7.0 Stage 3 Modification Mining Impacts and Management

During the consultation process and risk analysis undertaken for the project and outlined in **Section 6** and **Appendix 6**, potential subsidence impacts on landform, land use, ecology, historic and Aboriginal heritage values, houses and buildings, surface and groundwater, roads and service infrastructure were raised as potential risks associated with the proposed Stage 3 Modification. To address these issues, a range of detailed assessments investigating the potential impacts from subsidence have been undertaken. The results of these assessments and analysis of the potential environmental aspects, impacts, monitoring, and management measures from the proposed Stage 3 Modification underground mining operations are summarised in **Sections 7.1** to **7.7**.

7.1 Subsidence

7.1.1 Subsidence Prediction Methodology

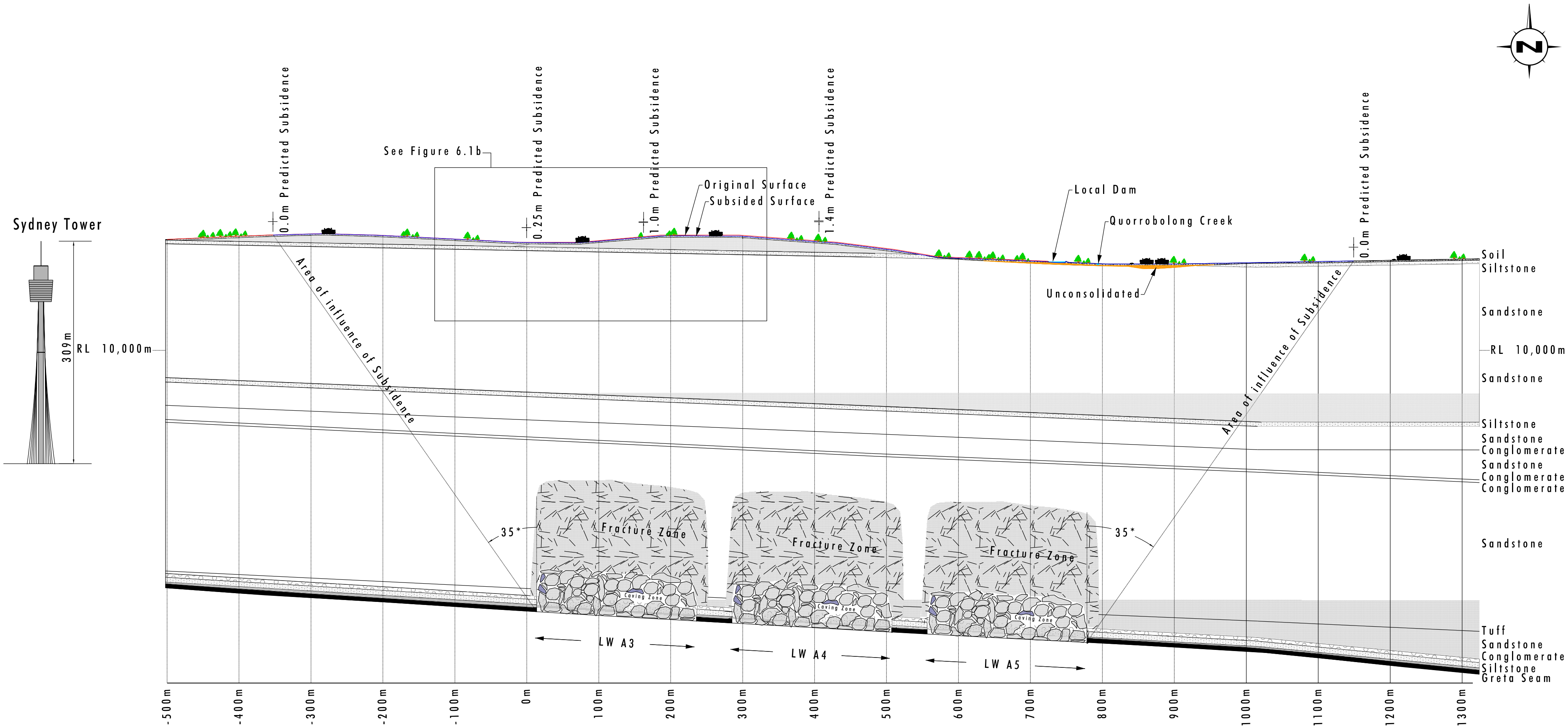
Underground longwall (LW) mining involves the removal of coal from a series of panels (extraction areas) within a coal seam. As the coal in each longwall panel is removed, the roof behind the mine workings is allowed to collapse causing the overlying rock to fracture and settle. The settlement potentially progresses up through the overlying strata and may result in movement of the ground surface. Ground movements are described by the following four parameters:

- **subsidence** refers to the vertical and horizontal displacement of the ground;
- **tilt** refers to the change in the slope of the ground as a result of differential subsidence;
- **curvature** refers to the rate of change of tilt – convex curvature is referred to as 'hogging curvature' and concave curvature is referred to as 'sagging curvature'; and
- **strain** refers to the change in horizontal distance between two points on the ground and is difficult to predict. Tensile strains occur when the distance between two points increases, common with hogging curvature, and compressive strains occur when the distance between two points decreases, common with sagging curvature.

A typical subsidence profile is illustrated in **Figure 7.1**.

Normal ground movements resulting from the extraction of longwalls are referred to as systematic subsidence movements. The movements may be reported as **incremental**, as the coal resource is extracted, **cumulative**, over a series of longwalls, or as a **total** value once mining is complete. Non-systematic subsidence movements include far-field horizontal movements; irregular subsidence movements and valley related movements. The impact of most non-systematic subsidence movements are not expected to be significant. Where impacts are expected to be noticeable they have been noted in relation to the relevant surface features in **Sections 7.1.7** to **7.1.18**.

Mine Subsidence Engineering Consultants Pty Limited (MSEC) was commissioned by Austar to prepare subsidence predictions based on the conceptual mine plan for the proposed Stage 3 Modification and undertake impact assessments in regard to natural and built features in the area of potential impact. The detailed subsidence impact assessment prepared by MSEC for this EA is provided in **Appendix 9**. The subsidence impact assessment area is bounded by the 20 mm subsidence contour for the proposed Stage 3



Anticipated Subsided Landform Stage 2 Area

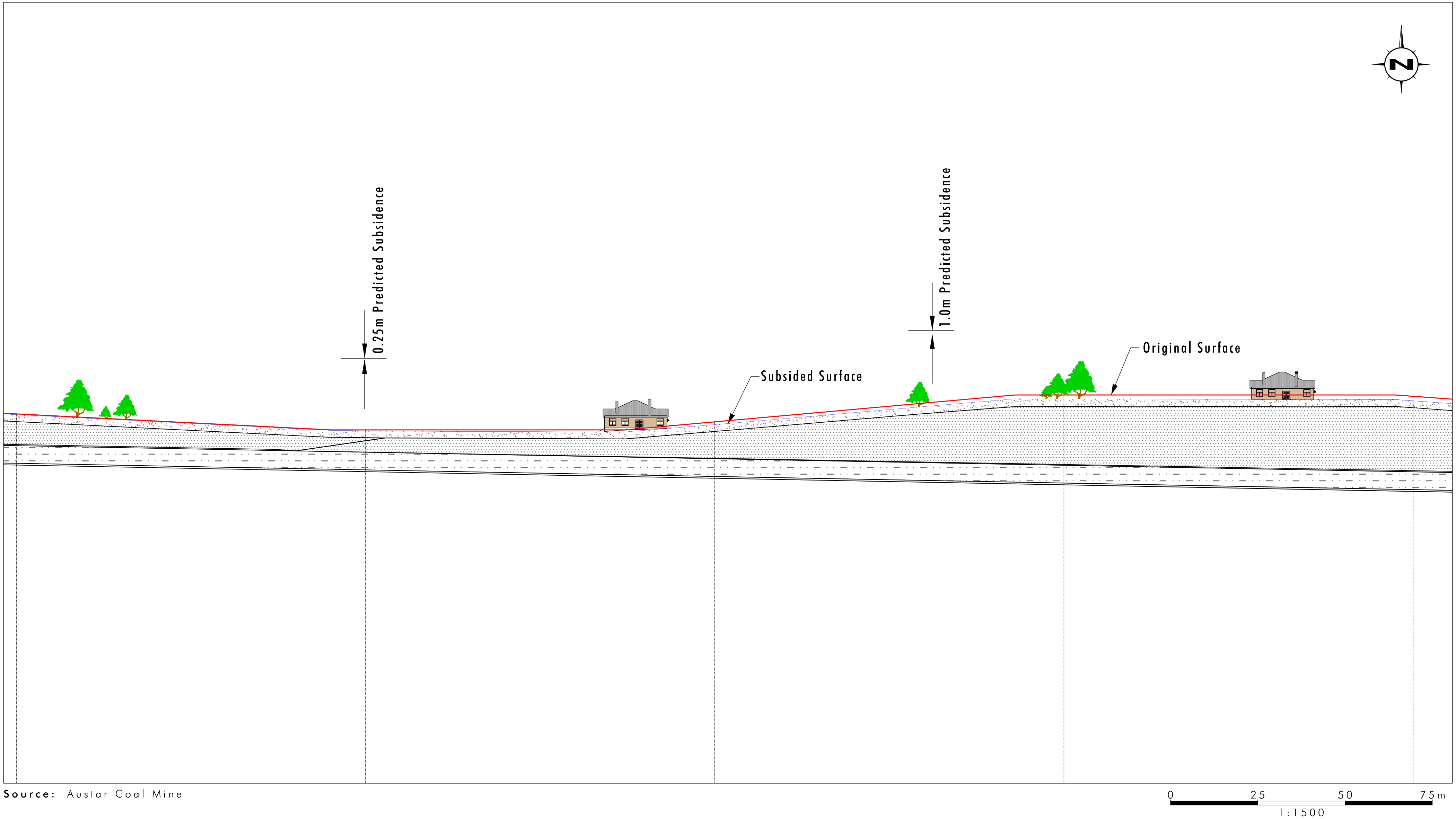
0 100 200 400m
1:8000

FIGURE 7.1a

Typical Cross Section - Stage 2

Source: Austar Coal Mine

File Name (A4): R64_V1/2274_988.dgn



Source: Austar Coal Mine

FIGURE 7.1b

Typical Cross Section - Stage 2
Inset

File Name (A4): R64_V1/2274_989.dgn

Modification longwall layout indicated in **Figure 1.4**. Integral to the subsidence impact assessment is the consideration of the application of Longwall Top Coal Caving (LTCC) technology and the presence of the massive Branxton Formation within the proposed Stage 3 Modification mining area.

An empirical approach to predicting systematic and non-systematic subsidence has generally been adopted in the coalfields of New South Wales and has been applied to the Project. This methodology has expanded in recent years by the development of the Incremental Profile Method ('the IPM'). The calibrated IPM has been used by MSEC to assess the subsidence parameters for the Project.

The IPM empirical methodology is based on a large database of observed monitoring data from previously extracted longwalls within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales. The IPM is based upon predicting the incremental subsidence profile for each longwall in a series of longwalls. The respective incremental profiles are then added to show the cumulative subsidence profile at any stage in the development of a series of longwalls. This method also allows for variations in tilt, curvature and strain to be determined across a series of longwalls.

7.1.2 Physical Context for Subsidence Impact Assessment

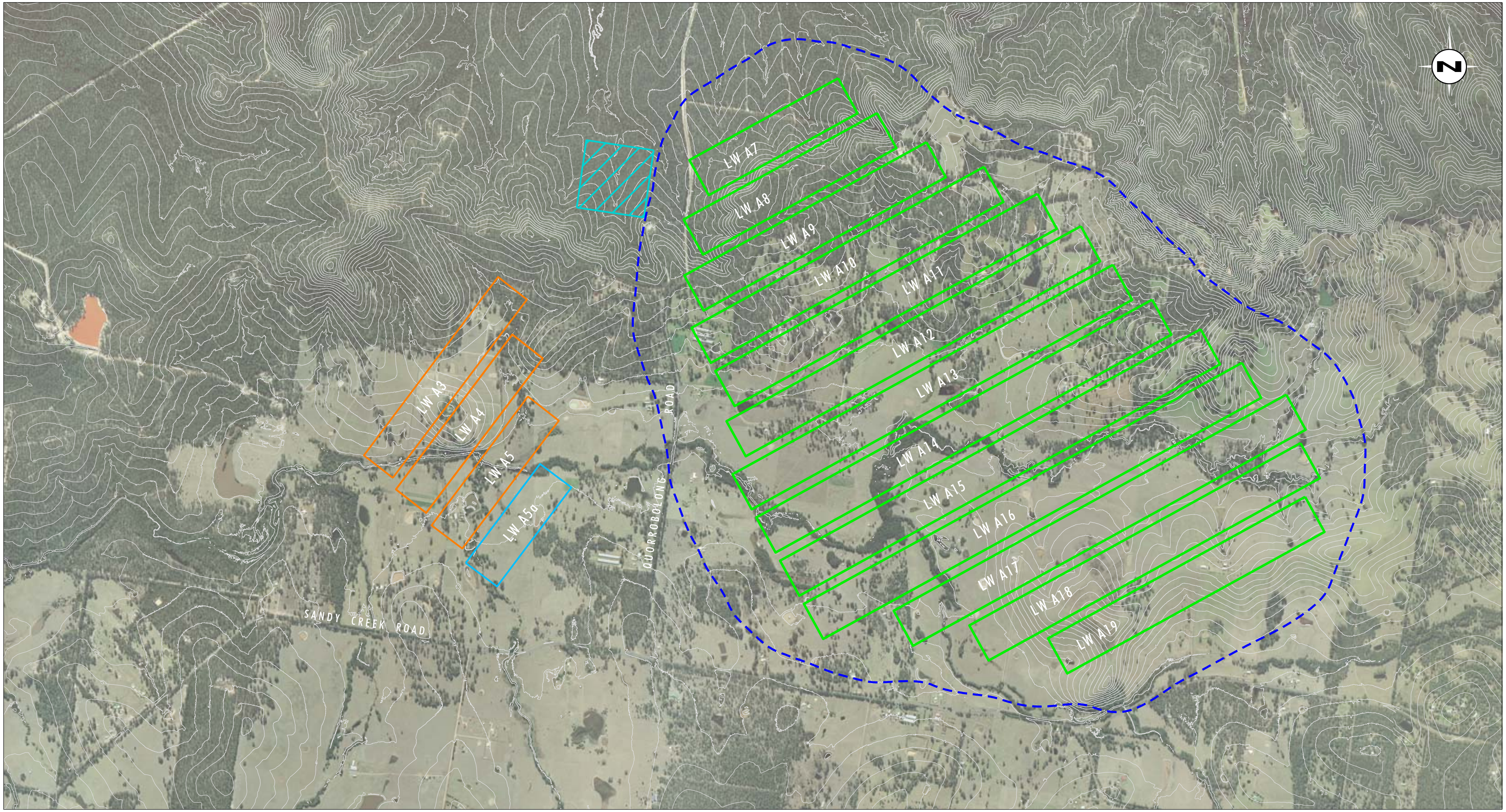
The substantial Branxton Formation which forms the geological strata above the Greta Coal Seam is very thick and acts as a beam over the mined areas. As a result the majority of subsidence results from the compression of the chain pillars and adjacent strata above and below them that are left between successive longwalls whilst the Branxton Formation effectively supports the landform above the longwalls, transferring the resultant load to the chain pillars. The beam action of the Branxton Formation has considerable bearing on subsidence potential and surface subsidence impacts. The landform above mined areas following subsidence tends to subside reasonably uniformly creating a broad shallow subsidence bowl that will extend from the north-west (LWA7) to the south-east (LWA19) of the proposed mining area.

The depth of cover to the Greta Coal Seam above the proposed Stage 3 Modification longwalls varies between a minimum of 445 metres at the north-western corner of proposed LWA7, to a maximum of 760 metres above the middle of proposed LWA19 (refer to **Figure 7.2**). The seam floor at the proposed longwalls generally dips from the north to the south.

Thickness of the Greta Coal Seam at the proposed longwalls varies between a minimum of 4.0 metres to a maximum of 8.0 metres (MSEC 2011:3). This includes a split from the eastern end of proposed LWA14, southward to the middle of LWA19. The coal seam is approximately 4 metres thick to the east of the split and approximately 6.5 to 7 metres thick, peaking at 8 metres near the north-western end of LWA11. The majority of the coal seam within the longwall mining area has a seam thickness of less than 7 metres **Figure 7.1** provides an indicative illustration of the cross sectional profile of Austar Coal Mine longwalls within the Stage 2 area.

A number of structures and natural features were identified in the vicinity of the proposed longwalls during the subsidence impact assessment. Creeks, drainage lines, steep slopes, roads, electrical services, telecommunication services, dams, water bores, archaeological sites, survey control marks and building structures were identified as occurring above or proximate to LWA7 to LWA19. The locations of these structures and features are detailed in **Appendix 9**.

Umwelt
Environmental Consultants



Source: Longwall Layout: Austar Coal Mine, Cadastre: LPI NSW, Aerial Photography: AAM Hatch 2006
Note: Contour Interval 5m

0 0.5 1 1.5km
1:32 000

Legend

- Proposed Stage 3 Modification Longwall Panels
- Layout for Stage 2 Longwall Panels
- Layout for Stage 2 Extension Longwall Panel
- 20mm Subsidence Contour for Proposed Stage 3 Modification
- Approved Surface Infrastructure Site

FIGURE 7.2

Maximum Predicted Subsidence Landform

File Name (A4): R64_V1/2274_990.dgn

7.1.3 Subsidence Predictions and Assessment

A subsidence profile may be projected once the maximum subsidence value, location of the inflection point, average goaf edge subsidence, and limit of subsidence have been determined. The limit of subsidence is determined from the depth of cover and the angle of draw.

The predicted maximum tilt, hogging curvature, and sagging curvature can be determined from the maximum subsidence and depth of cover. Profiles can be predicted in both the transverse and longitudinal directions, thus allowing the subsidence, tilts, systematic curvatures and systematic strains to be predicted at any point on the surface above a series of longwalls.

The predicted systematic subsidence parameters for the proposed underground mining of longwall panels LWA7 to LWA19 were made using a calibrated IPM. The model was calibrated using measured subsidence data from the Branxton Formation from previous mining at the Ellalong mine and Longwalls A1 to A3 from Stages 1 and 2 of the Austar Mine.

The extraction heights for proposed LWA7 to LWA19 range from 4 metres to 7.3 metres and are greater than many extraction heights of previously extracted longwalls in the empirical database of the IPM. The database includes observed subsidence profiles with extraction heights varying from less than 2 metres up to 5 metres. While the proposed extraction heights involved in the Stage 3 Modification vary from 4 metres up to 7.3 metres the height of the chain pillars would be 3.3 metres, giving a slenderness (height to width) ratio of 1 in 14, which is within the range of the empirical database. Furthermore, the extraction heights of LWA1 and LWA2 from Stage 1 of the Austar Mine were in the range of 6.5 metres, and MSEC (2011) reports that observed subsidence and tilt were typically less than or similar to the predicted subsidence and tilt (refer to **Appendix 9**). MSEC (2011) also report that observed tensile strain and compressive strain were typically less than or similar to the predicted levels of strain.

Subsidence impact assessment involves using the subsidence predictions to forecast the level of impact on natural and man-made surface features within the project area and beyond. A detailed review of natural features and surface infrastructure potentially impacted by the Stage 3 Modification project has been completed and both the detailed subsidence predictions and the impact assessment has been provided for these items (refer to **Appendix 9**).

Sections 7.1.4 to **7.1.17** provide a description of the potential physical impacts of subsidence on the land and surface features and the monitoring, management and contingency measures in place should impacts occur. Further details of the impact of subsidence on particular environmental aspects are provided in the following sections:

- vibration – **Section 7.2**;
- surface drainage systems – **Section 7.3**;
- groundwater resources – **Section 7.4**;
- Aboriginal heritage sites – **Section 7.5**;
- historic heritage sites – **Section 7.6**; and
- flora and fauna – **Section 7.7**.

7.1.4 Maximum Predicted Subsidence Parameters

Subsidence predictions have been presented as **Maximum Predicted Subsidence Parameters,** which are the parameters of the **maximum predicted systematic total subsidence** that is predicted to occur based on the calibrated IPM model MSEC developed for the site. The potential landform as a result of maximum predicted subsidence for the approved Stage 3 mine plan is shown on **Figure 7.3**. The potential landform as a result of maximum predicted subsidence for the proposed Stage 3 Modification mine plan is shown on **Figure 7.4**.

Within the EA for the Approved Stage 3 mining operations predicted systematic subsidence parameters were presented as **Upper Bound Subsidence**. This method of presentation was for formal risk assessment purposes and is based on a maximum total subsidence of 65% seam thickness. Upper Bound Subsistence predictions were assessed by MSEC (2011) to be approximately 1.6 times greater than the Maximum Predicted Subsidence indicated by the calibrated IPM model.

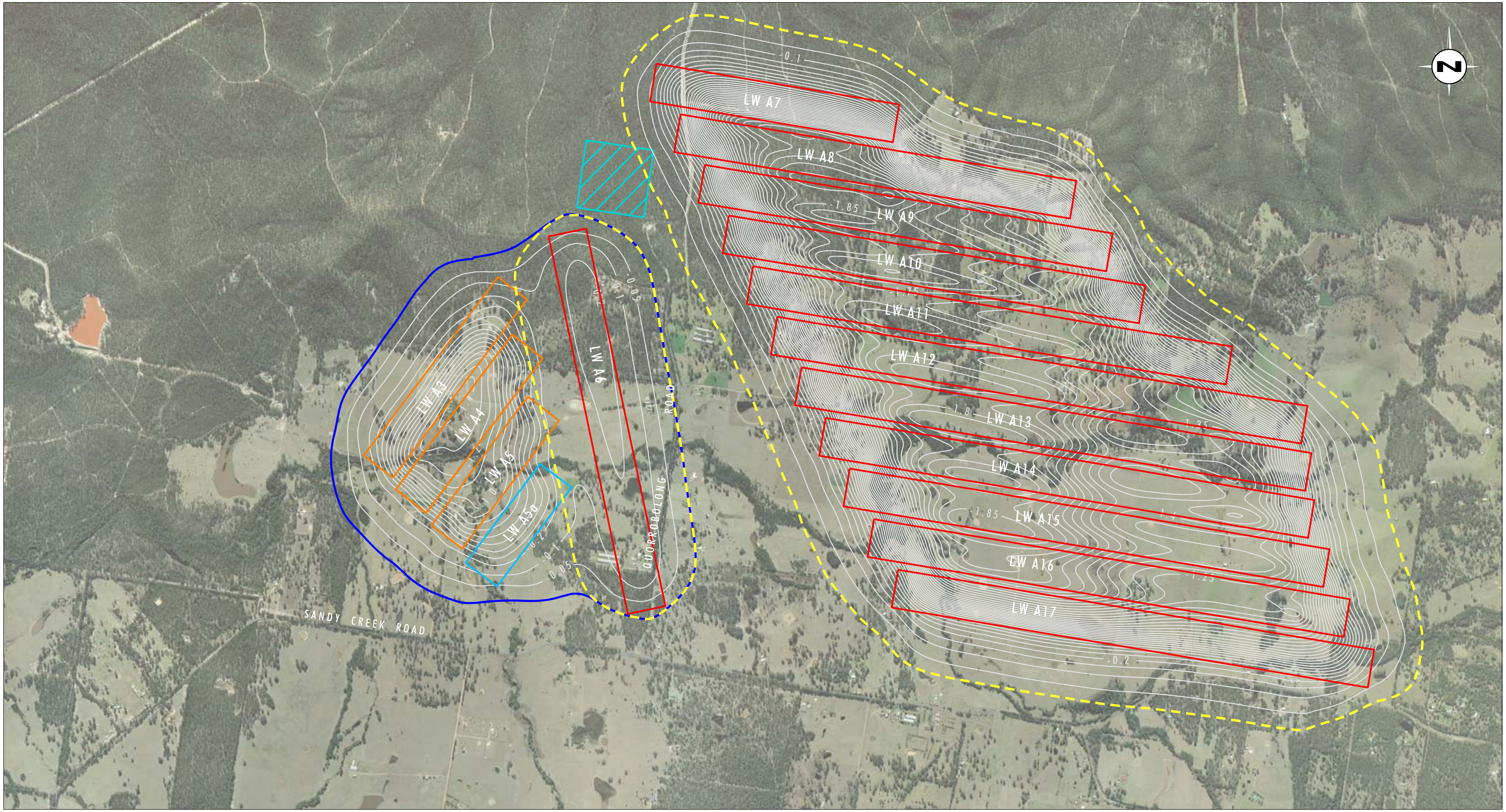
The observed maximum subsidence in the Newcastle Coalfield is typically 55 % to 60% of seam thickness. Furthermore the Branxton Formation is expected to be capable of spanning the extracted goafs proposed with the Stage 3 Modification with minimal sag subsidence. Based on a pillar height of 3.3 metres, the maximum subsidence due to pillar compression alone would be in the order of 45% of the maximum extracted seam thickness.

As previously observed subsidence is typically similar to or less than maximum predicted subsidence levels, Upper Bound Subsidence levels were not presented in relation to the Stage 3 Modification project. Subsidence levels based on Increased Predictions – similar to Upper Bound Subsidence levels – were generated by MSEC (2011) can be found in **Appendix 9**.

The maximum predicted subsidence parameters for the Stage 3 Modification are presented in **Table 7.1**.

Table 7.1 – Stage 3 Modification Maximum Predicted Subsidence Parameters

Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (km^{-1})	Maximum Predicted Sagging Curvature (km^{-1})
After LWA7	425	2.5	0.02	0.03
After LWA8	1200	4.5	0.04	0.09
After LWA9	1450	5.0	0.04	0.09
After LWA10	1525	5.5	0.04	0.09
After LWA11	1600	5.5	0.04	0.09
After LWA12	1650	6.0	0.04	0.09
After LWA13	1675	6.0	0.04	0.09
After LWA14	1675	6.0	0.04	0.09
After LWA15	1675	6.0	0.05	0.09
After LWA16	1675	6.5	0.05	0.09
After LWA17	1725	6.5	0.05	0.09
After LWA18	1775	6.5	0.05	0.09
After LWA19	1800	6.5	0.05	0.09



Source: Longwall Layout: Austar Coal Mine, Cadastre: LPI NSW, Aerial Photography: AAM Hatch 2006
Note: Contour Interval 0.1m

0 0.5 1 1.5km
1:32 000

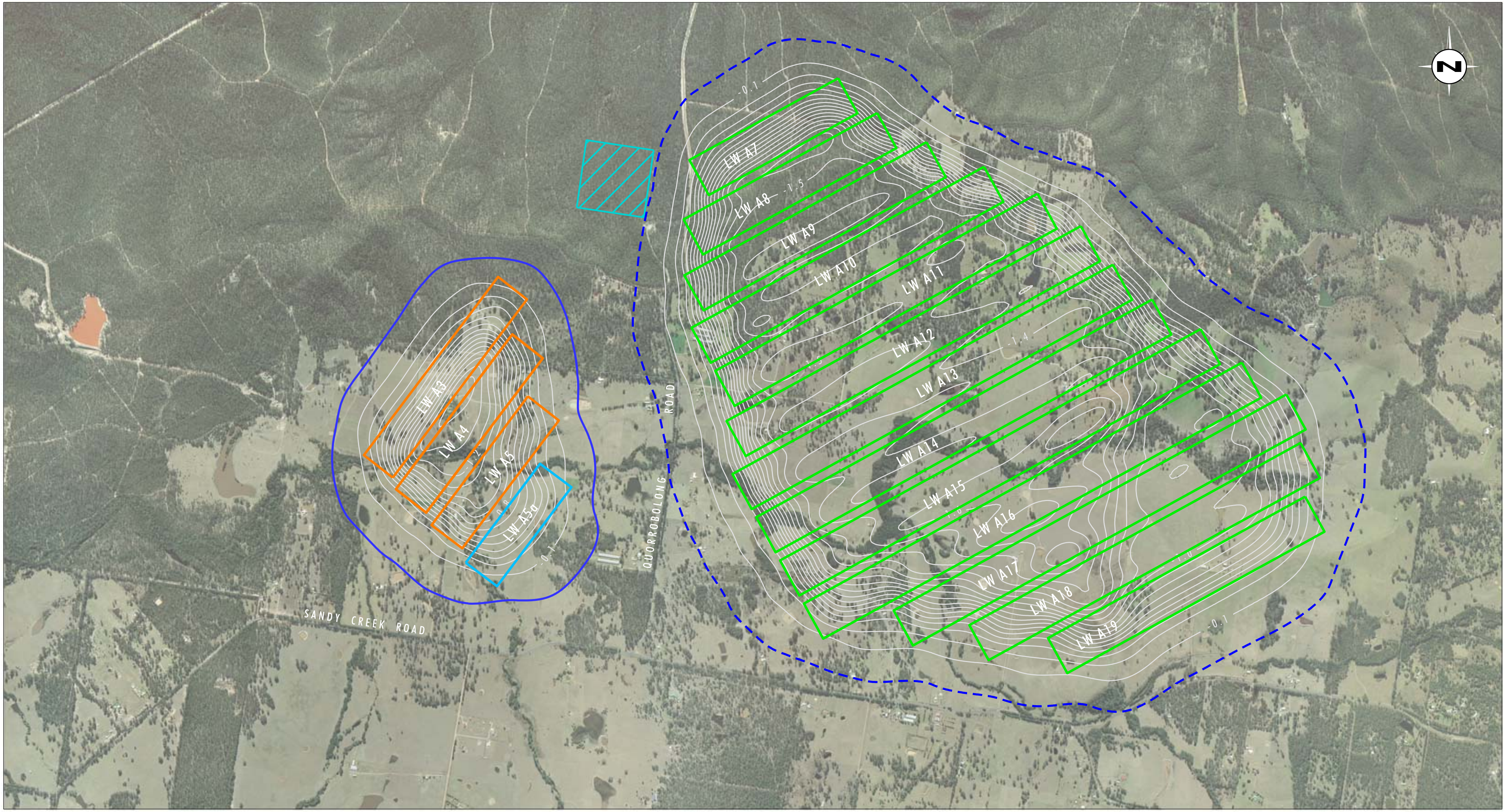
Legend

- Conceptual Layout for Stage 3 Longwall Panels as Approved
- Layout for Stage 2 Longwall Panels
- Layout for Stage 2 Extension Longwall Panel
- 20mm Subsidence Contour for Conceptual Panels as Approved
- 20mm Subsidence Contour for Stage 2 and LWA5a
- Approved Surface Infrastructure Site

FIGURE 7.3

Predicted Subsidence Stage 2 and 3 as Approved

File Name (A4): R64_V1/2274_991.dgn



Source: Longwall Layout: Austar Coal Mine, Cadastre: LPI NSW, Aerial Photography: AAM Hatch 2006
Note: Contour Interval 0.1m

Legend

- Proposed Stage 3 Modification Longwall Panels
- Layout for Stage 2 Longwall Panels
- Layout for Stage 2 Extension Longwall Panel
- 20mm Subsidence Contour for Proposed Stage 3 Modification
- 20mm Subsidence Contour for Stage 2 and LWA5a
- Approved Surface Infrastructure Site

FIGURE 7.4

Predicted Subsidence Stage 2 and Proposed Stage 3 Modification

File Name (A4): R64_V1/2274_992.dgn

As can be seen from **Table 7.1** for the proposed Stage 3 Modification mining area:

- **Maximum Predicted Subsidence** ranges from approximately 425 mm for LWA7 to approximately 1800 mm for LWA19.
- **Maximum Predicted Tilt** ranges from approximately 2.5 mm/m for LWA7 (i.e. 0.3%) to approximately 6.5 mm/m for LWA19 (i.e. 0.7%). This represents a maximum change in grade of 1 in 155.
- **Maximum Predicted Hogging Curvature** ranges from approximately 0.02 km^{-1} for LWA7 to approximately 0.05 km^{-1} for LWA19.
- **Maximum Predicted Sagging Curvature** ranges from approximately 0.03 km^{-1} for LWA7 to approximately 0.09 km^{-1} for LWA19.

The predicted landform as a result of maximum predicted subsidence following the extraction of the proposed Stage 3 Modification longwalls is provided in **Figure 7.3**.

A comparison between the maximum predicted subsidence, tilt, hogging curvature and sagging curvature for the Approved Stage 3 project and the proposed Stage 3 Modification project is summarised in **Table 7.2**

Table 7.2 – Comparison of the Maximum Predicted Subsidence Parameters between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project

Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (km^{-1})	Maximum Predicted Sagging Curvature (km^{-1})
Approved Stage 3 Project	1925	6.7	0.06	0.12
Proposed Stage 3 Modification Project	1800	6.5	0.05	0.09

As can be seen from **Table 7.2**, the maximum predicted subsidence parameters for the Stage 3 Modification project are similar to or slightly less than the maximum predicted subsidence parameters for the Approved Stage 3 project.

7.1.5 Likely Height of the Fractured Zone above the Proposed Longwalls

The height of the *collapsed zone*, which forms immediately above extracted longwalls, is generally between 21 to 33 times the thickness of the extracted seam. The height of the collapsed zone for the proposed longwalls varies between 65 and 155 metres depending on seam height.

The upper limit of the *fractured zone* will be reached when the strata above the collapsed zone are sufficiently strong to span the goaf area without significant bending or shear strains being developed. MSEC (2011) estimates that the upper limit of the fractured zone will be between 245 metres and 285 metres. The depth of cover above the proposed longwalls ranges from approximately 455 metres to 760 metres. It is unlikely, therefore, that the fractured zone would extend up to the surface.

7.1.6 Projected Impacts on Houses

As shown on **Figure 5.6** there are 26 houses located within the subsidence impact assessment area. Twenty two of these houses are single-storey houses with lengths less than 30 metres (Structure Type H1), and six are single-storey houses with lengths greater than 30 metres (Structure Type H2) (MSEC, 2011). No other significant residential features were identified within the subsidence assessment area.

Predictions of systematic subsidence, tilt, and curvature were made at the centroid and at the vertices of each house, as well as eight equally spaced points placed radially around the centroid and vertices at a distance of 20 metres. In the case of a rectangular shaped structure, predictions were made at a minimum of 45 points within and around the structure.

A comparison of the maximum subsidence parameters for houses between the Approved Stage 3 Project and the proposed Stage 3 Modification project is presented in **Table 7.3**.

Table 7.3 – Comparison of the Maximum Predicted Subsidence Parameters for Houses between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Houses	Approved Stage 3 Project	1875	5.5	0.06	0.08
	Proposed Stage 3 Modification Project	1675	5.5	0.04	0.08

As can be seen from **Table 7.3**, the maximum predicted subsidence parameters for the Stage 3 Modification project are similar to or slightly less than the maximum predicted subsidence parameters for the Approved Stage 3 project. As set out in **Appendix 9**, maximum predicted subsidence parameters for individual houses presented for the proposed Stage 3 Modification project are slightly greater, similar, or slightly less than the maximum predicted subsidence parameters presented for the Approved Stage 3 project.

The maximum predicted tilt for houses resulting from the extraction of the proposed longwalls is 5.5 mm/m (i.e. 0.6%) which represents a change in grade of 1 in 180. Tilts of less than 7 mm/m generally do not result in significant impacts of houses.

Eighty-seven per cent of houses are assessed to experience nil or negligible impacts. Seven per cent of the houses located directly above or immediately adjacent to the proposed longwalls are assessed to experience a very minor or minor impact. Only 4% of houses are assessed to experience moderate to extensive impact. All houses have a probability of less than 0.5% of experiencing an impact that would be considered severe.

No houses are assessed to experience hogging curvatures greater than 0.04 km^{-1} and experience sagging curvatures greater than 0.05 km^{-1}, which represent minimum radii of curvature of 25 kilometres and 20 kilometres, respectively.

All houses within the proposed Stage 3 Modification Impact Area are expected to remain safe, serviceable and repairable throughout the mining period, provided that they are in sound structural condition prior to mining.

Any remediation required would be carried out in accordance with **Section 7.1.16**.

7.1.7 Projected Impacts on Swimming Pools

There are eight privately-owned swimming pools (Structure Type P) which have been identified within the subsidence impact assessment area (see **Appendix 9**). Predictions of systematic subsidence, tilt and curvature have been made at the centroid and at the corners of each pool, as well as eight equally spaced points placed radially around the centroid and corners at a distance of 20 metres. A comparison of the maximum predicted subsidence parameters for pools between the Approved Stage 3 project and the proposed Stage 3 Modification project is presented in **Table 7.4**.

Table 7.4 – Comparison of the Maximum Predicted Subsidence Parameters for Swimming Pools between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Pools	Approved Stage 3 Project	1825	4.5	0.05	0.06
	Proposed Stage 3 Modification Project	1500	3.0	0.04	0.04

As can be seen from **Table 7.4**, the maximum predicted subsidence parameters for the Stage 3 Modification project are similar to or slightly less than the maximum predicted subsidence parameters for the Approved Stage 3 project. As set out in **Appendix 9**, maximum predicted subsidence parameters for individual pools presented for the proposed Stage 3 Modification project are slightly greater, similar, or slightly less than the maximum predicted subsidence parameters presented for the Approved Stage 3 Project.

The maximum predicted tilt at all pools is 3.0 mm/m (0.3%) or less, with minimal predicted impacts. This level of tilt is similar to or less than the Australian Standard guidelines for swimming pools.

Any remediation required would be carried out in accordance with **Section 7.1.16**.

7.1.8 Projected Impacts on Roads

Sandy Creek Road, Quorrobolong Road, Coney Creek Lane and Big Hill Road are each located across the subsidence impact assessment area. A comparison of the maximum predicted subsidence parameters for roads between the Approved Stage 3 project and the proposed Stage 3 Modification project is presented in **Table 7.5**.

Table 7.5 – Comparison of the Maximum Predicted Subsidence Parameters for Roads between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Sandy Creek Road	Approved Stage 3 Project	140	<0.5	<0.01	<0.01
	Proposed Stage 3 Modification Project	30	<0.5	<0.01	<0.01
Quorrobolong Road	Approved Stage 3 Project	550	2.1	0.03	0.03
	Proposed Stage 3 Modification Project	325	2.0	0.01	<0.01
Coney Creek Lane	Approved Stage 3 Project	1800	5.3	0.03	0.03
	Proposed Stage 3 Modification Project	1550	5.0	0.02	0.03
Big Hill Road	Approved Stage 3 Project	1850	5.5	0.05	0.11
	Proposed Stage 3 Modification Project	850	5.0	0.02	0.05

As can be seen from **Table 7.5**, the maximum predicted subsidence parameters for the Stage 3 Modification are similar to or less than the maximum predicted subsidence parameters for the Approved Stage 3 project.

The maximum predicted tilt at the roads, at any time during or after the extraction of the proposed longwalls, is 5 mm/m (i.e. 0.5%) which represents a change in grade of 1 in 200. The maximum predicted tilt is less than 1% and is unlikely, therefore, to result in any significant impacts on the road's serviceability or the drainage of water at the roads.

The maximum predicted hogging and sagging curvatures for the roads, at any time during or after the extraction of the proposed longwalls, are 0.02 km^{-1} and 0.05 km^{-1}, respectively, which equate to minimum radii of curvatures of 50 kilometres and 20 kilometres, respectively.

Quorrobolong Road has a bitumen seal within the assessment area and Coney Creek Lane and Big Hill Roads are unsealed roads. It would be expected that any surface cracking that may occur at these roads as a result of the extraction of the proposed longwalls would be of a minor nature due to the relatively small magnitudes of predicted strains and due to the relatively high depths of cover (see **Appendix 9**). Experience to date along the unsealed Nash Lane has been that no remediation due to mining impact has been required.

Any remediation required would be carried out in accordance with **Section 7.1.16**.

7.1.9 Projected Impacts on Local Bridges

The bridges on Sandy Creek Road over Sandy Creek and Quorrobolong Creek Road over Cony Creek are both located within the subsidence impact assessment area, but not directly above the proposed Stage 3 Modification longwalls. A comparison of the maximum predicted subsidence parameters for bridges between the Approved Stage 3 project and the Proposed Stage 3 Modification project is presented in **Table 7.6**.

Table 7.6 – Comparison of the Maximum Predicted Subsidence Parameters for Bridges between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Quorrobolong Road over Coney Creek	Approved Stage 3 Project	35	<0.5	<0.01	<0.01
	Proposed Stage 3 Modification Project	40	<0.5	<0.01	<0.01
Sandy Creek Road over Sandy Creek	Approved Stage 3 Project	<20	<0.5	<0.01	<0.01
	Proposed Stage 3 Modification Project	<20	<0.5	<0.01	<0.01

As can be seen from **Table 7.6**, the maximum predicted subsidence parameters for the proposed Stage 3 Modification project are of a similar order of magnitude to the maximum predicted subsidence parameters for the Approved Stage 3 project.

The maximum predicted tilt at the bridges, at any time during or after the extraction of the proposed longwalls, is less than 0.5 mm/m (i.e. less than 0.1%) which represents a change in grade of less than 1 in 2000. Any significant impacts on the serviceability of the bridges are unlikely (see **Appendix 9**). The predicted hogging and sagging curvatures at the bridges are less than 0.01 km^{-1}, which equates to a minimum radius of curvature of more than 100 kilometres. The proposed Stage 3 Modification is not likely to result in any significant impacts on the structural integrity of the bridges (see **Appendix 9**).

Any remediation required would be carried out in accordance with **Section 7.1.16**.

7.1.10 Projected Impacts on Local Drainage Culverts

Historical drainage culverts located across the mining area are expected to experience the full range of predicted subsidence movements. A comparison of the maximum subsidence parameters for drainage culverts between the Approved Stage 3 project and the Proposed Stage 3 Modification project is presented in **Table 7.7**.

Table 7.7 – Comparison of the Maximum Subsidence Parameters for Drainage Culverts between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Drainage Culverts	Approved Stage 3 Project	1925	6.7	0.06	0.12
	Proposed Stage 3 Modification Project	1800	6.5	0.05	0.09

As can be seen from **Table 7.7**, the predicted maximum subsidence parameters for the Stage 3 Modification project are similar to or slightly less than the predictions for the Approved Stage 3 project. As set out in **Appendix 9**, predictions for individual drainage culverts in relation to the proposed Stage 3 Modification are slightly greater, similar, or slightly less than the predictions for the same drainage culverts in relation to the Approved Stage 3 project.

The maximum predicted tilt at the drainage culverts, at any time during or after the extraction of the proposed longwalls, is 6.5 mm/m (i.e. 0.7%), or a change in grade of 1 in 150, and is unlikely to result in any significant impacts on the serviceability of the drainage culverts (see **Appendix 9**). The maximum predicted hogging and sagging curvatures at the bridges are less than 0.05 km^{-1} and less than 0.09 km^{-1} respectively, which equates to a minimum radii of curvature of 20 kilometres and 11 kilometres respectively. It is expected that drainage culverts will experience curvatures less than these maxima and consequently experience minimal impacts due to variations in the predicted curvatures and the orientation of the culverts relative to the subsidence trough (see **Appendix 9**).

Any remediation required would be carried out in accordance with **Section 7.1.16.**

7.1.11 Projected Impacts on Local Electrical Infrastructure

There are powerlines located across the mining area and they are expected to experience predicted subsidence movements. A comparison of the maximum subsidence parameters for electrical infrastructure between the Approved Stage 3 project and the Proposed Stage 3 Modification project is presented in **Table 7.8.**

Table 7.8 – Comparison of the Maximum Subsidence Parameters for Electrical Infrastructure between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)
Electrical Infrastructure	Approved Stage 3 Project	1925	6.7
	Proposed Stage 3 Modification Project	1800	6.5

As can be seen from **Table 7.8**, the predicted maximum subsidence parameters for the proposed Stage 3 Modification project are similar to or slightly less than the predictions for the Approved Stage 3 project.

The maximum predicted tilt experienced by power poles at any time during or after the extraction of the proposed longwalls, is 6.5 mm/m (i.e. 0.7%), or a change in grade of 1 in 150. This is unlikely to result in any significant impacts on the power poles (see **Appendix 9**). The incidence of impacts on the powerlines resulting from the extraction of the proposed longwalls is expected to be low and it is anticipated that any impacts would be relatively minor and easily repaired.

Any remediation required would be carried out in accordance with **Section 7.1.16.**

7.1.12 Projected Impacts on Local Optical Fibre Cable

The optical fibre cable within the subsidence impact assessment area (see **Appendix 9**) is directly buried and consequently will not be affected by the tilts or curvatures resulting from the extraction of the proposed longwalls. A comparison of the maximum subsidence parameters for the optical fibre cable between the Approved Stage 3 project and the Proposed Stage 3 Modification project is presented in **Table 7.9.**

Table 7.9 – Comparison of the Maximum Subsidence Parameters for Local Optical Fibre Cable between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Optical Fibre Cable	Approved Stage 3 Project	1900	5.5	0.04	0.09
	Proposed Stage 3 Modification Project	1575	4.0	0.03	0.04

As can be seen from **Table 7.9**, the predicted maximum subsidence parameters for the proposed Stage 3 Modification are similar to or slightly less than the predictions for the Approved Stage 3 Project.

The cable is likely to experience slight ground strains resulting from the extraction of the proposed longwalls. However the level of strain is expected to be minimal and should the cable be impacted by strains that exceed expectations then any necessary remediation would be minor and able to be achieved with minimal disruption of services.

Any remediation required would be carried out in accordance with **Section 7.1.16.**

7.1.13 Projected Impacts on Local Copper Cables

The aerial cables within the subsidence impact assessment area follow the alignment of Sandy Creek Road (see **Appendix 9**). A comparison of the maximum subsidence parameters for the copper cable between the approved Stage 3 project and the proposed Stage 3 Modification project is presented in **Table 7.10**.

Table 7.10 – Comparison of the Maximum Subsidence Parameters for Local Copper Cables between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project (Source: MSEC, 2011)

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Local Copper Cable	Approved Stage 3 Project	1900	5.0	0.04	0.07
	Proposed Stage 3 Modification Project	1575	5.0	0.02	0.03

As can be seen from **Table 7.10**, the predicted maximum subsidence parameters for the proposed Stage 3 Modification project are similar to or slightly less than the predictions for the approved Stage 3 project.

Buried copper cables are predicted to be under similar impacts to buried optical fibre cables, as discussed in **Section 7.1.12**. Aerial copper telecommunication cables are not affected by ground strains, as they are supported by the poles above ground level. The cables can, however, be affected by the tilting of the poles, which affects the catenary profiles of the cables. Any minor impacts are expected to be relatively infrequent and easily repaired.

In relation to the Quorrobolong Telephone Exchange, MSEC (2011) writes:

> The Quorrobolong Telephone Exchange is located 285 metres south of the finishing (south-eastern) end of Longwall A18, at its closest point to the proposed longwalls. At this distance, the exchange is predicted to experience approximately 20 mm of subsidence. While it is possible that the exchange could experience subsidence slightly greater than 20 mm, as the result of far-field vertical movements, it would not be expected to experience any significant tilts and curvatures.
>
> It is unlikely, therefore, that the exchange would experience any significant impacts resulting from the extraction of the proposed longwalls.

Any remediation required would be carried out in accordance with **Section 7.1.16.**

7.1.14 Projected Natural Feature Impacts

The impact assessment conducted by MSEC (2011) (see **Appendix 9**) for each identified natural feature has been made based upon the calibrated IPM model MSEC developed for the site. Predicted landforms resulting from maximum predicted subsidence are shown on **Figure 7.3**.

7.1.14.1 Cony and Sandy Creeks

The impact assessments for Cony and Sandy Creeks should be read in conjunction with the findings from the flood modelling work discussed in **Section 7.3**. As discussed in **Section 7.3** a detailed flood model of the creeks has been prepared by Umwelt using the maximum predicted subsidence movements resulting from the extraction of the proposed longwalls, which were provided by MSEC (2011).

Maximum predicted subsidence, upsidence and closure along Cony Creek and Sandy Creek are summarised in **Table 7.11**. Upsidence refers to the relative uplift within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of millimetres (mm), is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain. Closure is the reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of millimetres (mm), is the greatest reduction in distance between any two points on the opposing valley sides.

Table 7.11 – Maximum Predicted Subsidence, Upsidence and Closure along Cony and Sandy Creeks (Source: MSEC, 2011)

Creek	Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Cony Creek	After LWA11	<20	<20	<20
	After LWA12	50	<20	<20
	After LWA13	325	30	20
	After LWA14	1175	50	30
	After LWA15	1450	70	50
	After LWA16	1550	125	100
	After LWA17	1625	225	150
	After LWA18	1650	275	200
	After LWA19	1675	300	200
Sandy Creek	After LWA12	<20	<20	<20
	After LWA13	<20	<20	<20
	After LWA14	100	<20	<20
	After LWA15	825	40	20
	After LWA16	1400	70	30
	After LWA17	1600	75	35
	After LWA18	1600	80	40
	After LWA19	1600	80	40

As can be seen in **Table 7.11**, maximum predicted subsidence along Cony Creek ranges from 20 mm above LWA11 to 1750 mm above LWA19 while maximum predicted subsidence along Sandy Creek ranges from <20 mm above LWA12 to 1600 mm above LWA19. The potential for increases in ponding and flooding along Cony Creek and Sandy Creek as a result of this predicted subsidence is discussed further in **Section 7.3**.

A comparison of the maximum predicted subsidence parameters along Cony Creek and Sandy Creek between the Approved Stage 3 project and the Proposed Stage 3 Modification project is summarised in **Table 7.12**.

Table 7.12 – Comparison of the Maximum Predicted Subsidence Parameters along Cony Creek and Sandy Creek Between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project (Source: MSEC, 2011)

Creek	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Cony Creek	Approved Stage 3 Project	1865	320	250
	Proposed Stage 3 Modification Project	1675	300	200
Sandy Creek	Approved Stage 3 Project	1410	65	25
	Proposed Stage 3 Modification Project	1600	80	40

It can be seen from **Table 7.12** that the maximum predicted mine subsidence parameters for Cony Creek under the proposed Stage 3 Modification project are slightly less than for Cony Creek under the Approved Stage 3 project. It can also be seen that the maximum predicted mine subsidence for Sandy Creek under the proposed Stage 3 Modification project is slightly more than for Sandy Creek under the Approved Stage 3 project.

As previously discussed, the Branxton Formation forms the upper section of the constrained zone. This formation is massive, relatively homogeneous and contains relatively thick beds. As a result upsidence and valley closure impacts are expected to be less than those listed in **Table 7.12**. If surface cracking occurs as a result of the extraction of the proposed longwalls, any cracks are likely to be filled with alluvial materials during subsequent flow events. Discussion on the potential impacts of surface impacts and changes in surface water flows is provided in **Appendix 7**.

Any remediation required would be carried out in accordance with **Section 7.1.16.**

7.1.14.2 Steep Slopes

Steep slopes are defined as areas of land having a natural gradient greater than 1 in 3 (a grade of 33%, or an angle to the horizontal greater than 18°). No cliffs or escarpments have been identified within the potential subsidence impact area. A comparison of the maximum predicted, tilt and curvature between the Approved Stage 3 project and the proposed Stage 3 Modification project is presented in **Table 7.13**.

Table 7.13 – Comparison of the Maximum Predicted, Tilt and Curvature between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project (Source: MSEC, 2011)

Location	Project	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (km^{-1})	Maximum Predicted Sagging Curvature (km^{-1})
Broken Back Range	Approved Stage 3 Project	6.7	0.05	0.13
	Proposed Stage 3 Modification Project	5.0	0.04	0.09
Hill above Longwall A18	Approved Stage 3 Project	5.0	0.04	0.03
	Proposed Stage 3 Modification Project	4.5	0.03	0.03

The maximum predicted tilt for the steep slopes resulting from the extraction of the proposed longwalls is 5.0 mm/m, which is marginal in relation to the natural grade of the terrain, and the predicted change in grade is unlikely to result in any significant impact on the stability of the steep slopes. Steep slopes are more likely to be affected by curvatures and strains, where the down slope movement of soils causes tension cracks to form at the tops of slopes and compression ridges to form at the bottoms of the slopes.

The maximum predicted ground curvatures for the steep slopes are 0.03 km^{-1} hogging and 0.09 km^{-1} sagging, which represent minimum radii of curvature of 33 kilometres and 10 kilometres respectively. Potential impacts, as observed following coal mining in similar circumstances in the Southern Coalfield are typically isolated and narrow cracks with widths in the order of 50 mm. No large-scale slope failures have been observed in the Southern Coalfield.

Any remediation, if required, would be carried out in accordance with **Section 7.1.16**.

7.1.15 Subsidence Effects on Land Use and Agricultural Productivity

7.1.15.1 Local Rural Building Structures

A total of 73 rural building structures (Structure Type R) have been identified within the subsidence impact assessment area (MSEC 2011). These buildings include generally lightweight farm sheds, garages and other non-residential structures. Predictions of systematic subsidence are identical to the methods used to assess houses (refer to **Section 7.1.6**). A comparison of the maximum subsidence parameters for rural building structures between the Approved Stage 3 project and the Proposed Stage 3 Modification project is presented in **Table 7.14**.

Table 7.14 – Comparison of the Maximum Subsidence Parameters for Rural Building Structures between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project (Source: MSEC, 2011)

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Rural Building Structures	Approved Stage 3 Project	1825	6.0	0.07	0.08
	Proposed Stage 3 Modification Project	1675	6.0	0.05	0.08

As can be seen from **Table 7.14**, the predicted maximum subsidence parameters for the Stage 3 Modification project are similar to or slightly less than the predictions for the Approved Stage 3 project. As set out in **Appendix 9**, predictions for individual rural buildings in relation to the proposed Stage 3 Modification project are slightly greater, similar, or slightly less than the predictions for the same rural building structures in relation to the approved Stage 3 project.

The maximum predicted tilt for rural building structures resulting from the extraction of the proposed longwalls is 6 mm/m (i.e. 0.6%) which represent a change in grade of 1 in 165. Tilts of less than 7 mm/m are not expected to result in significant impacts.

The maximum predicted ground curvatures for rural building structures is 0.05 km^{-1} hogging and 0.06 km^{-1} sagging, which represent minimum radii of curvature of 20 kilometres and 17 kilometres, respectively. It is expected that all rural building structures will remain safe and serviceable for the life of the project, providing that they are in sound condition at the commencement of mining. Any minor impacts on rural building structures could be repaired using well established building techniques.

Any remediation required would be carried out in accordance with **Section 7.1.16.**

7.1.15.2 Tanks

There are a number of larger tanks (Structure Type T) that have been identified within the subsidence impact assessment area, which include water and fuel storage tanks. There are also a number of smaller rainwater and fuel storage tanks associated with the residences on each rural property. Predictions of subsidence, tilt and strain have been made at the centroid and at points around the perimeter of each identified tank, as well as at points 20 metres from the perimeter of each tank. A comparison of the maximum subsidence parameters for tanks between the Approved Stage 3 project and the Proposed Stage 3 Modification project is presented in **Table 7.15.**

Table 7.15 – Comparison of the Maximum Subsidence Parameters for Tanks between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Tanks	Approved Stage 3 Project	1850	5.0	306	0.10
	Proposed Stage 3 Modification Project	1650	3.5	0.04	0.08

As can be seen from **Table 7.15**, the predicted maximum subsidence parameters for the Stage 3 Modification project are of a similar to or slightly less than the predictions for the Approved Stage 3 project. As set out in **Appendix 9**, predictions for individual tanks in relation to the proposed Stage 3 Modification project are slightly greater, similar, or slightly less than the predictions for the same tanks in relation to the Approved Stage 3 project.

The maximum predicted tilt for tanks resulting from the extraction of the proposed longwalls is 4 mm/m (i.e. 0.4%) which represent a change in grade of 1 in 250. Tilts of less than 7 mm/m are not expected to result in significant impacts.

As tanks are typically constructed above ground level they are unlikely to experience curvature or ground strains resulting from the extraction of the proposed longwalls. Should any underground pipework attached to the tanks be impacted, it is expected to be minor in nature and easily repaired.

Any remediation required would be carried out in accordance with **Section 7.1.16.**

7.1.15.3 Fences

There are a number of fences which are constructed in a variety of ways, generally using either timber or metal materials. Fences are located across the impacted area and have been assessed according to the full range of subsidence impacts as per **Section 7.1.4**:

The maximum predicted conventional tilt within the proposed Stage 3 Modification Area is 6.5 mm/m (i.e. 0.7%), which represents a change in grade of 1 in 155.

It is possible that some of the fences within the Proposed Stage 3 Modification Area would be impacted as a result of the extraction of the proposed longwalls. Any impacts on the wire fences are likely to be of a minor nature and relatively easy to remediate by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing. Any impacts on Colorbond or timber paling fences are expected to be of a minor nature and relatively easy to remediate or, where necessary, to replace.

Any remediation required would be carried out in accordance with **Section 7.1.16.**

7.1.15.4 Farm Dams

There are 131 farms dams identified within the subsidence assessment area (see **Appendix 9**). Predictions have been made at the centroid and around the perimeters of each farm dam. Such dams are typically constructed of cohesive soils with reasonably high clay content and capable of withstanding tensile strains of up to 3 mm/m without impact because of their inherent elasticity. The dams may also be subjected to minimal valley related upsidence. A comparison of the maximum subsidence parameters for farm dams between the Approved Stage 3 project and the Proposed Stage 3 Modification project is presented in **Table 7.16.**

Table 7.16 – Comparison of the Maximum Subsidence Parameters for Farm Dams between the Approved Stage 3 Project and the Proposed Stage 3 Modification Project

Location	Project	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Farm Dams	Approved Stage 3 Project	1900	6.0	0.05	0.12
	Proposed Stage 3 Modification Project	1750	6.0	0.05	0.07

As can be seen from **Table 7.16**, the predicted maximum subsidence parameters for the Stage 3 Modification project are of a similar to or slightly less than the predictions for the Approved Stage 3 project. As set out in **Appendix 9**, predictions for individual dams in relation to the proposed Stage 3 Modification project are slightly greater, similar, or slightly less than the predictions for the same dams in relation to the Approved Stage 3 project.

Maximum predicted tilt at the farm dams, at any time during or after the extraction of the proposed longwalls, is 6 mm/m (i.e. 0.6%) or a change in grade of in 1 in 165.

The maximum predicted ground curvatures for farm dams is 0.04 km^{-1} hogging and 0.08 km^{-1} sagging, which represent minimum radii of curvature of 25 kilometres and 13 kilometres, respectively.

It is expected that the incidence of impacts on farm dams will be extremely low. If cracking or leaking were to occur it could be easily identified and repaired as required.

Any remediation required would be carried out in accordance with **Section 7.1.16**.

7.1.15.5 Wells and Bores

The nearest bores are a minimum 200 metres from the Stage 3 Modification longwalls. It is possible that bores may experience impacts due to mining such as the temporary lowering of the piezometric surface, blockage of the bore or changes to groundwater quality. Impacts can be readily managed and if required temporary alternative supplies of water could be provided.

Any remediation required would be carried out in accordance with **Section 7.1.16.**

7.1.16 Subsidence Monitoring, Management and Contingency Measures

The monitoring, management and mitigation of subsidence is an integral component of the current Austar Mining Operations Plan 2008-2015 (MOP) and the Austar Subsidence Management Plan (SMP).

Austar has communicated with surrounding stakeholders regarding the subsidence impact assessment, potential subsidence impacts, monitoring and management considerations and will continue this communication through the development of Extraction Plans (EP) and Built Features Management Plans prior to longwall mining taking place.

The following subsidence monitoring procedures will be implemented (subject to landholder approval) as part of the Project, and will be further refined in consultation as mining progresses:

- subsidence monitoring lines to be located as determined as part of the EP process;
- visual assessment of all natural features and items of surface infrastructure before, during and following longwall mining to detect subsidence impacts such as surface cracking, irregularities in the subsidence profile, erosion, damage to structures, changes in drainage patterns or loss of water from drainage structures;
- assessment of all building structures by a structural engineer before and after longwall mining; and
- verification and revision of subsidence predictions as mining progresses.

There will be ongoing refinement and calibration of the subsidence predictive model throughout the project life as a result of subsidence monitoring and comparison with predictions. As the coal resource is extracted, refinement and verification of the model will be incorporated into the EP for each set of longwalls, providing a continual refinement process for the assessment and management of subsidence impacts as the project progresses. Contingency measures such as revisions to the mine plan and extraction height will be explored if subsidence monitoring indicates that subsidence impacts are greater than predicted over the long term.

Significant subsidence impacts on the land surface from the proposed Stage 3 Modification underground mining are not predicted. However, in the event that subsidence impacts are greater than the predicted impacts, a variety of contingency measures and rehabilitation techniques are available to repair or avoid further the impacts of subsidence. Remediation techniques will vary depending on the extent of surface cracking or landform changes. These techniques will aim to minimise the impact on the surface whilst achieving an acceptable level of rehabilitation from a land user safety, mine safety and environmental perspectives.

In areas where smaller scale cracking is predicted to occur, remediation activities may include one, or a combination of the following methods:

- infilling of cracks with soil to seal cracks visible at the surface;
- tilling the ground surface using small agricultural equipment to blend fill material and restore the soil profile; and/or
- where necessary, using small machinery, such as a small excavator, bobcat or grader, to restore the surface profile.

Where subsidence remediation is required within sensitive areas such as adjacent to Aboriginal sites or significant ecological areas, hand methods can be used to repair any cracking and restore the soil profile.

Austar is committed to effective and timely rehabilitation of surface cracking should it occur, whilst minimising impact on the natural environment, cultural values and land use. The ground surface across the project area will be visually inspected during and following longwall extraction so that significant cracking or irregularities in the subsidence profile can be identified and remediated where required.

A summary of Subsidence Management and Remediation Measures is provided in **Table 7.17**.

Table 7.17 - Summary of Subsidence Management and Remediation Measures

Feature/Location	Typical Management and Remediation Options
Houses	• Built Features Management Plans developed for houses directly above proposed mining. Inspected prior to mining. • Houses visually monitored during mining.
Roads, Culverts and Bridges	• Tensile cracking or compressive rippling of the road surfaces remediated using normal road maintenance techniques. Roads will be visually monitored during mining. • Management strategies will be developed, in consultation with Cessnock City Council.
Powerlines (11kV)	• Management strategy developed in consultation with Ausgrid. • Visually inspected during mining.
Optical Fibre Cable	• Monitored using optical fibre sensing techniques, such as Optical Time Domain Reflector (OTDR) monitoring. • Establish management strategies, in consultation with Telstra.
Telecommunication Cables	• No significant impact predicted. • Management strategies will be developed in consultation with Telstra.
Building Structures	• Managed with the implementation of suitable management strategies. Each dwelling and rural building structure above the proposed longwalls will be inspected where possible prior to being mined beneath, to assess the existing condition and whether any preventive measures may be required. • Rural building structures are visually monitored during mining.
Swimming pools	• Built Features Management Plans will be developed for swimming pools within the 20mm subsidence contour. • Swimming pools and surrounding fences will be inspected prior to mining and visually monitored during the active subsidence period. • Appropriate remediation measures will be identified as necessary.
Tanks	• Suitable management strategies. • Tanks will be visually monitored during mining.
Farm dams	• No significant impact predicted. • All water retaining structures visually monitored during mining where possible. • Repair leaking dams if/as required. • Provide replacement water where required due to loss from mining activities

Table 7.17 - Summary of Subsidence Management and Remediation Measures (cont)

Feature/Location	Typical Management and Remediation Options
Cony, Sandy, Quorrobolong Creeks and other drainage lines	• No significant predicted impact. • Any significant tensile cracking will be remediated by infilling with alluvials or other suitable material or by locally regrading and recompacting surface.
Steep slopes	• Earthworks, soil remediation and revegetation as required.
Fences	• Repair impacted fences if required.
Bores	• Repair or replace impacted bores if required.

As part of ongoing subsidence management a Built Features Management Plan (BFMP) will be developed for each landholder whose property is potentially subject to subsidence of great than 20 millimetres. A comprehensive consultation program with landholders will be undertaken and current property-specific baseline data will be compiled prior to mining and provided to landholders in the form of a BFMP. BFMPs will be prepared for all properties within the 20 mm subsidence contour in consultation with the relevant landholder.

The above monitoring, management and remediation options are consistent with the monitoring, management and remediation options within the EA for the Approved Stage 3 project (Umwelt 2008a). MSEC (2011) report that:

> the proposed management strategies for all the features, therefore, are the same as those previously recommended in Report No. MSEC309 and the original Part 3A Application.

7.1.17 Land Use and Property Values

There are approximately 36 privately-owned land parcels in approximately 26 separate land ownerships directly above the proposed Stage 3 Modification underground mining area. There are an additional approximately 11 properties located between the perimeter of the proposed Stage 3 Modification underground mining area and the predicted 20 mm subsidence contour. As described in **Section 5.3**, land use within this area includes grazing land, chicken sheds, rural residential and hobby farms, forest plantations and vineyards.

The assessment of potential impacts from subsidence on the land surface, natural features and surface infrastructure as set out in **Sections 7.1.1** to **7.1.15** combined with the implementation of contingency and management measures as set out in **Section 7.1.16**, indicate that the proposed Stage 3 Modification will not have a significant adverse impact on land use above the proposed Stage 3 Modification underground mining area. In addition, mining is not expected to have a negative impact on the visual attributes, ecology, amenity of the area, stream flow or usable groundwater resources in the area.

Extraction Plans and Built Features Management Plans that will detail monitoring and management measures to be implemented on a property by property basis will be prepared in consultation with relevant authorities and landholders prior to longwall extraction.

Based on the low level of predicted surface impact and the management controls that are proposed, it is envisaged that land values and agricultural capability of the properties above Stage 3 Modification will not be adversely affected by the proposed underground mining.

Continued economic growth coupled with predicted growth in urban and rural residential development in the area, are likely to result in increased demand for property in the area.

7.2 Vibration

7.2.1 Overview of Ground Vibration

As discussed in MSEC (2011), the settlement of the ground during and following longwall mining generally occurs as a series of gradual movements over time. These movements generally cannot be detected by people on the ground surface. However, occasionally movements in the rock layers immediately above the longwall can result in vibration in the ground which can be felt as a minor effect on the surface.

According to Renzo Tonin and Associates (1995), ground vibration can be thought of as the rapid backwards and forwards motion of the ground. Ground vibration associated with underground mining can occur in two possible ways:

- sudden failure of rock lying above the mined out area; and
- slippage along a fault line or rock fracture zone.

The sudden release of energy that occurs with a sudden rock failure or slippage results in ground vibration not dissimilar to the kind experienced when a heavy weight falls on the ground (Renzo Tonin and Associates 1995). Ground vibration events from underground mining are short in duration, usually not lasting more than a second. These vibration events are referred to as 'ground tremors'.

Ground vibration is usually measured in terms of the maximum speed of movement of a point on the ground in the horizontal and vertical directions. This is known as the Peak Particle Velocity (PPV) and is measured by use of a vibration monitor.

7.2.2 Ground Vibration Criteria

No guideline criteria specifically relating to ground vibration as a result of underground mining are available for use in assessment of ground vibration at Austar Coal Mine. The following two more general guidelines provide guidance for vibration criteria for human response and structural damage respectively:

- *Assessing Vibration: a technical guideline* (NSW DECC, 2006); and
- *British Standard BS 7385:1993 Part 2 – Evaluation and Measurement for Vibration in Buildings.*

7.2.2.1 Human Response Criteria

The NSW Department of Environment and Climate Change (DECC) document *Assessing Vibration: a technical guideline* (February 2006) provides preferred and maximum vibration values for different receiver types such as residences, offices, workshops, and critical work areas (hospital operating theatres, precision laboratories etc). The criteria are non-mandatory goals that operations should seek to achieve through the application of all feasible and reasonable mitigation measures (DECC 2006). The criteria relate specifically to human response to vibration. Criteria for structural damage are provided separately in **Section 7.2.2.2**.

DECC (2006) presents vibration criteria for continuous vibration (i.e. vibration that continues uninterrupted for a defined period e.g. continuous construction activity), and impulsive vibration, defined as vibration that builds up rapidly to a peak followed by a damped decay.

As ground vibration as a result of mining is felt as infrequent, short duration events, the impulsive vibration criteria are more appropriate for Austar Coal Mine. The impulsive vibration criteria are listed in **Table 7.18** below.

Table 7.18 – Criteria for Exposure to Continuous and Impulsive Vibration

Place	Time[1]	Peak Velocity (mm/s)	
		Preferred	Maximum
Critical working areas (e.g. hospital operating theatres, precision laboratories)	Day- or night-time	0.14	0.28
Residences	Daytime	8.6	17.0
	Night-time	2.8	5.6
Offices	Day- or night-time	18.0	36.0
Workshops	Day- or night-time	18.0	36.0

1 Daytime is 7.00 am to 10.00 pm and night-time is 10.00 pm to 7.00 am

The criteria for residences listed in **Table 7.18** above are considered to be the most appropriate human response criteria given the land use of the Stage 3 Modification Area.

7.2.2.2 Structural Damage

For building damage, Australian Standard AS 2187: Part 2-2006 *Explosives – Storage and Use – Part 2: Use of Explosives* recommends the frequency dependant guideline values and assessment methods given in BS 7385 Part 2-1993 *Evaluation and Measurement for Vibration in Buildings Part* as they are considered to be applicable to Australian conditions.

The British Standard sets guideline values for building vibration based on the lowest vibration levels above which damage has been credibly demonstrated. These levels are judged to give a minimum risk of vibration-induced damage, where minimal risk for a named effect is usually taken as a 95% probability of no effect.

The recommended limits (guide values) for transient vibration to ensure minimal risk of cosmetic damage to residential and industrial buildings are presented in **Table 7.19**.

Table 7.19 – Transient Vibration Guideline Values – Minimal Risk of Cosmetic Damage

Type of Building	Peak Component Particle Velocity in Frequency Range of Predominant Pulse	
	4 Hz to 15 Hz	15 Hz and Above
Reinforced or framed structures Industrial and heavy commercial buildings	50 mm/s at 4 Hz and above	-
Unreinforced or light framed structures Residential or light commercial type buildings	15 mm/s at 4 Hz increasing to 20 mm/s at 15 Hz	20 mm/s at 15 Hz increasing to 50 mm/s at 40 Hz and above

The criteria for residential or light commercial type buildings is considered most appropriate for buildings within the proposed Stage 3 Modification Area.

7.2.3 Historic Vibration Levels at Ellalong Colliery

Longwall mining in the Greta Seam at Ellalong Colliery to the south of the current approval area (refer to **Figure 1.2**) began in 1983. Both Ellalong Colliery and the Mines Subsidence Board monitored ground vibrations at the ground surface over the longwalls and at nearby residences over a number of years. According to MSEC (2009), three vibration events with surface PPVs of between 22 mm/s to 28 mm/s were recorded in 1991 and 1992. The remaining events during 1991 and 1992 were generally less than 8 mm/s.

The 1995 EIS (HLA Envirosciences, 1995) included a vibration report by Renzo Tonin & Associates Pty Ltd (Renzo Tonin) which sets out vibration levels recorded at No. 2 Shaft (location shown on **Figure 1.2**) and at two locations within the Ellalong community between May 1993 and June 1994. The results of all significant vibration events are provided in **Figure 7.6**.

As shown in **Figure 7.6**, the majority of vibration events at Ellalong Colliery recorded during May 1993 to June 1994 were less than 8 mm/s at No. 2 Shaft. An additional five events over the 12 month period had velocities of over 8 mm/s, with two events having velocities of over 20 mm/s. An additional event was recorded on 21/09/1993 with a velocity of 150 mm/s at No. 2 Shaft. However, the validity of this record is questioned as on this occasion no corresponding data was recorded by the two vibration monitors located in the residential areas. This point has been discarded as an outlier as it is unlikely that an event of this magnitude would escape detection at the other vibration monitors within the study area.

7.2.4 Vibration Monitoring in the Stage 2 Area

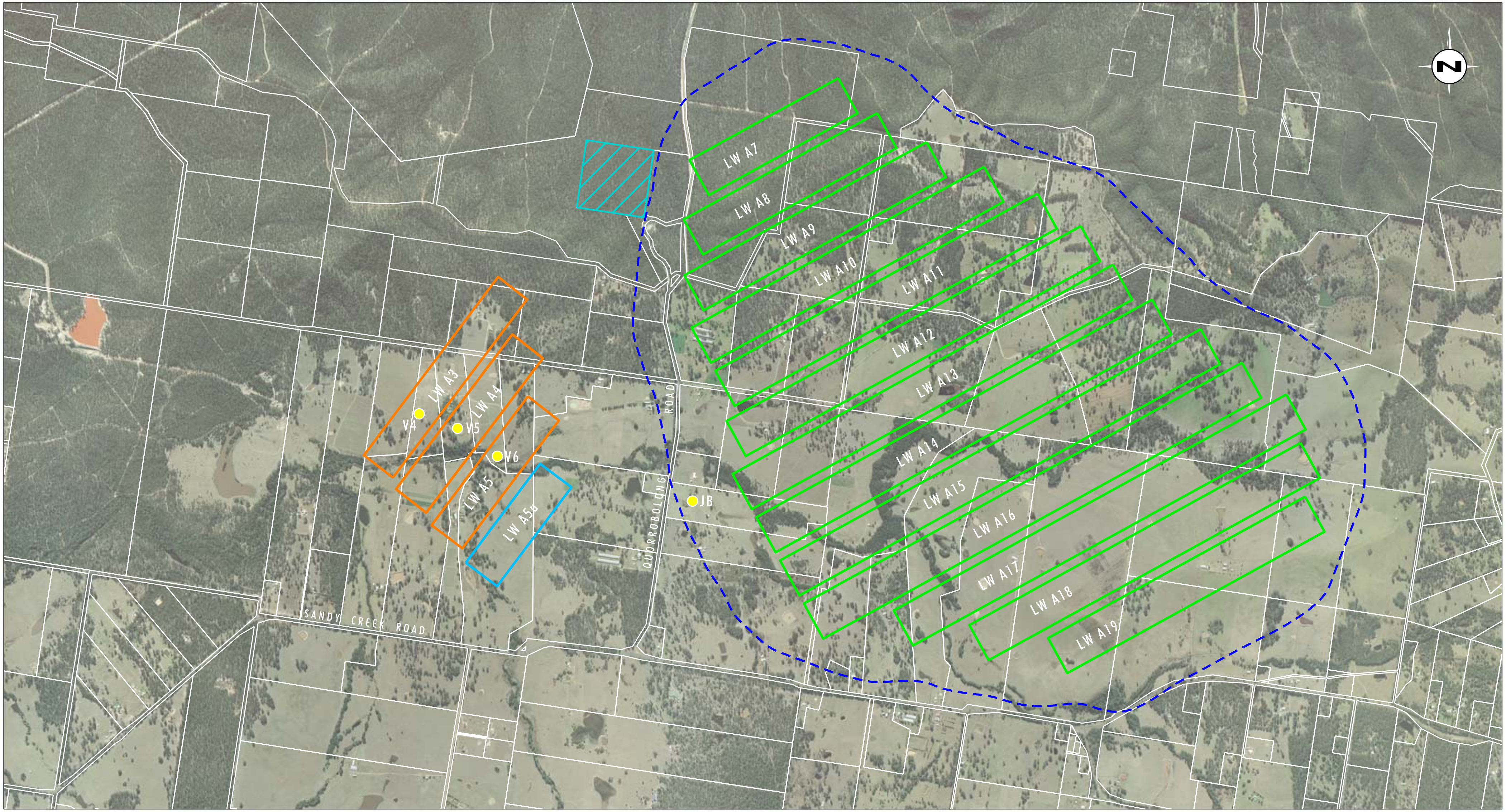
Austar is currently undertaking vibration monitoring in the Stage 2 area in accordance with *Austar Coal Mine Vibration Monitoring Plan – Longwall Panels A3, A4 & A5* (Austar 2009). Vibration monitoring has previously occurred over LW A3 at vibration monitoring location V4 and is currently occurring over LW A4 and LW A5 at vibration monitoring locations V5 and V6 respectively (refer to **Figure 7.5**). As shown on **Figure 7.5**, an additional vibration monitor was installed at one residence to the east of the Stage 2 mining area in March 2011 (monitoring location JB).

Monitoring results from August 2009 to May 2011 are shown in **Figure 7.7** for day time and night time periods. As shown in **Figure 7.7** the majority of vibration events during mining of LW A3 and LW A4 have been in the range of less than 8.6 mm/s PPV and have occurred up to ten times per month. The highest magnitude event in the period from August 2009 to May 2011 was recorded on 29 January 2010 with a PPV of 15.9 mm/s recorded by vibration monitor V4 directly over LW A3 within the Stage 2 mining area. Vibration monitor V5, located approximately 250 metres to the south-east of vibration monitor V4 recorded a PPV of 9.8 mm/s for the same event. This event was not large enough to result in any significant structural impact to residences in the Stage 2 mining area. All other events recorded within the Stage 2 mining area have remained below structural damage criteria.

As set out by MSEC (2011) the vibration experienced within the Stage 2 mining area is within the range of likely vibration levels that are expected as a result of mining in the Stage 3 Modification Area.

7.2.5 Vibration from Underground Mining in the Stage 3 Modification Area

Based on the data provided in MSEC (2011), and taking into account the findings of vibration monitoring in the Stage 2 area described above, it is considered that mining in the proposed Stage 3 Modification Area is unlikely to result in vibration impacts in excess of those already approved under Project Approval 08_0111. As discussed in the Subsidence Assessment



Source: Longwall Layout: Austar Coal Mine, Cadastre: LPI NSW,
Aerial Photography: AAM Hatch 2006

0 0.5 1 1.5km
1:32 000

Legend

- Proposed Stage 3 Modification Longwall Panels
- Layout for Stage 2 Longwall Panels
- Layout for Stage 2 Extension Longwall Panel
- 20mm Subsidence Contour for Proposed Stage 3 Modification
- Approved Surface Infrastructure Site
- Vibration Monitoring Locations

FIGURE 7.5

Austar Stage 2 Vibration Monitor Locations

File Name (A4): R64_V1/2274_993.dgn

Umwelt
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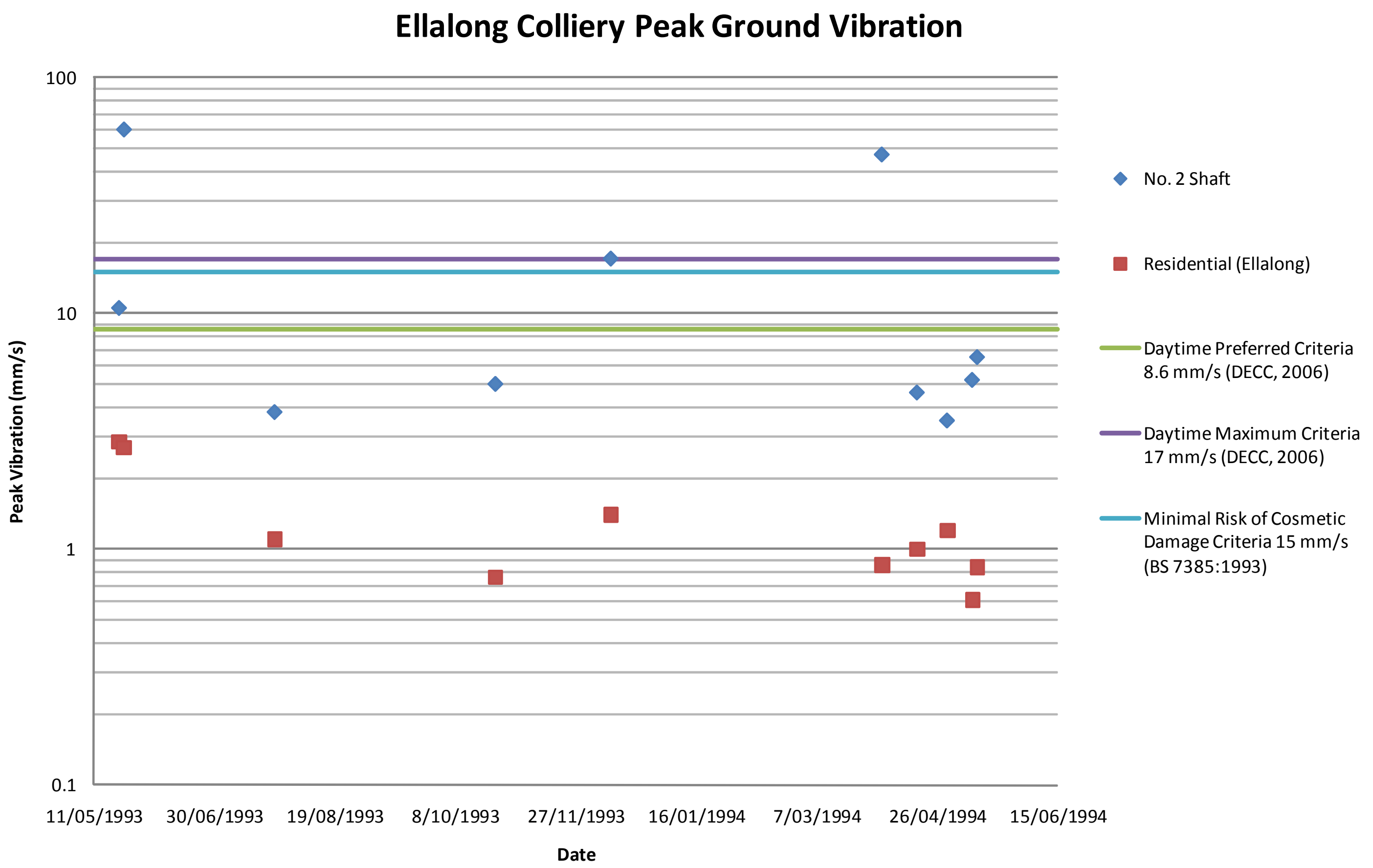


FIGURE 7.6

Ellalong Colliery Peak Ground Vibration

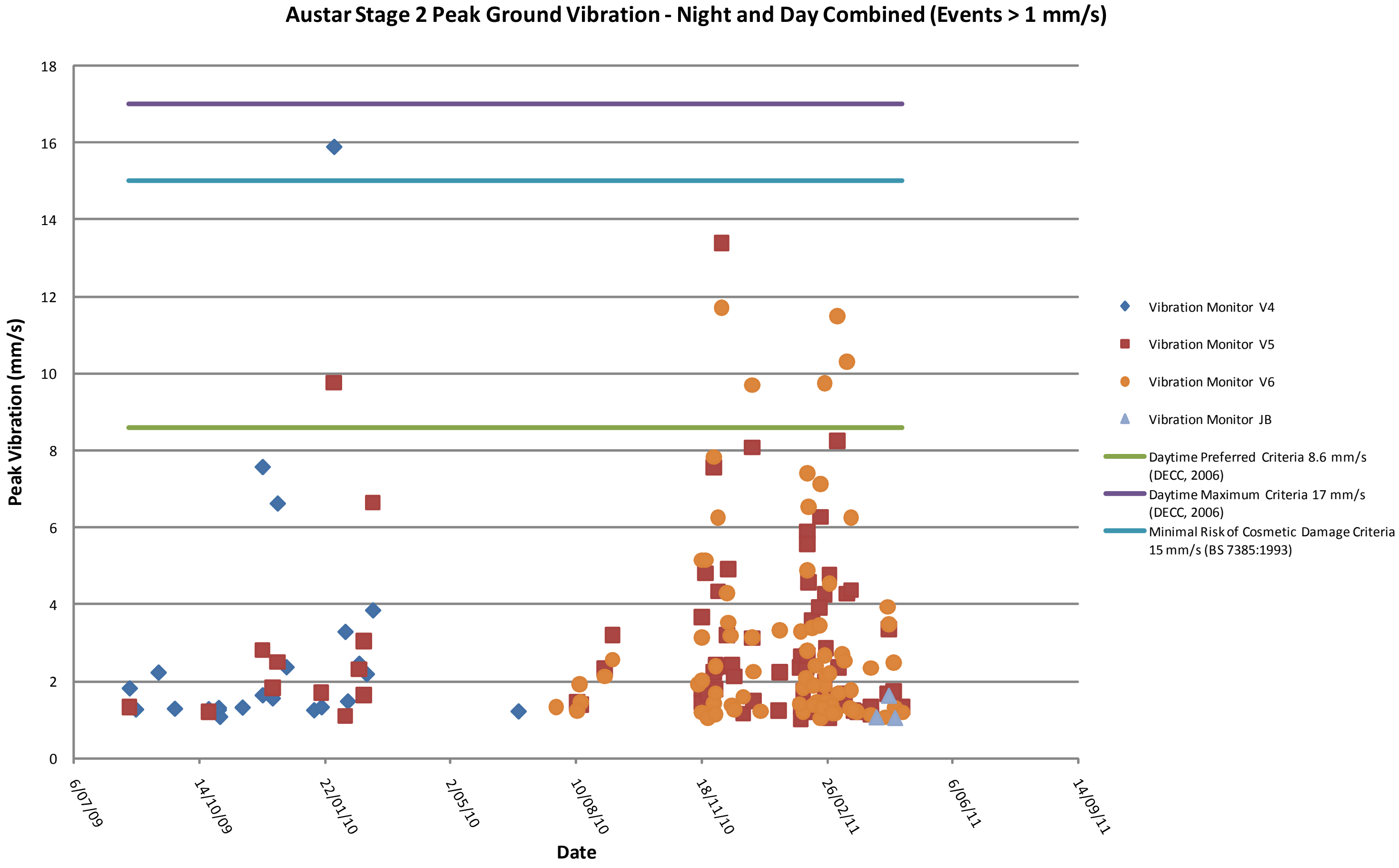


FIGURE 7.7

Austar Stage 2 Peak Ground Vibration

(refer to **Appendix 9**), the levels of vibration would generally be expected to be low and would not be of sufficient amplitude to result in any significant structural impact. Any structural impact which occurs due to vibration, resulting from underground mining in the Stage 3 Modification Area, is expected to be of a minor nature, and easily repaired using normal building maintenance techniques (MSEC 2011).

Vibration from underground mining within the Stage 3 Modification Area will be monitored via an extension of the existing Austar Stage 2 Vibration Monitoring Program (Austar 2009). Damage to structures as a result of vibration from the underground mining in the Stage 3 Modification Area should it occur will be managed in the same manner as damage to structures as a result of subsidence (refer to **Section 7.1** for further details).

7.3 Surface Water and Drainage

7.3.1 Surface Drainage and Flood Modelling

As discussed in **Section 5.2**, the Stage 3 Modification Area is predominantly located within the Cony Creek and Sandy Creek catchments, which form part of the Congewai Creek and Wollombi Brook drainage systems. The proximity of the Stage 3 Modification Area to Quorrobolong Creek and Cony Creek catchments is shown on **Figure 5.1**. A small section of the northern part of the proposed Stage 3 Modification Area underlies an upslope section of Black Creek catchment (see **Figure 5.1**).

To assess the potential impacts of the proposed Stage 3 Modification on flooding and drainage, a detailed flooding and drainage assessment has been undertaken and is presented in **Appendix 7**. The assessment builds on the previous flooding and drainage assessments undertaken for the Stage 2 and Stage 3 areas (Umwelt 2007, Umwelt 2008b, Umwelt 2010b) which examine the potential impacts on the flooding and drainage regime of Quorrobolong Creek and its tributaries as a result of mining longwalls A3 to A5 (Stage 2), longwalls A6 to A17 (Stage 3) and longwall A5a (Stage 2 Extension) respectively. The Stage 2, Stage 3 and Stage 2 Extension flood assessments are detailed in *Flooding Assessment: Longwalls A3, A4 and A5* (Umwelt 2007) and *Flood and Drainage Assessment: Stage 3* (Umwelt 2008b) and *Flood and Drainage Assessment: Stage 2 Extension* (Umwelt 2010b).

The methodology used to undertake the flooding and drainage assessment is detailed in **Appendix 7** and included the following components:

- review and modification of the previously developed flood model for Stages 2 and 3 to take into account predicted changes to the landform due to mine subsidence from the proposed Stage 3 Modification mine plan;
- investigation of potential impacts of the Stage 2 Extension Project on flooding and drainage for 1 year and 100 year Average Recurrence Interval (ARI) flood events for a range of landform scenarios including:
  - pre-mining landform (modelling results described in detail in Umwelt 2007);
  - post-Stage 3 mining landform as approved (including longwalls A3 to A5, A5a and A6 to A17);
  - post-Stage 3 Modification mining landform (including longwalls A3 to A5, A5a and A7 to A19); and

- analysis of predicted changes to flood depths, velocities, flood durations and hazards in the Quorrobolong Valley.

7.3.2 Surface Flows and Flooding Impacts

For each of the landform scenarios modelled as discussed above, the maximum water depths, maximum water velocities and maximum flood hazards were determined.

The predicted impacts on flooding as a result of the maximum predicted subsidence for the proposed Stage 3 Modification are discussed in **Sections 7.3.2.1** to **7.3.2.3**. The predicted impacts on flooding as a result of the upper bound subsidence were assessed as a part of the risk assessment process.

Figures 7.8 to **7.10** show the predicted maximum flood depths for the 100 year ARI flood events for the pre-Stage 2 mining landform, and the Post-Stage 3 mining landform as approved and the Post-Stage 3 Modification mining landform. **Appendix 7** contains flood depth, flow velocity duration and flood hazard information for all scenarios modelled.

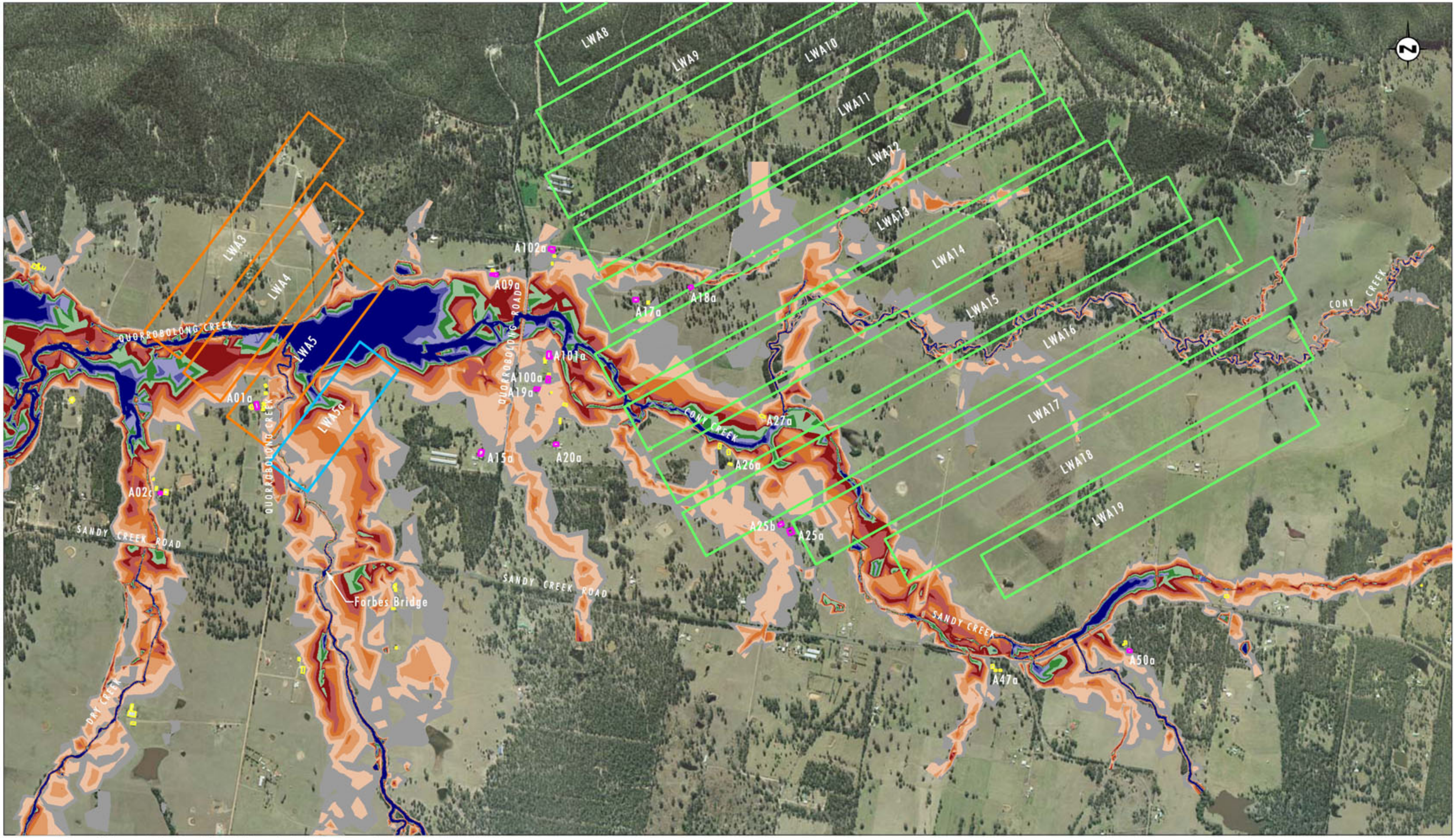
7.3.2.1 In Channel and out of Channel Flood Depths

A comparison of the modelled flood response for the predicted subsidence for Stage 3 Modification (i.e. Longwalls A7 to A19) with those previously modelled for the predicted subsidence for Stage 3 (i.e. Longwalls A3 to A17, including A5a), indicated that the Stage 3 Modification could potentially reduce flood levels at the junction of Cony Creek and Sandy Creek to a depth closer to the pre-mining flood depths (refer to **Figures 7.9** and **7.10**) for both the 100 year and 1 year ARI storm events. The maximum modelled decrease was in the order of 500 millimetres with an average decrease of 200 millimetres for the 100 year ARI storm event.

In the sections downstream from the junction of Cony Creek and Sandy Creek, modelling indicated an increase in the modelled maximum flood depths with the Stage 3 Modification. These predicted increases in maximum flood depths typically occur along Cony Creek in the vicinity of the western end Longwall A13, within an area that was not previously proposed to be mined. The maximum modelled increase in flood depth was in the order of 500 millimetres, with an average increase for this area in the order of 200 millimetres for the 100 year ARI storm event.

In the upper reaches of Cony Creek, modelled maximum flood depths typically remain within 50 millimetres of those estimated for the previously approved Stage 3 mine plan (for the 100 year ARI event). The sections of Cony Creek that are predicted to experience approximately 50 millimetres increased maximum flood depth (compared to the previously approved Stage 3 impacts) are typically limited to areas that are adjacent to the Stage 3 Modification longwalls, and are therefore within the predicted subsidence bowl. Reductions in the predicted flood depth are generally within areas that are no longer undermined as part of the proposed Stage 3 Modification.

In terms of out of channel flooding, modelling indicates that during the 1 year ARI storm event for the pre Stage 3 mining landform flood depths are typically in the order of up to 300 millimetres. These levels were predicted to increase by up to 180 millimetres for the post-mining condition with the approved upper bound subsidence. With the proposed modification it is estimated that predicted increase in flood levels will be similar to the pre-mining levels with out of channel flooding typically in the order of up to 300 millimetres for maximum predicted subsidence.



Source: Longwall Layout: Austar Coal Mine, Aerial Photography: AAM Hatch 2006
Note: Dwellings only shown for flood model extent

Legend

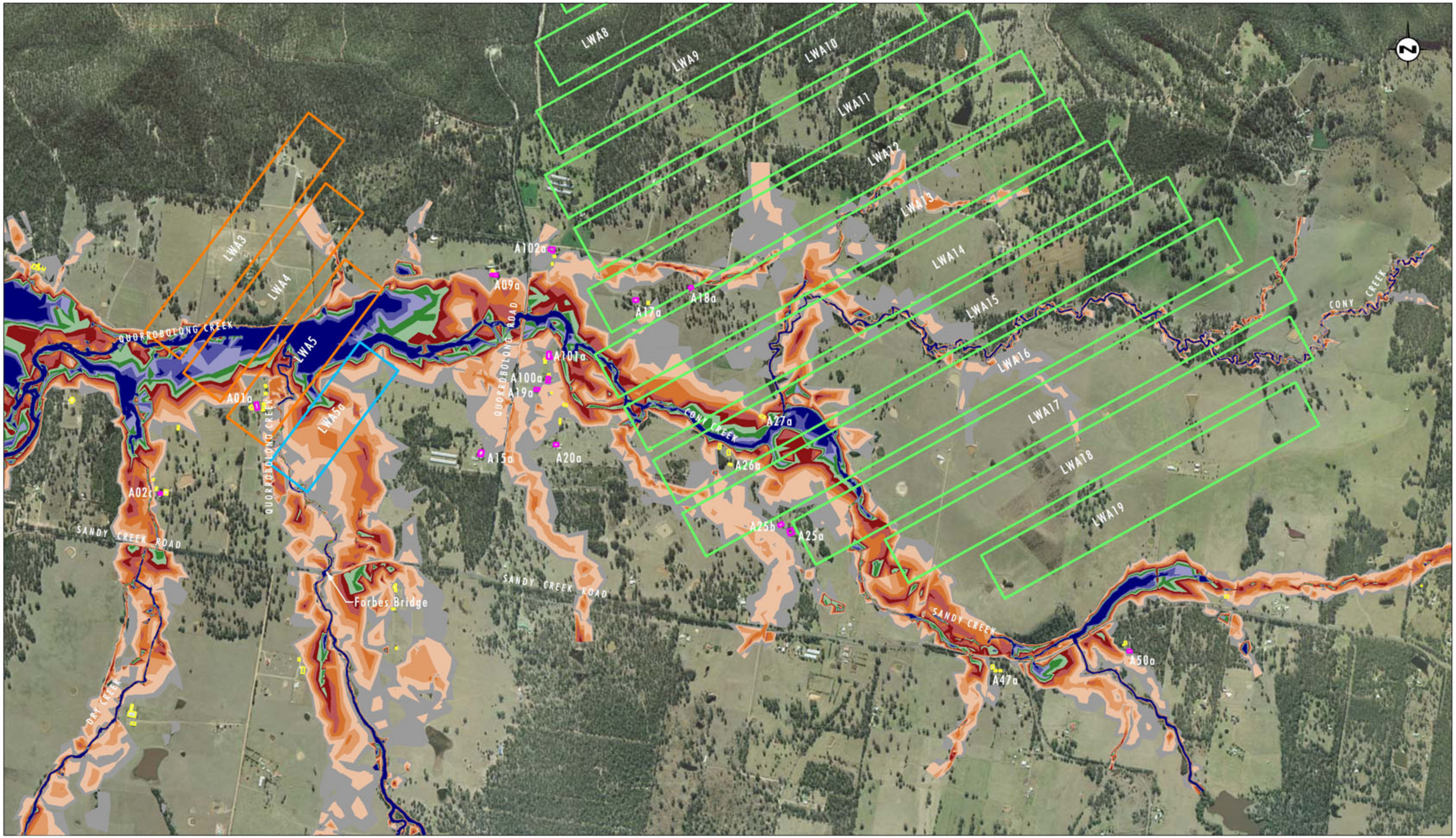
- Layout for Stage 2 Longwall Panels
- Layout for Stage 2 Extension Longwall Panel
- Layout for Proposed Stage 3 Modification Longwall Panels
- Building
- Dwelling
- A01a Dwelling Reference Number

Water Depth (m)

- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 7.8

**100 year ARI Storm: Maximum Water Depths
Pre Stage 2 Mining Landform**



Source: Longwall Layout: Austar Coal Mine, Aerial Photography: AAM Hatch 2006
Note: Dwellings only shown for flood model extent

0 300 600 900m
1:18 000

Legend

- Layout for Stage 2 Longwall Panels
- Layout for Stage 2 Extension Longwall Panel
- Layout for Proposed Stage 3 Modification Longwall Panels
- Building
- Dwelling
- A01a Dwelling Reference Number

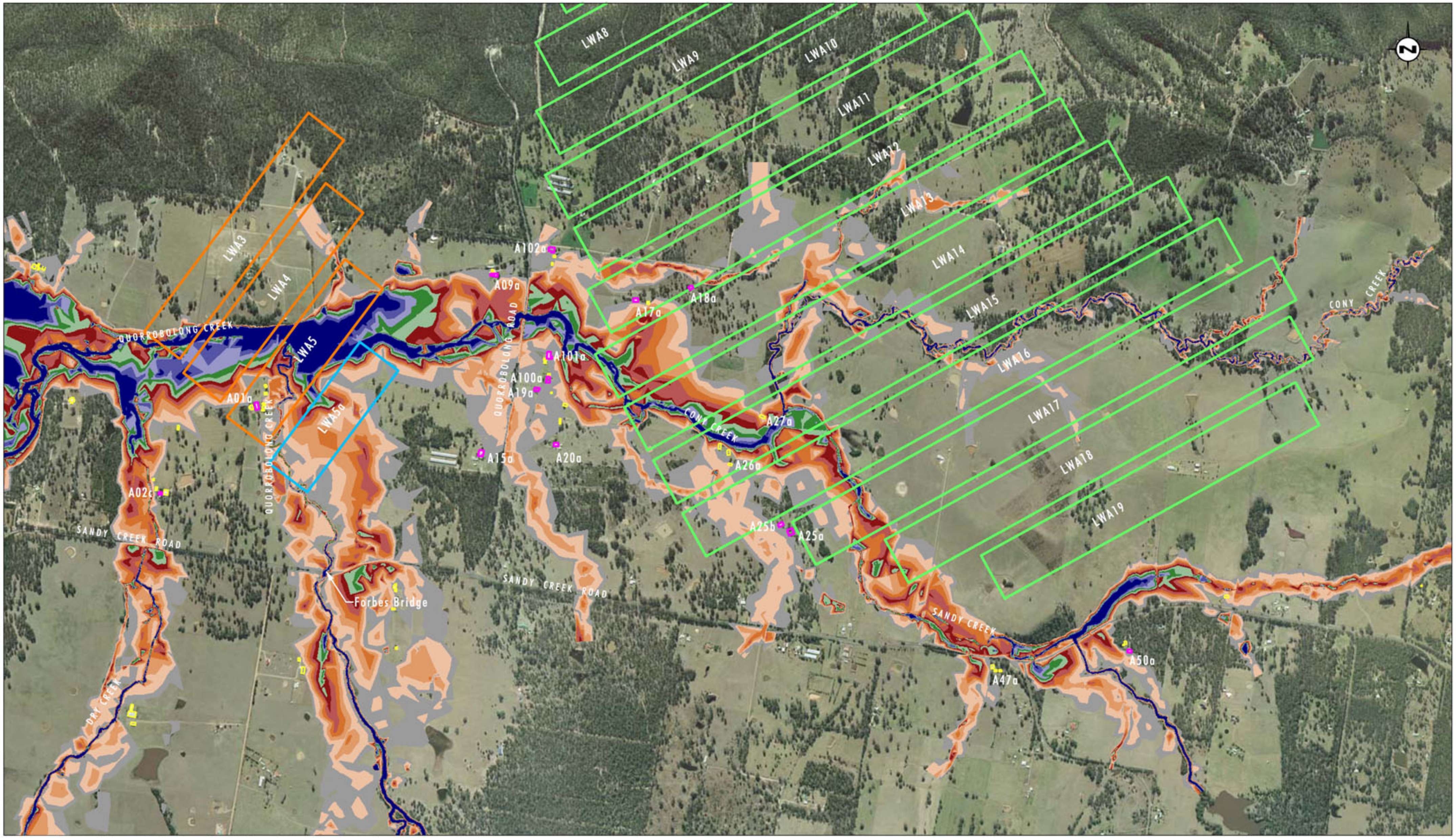
Water Depth (m)

- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 7.9

100 year ARI Storm: Maximum Modelled Water Depths for Maximum Predicted Subsidence (Approved Stage 3)

Umwelt
Environmental Consultants



Source: Longwall Layout: Austar Coal Mine, Aerial Photography: AAM Hatch 2006
Note: Dwellings only shown for flood model extent

0 300 600 900m
1:18 000

Legend

- Layout for Stage 2 Longwall Panels
- Layout for Stage 2 Extension Longwall Panel
- Layout for Proposed Stage 3 Modification Longwall Panels
- Building
- Dwelling
- A01a Dwelling Reference Number

Water Depth (m)

- Range [0.001 : 0.100]
- Range [0.100 : 0.300]
- Range [0.300 : 0.500]
- Range [0.500 : 0.700]
- Range [0.700 : 0.900]
- Range [0.900 : 1.100]
- Range [1.100 : 1.300]
- Range [1.300 : 1.500]
- Range [1.500 : 1.700]
- Range [1.700 : 1.900]
- Range [>1.900]

FIGURE 7.10

100 year ARI Storm: Maximum Modelled Water Depths for Maximum Predicted Subsidence (Stage 3 Modification)

File Name (A3): R64_V1/2274_998.dgn

7.3.2.2 Flood Depths at Dwellings

An analysis of flood depths at dwellings within the proposed Stage 3 Modification Area indicates that within the modelled area, access to properties were predicted to have only minor changes in maximum flood depths, with negligible changes to flood durations and hazard categories expected to impact on the accessibility of these properties.

The predicted maximum flood extent for the proposed Stage 3 modification is predicted to extend closer to dwelling A17a than was previously modelled for the approved Stage 3 mine plans (refer to **Appendix 7**). A closer inspection of the flood extent adjacent to dwelling A17a indicates that the edge of the predicted flood extent immediately adjacent to dwelling A17a, the predicted flood extent does not extend to include the dwelling itself. Maximum predicted flood depths were found to be no greater than 100 millimetres within approximately 10 metres of the dwelling, with predicted depths not exceeding 300 millimetres within approximately 30 metres of the dwelling. The increase in the predicted maximum 100 year ARI flood depths are therefore not anticipated to have a significant impacts on the amenity of dwelling A17a.

The maximum predicted flood depths and extents within the vicinity of dwellings A100a and A19a were found to decrease as a result of the Stage 3 modification, compared to the previously approved Stage 3 flooding impacts as well as the pre-Stage 2 conditions (refer to **Appendix 7**).

The predicted maximum flood extent and depths for the 100 year ARI flood at dwelling A102a were found to change negligibly as the result of the Stage 3 modification, compared to the previously approved Stage 3 flood impacts (refer to **Appendix 7**).

7.3.2.3 Velocities

The modelling indicates that for most of the area proposed to be undermined by Stage 3, the maximum flood velocities predicted for the Stage 3 Modification are generally similar to the previously modelled maximum flood velocities estimated for the approved Stage 3 mine plan. Downstream of the Quorrobolong Road crossing over Cony Creek, the changes in the predicted maximum velocities for the approved Stage 3 and Stage 3 Modification are negligible.

The lower reaches of Sandy Creek near the confluence with Cony Creek were found to experience a minor increase in the peak flow velocity from approximately 0.5 m/s to approximately 1.0 m/s (for the 100 year ARI event) compared to the approved Stage 3 impacts. This increase is however expected to be limited to the lower reaches of Sandy Creek, and is still within the range of velocities naturally experienced within other nearby sections of Sandy Creek. The increase is a result of the movement of ponded areas downstream as a result of the westward shift of longwall finish lines.

Downstream of the confluence of Cony Creek and Sandy Creek, the peak modelled flow velocities were predicted to decrease from approximately 1.7 m/s to approximately 1.1 m/s (for the 100 year ARI event) compared to the previously approved Stage 3 mine plan and the pre-Stage 2 landform.

Analysis of the modelling results for Sandy Creek, Cony Creek and Quorrobolong Creek system indicate that maximum modelled velocities will remain within non-scouring ranges for the 100 year event following the Stage 3 Modification. Therefore, no significant changes due to velocity induced scouring or erosion are expected as a result of the proposed Stage 3 Modification.

The upper reaches of Cony Creek are expected to experience little change in the predicted maximum flow velocities within the creek section compared to the approved Stage 3 impacts. This is despite the Stage 3 Modification no longer undermining this section of Cony Creek.

Modelling indicates that maximum velocities for the 1 year ARI storm event within Cony Creek would range from 0.6 m/s to 1.2 m/s for the pre Stage 3 mining conditions (refer to **Appendix 7**). Similarly modelling indicates that maximum velocities for the 1 year ARI storm event within Sandy Creek would range from 0.2 m/s to 0.6 m/s for the pre-Stage 3 mining conditions. With the currently approved mine plan, decreases in maximum velocities in Cony Creek of the order of 0.2 m/s to 0.3 m/s and increases in maximum velocities in Sandy Creek of the order of 0.2 m/s were predicted. With the proposed Stage 3 Modification it is predicted that maximum velocities in Cony Creek will decrease by up to approximately 0.3 m/s and maximum velocities in Sandy Creek will increase by up to approximately 0.3 m/s relative to the pre-mining conditions. However, the analysis indicates that the maximum velocities will remain within non-scouring ranges for the 1 year event following the Stage 3 Modification. No significant changes due to velocity induced scouring or erosion are expected as a result of the proposed Stage 3 Modification.

7.3.2.4 Flood Hazard

In order to assess the potential flood hazards associated with the proposed underground mining associated with the Stage 3 Modification Area, 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:

- unclassified;
- vehicles unstable;
- wading unsafe (and vehicles unstable); and
- damage to light structures.

Modelling indicated that negligible changes to the maximum flood hazard categories along access routes to dwellings would occur with the predicted subsidence for the Stage 3 Modification (i.e. Longwalls A7 to A19) compared to the predicted subsidence for the previously approved Stage 3 (i.e. Longwalls A6 to A17). **Table 7.20** compares the flood hazard categories along the access routes for the various dwellings potentially affected by flooding during the 100 year ARI storm event.

Table 7.20 – Flood Hazard Categories for Dwelling Access Routes 100 year ARI Storm Event[1]

Dwelling Access Route	Modelling Scenario		
	Pre Stage 3 Mining	Approved Stage 3 (Predicted)	Stage 3 Modification (Predicted)
A17a	Unclassified	Unclassified	Unclassified
A18a	Wading Unsafe	Wading Unsafe	Wading Unsafe
A19a	Unclassified	Unclassified	Unclassified
A20a	Vehicles Unstable	Vehicles Unstable	Vehicles Unstable
A26a	Unclassified	Unclassified	Unclassified
A100a	Vehicles Unstable	Vehicles Unstable	Unclassified
A101a	Vehicles Unstable	Vehicles Unstable	Vehicles Unstable
A102a	Unclassified	Unclassified	Unclassified

[1] Only dwellings with access routes within the flood extent are listed

The results provided in **Table 7.20** indicate that the flood hazard categories are not predicted to increase for any of the dwelling access routes within the modelled floodplain.

7.3.2.5 Flood Duration and Remnant Ponding

Flood model hydrographs immediately downstream of the Stage 3 Modification are comparable to the flood hydrographs derived previously for the approved Stage 3 mine plan, indicating that the proposed underground mining will have negligible additional effect on the flood response downstream of the Stage 3 Modification mining area during the 100 year ARI storm event.

The predicted subsidence as a result of the proposed underground mining of Stage 3 Modification indicates negligible changes to the remnant surface ponding in the area to be undermined are likely. The potential impacts on remnant ponding would be confined to existing flow paths, paddocks and dams, with no predicted impact on access routes to, or within, the properties along Cony Creek.

7.3.3 Potential Impacts on Stream Flow and Channel Stability

The flood modelling analysis indicates that the Stage 3 Modification is unlikely to have a significant impact on the flow regime of the Cony Creek and Quorrobolong Creek systems, with only minor changes predicted in runoff regimes and peak discharges.

Based on the subsidence predictions, the predicted subsidence associated with the mining operations of the Stage 3 Modification will result in maximum changes in grade of 0.3 per cent, 0.8 per cent and 0.3 per cent respectively within Quorrobolong Creek, Cony Creek and Sandy Creek, compared to the existing channel conditions. This predicted maximum change in grade is similar to the change in grade predicted to occur as a consequence of the approved Stage 3 mine plan.

As the predicted changes in in-channel grade are small and are considered to lie within the natural variations in grade of the creek lines of the Quorrobolong Valley, it is considered that the Stage 3 Modification will not significantly alter the flow capacity or stream velocities within the existing channels. It is also considered that there is minimal potential for channel realignment to occur as a result of the Stage 3 Modification.

The potential to increase erosion on the landform is also expected to be minimal due to the relatively small predicted changes in landform grades combined with the high level of groundcover and limited amount of exposed soils that exist in the area.

7.3.4 Impacts on Surface Water Users

As discussed in **Section 7.3.3**, modelling indicates that the proposed Stage 3 Modification mining is unlikely to have a significant impact on runoff or flow regimes within the Sandy Creek and Cony Creek systems and as a result flows within the creeks should remain relatively unchanged.

The potential for mining to result in stream capture within these creek systems is also considered negligible predominantly due to the depth of cover and the strength and thickness of the underlying Branxton Formation. As set out in **Section 7.1**, the predicted upper limit of the vertically connected cracking above the goaf is 285 metres or less with the depth of cover between the Greta Coal Seam and the bed of Cony Creek and Sandy Creek being in excess of 500 metres. Vertical fracturing within the constrained zone is generally discontinuous and is unlikely, therefore, to result in increased hydraulic connectivity. As a result the potential for