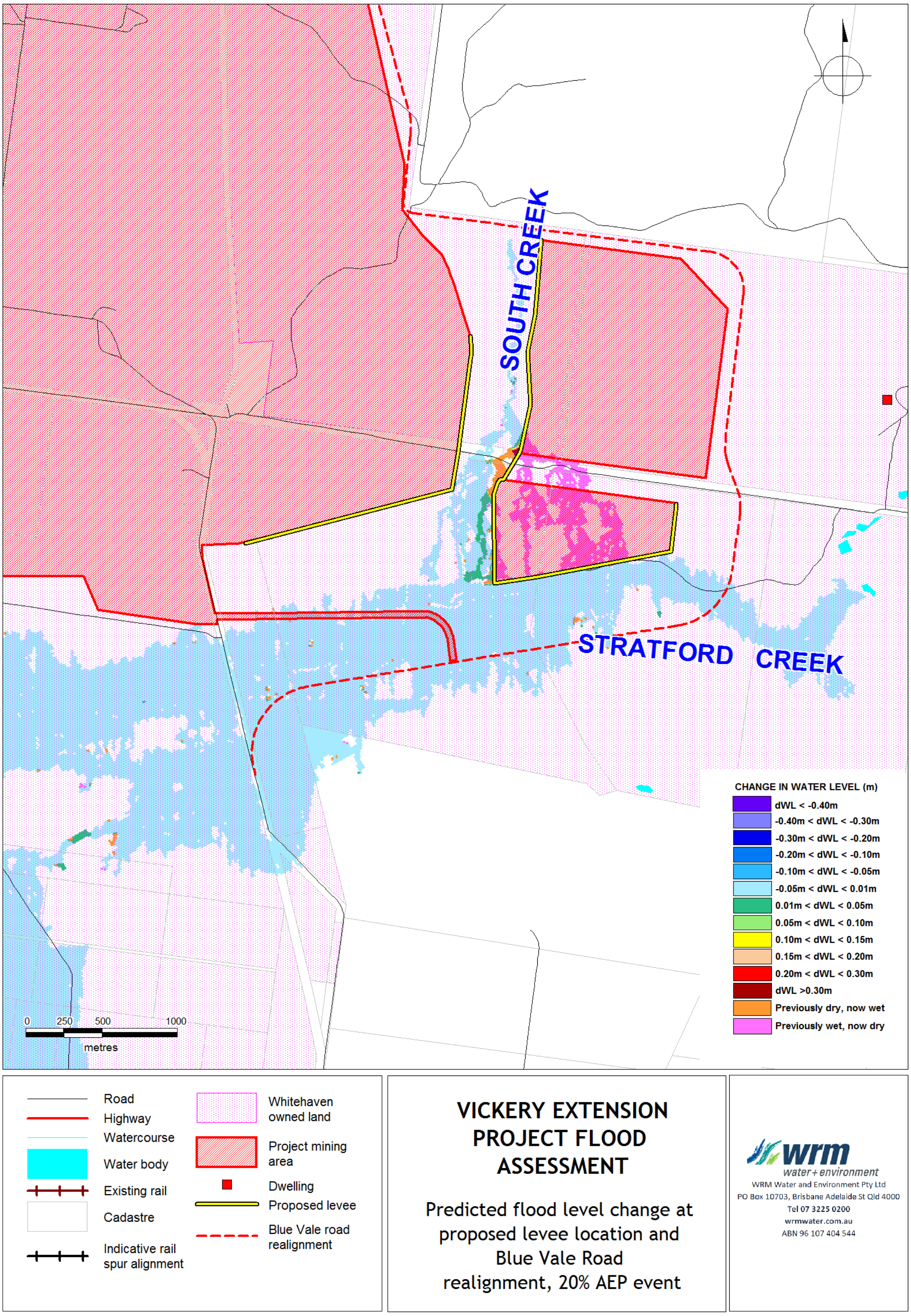


Figure 6.2 – Predicted flood level change at proposed levee location and Blue Vale Road realignment, 20% AEP event

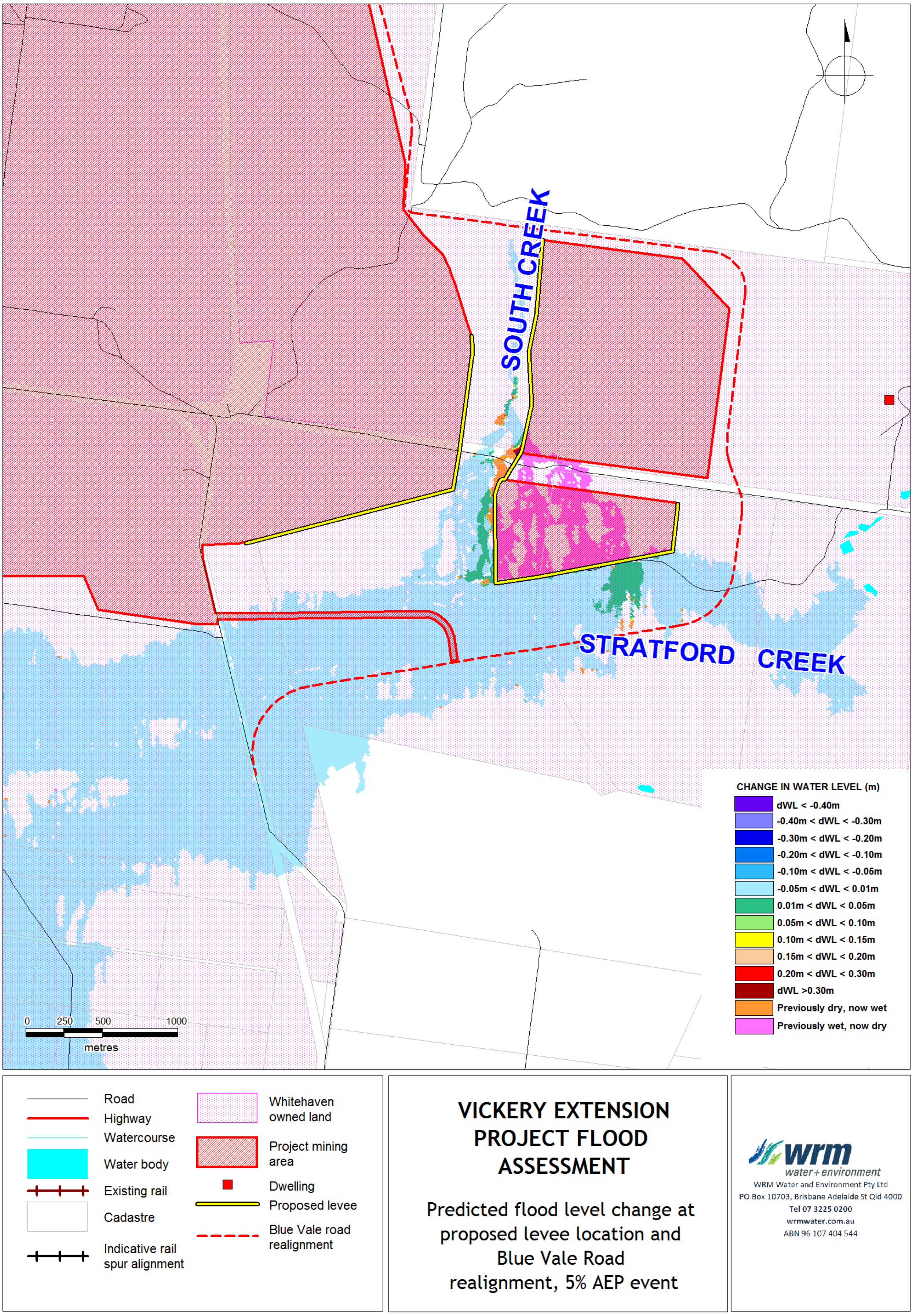


Figure 6.3 - Predicted flood level change at proposed levee location and Blue Vale Road realignment, 5% AEP event

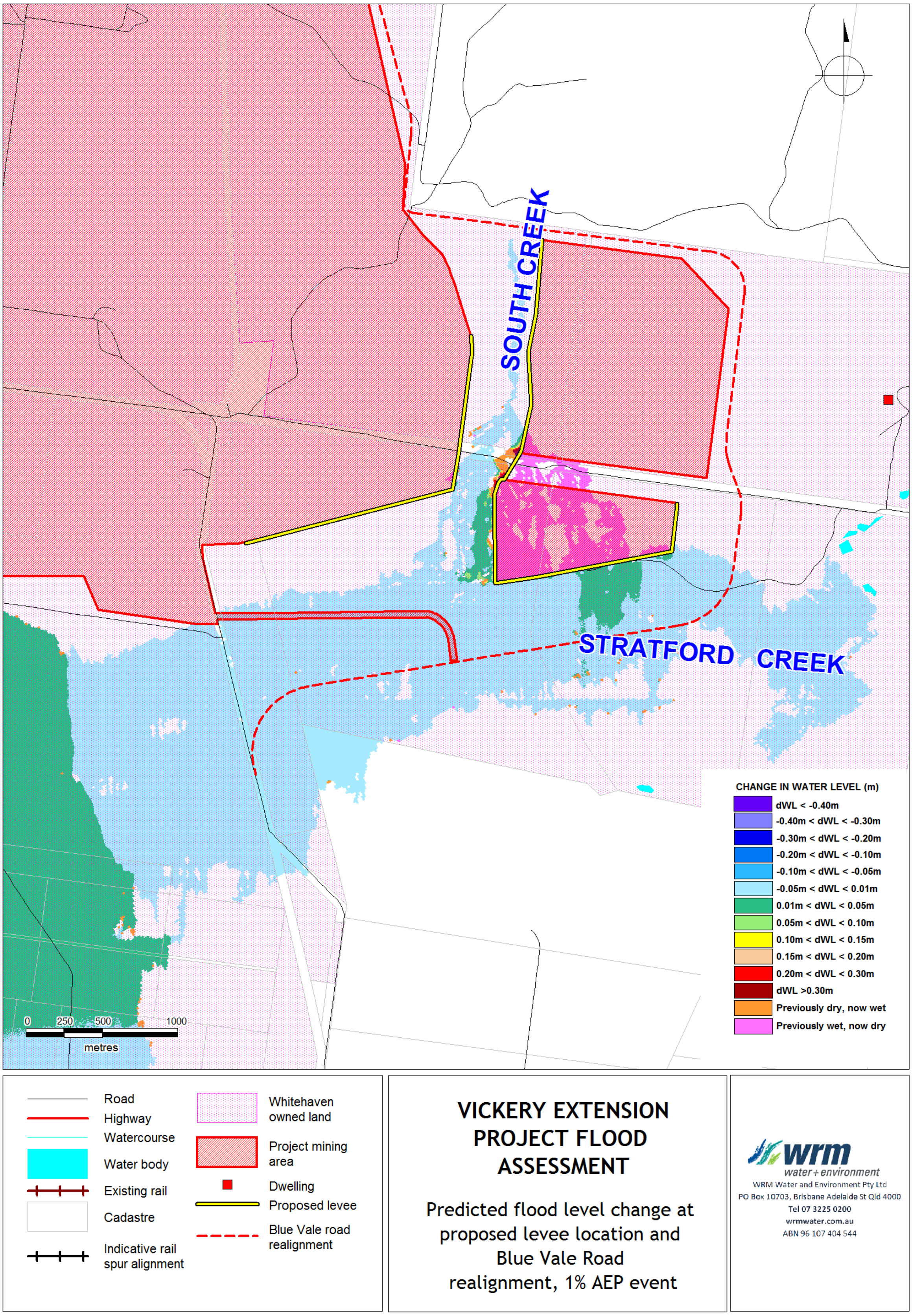


Figure 6.4 - Predicted flood level change at proposed levee location and Blue Vale Road realignment, 1% AEP event

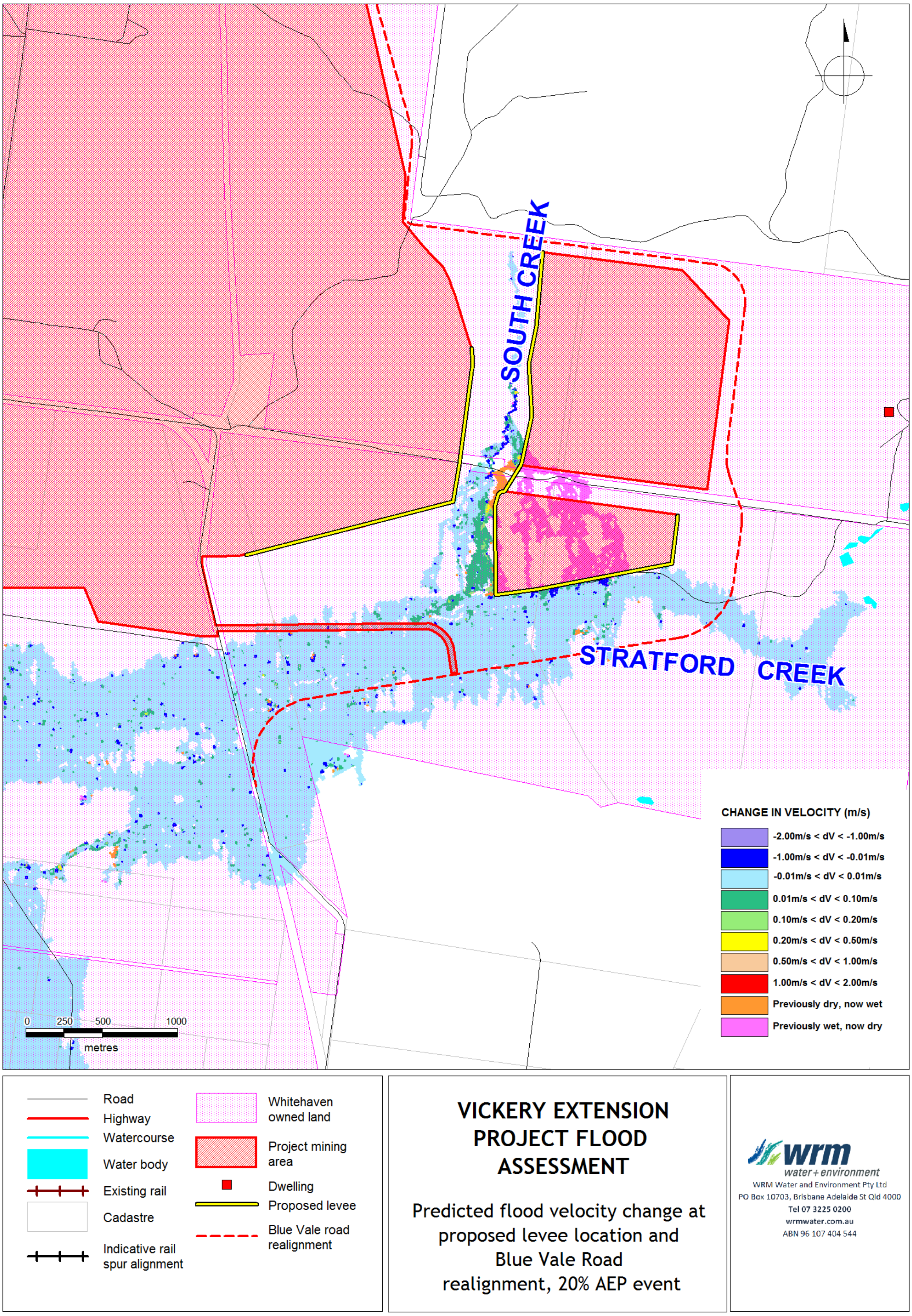


Figure 6.5 - Predicted flood velocity at proposed levee location and Blue Vale Road realignment, 20% AEP design event

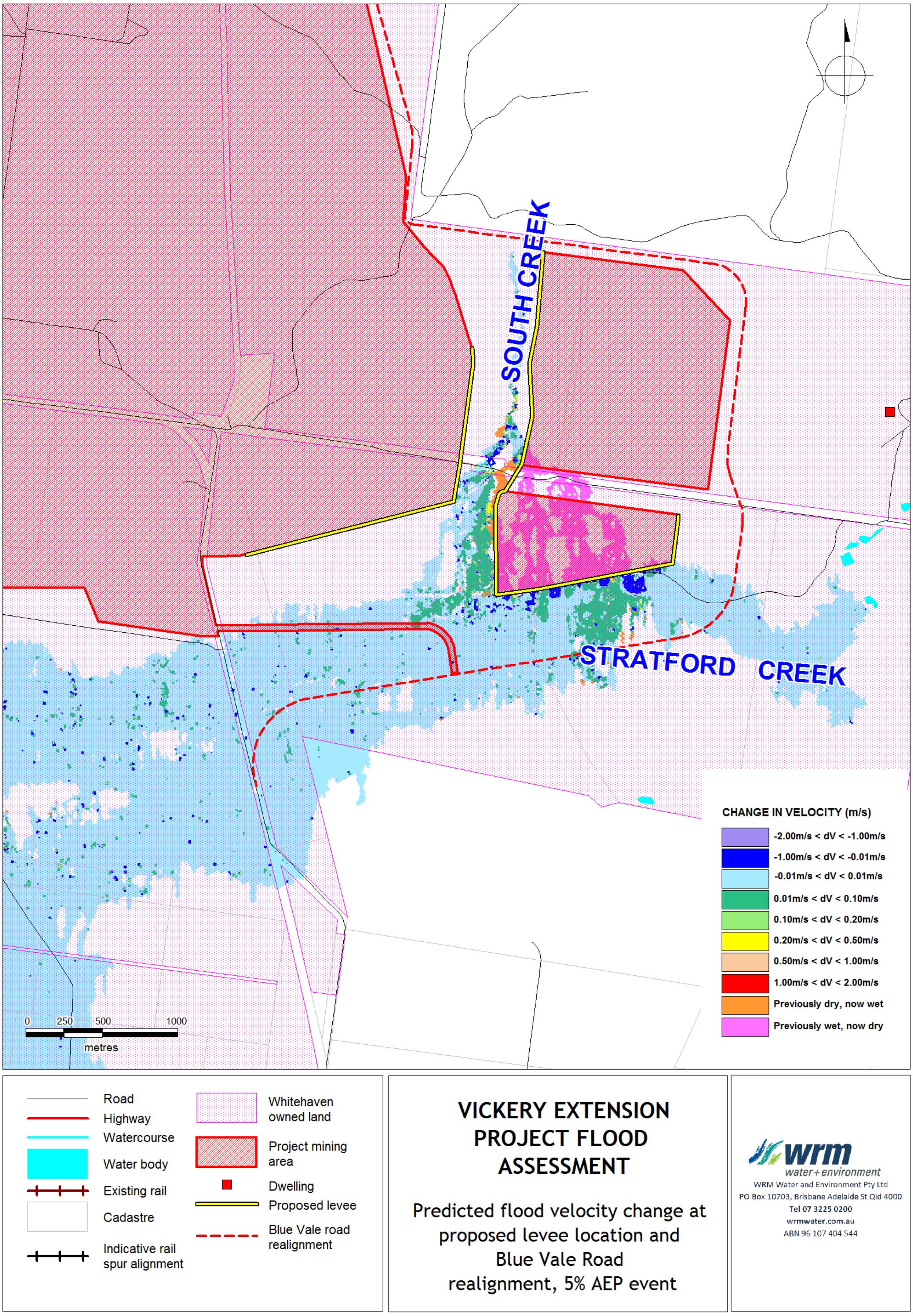


Figure 6.6 - Predicted flood velocity change at proposed levee location and Blue Vale Road realignment, 5% AEP design event

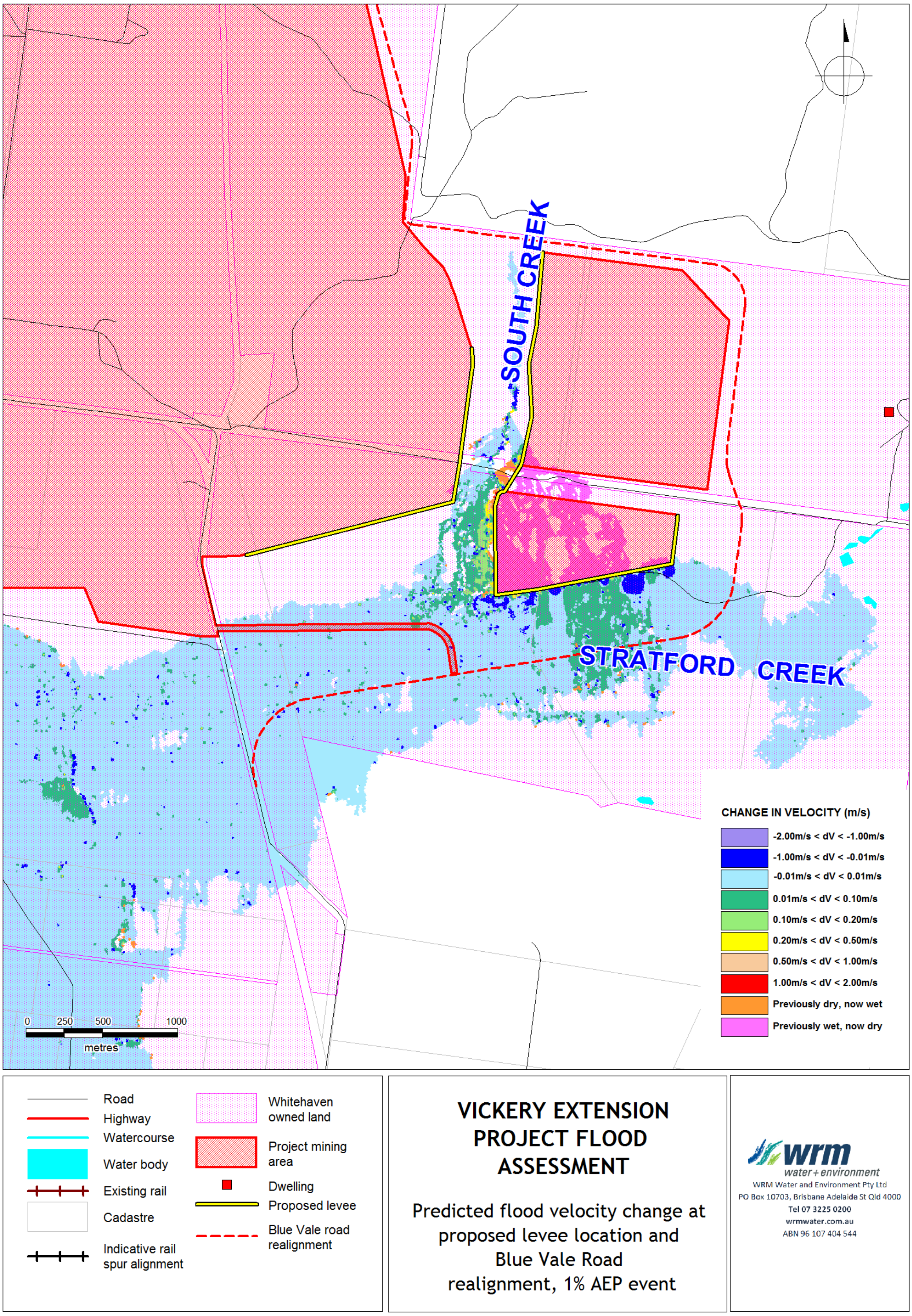


Figure 6.7 - Predicted flood velocity change at proposed levee location and Blue Vale Road realignment, 1% AEP design event

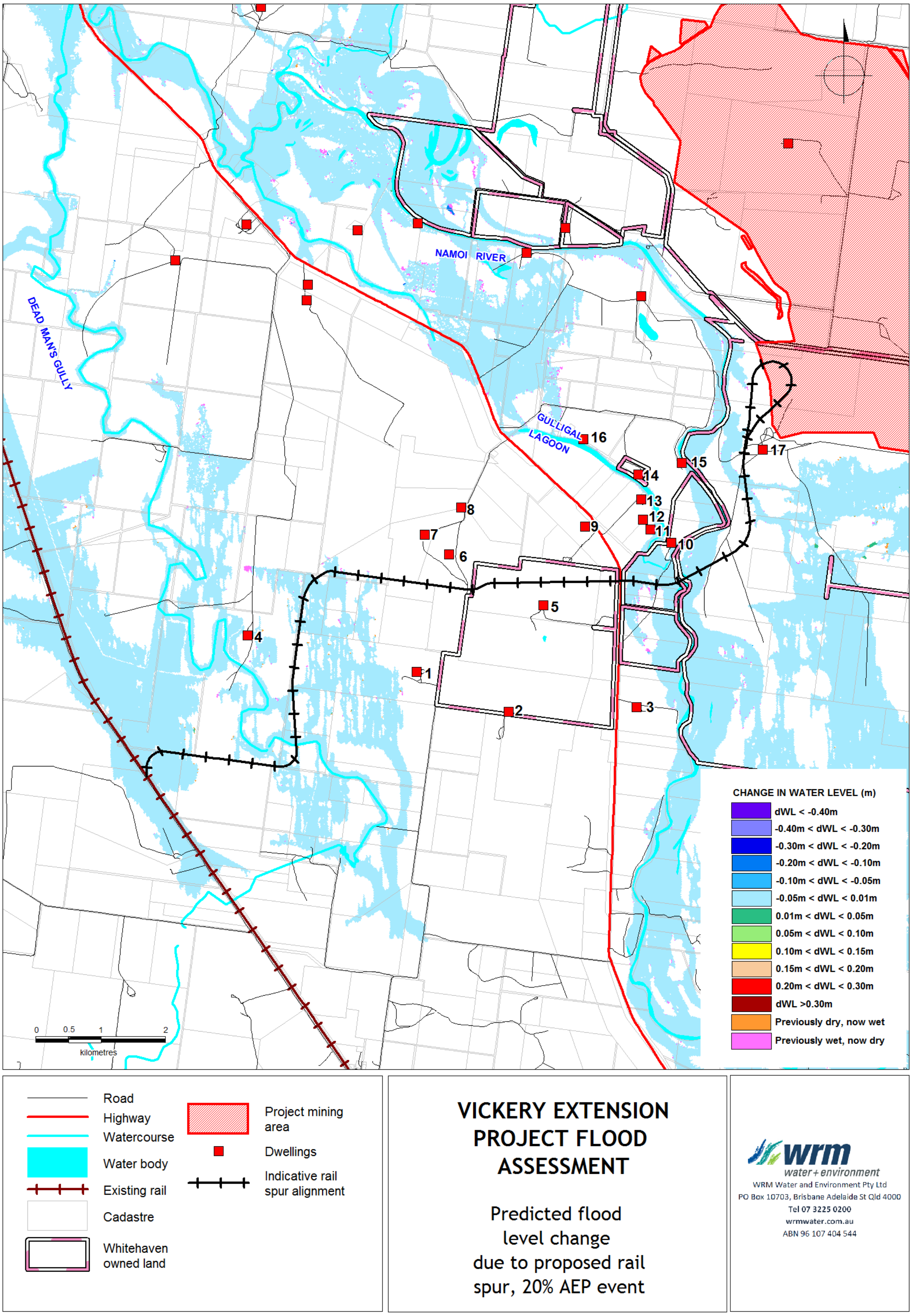
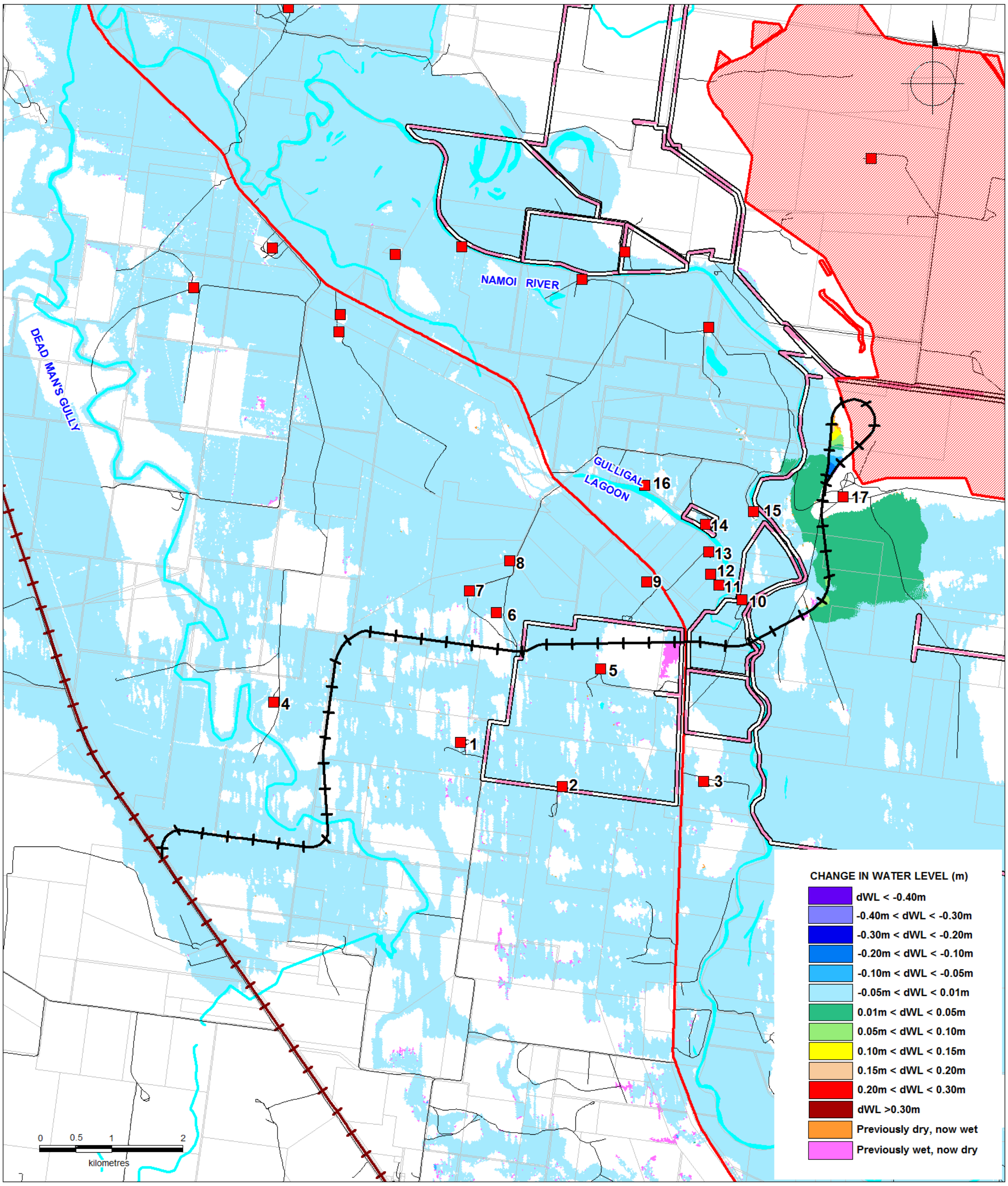


Figure 6.8 – Predicted flood level change due to Project rail spur, 20% AEP event



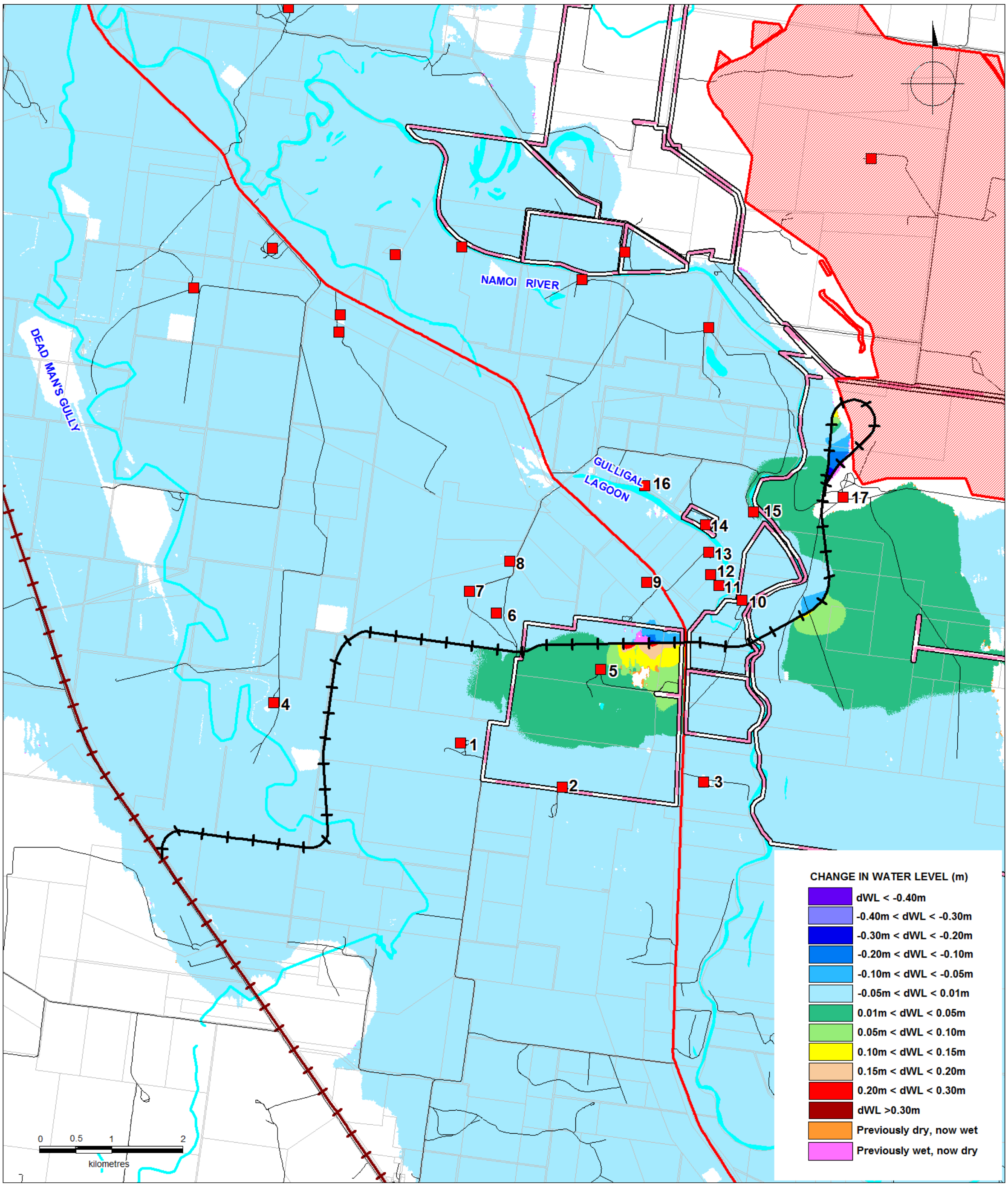
Road
Highway
Watercourse
Water body
Existing rail
Cadastre
Whitehaven owned land
Project mining area
Dwellings
Indicative rail spur alignment

VICKERY EXTENSION PROJECT FLOOD ASSESSMENT

Predicted flood level change due to proposed rail spur, 5% AEP event

wrm water+environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544

Figure 6.9 – Predicted flood level change due to Project rail spur, 5% AEP event



VICKERY EXTENSION PROJECT FLOOD ASSESSMENT

Predicted flood level change due to proposed rail spur, 1% AEP event

wrm water + environment
WRM Water and Environment Pty Ltd
PO Box 10703, Brisbane Adelaide St Qld 4000
Tel 07 3225 0200
wrmwater.com.au
ABN 96 107 404 544

Figure 6.10 - Predicted flood level change due to Project rail spur, 1% AEP Event

6.4.2 Impact on flood velocities

Figure 6.11, Figure 6.12 and Figure 6.13 show the predicted peak flood velocity impacts due to the Project rail spur for the 20%, 5% and 1% AEP events respectively. The velocity impacts for the 20% (small event) and 5% AEP (large event) are small and generally confined to the rail corridor itself on Whitehaven owned land. The velocity impacts at the boundaries of private landholdings are negligible. The velocity impacts under the rail are approximately 20% higher than existing conditions with the exception of isolated areas of very low existing conditions velocities. The impacts on land external to Whitehaven owned land are less than 0.1 m/s. Therefore, the Project rail spur would comply with the velocity impact requirement set in the draft FMP.

The velocity impacts for the 1% AEP event are similar to the small event and large event impacts described above and would also comply with the velocity impact requirement set in the draft FMP.

6.4.3 Impact on flow distribution

Given the flat nature of the Namoi River floodplain, the draft FMP has recognised that it is important to maintain the existing distribution of flood flows across the floodplain for both relevant small and large design events. For the purposes of this assessment, the Namoi River floodplain was delineated into the following flow paths:

- Namoi River (NR);
- Namoi River Branch (NRB);
- Gulligal Lagoon (GL);
- Deadmans Gully (DMG); and
- Primeag (conveying flow to the west of Deadmans Gully) (PA).

Figure 6.1 shows the locations of the flow paths and the cross sections that have been used to represent the flow paths. The impact of the Project rail spur on the flow distribution at each cross section for the 5% AEP event is summarised in Table 6.1.

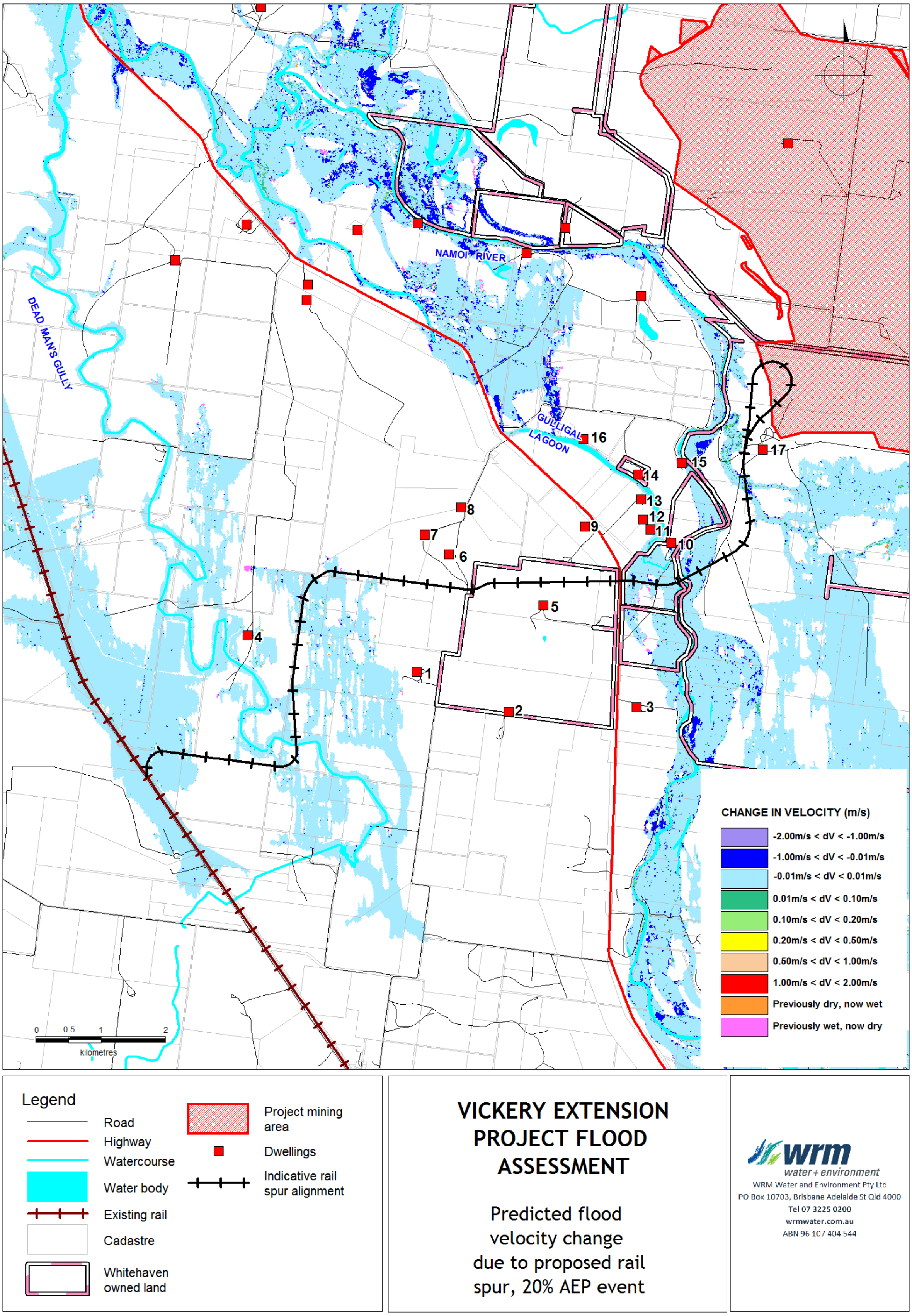


Figure 6.11 - Predicted flood velocity change due to Project rail spur, 20% AEP event

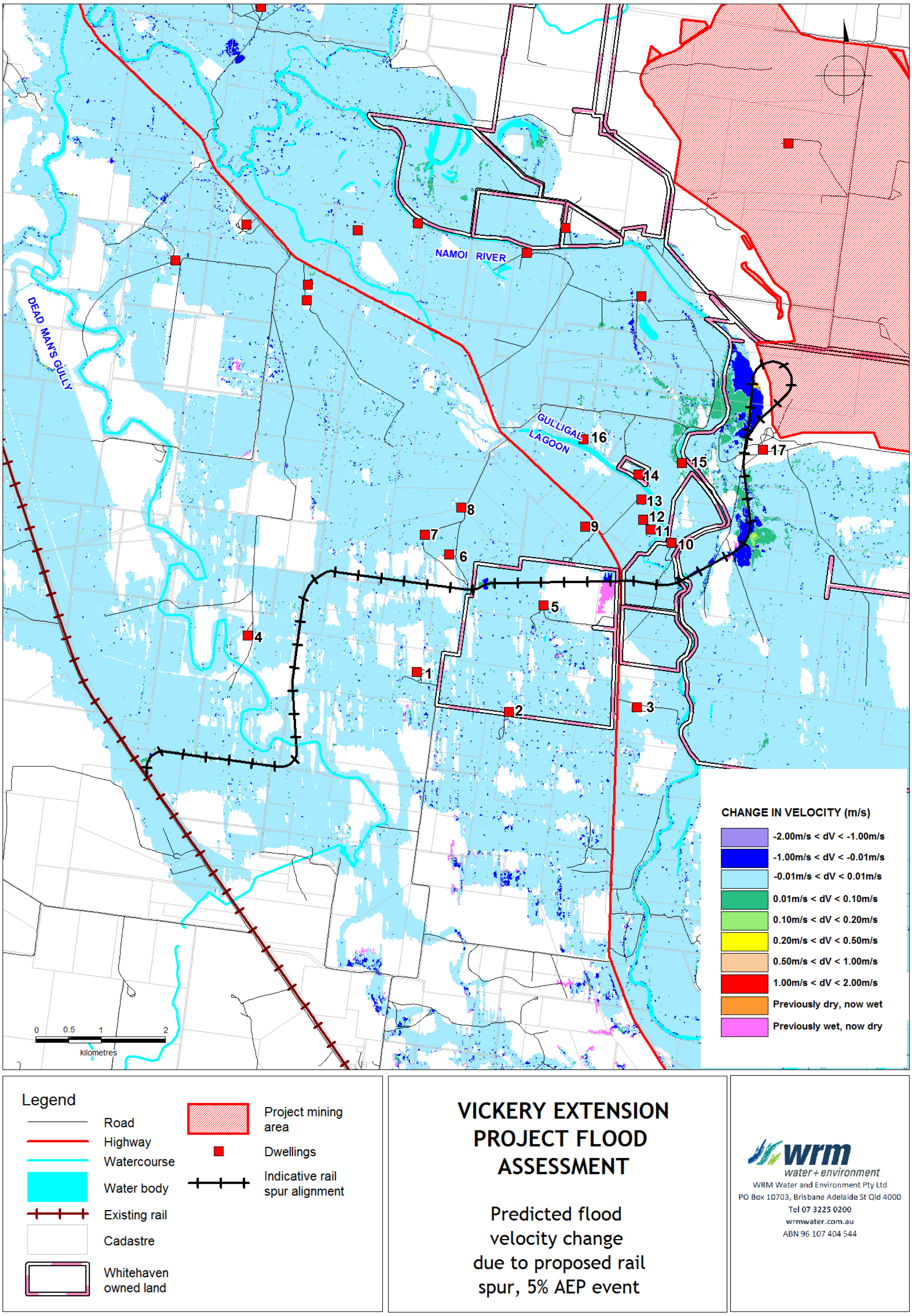


Figure 6.12 - Predicted flood velocity change due to Project rail spur, 5% AEP event

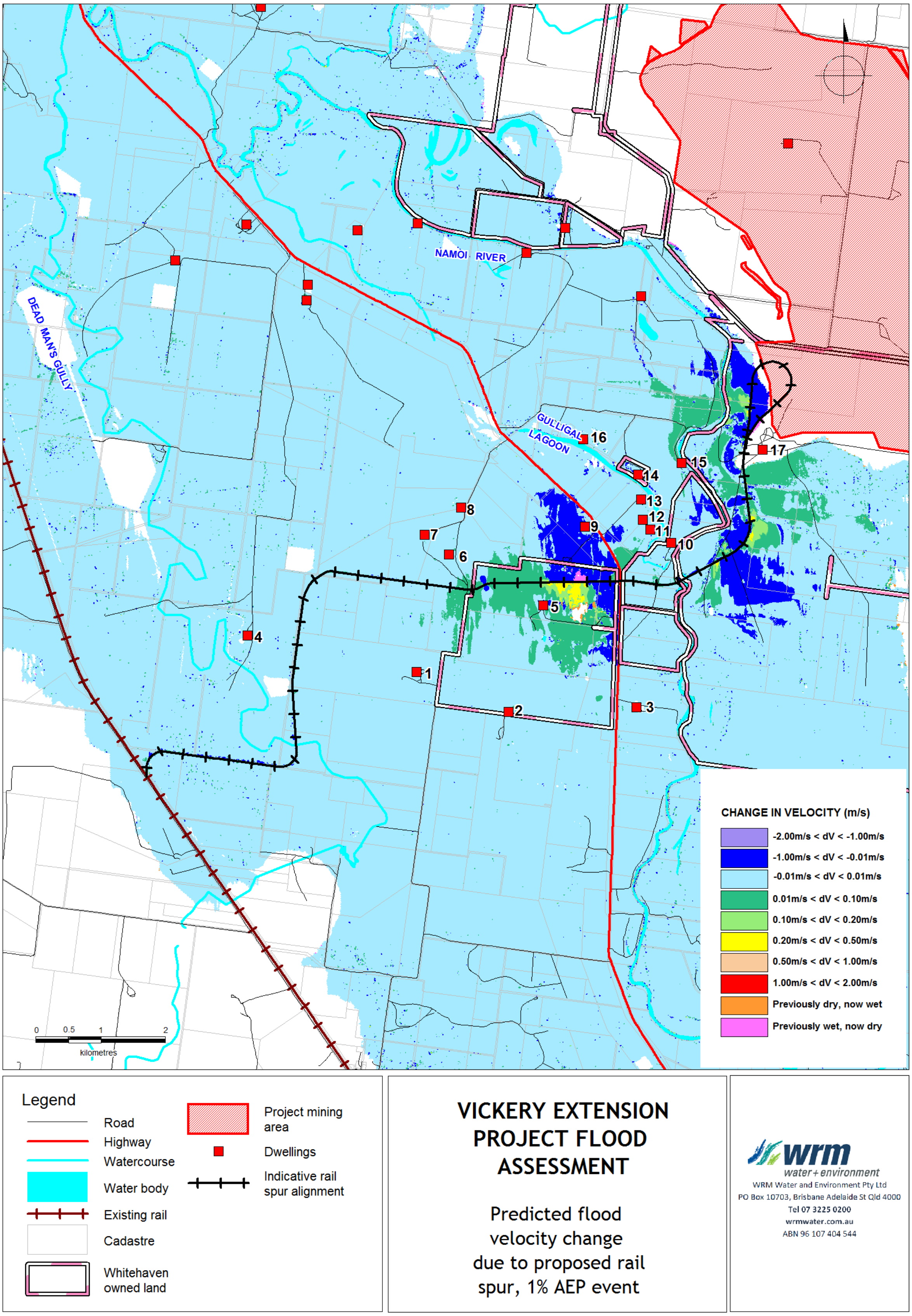


Figure 6.13 – Predicted flood velocity change due to Project rail spur, 1% AEP event

Table 6.1 – Peak flow distribution impacts for 5% AEP flood event

Flow ID	Existing	Proposed	Difference (%)
PA	185.5	185.4	0.0%
PA1	169.6	169.6	0.0%
PA2	159.7	159.8	0.0%
PA3	133.0	132.9	-0.1%
PA4	18.0	18.0	-0.2%
DMG	22.1	22.2	0.2%
DMG1	17.1	17.1	-0.2%
DMG2	12.2	12.1	-0.2%
DMG3	22.4	22.0	-1.8%
DMG4	73.0	73.0	-0.1%
GL	667.9	666.0	-0.3%
GL1	528.9	527.0	-0.4%
GL2	582.8	581.1	-0.3%
GL3	855.1	851.8	-0.4%
NR	1724.8	1718.8	-0.4%
NR1	1858.9	1853.0	-0.3%
NR2	1781.0	1774.4	-0.4%
NR3	1462.2	1458.8	-0.2%
NR4	1033.3	1030.6	-0.3%
NRB4	1236.0	1229.7	-0.5%
CoxsCk US	54.1	54.9	1.4%
Namoi DS	2416.4	2404.1	-0.5%

The results show that the distribution of flow across the floodplain is not significantly altered by the Project rail spur and would not result in a consequential effect to neighbouring properties or the environment.

6.4.4 Connectivity, fish passage and drainage times

The Project rail spur will be designed to satisfy the connectivity, fish passage and drainage time requirements of the draft FMP. For the Namoi River AD zone, D zone and associated AID zone, bridge structures will be used with only the piers impacting on flood flows and therefore will not impact on connectivity, fish passage or drainage times.

For Stratford Creek and Deadmans Gully, any culvert/bridge structure will be designed in accordance with DPI Fisheries *Policy and Guidelines for Fish Habitat Conservation and Management* (Update 2013) (DPI Fisheries 2013). Cross drainage structures on the floodplain will be designed to minimise or eliminate ponding to allow free drainage.

Consideration of the impacts on aquatic ecology is also presented in the Aquatic Ecology Assessment (Appendix N of the EIS).

6.4.5 Cumulative impacts

The flood impact maps include the existing floodplain infrastructure such as the levees and drains and therefore fully consider the cumulative impact that the proposed works and other existing works on the landholding may have on adjacent landholdings.

6.5 IMPACT OF CLIMATE CHANGE

The Surface Water Assessment prepared for the Project (Appendix B of the EIS) summarises climate change predictions for the Project region in consideration of the *New England North West Region Climate Change Snapshot* (OEH, 2014) and *Climate Change in Australia Projections for Australia's Natural Resource Management (NRM) Regions* (Ekström, M. et al. 2015).

With respect to annual/seasonal rainfall, the predictions indicate that in the near future (2030) natural variability is projected to predominate over trends. Late in the century, climate model results indicate decreasing winter rainfall with high confidence. Decreases are also projected in spring, with medium confidence.

With respect to rainfall intensity, the predictions indicate with high confidence a future increase in the intensity of extreme rainfall events, although the magnitude of the increases cannot be confidently projected.

Any increase in rainfall intensities as a result of climate change would result in increased peak flood discharges and peak flood levels across the study area. However, the magnitude of any changes in rainfall intensities over the 25-year mine life of the Project are not expected to significantly change the 1% AEP and PMF events that have been assessed, and therefore the predicted changes in flood levels and velocities due to the Project would not be significantly affected. Therefore, for the purpose of an impact assessment, an additional climate change flooding scenario was not considered to be required.

7 Summary of findings

The Project is partially located on and adjacent to the declared floodplain of the Upper Namoi Valley defined under the *Water Management (General) Regulation 2011*. The NSW Government has prepared a draft FMP, which sets out rules to coordinate the approval of new flood works or amendments to existing flood works on the floodplain (noting that the Project would not require a flood work approval under the *Water Management Act 2000* due to section 4.41 of the *Environmental Planning and Assessment Act 1979*). Hydrological and hydraulic computer models have been developed of the Namoi River and adjacent tributaries to assess the proposed works against the rules of the draft FMP and to address the SEARs. Computer models have been developed of existing and proposed conditions for a typical small event (20% AEP) and large event (5% AEP) (events used in the draft FMP) as well as for the 1% AEP and 3x1% AEP design events (representative of an extreme event).

The existing conditions flooding characteristics in the vicinity of the proposed mine area and the Project rail spur are summarised as follows:

- The disturbance areas associated with the Project (with the exception of the Project rail spur) are not located on land flooded by the Namoi River for the 3x1%AEP extreme design event. Therefore, flood protection levees are not required to prevent Namoi River inundation.
- The secondary infrastructure area is affected by flooding by Stratford Creek, a minor tributary of the Namoi River. Peak 1% AEP flood depths from Stratford Creek along the southern boundary of the secondary infrastructure area are up to 1.5 m.
- The secondary infrastructure area and the south-western corner of the open cut are affected by flooding from South Creek, a minor tributary of Stratford Creek. South Creek flood depths across the infrastructure areas are shallow and generally less than 1.6 m for events up to the PMF.
- The Project rail spur alignment is located across the Namoi River floodplain, which would be inundated to various depths during flood events.

Levees are proposed to mitigate flooding along South Creek and Stratford Creek. These levees are located in Zone C (flood fringe) of the draft FMP (although not flooded by the Namoi River). The Project rail spur crosses several zones. The proposed waterway openings of the Project rail spur will be designed to satisfy the criteria/objectives of the draft FMP. For the purposes of modelling impacts, it has been assumed that bridges will cross the Namoi River, Stratford Creek and Deadmans Gully (AD, D and AID zones) with the superstructure located above the 1% AEP flood level as well as across the Kamilaroi Highway with appropriate road clearance. A range of openings (bridges and culverts) with embankments have been used across the BL and C zones to maintain the flow distribution across the floodplain. The final vertical alignment of the rail and sizing of the openings (bridges and culverts) will be determined during the detailed design stage. A summary of the proposed conditions modelling is given below:

- All infrastructure proposed as part of the Project, including the rail, complies with the intent of the draft FMP, even with the conservative estimates predicted through the modelling.
- The predicted impact of the proposed South Creek and Stratford Creek levees on peak flood levels and velocities along South and Stratford Creeks is small (less than 0.05 m) and are generally localised near the levees (within land owned by Whitehaven). There are no predicted increases in peak flood levels or velocities at existing privately-owned land and dwellings due to the proposed levees and therefore the proposed levees would satisfy the hydraulic criteria of the draft FMP.

- The impact of the Project rail spur on peak flood levels and velocities are summarised as follows:
    - The flood level and velocity impacts for the 20% (small event) and 5% AEP (large event) are small and generally confined to Whitehaven owned land. There are no flood level impacts at the Kamilaroi Highway or at dwellings for these events.
    - With respect to the 1% AEP event, the impacts on flood level dissipates to zero within 1.5 km upstream of the Project rail spur. The impact at the Project rail spur is up to 0.3 m for the 1% AEP event within the Whitehaven owned land and not in the close vicinity of the high infrastructure. Peak 1% AEP flood levels on the Kamilaroi Highway increase by up to 0.1 m. However, Kamilaroi Highway is already inundated by up to 1 m for this event and is therefore impassable.
    - The distribution of flow across the floodplain is not significantly altered by the Project rail spur.

8 References

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XP Software, 2013	*XP-RAFTS, XP Software, Florida, USA.*

Appendix A - Draft Upper Namoi River Floodplain Management Zones

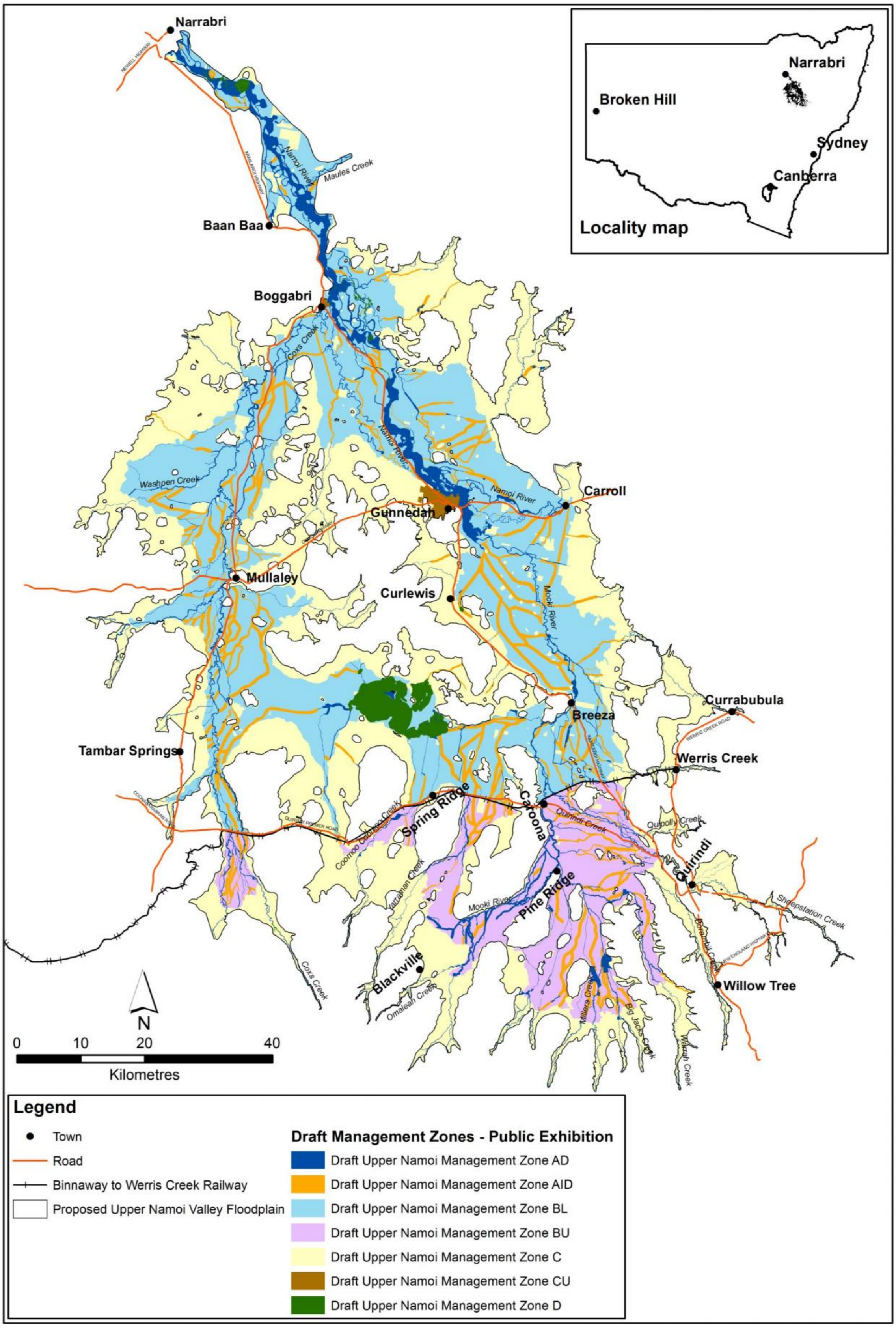

Figure A.1 – Floodplain Management Plan Zones (NSW OEH & NSW DPI, 2016)

Appendix B - 1998 Aerial flood photography

Figure B.1 – Aerial photograph, Namoi River in vicinity of Vickery South – 1998 event

Figure B.2 – Aerial photograph, Deadmans Gully and Collygra Creek – 1998 event

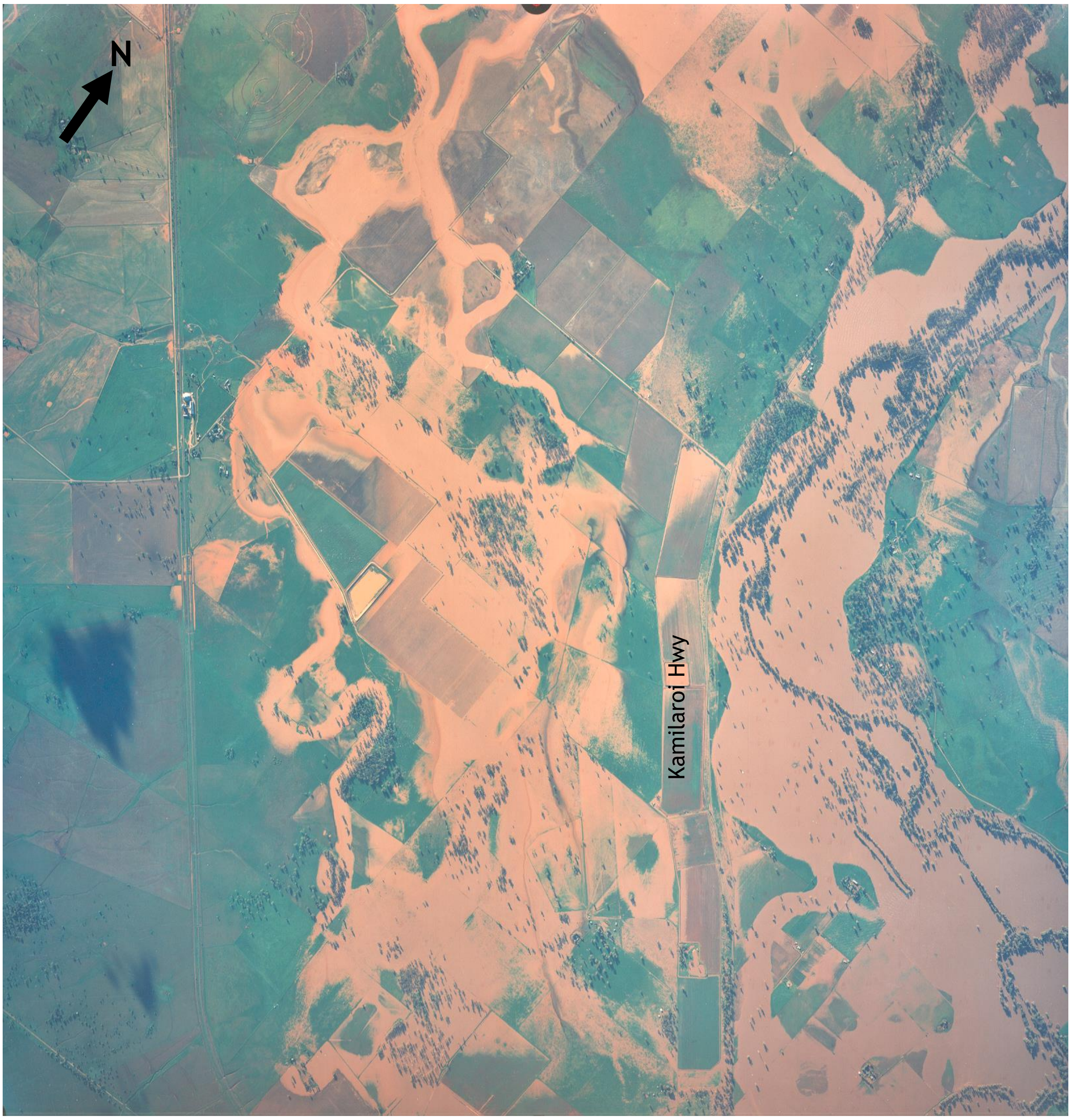

Figure B.3 – Aerial photograph, Namoi River and Deadmans Gully – 1998 event

Figure B.4 – Aerial photograph, Namoi River and Deadmans Gully – 1998 event