PROJECT CHINA STONE

Subsidence 6

CONTENTS

Tables

Figures

6 SUBSIDENCE

6.1 INTRODUCTION

This section provides an overview of mine subsidence issues for Project China Stone (the project). A detailed mine subsidence assessment was undertaken by Gordon Geotechniques Pty Ltd and is presented in the *Subsidence Report* (Appendix A). The key components of this section are:

- A general explanation of subsidence (Section 6.2.1);
- An overview of the subsidence prediction methodology (Section 6.2.2);
- A summary of subsidence predictions (Section 6.2.3); and
- An overview of the natural and man-made features within the proposed underground mining areas and an explanation of the way in which subsidence mitigation and management for these features will be addressed (Sections 6.3 and 6.4).

6.2 SUBSIDENCE PREDICTIONS

6.2.1 Introduction

The longwall mining methodology is discussed in detail in Section 4 – Project Description. The project involves establishing up to three longwall operations in the Northern and Southern Underground Mining Areas. The Southern Underground will involve single seam longwall mining. The majority of the Southern Underground is located beneath the open cut mine. The Northern Underground will involve both single and dual seam longwall mining.

Longwall mining typically results in subsidence which leads to progressive development of shallow, trough-like depressions on the surface above each extracted longwall panel. The trough-like depressions have gentle grades and develop relative to the natural surface topography.

The depressions on the surface develop as the roof strata above the coal seam progressively collapse to fill the void created by the extraction of coal in the area behind the longwall. As the roof collapses into the mined area (referred to as the ‘goaf’), the fracturing and settlement of rock progresses upwards through the overlying strata and results in sagging and bending of the near surface layers. This is illustrated in Figure 6-1.

Surface subsidence develops progressively on the surface in a wave across the active longwall panel that travels at the same rate as the longwall, in the order of approximately 100 m per week. The majority of subsidence at a point on the surface occurs within three months of undermining and all subsidence is generally completed within 12 months.

6.2.2 Prediction Method

The Surface Deformation Prediction System (SDPS) was used to model and predict subsidence, tilt and strain profiles for the project mine plan. This method involves the development of a model using coal seam floor contours, coal seam thickness contours and the proposed mine plan. The SDPS models the shape of the subsided surface using a Gaussian curve calibrated to surface data and mine geology. The modelling has taken into account the various extraction heights that will be mined and has considered the effects of dual seam mining. The SDPS is a proven and reliable prediction methodology widely used throughout Queensland and New South Wales for underground coal mine environmental impact studies.

The subsidence assessment has also referenced published literature with regard to single seam and dual seam longwall experience from the Australian and overseas coal mining industry.

6.2.3 Subsidence Predictions

Vertical Subsidence

The mine plan for the project was designed to ensure that surface subsidence will not occur outside the project site boundary.

The total surface area affected by mine subsidence (not including the part of the Southern Underground that will also be open cut mined) will be approximately 4,950 ha (i.e. the area within the limit of measurable subsidence). Predictions of vertical subsidence are shown in Figure 6-2 for the Northern Underground and Figure 6-3 for the Southern Underground. The post-mining surface topography is developed by subtracting subsidence profiles from pre-mining surface topography. Pre and post-mining topography are shown in Figure 6-4 and Figure 6-5, respectively.

As shown in Figure 6-2 the predicted maximum vertical subsidence is approximately 6 m in the Northern Underground where dual seam mining is undertaken and 2.5 m where only one seam is mined. The predicted maximum vertical subsidence is 2.7 m in the Southern Underground (Figure 6-3). The maximum vertical subsidence is predicted to occur in the Northern Underground where dual seam mining is proposed to be undertaken and the depths of cover are the shallowest.

The limit of measurable subsidence is defined as vertical ground movement of 20 mm or less. This limit is used to define the extent of subsidence as vertical movements of 20 mm or less occur naturally as a result of ground heave and shrinkage caused by changes in moisture content of surface soils and are therefore not differentiated from small vertical movements due to mine subsidence.

Tilting

The formation of subsidence troughs at the surface will change the ground surface slopes. The pre-mining surface slopes in the proposed underground mining areas range from very steep above the Northern Underground to relatively flat above the Southern Underground. The post-subsidence surface slopes will be steepened in localised areas around the edges of the subsidence troughs. Maximum tilts developed on the surface after the extraction of both seams in the Northern Underground range up to 11% while in the areas of single seam mining maximum tilts approach 3.9%. Maximum tilts developed on the surface after mining in the Southern Underground range up to 16.5%.

Surface Cracking and Buckling

The differential lowering of the ground surface due to subsidence creates areas of residual tensile strain, as shown in Figure 6-6 and Figure 6-7. Tensile strains can lead to the formation of tension cracks (subsidence cracks) on the ground surface. After longwall mining has been completed, permanent tension cracks can potentially develop in limited areas around the perimeter of the subsidence troughs, in areas of residual tensile strain (Figure 6-6).

Tension cracks are anticipated up to a maximum width of 0.2 m, and larger cracks may occur in isolated locations. Depending on the thickness of the near surface strata layers, the soil type, and the mining depth, surface cracking can extend to maximum depths in the order of 10 to 15 m.

Based on experience at operating longwall mines in the Bowen Basin subsidence cracking is expected to occur in less than 20% of the perimeter of the mined longwall panel sections within the residual tensile strain zone.

Buckling of surface soil may occur due to compressive strain on the ground surface. Buckling will potentially occur near the centre of the longwall panels in the zone of maximum compressive strain. Buckling typically results in mounds of soil being produced in areas where transient tension cracks above the longwall have over-closed.

Proposed rehabilitation measures for cracking and buckling are described in Section 8 – Rehabilitation.

Sub-Surface Cracking

Sub-surface cracking and fracturing occurs in the strata overlying the area from which coal has been extracted (i.e. the goaf). Figure 6-1 shows the various zones that form above the goaf, including the caved zone and fractured zone (area of continuous and discontinuous cracking).

Connective cracking occurs when fracturing above the goaf extends directly to overlying aquifers or the ground surface. Connective cracking may create new flow paths for groundwater and can potentially drain surface water bodies in shallow mining areas.

The *Subsidence Report* (Appendix A) predicts that connective cracking may occur up to 120 m above areas where single seam extraction is undertaken and 180 m above the upper A seam in areas of the Northern Underground where dual seam mining is proposed. Predictions of potential connective cracking have been taken into account in assessing the impact of subsidence on groundwater and further detail is provided in Section 12 - Groundwater. Figure 6-5 shows limited areas where there is potential for connective cracking to reach the surface. There are no water bodies or significant surface drainage features in these areas. Any surface cracks that develop in these areas will be sealed during crack rehabilitation, as described in Section 8 – Rehabilitation.

6.2.4 Reliability of Predictions

The SDPS is a recognised, credible method for predicting subsidence due to longwall mining. The model is based on a large dataset of observed subsidence monitoring data from both Queensland and New South Wales. In any areas of uncertainty, conservative assumptions have been applied. The *Subsidence Report* (Appendix A) discusses the limitations of the model and notes that these limitations are considered unlikely to present a material difference to the potential subsidence effects or impacts predicted.

It should be noted that the maximum predicted depth of vertical subsidence is approximately 6 m in the Northern Underground where dual seam mining is undertaken. The maximum extraction thickness of the combined seams in this area is 9 m and it is not physically possible for the maximum vertical subsidence at the surface to be as much as the extraction thickness. The predicted maximum vertical subsidence is approximately 67% of the maximum extraction thickness. In the unlikely event that maximum subsidence was 15% greater than that predicted (i.e. maximum vertical subsidence of 6.9 m), the impacts and mitigation would not be significantly different from those described in this Environmental Impact Statement (EIS).

6.3 SUBSIDENCE IMPACT ASSESSMENT

6.3.1 Natural Features

The natural features present in the project site are listed in Table 6-1 together with references to where potential impacts of subsidence on those features are addressed within the EIS document. This includes references to detailed assessments in specialist reports and the relevant summary in Volume 1 of the EIS.

The assessment of subsidence impacts on natural features and the development of mitigation and management measures have drawn on operational experience at other comparable longwall mining operations in Queensland. Where necessary, mitigation methods for specific subsidence effects on the relevant natural feature are proposed, using techniques that have been proven to be effective at other mining operations. Management plans and monitoring programs are also proposed, where necessary. The conclusion of the impact assessment is that the effects of subsidence on natural features will be manageable and will not give rise to any long term adverse impacts.

Table 6-1 Natural Features to be Impacted by Subsidence

FEATURE	EIS VOLUME 1	EIS VOLUMES 2 - 6
Land Suitability	Section 8 – Rehabilitation	*Soils and Land Suitability Report* (Appendix E)
Groundwater	Section 12 – Groundwater	*Groundwater Report* (Appendix I)
Surface Water –Surface Drainage	Section 13 – Surface Water	*Open Cut Mine Drainage Report* (Appendix J)
Terrestrial Ecology	Section 9 – Terrestrial Ecology	*Terrestrial Ecology Report* (Appendix F)
Aquatic Ecology	Section 10 – Aquatic Ecology	*Aquatic Ecology and Stygofauna Report* (Appendix G)

6.3.2 Infrastructure

There is no public infrastructure traversing the project site. Infrastructure within the project site is limited to minor farm and mining exploration infrastructure including unsealed access tracks, stock fencing and two farm dams.

Mine infrastructure has been located in areas outside of the predicted limit of measurable subsidence and will not be impacted by subsidence. Highwall drains and the southern section of the open cut mine will be developed on subsided ground after longwall mining and subsidence is completed.

6.3.3 Mine Plan and Schedule

It should be noted that modifications to the underground mine plan and mining schedule may be necessary following more detailed geological exploration and underground mine planning. However, any revised mine plans will not extend beyond the conceptual underground mining area specified in this EIS. Any revised mine plans or schedules would therefore not have any significant additional impacts beyond those presented in this EIS. Consequently no additional mitigation or rehabilitation measures to those discussed above would be required.

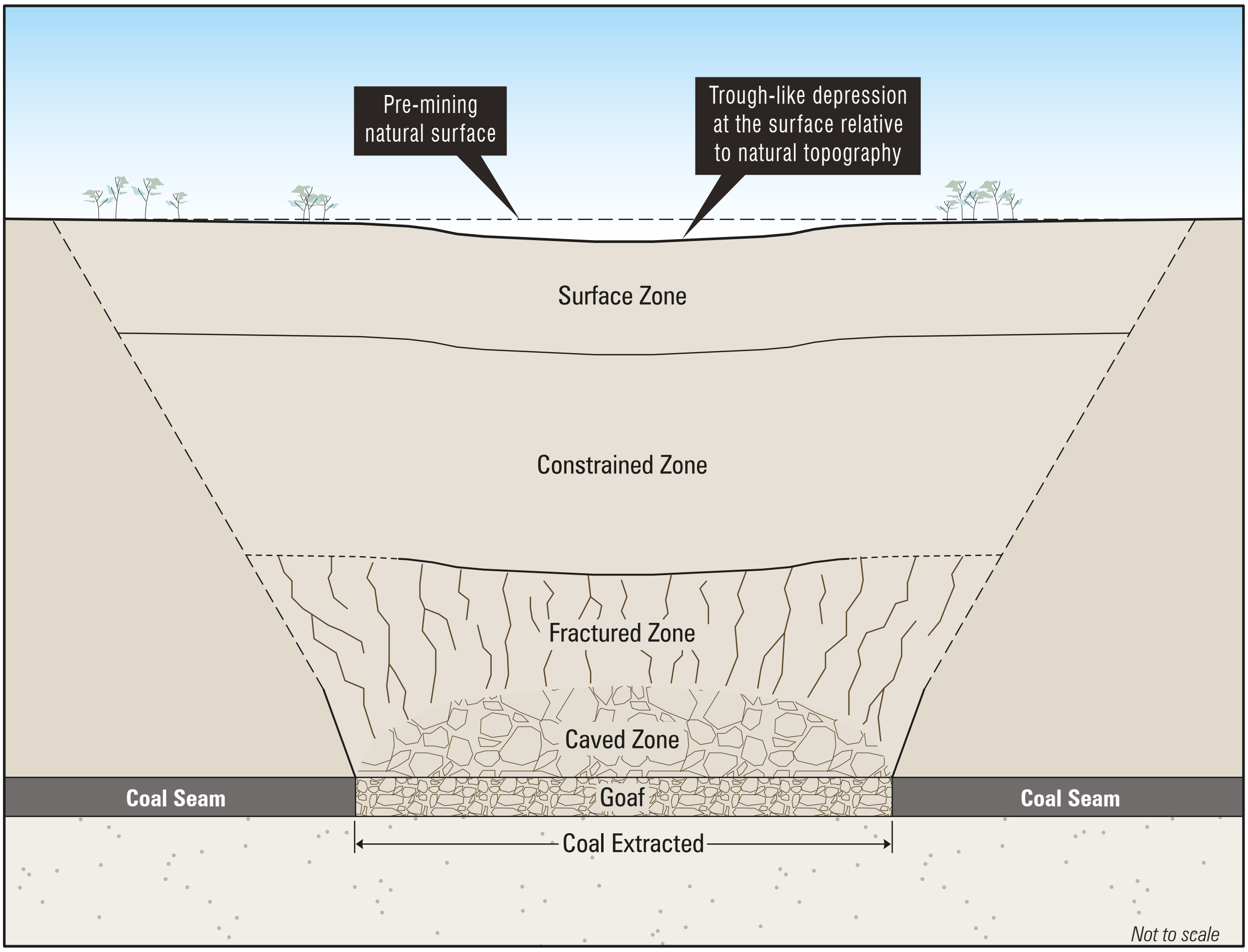
6.4 SUBSIDENCE MANAGEMENT AND MONITORING

Subsidence impacts will be managed in accordance with Subsidence Management Plans which will be prepared throughout the life of the project in accordance with the Department of Environment and Heritage Protection requirements. The plans will provide for the proper and effective management of environmental impacts resulting from mine subsidence. The plans will form the basis for all operational management activities related to the mitigation and management of subsidence impacts. Subsidence Management Plans will be authorised under the conditions of the Environmental Authority and are required to be prepared prior to the commencement of longwall mining that will result in subsidence.

A draft Subsidence Management Plan has been prepared as part of this EIS and is included in Appendix B. The plan broadly discusses:

- Subsidence predictions and the prediction method;
- The predicted impacts on natural and man-made features that are likely to be affected by subsidence including groundwater, surface water, terrestrial and aquatic ecology, existing infrastructure and mine infrastructure;
- The mitigation and management of subsidence impacts;
- Monitoring; and
- Reporting requirements including the process for annual review of the effectiveness of subsidence impact management and revision of the Subsidence Management Plan.

FIGURES



Plan based on MSEC Figure

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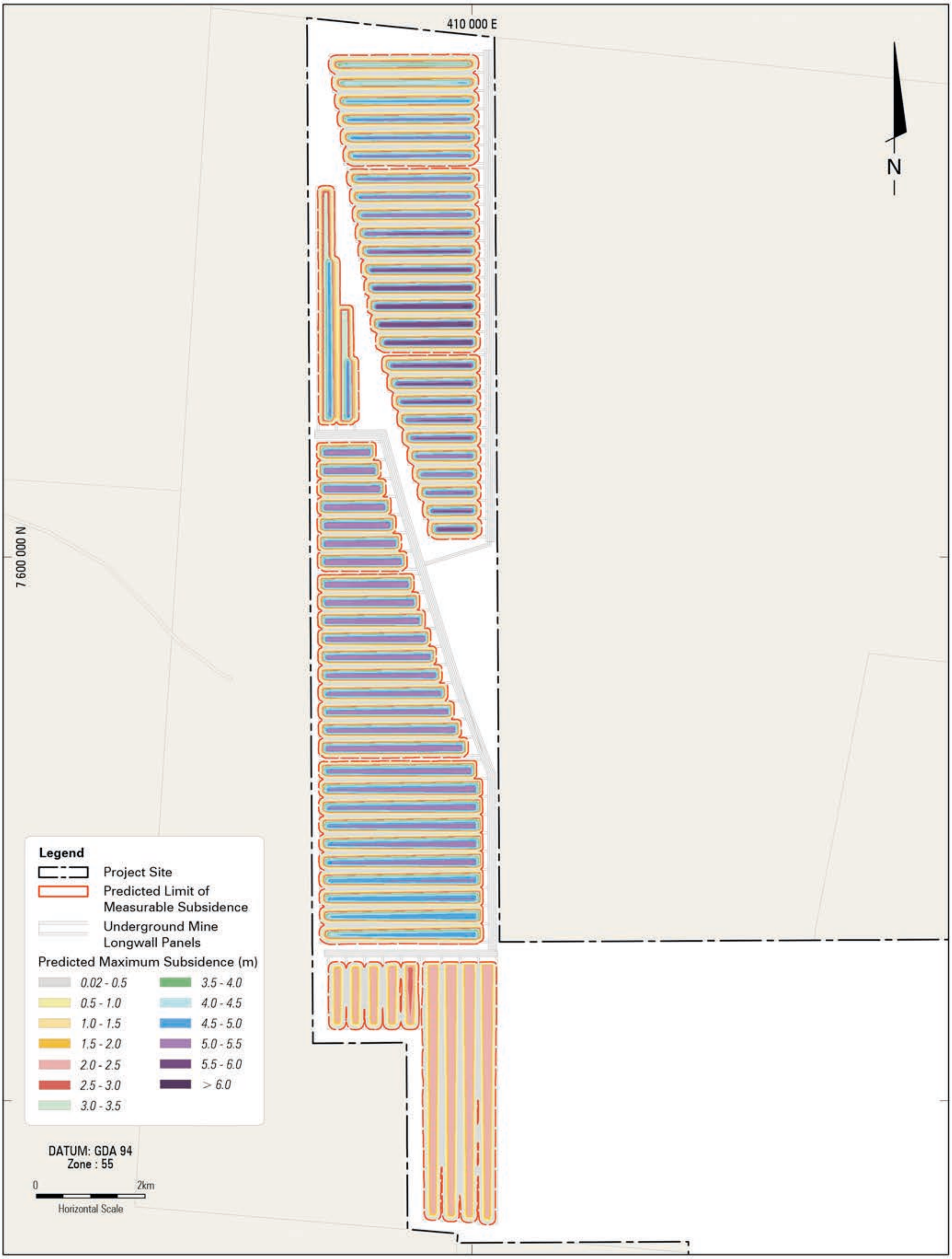
Subsidence Schematic

FIGURE 6-1



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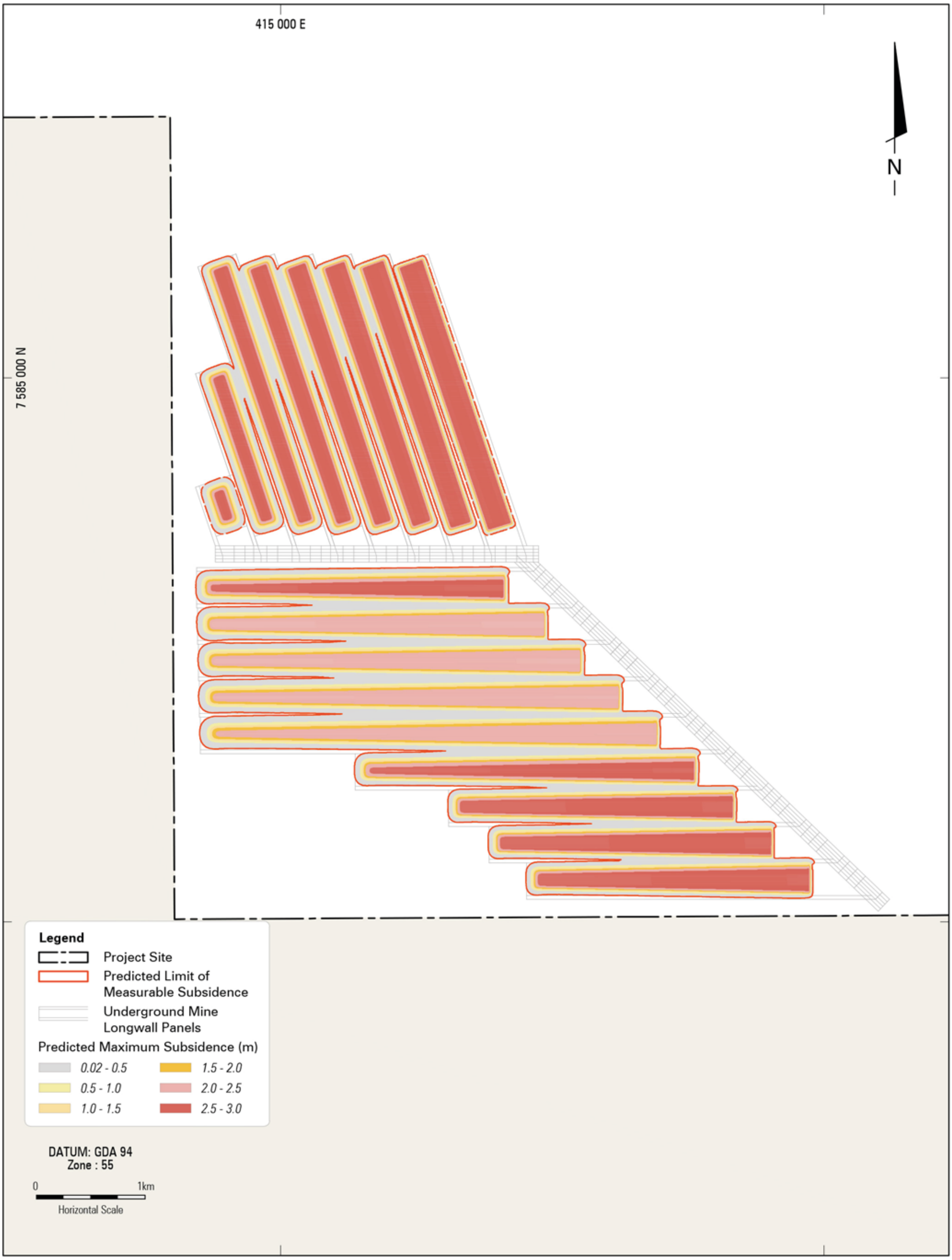
Northern Underground
Predicted Maximum Vertical Subsidence

FIGURE 6-2



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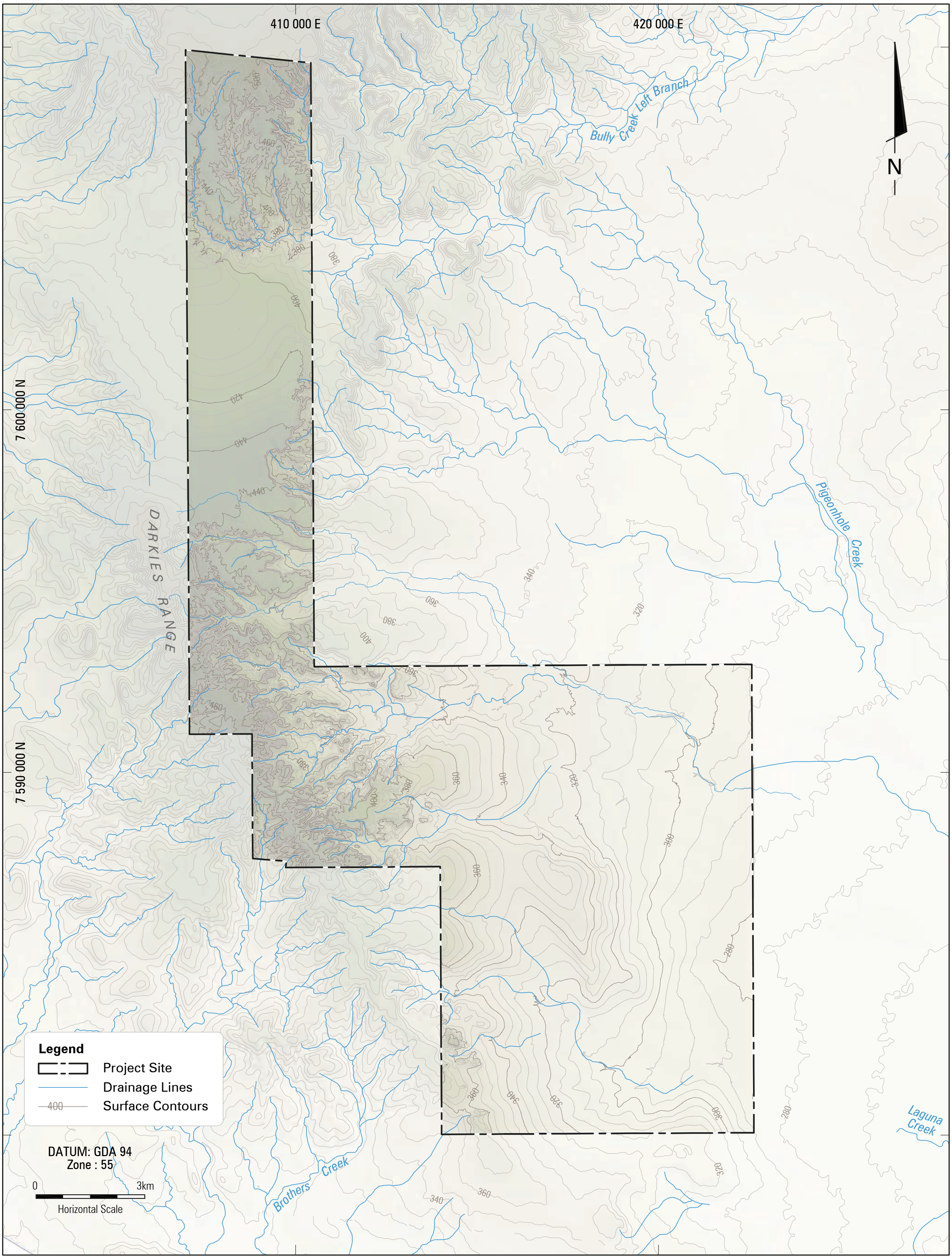
Southern Underground
Predicted Maximum Vertical Subsidence

FIGURE 6-3



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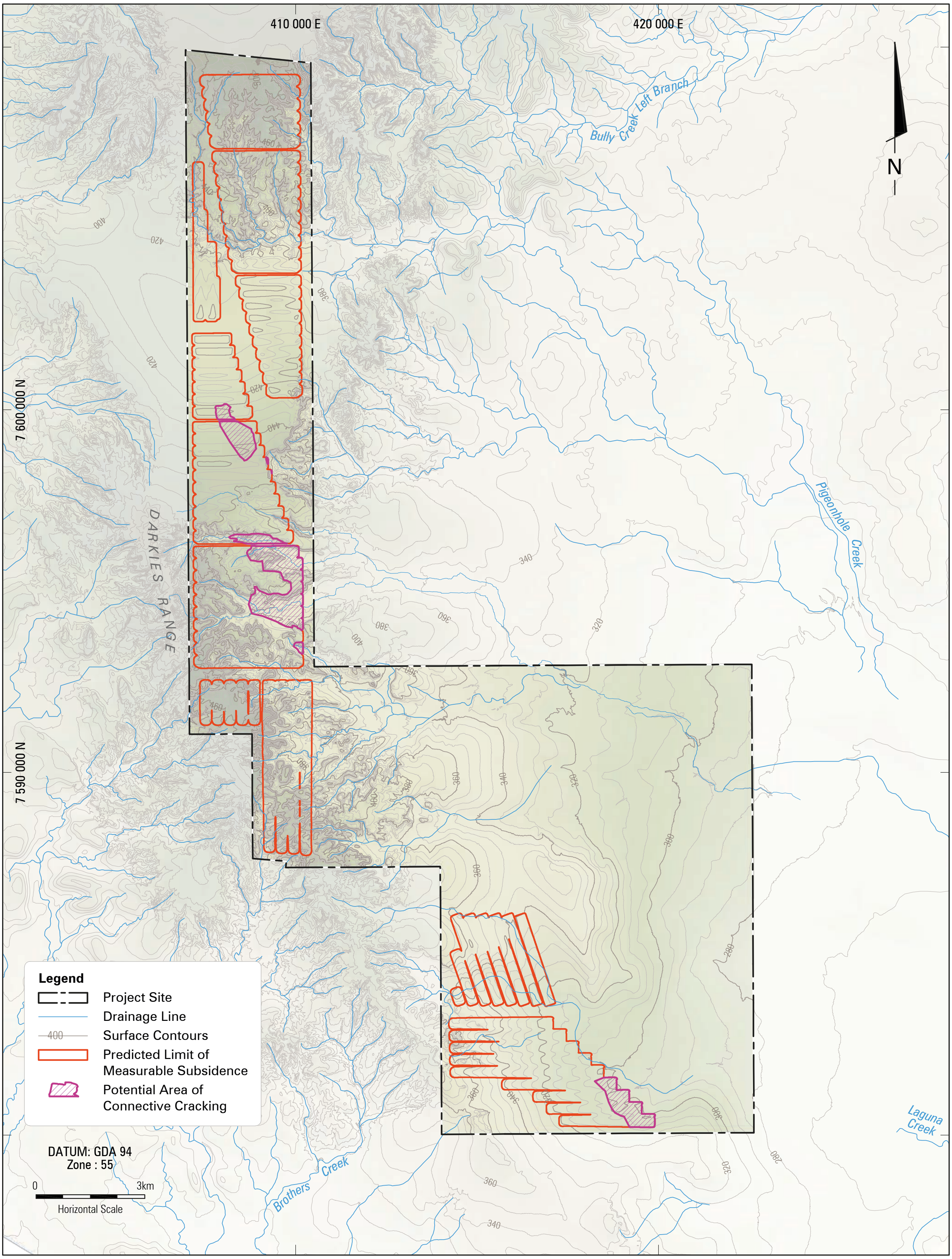
Pre Subsidence Contour Plan

FIGURE 6-4



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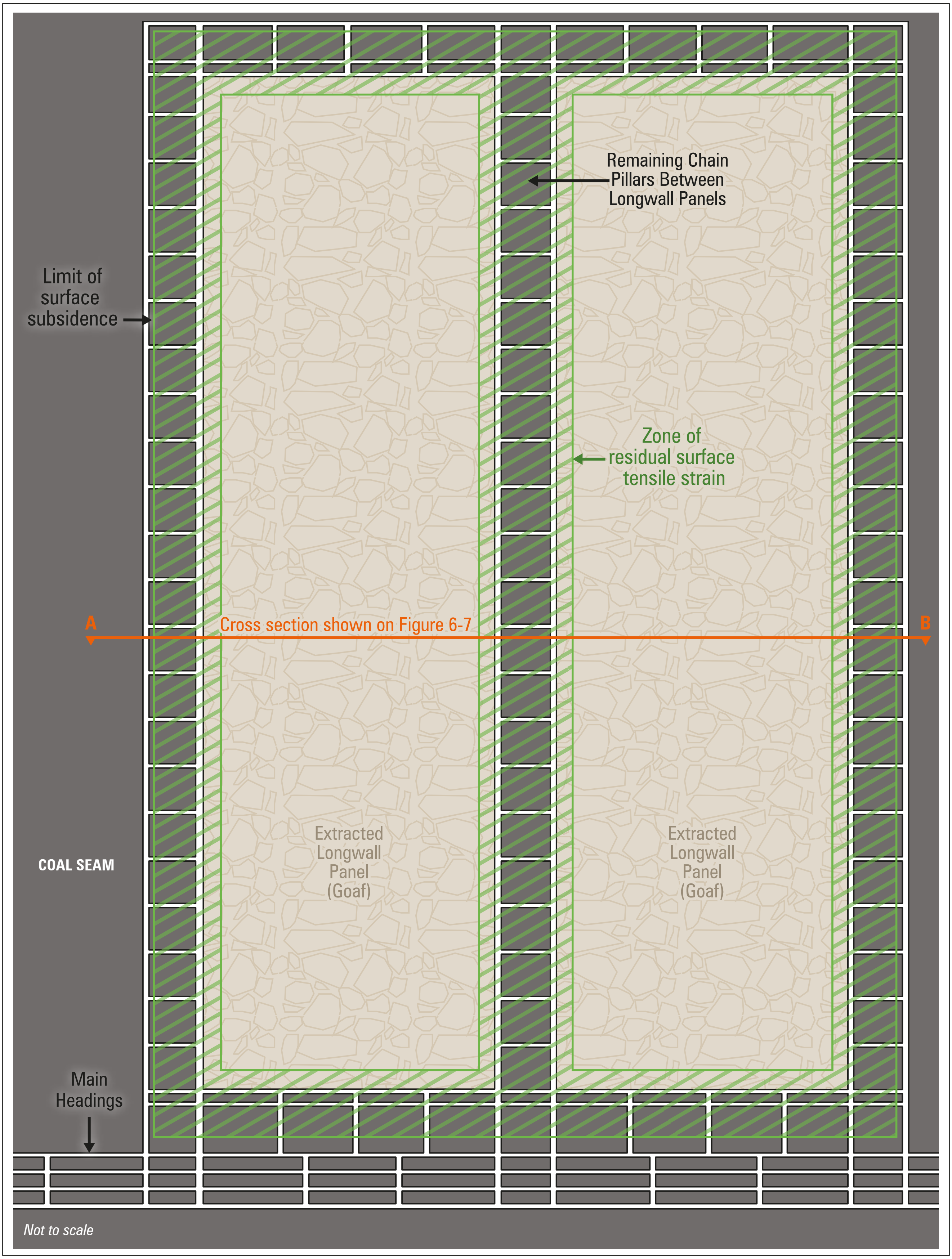
Post Subsidence Contour Plan

FIGURE 6-5



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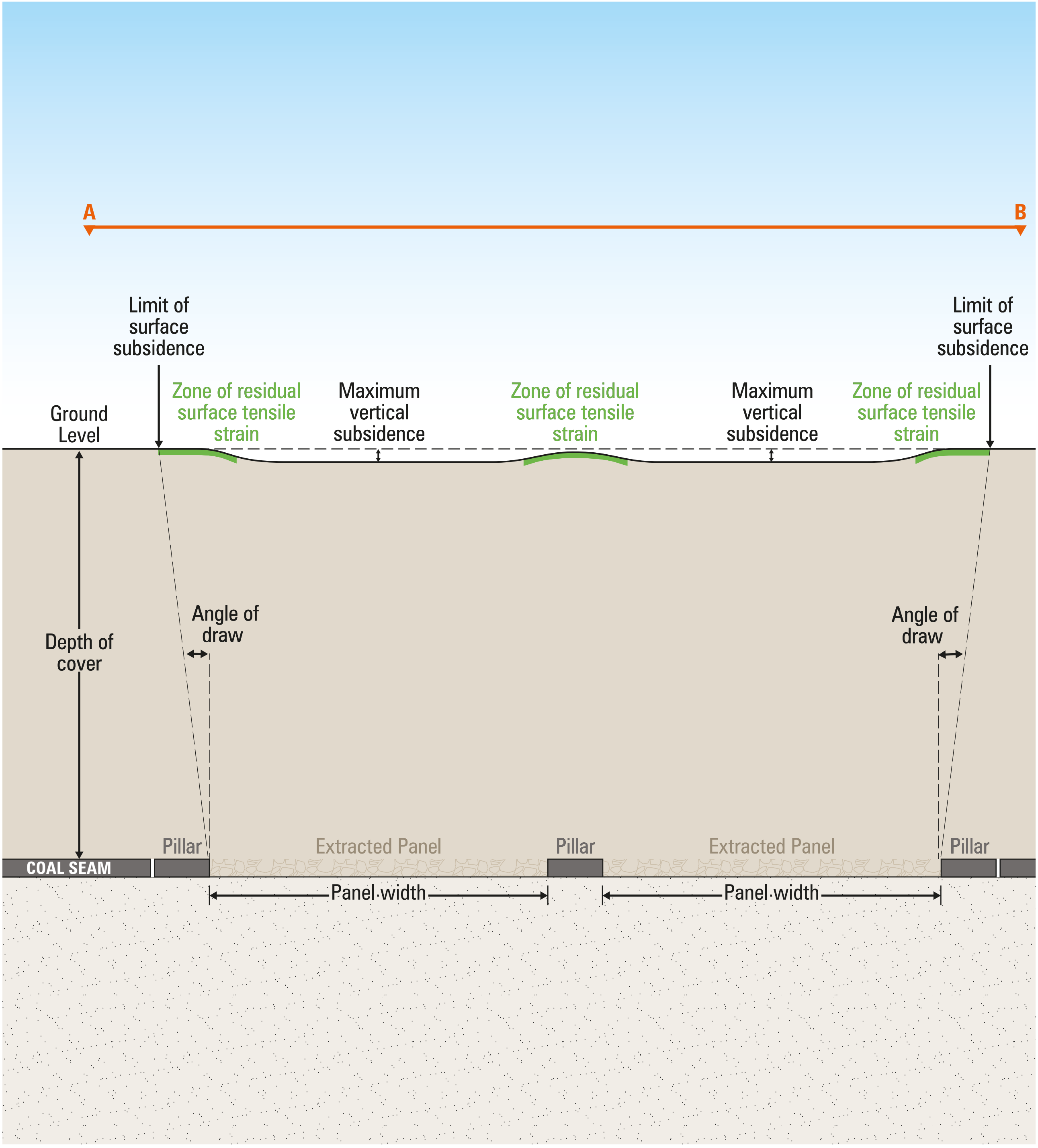
Zone of Residual Tensile Strain
Conceptual Plan View

FIGURE 6-6



Not to scale

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Zone of Residual Tensile Strain
Conceptual Cross Section

FIGURE 6-7