

Taroborah Coal Project

Appendix 10 – Surface Subsidence Report

REPORT TO

Shenhuo International Group Pty Ltd

on the

Surface Subsidence Assessment for the Taroborah Project

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EXECUTIVE SUMMARY

This report provides an assessment of the predicted subsidence due to underground longwall mining at the proposed Taroborah Coal Project (Taroborah).

IMC have predicted subsidence at Taroborah assuming longwall mining based a 3m overall extraction thickness for longwall panels to approximately N 7,400,000. North of this, the coal seam thins to 2.5m and the extraction thickness for modeling purposes is adjusted accordingly.

Longwall mining involves the full extraction of "panels" of coal that are separated by narrow "chain pillars" of coal, which are left in place for support. When coal has been extracted from the panel areas, the strata above each mined-out panel collapses, or caves, into the void and is described as a "goaf". The caving of the immediate strata results in the lowering of the overlying strata all the way up to the surface, and is termed "subsidence".

IMC Mining Group Pty Ltd (IMC) was requested to provide predictions of the likely amount of surface subsidence due to coal extraction of the target B seam, as well as provide a model of the post-mining surface contours for surface water drainage modeling. The nature and extent of other surface subsidence impacts (strain, tilt and cracking at the surface) have also been predicted. This is based largely on IMC experience in similar mining environments, together with empirical industry experience.

Predictions were made based on the site specific geological model data and interpretation of the overburden strata.

IMC have utilised the Surface Deformation Prediction Software (SDPS) to model and predict the magnitude and impact of longwall extraction on the overlying land surface. This modeling has allowed for a prediction of the total subsidence, as well as strains, tilts and curvature of the overlying land surface.

Modelled maximum subsidence of the surface (S_{max}) is summarised as follows:

- For a 3m extraction thickness, a maximum surface subsidence of approximately 1.9m is predicted (63% of extraction thickness); and
- For a 2.5m extraction thickness, a maximum surface subsidence of approximately 1.4m is predicted (56% of extraction thickness).

Figures showing contours of predicted subsidence to illustrate the variation across the mining area are presented in the report. IMC have also provided predictions of strains, tilts and curvatures based on SDPS subsidence model outcomes. As with subsidence, these predictions vary dependent on the mining extraction height and cover depths. These parameters are commonly quoted in subsidence assessments as they are relevant in providing inputs for assessment of the nature and style of surface deformation and cracking. Contoured figures showing predictions of strain, tilt and curvature across the mining area are also presented in the report.

Tensile cracks associated with the tensile strains developed at the chain pillar edges following subsidence are considered likely to extend approximately 35m into the panels either side of the chain pillar edges following the B seam extraction.

IMC anticipate worst case tension cracks as manifested on the ground surface may develop in the order of a maximum width of 0.2 - 0.3m and a maximum depth of approximately 5m. This is largely based on observation and experience at nearby longwall operations. In most cases, subsidence cracking at the surface due to tensile strain is anticipated to be less severe than this. Rehabilitation recommendations are beyond the scope of IMC's work and would require assessment by environmental scientists.

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1 INTRODUCTION

1.1 Scope of Work

IMC Mining Group Pty Ltd (IMC) was requested by Shenhuo International Group Pty Ltd to undertake a subsidence assessment based on the most recent mine layout for the Taroborah Coal project. The target mining seam, in this case, is the B seam.

Work completed and outlined in this report includes:

- An explanation of the subsidence prediction methodology, including key assumptions and limitations;
- A general description of the nature of the surface subsidence predictions – maximum vertical subsidence, strains, tilts and curvatures; and
- A description of the nature and extent of predicted surface cracking, including comparisons with experience from other similar longwall mines.

1.2 Overview of Longwall Mining and Subsidence

Longwall mining involves the progressive extraction of blocks of coal in "panels". These longwall panels are created by driving a set of gate roadways, commonly referred to as entries, from the main heading roadways in the mine. The gate roadways are separated by solid coal, referred to as longwall gate roadway pillars. When the entries have been driven a predetermined length, they are connected and a rectangular longwall block is formed. Figure 1-1 illustrates the formation of longwall panels.

The longwall face is then installed and the coal seam in the panel is entirely extracted as the longwall face retreats back to the original main headings development.

The projected longwall panel widths (the distance between adjacent gate roadways) for proposed workings at Taroborah are typically 300m. For the projected mining height, IMC have considered two extraction scenario as follows.

- For the initial panels up to approximately the, a 3m overall extraction thickness for the longwall is projected.
- For the later panels north of approximately the N 7,400,000 line, the coal seam thins to 2.5m and the longwall extraction thickness for subsidence modeling purposes is adjusted accordingly.

Coal is mechanically extracted from longwall panels using a shearer, which cuts out the panel of coal to a specified height in a series of slices or "web passes". Each web pass is typically 1m or less. The cut coal is collected onto an armoured face conveyor (AFC), and transported from the longwall face via the gate roadway entries and main mine drifts out of the mine.

The roof immediately above the longwall face is supported by a series of hydraulic roof supports, which temporarily hold up the roof strata and provide a working space for the shearing machinery and face conveyor. After each web of coal is removed, the hydraulic roof supports, the face conveyor and the shearing machinery are moved forward an equal distance.

Figure 1-2 shows a cross section of a typical longwall face, illustrating the formation of goaf as the panel of coal is cut by the longwall shearer. When coal is extracted by the longwall mining method, the roof above the seam collapses behind the roof supports into the void that is created as a result of extraction. This collapsed area is referred to as the goaf.

Creation of this goaf area results in fracturing and settlement of the overlying strata, commonly referred to as the overburden strata. There is an overall downwards movement of overburden strata as a result of longwall goaf formation, which also results in sagging and bending of the land surface overlying the extracted longwall panels. The overall process of deformation to both the overburden and overlying land surface as a result of underlying longwall extraction and goaf formation is called subsidence.

As the immediate roof strata, i.e. the rocks immediately above the seam, collapse into the goaf, the rocks above them lose support and sag to fill the void beneath them. The majority of the subsidence at the ground surface occurs over the centre of the longwall and tapers off around the perimeter of the longwall around adjacent to and over the gate roadway pillars.

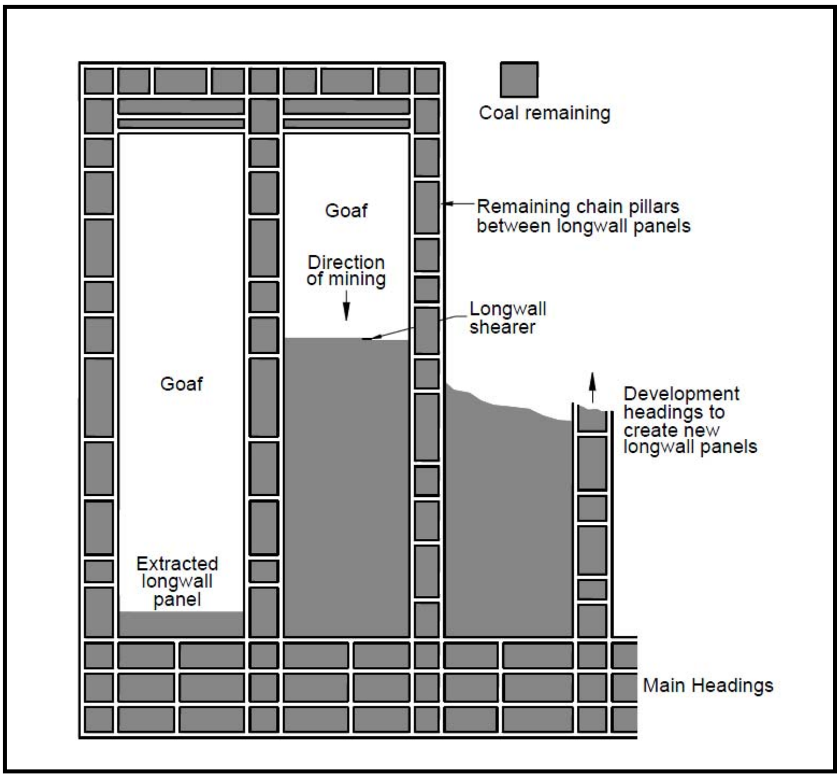

Figure 1-1: Typical Plan View of a Series of Longwall Panels

(From "Introduction to Longwall Mining and Subsidence – Mine Subsidence Engineering Consultants, 2007)

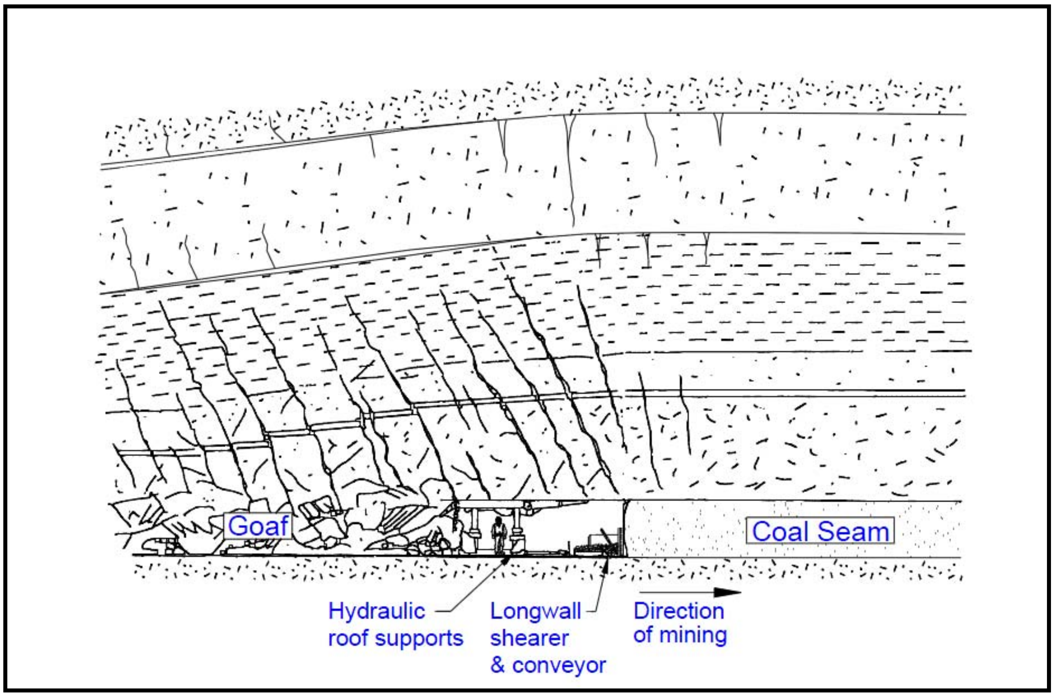

Figure 1-2: Cross Section of a Typical Longwall Face

(From "Introduction to Longwall Mining and Subsidence – Mine Subsidence Engineering Consultants, 2007)

2 GEOLOGY AND GEOTECHNICAL

2.1 Regional Geology

The Bowen Basin in Queensland, Australia, is one of the major global coal basins, providing some 5% of the coal traded in the seabourne export market.

The basin was part of a connected group of Permian coal basins in Eastern Australia, including the Sydney and Gunnedah basins. The eastern part of the basin was severely deformed during the Triassic, and mineable coals are preserved on protected tectonic platforms or syncline margins.

The Bowen Basin was an area of shallow water or terrestrial sedimentation for most of the Permian. Coals accumulated throughout almost all of this period, initially around the margins and in isolated sites, but extending to cover virtually the entire basin in the late Permian.

2.1.1 Basin Setting

The basin is made up of first-order NNW-SSE trending platforms, or shelves, separated by sedimentary troughs. This roughly parallels the late Palaeozoic continental margin. On the western side of the basin, the troughs and highs are known to overlie deformed early Palaeozoic or older metamorphic rocks. The main structural elements are illustrated in Figure 2-1. The Taroborah deposit is located in the northwestern area of the Denison Trough, the westernmost of the basin's troughs.

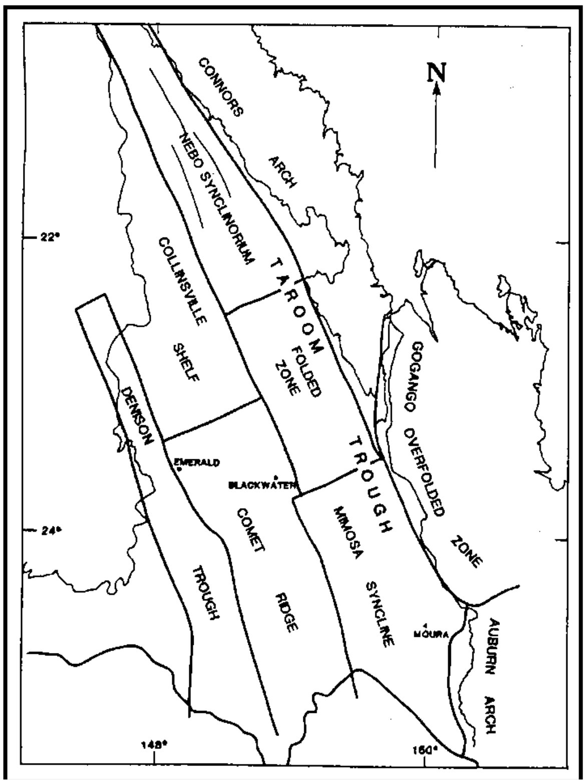

Figure 2-1: Main Structural Elements of the Bowen Basin

(After Pattison, Fielding, McWatters & Hamilton, 1995)

2.1.2 General Stratigraphic Sequence

The general stratigraphic sequence of the Bowen Basin is shown in Figure 2-2. For Taroborah, the southwest area of the basin is the relevant sequence.

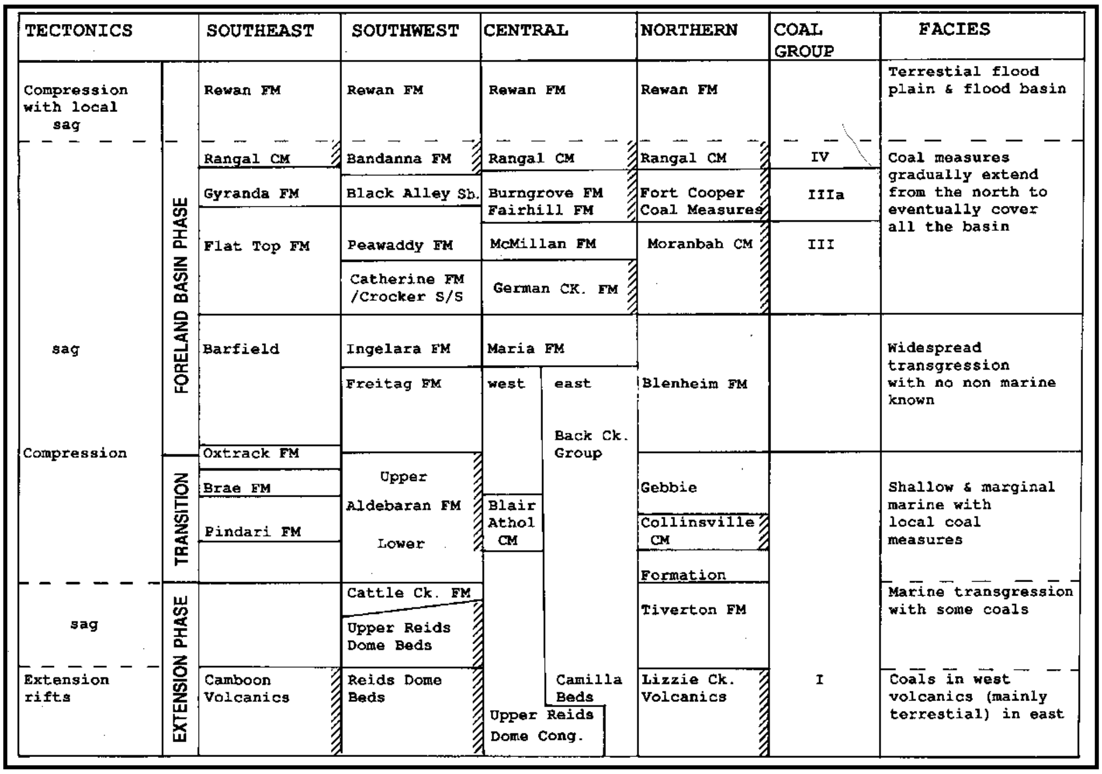

Figure 2-2: General Stratigraphic Units of the Bowen Basin by Area

(Modified by Mallett, Pattison, McLennan, Balfe and Sullivan 1995 after Draper and others, 1990)

2.2 Local Geology

2.2.1 Stratigraphy

At Taroborah, two successions of coal measures occur among marine beds unconformably overlying the Retreat Granite and Devonian-Carboniferous sediments.

Of the 5 seams occurring in the upper succession, the top 2 seams (“A” and “B” seam) are the most developed and thickest. The B seam is probably equivalent to the Cygnus seams in the Freitag Formation near Tieri. The Freitag Formation subcrops near Tieri to the northeast of Emerald, and contains thin and often split paralic coals. Exploration experience in the Denison Trough indicates that coal seams are often locally developed in this unit, but that consistent widespread seams are not present.

The lower coal measures succession is thin but apparently widespread, and tentative correlation from Taroborah to Springsure (some 100 km to the south) is possible.

The surface of the site is generally covered by 1.5-2m of soils, followed by 30-90m of weathered Tertiary grading into weathered, then fresh Permian. Contours of the depth to base of weathering are presented in Figure 2-3.

The immediate floor of the B seam is generally sandstone, with an occasional thin layer of carbonaceous mudstone overlying the sandstone.

2.2.2 Structure

Modelled floor elevation (RL) contours of the B seam through the explored resource area are shown inFigure 2-4. While a basic assessment of geological structure has been undertaken, at this stage the geological model has not incorporated interpreted geological structure other than seam dips, which the model has defined. The location of the two major faults to the east and west of the resource area are based on widespread (0.5-1km) borehole spacing, and are therefore preliminary only. While minor geological structure is possible between these faults, further significant geological structure (>10m faulting) within the explored resource area is considered unlikely due to the current spacing of exploration boreholes and the resultant seam elevation contours modelled from the borehole data.

Through the central and eastern portions of the mining area, the seams dip gently to the north away from the subcrop. A significant "kick" in the RL contours is observed in the central west area of the resource as shown in Figure 2-4. This is considered likely to represent an anticlinal roll (fold) feature with the axis running approximately north – south. It is possible that minor faulting may be associated with this anticline although at this stage no additional faulting has been incorporated in the geological model. The feature is also reflected by an observed shift to the north in the B seam LOX lines in the area. To the west of this anticline, the seams are interpreted to dip more steeply at around 5° to the northwest.

2.2.3 Depth of Cover

Modelled cover depths (or overburden thickness) to the B seam roof are shown in Figure 2-5, and range from 40-50m at the subcrop in the south to a maximum of 206m in the northeast. As with modelled RL contours, the cover depth is also influenced by the anticline in the central west portion of the resource as well as a rising topography to the east and west, resulting in relatively lower cover depths in the central portion of the mining area.

2.2.4 Seam Thickness

The total thickness of the target B seam has been modelled and is presented in Figure 2-6.

As shown in Figure 2-6, the total B seam thickness is reasonably consistent and typically around 3m. There is a slight reduction in total B seam thickness observable to the east of the opencut resource area with thicknesses typically 2.7m to 3m. In the north of the underground resource area, the B seam thickness is reduced to around 2.3m to 2.5m due to the bottom approximately 0.5m of the seam splitting off into the floor. This splitting occurs rapidly such that the interburden between the B seam and B seam floor split is 0.3-2.3m thick where encountered in drilling.

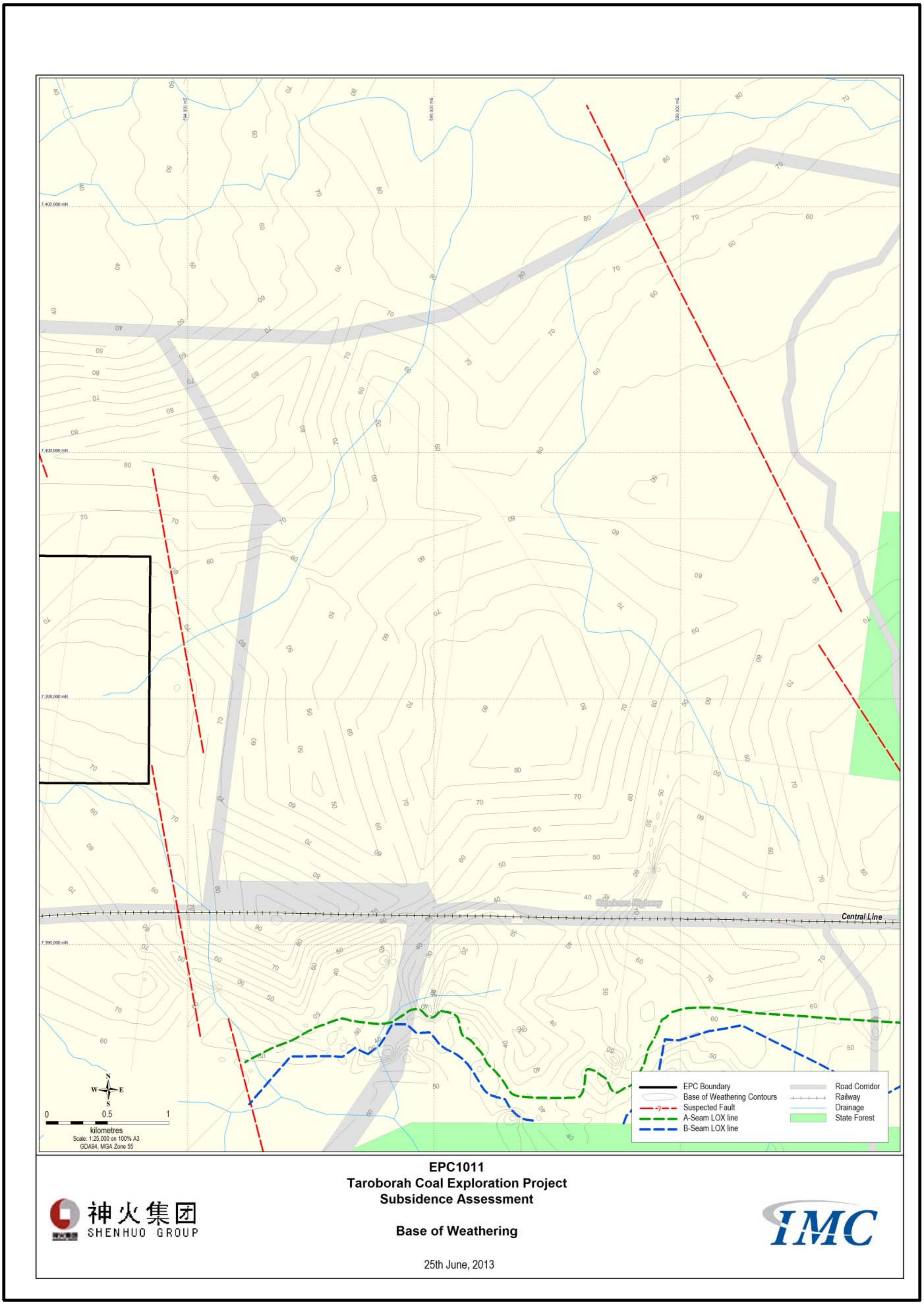

Figure 2-3: Depth to Base of Weathering (m)

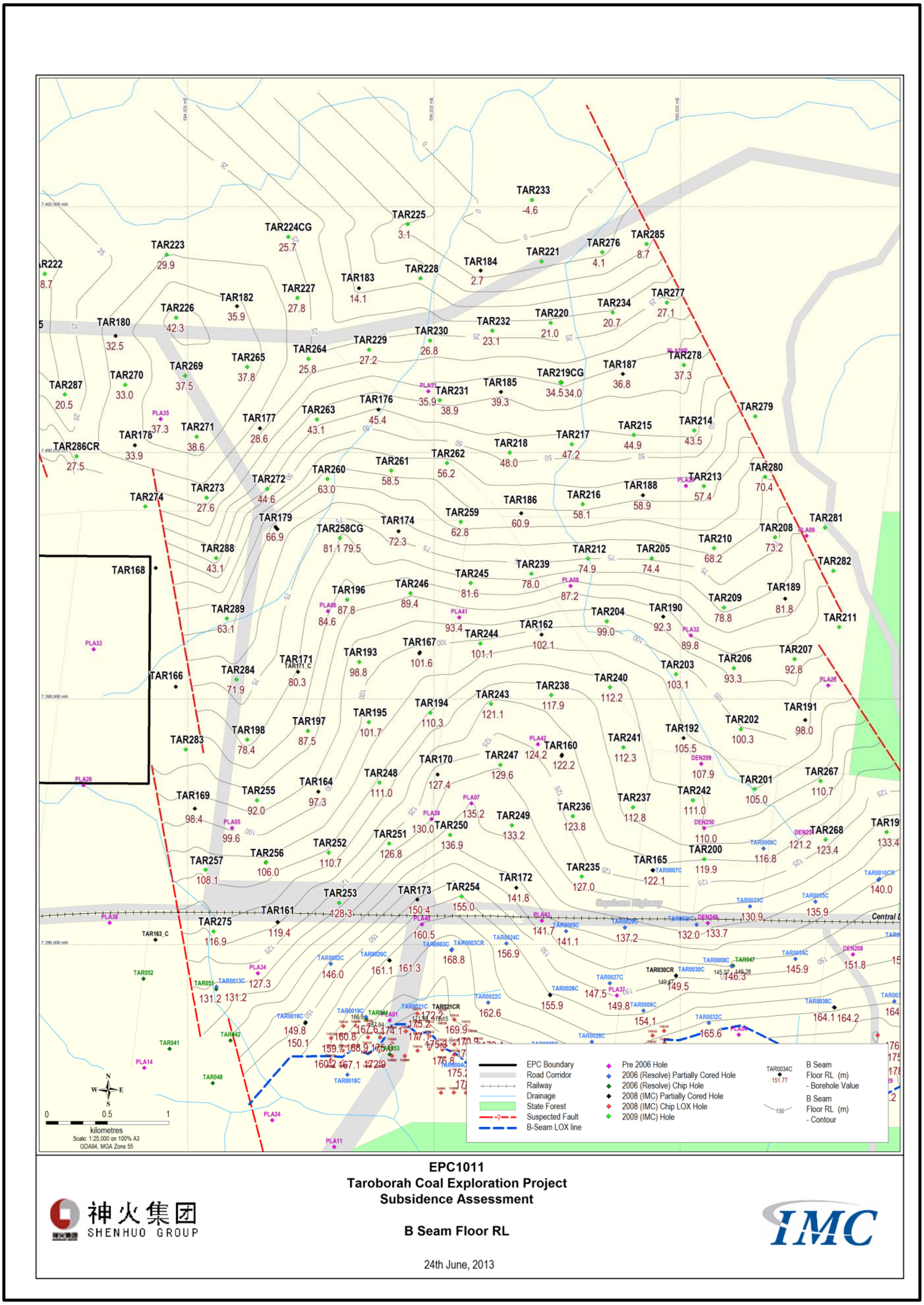

Figure 2-4: B Seam Floor RL Contours (masl)

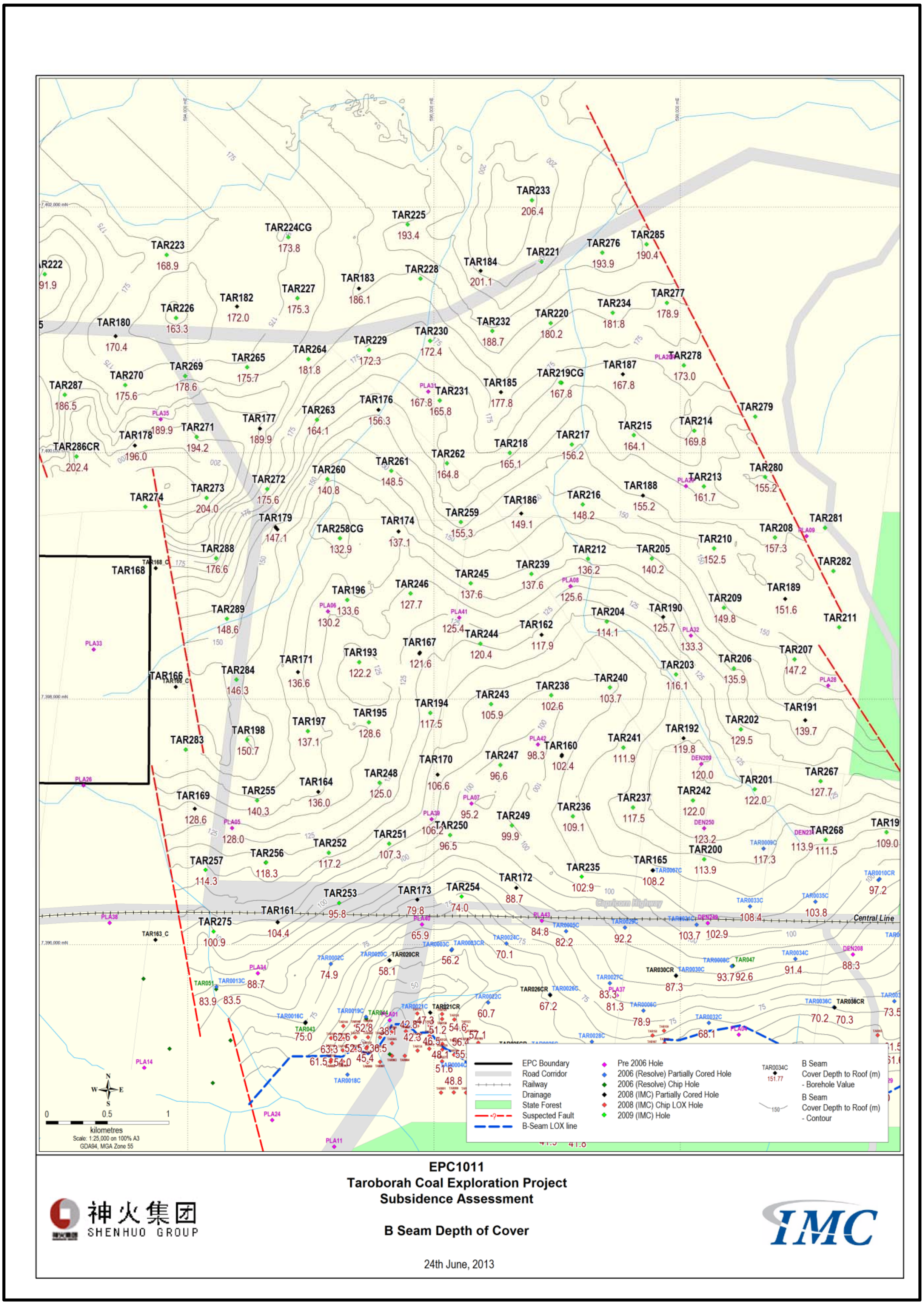

Figure 2-5: B Seam Depth of Cover Contours

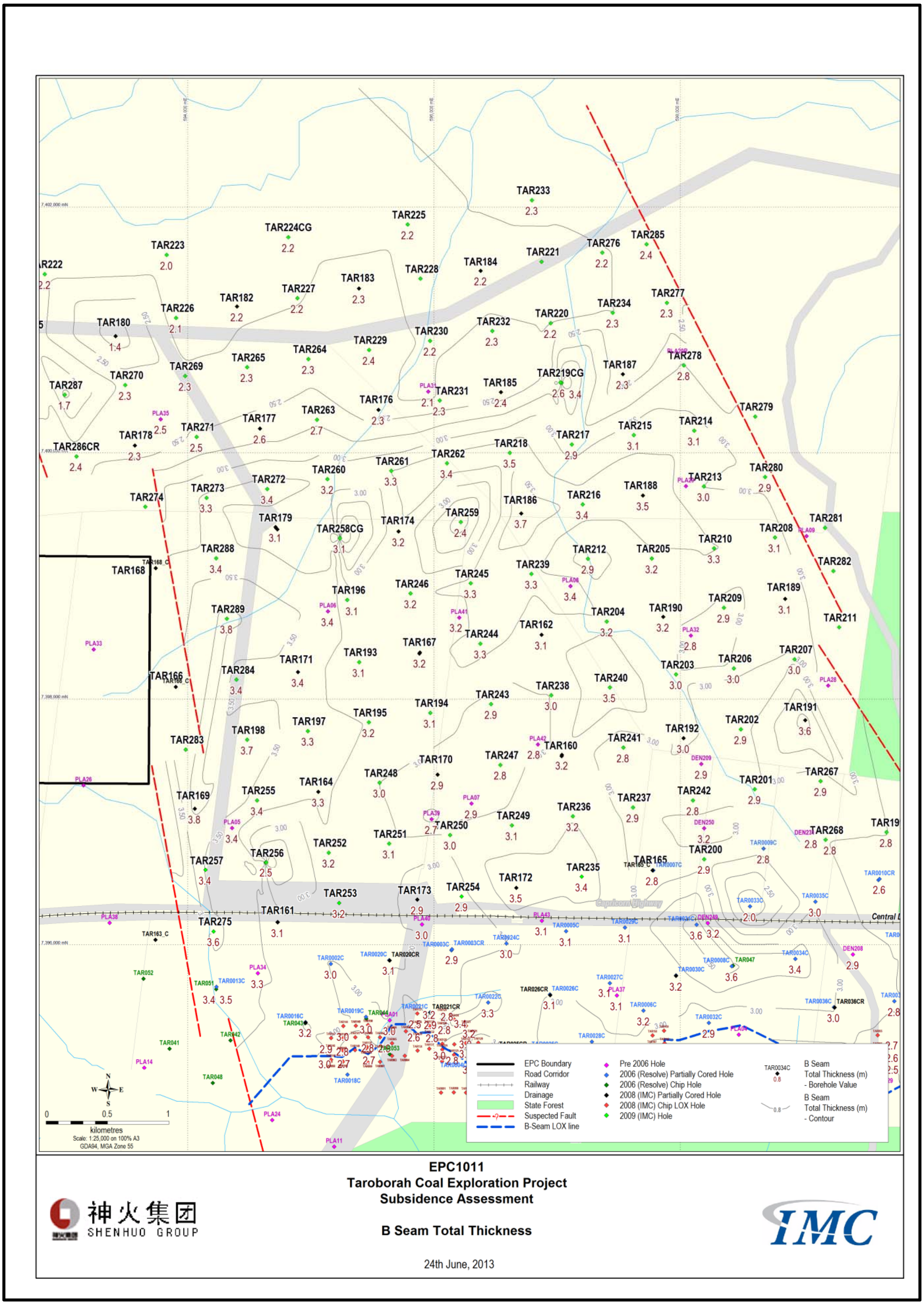

Figure 2-6: B Seam Thickness Contours

2.3 Rock Strength

Samples of roof material for the B seam were taken and sent to Cardno, Ullman & Nolan for uniaxial compressive strength (UCS) testing. In addition, a number of holes also had Young's Modulus and Poison's Ratio determined, and select boreholes cored above the A seam horizon had triaxial testing conducted.

The sandstone roof above the B seam and interburden units were examined to determine hard rock factors for subsidence modeling. UCS values of 15-25MPa were recorded for the samples tested, which can be classified as moderate strength rock, in accordance with the Bowen Basin guidelines, but weak rock in accordance with the International Society of Rock Mechanics (ISRM) guidelines.

No further geotechnical analysis was completed as part of this report.

2.4 Subsidence Prediction Methodology

Surface Deformation Prediction Software (SDPS) has been used for subsidence prediction for the Taroborah mine plan. SDPS is a software package that implements the Influence Function method to calculate a number of surface deformation indices, based on a digitised mine plan, and in this case digitised cover depth contours. Depth of cover to the target mining seam was provided as 5m interval contours as 3D (XYZ) strings from the latest Taroborah geological model.

The functionality provided by SDPS using a regional subsidence modeling approach is considered suitable and sufficiently accurate for greenfield sites such as the Taroborah project, for the purposes of an EIS. It has been used extensively for Queensland and New South Wales underground coal mine EIS's.

The SDPS subsidence predictions, when correlated to actual measurements in the Bowen Basin at a number of sites, have been reasonably accurate. IMC have incorporated recent relevant and documented industry experience, empirical research and data/measurements from the Goonyella Extension project to calibrate the subsidence model, and provide what are considered to be credible subsidence estimates, based on the current state of knowledge (described in Section 2.5).

2.5 Limitations

SDPS is a recognised credible method for predicting surface subsidence due to longwall mining. However, as with any predictive model, the method does have some limitations. In general, these limitations are considered unlikely to present a material difference to the outcomes or impacts predicted.

Specific limitations associated with the Influence function / SDPS approach are summarised as follows.

- SDPS utilises a single mathematical formula, and therefore makes the assumption that all panels are symmetrical. In this instance, and since all the undermined panels are of similar width, this will not have a material effect on the accuracy of the subsidence predictions.
- The applied modeling technique is limited in its capability to provide and combine contoured outputs across areas with variable resource

characteristics. In most instances, single specific assumptions and calibrated outputs are incorporated and apply to the whole resource area, based on the mining panel outline and a limited number of additional parameters and variations (usually cover depth and topography). In this instance, IMC have modeled subsidence predictions for the Taroborah mine plan area based on a basic assessment of the overburden and interburden to the target mining seam utilising a hard rock factor, which has been reduced to reflect the increased fracturing considered to be inevitable at the site. Assumptions regarding the percentage of hard rock within the overburden were applied across the entire resource area. This is considered reasonable, based on both calibrations with subsidence measurements elsewhere in similar circumstances, and the level of confidence and accuracy generally required for an EIS.

- Dynamic / incremental subsidence effects have not been modeled in this approach. This is not considered to have a significant material impact, given that the assessment of subsidence predictions, for the purpose of the EIS, are based on either final subsidence magnitudes following the completion of mining, or at selected points in time during the overall mining schedule. The final subsidence impacts as modeled will generally be greater than associated incremental impacts.
- The model does not account for anomalous effects of subsidence, including in the vicinity of faulting or impacts of other significant geological variations. It should be emphasised that, based on experience at similar Bowen Basin longwall mine sites, the impacts of subsidence associated with faulting are generally very localised and can usually be easily rehabilitated or managed on a case by case basis.

3 SDPS SUBSIDENCE MODEL CONSTRUCTION AND APPLIED PARAMETERS

The SDPS Incremental Profile Method of prediction is based upon predicting the incremental subsidence profiles for each longwall panel individually. IMC have calculated maximum subsidence based on cover depth contours at 1m increments. Predicted Smax (maximum subsidence) is calculated for the Influence Profile for the extracted seam at discreet locations along the lines of the cover depth contours. These maximum subsidence prediction points have further been contoured in Mapinfo utilising a smoothed Kriging function to provide graphical contoured outputs of predicted subsidence. Through estimating discreet points in the transverse and longitudinal directions, the tilt, curvature and strain can be predicted at any point on the surface above a series of longwalls.

The SDPS Influence Function Module allows for the shape of a subsided surface to be modeled using a Gaussian (bell shaped) curve that is centred on the point of inflexion of a subsidence profile. The empirical SDPS package is based on several empirical relationships (including some correlations) developed through statistical analysis of data from a number of case studies including:

- A correlation between the maximum subsidence factor with the width to depth ratio of a panel and the percent hard rock (%HR) in the overburden (or interburden in the case of multiple extracted seams);
- A correlation of the distance of the inflection point from the rib of the panel, with respect to the width to depth ratio of the panel;
- A regional value for the tangent of the influence angle (tan β), and the radius of influence; and
- A regional value for the horizontal strain coefficient.

3.1.1 Maximum Subsidence Factor (Smax/m)

The Maximum Subsidence Factor (Smax/m) required for SDPS modeling is a function of the panel width, the cover depth and the estimated percentage of hardrock in the overburden. Smax/m refers to the maximum vertical displacement of the subsidence profile per metre of extraction height. SDPS incorporates the Maximum Subsidence Factor as a function of the width-to-depth ratio (W/h) and the percent hardrock in the overburden as shown in Table 3-1.

The percent of hardrock in the overburden has been estimated as 30% for the subsidence models, based on IMC's knowledge of overburden characteristics gained from a preliminary assessment of the available geotechnical logs and laboratory results.

Table 3-1 : SDPS Maximum Subsidence Factors for Longwall Panels

	Percent Hardrock in the Overburden							
W/h	10%	20%	30%	40%	50%	60%	70%	80%
0.6	0.64	0.59	0.51	0.42	0.34	0.26	0.21	0.16
0.7	0.69	0.63	0.55	0.46	0.36	0.28	0.22	0.18
0.8	0.71	0.65	0.57	0.47	0.38	0.29	0.23	0.18
0.9	0.72	0.66	0.58	0.48	0.38	0.30	0.23	0.19
1.0	0.73	0.67	0.58	0.49	0.39	0.30	0.24	0.19
1.1	0.74	0.68	0.59	0.49	0.39	0.31	0.24	0.19
1.2	0.74	0.68	0.59	0.49	0.39	0.31	0.24	0.19
1.3	0.74	0.68	0.60	0.49	0.40	0.31	0.24	0.19
1.4	0.75	0.69	0.60	0.50	0.40	0.31	0.24	0.19
1.5	0.75	0.69	0.60	0.50	0.40	0.31	0.24	0.19
1.6	0.75	0.69	0.60	0.50	0.40	0.31	0.24	0.19
1.7	0.75	0.69	0.60	0.50	0.40	0.31	0.24	0.19
1.8	0.75	0.69	0.60	0.50	0.40	0.31	0.24	0.19
1.9	0.76	0.69	0.60	0.50	0.40	0.31	0.24	0.19
2.0	0.76	0.69	0.60	0.50	0.40	0.31	0.24	0.19

3.1.2 Critical Width Concepts

Based on the cover depth and panel extraction width, a longwall panel may be classified as being of sub-critical, critical or super-critical width. Panel critical width is defined as the panel width for which maximum possible subsidence for a given extraction height is developed. The critical width represents the cross-over point from a “wide and \ or shallow” longwall panel to a “narrow and / or deep” longwall panel, the width and depth being determined relative to one another. The magnitude of the critical width depends upon the geological characteristics of the overburden and can range from 1.4 to 2 times the mining depth. The geometry of these three cases is illustrated in Figure 3-1 below.

The extraction of coal removes support from the overlying strata, causing this strata to sag into the void space created. The sag is propagated upward to the surface and, it follows, that the maximum surface subsidence can be no greater than the thickness of the coal bed mined. However, the lateral extent of subsidence at the surface is greater than the extent of underground mining.

The surface position of the boundary between areas of subsidence and no subsidence, which is often described as the “limit of mining influence”, is defined by the "Angle of Draw." This is the angle between a vertical line drawn upward to the surface from the edge of the underground opening and a line drawn from the edge of the opening to the point of zero surface subsidence. The angle of draw varies from approximately 24° to 35° degrees in most instances. The larger the angle of draw the wider will be the zone on the surface in which subsidence should occur.

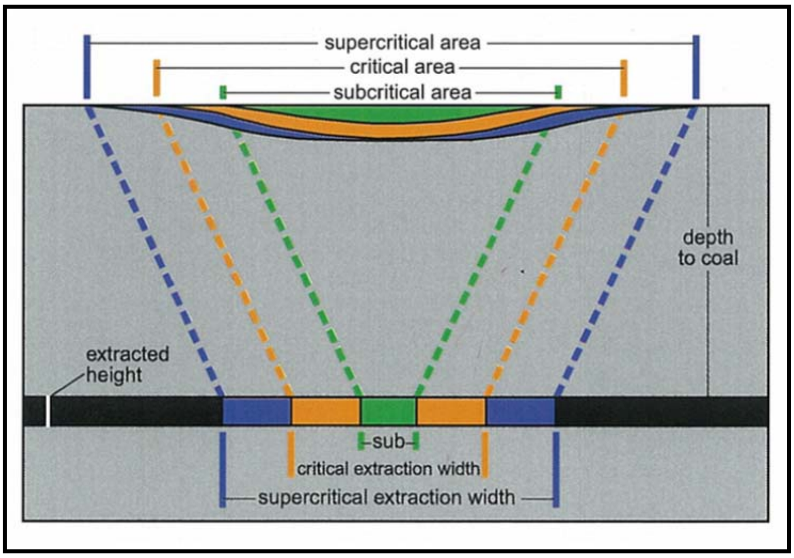

Figure 3-1 : The Development of Surface Subsidence based on Critical Width Concepts

(after New South Wales Coal Association 1989)

Supercritical (wide and \ or shallow) extractions result in flat-bottomed subsidence troughs as illustrated in Figure 3-1. Sub-critical (narrow and / or deep) subsidence troughs are shallower than supercritical troughs with more gentle bending of the strata towards the centre of the panels and less steep sided, high differential subsidence strains adjacent to the chain pillar edges.

For SDPS subsidence modeling, a panel is considered supercritical for a W/h ratio greater than 1.2. Due to numerical approximations, there may be slight variations to the supercritical subsidence factors determined as a result of critical width assessments, although these are anticipated to be minor.

For the Taroborah mine layout, all panels are considered to be supercritical, with W/h ratios of approximately 1.6 for the northern portion of the mine layout and >2 for the central and southern portion.

3.1.3 Inflection Point

Figure 3-2 illustrates the geometry of a typical subsidence profile. The inflection point of the profile is the transition point from positive to negative curvature, or point of zero curvature, and corresponds to the position of S = Smax/2 on the subsidence profile. The inflection point therefore, is the point at which the subsidence profile changes from concave to convex. The inflection point is estimated with respect to overburden depth and can be estimated based on empirical curves.

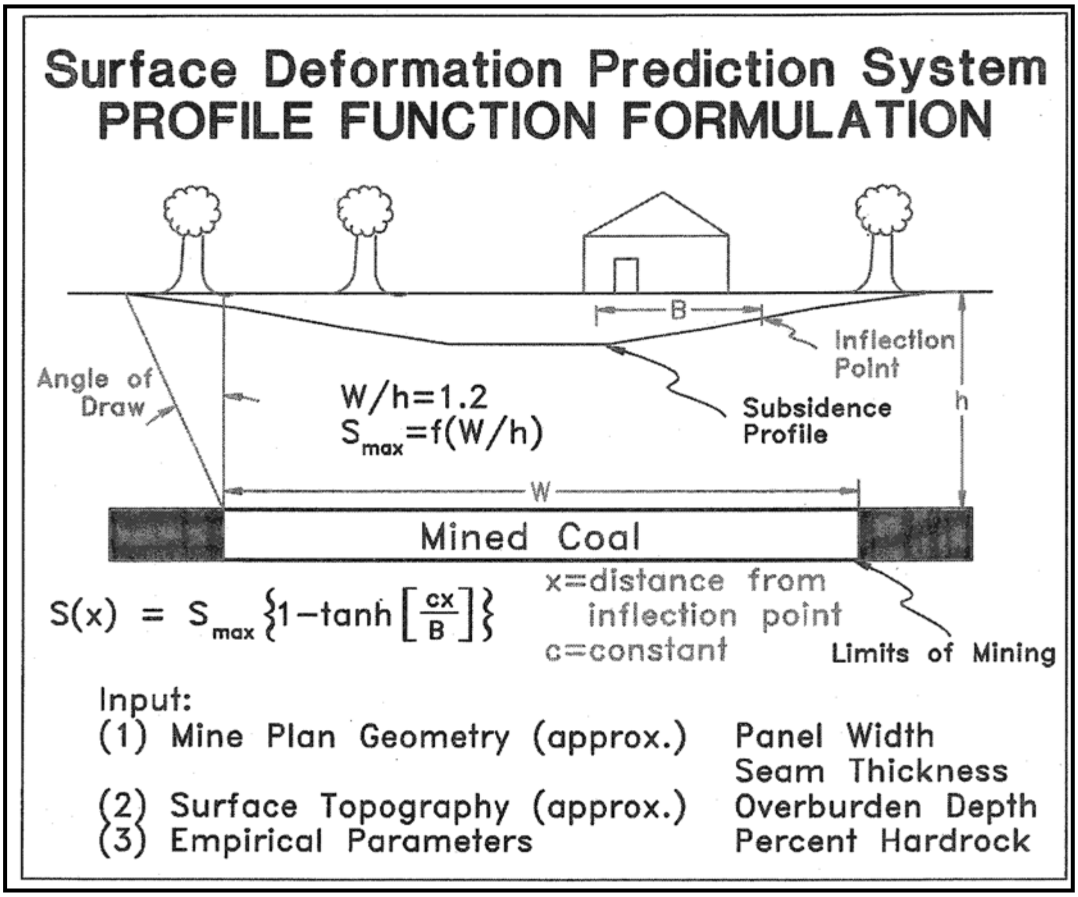

Figure 3-2: Illustration of Profile Function Parameters in SDPS

(Agioutantis, Z and Karmis, M)

3.1.4 Angle of Influence (β)

The Angle of Influence (β) is the angle between the horizontal and the line connecting the projection of the inflection point position of the subsidence trough (at the seam level) with the surface point of "zero influence" i.e. where subsidence is about 0.6 percent of the maximum subsidence value. This is one of the basic parameters used in the Influence Function method of subsidence prediction. Figure 3-3 illustrates the Angle of Influence definition.

The Angle of Influence is related to the Radius of Influence by the equation:

Tanβ = h/r

Where:

h = the overburden depth

r = the radius of influence

Based primarily on experience at adjacent operations, IMC have set the angle of influence (β) at 56^{o} (or tangent of the influence angle of 1.48 for model input). Sensitivities associated with the range of (considered) probable angles (56° to 65°) have not been considered as part of this assessment.

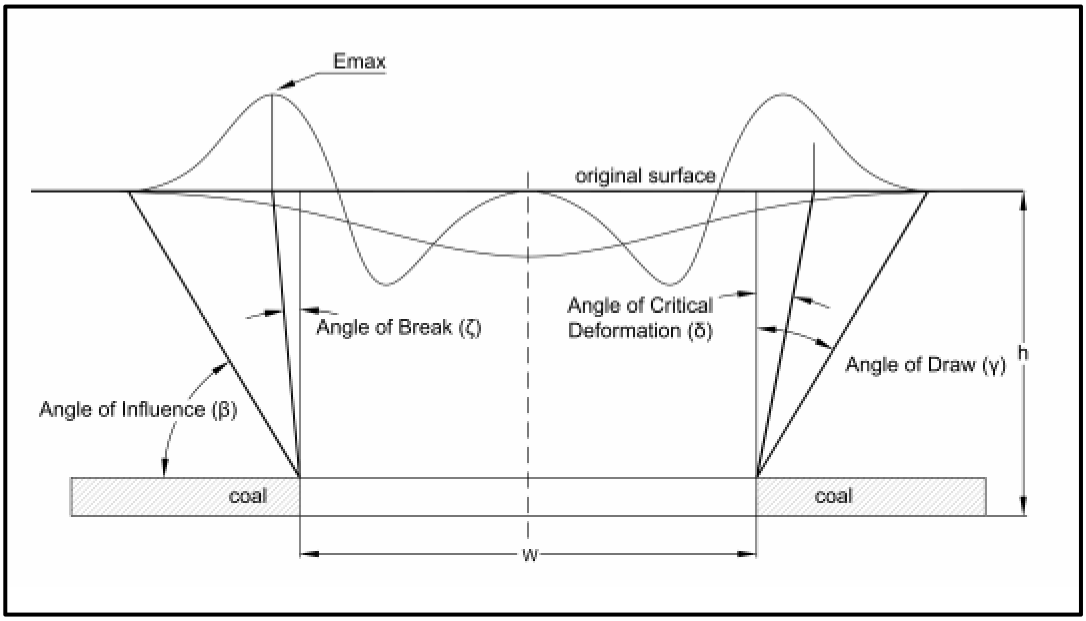

Figure 3-3: Illustration of the Angle of Influence in SDPS

(Agioutantis, Z and Karmis, M)

3.1.5 Horizontal Strain Factor (Bs)

This value is directly related to the magnitude of calculated strains and curvatures over an undermined area and can be empirically calculated by the average ratio of strain and curvature over a set of surface points. The higher the value for this coefficient, the larger the predicted strains and displacements. IMC have used the default SDPS strain coefficient of 0.35 in the absence of more detailed subsidence data.

4 SURFACE SUBSIDENCE PREDICTIONS

The following section provides commentary on the interpretation of the SDPS predictions. It must be noted that a water body exists on the western periphery of the central portion of the mine layout. In this case, Digital Terrain Model (DTM) points were not recorded for this area, therefore subsidence predictions are likely to be inaccurate.

4.1 Differential Surface Subsidence

In addition to the estimate of the subsidence magnitude, it is important to have an understanding of the parameters relating to longwall extraction and subsidence for the Taroborah mine layout as illustrated in Figure 4-1 namely:

- Horizontal tensile and compressive ground strains ($+E_{max}$ and $–E_{max}$);
- Tilt (T_{max}); and
- Curvature (K_{max}).

The tilt of the ground surface between two points is found by dividing the difference in subsidence at the two points by the distance between them. The maximum tilt occurs at the point of inflection where the subsidence is roughly equal to half of maximum subsidence (S_{max}). The curvature is concave towards the centre of the longwall panel and convex over the margin and chain pillars. Horizontal strain is the change in length per unit of original length of the ground surface and is critical in the context of pipeline design and impacts.

Both strain and tilt are directly proportional to subsidence and inversely proportional to the cover depth. The change in the horizontal stress field caused by mining has the potential to generate movement along the bedding planes in the overburden. This movement need not be confined to the strata directly above an extraction panel and may extend well outside the extraction panel (and the angle of draw).

Strain profiles across sub-critical panels are generally smooth, with a distinct tensile peak over the edge of the extraction panel and a compressive peak over the central part of the panel. It will tend to be more variable under more rugged surface topography. This is reflected by modelled zones of tensile strain at the pillar edges, with compression towards the centre of the extracted longwall panels.

SDPS modelled subsidence predictions are shown in Figure 4-2 to Figure 4-5.

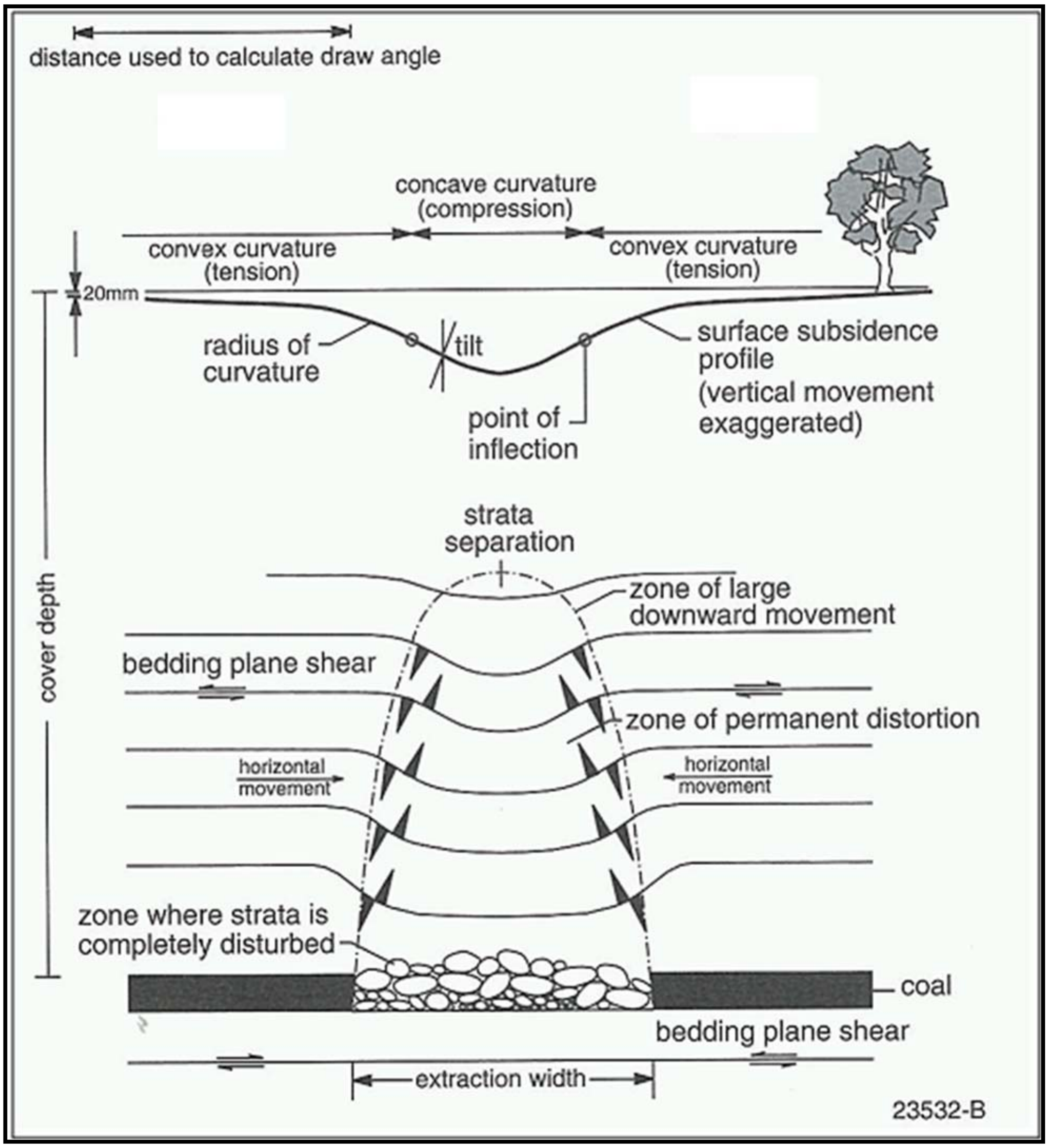

Figure 4-1: Formation of a Subsidence Trough above an Extraction Panel

(Holla and Barclay, 2000)

4.2 Subsidence Predictions

Predicted subsidence contours for extraction based on SDPS modelling of the Taroborah mine layout is shown in Figure 4-2.

Subsidence following B seam extraction in the southern and central portion of the mine layout is predicted to reach a maximum of approximately 1.9m (equivalent to 63% of extraction thickness). In the northern portion of the mine layout (north of approximately N 7,400,000), where the B seam thins to 2.5m thick, the modelled subsidence is predicted to reach a maximum of approximately 1.4m (equivalent to 56% of extraction thickness). These wide / shallow supercritical longwall panels are characterised by high strains, tilts and curvatures at the longwall panel / chain pillar edges, and by reaching and maintaining the maximum subsidence (S_{max}) over a

greater proportion of the longwall panel width. This style of subsidence is clearly illustrated in the prediction contours as shown in Figure 4-2.

4.3 Strain Predictions

Predicted strain (measured in mm/m or millistrains – divide by 100 to obtain result) following extraction of the B seam is shown in Figure 4-3. Strain is generally the result of differential horizontal movement, and can be either compressive or tensile.

Areas of indicated tensile strains are associated with the longwall panel edge / chain pillar interface and are predicted to reach a maximum of approximately 12 mm/m.

Typical compressive strains in the panels were modelled up to maximum of approximately -8 mm/m. It should be emphasised that compressive strain does not equate to positive subsidence or "supersidence" over these areas. There is likely to be an overall lowering of the surface profile throughout as indicated by the predicted subsidence (Figure 4-2).

4.4 Tilt Predictions

Predicted tilts reflect the difference in subsidence at two points divided by the distance between them, and is expressed as a percentage (%). The variation in tilt of course reflects the maximum strains predicted at the longwall panel edge / chain pillar interfaces. The maximum tilt tends to occur at the point of inflection where the subsidence is roughly equal to one half of maximum subsidence (S_{max}). This is illustrated schematically in Figure 4-1.

The predicted tilts (T (%)) are shown in Figure 4-4. Typical maximum tilts around the perimeter of longwall panels are predicted at approximately 1.2%.

4.5 Curvature Predictions

Curvature reflects the rate of change of tilt and is therefore calculated from the tilt profile.

The predicted curvatures (in hundreds of ppm) are shown in Figure 4-5. Typical maximum curvatures are predicted at approximately -260 ppm in the roadways and panel peripheries to approximately 160 ppm towards the panel centres. The highest curvatures are generally in the high strain zones adjacent to chain pillar / longwall panel edges and near the maximum subsidence trough. Figure 4-5 clearly illustrates (as expected) a reduction in both positive (convex) and negative (concave) curvature magnitudes in the centre of the supercritical panels.

4.6 Pre and Post Mining Topography

The topography at Taroborah is gently undulating, with an elevation range between RL240 in the south and along the eastern and western margins to about RL200 in the north along Retreat Creek. Two ephemeral watercourses separated by a low ridge traverse the site and drain into Retreat Creek in the north. As mentioned previously, there is a relatively large water body in the central western portion of the mine layout associated with a dam on the western ephemeral watercourse.

Figure 4-6 and Figure 4-7 present plans illustrating the pre and post mining topography across the site. The plans show minor elevation differences post mining, as would be expected after seam extraction and subsidence. The post mining contours also illustrate the small difference between subsidence amounts in the centre of the panels versus over the chain pillars between panels, indicating that the general drainage patterns in the area will not be greatly affected by the subsidence, and therefore, easily mitigated.

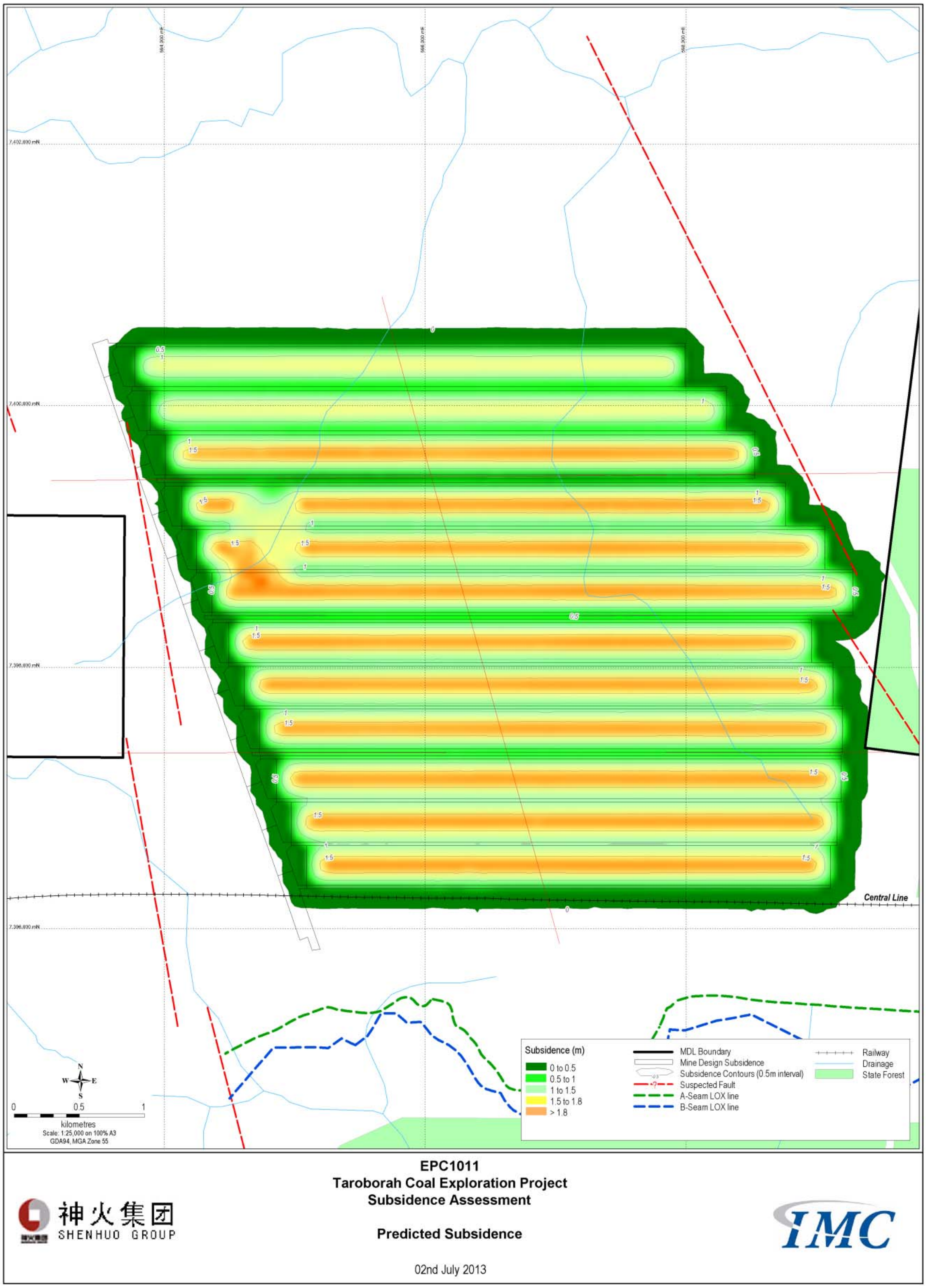

Figure 4-2: Predicted Subsidence for Taroborah Mine Layout

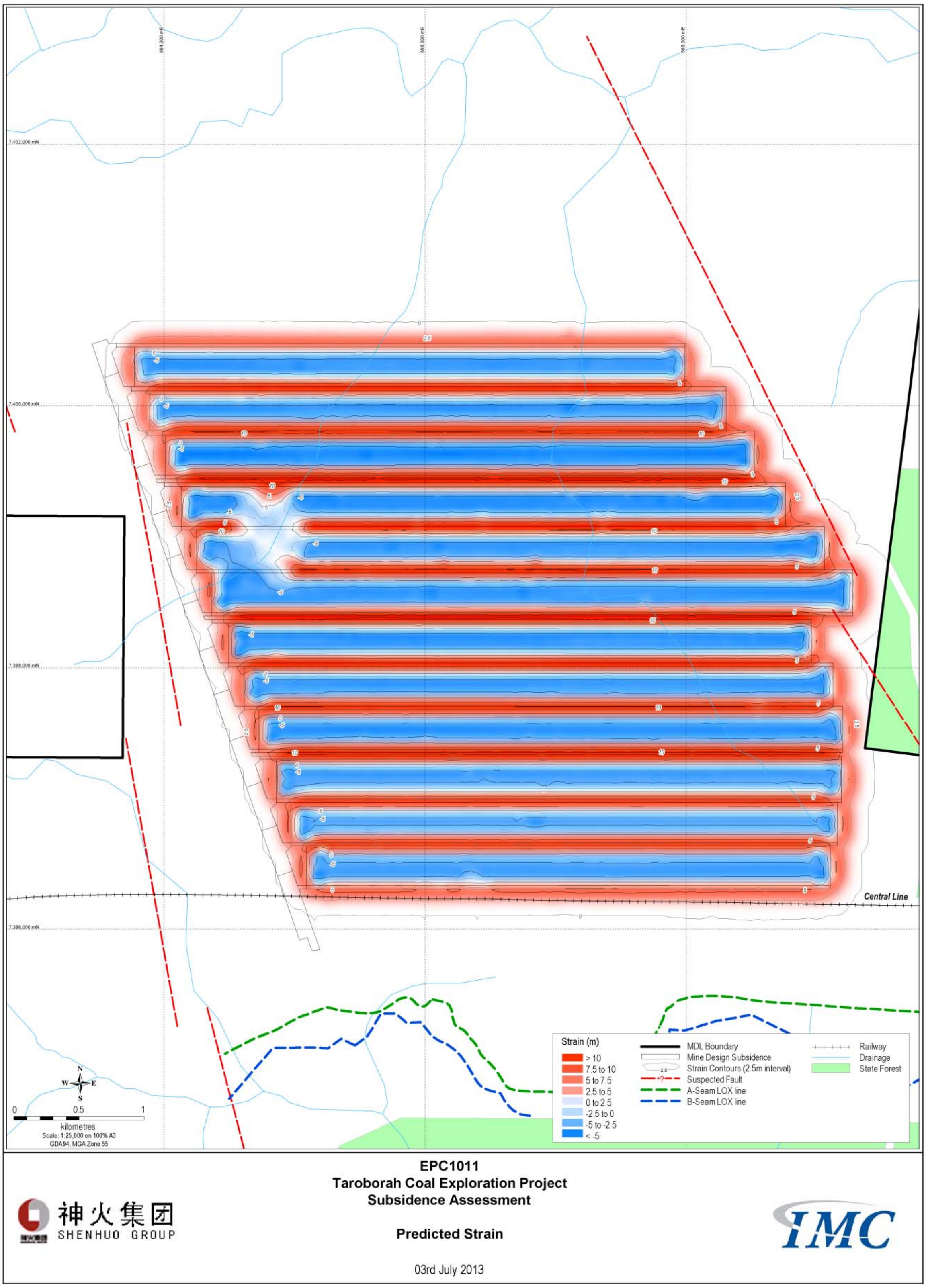

Figure 4-3: Predicted Strain for the Taroborah Mine Layout

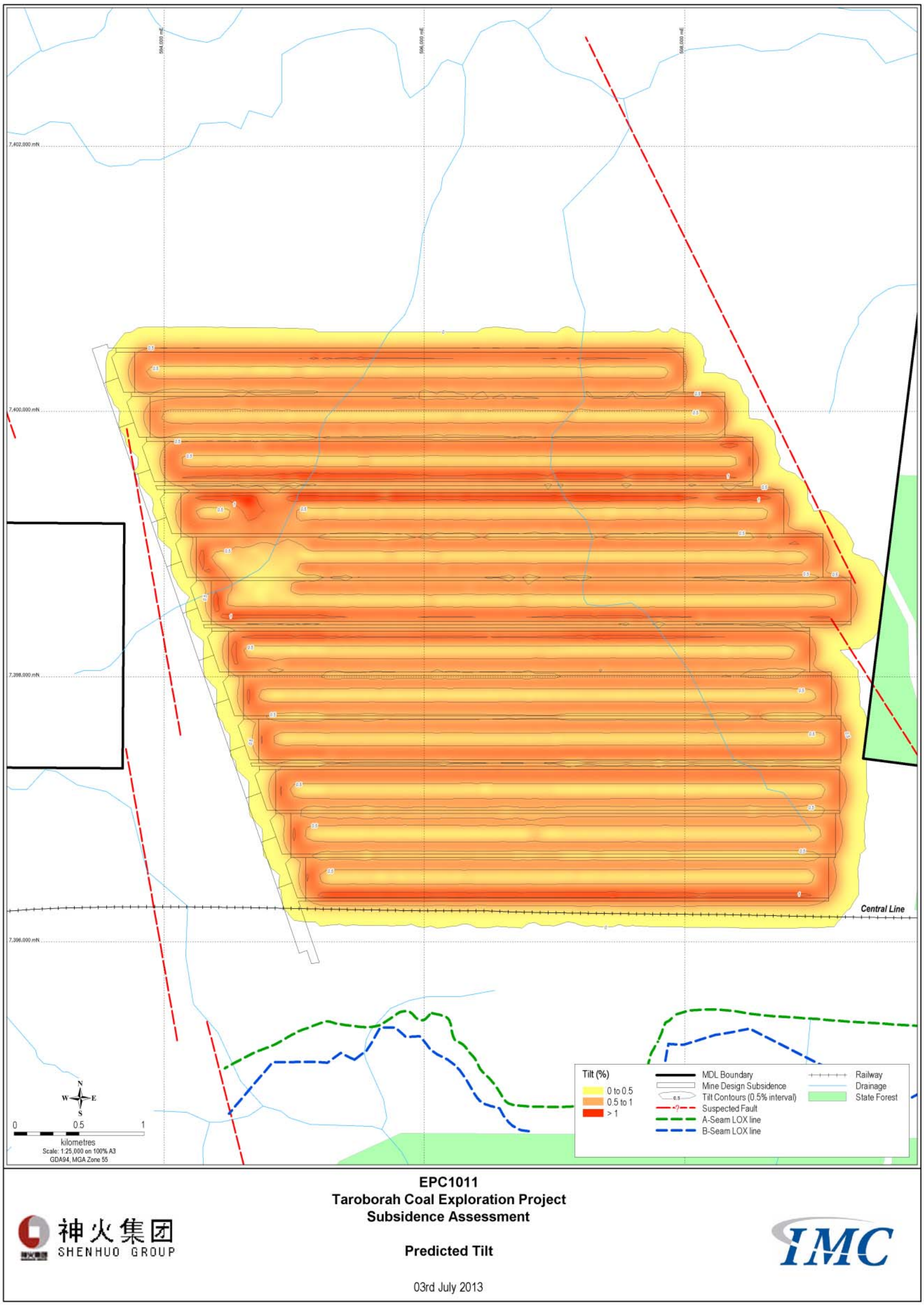

Figure 4-4: Predicted Tilt for the Taroborah Mine Layout

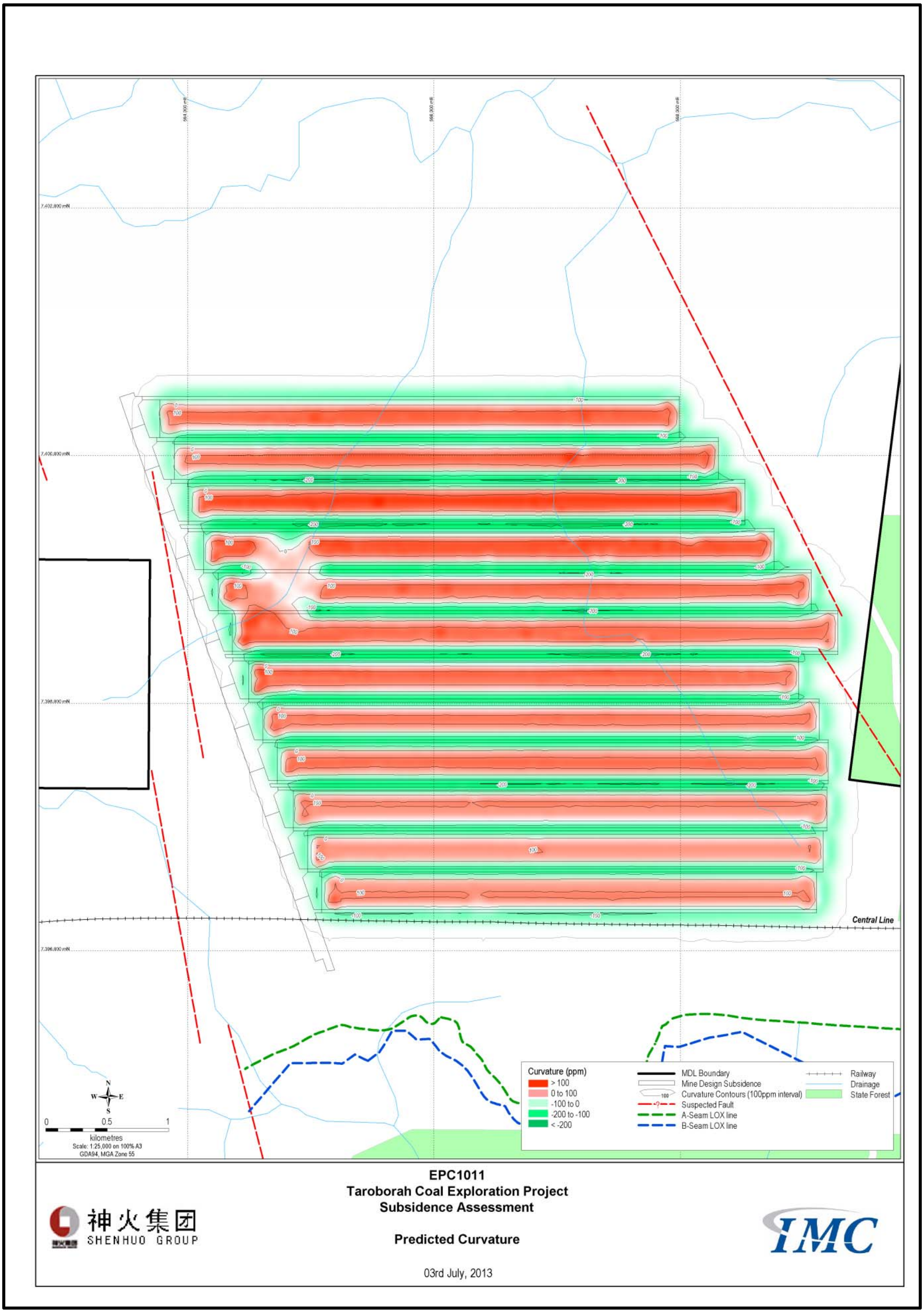

Figure 4-5: Predicted Curvature for the Taroborah Mine Layout

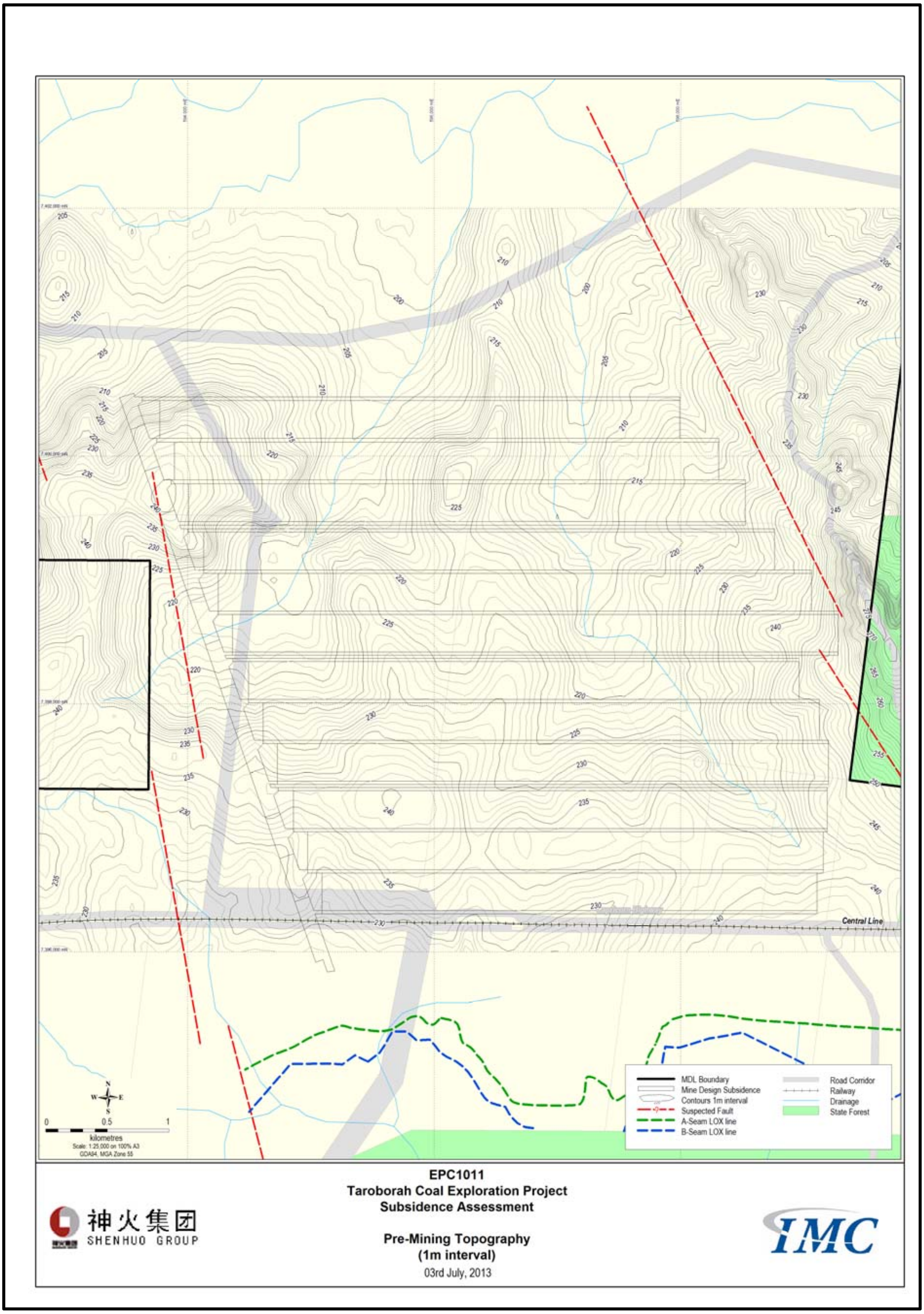

Figure 4-6: Pre-Mining Topography

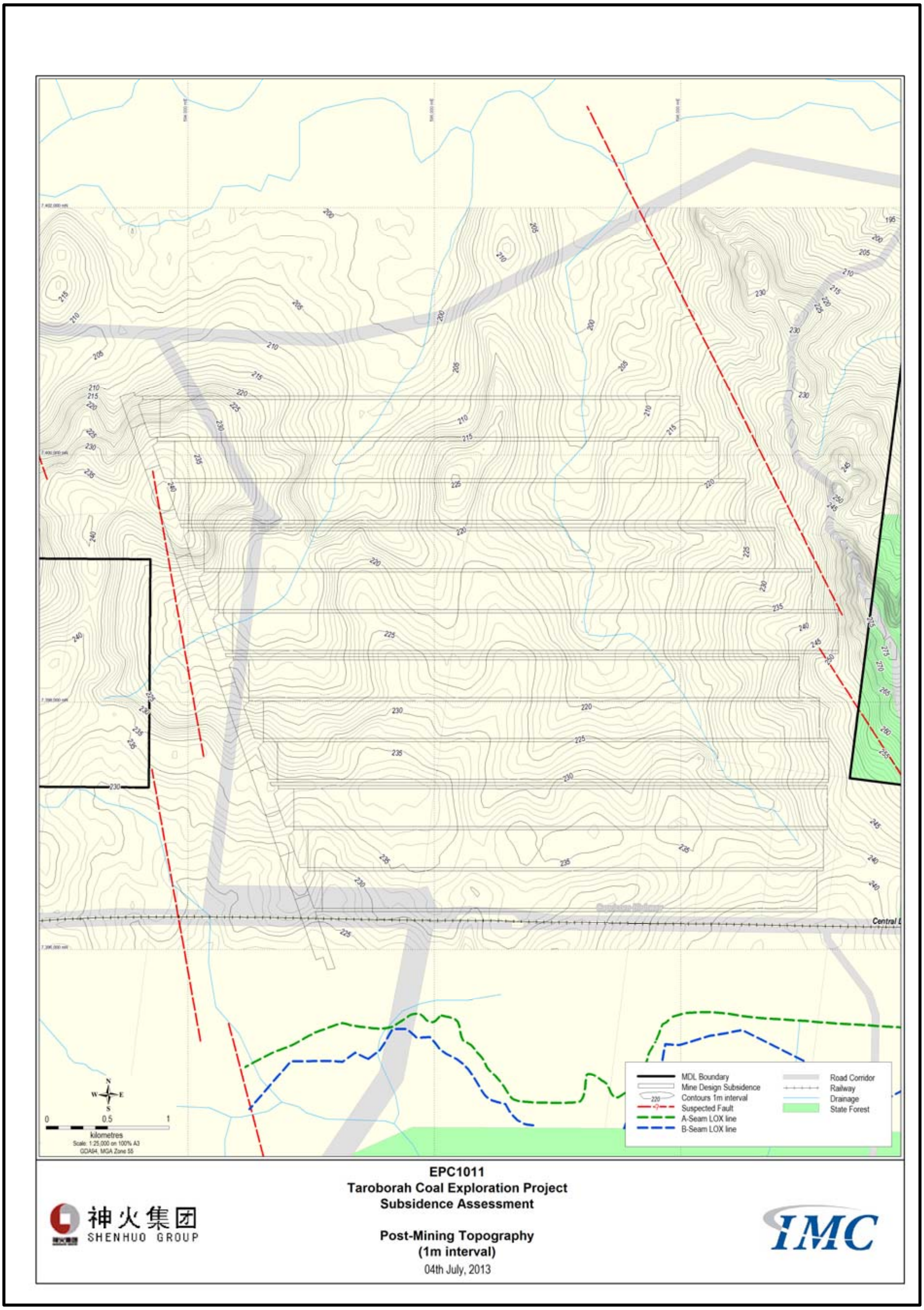

Figure 4-7: Post-Mining Topography

5 ANTICIPATED SURFACE IMPACTS OF SUBSIDENCE

Maximum total subsidence (S_{max}) is predicted at approximately 1.9m (or 63%) of the planned 3m B seam recovered thickness. Maximum tensile strains to approximately 12 mm/m are anticipated at the chain pillar edges with maximum compressive strains towards the central parts of the longwall panels developed to a maximum of approximately -8mm/m.

These levels of predicted subsidence and strain are likely to have some impact on the overlying landscape.

The following discussion broadly assesses the impacts on the surface landscape based on the modeling of predicted subsidence from proposed underground mining at Taroborah.

5.1 Surface Subsidence Impacts for B Seam Extraction

Based on subsidence prediction modeling, the zone of rehabilitation over surface tension cracking following seam undermining is anticipated over the chain pillars and to extend approximately 35m either side into the panels. Rehabilitation of the resultant tensile cracks will be required and cracks in the order of a maximum width of 0.2 - 0.3m and a maximum depth of 5m are possible in the worst case instances. Surface crack rehabilitation is likely to require remedial earthworks and the use of sealants.

Compressive strains are predicted over the central parts of the longwall panels. The surface manifestation of compression is humping, and is also considered likely to require minor remedial earthworks.

5.2 Site Drainage

Although subtle changes in the drainage profile of the site may occur as a result of subsidence, further assessment would need to be undertaken to quantify the drainage impacts post mining. It is likely that the impacts on surface drainage, and any other sensitive surface landscape features, would require consideration and management through subsidence management strategies.

6 REFERENCES

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