Section 4B

Environmental Features, Management Measures and Impacts

This section describes the specific environmental features of the Mine Site and its surrounds that would or may be affected by the proposed Stage 2 Longwall Project. Information on existing conditions, proposed safeguards and controls and potential impacts the project may have after implementation of these measures is presented for those issues identified in Section 3 as being of greatest significance.

Where appropriate, proposed monitoring programs are also described.

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4B.1 SUBSIDENCE

The Mine Subsidence Predictions and Impact Assessment was undertaken by Ditton Geotechnical Services Pty Ltd. The full assessment is presented in Volume 1 Part 1 of the Specialist Consultant Studies Compendium, with the relevant information from the assessment summarised in the following subsections. The full assessment is referred to as DGS (2009) throughout this report. A peer review of the predicted subsidence was undertaken by Dr Bruce Hebblewhite. A copy of the review is included behind the subsidence assessment in the compendium.

4B.1.1 Introduction

Based on the risk analysis undertaken for the proposed Longwall Project (see Section 3.3 and **Table 3.5**), the potential environmental impacts related to subsidence requiring assessment and their unmitigated risk rating are as follows.

- Damage or destruction of structures / infrastructure (high risk).
- Alteration of local drainage resulting in ponding, realignment or other impacts on local drainage (moderate to high risk).
- Increased erosion along drainage lines and subsequent decrease in water quality (moderate risk).
- Change to structure or composition of vegetation communities and fauna habitat (high risk).
- Reduced availability of groundwater as a result of fracturing altering hydrogeological flow paths (high risk).
- Disturbance of, or damage to, Aboriginal sites or artefacts (moderate risk).

In addition, the Director-General’s Requirements issued by DoP identifies subsidence as a key issue for consideration within the *Environmental Assessment*.

The following subsections present a summary of existing conditions and impacts associated with subsidence, the method of assessment, predictions of subsidence and subsidence related impacts, the proposed management of identified sites and an assessment of the significance of the residual impacts (once the proposed management measures are implemented).

4B.1.2 The Existing Environment

4B.1.2.1 Surface Features

An overview of the principal surface features relating to the proposed mine subsidence is outlined as follows.

As noted in Section 4A.3.2, the Mine Site comprises privately owned land, the majority of which is owned by the Proponent and related companies, ie. 3 825ha or approximately 75% of the total area of ML1609. A small proportion of the Mine Site, predominantly with the southwestern corner, occurs within NSW State Forests (Jacks Creek and Pilliga East Stage

Forests). The Mine Site is used primarily for livestock grazing with some cereal crop farming over the eastern half of the Mine Site. The western half of the Mine Site is covered by native woodlands and the Jacks Creek and Pilliga East State Forests.

As noted in Section 4A.1.2, the terrain of the Mine Site is generally flat to undulating in the east with two low-level ridges with moderate slopes (up to 18^{o}) in the west. Two ephemeral creeks (Kurrajong Creek and Pine Creek) and their tributaries drain towards the northeast across ML1609. Elevations above the mining area vary from 270m AHD above the eastern longwall panels to 370m AHD above the western longwall panels.

The maximum slope of approximately 18^{o} occurs along the northeast-southwest trending ridge, with the minimum slopes of $<1^{o}$ common in the northeast, on ridge crests, foot slopes, valley floors and creek channels. No cliff lines are present above the mining area. **Figure 4B.1** illustrates the elevations, slopes and drainage features of the Mine Site.

In order to accurately predict impacts related to subsidence, DGS (2009) assembled an inventory of significant surface, natural and archaeological features. DGS (2009) has identified the following features of significance on the Mine Site.

Natural Features

- The ephemeral tributaries that form the headwaters of Pine Creek (located above the northern longwalls) and Kurrajong Creek (located above the southern longwalls). All tributaries of the two creeks drain the Mine Site generally in a northeasterly direction.
- Sandy alluvial deposits (up to 15m deep) are present along the creek channels with virtually no rock exposures evident.
- The silty sand and sandy clay surface soils present on the Mine Site display moderate erodibility and may be susceptible to erosion if exposed to concentrated runoff.
- Vegetation over the relatively undisturbed western half of the underground mine area consists of low mallee woodland with a dense shrub layer to open forest with sparse shrub layer. This vegetation merges with the cleared agricultural land to form partially cleared and disturbed woodland dominated by species adapted to, or tolerant of drier conditions, with occasional inundation due to flooding. Riparian zones along creeks within the predominantly cleared agricultural land over the eastern two thirds of the Mine Site provide partially cleared but relatively intact open forest to woodland dominated by casuarinas and species adapted to higher water availability. Section 4B.4 provides further detail on the vegetation of the Mine Site.
- Notably, there is a lack of significant rock outcropping or rock features such as caves or overhangs on the Mine Site.

Archaeological Features

- Aboriginal heritage features that are present across the Mine Site include open scatters of up to 100+ artefacts, isolated artefacts, axe grinding grooves and scarred trees. Section 4B.5.3 provides greater detail on the type and distribution of Aboriginal Sites across the Mine Site.

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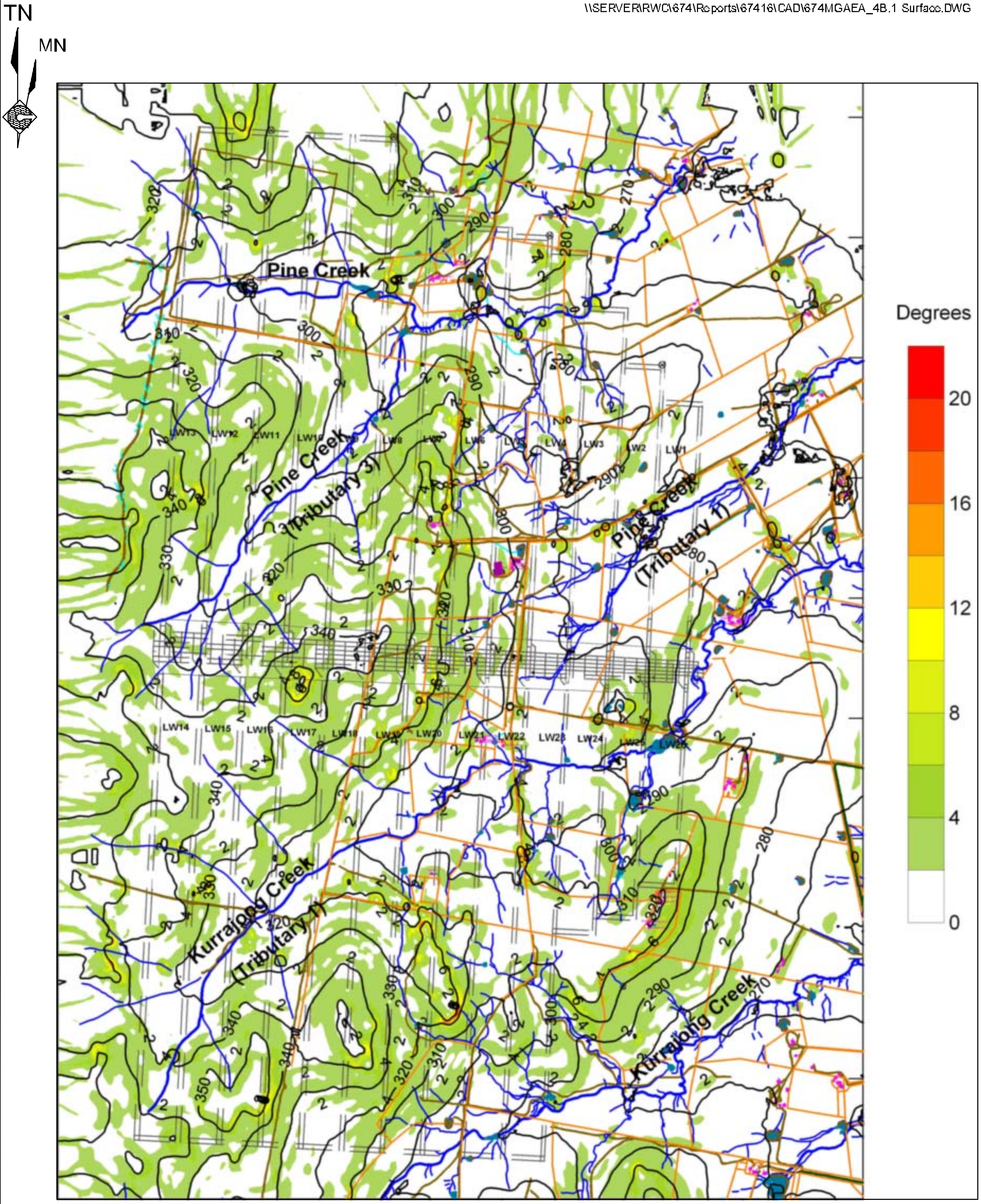

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Source: DGS (2009) - Figure 5

Figure 4B.1
MINE SITE SURFACE ELEVATIONS, SLOPES AND DRAINAGE FEATURES

Developed Features

Buildings, in particular residences, on the rural properties above the underground mine area. **Figure 4A.4** provides the locations of the three residences above the underground mine, all of which are owned by Narrabri Coal Pty Ltd.

- Soil conservation structures, eg. contour banks.
- Earth embankment dams for the watering of livestock.
- Unsealed gravel access roads and access tracks.
- Property boundary-line fences.
- Single-phase suspended power lines (for domestic power supply).
- Suspended Telstra telephone lines.

These features have all been considered in the assessment of subsidence-related impacts.

4B.1.2.2 Sub-Surface Conditions

Subsidence is influenced not only by the type and scale of longwall mining, but also by the type and condition of the geological strata above the area mined. The following considers the sub-surface conditions, specifically with respect to how these conditions may influence the prediction of subsidence.

As noted in Section 2.2.1, the Mine Site is situated within the Mullalley Sub-basin, which is in the northern part of the Gunnedah Basin. The sub-basin contains Permian to Jurassic Age sedimentary and igneous strata overlying the Hoskissons Coal Seam, which generally dips westwards at approximately 2^{o}. Several northwest to southwest and northeast to northwest trending normal and reverse faults, which have throws ranging from 1m to 5m, ie. less than half the coal seam thickness, have been identified within the mining area. A typical profile of the Mine Site stratigraphy is provided by **Figure 2.3**.

Typically, the geological strata above the Hoskissons Coal Seam comprises thin to medium bedded siltstone / sandstone laminite with minor claystone (Pilliga Sandstone, Purlawaugh Formation and Napperby Formation) between several massive 15m to 40m thick units of conglomerate (Digby Formation), basalt sills and lava flows (Garrawilla Volcanics). The depth of cover above the Hoskissons Coal Seam ranges from 160m to 380m with the depth of weathering typically varying from about 15m to 35m from the surface. Through a review of the available exploration data, DGS (2009) determined that the potential subsidence reducing 'massive' units in the overburden are the conglomerate of the Digby Formation, the intrusive basalt sill in the Napperby Formation and basalt lava flows of the Garrawilla Volcanics.

A summary of the thickness of the massive units in descending order from surface is presented in **Table 4B.1**.

Table 4B.1
Summary of Massive Strata Units of the Mining Area

Lithological Unit	Massive Unit Thickness (m)	Unit Distance Above the Mining Area (m)	Laboratory UCS Strength Range (Mean) (MPa)
Garrawilla Volcanics*	1 to 62	110 to 250	65 to 252 (140)
Basalt Sill of the Napperby Formation	7 to 27	44 to 80	91 to 189 (140)
Digby Conglomerate	13 to 25	0 to 34	21 to 42 (28)
Note *: The top 1m to 3m may be affected by weathering. Unit may have a maximum thickness of 20m			
Source: Modified after DGS (2009) – Table 1			

Each of the three geological units above the Hoskissons Coal Seam has been assessed for their potential for bridging behaviour. DGS (2009) determined (based on strength testing, empirical data base and an analytical Voussoir Beam model) that only the Garrawilla Volcanics has the potential to bridge the longwall panels and therefore reduce subsidence.

4B.1.3 Subsidence Development Mechanism

After the extraction of coal within a longwall panel, the immediate mine roof usually collapses into the void left by the removal of the coal. The overlying strata or overburden then sags down onto the collapsed material, resulting in settlement of the land surface. **Figure 4B.2** provides an illustration of this mechanism which is discussed in more detail, as follows.

As illustrated on **Figure 4B.2**, the maximum subsidence would occur in the middle of the extracted panel and would be dependent on the following.

- The height of the longwall panel which determines the height of the initial collapse. The longwall panels would be 4.2m high while the gate road headings and chain pillars between the panels would be 3.5m in height.
- The cover depth above each longwall panel influences rock fracture, swelling and bridging, all of which reduce the effect of the initial collapse with height. As noted in Section 4B.1.2.2, cover depths range from 160m in the east up to 380m in the west with a single row of chain pillars to be left between the extracted longwall blocks. The widths of the chain pillars would increase with cover depth from 24.6m in the east to 37.6m in the west.
- The geological properties of the strata above the collapsed section of mine including any massive structures above the longwall panel would influence the bulking characteristics of the collapsed strata, as well as any 'bridging' by the massive units over collapsed rock beneath it. As noted in Section 4B.1.2.2, only the Garrawilla Volcanics are likely to bridge over collapsed strata lower in the sequence.
- Features of surface geology and topography may exacerbate the impacts of surface subsidence through cracking or impacts on structurally vulnerable features such as creeks, caves, overhangs etc.

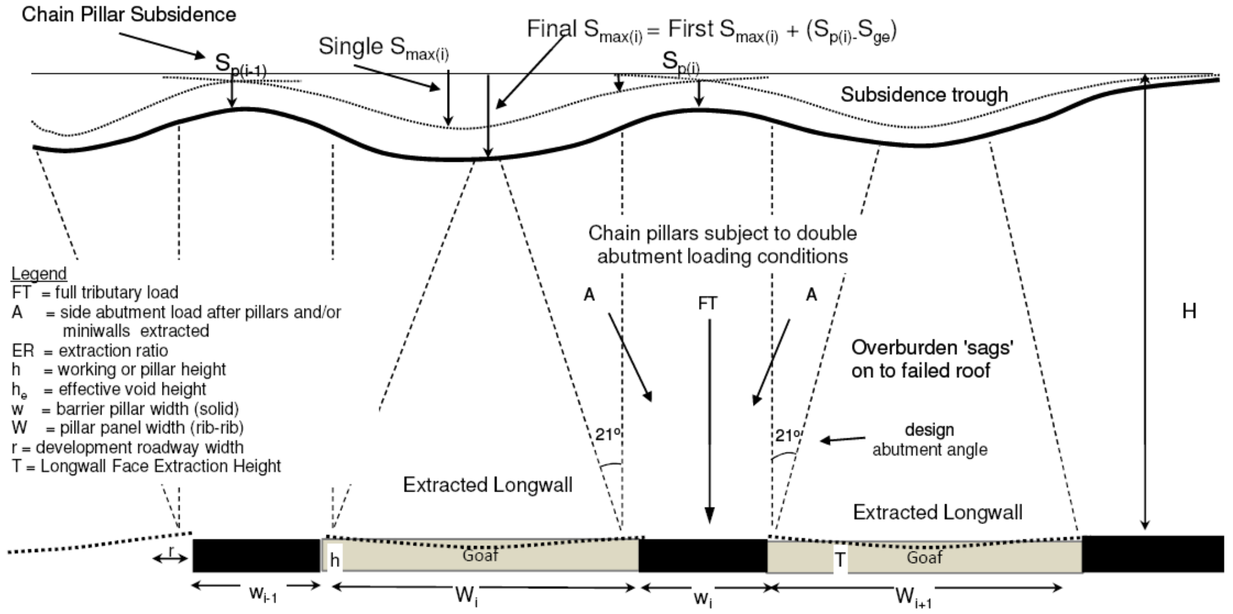


Figure 4B.2
LONGWALL PANEL SUBSIDENCE MECHANISM

Source: DGS (2009) – Figure 13

The combination of the above factors determines whether a single longwall panel would be sub-critical, critical or supercritical in terms of maximum subsidence. The terms sub-critical, critical or supercritical are defined as follows.

- Sub-critical subsidence refers to panels that are narrow and deep enough for the overburden to bridge or 'arch' across the extracted panel regardless of geology. It is also termed 'geometrical' or 'deep beam arching'.
- Critical subsidence refers to panels that are unable to arch without the presence of massive, competent strata, ie. the strata above the panel sags down onto the collapsed or caved roof strata immediately above the extracted seam. If relatively thick and strong massive strata exist, then 'critical arching' or 'shallow Voussoir beam' behaviour can occur for panel W/H ratios up to1.8.
- Supercritical panels refer to panels with widths that cause complete collapse of the overburden.

In Australian coalfields, sub-critical or (geometrical arching) behaviour generally occurs when the panel width (W) is <0.6 times the cover depth (H) and supercritical when W:H > 1.4. Critical behaviour usually occurs between W/H ratios of 0.6 and 1.4 and represents the transition between 'geometrical arching' to 'shallow beam bending' to 'complete failure' of the overburden. The maximum subsidence for sub-critical and critical panel widths is < 60% of the longwall extraction height and could range between 10% and 40% (of the extraction height).

With an ultimate panel width of 305m (including the gate road heading either side) and cover depth of between 160m and 380m, the W/H ratio varies from 0.8 in the west to 1.9 in the east and falls outside the sub-critical range. However, it is possible that the Garrawilla Volcanics may bridge over the collapsed lower strata creating sub-critical behaviour in some or all of the longwall panels. This assessment has considered both sub-critical and critical longwall behaviour.

The surface effect of extracting several adjacent longwall panels is dependent on the stiffness of the overburden and the dimensions of the chain pillars left between the panels. Invariably, 'extra' subsidence occurs above a previously extracted panel and is caused primarily by the compression of the chain pillars and adjacent strata between the extracted longwall panels.

A longwall chain pillar undergoes the majority of life-cycle compression when subject to double abutment loading, ie. the formation of goaf on both sides of it, after two adjacent panels have been extracted. Surface survey data indicates that an extracted panel can affect the chain pillars between three or four previously extracted panels. The stiffness of the overburden and chain pillar system would determine the extent of load transfer to the preceding chain pillars. If the chain pillars go into yield, the load on the pillars would be mitigated to some extent by load transfer to adjacent fallen roof material or goaf.

The surface subsidence would extend beyond the limit of underground mining for a certain distance (i.e. the angle of draw). The angle of draw distance is usually less than or equal to 0.5 to 0.7 times the depth of cover (or angles of draw to the vertical of 26.5^o to 35^o) in the NSW and Queensland Coalfields.

4B.1.4 Potential Impacts and Management Issues

As a result of subsidence, the following impacts could be expected. Each of these is considered in relation to the subsidence predictions of DGS (2009) in Section 4B.1.6.

Surface Cracking

The development of surface cracking above a longwall panel is caused by the bending of the overburden strata as it sags down into the newly created void in the coal seam. The sagging strata is initially supported by previously collapsed roof material (goaf), which then slowly compresses to a maximum subsidence.

The tensile fractures generally occur between the chain pillars and the point of inflexion, which is where convex curvatures and tensile strains would develop. Compressive shear fractures or shoving zones would generally also develop in the area above the longwall panel and inside the inflexion points.

Sub-surface Cracking

The caving and subsidence development processes above a longwall panel usually results in sub-surface fracturing and shearing of sedimentary strata in the overburden (see **Figure 4B.2**). The extent of fracturing and shearing is dependent on mining geometry and overburden geology. As illustrated on **Figure 4B.2**, sub-surface fracturing may be defined as either 'continuous' or 'discontinuous' hydraulic fracturing.

Continuous sub-surface fracturing refers to cracking above a longwall panel that would provide a direct flow-path or hydraulic connection to the workings if a sub-surface aquifer (or surface) were intersected. The presence of sub-surface aquifers above the workings and within the continuous fracture zone could therefore result in increased water inflow into the seam level during longwall extraction.

Discontinuous fracturing refers to the additional extent above a longwall to which there could be a general increase in horizontal and vertical permeability, due to bending or curvature deformation of the rock mass. This type of fracturing does not usually provide a direct flow path or connection to the workings, however, it is possible that they would interact with surface cracks, joints, or faults. This type of fracturing can also result in an adjustment of:

- surface and sub-surface flow paths; and
- rock mass conductivity and storage magnitudes, but may not result in a significant change to the groundwater or surface water resource in the long-term.

Slope Stability and Erosion

As a consequence of changes in surface slopes and drainage paths, erosion may be accelerated leading to possible en-masse sliding, ie. a landslip, of the ridges or hills of the Mine Site. The occurrence or scale of erosion and/or landslip is likely to be influenced by soil type and pre-subsidence slopes with dispersive soils and slopes >10º more susceptible to these impacts.

Valley Closure and Uplift

'Valley closure' (or opening) movements can be expected along cliffs and sides of deep valleys wherever longwalls are mined beneath them. Valley closure can also occur across broader drainage gullies where shallow surface rock is present.

When creeks and river valleys are subsided, the observed subsidence in the base of the creek or river is generally less than would normally be expected in flat terrain. This reduced subsidence is due to the floor rocks of a valley buckling upwards when subject to compressive stresses generated by surface deformation. This phenomenon is termed as 'valley uplift'. In most cases in the Newcastle and Southern NSW Coalfields, the observed uplift has extended outside steep sided valleys and included the immediate cliff lines and the ground beyond them.

Ponding and Other Impacts on Local Drainage

Surface slopes in the elevated areas of the Mine Site range between 1° and 18° and are unlikely to be affected by ponding caused by closed form depressions from subsidence trough development, ie. the net fall across the area would therefore be sufficient to allow surface drainage to continue unimpeded after mining is completed.

Some watercourses present within the Mine Site, however, occur where the surface slope is considerably less than 1º and these could be susceptible to potential ponding depths of between 0.5m and 1.5m. The actual ponding depths would depend upon several other factors, such as rain duration, surface cracking and effective percolation rates of the surface soils and fractured rock bars/outcrops along the creeks.

In some instances, the ponding effect could result in a change to the alignment of the creek or tributary. This could impact on local erosion processes and impact on the vegetation along the pre-subsidence and altered drainage line.

Far-Field Horizontal Displacements

Horizontal movements due to longwall mining have been recorded at distances well outside of the angle of draw in the Newcastle, Southern and Western Coalfields. Horizontal movements recorded beyond the angle of draw are referred to as far-field horizontal displacements.

This phenomenon is strongly dependent on:

- cover depth;
- distance from the goaf edges;
- the maximum subsidence over the extracted area;
- topographic relief; and
- the horizontal stress field characteristics.

An empirical model for predicting Far-field displacement (FFDs) indicates that measurable FFD movements, ie. 20mm, generally occur in relatively flat terrain for distances up to three to four times the cover depth. The direction of the movement is generally towards the extracted area, but can vary due to the degree of regional horizontal stress adjustment around extracted area and the surface topography.

Aboriginal Artefacts

As a consequence of the potential impacts identified above, in particular surface cracking, Aboriginal artefacts may be damaged or vertically or laterally displaced.

Surface Infrastructure

As a consequence of the changing elevation caused by subsidence, or the potential impacts such as surface cracking and erosion resultant from erosion, surface infrastructure such as houses and other buildings, roads, pipelines, services (eg. power / telephone) and water management structures such as dams and contour banks may be damaged.

4B.1.5 Subsidence Modelling

4B.1.5.1 Subsidence Prediction Methodology

Subsidence Models

DGS (2009) used two empirically based prediction models (ACARP, 2003 and SDPS®, 2007) to generate subsidence contours above the proposed longwall panels after mining is complete. A summary of these two models is as follows.

- **ACARP, 2003.** An empirical model originally developed for predicting maximum single and multiple longwall panel subsidence, tilt, curvature and strain in the Newcastle Coalfield. The model database included measured subsidence parameters and overburden geology data which have been back analysed to predict the subsidence reduction potential (SRP) of massive lithology in terms of 'Low', 'Moderate' and 'High' SRP categories.

- The model database also includes chain pillar subsidence, inflexion point distance / subsidence, goaf edge subsidence and angle of draw prediction models, which allow subsidence profiles to be generated for any number of panels and a range of appropriate confidence limits. The Upper 95% Confidence Limit (U95%CL) has been adopted in this study for predictions of the Credible Worst-Case values.

- The model has been recently updated by Ditton Geotechnical Services Pty Ltd to allow the original model to be applied to other Australian Coalfields (including the Gunnedah Basin) due to its generic nature. DGS (2009) provides the detail of the model modification undertaken to improve compatibility between the ACARP, 2003 prediction model and the SDPS®, 2007 model.

- **SDPS®, 2007.** Developed as an influence function model for subsidence predictions above longwalls or pillar extraction panels. The model requires calibration to measured subsidence profiles to reliably predict the subsidence and differential subsidence profiles required to assess impacts on surface features.

- The value of this model is that it includes a database of percentage of hard rock, ie. massive sandstone / conglomerate, that effectively reduces subsidence above super-critical and sub-critical panels due to either bridging or bulking of collapsed material.

- Subsidence, tilt, horizontal displacement, and strain contours were ultimately produced using the modelled results of the SDPS®, 2007 model.

Further detail on the use of both models for the proposed Longwall Project is provided by DGS (2009).

Modelling Methodology

Using the two empirical prediction models, DGS (2009) produced total and differential subsidence predictions across the Mine Site at the following time sequence intervals:

- after each longwall block has been extracted, and

- after mining of all of the proposed longwall panels is complete.

Without prior experience longwall mining the Hoskissons Coal Seam, the following parameters influencing subsidence were considered.

- The subsidence reduction potential (SRP) of the overburden and the influence of proposed mining geometry on single panel subsidence development, ie. whether the panels are likely to be sub-critical, critical or supercritical. As noted in Section 4B.1.2.2, the Garrawilla Volcanics displays spanning potential that may influence the development of subsidence impacts, although the level of this influence is not known.

- The behaviour of the chain pillars and immediate roof and floor system under double-abutment loading conditions when longwall panels have been extracted along both sides of the pillars.

- The combined effects of single panel and chain pillar subsidence to estimate final subsidence profiles and subsidence contours for subsequent environmental impact assessment.
- In order to account for these uncertainties in model parameters and subsidence development, DGS (2009) considered the modelling predictions of the following three cases.
  - Case 1: Non-spanning Garrawilla Volcanics and maximum chain pillar subsidence.
  - Case 2: Spanning Garrawilla Volcanics (where thick enough) and maximum chain pillar subsidence.
  - Case 3: Non-spanning Garrawilla Volcanics and minimum chain pillar subsidence.

DGS (2009) based maximum panel and chain pillar subsidence predictions for the three cases on 'Credible Worst Case' values derived from ACARP (2003). The term 'Credible Worst Case' infers that the predictions would be exceeded by 5% of panels mined with similar geometry and geology etc., and is identified as the Upper 95% Confidence Limit (U95%CL) value.

Minimum values have been based on the 'mean' values derived from the ACARP (2003). The term 'mean' infers that the predictions would be exceeded by 50% of panels mined with similar geometry and geology etc., and is identified as the 50% Confidence Limit value.

4B.1.5.2 Results of Subsidence Modelling

DGS (2009) predicts single panel, chain pillar, goaf edge and multi-panel subsidence values for each of the three modelled cases.

Single Panel Subsidence

Based on an assumed SRP of 'Low', 'Moderate' and 'High', and a longwall extraction height (T) of 4.2m, DGS (2009) provides the predicted single panel subsidence for each longwall panel. **Table 4B.2** provides the mean and U95%CL subsidence for Cases 1 and 2 predicted by DGS (2009).

Table 4B.2
Predicted Maximum Single Panel Subsidence

Page 1 of 2

Longwall Panel No.	Cover Depth (m)	W/H	Unit (m)	SRP	Case 1		Case 2	
					Mean	U95%CL	Mean	U95%CL
1	165	1.85	30	H	2.40	2.44	1.93	2.14
2	175	1.75	30	H	2.44	2.44	1.81	2.02
3	195	1.57	20	M	2.41	2.44	2.19	2.40
4	210	1.45	15	L	2.33	2.44	2.33	2.44
5	230	1.33	20	H	2.24	2.44	1.93	2.14
6	250	1.22	35	H	2.18	2.39	1.75	1.96
7	275	1.11	40	M	2.12	2.33	1.96	2.33
8	290	1.05	40	M	2.06	2.27	1.87	2.27
9	290	1.05	40	M	2.06	2.27	1.87	2.27
10	300	1.02	40	M	2.02	2.23	1.81	2.23

Table 4B.2 (Cont'd)
Predicted Maximum Single Panel Subsidence

Page 2 of 2

Longwall Panel No.	Cover Depth (m)	W/H	Unit (m)	SRP	Case 1		Case 2	
					Mean	U95%CL	Mean	U95%CL
11	310	0.99	40	L	1.99	2.20	1.99	2.20
12	330	0.93	35	L	1.92	2.13	1.92	2.13
13	360	0.85	30	L	1.80	2.01	1.80	2.01
14	365	0.84	35	L	1.77	1.98	1.77	1.98
15	345	0.89	38	L	1.88	2.09	1.88	2.09
16	335	0.91	42	M	1.91	2.12	1.64	1.85
17	310	0.99	42	M	1.99	2.20	1.76	1.97
18	290	1.05	42	M	2.06	2.27	1.87	2.08
19	265	1.15	41	M	2.14	2.35	1.96	2.17
20	251	1.22	30	L	2.19	2.40	2.18	2.39
21	230	1.33	25	M	2.24	2.44	1.93	2.14
22	215	1.42	20	M	2.31	2.44	2.01	2.22
23	200	1.53	20	M	2.38	2.44	2.14	2.35
24	200	1.53	20	M	2.38	2.44	2.14	2.35
25	195	1.57	20	M	2.41	2.44	2.19	2.40
26	185	1.65	25	M	1.77	1.98	2.25	2.44
Source: Modified after DGS (2009) – Table 3								

Chain Pillar Subsidence

The predicted mean and maximum subsidence values above the proposed chain pillars (under double abutment loading conditions and a mining height of 4.2m) predicted by the empirical modelling of DGS is summarised in **Table 4B.3**.

Table 4B.3
Predicted Chain Pillar Subsidence

Page 1 of 2

Longwall Panel No.	Cover Depth (m)	Chain Pillar Width (m)	Chain Pillar Stress (MPa)	Pillar FoS under DA[1] Loading Conditions	Subsidence			
					Cases 1 and 2		Case 3	
					Initial Subsidence (U95%CL)	Final Subsidence (U95%CL)	Initial Subsidence (mean)	Final Subsidence (mean)
1	165	24.6	17.3	1.51	0.46	0.51	0.26	0.31
2	175	24.6	19.8	1.32	0.53	0.59	0.33	0.39
3	195	24.6	23.3	1.13	0.63	0.72	0.43	0.51
4	210	29.6	23.2	1.42	0.63	0.71	0.43	0.51
5	230	29.6	27.0	1.22	0.75	0.86	0.55	0.66
6	250	29.6	31.5	1.05	0.89	1.03	0.69	0.82
7	275	29.6	36.0	0.92	1.00	1.16	0.80	0.96
8	290	34.6	33.6	1.24	0.94	1.09	0.74	0.89
9	290	34.6	34.4	1.21	0.96	1.12	0.76	0.91
10	300	34.6	36.5	1.14	1.01	1.17	0.81	0.97
11	310	37.6	37.1	1.28	1.02	1.18	0.82	0.98
12	330	37.6	42.2	1.13	1.10	1.28	0.90	1.08
14	365	37.6	45.1	1.05	1.13	1.32	0.93	1.11
15	345	37.6	41.7	1.14	1.09	1.27	0.89	1.07
16	335	34.6	40.8	1.02	1.08	1.26	0.88	1.06
17	310	34.6	35.9	1.16	1.00	1.16	0.80	0.95
18	290	34.6	31.5	1.32	0.89	1.03	0.69	0.82
19	265	29.6	30.7	1.08	0.86	1.00	0.66	0.79
20	245	29.6	27.1	1.22	0.75	0.86	0.55	0.66
21	230	29.6	24.2	1.37	0.66	0.75	0.46	0.55

Table 4B.3 (Cont'd)
Predicted Chain Pillar Subsidence

Page 2 of 2

Longwall Panel No.	Cover Depth (m)	Chain Pillar Width (m)	Chain Pillar Stress (MPa)	Pillar FoS under DA[1] Loading Conditions	Subsidence			
					Cases 1 and 2		Cases 1 and 2	
					Initial Subsidence (U95%CL)	Initial Subsidence (U95%CL)	Initial Subsidence (U95%CL)	Initial Subsidence (U95%CL)
22	215	29.6	21.5	1.54	0.58	0.65	0.37	0.45
23	200	24.6	23.0	1.14	0.62	0.71	0.42	0.50
24	200	24.6	22.6	1.16	0.61	0.69	0.41	0.49
25	180	24.6	21.2	1.23	0.57	0.64	0.37	0.44

Notes:
1. DA = Double abutment loading conditions.
2. The chain pillars referred to in the above table are on the Maingate side. As LW13 and LW26 are the last panels mined in the northern and southern panel series, they would not be subject to double abutment loading conditions, because they are adjacent to solid coal

Source: Modified after DGS (2009) – Table 4

The predicted initial subsidence over the chain pillars between the extracted panels is estimated to range from 0.26m to 1.32m for the range of pillar sizes and geometries proposed. The final subsidence over the chain pillars (after mining is completed) is estimated to range from 0.31m to 1.58m (an overall increase of 20%).

Goaf Edge Subsidence

DGS (2009) reports the mean and maximum goaf edge subsidence to be 0.07m to 0.58m respectively.

Multiple Panel Subsidence

Based on the single panel, chain pillar and goaf edge subsidence predictions, **Tables 4B.4** and **4B.5** present the maximum (Credible Worst Case) first and final maximum multi-panel subsidence predictions (and associated impact parameters) for Cases 1 and 2.

Table 4B.4
Predicted Credible Worst-Case First and Final Maximum Panel Subsidence Parameters (Case 1)

Page 1 of 2

Longwall Panel No.	Cover Depth (m)	Panel Width: Cover Depth Ratio	Predicted Subsidence					Max Tilt T_{max} (mm/m)	Max Curvature, C_{max} (km^{-1})		Maximum Strain, E_{max} (mm/m)*	
			Final Goaf Edge (m)	Single Panel S_{max} (m)	First Pillar S_p (m)	First Panel S_{max} (m)	Final Panel S_{max} (m)		Convex	Concave	Tensile	Compressive
1	165	1.85	0.22	2.44	0.46	2.44	2.44	45	1.05	1.36	11	14
2	175	1.75	0.22	2.44	0.53	2.44	2.44	41	0.95	1.20	9	12
3	195	1.57	0.22	2.44	0.63	2.44	2.44	35	0.76	0.97	8	10
4	210	1.45	0.22	2.44	0.63	2.44	2.44	32	0.63	0.84	6	8
5	230	1.33	0.24	2.44	0.75	2.44	2.44	30	0.56	0.78	6	8
6	250	1.22	0.28	2.39	0.89	2.44	2.44	30	0.55	0.78	5	8
7	275	1.11	0.34	2.33	1.00	2.44	2.44	30	0.53	0.78	5	8
8	290	1.05	0.38	2.27	0.94	2.44	2.44	30	0.52	0.78	5	8
9	290	1.05	0.38	2.27	0.96	2.44	2.44	30	0.52	0.78	5	8
10	300	1.02	0.40	2.23	1.01	2.44	2.44	30	0.51	0.78	5	8
11	310	0.99	0.43	2.20	1.02	2.44	2.44	30	0.50	0.78	5	8
12	330	0.93	0.49	2.13	1.10	2.44	2.44	30	0.48	0.78	5	8
13	360	0.85	0.58	2.01	-	2.40	2.44	30	0.45	0.78	5	8

Table 4B.4 (Cont'd)
Predicted Credible Worst-Case First and Final Maximum Panel Subsidence Parameters (Case 1)

Page 2 of 2

Longwall Panel No.	Cover Depth (m)	Panel Width: Cover Depth Ratio	Predicted Subsidence: Final Goaf Edge (m)	Single Panel S_{max} (m)	First Pillar S_p (m)	First Panel S_{max} (m)	Final Panel S_{max} (m)	Max Tilt T_{max} (mm/m)	Max Curvature, C_{max} (km^{-1}): Convex	Concave	Maximum Strain, E_{max} (mm/m)*: Tensile	Compressive
14	365	0.84	0.59	1.98	1.13	2.04	2.44	30	0.44	0.78	4	8
15	345	0.89	0.53	2.09	1.09	2.44	2.44	30	0.47	0.78	5	8
16	335	0.91	0.50	2.12	1.08	2.44	2.44	30	0.48	0.78	5	8
17	310	0.99	0.43	2.20	1.00	2.44	2.44	30	0.50	0.78	5	8
18	290	1.05	0.38	2.27	0.89	2.44	2.44	30	0.52	0.78	5	8
19	265	1.15	0.32	2.35	0.86	2.44	2.44	30	0.54	0.78	5	8
20	245	1.25	0.27	2.40	0.75	2.44	2.44	30	0.55	0.78	6	8
21	230	1.33	0.24	2.44	0.66	2.44	2.44	30	0.56	0.78	6	8
22	215	1.42	0.22	2.44	0.58	2.44	2.44	31	0.60	0.80	6	8
23	200	1.53	0.22	2.44	0.62	2.44	2.44	34	0.71	0.92	7	9
24	200	1.53	0.22	2.44	0.61	2.44	2.44	34	0.71	0.92	7	9
25	195	1.57	0.22	2.44	0.57	2.44	2.44	35	0.76	0.97	8	10
26	185	1.65	0.22	2.44	-	2.44	2.44	38	0.85	1.08	8	11

Notes:
Single Panel S_{max}: Maximum surface subsidence predicted for a single, isolated longwall panel.
Final Panel S_{max}: Estimated final subsidence for a given panel (including chain pillar compression effects) after all longwall panels have been extracted.
*: Predicted strains are for a surface with a deep soil cover and likely to have 'smooth' profile strains. A surface with rock exposures is likely to cause strain concentrations which are 2 x 'smooth' profile strains.
Source: Modified after DGS (2009) – Tables 6A and 6B

Table 4B.5
Predicted Credible Worst-Case First and Final Maximum Panel Subsidence Parameters <u>with</u> Spanning Garrawilla Volcanics (Case 2)

Page 1 of 2

Longwall Panel No.	Cover Depth (m)	Panel Width: Cover Depth Ratio	Predicted Subsidence: Final Goaf Edge (m)	Single Panel S_{max} (m)	First Pillar S_p (m)	First Panel S_{max} (m)	Final Panel S_{max} (m)	Max Tilt T_{max} (mm/m)	Max Curvature, C_{max} (km^{-1}): Convex	Concave	Maximum Strain, E_{max} (mm/m)*: Tensile	Compressive
1	165	0.02	0.41	0.26	0.41	0.70	0.70	6	0.21	0.26	2	3
2	175	0.03	0.44	0.33	0.56	0.93	0.93	8	0.24	0.31	2	3
3	195	0.07	2.19	0.43	2.32	2.44	2.44	25	0.51	0.65	5	6
4	210	0.07	2.33	0.43	2.44	2.44	2.44	23	0.44	0.56	4	6
5	230	0.09	1.93	0.55	2.11	2.44	2.44	22	0.41	0.52	4	5
6	250	0.07	0.53	0.69	0.79	1.58	1.58	12	0.26	0.34	3	3
7	275	0.10	0.55	0.80	0.88	1.78	1.78	14	0.30	0.38	3	4
8	290	0.11	0.52	0.74	0.90	1.73	1.73	13	0.29	0.37	3	4
9	290	0.11	0.48	0.76	0.83	1.70	1.70	13	0.28	0.36	3	4
10	300	0.12	0.44	0.81	0.80	1.72	1.72	13	0.29	0.36	3	4
11	310	0.13	0.37	0.82	0.76	1.68	1.68	13	0.28	0.36	3	4
12	330	0.16	0.47	0.90	0.86	1.86	1.86	15	0.31	0.39	3	4
13	360	0.18	0.62	-	1.04	1.64	1.64	12	0.27	0.35	3	3
14	365	0.17	0.46	0.93	0.46	1.52	1.52	11	0.26	0.32	3	3
15	345	0.18	0.35	0.89	0.80	1.79	1.79	14	0.30	0.38	3	4
16	335	0.16	0.30	0.88	0.73	1.72	1.72	13	0.29	0.37	3	4
17	310	0.12	0.30	0.80	0.72	1.62	1.62	12	0.27	0.34	3	3
18	290	0.10	0.36	0.69	0.74	1.52	1.52	11	0.25	0.32	3	3
19	265	0.08	0.40	0.68	0.73	1.51	1.51	11	0.25	0.32	3	3
20	245	0.11	1.49	0.57	1.79	2.40	2.40	21	0.40	0.51	4	5
21	230	0.08	1.46	0.46	1.72	2.22	2.22	19	0.37	0.47	4	5
22	215	0.07	2.01	0.37	2.20	2.44	2.44	22	0.42	0.53	4	5

Table 4B.5 (Cont'd)
Predicted Credible Worst-Case First and Final Maximum Panel Subsidence Parameters with Spanning Garrawilla Volcanics (Case 2)

Page 2 of 2

Longwall Panel No.	Cover Depth (m)	Panel Width: Cover Depth Ratio	Predicted Subsidence					Max Tilt T_{max} (mm/m)	Max Curvature, C_{max} (km^{-1})		Maximum Strain, E_{max} (mm/m)*	
			Final Goaf Edge (m)	Single Panel S_{max} (m)	First Pillar S_p (m)	First Panel S_{max} (m)	Final Panel S_{max} (m)		Convex	Concave	Tensile	Compressive
23	200	0.07	2.14	0.42	2.29	2.44	2.44	24	0.48	0.61	5	6
24	200	0.07	2.14	0.41	2.31	2.44	2.44	24	0.48	0.61	5	6
25	195	0.07	2.19	0.37	2.36	2.44	2.44	25	0.51	0.65	5	6
26	185	0.03	0.67	-	0.85	1.02	1.02	8	0.24	0.30	2	3

Notes:
Single Panel S_{max}: Maximum surface subsidence predicted for a single, isolated longwall panel.
Final Panel S_{max}: Estimated final subsidence for a given panel (including chain pillar compression effects) after all longwall panels have been extracted.
*: Predicted strains are for a surface with a deep soil cover and likely to have 'smooth' profile strains. A surface with rock exposures is likely to cause strain concentrations which are 2 x 'smooth' profile strains.
Source: Modified after DGS (2009) – Tables 7A and 7B

The predicted multi-panel subsidence impacts are illustrated on **Figures 4B.3** and **4B.4** for Cases 1 and 2. Derived from the mean goaf edge subsidence predictions, DGS (2009) estimates the angel of draw to range from 10º to 26.5º, where the angle of draw (AoD) is the angle from the vertical of the line drawn between the tailgate edge of the longwall panel to the 20mm subsidence contour[1] at the surface. Based on these AoDs, DGS (2009) anticipates that subsidence would extend the following distances beyond the limit of mining.

- 150m to 220m beyond the western boundary (23^o to 31^o draw angle).
- 35m to 70m beyond the eastern boundary (12^o to 21^o draw angle).
- 130m to 200m beyond the northern and southern boundaries at the western end, reducing to 35m to 70m in the east (12^o to 31^o draw angle).

Section 4B.1.6 provides an assessment of these results.

Reliance would be placed upon the monitoring to confirm the angle of draw well ahead of the commencement of Panels LW9 to LW13 to ensure that subsidence exceeding 20mm is confined within the northern boundary of ML1609.

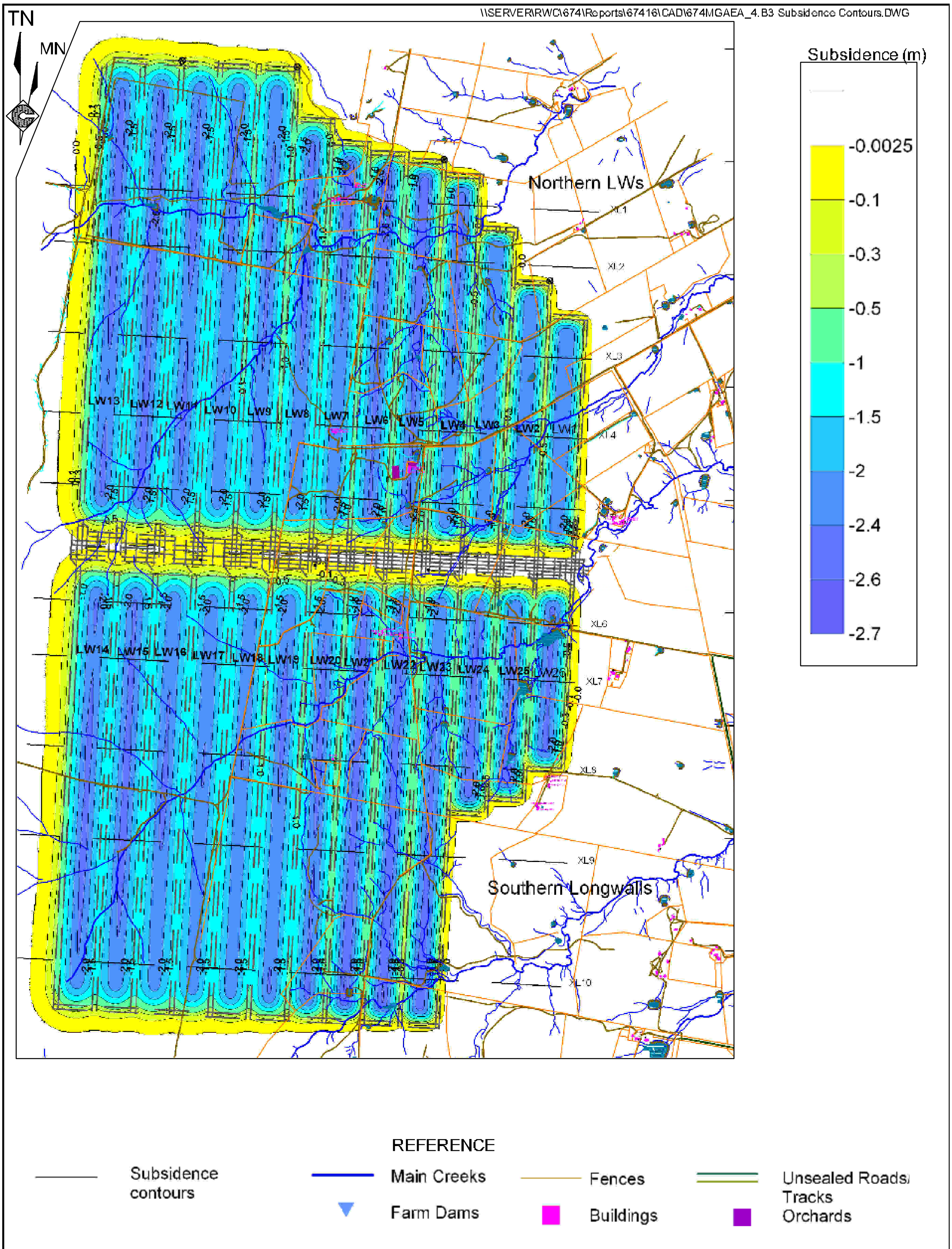
4B.1.6 Assessment of Impacts and Management

4B.1.6.1 Surface Cracking

Predicted Impacts

Surface cracks caused by tensile fractures generally occur between the chain pillars and the point of inflexion, which is where convex curvatures and tensile strains would develop. Based on the predicted panel subsidence and tilt (see **Tables 4B.4** and **4B.5**), the point of inflexion is assessed to be located 20m to 60m from the panel ribs for the range of mining geometries proposed. Tensile fractures can also develop above chain pillars that are located between extracted panels.

1 The 20 mm subsidence contour is an industry defined limit and represents the practical measurable limit of subsidence.



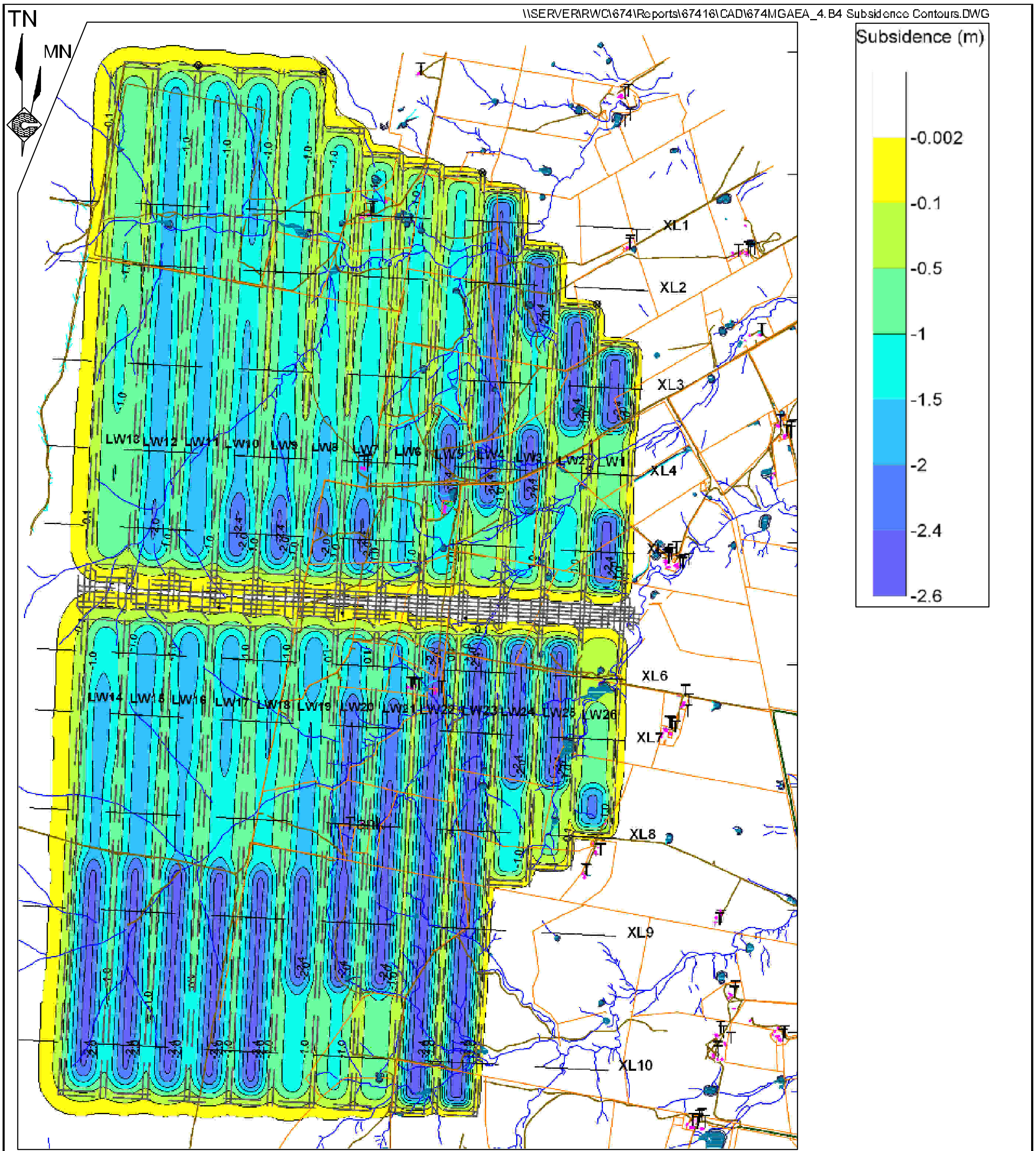
SCALE 1:50 000

0.5 0 0.5 1.0 1.5 2.0 2.5 km

Source: DGS (2009) - Figure 35

Figure 4B.3
PREDICTED MINE SUBSIDENCE CONTOURS (CASE 1)

\\SERVER\RWC\674\Reports\67416\CAD\674MGAEA_4.B4 Subsidence Contours.DWG



REFERENCE

Subsidence contours

Main Creeks

Farm Dams

Fences

Buildings

Unsealed Roads, Tracks

Orchards

SCALE 1:50 000

0.5 0 0.5 1.0 1.5 2.0 2.5 km

Source: DGS (2009) - Figure 36

Figure 4B.4

PREDICTED MINE SUBSIDENCE CONTOURS (CASE 2)

The compressive shear fractures or shoving zones would generally develop in the area above the longwall panel and inside the inflexion points.

Surface crack widths (in mm) have been estimated by multiplying the predicted strains by 10 (and assuming a 10m distance between survey pegs). Therefore, based on the predicted range of maximum transverse tensile and compressive strains predicted by DGS (2009), ie. 19mm/m to 2mm/m, maximum surface cracking widths of between 20mm and 190mm may occur above the panels. It is acknowledged by both DGS (2009) and in the peer review by Dr Bruce Hebblewhite (see Volume 1, Part 1 of the *Specialist Consultant Studies Compendium*) that the crack widths could be greater than 190mm.

It is noted that the wider cracks would appear in the eastern side of the mining area and the narrower cracks would appear in the western side of the mining area. Strain concentrations in near surface rock, could also double the above crack widths to 40mm and 380mm respectively. The above crack width estimation method assumes all of the strain would concentrate at a single crack between the survey pegs. This could occur where near surface bedrock exists, but is more likely to develop as two or three smaller width cracks, over a tensile zone of 20m in width, in deep alluvial soil profiles. Therefore, the crack widths are expected to be wider on ridges than along sandy-bottomed creek beds.

The cracks in the tensile strain zones would probably be tapered and extend to depths ranging from 5m to 15m, and possibly deeper in near surface rock exposures and ridges. Cracks within compressive strain zones are generally low-angle shear cracks caused by failure and shoving of near surface strata. The cracks would probably have developed by the time the longwall face has retreated past a given location for a distance equal to 1 to 2 times the cover depth.

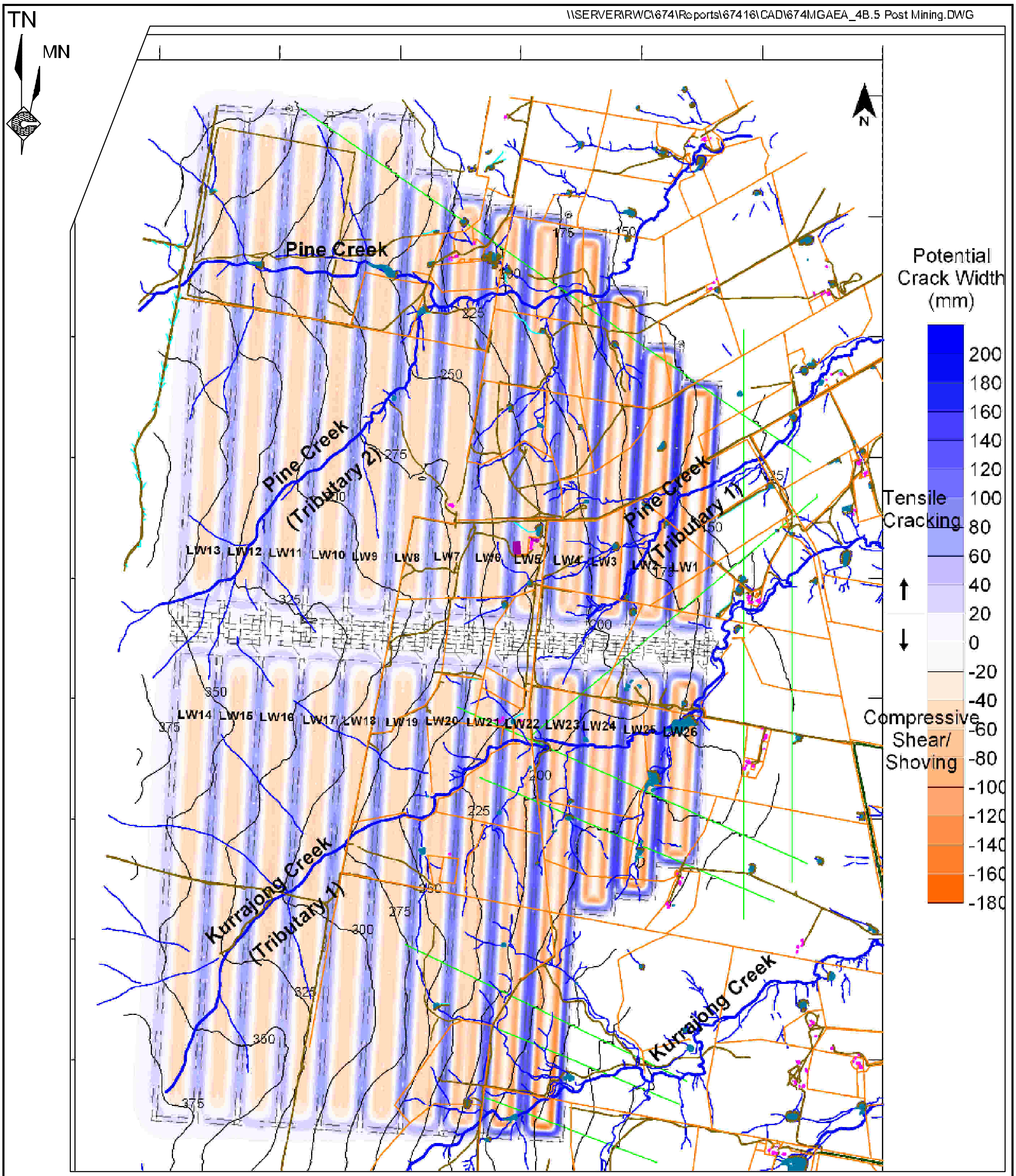
Figure 4B.5 presents the predicted subsidence crack width location zones associated with post-mining tensile and compressive strains for the worst-case scenario (Case 1 – Maximum chain pillar subsidence and non-spanning Garrawilla Volcanics). It is expected that the cracks would be orientated sub-parallel to the sides and ends of each panel, with diagonal cracking at the corners.

Undermining ridges can also result in surface cracks migrating up-slope and outside the limits of extraction for significant distances due to rigid block rotations. This phenomenon depends upon the slope angle, vertical jointing and the subsidence at the toe of the slope. There are few if any ridges within the Mine Site likely to enable upslope migration of cracking.

Proposed Management

The Proponent would regularly monitor areas of the Mine Site likely to be affected by surface cracking (see **Figure 4B.5**). This would involve inspection of the areas on foot, or where access is available by vehicle.

On identification of cracking, the location would be noted but no further action taken at that time as with many smaller width cracks, natural erosive forces are likely to result in these being in-filled naturally. For larger cracks (>100mm) or those persisting without being naturally in-filled, the Proponent would undertake remedial works involve the scarification or light ripping of surface over and both sides of the crack.



* Assuming Non-spanning Garrawilla Volcanics and minimum Chain Pillar Subsidence

SCALE 1:50 000

0.5 0 0.5 1.0 1.5 2.0 2.5 km

Source: DGS (2009) - Figure 41

Figure 4B.5
POST-MINING SURFACE CRACK WIDTH *

In the unlikely event that ripping alone is insufficient to fill in a deeper or wider crack, the Proponent would excavate the required volume of subsoil from stockpiles located at nearby gas drainage or ventilation sites or footprint of the Reject Emplacement Area, transfer it to the crack site and fill it in.

4B.1.6.2 Sub-Surface Cracking

Predicted Impacts

Two heights of fracturing models (A and B) were used by DGS (2009) to:

- ascertain the sensitivity of the predictions; and
- demonstrate which model is more conservative.

The predicted mean and U95%CL values for the continuous and discontinuous sub-surface cracking heights above longwall panels are summarised in **Table 4B.6**.

Table 4B.6
Summary of Predicted Sub-Surface Fracturing Heights

Longwall Panel No.*	**Cover Depth (m)**	**Mining Height, T (m)**	**Single Panel S_{max} (mean) (m)**	**Predicted Fracture Heights (m)**		
				Continuous (A Horizon)		**Discontinuous (B Horizon)** (mean - U95%CL)
				Model A (mean - U95%CL)	**Model B** 21T - 33T	
Northern Longwalls						
1	165	4.2	2.40	69 - 114	**88 - 139**	141 - *170*
2	175	4.2	2.44	69 - 116	**88 - 139**	147 - *177*
3	195	4.2	2.41	67 - 120	**88 - 139**	156 - *190*
4	210	4.2	2.33	64 - 120	**88 - 139**	161 - *198*
5	230	4.2	2.24	63 - 125	**88 - 139**	172 - *212*
6	250	4.2	2.18	68 - 135	**88 - 139**	186 - 230
7	275	4.2	2.12	**73 - 146**	88 - 139	204 - 252
8	290	4.2	2.06	**75 - 152**	88 - 139	213 - 264
9	290	4.2	2.06	**75 - 152**	88 - 139	213 - 264
10	300	4.2	2.02	**76 - 156**	88 - 139	220 - 272
11	310	4.2	1.99	**77 - 160**	88 - 139	226 - 280
12	330	4.2	1.92	**80 - 168**	88 - 139	239 - 296
13	360	4.2	1.80	**81 - 178**	88 - 139	256 - 319
Southern Longwalls						
14	365	4.2	1.77	**81 - 179**	88 - 139	259 - 323
15	345	4.2	1.88	**81 - 174**	88 - 139	248 - 308
16	335	4.2	1.91	**80 - 170**	88 - 139	242 - 300
17	310	4.2	1.99	**77 - 160**	88 - 139	226 - 280
18	290	4.2	2.06	**75 - 152**	88 - 139	213 - 264
19	265	4.2	2.14	**71 - 142**	88 - 139	197 - 243
20	245	4.2	2.19	67 - 132	**88 - 139**	183 - 226
21	230	4.2	2.24	63 - 125	**88 - 139**	172 - 212
22	215	4.2	2.31	62 - 120	**88 - 139**	163 - *201*
23	200	4.2	2.38	66 - 120	**88 - 139**	158 - *193*
24	200	4.2	2.38	66 - 120	**88 - 139**	158 - *193*
25	195	4.2	2.41	67 - 120	**88 - 139**	156 - *190*
26	185	4.2	2.44	69 - 118	**88 - 139**	152 - *184*

Notes:
*: Predictions determined along XL 4 and XL 7 (see **Figure 1** for cross line location)
T: Mining Height
Italics: Discontinuous fracturing may interact with surface cracks if B-Horizon within 15m of surface, resulting in surface flow re-routing.
Bold: Conservative modelling result
Source: Modified after DGS (2009) – Table 10

The results indicate that Model A is generally the more conservative model for cover depths >260m and less conservative for cover depths <260m. Model B predicts direct surface to seam fracturing could occur for cover depths between 88m and 139m.

The results indicate that continuous fracturing from seam to surface would not occur (given the predicted depth of continuous fracturing does not exceed the cover depth of any of the longwall panels). Subsurface aquifers within 110m to 180m above the proposed panels, ie. 50% to 70% of the cover depth, may however, be affected by direct hydraulic connection to the workings, with significant long-term increases to vertical permeability. DGS (2009) notes that the continuous fracture would not extend above the Garrawilla Volcanics, ie. not result in direct hydraulic connection between the groundwater of the Great Artesian Basin Intake Beds and the underground mine.

Table 4B.6 indicates that discontinuous sub-surface fracturing could interact with surface cracks where cover depths are <215m. This accounts for approximately 28% of the mining area. As a result, creek flows could be re-routed to below-surface pathways and re-surfacing down-stream of the mining extraction limits in these areas. DGS (2009) notes, however, that this phenomenon would normally only occur where shallow surface rock is present and is unlikely where deep soil profiles exist. Deep soil profiles occur over that area of the Mine Site where cover depth <215m (LW1 to LW4 and LW 23 to 26) and it is therefore considered unlikely that there would be any interaction between discontinuous sub-surface cracks and local creeks or their tributaries.

The potential impacts of the predicted sub-surface fracturing has been included in groundwater modelling undertaken by Aquaterra (2009), which is summarised in Section 4B.2.5.

Proposed Management

The management of sub-surface cracking impacts on local groundwater is considered as part of the Longwall Project groundwater assessment (see Section 4B.2.5).

4B.1.6.3 Slope Stability and Erosion

Predicted Impacts

The likelihood of en-masse sliding, ie. a landslip, of the ridges or hills over basal siltstone beds tilted by subsidence has been assessed based on landslide risk assessment terminology. The predicted post mining surface slope elevations and gradients for the proposed mining layout are presented in **Figure 4B.6**.

Based on the predictions presented in **Tables 4B.4** and **4B.5**, DGS (2009) indicates that the predicted tilts for the longwall panels are expected to change existing slopes by between 10mm/m and 45mm/m, ie. approximately 1° to 2° (see **Figure 4B.6**). This would indicate that any near surface creek beds might have their dip increased from about 3° to 5° to a range of 4° to 7° on east and west facing slopes within the Mine Site.

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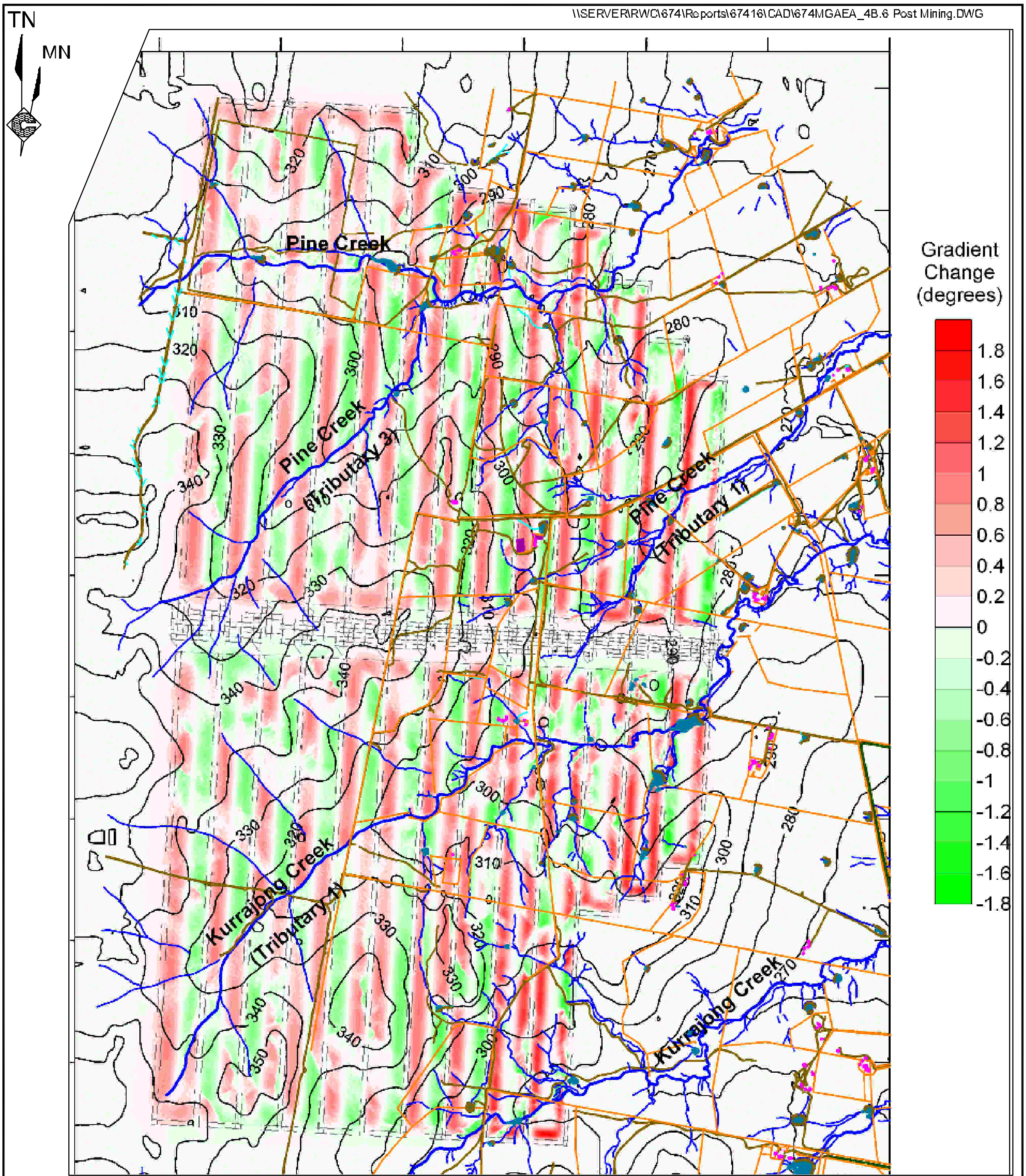

* Assuming Non-spanning Garrawilla Volcanics and minimum Chain Pillar Subsidence

SCALE 1:50 000

0.5 0 0.5 1.0 1.5 2.0 2.5 km

Source: DGS (2009) - Figure 47

Figure 4B.6
POST-MINING SURFACE LEVELS AND GRADIENT CHANGES *

Referring to Factors of Safety (FoS) against en-masse sliding of a natural slope, DGS (2009) calculated that the probability of the minimum recommended FoS for slopes with lower bound material strengths (1.2 to 1.3) being exceeded was 1% to 5%. That is, it is 'very unlikely' that a large scale instability or landslip would occur in the long-term due to the proposed longwall mining. Further, studies in terrain above the NSW coalfields to-date indicate longwall mining in undulating terrain with ground slopes up to 25^o has not resulted in any large scale, en-masse sliding instability due to mine subsidence (or other natural weathering processes etc.)

The predicted impacts of the tilts predicted by DGS (2009) and presented in **Table 4B.4** are also considered 'unlikely' (<10% probability) to cause localised surface slope instability unless mining-induced cracking and increased erosion rates also develop. The areas most susceptible to surface slope instability include any steeply eroded banks of Kurrajong and Pine Creeks and their tributaries on the Mine Site. These may slump or topple if cracks develop through them.

The rate of soil erosion is expected to increase in areas with exposed dispersive/reactive soils and slopes >10°. The topsoil layer of all soil types encountered on the Mine Site do not display significant dispersive tendencies and are therefore unlikely to be at significant risk of soil erosion (directly attributable to subsidence) (GCNRC, 2009). The subsoil layers of all soil types generally tend to display higher dispersion than the topsoil, with this especially evident in the soils derived from the Purlawaugh Formation (which represents less approximately 25% of the soils likely to be affected by subsidence – see **Figure 2.11**). However, as the subsoil layers are unlikely to be disturbed the erosion risk associated with the soils of the Purlawaugh Formation is likely to be minimal.

Areas with slopes <10° (see **Figure 4B.1**) are expected to have low erosion rate increases, except for the creek channels, which would be expected to re-adjust to any changes in gradient. **Figure 4B.7** provides a cross-section along Kurrajong and Pine Creeks illustrating the predicted gradient changes along these watercourses.

Proposed Management

The Proponent would regularly inspect areas of the Mine Site susceptible to landslip of accelerated erosion, eg. drainage lines and steeply sloped areas of exposed Purlwaugh Formation derived subsoils.

While considered unlikely, should large-scale slope instability after mining be identified, the Proponent would undertake stabilisation works, such as the installation of deep sub-surface drainage trenches (to reduce pore pressures) and construct strategic catch drains along slope crests to improve surface run-off.

In the event erosion is identified, in particular along Kurrajong and Pine Creeks and their tributaries, the sections of damaged or steeply eroded banks would be stabilised. Any stabilisation works would be undertaken in accordance with an Erosion and Sediment Control Plan (ESCP) which would be prepared for the Mine Site. It is proposed that the ESCP be prepared in consultation with Narrabri Shire Council and relevant government agencies.