APPENDIX 3

Flooding and Drainage Assessment

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AUSTAR COAL MINE

LWB4-B7 MODIFICATION FLOODING AND DRAINAGE ASSESSMENT

Austar Coal Mine

FINAL

May 2017

LWB4-B7 MODIFICATION FLOODING AND DRAINAGE ASSESSMENT

Austar Coal Mine

FINAL

Prepared by
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on behalf of
Yancoal

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1.0 Introduction

1.1 Background

Austar Coal Mine Pty Ltd (Austar), a subsidiary of Yancoal Australia Limited (Yancoal) operates the Austar Coal Mine, an underground coal mine located approximately 10 kilometres south of Cessnock in the Lower Hunter Valley in NSW (refer to **Figure 1.1**). The Austar Coal Mine incorporates the former Pelton, Ellalong, Cessnock No. 1 (Kalingo) and Bellbird South Collieries and includes coal extraction, handling, processing and rail and road transport facilities (refer to **Figure 1.2**).

Extensive mining has been undertaken within the Austar Coal Mine since 1916. Historical mining was predominantly via bord and pillar mining and more recently via conventional longwall mining and Longwall Top Coal Caving (LTCC) methods. Mining within the Bellbird South areas (Southland, Stage 1 and Stage 2, refer to **Figure 1.2**) was approved by the Minister for Urban Affairs and Planning in 1996 under DA 29/95, while mining of Stage 3 was approved by the Minister for Planning in 2009 under Project Approval 08_0111. Mining is currently proceeding in the LWB1-B3 mining area in accordance with DA 29/95 (as modified).

A review of accessible coal resources within the Bellbird South/Ellalong Colliery areas has identified the potential for four additional longwall panels (LWB4-B7) adjacent to LWB3 that can be accessed from the Bellbird mains (refer to **Figure 1.3**). Austar proposes to modify DA 29/95 to permit the transfer and processing of coal from the four proposed longwall panels (LWB4-B7) via the existing Bellbird mains and to extend the development consent area to cover the four longwall panels (refer to **Figure 1.3**).

No other changes to the approved mining operations, associated surface facilities or production rates are proposed as part of the modification.

1.2 Scope of Assessment

The primary aim of this flood and drainage assessment is to determine the potential impacts of the proposed mining of LWB4 to LWB7 on the flood and drainage behaviour of the surrounding area, including cumulative impacts to the estimated flood behaviour in relation to the previously approved LWB1-B3, Stage 2 and Stage 3 mine plans.

This report has been prepared to accompany an Environmental Assessment (EA) that identifies and assesses the potential environmental impacts of LWB4-B7.

1.3 Catchment Context

The LWB4-B7 Modification Area (delineated by the predicted 20mm subsidence contour for LWB4-B7) is located within the Quorrobolong Creek catchment area (refer to **Figure 1.3**). Quorrobolong Creek drains in a westerly direction through the north of the LWB4-B7 Modification Area above proposed LWB6 and LWB7. The total length of Quorrobolong Creek above these longwalls is approximately 1.3 kilometres. Quorrobolong Creek is ephemeral with localised areas of natural ponding occurring along its alignment (refer to **Plates 1.1** and **1.2**). Quorrobolong Creek has been previously directly mined beneath within the Ellalong Colliery and Stage 2 mining area at the Austar Coal Mine, with a total length of approximately 4 kilometres located directly above these previously extracted longwalls. Monitoring of these previous extracted longwalls has shown no significant surface cracking or loss of surface water flows as a result of mining.

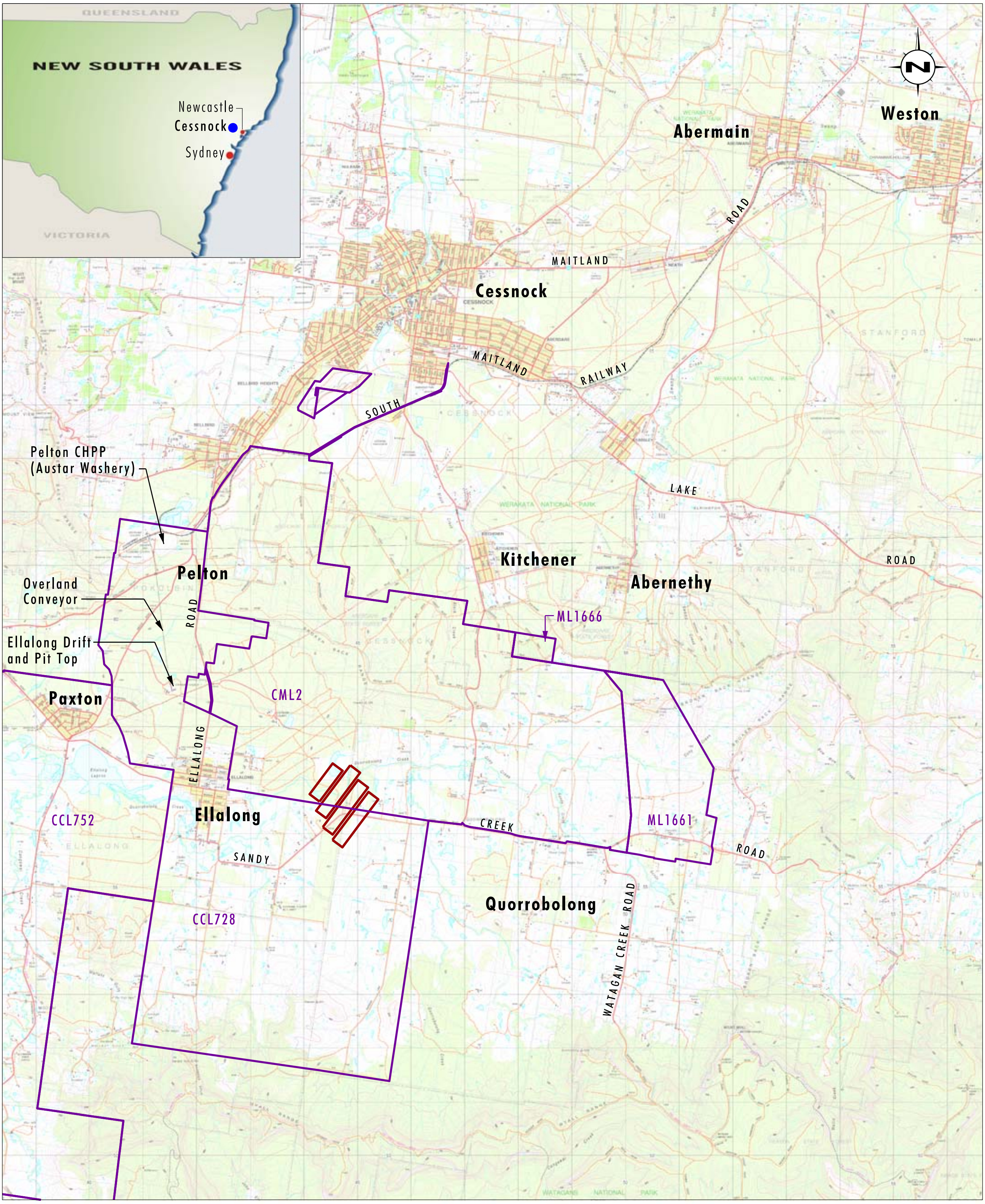


Image Source: LPI NSW (2009)
Data Source: Austar Coal Mine (2016)

0 1.0 2.5 5.0km
1:100 000

Legend

Proposed LWB4-B7 Longwall Panels
Mining Lease Boundary

FIGURE 1.1

Locality Plan

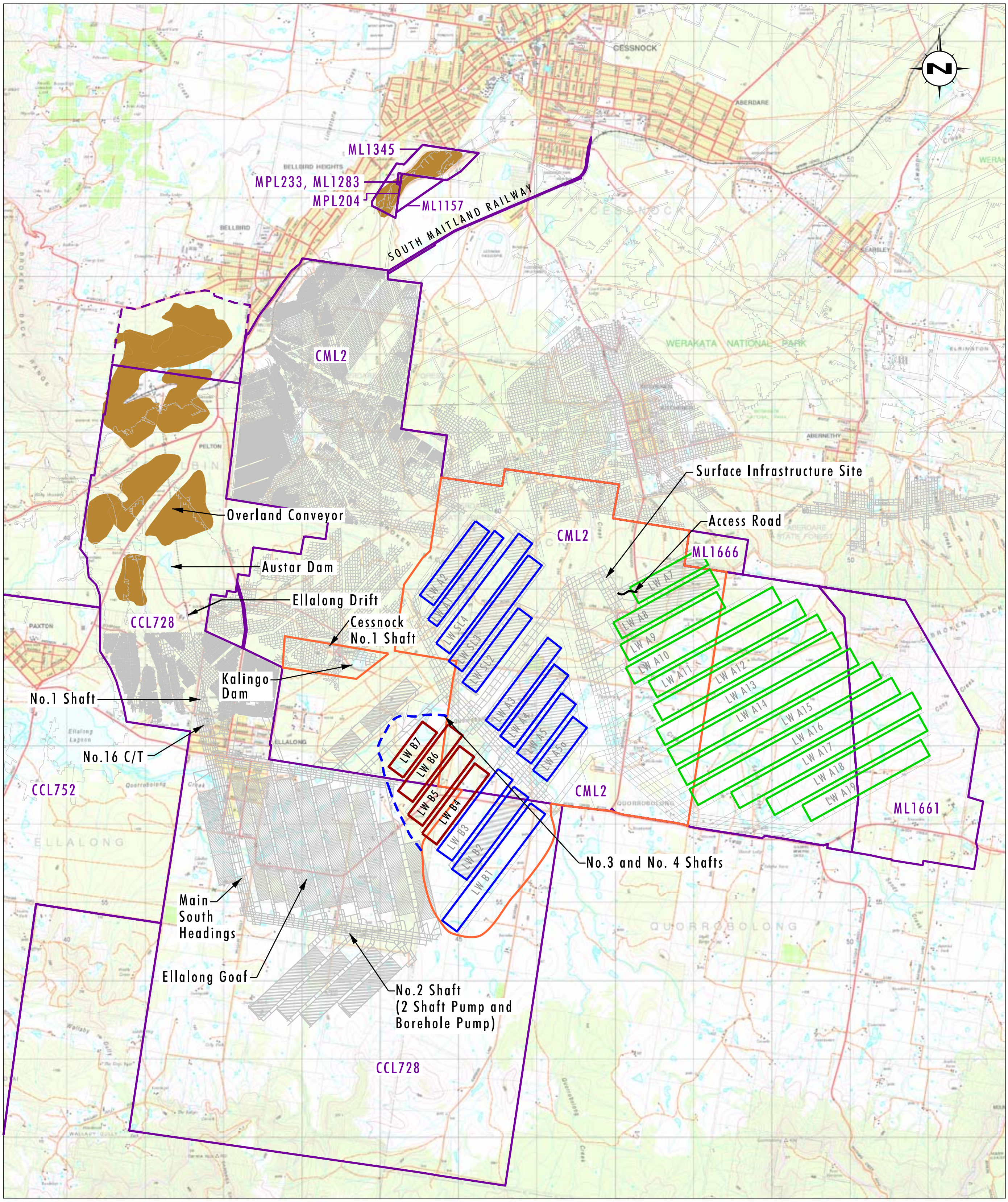


Image Source: LPI NSW (2009)
Data Source: Austar Coal Mine (2016)

0 1 2 3km
1:70 000

Legend

- Bellbird South Stage 1, Stage 2, Southland and LWB1-B3 Longwall Panels (DA 29/95)
- Proposed LWB4-B7 Longwall Panels (DA 29/95)
- Stage 3 Longwall Panels (PA08_0111)
- DA 29/95 Bellbird South Consent Area (Subsurface) - As Approved
- DA 29/95 Bellbird South Consent Area (Subsurface) - Proposed Extension
- Approved Reject Emplacement Areas
- Completed Underground Workings
- Mining Lease Boundary
- Austar owned CHPP Land

FIGURE 1.2

Austar Coal Mine and Proposed LWB4-B7

File Name (A4): R03/3900_030.dgn
20170216 10.47

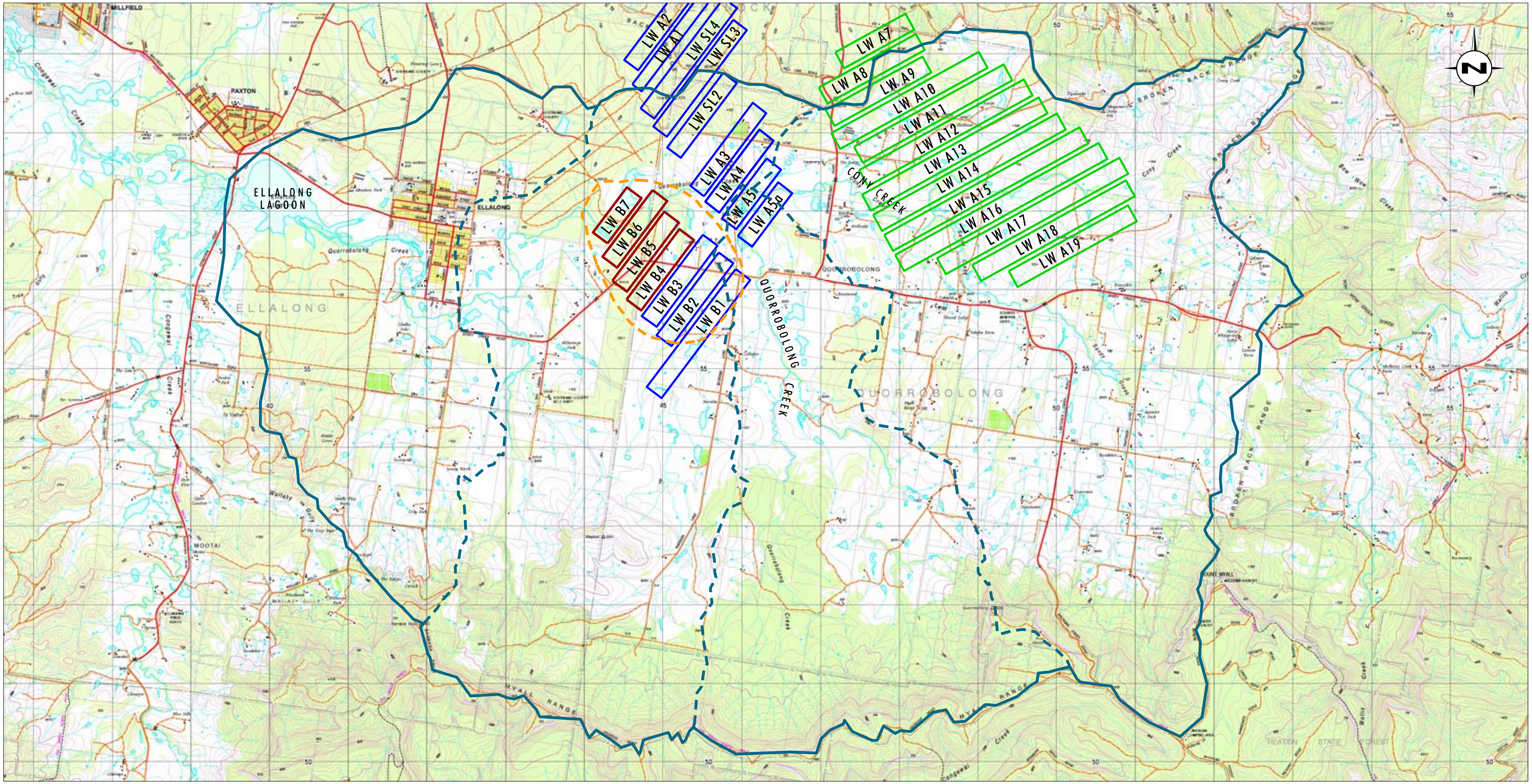


Image Source: LPI NSW 1:25 000 Topographic Map
Data Source: Austar Coal Mine

0 1 2 3km
1:70 000

Legend

- Bellbird South Stage 1, Stage 2, Southland and LWB1-B3 Longwall Panels (DA 29/95)
- Stage 3 Longwall Panels (PA08_0111)
- Proposed LWB4-B7 Longwall Panels (DA 29/95)
- LWB4-B7 Modification Area
- Quorrobolong Creek Catchment Boundary
- Quorrobolong Creek Sub-Catchment Boundary

FIGURE 1.3

Catchment Context

File Name (A4): R03/3900_035.dgn
20170216 10.54

An unnamed tributary (4th order) of Quorrobolong Creek that includes a number of secondary drainage channels drains in a northerly direction through the LWB4-B7 Modification Area above LWB1 to LWB4, converging with Quorrobolong Creek upstream of LWB5 (refer to **Plates 1.3** and **1.4**). A large farm dam water body is located to the north of the main channel of Quorrobolong Creek above LWB7 (refer to **Plate 1.5**), and is referred to in subsequent sections as the Northern farm dam water body. This feature is located within the floodplain of Quorrobolong Creek and overflows to the main channel. A 1st order drainage line also traverses above LWB6 and LWB7 and includes an ephemeral ponded area adjacent to Quorrobolong Creek above LWB7 (refer to **Plate 1.6**). This drainage line acts as an overland flow path for Quorrobolong Creek during high out of bank flows. Quorrobolong Creek, its unnamed tributary and the 1st order drainage line are ephemeral watercourses with flows only occurring as a result of prolonged or high rainfall periods.

Plate 1.1 Quorrobolong Creek main channel

Plate 1.2 Quorrobolong Creek main channel

© Umwelt, 2017

Plate 1.3 Unnamed tributary of Quorrobolong Creek at Sandy Creek Road culvert

© Umwelt, 2015

Plate 1.4 Unnamed tributary of Quorrobolong Creek south of Sandy Creek Road

© Umwelt, 2015

Plate 1.5 Northern farm dam water body located north of Quorrobolong Creek main channel, fed by surrounding paddock areas and a drainage line through the slopes of the treed hillslope in the background

© Umwelt, 2017

Plate 1.6 Ephemeral ponded area associated with 1st order drainage line south of Quorrobolong Creek main channel

One soil landscape type is found within the LWB4-B7 Modification Area, being the Quorrobolong soil landscape (Kovac and Lawrie 1991). The main soils within this landscape are prairie soils which form in alluvium and occur in drainage depressions and on lower slopes. They are generally poorly drained, have moderate permeability and the upper horizon has moderate erodibility (Kovac and Lawrie 1991).

The dominant land use within and surrounding the LWB4-B7 Modification Area is grazing, however other land uses also include rural residential, vegetated land, underground mining, and surface mining infrastructure uses associated with the Austar Coal Mine. The villages of Kitchener, Abernethy, Ellalong and Paxton are located within four kilometres to the north and west of the LWB4-B7 Modification Area (refer to **Figure 1.2**). The Watagans National Park is located approximately four kilometres south of the LWB4-B7 Modification Area, the Werakata State Conservation Area is located approximately one kilometre to the north and Werakata National Park is located approximately five kilometres to the north-east.

1.4 Modelling and Assessment Approach

A two dimensional (2D) hydrodynamic model previously developed for Austar Coal Mine to describe the flood behaviour of Quorrobolong Creek and its tributaries was used to assess the potential impacts of the LWB4-B7 Modification. The development of the 2D hydrodynamic model is detailed fully in previous reports, being *Flooding Assessment: Longwalls A3, A4 and A5* (Umwelt, 2007), and *Flood and Drainage Assessment: Stage 3* (Umwelt, 2008). Further flood and drainage assessment of underground mining at the Austar Coal Mine using the 2D hydrodynamic model is documented in *Proposed Stage 2 Extension – Flood and Drainage Assessment for Longwall A5a (Umwelt, 2010), Flood and Drainage Assessment: Stage 3 Modification* (Umwelt, 2011), *Longwall A5a Extension Flood and Drainage Assessment* (Umwelt, 2012), *Austar Coal Mine LWA7-A10 Modification – Stage 3 Area Environmental Assessment* (Umwelt, 2013) and *Flood and Drainage Assessment LWB1-B3 Modification* (Umwelt, 2015).

The previously developed 2D hydrodynamic model was modified to incorporate the predicted subsidence expected as a consequence of the mining operations proposed in the LWB4-B7 Modification. This includes the cumulative impacts of subsidence from the earlier approved mining stages.

Inflows, boundary conditions, roughness categories and values, and the mesh structure adopted for the previous studies undertaken for the Austar Coal Mine (as listed above) were again used to model the likely changes to the flood and drainage responses due to the proposed mining operations. Consistent with previous studies (Umwelt, 2007), the 100% and 1% Annual Exceedance Probability (AEP) design storm events were assessed. In addition, in response to a request from the Office of Environment and Heritage for the LWB1-B3 Modification assessment, the scope of modelling has been expanded to include the 5% AEP storm event and the Probable Maximum Flood (PMF) event. This required modelling the 5% AEP storm event and PMF inflows to the model, re-running the flood model and subsequent lateral adjustments to the flood model mesh (where required) to assess the flood impacts for the PMF event.

Modelling was undertaken to assess the cumulative impact of the proposed modification on flooding and drainage, for the following scenarios:

1. Approved landform (incorporating mining within LWA3-19 and LWB1-B3); and

2. Proposed landform (incorporating all approved underground mining within the Stage 2 and 3 areas, being LWA3 to A19 and LWB1-B3 and the proposed mining of LWB4-B7 as shown on **Figure 1.3**).

The following terminology is subsequently used in this report to refer to the modelling results:

- Approved mining scenario – Approved longwalls A3 to A19 and B1 to B3 in the Bellbird South and Stage 3 area; and

- Proposed mining scenario – Approved longwalls A3 to A19 and B1 to B3 in the Bellbird South and Stage 3 area, plus proposed LWB4-B7.

After running the models, the output data was loaded into a database. From this database the peak flood depths, elevations and velocities were extracted and flood hazard categories generated according to Appendix G of the *Floodplain Development Manual* (NSW Government, 2005).

Flood depth, velocity and flood hazard category maps for the approved mining scenario were prepared for the 100%, 5% and 1% AEP storm events and the PMF event in order to demonstrate the impact of the proposed modification on the existing approved landform. Similar maps were produced for the proposed mining scenario in order to demonstrate the cumulative impacts of the proposed modification (refer to **Section 3.0**).

Based on the modelling outcomes, the following potential impacts of the proposed modification were assessed against approved impacts (refer to **Section 3.0**):

- changes to flood depths (in channel and out of channel)

- changes to freeboard at dwellings

- impacts on scouring and erosion due to changes in flow velocities

- flood hazard categories for dwellings and private property access routes and

- changes to flood regimes, including impacts on flood prone land, creek channels, flow paths and remnant ponding.

1.4.1 Design flood estimation

Australian Rainfall and Runoff (AR&R) is a national guideline document, accompanied by data and software, that can be used for the estimation of design flood characteristics in Australia. The most recent updates to the AR&R guidelines were published in 2016 (version 4). Historically, the AR&R 1987 guidelines (version 3) and terminology have been used to estimate the design inflows to the 2D model for Austar Coal Mine. To maintain consistency with previous reports and enable comparison to previous models the terminology and design flood estimation methodology as used in the AR&R 1987 guidelines have been used in this assessment to develop the 1%, 5% and 100% AEP design rainfall events. The intensity-frequency-duration (IFD) data was sourced from the Bureau of Meteorology (BOM) 2016 Rainfall IFD Data System for the 5% AEP event and from the 1987 Rainfall IFD Data System for the 1% and 100% AEP events. The 1987 data was used for the 1% and 100% AEP events to maintain consistency with previous reports. As the 5% AEP storm event has not previously been modelled the updated 2016 BOM IFD data was used for this storm event only.

The PMF event was modelled using the Probable Maximum Precipitation (PMP). The PMP can be estimated for any catchment in Australia using three generalised methods:

1. Generalised Short Duration Method (GSDM) – for durations up to 6 hours and areas up to 1,000 km^2.

2. Revised Generalised Tropical Storm Method (GTSMR) – for durations up to 120 hours and areas up to 150,000 km^2 in the regions of Australia where tropical storms are the source of the greatest depths of rainfall.

3. Generalised Southeast Australia Method (GSAM) – for durations up to 96 hours and areas up to 100,000 km^2 in the region of Australia where tropical storms are not the source of the greatest depths of rainfall.

All three methods apply to Austar Coal Mine due to the mine being located in the GSAM – GTSMR Coastal Transition Zone, and Quorrobolong Creek having a catchment area less than 1,000 km^2. Each method was applied to determine the maximum PMP. The resulting rainfall depths were 760 mm for GSDM; 880 mm for GSAM (36 hours); and 980 mm for GTSMR (48 hours). Both the GSAM and GTSMR events were modelled to determine which event type created the maximum flood depths. The modelling indicated that the GTSMR created the maximum flood depths and subsequently this PMP event was used for the modelling of and assessment of impacts for the PMF event.

2.0 Subsidence Predictions

In order to model the potential impacts that the proposed mining operations could have on the flood response of the Quorrobolong Valley, predictions of the likely subsidence are required. Subsidence predictions provided by MSEC (2017) for the proposed mining operations were used for this purpose. Subsidence monitoring completed within the previously extracted Stage 2, Stage 3 and LWB1-B3 mining areas indicates that predicted subsidence provides a reasonable, if not slightly conservative prediction for subsidence at the Austar Coal Mine. Therefore, flood modelling was conducted using maximum predicted subsidence only.

The subsidence predictions indicate that the landform after extraction of LWB1 to LWB7 is estimated to be subsided by up to 1.35 metres, and subsidence is predicted to occur as a broad, shallow bowl as shown in **Figure 2.1**.

Predicted subsidence impacts on the landform will occur within the vicinity of Quorrobolong Creek, the unnamed tributary of Quorrobolong Creek (refer to **Figure 2.1**) and its associated culvert under Sandy Creek Road, and the 1st order drainage line and ponded area adjacent to Quorrobolong Creek (refer to **Section 1.3**).

The predicted subsidence has the potential to change the flooding and drainage behaviour of the area. This report aims to quantify these changes and assess the potential impacts to the surrounding area, with regard to both natural and built features.

The predicted landform following subsidence is shown on **Figure 2.2**.

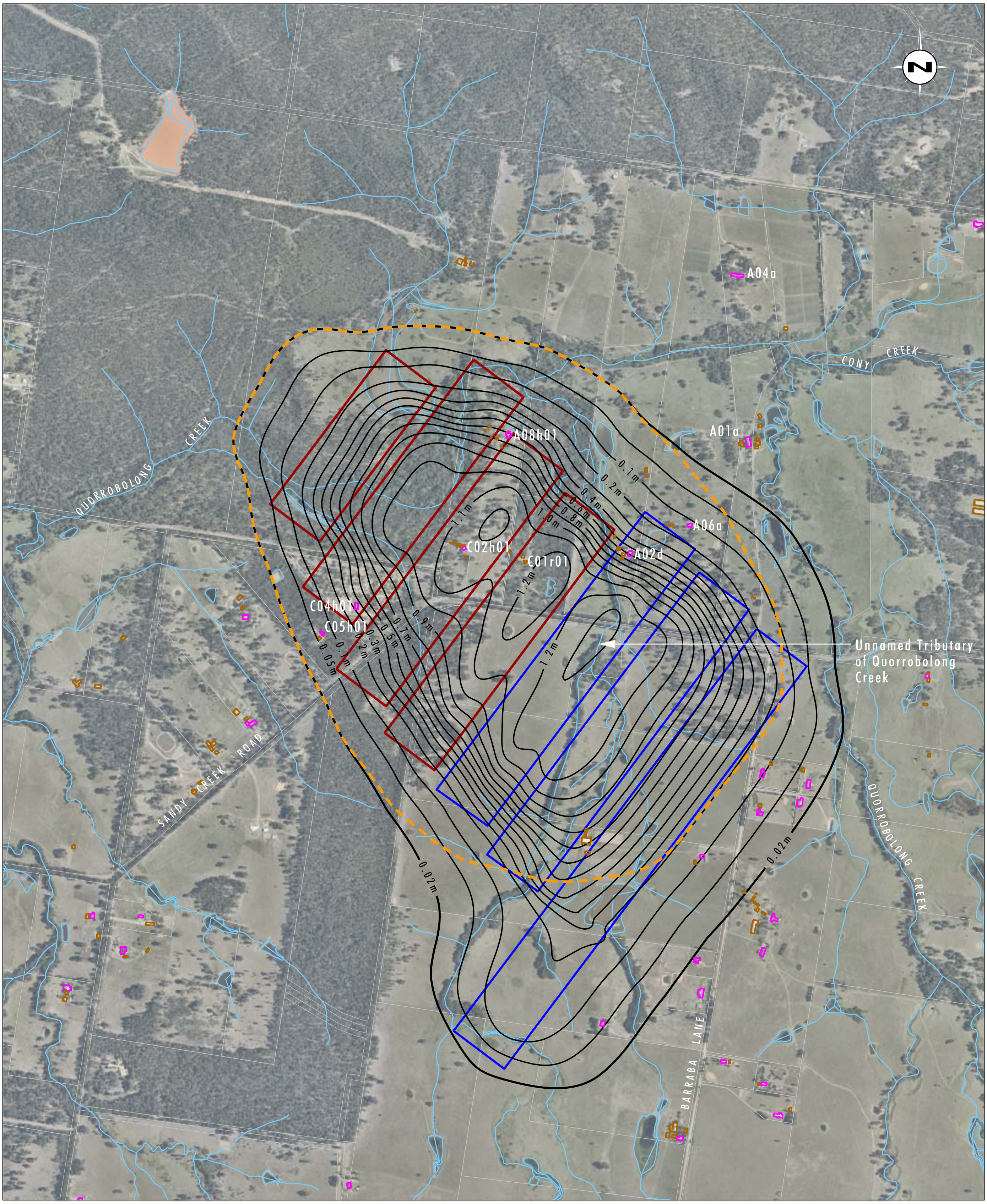


Image Source: Nearmap (2017)
Data Source: Austar Coal Mine (2017), MSEC (2017)

0 0.25 0.5 1.0km
1:20 000

Legend

- Proposed LWB4-B7 Longwall Panels
- LWB4-B7 Modification Area
- Approved LWB1-B3 Longwall Panels
- Subsidence Contour
- Dwelling
- Other Structure

FIGURE 2.1

Predicted Cumulative Subsidence - LWB1-B7

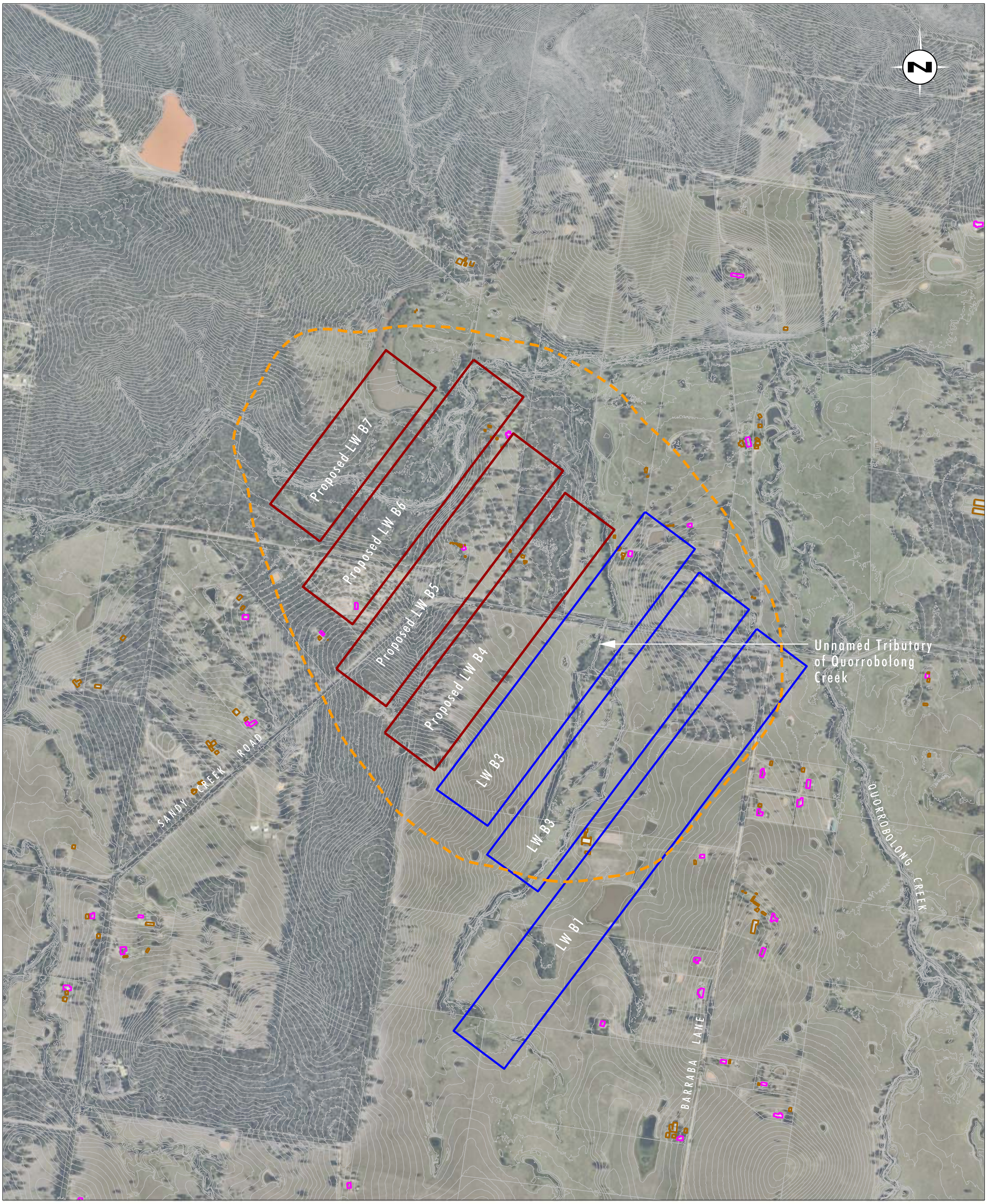


Image Source: Nearmap (2017)
Data Source: Austar Coal Mine (2015), Cessnock LEP (2011), MSEC (2017)
Note: 1m Contours Interval

Legend

- Proposed LWB4-B7 Longwall Panels
- LWB4-B7 Modification Area
- Approved LWB1-B3 Longwall Panels
- Dwelling
- Other Structure

FIGURE 2.2

Predicted Subsided Landform - LWB1-B7

3.0 Model Outcomes

3.1 Key Modelling Outcomes

The modelling indicates that the potential impacts on flooding and drainage associated with LWB4-B7 are generally limited in extent to the LWB4-B7 Modification Area. A detailed description of the outcomes of the flood and drainage assessment is included in **Sections 3.2** to **3.6**, with a summary of impacts described below.

Modelling indicates that mining of LWB4-B7 will result in increased flood depths and associated flow velocities where the longwalls intersect the central drainage channels of the unnamed tributary of Quorrobolong Creek and the main channel of Quorrobolong Creek downstream of the junction with Cony Creek. In addition, there are predicted increases and decreases in out of channel flood depths above the southern end of LWB6 and LWB7 in the catchment of Quorrobolong Creek and above the northern end of LWB4 in the catchment of the unnamed tributary.

Analysis of the flood modelling results indicate no changes will occur to the flood hazard category at Sandy Creek Road during the 1% AEP or PMF storm event with the road remaining impassable to vehicles during this event, however the analysis also indicates that the flood hazard category will decrease from the "vehicles unstable" category to "walking and vehicle access" for the 5% AEP storm event.

There are only minor predicted impacts on freeboards at dwellings and all dwellings remain flood free for all modelled storm events and there are no predicted impacts to private access routes.

There are only minor impacts predicted to remnant ponding with the analysis indicating ponding up to 0.5 metres deeper on the 1st order drainage line south of Quorrobolong Creek extending over an area of approximately 1.5 hectares, approximately 100 metres to 125 metres further upstream than in the approved scenario.

3.1.1 Detailed Model Results

Flood depth, velocity and flood hazard category maps for the current approved mining scenario for the 100%, 5%, 1% AEP storm events and the PMF event are provided in **Appendix A.**

Figures showing predicted flooding behaviour as a result of mining LWB4-B7 are provided in **Appendix B** which contains the following:

- Figures B1 to B4 describe the maximum modelled **flood depths** for the 100%, 5%, 1% AEP and PMF storm events with the maximum predicted subsidence for the four modelled scenarios.
- Figures B5 to B8 describe the maximum modelled **velocities** for the 100%, 5%, 1% AEP and PMF storm events with the maximum predicted subsidence for the four modelled scenarios.
- Figures B9 to B12 describe the maximum modelled **flood hazard categories** for the 100%, 5%, 1% AEP and PMF storm events with the maximum predicted subsidence for the four modelled scenarios.
- Figures B13 and B14 shows **flow hydrographs** extracted from the modelling for the 100%, 5%, 1% AEP and PMF storm events on Quorrobolong Creek downstream of the proposed LWB4 to B7 Modification Area.

- Figures B15 and B16 show the locations of and the profiles of Quorrobolong Creek and the Unnamed Tributary of Quorrobolong Creek.

3.2 Flood Depths

3.2.1 Within Channel

As shown on Figures B1 to B4, predicted impacts on flood depths are mostly limited to within the LWB4-B7 Modification Area. Modelling predicts increases to flood depths within the channel of Quorrobolong Creek, in particular downstream of the Cony Creek junction for all modelled storm events (100%, 5%, 1% AEP and PMF). Along the unnamed tributary, the modelling predicts increases in channel flood depths within the LWB4-B7 Modification Area in areas both upstream and downstream of Sandy Creek Road in all modelled storm events (100%, 5%, 1% AEP and PMF).

The maximum and average modelled increase in flood depths for Quorrobolong Creek and its unnamed tributary are summarised in **Table 3.1** and described in further detail below.

Table 3.1 Maximum and Average Modelled Increase in Flood Depth within Channel

Watercourse	Maximum Modelled Increase in Flood Depth (m)				Average Modelled Increase in Flood Depth (m)			
	100% AEP Storm Event	5% AEP Storm Event	1% AEP Storm Event	PMF Storm Event	100% AEP Storm Event	5% AEP Storm Event	1% AEP Storm Event	PMF Storm Event
Quorrobolong Creek upstream of Cony Creek junction	0.01	0.008	0.006	0.007	0.003	0.002	0.002	0.003
Quorrobolong Creek downstream of Cony Creek junction	0.50	0.78	0.82	0.90	0.21	0.35	0.36	0.40
Unnamed tributary of Quorrobolong Creek	0.17	0.33	0.34	0.35	0.08	0.10	0.09	0.11

There are minimal changes in peak flood depths predicted within the channel of Quorrobolong Creek upstream of the Cony Creek junction, with the maximum modelled increase in peak flood depths being 0.01 metres for the 100% AEP storm event (as shown in **Table 3.1**).

The modelled flood response indicates that the proposed modification will increase peak flood depths in Quorrobolong Creek downstream of the Cony Creek junction for all modelled storm events as outlined below:

- Increases in peak flood depths extend approximately 1000 metres downstream of the southern end of the Northern farm dam water body during the 100% AEP storm event. The maximum modelled increase for the 100% AEP storm event is approximately 0.50 metres and occurs at the point where the Quorrobolong Creek channel crosses the centreline of LWB6 in an area where existing modelled peak flood depths are in the order of 4 metres. The average modelled increase in flood depths during the 100% AEP storm event within the channel is approximately 0.21 metres.

- Increases in peak flood depths extend approximately 1020 metres downstream of the southern end of the Northern farm dam water body during the 5% AEP storm event. The maximum modelled increase for the 5% AEP storm event is approximately 0.78 metres and occurs at the point where the Quorrobolong Creek channel crosses the centreline of LWB6 in an area where existing modelled peak flood depths are in the order of 4.5 metres. The average modelled increase in flood depths during the 5% AEP storm event within the channel is approximately 0.35 metres.

- Increases in peak flood depths extend approximately 1050 metres downstream of the southern end of the Northern farm dam water body during the 1% AEP storm event. The maximum modelled increase for the 1% AEP storm event is approximately 0.82 metres and occurs at the point where the Quorrobolong Creek channel crosses the centreline of LWB6 in an area where existing modelled peak flood depths are in the order of 5 metres. The average modelled increase in flood depths during the 1% AEP storm event within the channel is approximately 0.36 metres.

- Increases in peak flood depths extend approximately 1100 metres downstream of the southern end of the Northern farm dam water body during the PMF event. The maximum modelled increase for the PMF event is approximately 0.90 metres and occurs at the point where the Quorrobolong Creek channel crosses the centreline of LWB6 in an area where existing modelled peak flood depths are in the order of 6 metres. The average modelled increase in flood depths during the PMF event within the channel is approximately 0.4 metres.

The modelled flood response indicates that the proposed modification will increase peak flood depths in the unnamed tributary of Quorrobolong Creek for all modelled storm events as outlined below:

- Increases in peak flood depths extend from the junction with Quorrobolong Creek to approximately 120 metres upstream of Sandy Creek Road during the 100% AEP storm event. The maximum modelled increase for the 100% AEP storm event is approximately 0.17 metres and occurs 360 metres upstream of junction with Quorrobolong Creek in an area where existing modelled peak flood depths are in the order of 1.4 metres. The average modelled increase in flood depths during the 100% AEP storm event within the channel is approximately 0.08 metres.

- Increases in peak flood depths from the junction with Quorrobolong Creek to approximately 50 metres upstream of Sandy Creek Road for the 5% AEP storm event. The maximum modelled increase for the 5% AEP storm event is approximately 0.33 metres and occurs 360 metres upstream of junction with Quorrobolong Creek in an area where existing modelled peak flood depths are in the order of 1.8 metres. The average modelled increase in flood depths during the 5% AEP storm event within the channel is approximately 0.10 metres.

- Increases in peak flood depths extend from the junction with Quorrobolong Creek to approximately the middle of LWB3 for the 1% AEP storm event. The maximum modelled increase for the 1% AEP storm event is approximately 0.34 metres and occurs 360 metres upstream of junction with Quorrobolong Creek in an area where existing modelled peak flood depths are in the order of 2 metres. The average modelled increase in flood depths during the 1% AEP storm event within the channel is approximately 0.09 metres.

- Increases in peak flood depths extend from the junction with Quorrobolong Creek to approximately the middle of LWB3 for the PMF event. The maximum modelled increase for the PMF event is approximately 0.35 metres and occurs 360 metres upstream of junction with Quorrobolong Creek in an area where existing modelled peak flood depths are in the order of 2.7 metres. The average modelled increase in flood depths during the PMF event within the channel is approximately 0.11 metres.

3.2.2 Out of Channel

The maximum and average modelled increase to out of channel flood depths adjacent to Quorrobolong Creek and its unnamed tributary are summarised in **Table 3.2** and described in further detail below.

Table 3.2 Maximum and Average Modelled Increase in Out of Channel Flood Depths

Watercourse	Maximum Modelled Increase in Flood Depth (m)				Average Modelled Increase in Flood Depth (m)			
	100% AEP Storm Event	5% AEP Storm Event	1% AEP Storm Event	PMF Storm Event	100% AEP Storm Event	5% AEP Storm Event	1% AEP Storm Event	PMF Storm Event
Quorrobolong Creek upstream of Cony Creek junction	0.04	0.03	0.03	0.09	0.005	0.004	0.004	0.004
Quorrobolong Creek downstream of Cony Creek junction	0.97	0.89	0.89	0.94	0.28	0.32	0.34	0.38
Unnamed tributary of Quorrobolong Creek	0.25	0.38	0.42	0.71	0.07	0.09	0.09	0.11

As shown in **Table 3.2**, modelling indicates that there will be minimal changes in the peak and average flood depths in Quorrobolong Creek upstream of the Cony Creek junction for all modelled storm events for the proposed modification when compared to the approved mine plan.

The modelled flood response indicates that the proposed modification will increase peak out of channel flood depths in Quorrobolong Creek for all modelled storm events as outlined below:

- Out of channel flooding for Quorrobolong Creek downstream of the Cony Creek junction within the LWB4-B7 Modification Area will increase on average by 0.28 metres in depth for an extent of approximately 1000 metres parallel to the main creek channel in the 100% AEP storm event where the channel passes over LWB6 and LWB7. This increase in out of channel flooding in this portion of the creek is associated with an average decrease (in the order of 0.26 metres) in out of channel flooding encompassing the Northern farm dam water body to the north of LWB6 and LWB7.

- Out of channel flooding for Quorrobolong Creek downstream of the Cony Creek junction within the LWB4-B7 Modification Area will typically on average by0.32 metres in depth for an extent of approximately 1020 metres parallel to the main creek channel in the 5% AEP storm event where the channel passes over LW6 and LW7. This increase in out of channel flooding in this portion of the creek is associated with an average decrease (in the order of 0.24 metres) in out of channel flooding encompassing the Northern farm dam water body to the north of LW 6 and LW7.

- In the 1% AEP storm event modelling indicates out of channel flooding for Quorrobolong Creek downstream of the Cony Creek junction within the LWB4-B7 Modification Area will increase on average by 0.34 metres in depth where the channel passes over LW6 and LW7 for an extent of approximately 1050 metres parallel to the creek. This increase in out of channel flooding in this portion of the creek is associated with an average decrease (in the order of 0.23 metres) in out of channel flooding encompassing the Northern farm dam water body to the north of LW 6 and LW7.

- In the PMF storm event modelling indicates out of channel flooding for Quorrobolong Creek downstream of the Cony Creek junction within the LWB4-B7 Modification Area will increase on average by 0.38 metres in depth for an extent of approximately 1100 metres parallel to the main creek channel where the channel passes over LW6 and LW7. This increase in out of channel flooding in this portion of the creek is associated with an average decrease (in the order of 0.19 metres) in out of channel flooding encompassing the Northern farm dam water body to the north of LW6 and LW7.

The modelled flood response indicates that the proposed modification will increase peak out of channel flood depths in the unnamed tributary of Quorrobolong Creek for all modelled storm events as outlined below:

- Adjacent to the unnamed tributary of Quorrobolong Creek, modelling indicates that out of channel flooding during the 100% AEP storm event for the approved mining scenario is typically in the order of 0.30 metres. With the proposed modification, out of channel flooding is predicted to increase on average 0.07 metres (extending approximately 850 metres downstream of the central section of LWB3) adjacent to the unnamed tributary of Quorrobolong Creek, and to decrease on average by approximately 0.05 metres (extending approximately 500 metres upstream of the central section of LWB3). The modelled changes to out of channel flooding are typically predicted to occur over LWB2 to LWB4. A minor change to out of channel flooding is also predicted over the southern extent of LWB1.

- During the 5% AEP storm event for the approved mining scenario, modelling indicates that out of channel flooding adjacent to the unnamed tributary of Quorrobolong Creek is typically in the order of 0.50 metres. With the proposed modification, out of channel flooding is predicted to increase on average 0.09 metres (extending approximately 850 metres downstream of the central section of LWB3) adjacent to the unnamed tributary of Quorrobolong Creek, and to decrease on average by approximately 0.07 metres (extending approximately 900 metres upstream of the central section of LWB3). The modelled changes to out of channel flooding are typically predicted to occur over LWB2 to LWB4. A minor increase to out of channel flooding is also predicted over the southern extent of LWB1.

- During the 1% AEP storm event for the approved mining scenario, modelling indicates that out of channel flooding adjacent to the unnamed tributary of Quorrobolong Creek is typically in the order of 0.55 metres. With the proposed modification, out of channel flooding is predicted to increase on average 0.09 metres (extending approximately 850 metres downstream of the central section of LWB3) adjacent to the unnamed tributary of Quorrobolong Creek, and to decrease on average by approximately 0.07 metres (extending approximately 950 metres upstream of the central section of LWB3). The modelled changes to out of channel flooding are typically predicted to occur over LWB2 to LWB4. A minor increase to out of channel flooding is also predicted over the southern extent of LWB1.

- During the PMF storm event for the approved mining scenario, modelling indicates that out of channel flooding adjacent to the unnamed tributary of Quorrobolong Creek is typically in the order of 0.75 metres. With the proposed modification, out of channel flooding is predicted to increase on average 0.11 metres (extending approximately 850 metres downstream of the central section of LWB3) adjacent to the unnamed tributary of Quorrobolong Creek, and to decrease on average by approximately 0.07 metres (extending approximately 950 metres upstream of the central section of LWB3). The modelled changes to out of channel flooding are typically predicted to occur over LWB2 to LWB4. An increase (in the order of 0.06 metres) to out of channel flooding is also predicted for an area extending approximately 400 m downstream of the southern end of LWB1.

3.2.3 At Dwellings

The modelling indicates that the maximum predicted flood extent for the 1% AEP flood event and the PMF event does not result in flooding of any dwellings within the LWB4-B7 Modification Area for the approved mining scenario. The flood planning level (FPL) is defined as the 1% AEP flood event plus 500 millimetres freeboard. The PMF flood event is typically used for emergency planning. As such, the modelled impacts of the 1% AEP flood event and the PMF event on the freeboard levels for the dwellings lying within and adjacent to the LWB4-B7 Modification Area are listed in **Table 3.3**. A further discussion of flood hazard categories at dwellings and access routes is provided in **Section 3.4.**

In summary, the modelling of the impacts of subsidence on flooding during the 1% AEP flood event and PMF event presented in **Table 3.3** indicates that for the proposed scenario no dwellings will be flooded above floor level.

For the 1% AEP flood event, no dwelling has a freeboard reduced to less than 500 millimetres, therefore all dwellings have sufficient freeboard to meet flood planning level requirements.

The PMF event results are provided in **Table 3.3** for the context of emergency management as a flood refuge. As the floor level of all dwellings will remain free from flooding, the proposed modification will not impact the ongoing suitability of these dwellings as a flood refuge for occupants. It is noted that in the PMF event, the freeboard for dwelling A08h01 is likely to be reduced below 500 millimetres under the proposed scenario, however the dwelling will remain flood free during the PMF event and has sufficient freeboard to meet the flood planning level requirements (1% AEP plus 500 millimetres freeboard).

Table 3.3 Predicted Freeboard, 1% AEP flood event and PMF event

Dwelling ID	Structure	Freeboard 1% AEP Flood Event (m)		Freeboard PMF Event (m)	
		Approved mining scenario	Proposed mining scenario	Approved mining scenario	Proposed mining scenario
A06a	Residence	5.811	5.882	4.955	4.988
B12h01	Residence	9.414	9.400	9.096	9.090
B11h01	Residence	2.872	2.873	2.636	2.636
B09h01	Residence	6.108	6.099	5.883	5.875
A02c	Residence	1.951	2.210	1.959	1.629
B10h01	Residence	1.893	1.893	1.747	1.746
B04h03	Residence	2.483	2.482	1.890	1.889
A08h01	Residence	1.342	1.239	0.642	0.162
C01r01	Residence	4.199	2.815	3.814	2.667
C02h01	Residence	9.092	8.162	8.013	6.997

Legend	
1	Not flooded pre-mining, predicted to flood
2	Flooded pre-mining, predicted higher flooding
3	Flooded pre-mining, predicted lower flooding
4	Not flooded pre-mining, predicted more freeboard (i.e. a lower flood water height at residence)
5	Not flooded pre-mining, predicted less freeboard (i.e. a higher flood water height at residence)
6	No change

3.3 Flow Velocities

3.3.1 Within Channel

The maximum and average modelled increases in flow velocities for the 100%, 5% and 1% AEP storm events and PMF event within the main channel of Quorrobolong Creek and the unnamed tributary of Quorrobolong Creek are presented in **Table 3.4.** The range (minimum and maximum) of modelled flow velocities for the 100%, 5% and 1% AEP storm events and PMF event within channel are presented in **Table 3.5**.

Table 3.4 Maximum and Average Modelled Increase in Flow Velocity within Channel

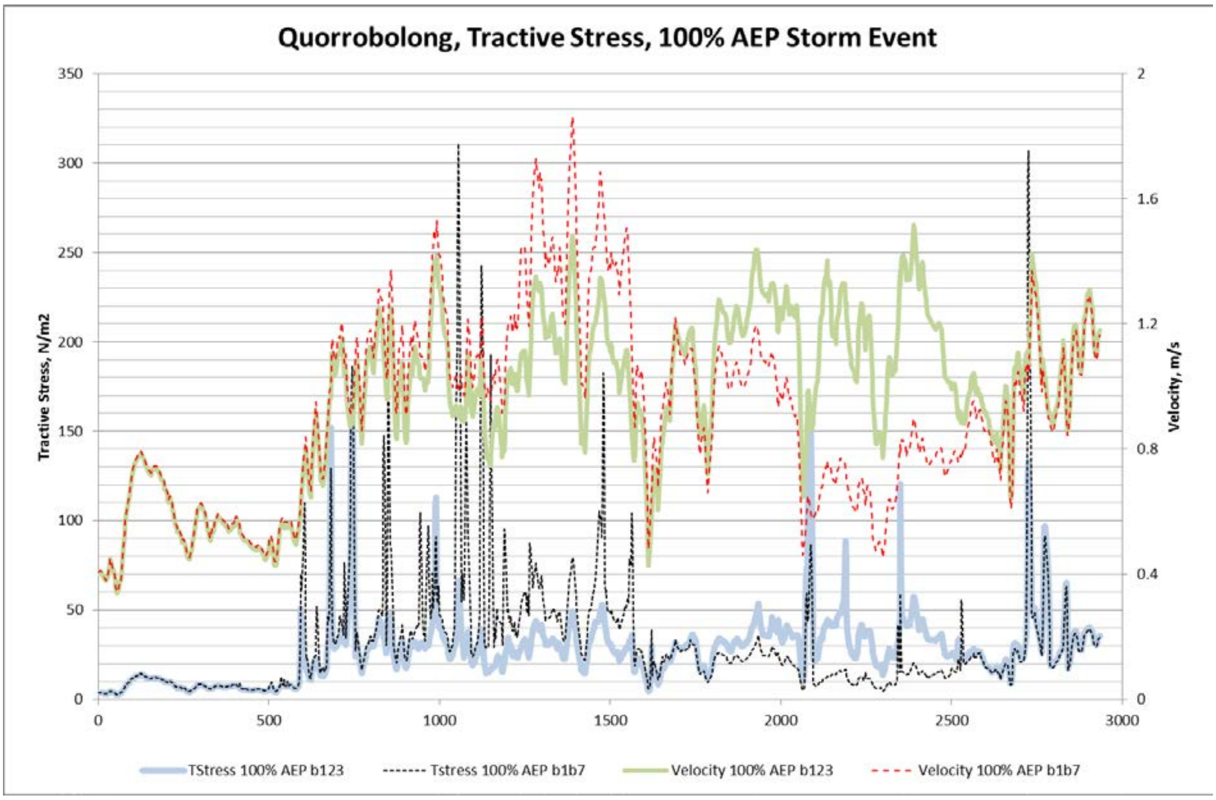
Watercourse	Maximum Modelled Velocity Increase (m/s)				Average Modelled Velocity Increase (m/s)				Average Modelled Velocity Decrease (m/s)			
	100% AEP	5% AEP	1% AEP	PMF	100% AEP	5% AEP	1% AEP	PMF	100% AEP	5% AEP	1% AEP	PMF
Quorrobolong Creek upstream of Cony Creek junction	0.01	0.01	0.01	0.02	0.003	0.003	0.003	0.004	0.004	0.005	0.005	0.009
Quorrobolong Creek downstream of Cony Creek junction	0.44	0.61	0.65	0.68	0.08	0.10	0.11	0.11	0.18	0.19	0.19	0.16
Unnamed tributary of Quorrobolong Creek	0.35	0.36	0.36	0.42	0.05	0.08	0.08	0.09	0.06	0.08	0.09	0.11

Table 3.5 Ranges in Flow Velocity within Channel

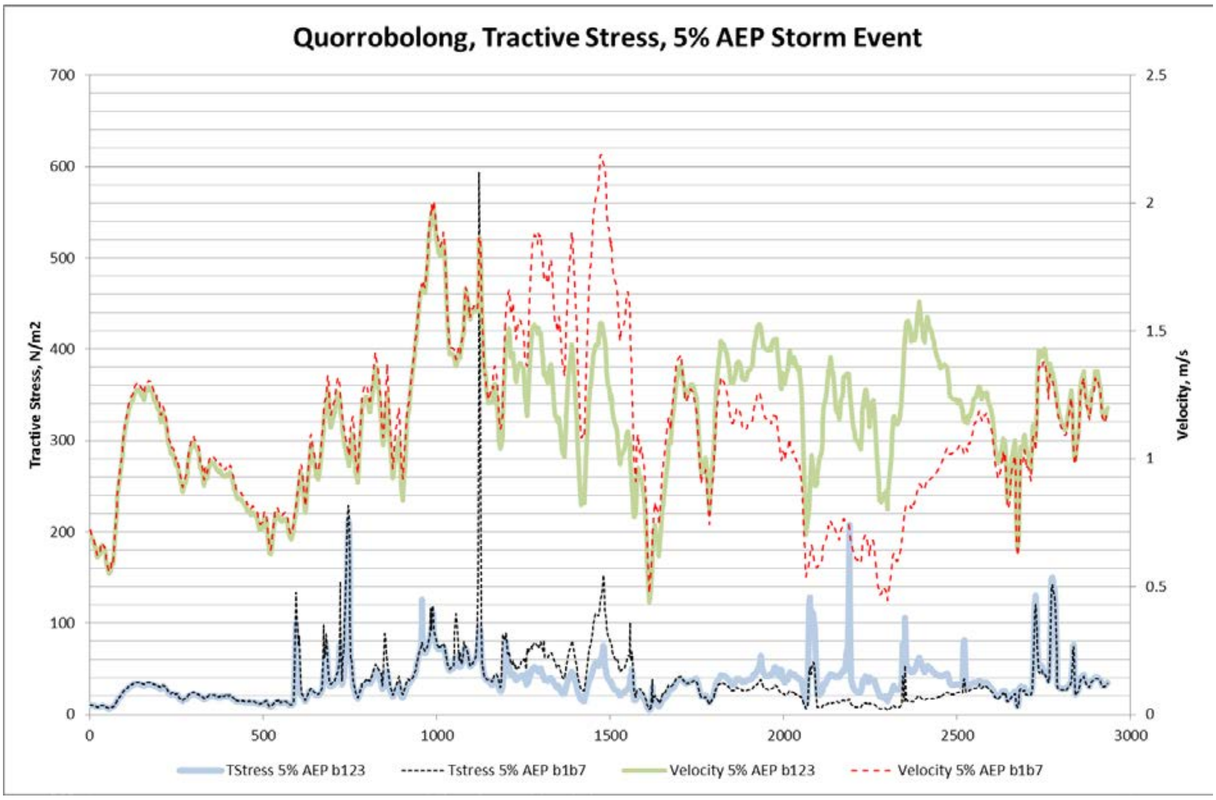
Watercourse	Velocity Ranges (m/s), Approved				Velocity Ranges (m/s), Proposed			
	100% AEP	5% AEP	1% AEP	PMF	100% AEP	5% AEP	1% AEP	PMF
Quorrobolong Creek upstream of Cony Creek junction	0.14 - 1.28	0.18 - 1.86	0.19 - 1.91	0.27 - 2.07	0.15 - 1.29	0.19 - 1.86	0.19 - 1.91	0.27 - 2.07
Quorrobolong Creek downstream of Cony Creek junction	0.32 - 1.41	0.47 - 1.73	0.49 - 1.79	0.58 - 2.02	0.30 - 1.56	0.41 - 1.91	0.41 - 1.99	0.51 - 2.17
Unnamed tributary of Quorrobolong Creek	0.12 - 1.62	0.19 - 2.05	0.22 - 2.19	0.33 - 2.44	0.11 - 1.69	0.19 - 2.13	0.22 - 2.17	0.34 - 2.42

3.3.1.1 Channel Stability

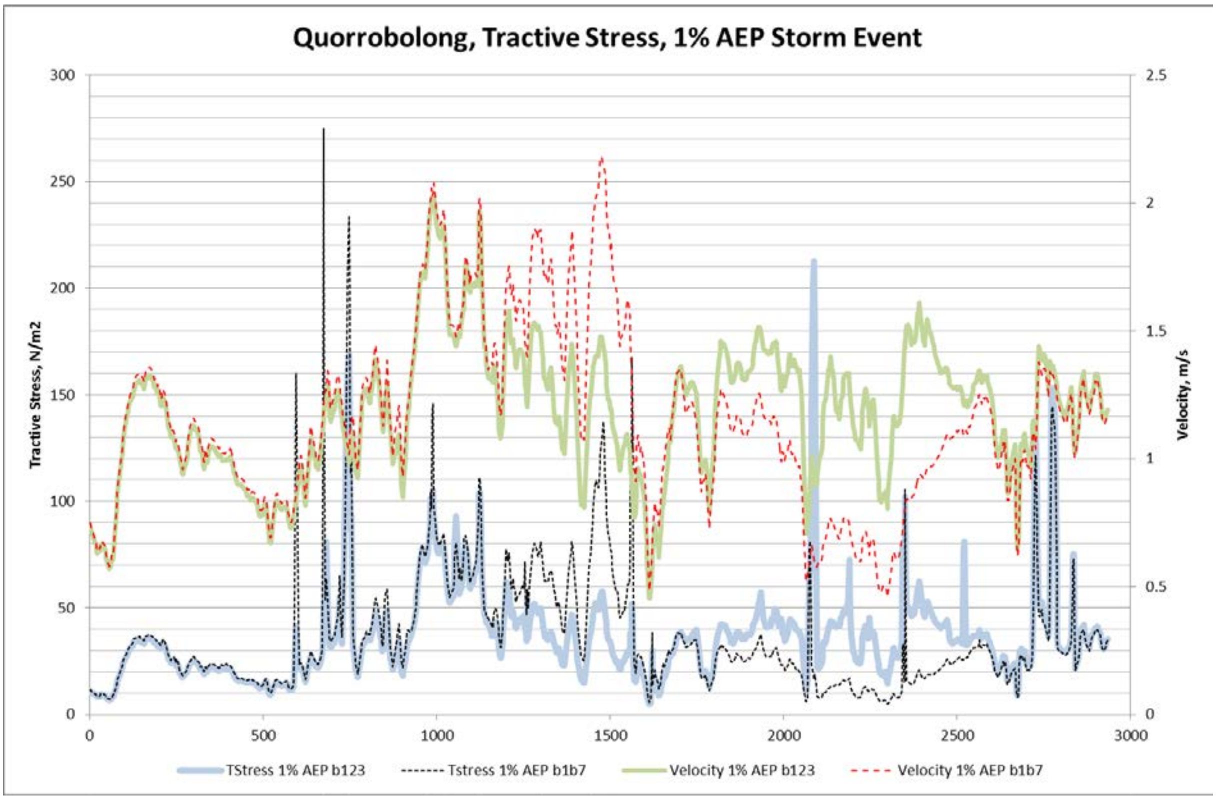
Channel stability can be impacted by flow velocities and bed shear stresses (tractive stress). Graphs displaying the relationship between velocity and tractive stress for the 100% AEP, 5% AEP, 1% AEP flood events and the PMF event for Quorrobolong Creek are shown in **Graph 3.1** to **Graph 3.4.** Graphs displaying the relationship between velocity and tractive stress for the 100% AEP, 5% AEP, 1% AEP flood events and the PMF event for the unnamed tributary of Quorrobolong Creek are shown in **Graph 3.5** to **Graph 3.8**.



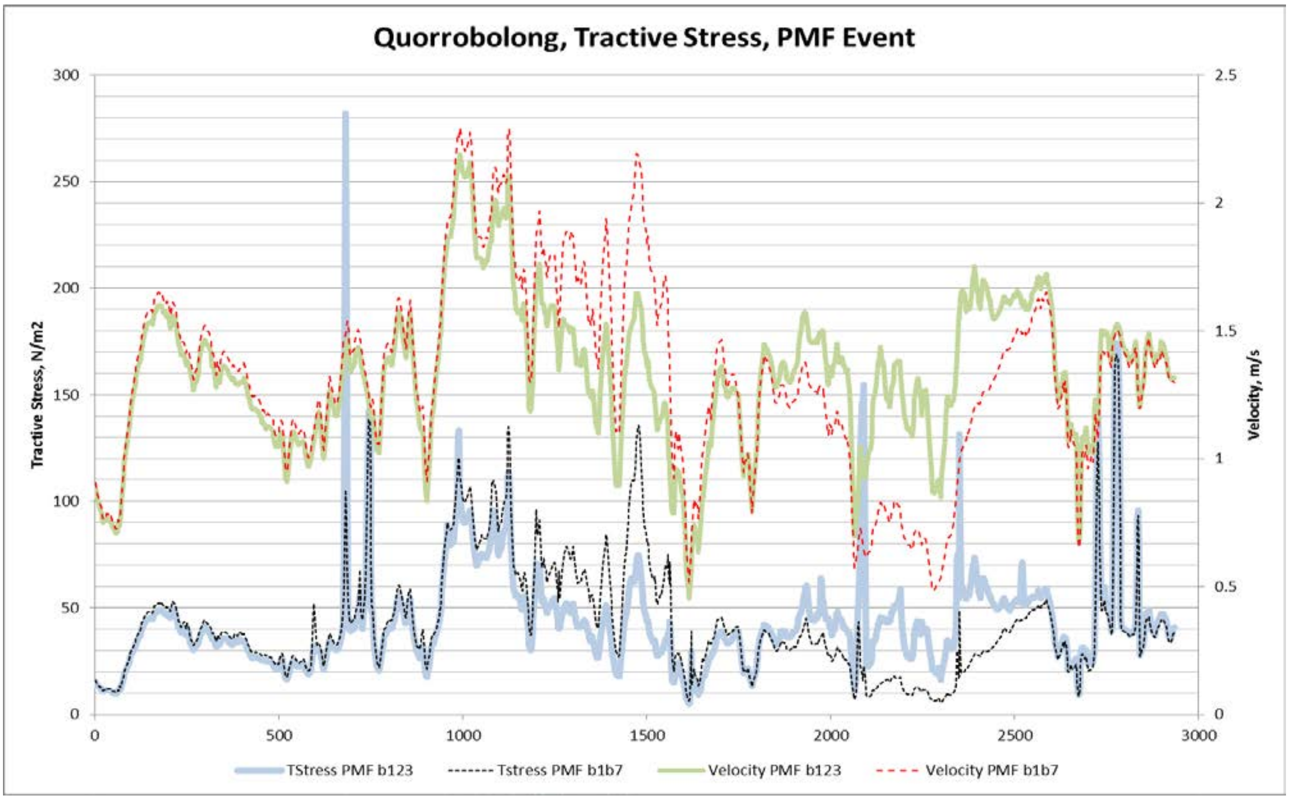
Graph 3.1 Tractive Stress and Velocity Relationship Quorrobolong Creek – 100% AEP storm event.



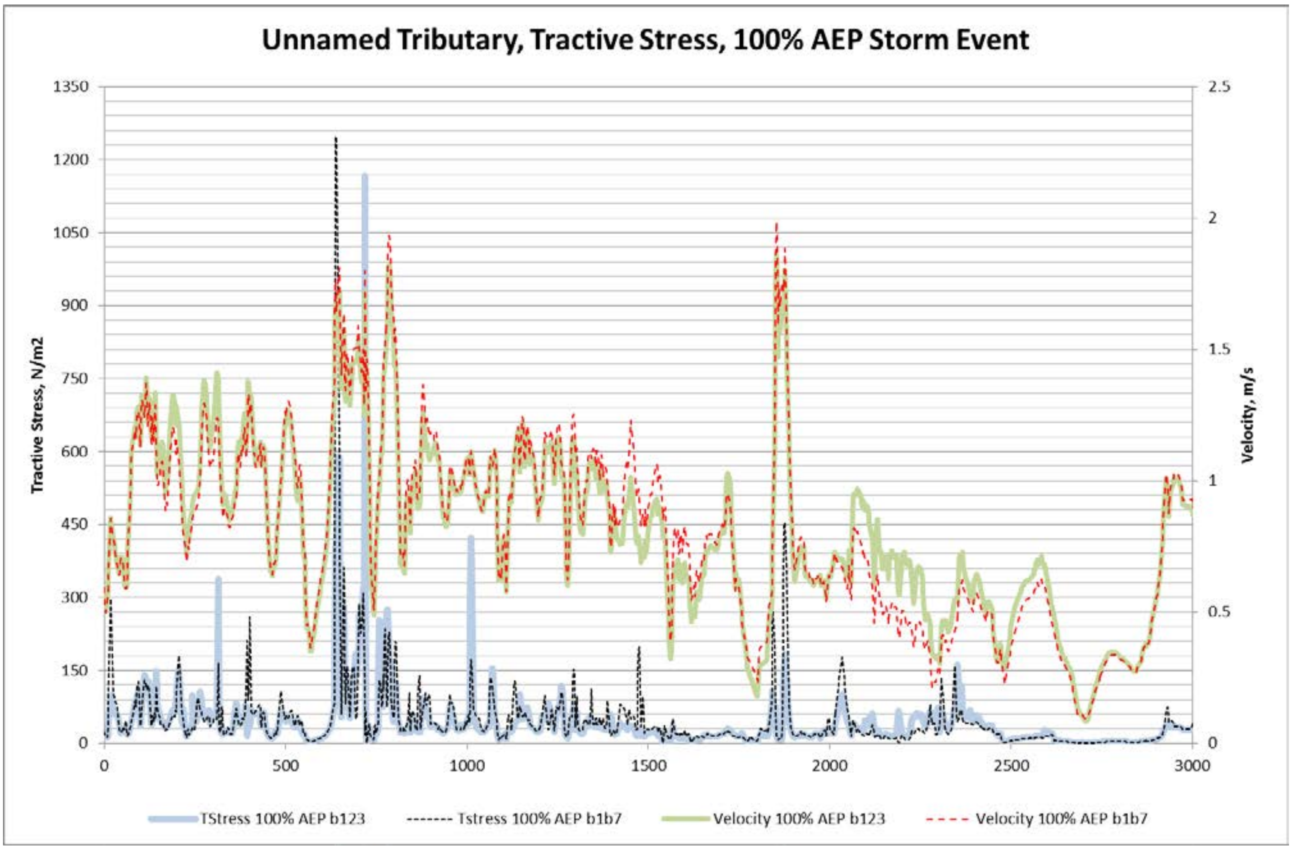
Graph 3.2 Tractive Stress and Velocity Relationship Quorrobolong Creek – 5% AEP storm event.



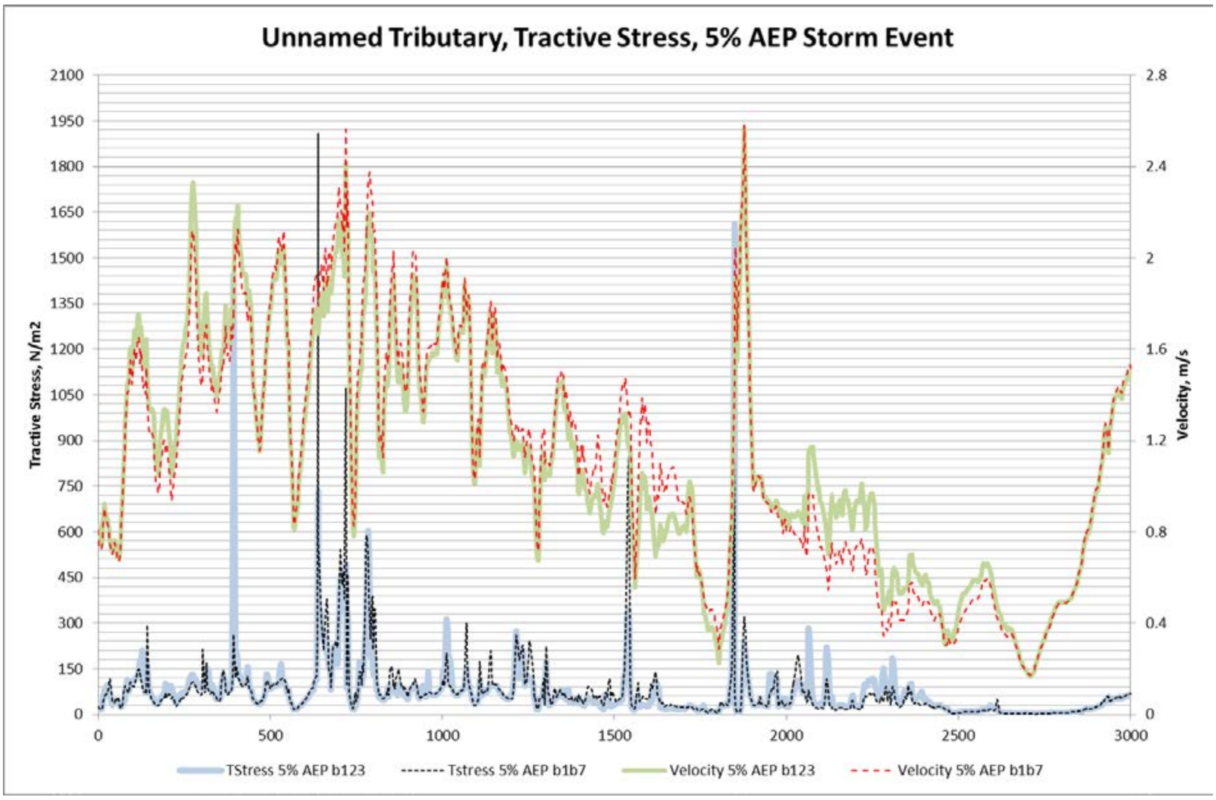
Graph 3.3 Tractive Stress and Velocity Relationship Quorrobolong Creek – 1% AEP storm event.



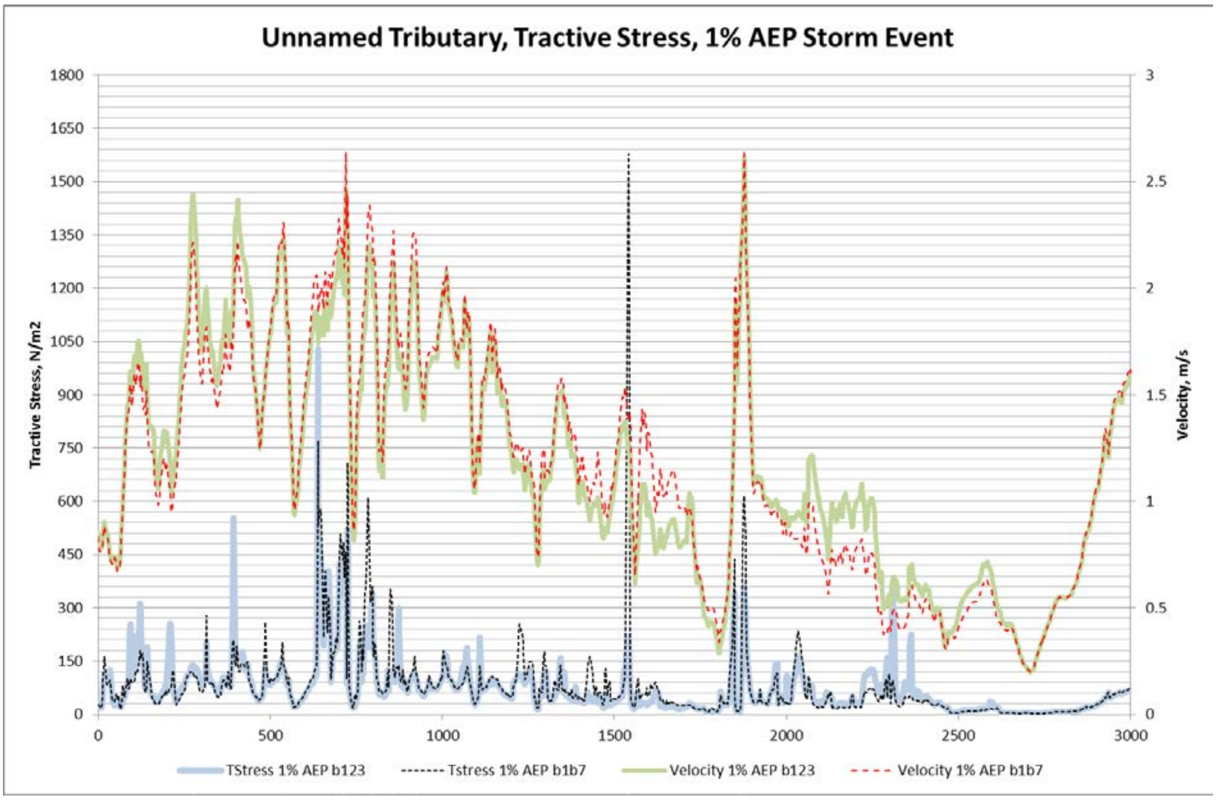
Graph 3.4 Tractive Stress and Velocity Relationship Quorrobolong Creek – PMF event.



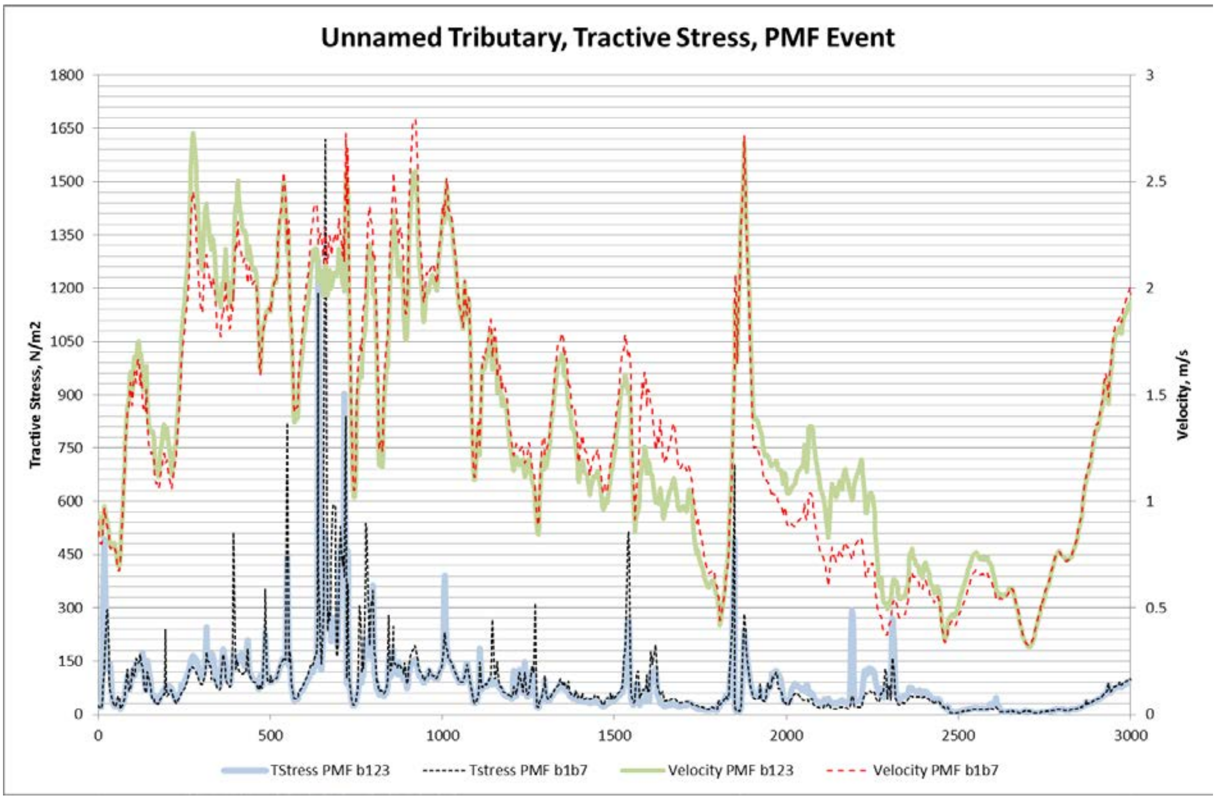
Graph 3.5 Tractive Stress and Velocity Relationship Unnamed Tributary of Quorrobolong Creek – 100% AEP storm event.



Graph 3.6 Tractive Stress and Velocity Relationship Unnamed Tributary of Quorrobolong Creek – 5% AEP storm event.



Graph 3.7 Tractive Stress and Velocity Relationship Unnamed Tributary of Quorrobolong Creek – 1% AEP storm event.



Graph 3.8 Tractive Stress and Velocity Relationship Unnamed Tributary of Quorrobolong Creek –PMF event.

As displayed in **Graphs 3.1** to **3.8** and **Table 3.4** and **3.6**, the modelling indicates that with the proposed modification the flow velocities in Quorrobolong Creek and the unnamed tributary will have localised increases and decreases for all modelled storm events. Modelling also indicates that the absolute maximum and minimum peak flow velocities along both Quorrobolong Creek and the unnamed tributary with the proposed modification will remain within similar ranges to those modelled for both the approved mining scenario and the proposed mining scenario.

Based on review of site inspection photographs and analysis of the modelling results contained within **Graphs 3.1 to 3.8**, the calculated tractive stresses for the proposed modification lie within the ranges modelled for Quorrobolong Creek and the unnamed tributary for the approved mining scenario. As such it is considered that the changes to velocities and tractive stresses are within the natural capacity / variability of the creek system and is unlikely to result in scouring of the channel.

To ensure no impacts from the proposed modification occur it is recommended that a channel stability monitoring program of the reaches of the creek systems where velocity and tractive stress changes are predicted via modelling is implemented.

3.3.2 Out of Channel

The maximum and average modelled increases in flow velocities for the 100%, 5% and 1% AEP storm events and PMF event for out of channel flooding are presented in **Table 3.6.** The range (minimum and maximum) of modelled flow velocities for the 100%, 5% and 1% AEP storm events and PMF event out of channel flooding are presented in **Table 3.7**.

Table 3.6 Maximum and Average Modelled Increase in Flow Velocity out of Channel

Watercourse	Maximum Modelled Increase				Average Modelled Increase				Average Modelled Decrease			
	100% AEP	20% AEP	1% AEP	PMF	100% AEP	20% AEP	1% AEP	PMF	100% AEP	20% AEP	1% AEP	PMF
Quorrobolong Creek upstream of Cony Creek junction	0.32	0.02	0.01	0.76	0.004	0.004	0.004	0.004	0.002	0.004	0.003	0.004
Quorrobolong Creek downstream of Cony Creek junction	0.25	0.25	0.24	0.50	0.05	0.05	0.05	0.04	0.02	0.06	0.06	0.06
Unnamed Tributary of Quorrobolong Creek	0.08	0.41	0.50	1.60	0.04	0.05	0.06	0.05	0.03	0.06	0.04	0.05

Table 3.7 Ranges in Flow Velocity out of Channel

Watercourse	Velocity Ranges, Approved				Velocity Ranges, Proposed			
	100% AEP	20% AEP	1% AEP	PMF	100% AEP	20% AEP	1% AEP	PMF
Quorrobolong Creek upstream of Cony Creek junction	0.05 - 0.83	0.06 - 1.09	0.06 - 1.14	0.13 - 1.43	0.05 - 0.83	0.06 - 1.09	0.06 - 1.14	0.13 - 1.43
Quorrobolong Creek downstream of Cony Creek junction	0.01 - 0.77	0.10 - 1.08	0.10 - 1.13	0.09 - 1.38	0.01 - 0.77	0.09 - 1.11	0.11 - 1.17	0.09 - 1.42
Unnamed Tributary of Quorrobolong Creek	0.05 - 1.00	0.10 - 1.34	0.11 - 1.4	0.06 - 1.60	0.06 - 1.00	0.1 - 1.36	0.1 - 1.42	0.07 - 1.62

With the proposed modification, it is predicted that maximum out of channel flow velocities for Quorrobolong Creek both upstream and downstream of the junction with Cony Creek will have localised increases and decreases for all modelled storm events. Modelling indicates that the absolute maximum and minimum peak flow velocities with the proposed modification will remain similar to those modelled for both the approved mining scenario and the proposed mining scenario. As such, similar to in channel flows, it is considered that the maximum flow velocities will remain within non-scouring ranges for the 100%, 5% and 1% AEP storm events and the PMF event as a result of the proposed modification within in Quorrobolong Creek.

With the proposed modification, it is predicted that maximum flow velocities in the unnamed tributary of Quorrobolong Creek will experience localised increases and decreases out of channel for all modelled storm events. The maximum modelled increase in out of channel flow velocity for the 100% AEP event was 0.08 m/s. The maximum modelled increase in out of channel flow velocity for the 5% AEP event was 0.41 m/s. The maximum modelled increase in out of channel flow velocity for the 1% AEP event was 0.5 m/s. The PMF event produced the largest maximum modelled flow velocity out of channel for the unnamed tributary of Quorrobolong Creek in the order of 1.6 m/s. Modelling indicates that the absolute maximum and minimum peak flow velocities out of channel for the unnamed tributary of Quorrobolong Creek with the proposed modification will remain similar to those modelled for both the approved mining scenario and the proposed mining scenario. As such, it is considered that the maximum flow velocities will remain within non-scouring ranges for the 100%, 5% and, 1% AEP storm events and the PMF storm events as a result of the proposed modification.

3.4 Flood Hazard

In order to assess the potential flood hazards associated with the proposed modification, the flood hazard categories outlined in Appendix G of the *Floodplain Development Manual* (2005) were utilised. The four flood hazard categories, in order of increasing hazard, are:

- Walking and vehicle access
- Vehicles unstable
- Wading unsafe (and vehicles unstable) and
- Damage to light structures.

Flood hazard category maps for the approved mining scenario and the proposed mining scenario for the 100% AEP, 5% AEP and 1% AEP storm events and PMF event are provided in **Appendix A** (Figures A9 to A12) and **Appendix B** (Figures B9 to B12).

Modelling for the 1% AEP flood event indicates that the access routes to properties in the LWB4-B7 Modification Area are currently flood free and will remain so with the proposed modification.

Modelling for the PMF event indicates that the existing driveway access route to property ID A08h01 in the LWB4-B7 Modification Area is flood free for the approved scenario, however will be partially inundated within a localised portion of the existing access route close to the dwelling with the proposed scenario. Modelling for the PMF event indicates that the flood hazard category for the existing access route to the dwelling will change from “No Flooding” for the approved scenario to “Vehicle Unstable” for the proposed scenario within the small area that is inundated in the PMF event. The dwelling on property ID A08h01 will remain flood free and will not be isolated due to flooding. In addition, there is an existing alternate access from this dwelling to Sandy Creek Road which would mitigate this potential impact.

Modelling of the PMF event also indicates that all other access routes to properties in the LWB4-B7 Modification Area are currently flood free and will remain so with the proposed modification.

A flood hazard category analysis was also undertaken for Sandy Creek Road. The analysis indicates that the road will remain in the “vehicles unstable” flood hazard category for the 1% AEP storm event and PMF event with the proposed modification. The analysis also indicates that the flood hazard category will decrease from the “vehicles unstable” category to “walking and vehicle access” for the 5% AEP storm event.

The modelling also predicts a decrease in the duration when the road is flooded:

- from approximately 3 hours 25 minutes to approximately 2 hours 40 minutes with the proposed modification during the 5% AEP storm event
- from approximately 4 hours 45 minutes to approximately 4 hours 15 minutes with the proposed modification during the 1% AEP storm event and
- from approximately 25 hours 25 minutes to approximately 23 hours 50 minutes with the proposed modification during the PMF event.

3.5 Flood Duration and Remnant Ponding

Flood model hydrographs on Quorrobolong Creek immediately downstream of the unnamed tributary and downstream of LWB4-B7 (refer to **Appendix B** - Figure B13 and Figure B14) are comparable to the flood hydrographs derived previously for the approved LWB1-B3 and Stage 2 and 3 mine plans, indicating that the proposed modification will have negligible effect on the flood response downstream of the mining area during the 100%, 5% and 1% AEP and PMF storm events.

There are predicted to be minor changes to the extent of remnant surface ponding in the area to be undermined (refer to **Figure 3.1** and **Appendix B** - Figure B15 and B16). The predicted impacts on remnant ponding are primarily confined to existing flow paths, paddocks and farm dams, with no predicted impact on access routes to, or within, the properties along Quorrobolong Creek or its unnamed tributary.

As shown on **Figure 3.1**, an increase in the extent of remnant surface ponding is predicted along an overflow channel south of Quorrobolong Creek on Austar owned land. The analysis indicates ponding up to 0.5 metres deeper may occur on the overflow channel from Quorrobolong Creek extending 100 metres to 125 metres further upstream than in the approved scenario. Statistical analysis of the daily rainfall volumes experienced from 1973 to 2006 indicates that this area may be inundated during an average year (50^{th} percentile) approximately 85 days per year, during a dry year (10^{th} percentile) approximately 31 days per year and during a wet year (90^{th} percentile) approximately 156 days per year.

A minor increase in the extent of ponding is predicted along the eastern edge of a farm dam located above the northern edge of LWB5 near dwelling ID A08h01 (refer to **Figure 3.1**). Modelling also indicates that there will be a minor increase in the extent of ponding associated with a culvert under Sandy Creek Road above LWB3.

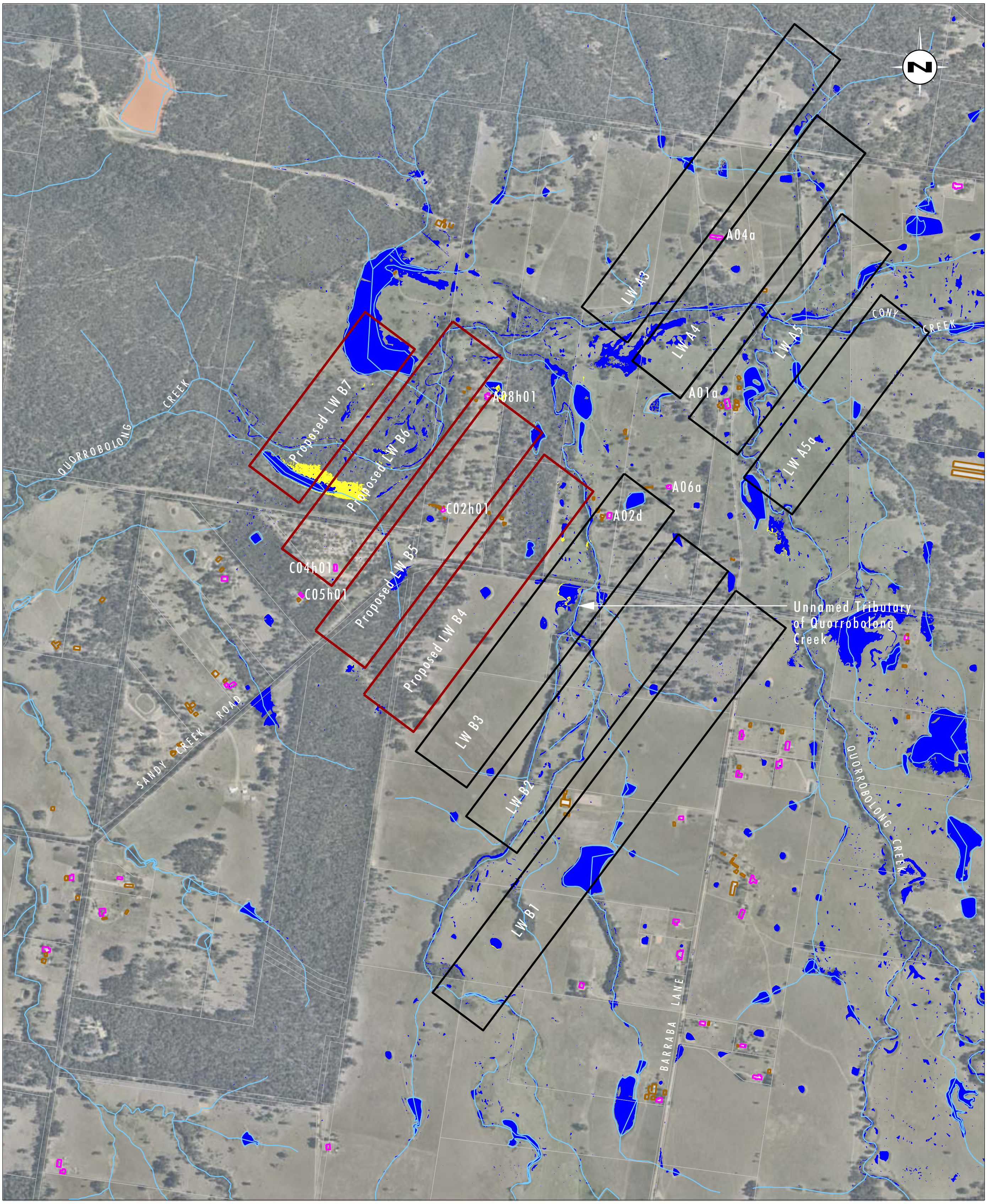


Image Source: Nearmap (2017)
Data Source: Austar Coal Mine (2017)

0 0.25 0.5 1.0km
1:20 000

Legend

- Proposed LWB4-B7 Longwall Panels
- Approved LWA3-A19 and LWB1-B3 Longwall Panels
- Dwelling
- Other Structure
- Remnant Ponding Approved LWA3-A19 and LWB1-B3
- Remnant Ponding Approved LWA3-A19 and LWB1-B3, Proposed LWB4-B7

FIGURE 3.1

Remnant Ponding Approved LWA3-A19 and LWB1-B3, Proposed LWB4-B7

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20170515 15.20

3.6 Stream Flow and Channel Stability

The flood modelling analysis indicates that the proposed modification is unlikely to have a significant impact on the flow regimes of Quorrobolong Creek or its unnamed tributary, with only minor changes predicted in runoff regimes and peak discharges.

Based on the subsidence predictions (refer to **Section 2.0**), the maximum predicted subsidence associated with the extraction of LWB1 to LWB7 will result in maximum changes in longitudinal channel grade of approximately 0.40 per cent within Quorrobolong Creek channel (refer to **Appendix B** - Figure B15 and B16), and approximately 0.45 per cent within the drainage channels of the unnamed tributary of Quorrobolong Creek compared to the approved mining scenario channel conditions.

As the predicted changes in longitudinal channel grade are minor and lie within the natural variations in longitudinal grades of the drainage channels within the Quorrobolong Valley, it is considered that the proposed modification will not significantly alter the flow capacity or stream velocities within the existing channels relative to the existing ranges within the channels. It is also considered that there is minimal potential for channel realignment to occur as a result of the proposed modification as the modelled changes to the longitudinal channel grade and changes to flow velocities and tractive stresses are consistent with the ranges that occur naturally within the Quorrobolong Valley as discussed in **Section 3.3.1**.

The potential to increase erosion of the landform is also expected to be minimal due to the relatively small predicted changes in landform grades and modelled changes to out of channel flow velocities, combined with the high level of groundcover and limited amount of exposed soils in the area.

4.0 Summary and Conclusions

Analysis indicates that the maximum predicted subsidence associated with the proposed modification would have only a minor impact on the flood response in the surrounding area. Modelling indicates there will be some changes to the freeboard of ten dwellings during the 1% AEP flood event and/or PMF event however there will be no flooding of dwellings. Modelling indicates that no dwellings will have their freeboard reduced below the flood planning level (1%AEP flood event plus 500 mm freeboard) as a result of the proposed modification.

The main area that is likely to be affected by changes to the flood response is the section of Quorrobolong Creek downstream of the junction with Cony Creek from the northern most end of LWB6 downstream to the southernmost end of LWB7, with changes predicted to both peak flood depths and flow velocities. To ensure there are no significant impacts as a result of velocity induced scouring or erosion it is recommended that a channel stability monitoring program of these reaches where velocity and tractive stress changes are predicted via modelling are implemented.

The modelled changes to flood hazard categories and flood extents as a result of the proposed modification are considered to be negligible. No access routes to private properties will be adversely affected as a result of the proposed modification for the 1% AEP flood event. A small portion of the existing access route to dwelling ID A08h01 may be inundated during the PMF event however the dwelling will remain flood free and will not be isolated. In addition, there is an existing alternate access from this dwelling to Sandy Creek Road which mitigates this potential impact. The modelling indicates that Sandy Creek Road will continue to be flood affected during the 1% AEP storm event and the PMF event, with the road remaining impassable to vehicles during the flood peak but with a shorter modelled duration of flood inundation over the road.

Minor changes to remnant ponding are predicted as a result of the proposed modification, and relate primarily to a predicted increase in the extent of remnant ponding within an approximately 1.5ha area along an overflow channel south of Quorrobolong Creek on Austar owned land.

5.0 References

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