WAMBO COAL PTY LIMITED

SOUTH BATES (WHYBROW SEAM) UNDERGROUND MINE

EXTRACTION PLAN LONGWALLS 11 TO 13

REPORT 3

SURFACE WATER ASSESSMENT REVIEW

Peabody ENERGY

Advisian
WorleyParsons Group

Wambo Coal Pty Ltd

Wambo South Bates Extraction Plan - LW11 - 13

Surface Water Assessment

September 2015

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Version Control

Revision	Date	Author	Reviewed by	Comments
0.1	August 2015	Alison Tourle	Steve Perrens	Preliminary draft
02	August 2015	Steve Perrens	Resource Strategies	First draft for review
03	September 2015	Steve Perrens	Resource Strategies	Second draft for review
04	September 2015	Steve Perrens		

List of Abbreviations

ARI	Average Recurrence Interval
LMP	Land Management Plan
m AHD	metres Australian Height Datum
NWUM	North Wambo Underground Mine
EP&A Act	*Environmental Planning and Assessment Act 1979*
WCPL	Wambo Coal Pty Limited
LW	Whybrow Seam Longwall

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1 Introduction

1.1 Background

Advisian has been engaged by Wambo Coal Pty Limited (WCPL), a subsidiary of Peabody Energy Australia Pty Limited, to prepare a contemporary Surface Water Assessment to support the Extraction Plan for the approved Longwalls 11 to 13 in the Whybrow Seam (LW11, LW12 and LW13) at the proposed South Bates Underground Mine (Figure 1.1).

The South Bates Underground Mine is located at the Wambo Coal Mine in the Hunter Coalfield of New South Wales (NSW), approximately 15 kilometres (km) west of Singleton NSW. The mine was approved in February 2004 under Part 4 of the *Environmental Planning and Assessment Act 1979*.

As shown in Figure 1.2, the North Wambo Creek Diversion is located above the north eastern end of the longwalls. Stony Creek is located adjacent to the south-western ends of LW11 and LW12 and is directly above LW13. The longwalls are also located below a number of minor ephemeral watercourses that drain in an easterly direction across the proposed mine area.

This report draws upon information presented in a number of related studies, particularly the *South Bates (Whybrow Seam) Subsidence Assessment* (MSEC, 2015).

1.2 Scope

This report has been prepared to assess potential surface water impacts to North Wambo Creek Diversion, Stony Creek and other minor watercourses as a result of subsidence associated with the proposed LW11 to LW13 and identify mitigation measures to minimise subsidence effects. Potential impacts considered include:

- possible increased ponding as a result of differential subsidence;
- possible increased erosion as a result of increased bed gradients; and
- possible cracking of creek beds as a result of tensile strains, leading to loss of flow.

Existing creek conditions in the three watercourses potentially impacted by the longwalls (North Wambo Creek Diversion, Stony Creek and a representative minor watercourse designated as Drainage Line 1) are described in Section 2, potential impacts are described in Section 3 and proposed monitoring and mitigation measures that would be implemented as part of the Extraction Plan are provided in Section 4.

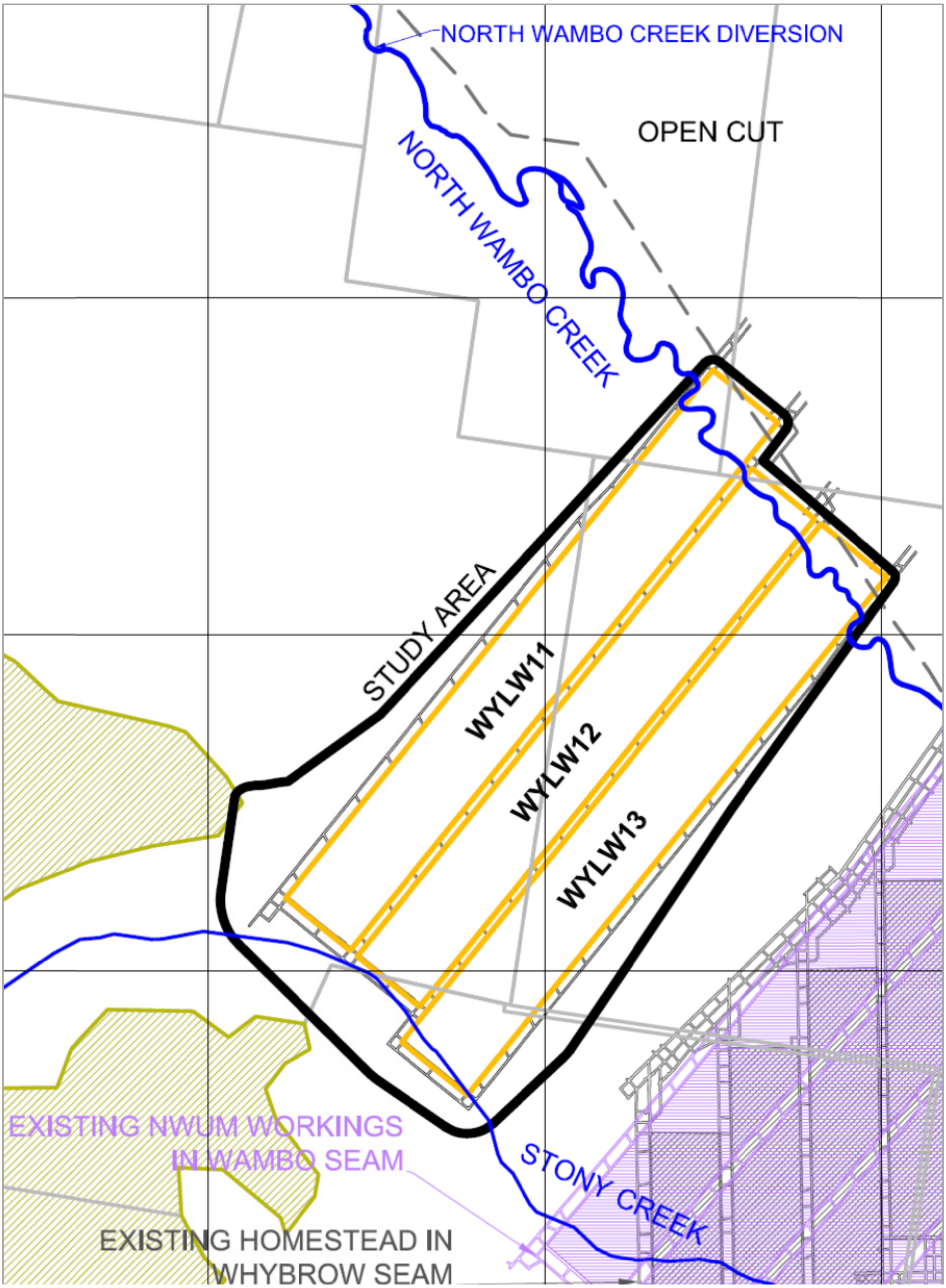

Figure 1.1: Location of Proposed Longwalls 14 to 16 and Outline of the Subsidence Study Area

Source: MSEC (2015) - Extract from Drawing 692-01

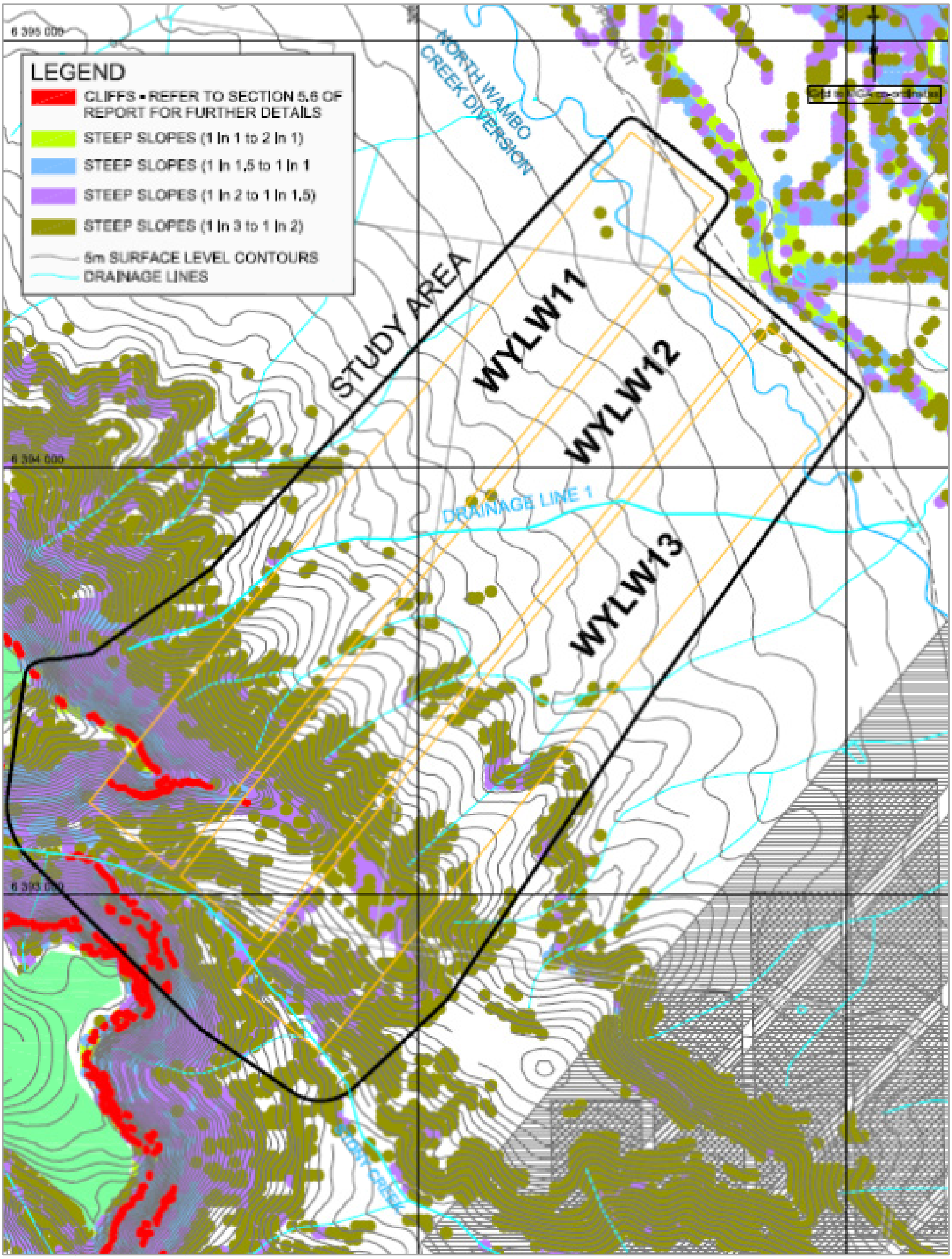

Figure 1.2: Natural Features

(Source: MSEC 2015, Drawing 692-08)

2 Existing Creek Conditions

2.1 Overview

As shown in Figure 1.2, the watercourses within the area potentially impacted by Longwalls 11 to 13 comprise:

- **North Wambo Creek Diversion**, which is located above the north eastern end of the longwalls. Table 2.1 summarises the depths of cover and the lengths of the creek diversion located directly above each of the longwalls.

Table 2.1: Depth of Cover and Lengths of North Wambo Diversion above LW11 to 13

Longwall	Length of Creek Diversion Above Longwall (m)	Depth of Cover (m)
LW11	340	70 - 85
LW12	290	65 - 80
LW13	350	60 - 65

(Source: MSEC 2015)

- **Stony Creek**, which is located adjacent to the south-western ends of LW11 and LW12 and directly above LW13.
- A number of **minor ephemeral watercourses** that drain in an easterly direction across the proposed mine area including 'Drainage Line 1' which is representative of these minor watercourses.

2.2 Stream Order

In the vicinity of Longwalls 11 to 13, Stony Creek is a fourth order stream and Drainage Line 1 is a first order stream in accordance with the Strahler stream ordering system (based on defined watercourses on 1:25,000 topographic maps).

Stream order is not a relevant consideration for the North Wambo Creek Diversion which is a constructed channel.

2.3 Creek Characteristics

2.3.1 North Wambo Creek and Diversion

North Wambo Creek rises in the Wollemi National Park escarpment west and north of the mine area and extends to the confluence with Wollombi Brook south and east of the mine area. The natural catchment had a total area of around 48.5 square kilometres (km^2) which contains two distinct landforms:

- steep, heavily forested, headwaters with elevations ranging up to 650 metres Australian Height Datum (m AHD) on the ridges down to about 140 m AHD where the creek drains onto open country; and
- cleared grassy plains within which sections of the pre-existing creek have been subsumed by the open-cut mine.

Diversion of North Wambo Creek was undertaken to divert flow away from the active South Bates Open Cut Pit in two main stages:

- **Stage 2 Diversion** (incorporating Stage 1), comprising about 3.6 km of meandering channel containing two 'billabongs', was constructed in 2008. The catchment area at the upstream end the Stage 2 Diversion is about 26.5 km^2.
- **Stage 3 Diversion**, comprising a further 5.6 km of meandering channel commencing at the downstream end of the meandering section of Stage 2, was completed in late 2013. An off-stream 'billabong' is located on the eastern side of the diversion near the junction of Stages 2 and 3. As a result of internal drainage to the mine pit, the contributing catchment of the creek at the outlet of the Stage 3 Diversion has been reduced from about 42.6 km^2 to approximately 34.2 km^2.

The approved Longwalls 11 to 13 would extract beneath the downstream section of the Stage 2 Diversion and the upstream section of the Stage 3 Diversion.

The cross section of the original creek was highly variable ranging from sections where the channel comprised a small, shallow swale with broad fringing overflow areas and floodplains, to other areas where it was deeply incised and confined within limited overflow areas. The cross sectional profile of the diversion was intended to be a compromise between these extremes and to provide a section which approximated the average of the existing creek profile. Accordingly, the design cross section comprised a confined low flow channel with a 2 m wide base, banks of 1 m to 2 m height and relatively wide overbank (floodplain) areas on both sides to mimic the original fringing floodplain areas of North Wambo Creek (see Figure 2.1).

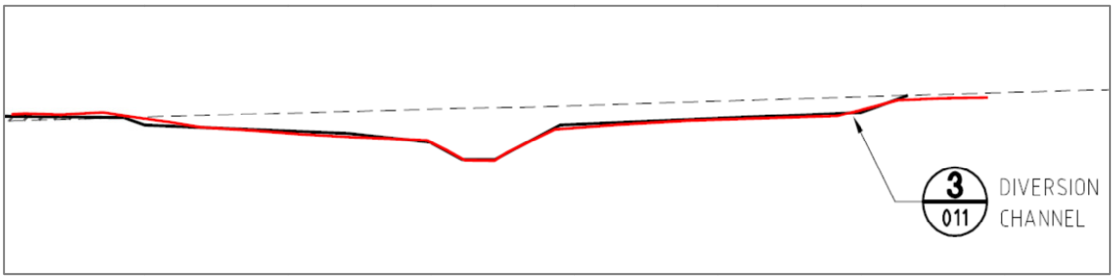

Figure 2.1: Typical Diversion Channel Design Cross-Section

Source: *Diversion Channel Cross Section* (ACT Williams Drawing 09, March 2013)

The diversion channel runs in a north-west to south-east direction over an area which was originally a hillside sloping downwards to the east. Accordingly, the constructed channel and overbank floodplain area is bounded by an extensive cut batter to the west. Overland flow from the natural land surface above the cut batters is directed along the contour to a series of rock chutes that convey concentrated flow down the batters. To the east a large bund wall has been constructed to prevent floodwater entering into the mine pit. Construction of the diversion channel involved 'over excavation' of the bed of the low flow channel in order to provide room for placement of alluvium in the bed of the channel.

As a result of flooding that occurred in early 2013, shortly after Stage 3 was commissioned, the majority of the alluvium placed in this section of 'over excavated' channel was scoured out. Extensive rehabilitation works were subsequently undertaken (Gilbert & Associates, 2013b), but the Stage 3 low flow channel remains larger than the Stage 2 channel and has areas of exposed bedrock as described below.

Figure 2.2 is a general view of part of the Stage 2 Diversion which would be subject to subsidence associated with LW11 and 12, while Figure 2.3 is a typical view of the low flow channel with an alluvial bed and exhibiting some minor erosion on the banks arising from runoff draining across the side of the channel from the extensive batters either side of the overbank floodplain.

Figure 2.2: North Wambo Creek Diversion (Stage 2)

Figure 2.3: North Wambo Creek Diversion (Stage 2) – Typical Low Flow Channel

Figure 2.4 is a general view of part of the Stage 3 Diversion which would be subject to subsidence associated with LW 13, while Figure 2.5 is a typical view of the low flow channel which is much larger than the Stage 2 channel with large areas of exposed rock on the bed and banks as a result of scouring by a flood that occurred in early 2013.

Figure 2.4: North Wambo Creek Diversion (Stage 3)

Figure 2.5: North Wambo Creek Diversion (Stage 3) – Typical Low Flow Channel

2.3.2 Stony Creek

Stony Creek is an ephemeral creek which has steep heavily forested headwaters in the Wollemi National Park escarpment with elevations ranging up to 650 m AHD on the ridges down to about 230 m AHD at the point where Stony Creek passes the southern corner of the Study Area. At this point the creek is a fourth order ephemeral stream with a catchment area of about 6.7 km². Downstream of the Study Area, the creek flows in a south-westerly direction for about 4 km to join Wambo Creek. The lower reaches of the creek, to the south-east of the Study Area, have been directly mined beneath by Longwalls 1 to 6 in the Wambo Seam.

The bed of Stony Creek is formed in the natural surface soils and has a sandy base with rounded gravel. In some locations there is exposed sandstone bedrock which has formed into small cascades with isolated pools. There is also significant debris along the creek, including boulders, tree branches and other vegetation. The natural grade along the section of Stony Creek within the Study Area varies between 50 mm/m (i.e. 5 % or 1 in 20) and 200 mm/m (i.e. 20 % or 1 in 5), with an average natural grade of approximately 100 mm/m (i.e. 10 % or 1 in 10).

The upper reaches of Stony Creek are located above the commencing end of LW13 and immediately adjacent to the commencing ends of LW11 and LW12.

The section of Stony Creek adjacent to the south-western ends of the longwalls has a steep, boulder strewn channel with numerous pools as shown in Figure 2.6. The bed of the channel comprises a mixture of gravel and coarse sand as shown in Figure 2.7. At the time of an inspection carried out in June 2015, shortly after days of rain, minor flow could be observed at some locations, but at other locations all flow was conveyed through the gravel and coarse sand in the bed and no flow was visible. Iron staining was observed at a number of locations along the creek. Algae were also observed in a number of locations, suggesting a source of nutrients in the catchment. However, as the majority of the catchment is within the National Park and there are no known agricultural activities upstream of the section of creek in the vicinity of the longwalls, the source of the nutrients is assumed to be natural.

Figure 2.6: Stony Creek in the Vicinity of LW11, 12 and 13

Figure 2.7: Typical Creek Bed Material – Stony Creek

2.3.3 Ephemeral Drainage Lines

Ephemeral drainage lines, including Drainage Line 1 on Figure 1.2, are located directly above the longwalls and flow in an easterly directly to join the North Wambo Creek Diversion further downstream. These drainage lines have shallow incisions into the natural surface soils, with some isolated bedrock outcropping along the upper reaches.

Within the Study Area, the natural grades of these drainage lines vary between 20 mm/m (i.e. 2 % or 1 in 50) and 400 mm/m (i.e. 40 % or 1 in 2.5), averaging approximately 100 mm/m (i.e. 10 % or 1 in 10). Drainage Line 1 has a heavily forested catchment with an area of about 0.5 km^2 and channel slopes ranging from 5% to 20%.

2.4 Hydrology

2.4.1 Flow Probability

Flow gauging stations have been established at various locations along North Wambo Creek and the Diversion:

1. Upstream of the diversion,
2. Near the centre of Stage 2,
3. Near the centre of Stage 3,
4. Near the junction with Wollombi Brook.

Water level records and the inferred flow from these locations are available from late 2013 to mid-2015. These records are not of sufficient length to provide a basis for assessment of the long term flow regime in the creek. However, records are available from two regional gauging stations (Doyles Creek and Apple Tree Creek), which are operated by the DPI Water (formerly NSW Office of Water). These catchments, which are located west of the North

Wambo Creek catchment, are similar in area and topography to North Wambo Creek and are expected to exhibit similar hydrological behaviour. Gilbert & Associates (2007) analysed the flow data from these two creeks to derive parameters for a daily water balance model (AWBM) that represents the relationship between rainfall and runoff for the particular catchment. For purposes of this report, Gilbert & Associates provided the relevant calibrated parameters for Doyles Creek and Apple Tree Creek AWBM models.

For purposes of assessing the flow regime in the North Wambo Creek Diversion, an AWBM model for the creek has been developed based on the parameters derived for Doyles Creek and Apple Tree Creek. Adjustments were made to the derived parameters to take account of the flow records in the North Wambo Creek. Inspection of the available records showed that the longest, most representative record was from Site 2 (near the centre of the Stage 2 diversion). That record shows (see Annexure 1) that for the period February 2014 to January 2015, there were 31 days on which some flow was recorded. Using daily rainfall data from the Wambo meteorological station, model parameters were adjusted to give total runoff consistent with the volume of runoff based on data from Doyle Creek and Apple Tree Creek and the timing of runoff to be consistent with the recorded flow frequency on the North Wambo Creek Diversion.

In order to assess the likely long term flow regime in the diversion, a composite 131 year rainfall record was compiled from long term local daily rainfall collected by the Bureau of Meteorology in the central Hunter Valley (Doyles Creek, Jerrys Plains, Singleton and Denman). The degree to which this composite long term record was representative of the rainfall conditions at Wambo was assessed by correlation of the available data from Wambo (1/7/2008 to 30/4/2015) with the corresponding data for the composite record. This analysis indicated the correlation coefficient (R^2) between the two records was 0.998, indicating that the long term composite record provides a good representation of the rainfall at Wambo.

Figure 2.8 is a flow duration graph for the North Wambo Creek Diversion based on the rainfall:runoff modelling described above.

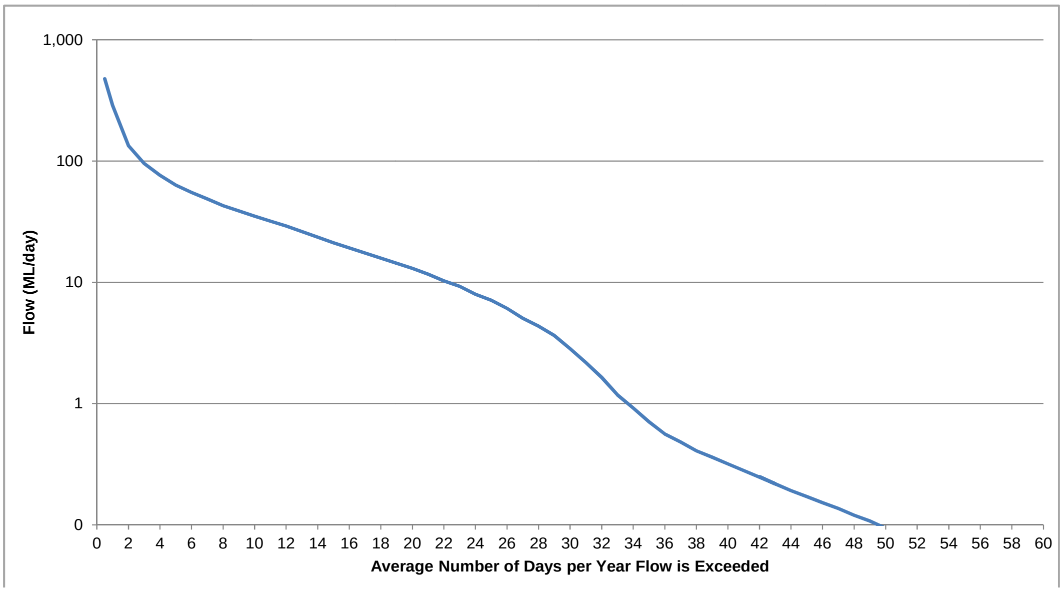

Figure 2.8: Flow Duration Graph for North Wambo Creek Diversion

Figure 2.8 shows that some flow into the diversion can be expected on about 50 days per year on average. However, on many days, the flow would be so small as to not be noticeable. Flow in excess of 1 ML/day (average of 0.01 m^3/s) can be expected on only 34 days per year. The modelling also indicates that in 10th percentile dry years, flow greater than 1 ML/day are likely on about 23 days/year while in 90th percentile wet years this flow would occur on about 46 days. This data confirms the ephemeral nature of the flow in the North Wambo Creek Diversion.

2.4.2 Peak Discharges

To estimate peak discharges in North Wambo Creek for average recurrence intervals (ARIs) of 2, 20 and 100 years, Gilbert and Associates (2007) used a runoff routing model (RORB) which had been calibrated to recorded floods on Doyles Creek.

Estimated flows for Stony Creek have been derived by scaling the flows for North Wambo Creek using the general relationship for peak flows set out in *Hydrological Recipes* (Grayson et.al, 1996) ($Q \sim A^{0.63}$) and are provided in Table 2.2. Flows for 5, 10 and 50 year ARI events have been estimated by interpolation.

Table 2.2: Catchment Areas and Estimated Peak Flood Discharges (m^3/s)

Creek	Catchment Area (km^2)	ARI (years)					
		2	5	10	20	50	100
Stony Creek (downstream of proposed Longwall 13)	6.7	16	19	22	26	33	39
Diversion Inlet (Stages 1 and 2)	26.5	38	44	52	61	77	91
Diversion Outlet (Stage 3) – excluding mine pit area	34.2	45	53	62	73	92	109

2.4.3 Water Quality

Routine water quality monitoring has been carried out at a number of locations on North Wambo Creek and Stony Creek since 2003. Table 2.3 summarises the monitored water quality in North Wambo Creek and Stony Creek for:

- pH;
- Electrical conductivity (EC);
- Total suspended solids (TSS); and
- Total dissolved solids (TDS).

The main features of the monitored water quality summarised in Table 2.3 are:

North Wambo Creek

- pH is generally alkaline with mean in the range of 7.4 to 7.9;
- EC shows an increasing trend from upstream to downstream with the mean ranging from 315 µS/cm upstream to 2,025 µS/cm near Wollombi Brook. (Although there are only a limited number of upstream samples (4), the data is consistent with the data for the upstream catchment on Stony Creek (22 samples – see below);

- TSS concentrations are highly variable reflecting the fact that TSS concentrations are closely related to flow rate;
- TDS concentrations mirror the variation in EC (as would be expected because the two parameters are related).

Stony Creek

- pH ranges from slightly acidic (6.2) to slightly alkaline (8.4);
- EC is generally low (range 190 – 479 µS/cm);
- TSS is generally low (range 0.5 - 24 mg/L);
- TDS is generally low (range 58 – 276 mg/L).

Table 2.3: Surface Water Quality Summary

Monitoring Site	Parameter	Count	Min	20%	Mean	80%	Max
North Wambo Creek Upstream (SW04)	pH	4	7.3	-	8.1	-	8.4
	EC(µS/cm)	4	256	-	315	-	393
	TSS (mg/L)	4	2.5	-	37.5	-	2,712
	TDS (mg/L)	4	154	-	165	-	214
North Wambo Creek Middle-Lower (SW27)	pH	29	7.0	7.4	7.9	8.4	8.8
	EC(µS/cm)	30	52	209	341	738	2,700
	TSS (mg/L)	30	18	58	339	1,138	5,440
	TDS (mg/L)	30	252	432	673	947	2,000
North Wambo Creek near Wollombi Brook (SW05)	pH	104	7.0	7.3	7.6	7.9	9.0
	EC(µS/cm)	104	113	1,118	2,025	2,294	3,200
	TSS (mg/L)	104	1	6	15	70	1,100
	TDS (mg/L)	104	172	636	1,110	1,286	2,162
Stony Creek Upstream (SW08)	pH	22	6.2	6.8	7.2	7.4	8.4
	EC(µS/cm)	22	190	295	360	423	479
	TSS (mg/L)	23	0.5	1.0	2.5	3.4	24
	TDS (mg/L)	23	58	155	203	238	276

Source: WCPL, 2014

3 Potential Subsidence Impacts

Mining can potentially result in increased levels of ponding in locations where the mining induced tilts oppose and are greater than the natural stream gradients that exist before mining. Mining can also potentially result in an increased likelihood of scouring of the stream beds in the locations where the mining induced tilts considerably increase the natural stream gradients that exist before mining.

MSEC (2015) assessed subsidence impacts of mining in the Whybrow Seam on North Wambo Creek Diversion, Stony Creek and Drainage Line 1. Further details of the specific impacts of subsidence for these watercourses are provided below.

3.1 Summary of Previous Assessments

3.1.1 North Wambo Creek Diversion

Section 4.2.3 of the Wambo Development Project Environmental Impact Statement (WCPL, 2003) described the North Wambo Creek Diversion that would be constructed following the extraction of the Whybrow Seam longwall panels. The Subsidence Assessment concluded that due to the shallow depth of the Whybrow Seam in this area (approximately 60 m to 80 m) subsidence was predicted to be variable resulting in a hump and hollow effect along the channel alignment.

An application to modify the Development Consent (DA 305-7-2003 MOD 2) was lodged in January 2005 to modify the timing and orientation of the North Wambo Underground Mine. The modification was approved on 4 May 2005 and resulted in the construction of the North Wambo Creek Diversion prior to the commencement of mining in the approved Whybrow Seam longwall panels at the South Bates Underground Mine.

3.1.2 Stony Creek

In regard to potential environmental consequences on Stony Creek, Section 4.2.3 of the Wambo Development Project Environmental Impact Statement (WCPL, 2003) described that extraction of the western most portions of the Whybrow Seam longwall panels would result in subsidence of Stony Creek. WCPL (2003) predicted that potential impacts above the approved Whybrow Seam longwall panels would include bank and headward erosion.

3.2 North Wambo Creek Diversion

3.2.1 Subsidence Predictions

The North Wambo Creek Diversion is located directly above the finishing ends of LW11 to LW13, where the depths of cover are the shallowest and where the predicted subsidence parameters are the greatest.

The predicted profiles of conventional subsidence, tilt and curvature along the Diversion due to the extraction of each of the longwalls are summarised in Table 3.1 and shown in Figure 3.1.

Table 3.1: Subsidence Impacts on the North Wambo Creek Diversion

Longwall	Max Predicted Total Subsidence (mm)	Max Predicted Total Tilt (mm)	Max Predicted Total Hogging Curvature (km⁻¹)	Max Predicted Total Sagging Curvature (km⁻¹)
After LW11	1,850	65	>3.0	>3.0
After LW12	1,950	70	>3.0	>3.0
After LW13	1,950	75	>3.0	>3.0

(Source: MSEC 2015)

3.2.2 Subsidence Impacts

Surface Levels and Grades

The natural and predicted post-mining surface levels and grades along the Diversion are illustrated in Figure 3.1. Figure 3.1 indicates that the grade at the upstream edge of LW 11, 12 and 13 is estimated to increase from about 0.5% to 5%.

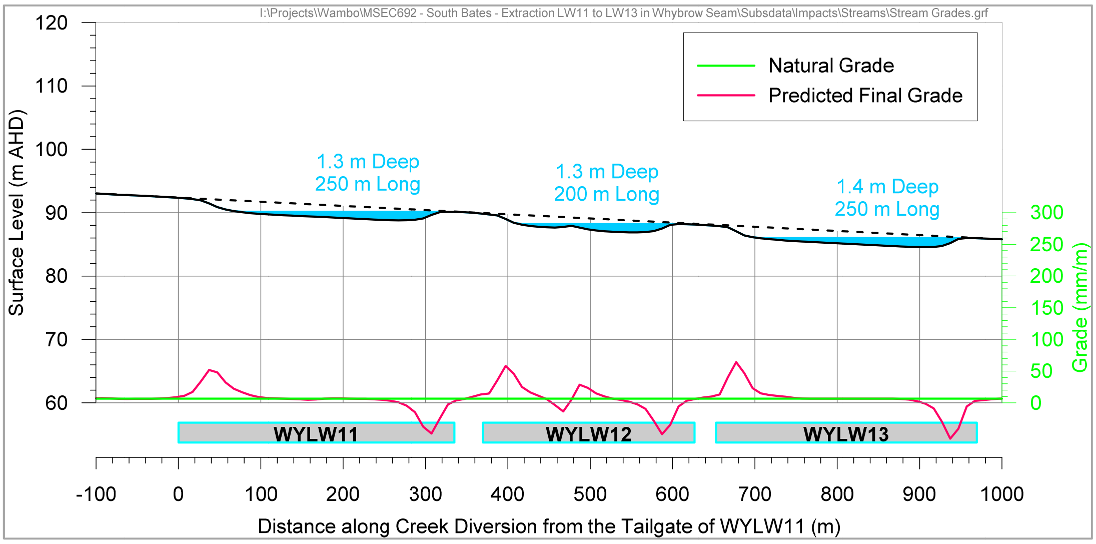

Figure 3.1: Natural and Predicted Subsided Surface Levels and Grades – North Wambo Creek Diversion
(Source: MSEC 2015)

Potential for Ponding

Figure 3.1 shows that three pools are predicted to form along the Diversion directly above LW11, LW12 and LW13. The ponding areas above these longwalls are estimated to be up to 1.4 metres deep and up to 250 metres long. The predicted maximum extent of the ponding (governed by the level of the channel downstream of each pond) is shown in Figure 3.2. The maximum water area of the pools above LW 11, 12 and 13 are estimated to be about 0.9, 0.8 and 0.4 ha respectively. The smaller predicted area of the pond above LW13 occurs because of the channel in Stage 3 is larger and more incised than in Stage 2.

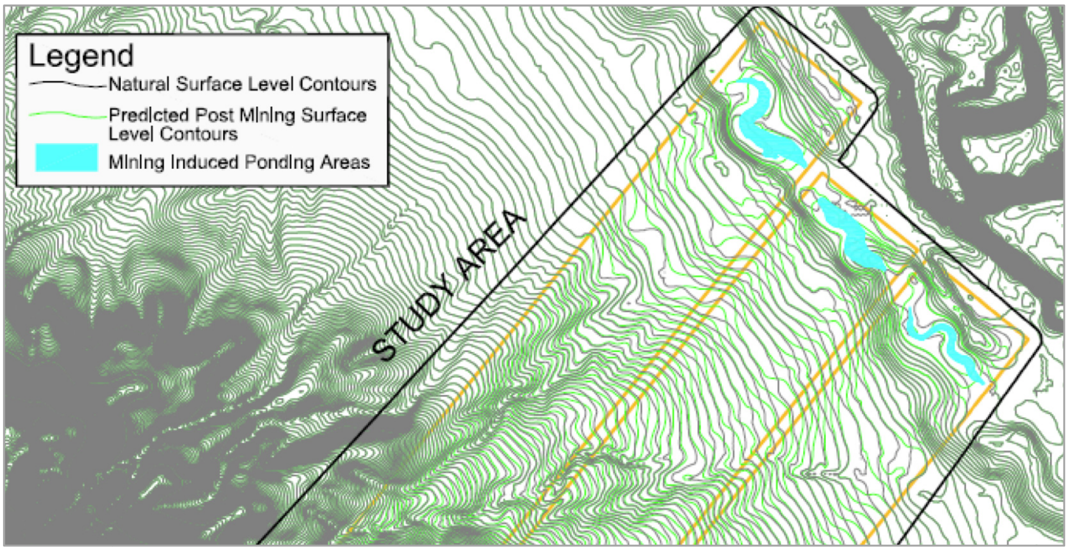

Figure 3.2: Predicted Extent of Ponding – North Wambo Creek Diversion
(Source: MSEC 2015, extract from Figure 5.22)

Assuming that remedial works undertaken immediately following longwall extraction provide adequate sealing to minimise leakage from the pond areas (see discussion below relating to cracking in the bed of the diversion and mitigation measures described in Section 4.4.1), permanent pools can be expected to develop as shown in Figure 3.1 and Figure 3.2. The AWBM model described in Section 2.4.1 has been used to estimate daily flows in the Diversion corresponding to the 131 years of regional rainfall data that is consistent with the observed rainfall at Wambo. Based on the geometry of the pools shown in Figure 3.1 and Figure 3.2, a simple daily water balance model has been established that accounts for flow from the catchment, direct rainfall, loss by evaporation and seepage, and overflow from the pools. Based on the 131 years of rainfall data and the associated simulated flow in the Diversion, Figure 3.3 shows the expected water level in the pools expressed as the average time that the water level would be at the stated level. Whilst this analysis has a number of simplifications, it indicates that small flows in the North Wambo Creek Diversion can be expected to occur sufficiently frequently to maintain the average pool level above 1.2 m most of the time.

In the short term, some silt deposition can be expected to enhance the sealing of the base of the pools. In the long term, however, the pools can be expected to gradually silt up and loose storage capacity.

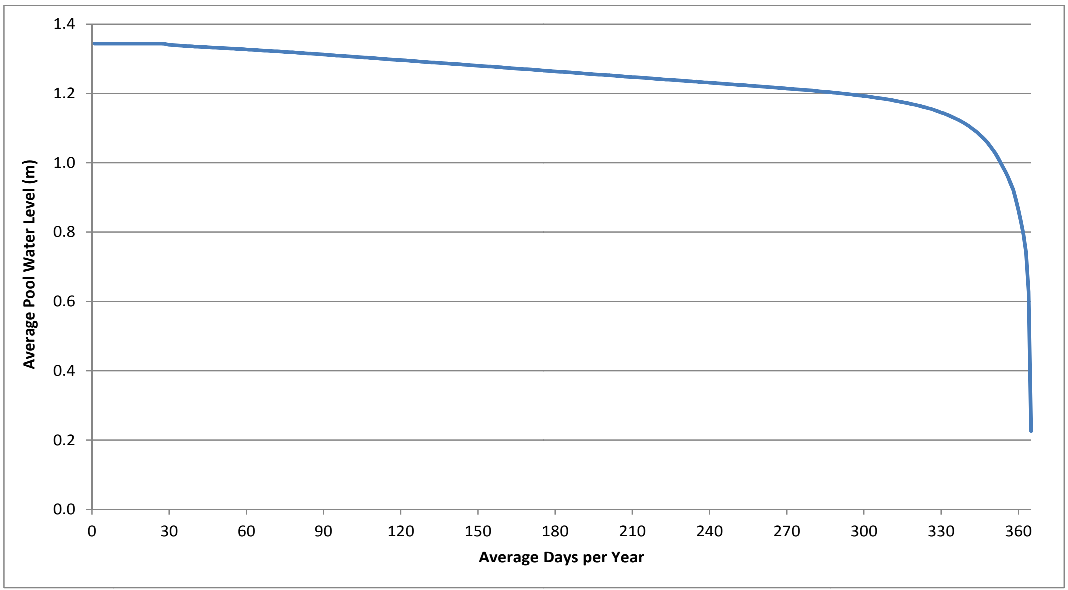

Figure 3.3: Simulated Long Term Water Level Behaviour of Pools in North Wambo Creek Diversion

Potential for Cracking in the Creek Beds and Fracturing of Bedrock

It is likely that extensive surface cracking will occur along the alignment of the Diversion. The depths of cover along the alignment of the Diversion above the finishing ends of the longwalls vary between 60 and 85 metres and therefore it is likely that fracturing would occur from the seam up to the surface in this location.

It is possible that some of the surface water flows in the Diversion could flow into the workings as a result of the cracking. As flow in the Diversion is ephemeral, this would only occur during, and for short periods after, rain events before remediation activities can be completed. The longwalls will be extracted in the up-dip direction of the seam, so any increased water flows into the mine will flow away from the extraction face.

Mining was conducted under Wambo Creek at similar depths of cover at the nearby Homestead Mine in Longwalls 9 and 9A in the Whybrow Seam. A large flow event in Wambo Creek occurred while mining was occurring in Longwall 9 immediately below the creek. Coffey (2000) reported "*a maximum of about 200 L/s of surface flow was being transferred to the mine*". Subsequent flow monitoring was conducted during the period when Longwall 9A was undermining the creek. This involved pumping water from Wollombi Brook at a measured rate to an un-subsided area between Longwalls 9 and 9A. Outflow to Wollombi Brook, which was monitored by means of a weir, stabilised at 12.4 to 14.1 L/s (1.1 to 1.2 ML/day). In response to the cracking, grouting of the bed rock to a depth of about 10 m was undertaken along the sections of creek where cracking occurred.

Although the North Wambo Creek Diversion is dry for most of the time, Gilbert & Associates (2013a) estimated the flood in early 2013 had a peak flow of 35 to 50 m^3/s. Analysis of subsequent recorded flows indicates that typically the flow reaches a peak in about 24 hours following a storm and then returns to negligible flow about 2 days later. Based on this typical hydrograph shape, the flood in early 2013 would have a maximum volume in any 24 hour period of the order of 2,000 to 3,000 ML/day. This flow would be sufficient to support the inflows to the underground workings should the creek be flowing during the period of mining when the cracks are open.

A critical consideration is the probability of a high rainfall event occurring in the 1-2 week period between the longwall face passing under the creek and being able to undertake remediation works to reduce the inflow rate to tolerable levels. As shown in Figure 2.8, flows in excess of 10 ML/day can be expected on about 22 days per year, comprising events of 2-3 days duration. The recommended rehabilitation strategy that takes account of these features of the flow regime is set out in Section4.4.1.

Potential Water Quality Impacts

The subsidence along the North Wambo Creek Diversion has the potential to increase TSS concentrations as a result of increased scouring of the channel during high flows in areas where the gradient is predicted to increase up to 5%. The potential for scour will be mitigated by the proposed scour protection works described in Section 4.2.1. Under low flow conditions, the pools created as a result of subsidence are likely to retain fine sediment and reduce TSS concentration in the downstream flow. Overall, once the scour protection works have been implemented, there is not expected to be any measurable change in the range of TSS concentrations downstream of the Diversion.

Subsidence is not expected to lead to any change in the pH or EC of the flow in the Diversion.

3.3 Stony Creek

3.3.1 Subsidence Predictions

The predicted profiles of conventional subsidence, tilt and curvature along Stony Creek are summarised in Table 3.2.

Table 3.2: Subsidence Impacts on Stony Creek

Longwall	Max Predicted Total Subsidence (mm)	Max Predicted Total Tilt (mm)	Max Predicted Total Hogging Curvature (km^{-1})	Max Predicted Total Sagging Curvature (km^{-1})
After LW11	40	<0.5	<0.01	<0.01
After LW12	90	1	0.01	0.01
After LW13	400	6	0.1	0.1

(Source: MSEC 2015)

3.3.2 Subsidence Impacts

Surface Levels and Grades

The natural and predicted post-mining surface levels and grades along Stony Creek are shown in Figure 3.4.

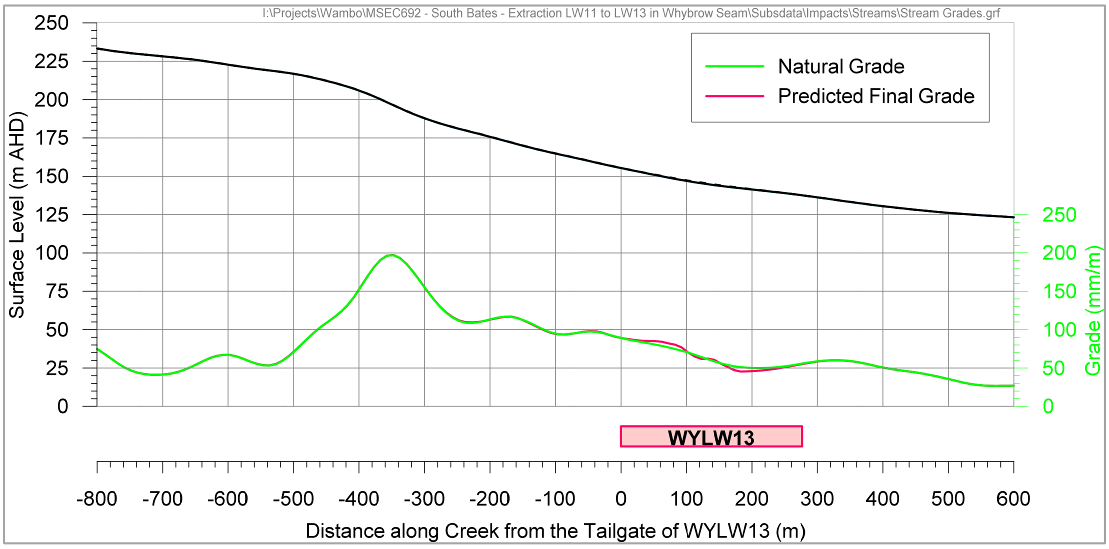

Figure 3.4: Natural and Predicted Subsided Surface Levels and Grades – Stony Creek
(Source: MSEC 2015)

Potential for Ponding

As the predicted post-mining grades along Stony Creek are similar to the natural grades, no adverse changes in the levels of ponding or scouring along this creek are expected as a result of the proposed mining.

Potential for Cracking in the Creek Beds and Fracturing of Bedrock

Fracturing of the uppermost bedrock as a result of mining has been observed where the tensile strains are greater than 0.5 mm/m or where the compressive strains are greater than 2 mm/m. The predicted conventional strains along Stony Creek are 1 mm/m tensile and compressive.

Compressive strains between 5 mm/m and 10 mm/m could occur along the section of Stony Creek located directly above and immediately adjacent to the longwalls due to the valley related movements.

The sections of Stony Creek within the Study Area typically have shallow incisions into the natural surface soils. Cracking in the beds of the streams would only be visible at the surface where the depths of the surface soils are shallow, or where the bedrock is exposed.

Some sections of Stony Creek have exposed bedrock which has formed into small cascades with isolated pools. Fracturing of the exposed bedrock could result in spalling or dislodgement of rocks. There could also be some diversion of the surface water flows into the dilated strata beneath the beds, which could drain any ponded surface water upstream of the outcropping. It is expected that any diverted surface water would re-emerge further downstream due to the high natural grades in these locations.

It is expected that the fractured zone above north-eastern and central parts of the longwalls would extend up to the surface. However it is not expected that there would be a hydraulic connection between the surface and seam at Stony Creek, as there have been no adverse impacts reported along the sections of Stony and North Wambo Creeks which have been previously mined beneath at the North Wambo Underground Mine (NWUM) at lower depths of cover. This includes the extraction of the Homestead/Wollemi workings in the Whybrow Seam directly beneath Stony Creek and the extraction of Longwalls 1 to 7 in the Wambo Seam beneath both Stony and North Wambo Creeks.

Potential Water Quality Impacts

Any cracking of exposed bedrock along Stony Creek has the potential to lead to a decrease in pH and an increase in the iron staining that has already been observed in the creek (Section 2.3.2). Given that slightly acid conditions have been recorded in the creek (Table 2.3) and iron staining is already present, no significant pH impacts are predicted.

No changes in TSS or EC are predicted.

3.4 Ephemeral Creeks

3.4.1 Subsidence Impacts

Surface Levels and Grades

The natural and predicted post-mining surface levels and grades along a representative ephemeral minor drainage line designated as Drainage Line 1 are shown in Figure 3.5.

Potential for Ponding

It can be seen in Figure 3.5 that there are no reversals (i.e. negative grades) along Drainage Line 1 after the completion of mining. The post-mining grade upstream of the maingate of LW13 is, however, very small and localised increased ponding could occur in this location. It is unlikely that increased levels of ponding would occur along the other drainage lines located to the south of Drainage Line 1 because the predicted tilts are smaller due to the higher depths of cover and because the natural gradients are greater than those along Drainage Line 1.

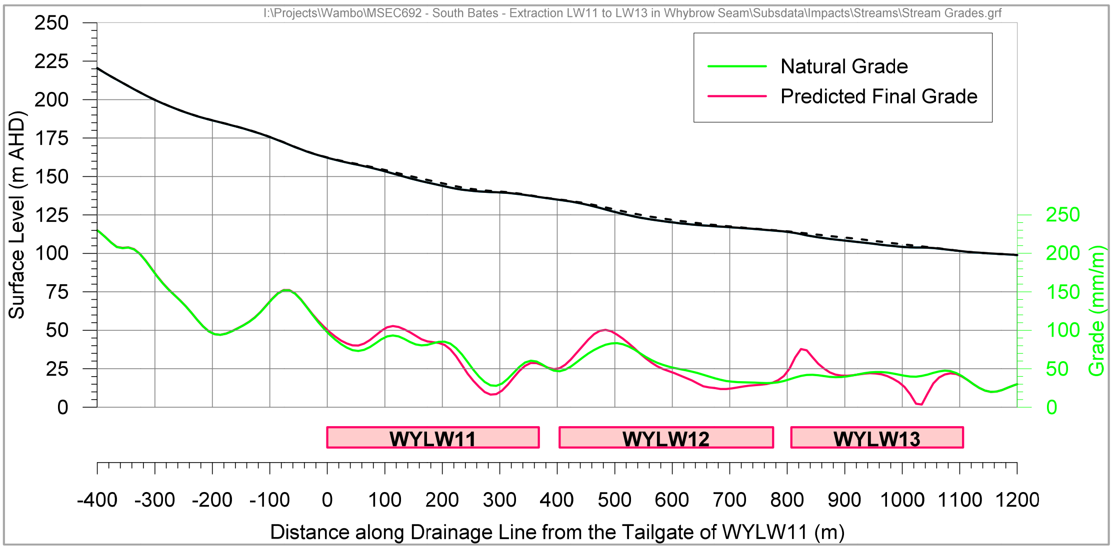

Figure 3.5: Natural and Predicted Subsided Surface Levels and Grades – Drainage Line 1
(Source: MSEC 2015)

Potential for Cracking in the Creek Beds and Fracturing of Bedrock

The sections of the ephemeral drainage lines within the Study Area typically have shallow incisions into the natural surface soils. Cracking in the beds of the streams would only be visible at the surface where the depths of the surface soils are shallow, or where the bedrock is exposed.

Some sections of the upper reaches of ephemeral drainage lines have exposed bedrock which has formed into small cascades with isolated pools. Fracturing of the exposed bedrock could result in spalling or dislodgement of rocks. There could also be some diversion of the surface water flows into the dilated strata beneath the beds, which could drain any ponded surface water upstream of the outcropping. It is expected that any diverted surface water would re-emerge further downstream due to the high natural grades in these locations.

Potential Water Quality Impacts

The water quality conditions in the ephemeral drainage lines are likely to be similar to those monitored in Stony Creek and the upstream monitoring in North Wambo Creek.

Any cracking of exposed bedrock has the potential to lead to a decrease in pH and lead to iron staining similar to that already been observed in Stony Creek (Section 2.3.2). Given that slightly acid conditions have been recorded in the Stony Creek (Table 2.3) no significant pH impacts are predicted in the ephemeral drainage lines. No significant changes in TSS or EC are expected as a result of subsidence.

4 Mitigation and Management Measures

The following sections provide recommended impact monitoring and management measures which would be applied to manage any flow and channel stability impacts resulting from mining LW11 to 13. The impacts on Stony Creek and the ephemeral drainage lines are predicted to be minor and are unlikely to require extensive remedial works. However, as described in Section 3.2.2, it is predicted that three long pools would develop within the North Wambo Creek Diversion directly above the north-eastern end of the longwalls. Works to allow free drainage of the pools would require re-grading of the bed of the channel for about 1,500 m downstream. This section of the Diversion has been subject to extensive rehabilitation following the flooding in early 2013 and further extensive disturbance and rehabilitation is considered undesirable. Accordingly, mitigation works should be undertaken to:

- Seal surface cracks in order to minimise loss of flow through any connective cracking along the edges of the subsidence troughs, and
- Provide scour protection along the sections where the gradient is predicted to increase up to 5%.

Longwall 13 will encroach into the Stage 3 Diversion by approximately 150 metres. The Stage 3 diversion is still in the process of recovering from the flooding in early 2013 which has required significant rehabilitation works. Accordingly, any works in this area will have to be undertaken in a manner that minimises disturbance of the previous rehabilitation work.

WCPL should stockpile sufficient materials for:

- Sealing any cracks (particularly in areas that are predicted to be ponded) and
- Installation of scour protection works.

Planning of the works should ensure that all construction materials, equipment and the necessary resources are in place prior undermining by each longwall in order to permit prompt completion of works once subsidence and any cracking has occurred. Works should be implemented sequentially to minimise exposure to flow events. Priority should be given to sealing any cracks if significant rainfall is forecast during the construction period.

A specific management plan will be prepared for works to be undertaken as soon as practical after each longwall has undermined the Diversion.

4.1 Monitoring and Survey

As recommended by Gilbert and Associates (2003), detailed longitudinal geomorphological surveys should be conducted along all creek reaches affected by subsidence. The surveys should include a photographic record with location co-ordinates and any areas of potential instability noted. Surveys should be undertaken at least three times:

- prior to subsidence (i.e. the commencement of mining);
- immediately following subsidence; and
- following the completion of any restoration or remediation works.

During mining in the Whybrow Seam, daily monitoring of the North Wambo Creek Diversion should be undertaken during the period when mining occurs immediately below the creek to allow prompt remedial works to be undertaken.

4.2 Bed and Bank Stability

4.2.1 North Wambo Creek Diversion

As discussed in Section 3, the area most vulnerable to scour is confined to the sections of North Wambo Creek Diversion and adjoining floodplain near the upstream edge of each longwall subsidence trough. To protect these areas from scour, a variety of measures will be employed as discussed below.

Localised Rock Armouring

Localised rock armouring will be placed for a distance of approximately 100 metres from the upstream edge of each of the pools and adjoining floodplain, using similar techniques to those developed for stabilisation of Stage 3 of the Diversion following the flood of early 2013. This would involve the placement of a geofabric on the surface to control erosion/movement of sub-grade material beneath the surface armour layer, with trench anchoring into the ground on all sides. Individual rocks would be placed in an interlocking pattern over the geofabric. Figure 4.1 illustrate similar remediation techniques used to stabilise the batters in Stage 3 of the Diversion in 2013.

In some locations the natural ground level falls away to the west sufficiently to require the placement of fill on the western floodplain area in order to create a surface that, in cross section, slopes back toward the diversion channel.

The indicative extent of the proposed armouring is shown on Figure 4.2, Figure 4.3 and Figure 4.4.

Figure 4.1: Remediation Works on the North Wambo Creek Diversion (March 2013)

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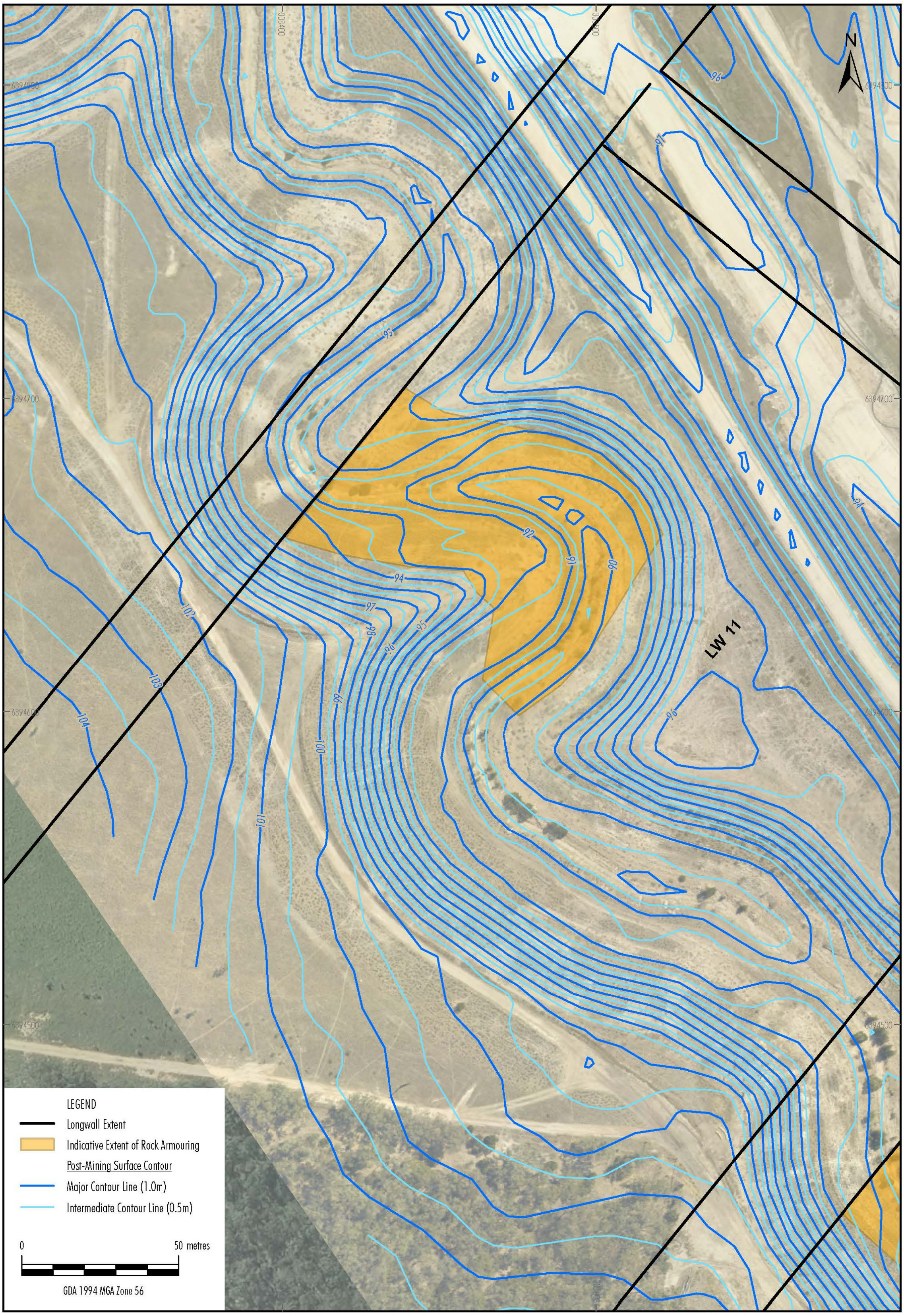

R:\WAM-09-15\External Data\James Barbato 4-8-15\0.5m Predicted Subsided Surface Levels (150623)_Chainage 1-2_LW.mxd

Figure 4.2: Indicative Extent of Rock Armouring – LW11

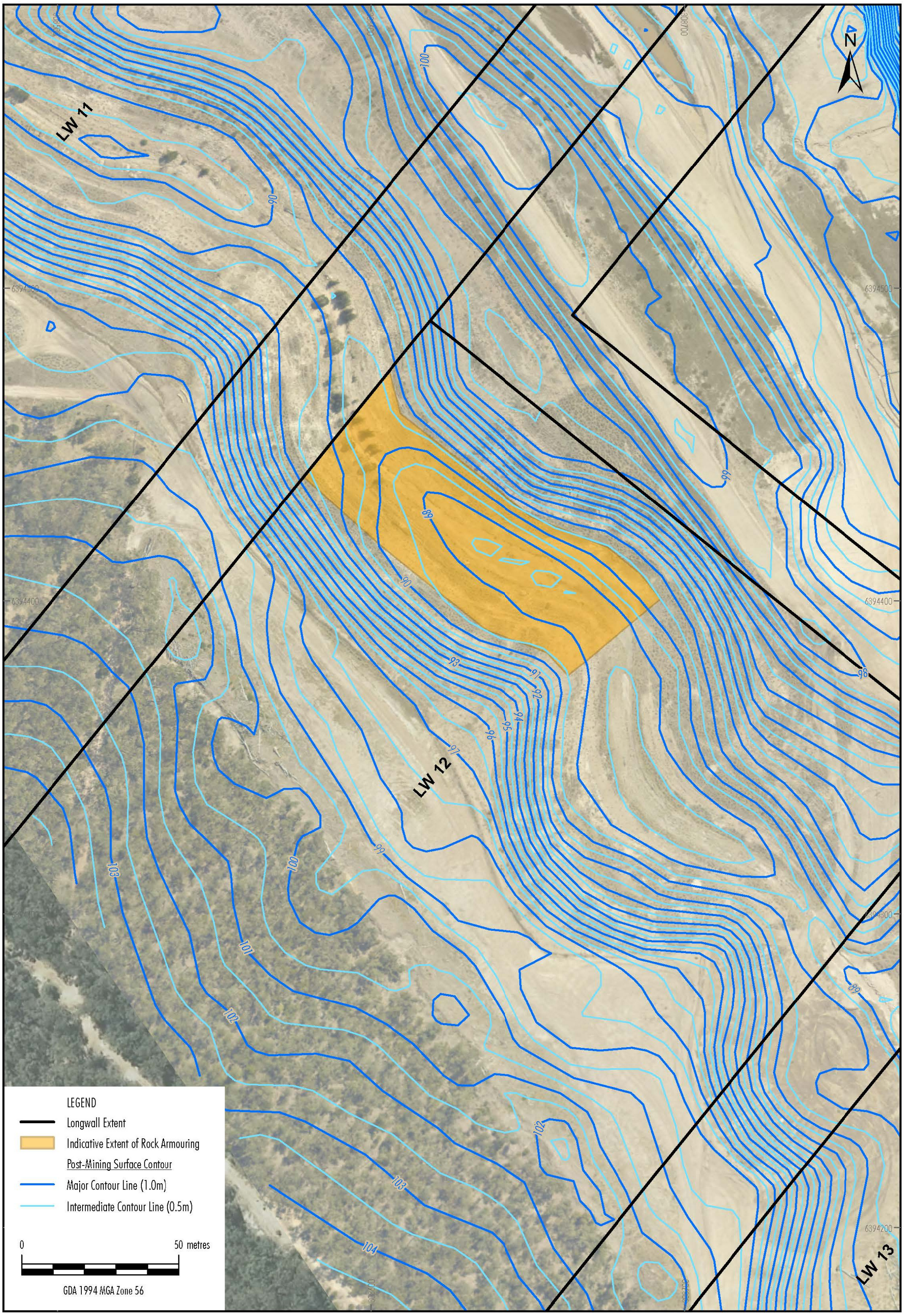

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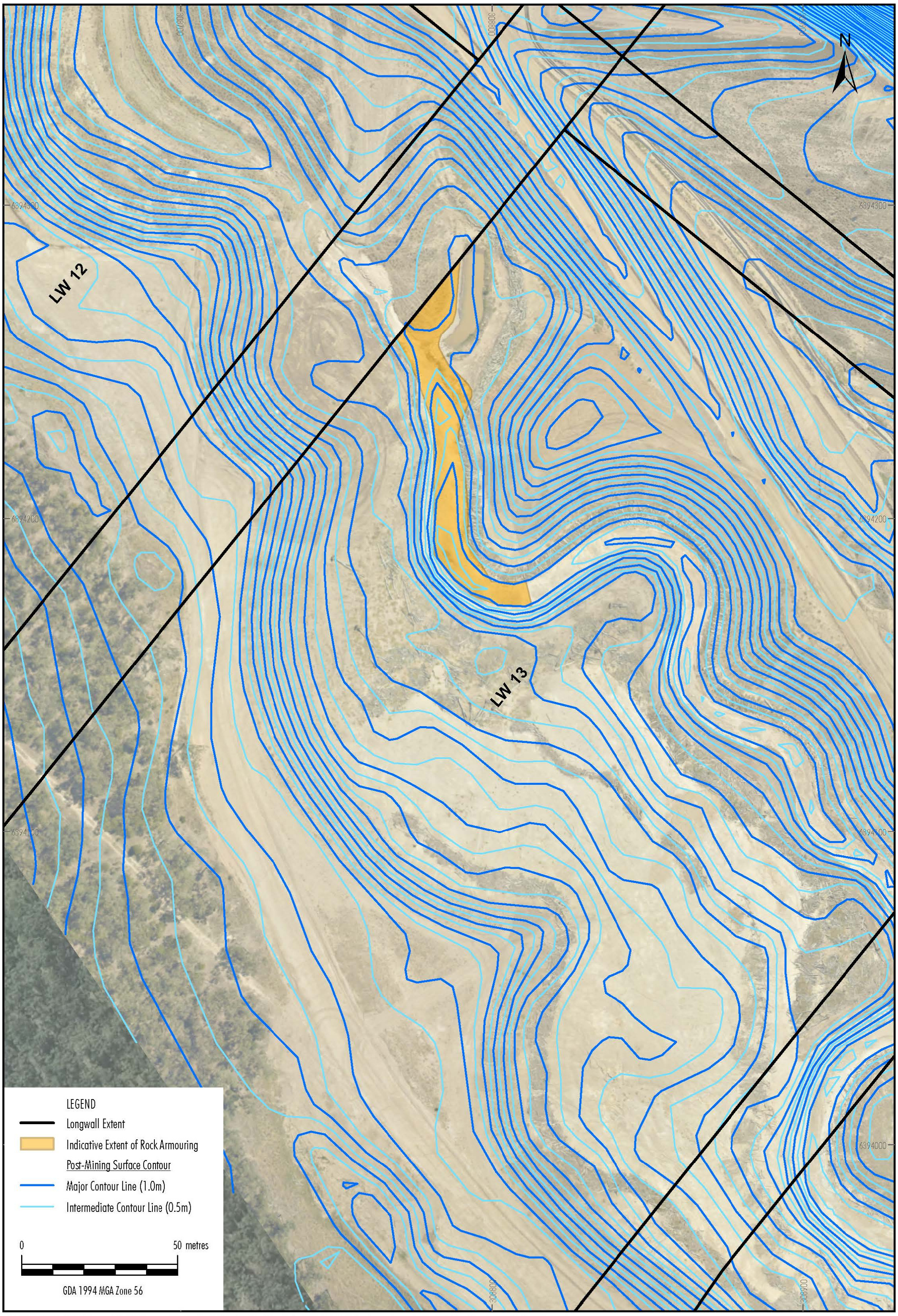
Figure 4.3: Indicative Extent of Rock Armouring – LW12



R:\WAM-09-15\External Data\James Barbato 4-8-15\0.5m Predicted Subsided Surface Levels (150623)_Chainage 5-6_LW.mxd

Figure 4.4: Indicative Extent of Rock Armouring – LW13

Batter Stabilisations and Vegetation Establishment

Some of the channel sections in Stage 2 of the Diversion that will be ponded exhibit erosion as a result of runoff from the batter slopes on each side of the inset floodplain. In areas where the pool water level is above the level of the low flow channel bank, ongoing erosion will be eliminated. However, in areas where the pool water level is below the top of the low flow channel bank, the bank may need to be graded back and revegetated.

Any vegetation establishment would be undertaken using the techniques used previously by Wambo Mine and described in the *Wambo and Stony Creek Management Plan* (Coffey, 1999). Temporary use of fast growing hydro seeding would be used to protect the ground whilst longer term species are established. Native vegetation species, such as *Allocasuarina leuhmannii* (Bull Oak), *Casuarina cunninghamiana* (River Oak), *Eucalyptus tereticornis* (River Red Gum) and *Eucalyptus crebra* (Narrow Leaved Iron Bark) would be used for long term protection. Rehabilitated areas would be fenced to prevent access by stock and marsupials. Vegetation would be monitored and managed in accordance with the *Flora and Fauna Management Plan* (WCPL, 2014).

4.2.2 Stony Creek and the Ephemeral Drainage Lines

No increase in gradient is predicted within Stony Creek.

An increase in gradient is predicted at two locations in Drainage Line 1. Post-subsidence inspection of Drainage Line 1 and the other ephemeral drainage lines immediately following a number of significant rain events (greater than 10 mm in 24 hours) would provide the basis for triggering any minor erosion control works following extraction.

4.3 Ponding

4.3.1 North Wambo Creek Diversion

As pools are a natural feature of the creeks in the area and Stage 2 of the Diversion already includes a number of pools (two upstream and one within of the Study Area), the pools that are predicted to form as a result of mining of the Whybrow Seam are proposed to be retained. The creation of additional pools as a result of longwall mining would further enhance the diversity of habitat along the Diversion.

The formation of the pools is expected to require prompt remedial works to minimise drainage of water from the pools into the underground workings. Recommendations for these works are set out on Section 4.4.1 below.

4.3.2 Stony Creek and the Ephemeral Drainage Lines

Ponding as a result of mining of LW11-13 is not expected on Stony Creek.

Very minor ponding is possible for Drainage Line 1 as result of mining in the Whybrow Seam and may occur on other minor drainage lines. This ponding is not expected to require any remedial action. However, if subsidence creates pools that are significantly larger than occur natrually, remedial actions could include:

- Assessment of the ecological significance of the pool and its impact on the aquatic and riparian habitat by an appropriately qualified ecologist.

- Consultation with regulatory agencies to determine whether action is warranted to reduce or eliminate the pool.
- Drainage works and rehabilitation of subsidence troughs as necessary, similar to those outlined in the *Land Management Plan for North Wambo Underground Mine Longwalls 8 to 10A* (WCPL, 2015).
- Channel excavation and stabilisation works to re-grade a downstream section of channel in order to eliminate or reduce the length of the pool.

4.4 Stream Bed Cracking

4.4.1 North Wambo Creek Diversion

As noted in Section 3.2.2 previous loss of flow as a result of cracking in Wambo Creek was mitigated by grouting the underlying rock up to 10 m deep (Coffey, 2000). In that instance, grouting was adopted because the underlying rock was located beneath about 5 m of alluvium and not all cracks in the rock were expected to be reflected at the surface. In the North Wambo Creek diversion, the bed of the creek is in exposed rock in parts of Stage 3 and the depth of soil is typically less than 1 m elsewhere.

Subsidence cracks are not expected to develop until the longwall face is directly under the creek and for the next 100 m of longwall retreat. The Diversion crosses the panel approximately perpendicular to the gateroads in its general alignment but meanders up to about 30 m either side, so there is about 160 m of retreat distance where new cracks could open within the immediate vicinity of the Diversion. For 160 m of longwall retreat, the window where cracking might occur on the creek bed would be about 2 weeks.

During this period, remediation works would be undertaken to reduce the hydraulic conductivity of any cracks that might open up. All significant cracks are expected to be visible and should be sealed using the following sequence of actions commencing as soon as cracks appear:

- Washing a slurry containing well graded sandy-silt into the cracks to fill cracks in the underlying rock. Water for this operation should be pumped from the mine workings;
- Infilling larger surface cracks with typical alluvial material.

In order to reduce the time that subsidence cracks are open, and the longwall panel is vulnerable to an inflow event, a program of filling the cracks with material to limit the hydraulic conductivity of the rock mass should be initiated as soon as cracking is observed and be ongoing during the period of mining. Priority should be given to remediating cracks near the downstream end of each longwall trough where ponding will occur.

Suitable materials and equipment should be stockpiled close to the potentially affected areas prior to undermining occurring so that remediation can be undertaken as soon as practicable in order to minimise the risk of flow in the creek occurring while cracks are open.

There may still be a vulnerability to a high flow event during the period of the treatment and options to divert water into the open-cut should be considered to avoid flooding the longwall panel.

In the event that inflow to the workings indicates that sealing is inadequate, the relevant pool would be drained by pumping to allow access for visual inspection and any required remedial action, including the option of grouting.

4.4.2 Stony Creek and Ephemeral Drainage Lines

At the completion of mining, it may be necessary to remediate some sections of Stony Creek and the ephemeral drainage lines where the depths of cover are the shallowest. This could include re-grading the beds and infilling any larger surface cracking. It is expected that there would be no long term adverse impacts on these streams after the completion of the necessary surface remediation.

5 Conclusions

5.1 North Wambo Creek Diversion

Subsidence resulting from mining of LW11 to 13 is predicted to have the greatest impact on North Wambo Creek Diversion where three pools are predicted to form. The pools above these longwalls are estimated to be up to 1.4 metres deep and 250 metres long. Pools are a natural feature of the creeks in the area and, therefore, the pools that are predicted to form as a result of mining of the Whybrow Seam are proposed to be retained to contribute to the local ecology of the area.

The sections of North Wambo Creek Diversion and adjoining floodplain near the upstream edge of each longwall pool are the areas most vulnerable to scour. To protect these areas localised rock armouring will be placed at the upstream edge of each of the pools and adjoining floodplain, in conjunction with placement of woody debris and vegetation establishment.

Cracking of the surface soil and underlying rock is predicted for the North Wambo Creek Diversion. This will be remediated by washing fine sediment into the underlying rock and filling surface soil cracks.

Following the remediation works, no significant change is expected in the water quality in North Wambo Creek.

5.2 Stony Creek and the Ephemeral Drainage Lines

Mining of LW11 to 13 is predicted to have minimal subsidence impact on Stony Creek and the ephemeral drainage lines. Any erosion impacts will be managed using techniques developed and used elsewhere at the Wambo Coal Mine. Any ponding or cracking will be managed using techniques developed and used elsewhere at the Wambo Coal Mine, including locally re-grading the beds to re-establish natural gradients and infilling the larger surface cracking. No significant change is expected in the water quality in Stony Creek and the ephemeral drainage lines as a result of the extraction of Longwalls 11 to 13.

6 References

Coffey (1999). *Wambo and Stoney Creek Management Plan.*

Coffey (2000). *Hydrological Response to Mining Panels 9 and 9A in South Wambo Creek, Warkworth NSW.*

Gilbert and Associates Pty Ltd (2003). *Wambo Development Project – Surface Water Assessment.*

Gilbert and Associates Pty Ltd (2007). *North Wambo Creek Diversion Design Report.*

Gilbert and Associates Pty Ltd (March 2013a). *Hydrological Significance of Storm Events Experienced in the North Wambo Creek Catchment January February 2013*

Gilbert and Associates Pty Ltd (March 2013b). *Remediation Plan – North Wambo Creek Diversion Stage 3*

Grayson et al. (1996). *Hydrological Recipes – Estimation Techniques in Australian Hydrology.* Cooperative Research Centre for Catchment Hydrology.

MSEC (2015). *South Bates (Whybrow Seam) Subsidence Assessment.*

NSW Office of Water (2012). *Controlled Activities on Waterfront Land – Guidelines for instream works on waterfront land*, NSW Department of Primary Industries.

WCPL (2003). *Wambo Development Project – Environmental Impact Statement*

WCPL (2014). *Flora and Fauna Management Plan.*

WCPL (2014). *Surface Water Monitoring Program*

WCPL (2015). *Land Management Plan (LMP) for North Wambo Underground Mine Longwalls 8 to 10A.*

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Annexure 1

North Wambo Creek Diversion – Flow Records

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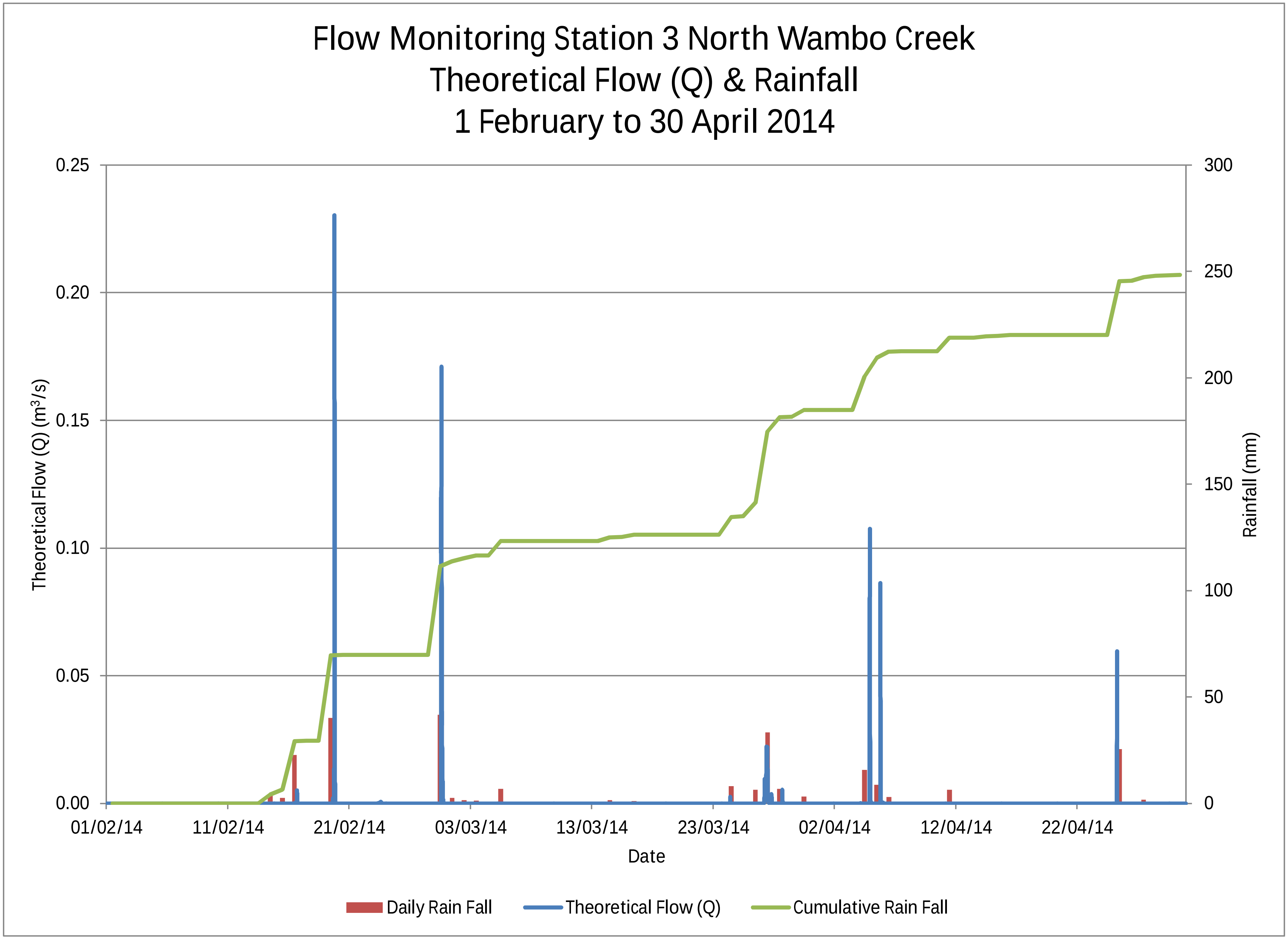
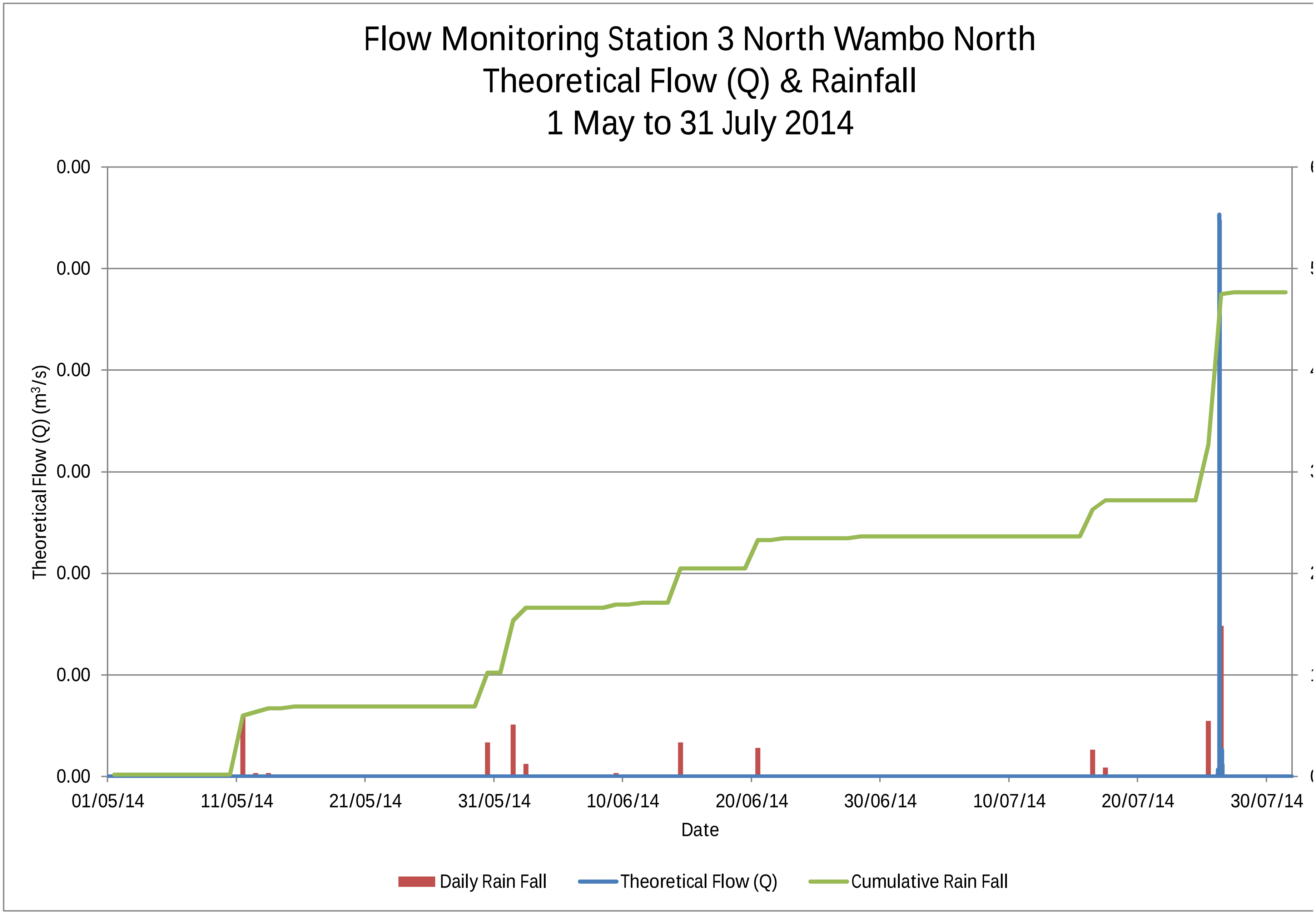
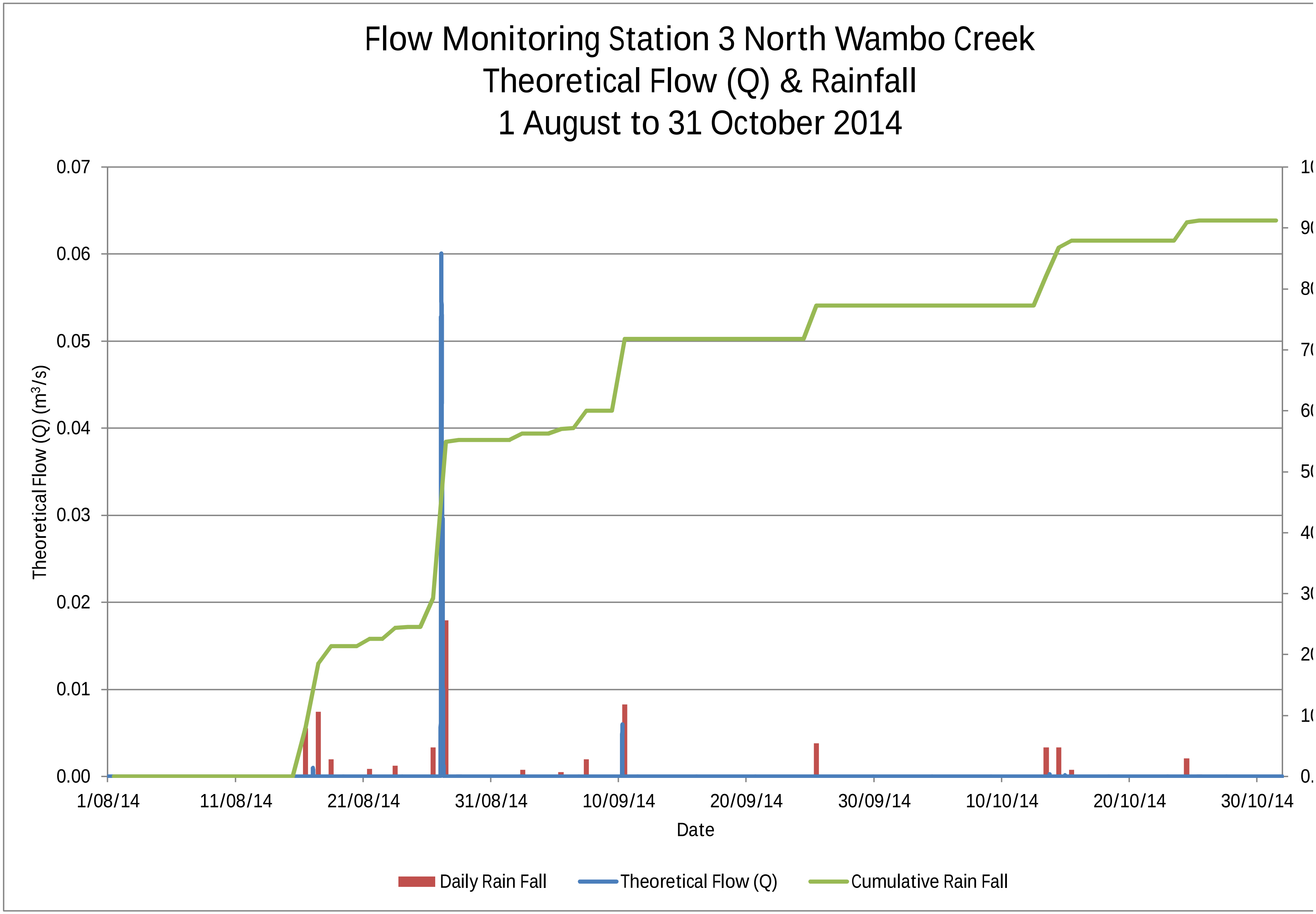
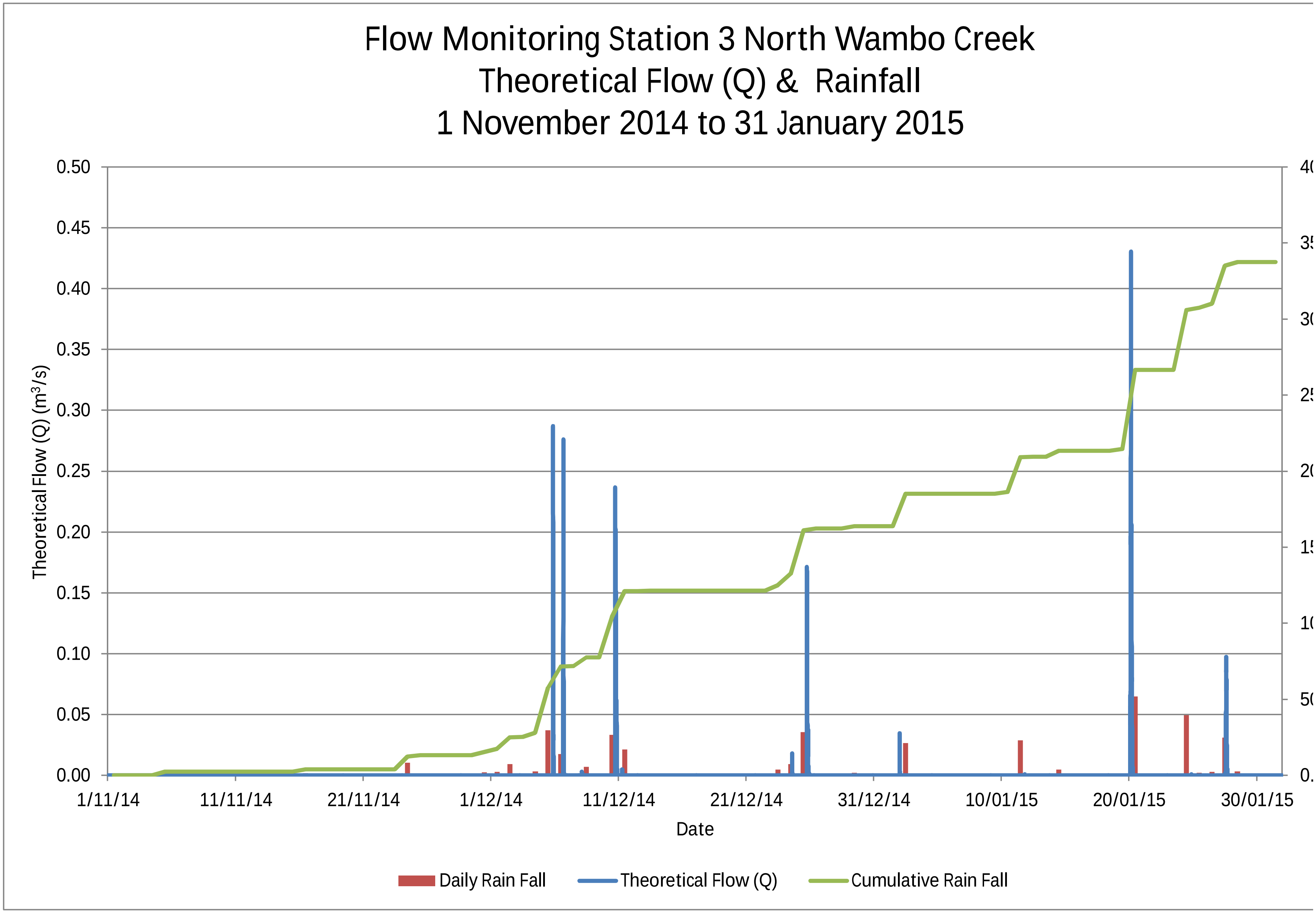

Flow Monitoring Station 3 North Wambo Creek
Theoretical Flow (Q) & Rainfall
1 February to 30 April 2014
Theoretical Flow (Q) (m³/s)
0.25
0.20
0.15
0.10
0.05
0.00
Rainfall (mm)
300
250
200
150
100
50
0
01/02/14
11/02/14
21/02/14
03/03/14
13/03/14
23/03/14
02/04/14
12/04/14
22/04/14
Date
Daily Rain Fall
Theoretical Flow (Q)
Cumulative Rain Fall



Flow Monitoring Station 3 North Wambo North
Theoretical Flow (Q) & Rainfall
1 May to 31 July 2014
0.00
Theoretical Flow (Q) (m3/s)
01/05/14
11/05/14
21/05/14
31/05/14
10/06/14
20/06/14
30/06/14
10/07/14
20/07/14
30/07/14
Date
Daily Rain Fall
Theoretical Flow (Q)
Cumulative Rain Fall


Flow Monitoring Station 3 North Wambo Creek
Theoretical Flow (Q) & Rainfall
1 August to 31 October 2014
Theoretical Flow (Q) (m³/s)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
1/08/14
11/08/14
21/08/14
31/08/14
10/09/14
20/09/14
30/09/14
10/10/14
20/10/14
30/10/14
Date
Daily Rain Fall
Theoretical Flow (Q)
Cumulative Rain Fall



Flow Monitoring Station 3 North Wambo Creek
Theoretical Flow (Q) & Rainfall
1 November 2014 to 31 January 2015
Theoretical Flow (Q) (m³/s)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1/11/14
11/11/14
21/11/14
1/12/14
11/12/14
21/12/14
31/12/14
10/01/15
20/01/15
30/01/15
Date
Daily Rain Fall
Theoretical Flow (Q)
Cumulative Rain Fall