Illawarra Coal

Dendrobium Mine
Area 3

REPORT

on

THE PREDICTION OF SUBSIDENCE PARAMETERS AND THE ASSESSMENT OF MINE SUBSIDENCE IMPACTS ON NATURAL FEATURES AND SURFACE INFRASTRUCTURE RESULTING FROM THE EXTRACTION OF PROPOSED LONGWALLS 6 TO 10 IN AREA 3A AND FUTURE LONGWALLS IN AREAS 3B AND 3C AT DENDROBIUM MINE

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Report Number MSEC311
Revision D
October 2007

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
A	DRAFT Subsidence Predictions and Impact Assessment for the Proposed Longwalls 6 to 10 in Area 3A and the Future Longwalls in Areas 3B and 3C	JB	DRK	9th Aug 07
B	BHPB comments incorporated	JB	DRK	29th Aug 07
C	Final issue	JB	DRK	3rd Oct 07
D	Minor amendments	JB	DRK	22nd Oct 07

Report produced for:-	Submission to the Department of Primary Industries Submission to the Dams Safety Committee Submission to the Department of Planning
Previous reports:-	WKA77 (January 2001) – Dendrobium Mine Project – Report on the Prediction of Mining Subsidence Parameters and the Assessment of Impacts on Surface Infrastructure – Longwalls 1 to 18 (In support of the EIS).

Background reports available at *www.minesubsidence.com:-*

Introduction to Longwall Mining and Subsidence (Revision A)
General Discussion on Mine Subsidence Ground Movements (Revision A)
General Discussion on Upsidence and Closure Predictions (Revision A)

EXECUTIVE SUMMARY

BHP Billiton Illawarra Coal (IC) proposes to continue its underground coal mining operations at Dendrobium Mine located in the Southern Coalfield of New South Wales. Coal is proposed to be extracted from the Wongawilli Seam in Area 3 using longwall mining techniques. IC has previously extracted Longwalls 1 and 2 in Area 1 and has approval to extract Longwalls 3 to 5 in Area 2. At the time of writing this report IC was extracting Longwall 3.

The overall layout of the longwalls at Dendrobium Mine is shown in Drawing No. MSEC311-01, which together with all other drawings is included in Appendix F. Area 3 has been separated into three sub-areas for mining purposes which have been called Areas 3A, 3B and 3C, which are also shown in this drawing.

Mine Subsidence Engineering Consultants Pty Limited (MSEC) has been commissioned by IC to study the mining proposals, identify all natural features and items of surface infrastructure and to prepare subsidence predictions and impact assessments to support the following applications:-

- A SMP Application for submission to the Department of Primary Industries seeking approval to mine Longwalls 6 to 10 in Area 3A,
- An application to the Dams Safety Committee seeking approval to mine within the Notification Area for Lake Cordeaux,
- An application to the Department of Planning seeking approval to mine within Staged Development Area C, and
- An Application to the Department of Planning seeking modification of the development consent for Longwalls 6 to 10 in Area 3A and for the future longwalls in Areas 3B and 3C.

The format of this report follows the Guidelines for the Preparation of Subsidence Management Plans, however, it also addresses the requirements of the Dams Safety Committee and the Department of Planning.

The Study Area has been defined, as a minimum, as the surface area enclosed by a 35 degree angle of draw line from the limit of proposed mining for Longwalls 6 to 10 in Area 3A and from the maximum longwall footprints for the future longwalls in Areas 3B and 3C. The Study Area has been extended to include features outside this area which could be subjected to valley related or far-field horizontal movements and could be sensitive to such movements.

A number of natural features and items of surface infrastructure have been identified within the general Study Area, including Wongawilli, Sandy and Donalds Castle Creeks, drainage lines, Lake Cordeaux and Lake Avon, cliffs, rock outcrops, steep slopes, upland swamps, the abandoned Maldon–Dombarton railway corridor, fire trails and four wheel drive tracks, a 330 kV transmission line and 33 kV powerline, exploration bore holes, archaeological sites and survey control marks.

A number of other natural features and items of surface infrastructure, which are located outside the general Study Area and have been included in the assessments, include the Cordeaux River, Cordeaux and Upper Cordeaux No. 2 Dams and exploration bore holes and survey control marks further afield.

The layout of proposed Longwalls 6 to 10 in Area 3A are shown in Drawing No. MSEC311-01. The longwalls are located to the west of Lake Cordeaux, between Wongawilli and Sandy Creeks. The proposed longwalls are partly located within the Dams Safety Committee Notification Area for Lake Cordeaux and partly within Staged Development Area C as defined in the Development Consent.

The longwall layout in Area 3A has been optimised such that:-

- It is assessed that it is unlikely that significant impacts would occur along Wongawilli and Sandy Creeks, and
- The maximum volume of coal could be extracted within the mining and environmental constraints of the area.

The potential for significant impacts along Wongawilli and Sandy Creeks has been assessed by comparing the predicted movements along these creeks with back-predicted movements along a number of creeks and rivers which have been previously affected by longwall mining within the Southern Coalfield. Based on these case studies, the following limits were adopted for the predicted subsidence parameters along Wongawilli and Sandy Creeks, such that it could be assessed that it was unlikely that significant impacts would occur along the creeks:-

- a maximum predicted total valley closure across the creeks of 200 mm,
- a maximum predicted total systematic tensile strain within the beds of the creeks of 0.5 mm/m, and
- a maximum predicted total systematic compressive strain within the beds of the creeks of 2 mm/m.

The proposed longwalls in Area 3A have been set back from Wongawilli and Sandy Creeks such that the maximum predicted parameters along these creeks were less than the above parameters. These set backs have necessitated sterilising of coal resources that otherwise could have been extracted. It has been assessed that it is unlikely that significant impacts, such as major fracturing or draining of pools, would occur along Wongawilli and Sandy Creeks as a result of the extraction of the proposed longwalls in Area 3A. It is likely, however, that minor impacts would occur along these creeks as a result of the extraction of the proposed longwalls.

The future longwalls in Areas 3B and 3C will be located within the maximum footprint area which is shown in Drawing No. MSEC311-01. The finalisation of the future longwall layouts in these areas will progress as additional exploration data is gathered to better define the extractable resource. An application for SMP Approval will be developed for the future longwalls in Areas 3B and 3C at a later date, which will be supported by detailed subsidence modelling of the future longwalls in these areas.

Chapter 1 of this report provides a general introduction to the study, which also includes a description of the mining geometry and geological details of the proposed mining area.

Chapter 2 identifies the natural features and items of surface infrastructure within the Study Area.

Chapter 3 includes a brief overview of longwall mining, the development of mine subsidence and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the proposed and future longwalls in Area 3.

Chapter 4 provides the maximum predicted systematic subsidence parameters resulting from the extraction of the proposed and future longwalls in Area 3.

Chapter 5 provides the predicted systematic subsidence and valley related movements for the natural features and items of surface infrastructure within the Study Area. The impact assessments and recommendations for each of these features are also provided, which have been based on the predicted subsidence parameters.

Chapter 6 provides recommendations for ground movement monitoring.

Chapter 7 discusses the effects of changes to the mine layout on the predicted subsidence parameters and impact assessments.

The maximum predicted systematic subsidence parameters for Longwalls 6 to 10, which were obtained using the Incremental Profile Method, have been compared to those obtained using the Holla Series and Department's Handbook Methods. The maximum predicted systematic subsidence parameters obtained using the Incremental Profile Method are similar to, but slightly greater than those obtained using the Holla Series and Department's Handbook Methods.

The predicted systematic subsidence parameters have also been compared to those observed for Longwalls 1 and 2 in Area 1, Longwall 3 in Area 2 and Longwalls 1 to 10 at the nearby Elouera Colliery. The predicted profiles showed reasonable correlation to the observed profiles.

The assessments in this report indicate that the levels of impact on the natural features and items of surface infrastructure are not significant and can be managed by the preparation and implementation of management strategies. It should be noted, however, that more detailed assessments of some natural features and items of surface infrastructure have been undertaken by other consultants, and the findings in this report should be read in conjunction with the findings in all other relevant reports.

Monitoring of ground movements is recommended, as subsidence occurs, so that the observed ground movements can be compared with those predicted and to allow regular reviews of the predictions and impact assessments in the light of measured data.

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CHAPTER 1. BACKGROUND

1.1. Introduction

BHP Billiton Illawarra Coal (IC) proposes to continue its underground coal mining operations at Dendrobium Mine located in the Southern Coalfield of New South Wales. Coal is proposed to be extracted from the Wongawilli Seam in Area 3 using longwall mining techniques. IC has previously extracted Longwalls 1 and 2 in Area 1 and has approval to extract Longwalls 3 to 5 in Area 2. An application to extract Longwall 5A in Area 2 has been submitted for approval. At the time of writing this report IC was extracting Longwall 3. The overall layout of the longwalls at Dendrobium Mine is shown in Drawing No. MSEC311-01, which together with all other drawings is included in Appendix F.

Mine Subsidence Engineering Consultants Pty Limited (MSEC), formerly trading as Waddington Kay & Associates, was previously commissioned by IC in August 2000, to study the mining proposals, to prepare subsidence predictions for the proposed Longwalls 1 to 18 at Dendrobium Mine, and to identify and prepare detailed subsidence impact assessments for all major natural features and items of surface infrastructure above the proposed longwalls. Report No. WKA77 was issued in January 2001 on completion of that work in support of the Dendrobium EIS. The layout of the previously proposed longwalls in Area 3 adopted in the EIS and the layout of the currently proposed longwalls in Area 3A are shown in Drawing No. MSEC311-02.

Area 3 has subsequently been separated into three sub-areas for mining purposes which have been called Areas 3A, 3B and 3C. The layout of the currently proposed Longwalls 6 to 10 in Area 3A are shown in Drawing No. MSEC311-01. The future longwalls in Areas 3B and 3C will be located within the maximum footprint area also shown in this drawing. The Study Area for the proposed and future longwalls in Areas 3A, 3B and 3C and the SMP Area for the proposed longwalls in Area 3A are defined in Chapter 2.

MSEC has now been commissioned by IC to study the current mining proposals in Area 3, identify all the natural features and items of surface infrastructure, and to prepare subsidence predictions and impact assessments for the proposed and future longwalls. The format of this report follows the Guidelines for the Preparation of Subsidence Management Plans, however, it also addresses the requirements of the Dams Safety Committee and the Department of Planning.

This report provides information that will support the following applications:-

- A SMP Application for submission to the Department of Primary Industries (DPI SMP Guideline 2003), as summarised in Table 1.1, seeking approval to mine Longwalls 6 to 10 in Area 3A,
- An application to the Dams Safety Committee seeking approval to mine within the Notification Area for Lake Cordeaux,
- An application to the Department of Planning seeking approval to mine within Staged Development Area C, and
- An Application to the Department of Planning seeking modification of the development consent for Longwalls 6 to 10 in Area 3A and for the future longwalls in Areas 3B and 3C.

Table 1.1 Information Provided in Support of a SMP Application

Information	Section of the Guideline for "Applications for Subsidence Management Approvals"
The SMP Area or Application Area	Section 6.2
Site Conditions of the SMP Area	Section 6.4
Characterisation of Surface and Sub-surface Features within the SMP Area	Section 6.6
Subsidence Prediction	Section 6.7
Subsidence Impacts	Section 6.10.1
Impact Assessment based on Increased Subsidence Predictions	Section 6.10.3

In some cases, this report will refer to other sources for information on specific natural features and items of surface infrastructure. This report will also provide information to assist the risk assessment section for the SMP Application (DPI SMP Guideline 2003, Section 6.10.2).

A number of natural features and items of surface infrastructure have been identified within the Study Area, which are described in Chapter 2 of this report. The major natural features and items of surface infrastructure can be seen in Fig. 1.1, which shows the proposed Longwalls 6 to 10 in Area 3A and the maximum footprint for Areas 3B and 3C overlaid with an orthophoto of the area.

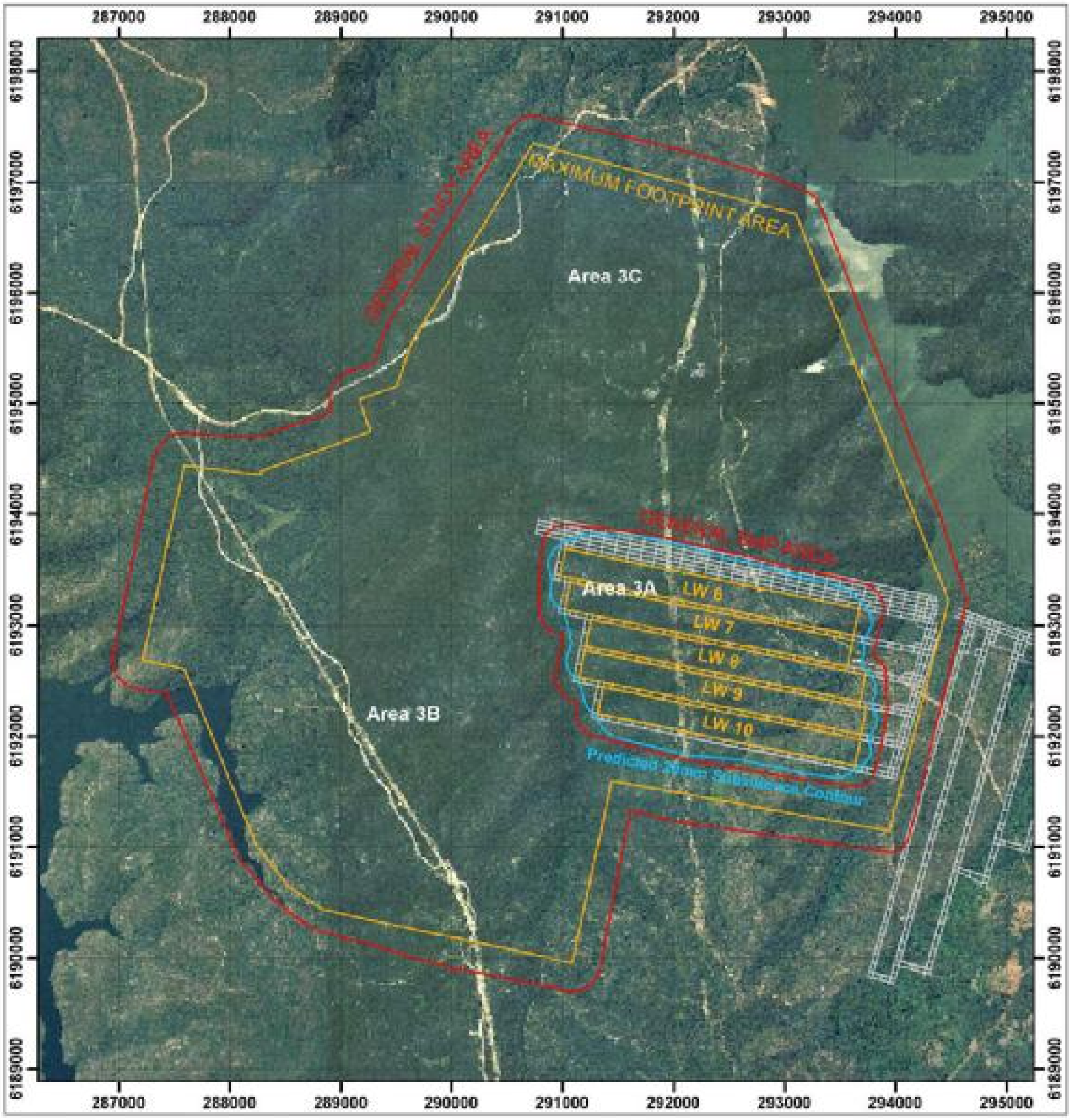


Fig. 1.1 Aerial Photograph Showing Longwalls 6 to 10 in Area 3A, the Maximum Longwall Footprint for Areas 3B and 3C, the General Study Area and General SMP Area

Chapter 3 includes a brief overview of longwall mining, the development of mine subsidence and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the proposed longwalls and future longwalls in Area 3.

Chapter 4 provides the maximum predicted systematic subsidence parameters resulting from the extraction of the proposed and future longwalls in Area 3.

Chapter 5 provides the predicted systematic subsidence and valley related movements for the natural features and items of surface infrastructure within the Study Area. The impact assessments and recommendations for each of these features are also provided, which have been based on the predicted subsidence parameters.

Chapter 6 provides recommendations for ground movement monitoring in Area 3A.

Chapter 7 discussed the effects of changes in the mine layout on the predicted subsidence parameters and impact assessments.

1.2. Development of the Mining Geometry

A number of alternative longwall layouts were considered in Area 3A as part of the process to develop the final mining geometry. These layouts included variations in the numbers of longwalls and variations in the orientations, lengths and offsets of the longwalls from key surface features. These options were reviewed, analysed and modified until an optimised longwall layout in Area 3A was achieved.

Two important objectives which formed part of the longwall layout optimisation were:-

- Avoidance of significant impact on the major natural features, including Wongawilli Creek, Sandy Creek and the waterfall where Sandy Creek flows into Lake Cordeaux, and
- Minimisation of the volume of sterilised coal which could be efficiently extracted within the mining and environmental constraints of the area.

Three examples of the longwall layouts which were considered in Area 3A as part of this process are provided in Appendix C at the end of this report. The first example comprises a series of five longwalls, orientated east-west, having a range of offsets from Wongawilli Creek. The second example comprises a series of up to nine longwalls, orientated north-south, mined progressively towards Wongawilli Creek. The third example comprises a series of five longwalls, orientated east-west, having a range of offsets from Sandy Creek. For each example, the predicted systematic subsidence, valley related movements and volume of sterilised coal are shown for a range of longwall offsets from the creeks.

The potential for significant impact along Wongawilli and Sandy Creeks has been assessed by comparing the predicted movements along these creeks with back-predicted movements along a number of creeks and rivers which have been affected by longwall mining within the Southern Coalfield. A detailed description of the methodology is provided in Section 5.3.5.2 and details of the case studies are provided in Appendix D at the end of this report. Based on these case studies, the following limits were adopted for the predicted subsidence parameters along Wongawilli and Sandy Creeks, such that it could be assessed that it was unlikely that significant impacts would occur along the creeks:-

- a maximum predicted total valley closure across the creeks of 200 mm,
- a maximum predicted total systematic tensile strain within the beds of the creeks of 0.5 mm/m, and
- a maximum predicted total systematic compressive strain within the beds of the creeks of 2 mm/m.

Based on this process, the proposed longwalls in Area 3A have been set back from Wongawilli and Sandy Creeks such that the maximum predicted parameters along these creeks were less than the above parameters. These set backs have necessitated sterilising of coal resources that otherwise could have been extracted.

As described in Section 5.3.5.2, it has been assessed that it is unlikely that significant impacts, such as major fracturing or draining of pools, would occur along Wongawilli and Sandy Creeks as a result of the extraction of the proposed longwalls in Area 3A. It is likely, however, that minor impacts would occur along these creeks as a result of the extraction of the proposed longwalls.

It is proposed that the future longwalls in Areas 3B and 3C would also be set back from Wongawilli Creek using the methodology described above and, hence, such that it is assessed that it is unlikely that significant impacts would occur along the creek. The preliminary concept maximum longwall mining domains for the future longwalls in Areas 3B and 3C are shown in Appendix C at the end of this report, which are based on limiting the maximum predicted systematic tensile and compressive strains at Wongawilli Creek, Lake Cordeaux and Lake Avon to less than 0.5 mm/m and 2 mm/m, respectively. These mining domains will be further refined as part of the SMP Approval process as additional resource data becomes available and prior to any mining in these areas. A similar process of mine layout evaluation described above will be used to develop longwall layouts for these areas.

1.3. Proposed Mining Geometry

The proposed layout of Longwalls 6 to 10 within the Wongawilli Seam in Area 3A is shown in Drawing No. MSEC311-01. A summary of the proposed dimensions of these longwalls are provided in Table 1.2. The future longwalls in Areas 3B and 3C will be located within the maximum footprint area which is also shown in this drawing.

Table 1.2 Proposed Dimensions of Longwalls 6 to 10 in Area 3A

Longwall	Overall Length (m)	Void Width Including Headings (m)	Solid Chain Pillar Width (m)
Longwall 6	2700	250	-
Longwall 7	2600	250	40
Longwall 8	2525	250	40
Longwall 9	2590	250	40
Longwall 10	2375	250	40

The longwalls in Area 3 are proposed to be extracted from the Wongawilli Seam, which underlies the Bulli Seam by approximately 20 metres. The Bulli Seam is not proposed to be extracted in Area 3 as part of these applications. Accordingly, all the predicted systematic subsidence parameters provided in this report have been made using single-seam conditions, rather than multi-seam conditions as was undertaken for parts of Area 1.

The depth of cover to the Wongawilli Seam within the Study Area varies between a minimum of 215 metres, below Lake Cordeaux on the eastern side of the Study Area, and a maximum of 425 metres below the ridgeline on the western side of Wongawilli Creek. The depth of cover above the proposed longwalls in Area 3A varies between a minimum of 255 metres at the finishing (eastern) end of Longwall 10, and a maximum of 400 metres above the tailgate of Longwall 6. The seam floor within the Study Area generally dips from the south-east to the north-west.

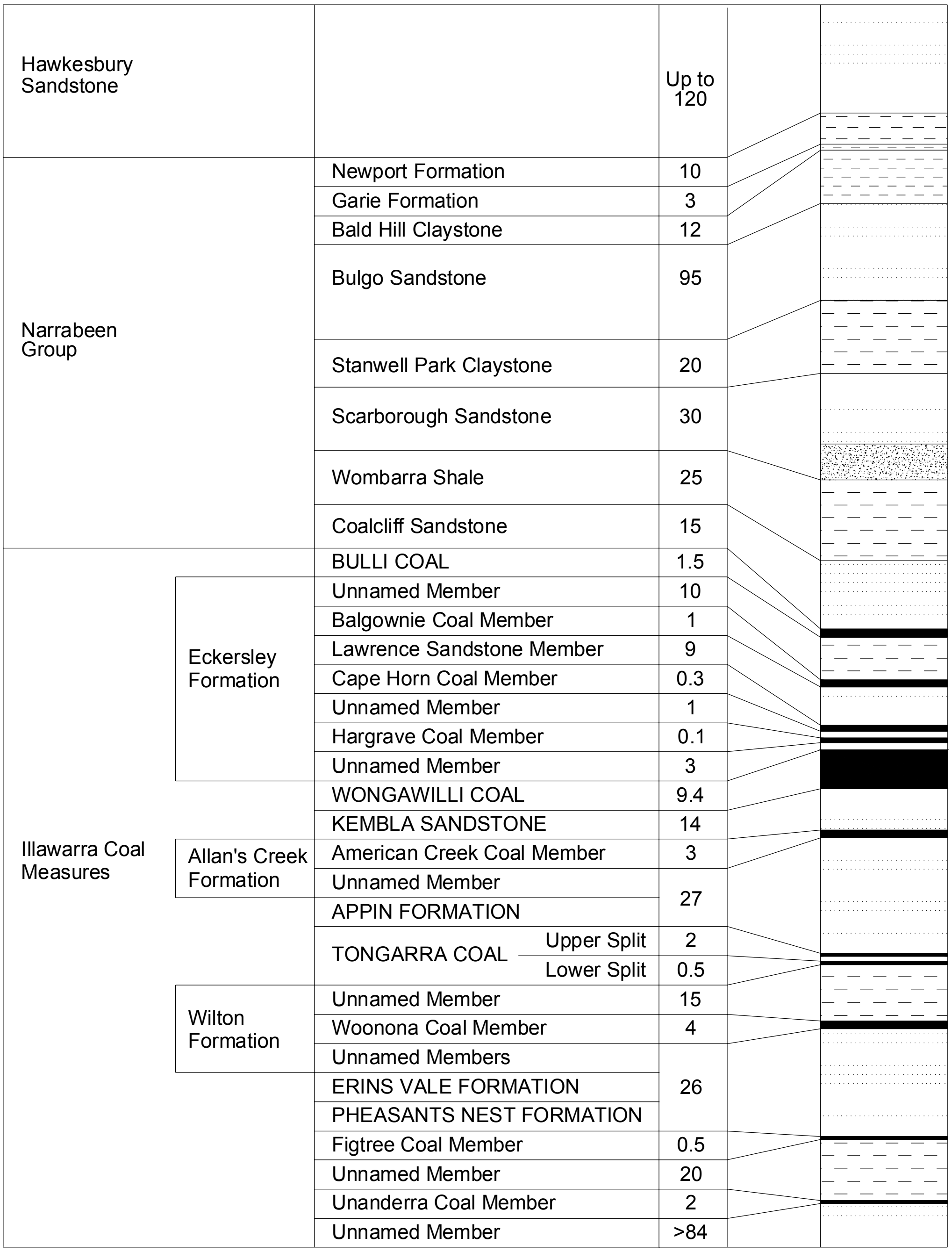
The Wongawilli Seam in Area 3 is nominally 10 metres thick and contains numerous bands of non-coal material. The economic section of the Wongawilli Seam is the basal 3 to 4 metres. IC has reviewed the nature of the banding in Area 3 and has proposed to extract a maximum height of 3.9 metres. To ensure roof and floor conditions suitable for a longwall mining operations, various bands within the coal seam are proposed to be targeted to achieve the overall extraction height.

The surface level contours, seam floor contours and depth of cover contours are shown in Drawings Nos. MSEC311-03, MSEC311-04 and MSEC311-05, respectively.

1.4. Geological Details

The geology of the Dendrobium Area is outlined in Chapter 1 of the Waddington Kay and Associates Report No. WKA77, which was included as Volume 2 of the EIS for the Dendrobium Mine Project. The geology mainly comprises sedimentary sandstones, shales and claystones of the Permian and Triassic Periods, which have been intruded by igneous sills. The major geological features in Area 3 are shown in Drawing No. MSEC311-06. A generalised sedimentary stratigraphic section is shown in Fig. 1.2.

The sandstone units vary in thickness from a few metres to as much as 120 metres. The major sandstone units are interbedded with other rocks and, though shales and claystones are quite extensive in places, the sandstone predominates.



Hawkesbury Sandstone			Up to 120
Narrabeen Group		Newport Formation	10
		Garie Formation	3
		Bald Hill Claystone	12
		Bulgo Sandstone	95
		Stanwell Park Claystone	20
		Scarborough Sandstone	30
		Wombarra Shale	25
		Coalcliff Sandstone	15
Illawarra Coal Measures		BULLI COAL	1.5
	Eckersley Formation	Unnamed Member	10
		Balgownie Coal Member	1
		Lawrence Sandstone Member	9
		Cape Horn Coal Member	0.3
		Unnamed Member	1
		Hargrave Coal Member	0.1
		Unnamed Member	3
		WONGAWILLI COAL	9.4
		KEMBLA SANDSTONE	14
	Allan's Creek Formation	American Creek Coal Member	3
		Unnamed Member	27
		APPIN FORMATION	
		TONGARRA COAL – Upper Split	2
		TONGARRA COAL – Lower Split	0.5
	Wilton Formation	Unnamed Member	15
		Woonona Coal Member	4
		Unnamed Members	26
		ERINS VALE FORMATION	
		PHEASANTS NEST FORMATION	
		Figtree Coal Member	0.5
		Unnamed Member	20
		Unanderra Coal Member	2
		Unnamed Member	>84

Fig. 1.2 Generalised Stratigraphic Column (after Williams 1979)

The major sedimentary units in the Dendrobium Area are, from the top down:-

- The Hawkesbury Sandstone,
- The Narrabeen Group, and
- The Eckersley Formation.

The Narrabeen Group contains the Newport Formation (sometimes referred to as the Gosford Formation), the Bald Hill Claystone, the Bulgo Sandstone, the Stanwell Park Claystone, the Scarborough Sandstone, the Wombarra Shale and the Coalcliff Sandstone.

The Eckersley Formation contains sandstones, shales and minor coal seams and forms the upper section of the Illawarra Coal Measures. The Bulli Seam lies directly above the Eckersley Formation and the Wongawilli Seam lies directly below it.

The geology varies throughout Area 3 and this will have some effect on the subsidence movements that will occur from place to place. The exploration boreholes within the proposed mining area have been studied, together with some surface mapping of outcrops undertaken by IC, and this information has enabled the variations in the geology to be more closely defined.

There are several igneous structures within Area 3 with the most noteworthy igneous sill being the Nepheline Syenite intrusion, the approximate location of which is shown in Drawing No. MSEC311-06. Mapping of the sill will be refined as further geological investigations are undertaken using in-seam drilling. The extent of sill cannot be mapped using surface geophysical techniques and drilling from the surface has provided the present definition of the margin. The intrusion is generally located to the south of the proposed longwalls in Area 3A and has only intruded at the level of the Wongawilli Seam.

Several geological structures have been identified at seam level near the proposed longwalls in Area 3A, including a fault and a dyke near the finishing ends of Longwalls 9 and 10. A series of dykes have also been identified to the north of Longwall 6. Another sill and cindered zone have been identified along the western sides of Areas 3B and 3C. Mapping of the geological structures will be refined as further geological investigations are undertaken.

In common with the rest of the Southern Coalfield, the in-situ horizontal stresses at the Dendrobium Mine are relatively high. SCT Operations has reported that the maximum horizontal stress ($\sigma_{H\ max}$) is 14 MPa to 16 MPa at 200 metres depth of cover and 20 MPa to 24 MPa at 450 metres depth of cover. The maximum principal stress direction, based on borehole breakout data, is NE to SW (032° – 65° TN).

The rocks of the Hawkesbury Sandstone and the Narrabeen Group are of relatively low permeability and have a limited capacity to facilitate migration of water from the surface into the proposed mine workings. This capacity is further reduced by the relatively high level of in situ horizontal stress that is a feature of the Southern Coalfield. As mining occurs, the subsidence of the strata above the goaf areas can lead to some fracturing of the strata, which in turn can increase vertical permeability. This increased permeability is referred to as the fracture permeability.

The vertical permeability is reduced by the claystone layers, which, on exposure to water, tend to swell and seal any fractures, inhibiting the passage of water. Such layers are referred to as aquicludes or aquitards. If the claystone layers are in the collapsed or fractured zones above the proposed longwalls, the fractures could be too large to be sealed by this process. The height of the fractured zone over the proposed longwalls is discussed in Section 5.21.3.

The Bald Hill Claystone is generally considered to be the most impervious aquiclude and any cracking that occurs in the strata above this layer will generally have little impact on the quantity of water migrating from the surface to the seam. The Bald Hill Claystone is only present over part of the proposed mining area and is located above the maximum supply level of Lake Cordeaux and Lake Avon. The Stanwell Park Claystone is located over the full area of the proposed longwalls and will also tend to reduce the vertical permeability between the surface and the seam. The Wombarra Shale lies within the collapsed zone above the proposed longwalls and will be less effective in reducing vertical permeability.

Normally, in the Southern Coalfield, where the depth of cover to the seam is reasonably high and where the seam extraction height varies up to 4 metres, the fracturing of the strata does not form continuous paths from the surface to the seam and any cracks that might form tend to re-seal within the aquicludes.

The surface geology within Area 3 can be seen in Fig. 1.3, which shows the proposed longwalls in Area 3A and the maximum footprint for Areas 3A, 3B and 3C overlaid on Geological Series Sheet 9029-9129, which is published by the Department of Primary Industries.

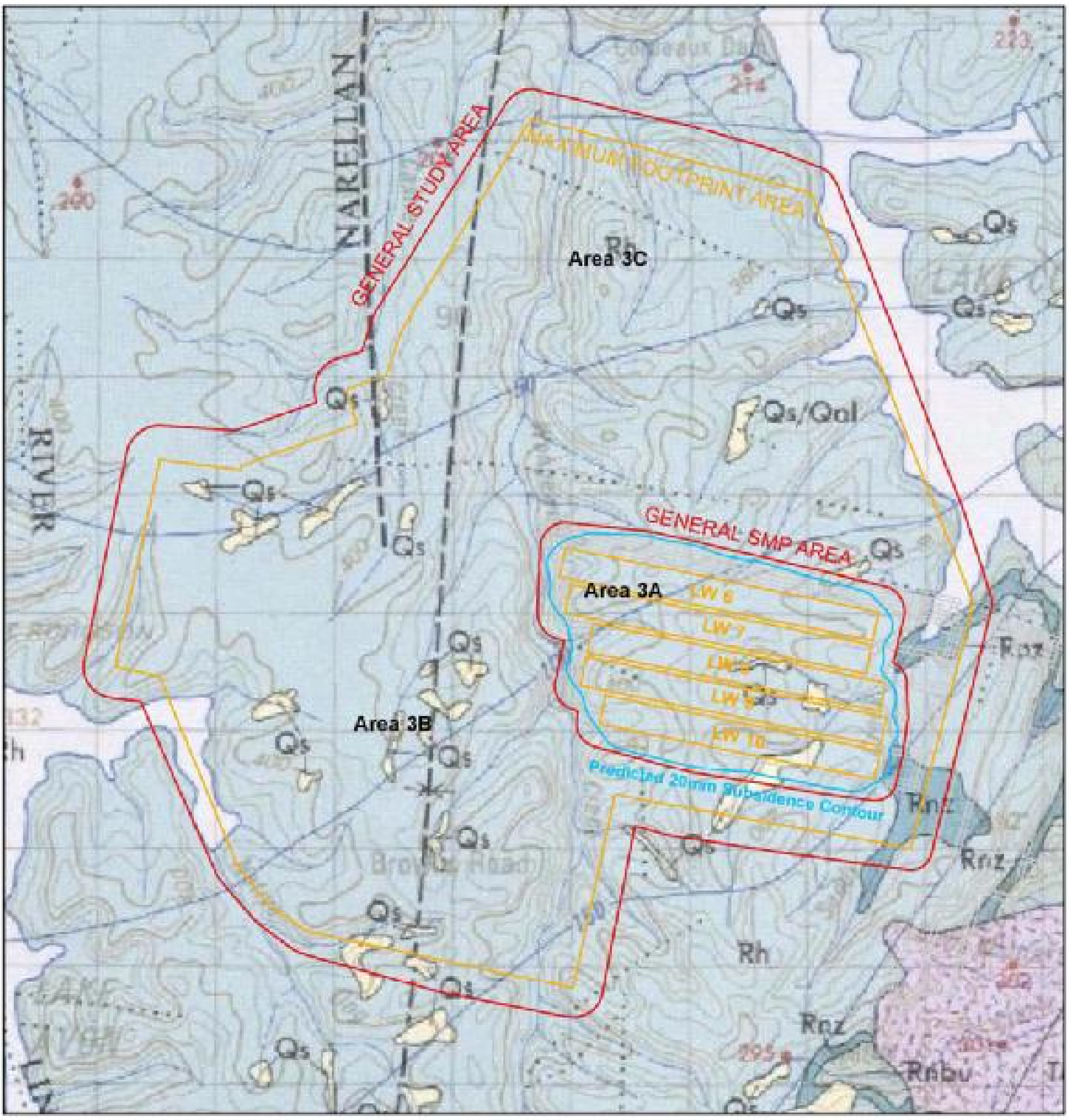


Fig. 1.3 Surface Geology at Dendrobium Area 3

It can be seen from the above figure that the surface geology in the area generally comprises of Hawkesbury Sandstone (Rh), with small isolated areas of quaternary soils (Qs) and Bald Hill Claystone (Rnz). There are also some small isolated areas within Area 3B, which are not shown in the above figure, which have been identified as comprising of Wianamatta Shale (Rwb).

CHAPTER 2. IDENTIFICATION OF SURFACE FEATURES IN AREA 3

2.1. The Study and SMP Areas

The "Study Area" has been defined as the surface area that is likely to be affected by the mining of proposed Longwalls 6 to 10 in Area 3A and by the mining of the future longwalls in Areas 3B and 3C. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:-

- The 35 degree angle of draw line from the maximum footprint for Areas 3A, 3B and 3C, and
- Features sensitive to far-field movements.

Given that the depth of cover within Area 3 varies between 215 and 425 metres, the 35 degree angle of draw has been conservatively determined by drawing a line that is a horizontal distance, varying between 150 and 300 metres around the maximum footprint for Areas 3A, 3B and 3C. A line has been drawn defining the general Study Area, based upon the 35 degree angle of draw line, which is shown in Drawing No. MSEC311-01.

The "SMP Area" has been defined as the surface area that is likely to be affected by the mining of proposed Longwalls 6 to 10 in Area 3A only. The extent of the SMP Area has been calculated by combining the areas bounded by the following limits:-

- The 35 degree angle of draw line from the goaf edges of proposed Longwalls 6 to 10,
- The predicted vertical limit of subsidence, taken as the 20 mm subsidence contour, resulting from the extraction of proposed Longwalls 6 to 10, and
- Features sensitive to far-field movements.

The 35 degree angle of draw line is described as the "surface area defined by the cover depths, angle of draw of 35 degree and the limit of the proposed extraction area in mining leases of the Southern Coalfield", as stated in Section 6.2 of the Department of Primary Industries (DPI) SMP Guideline 2003. Given that the depth of cover above proposed Longwalls 6 to 10 varies between 255 and 400 metres, the 35 degree angle of draw has been conservatively determined by drawing a line that is a horizontal distance, varying between 180 and 280 metres around the limit of the proposed extraction area.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the Incremental Profile Method, which is described in Section 3.4. Further details on the Incremental Profile Method are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

In all locations, the predicted total 20 mm subsidence contour resulting from the extraction of Longwalls 6 to 10 in Area 3A is located within the area bounded by the 35 degree angle of draw line. A line has therefore been drawn defining the general SMP Area, based upon the 35 degree angle of draw line and is shown in Drawing No. MSEC311-01.

There are areas that lie outside the general Study and general SMP Areas that are expected to experience either far-field movements, or valley related upsidence and closure movements. The surface features which may be sensitive to such movements have been identified in this report and have been included as part of the assessments. The features that have been included within the Study and SMP Areas, beyond the extents of the general Study and general SMP Areas, are listed below:-

- Creeks within the predicted limit of 20 mm total upsidence,
- Lake Cordeaux and Lake Avon,
- Cordeaux and Upper Cordeaux No. 2 Dams,
- Exploration bore holes, and
- Survey Control Marks.

2.2. General Description of the Natural Features and Items of Surface Infrastructure

The major natural features and items of surface infrastructure within the Study Area can be seen in the 1:25,000 Topographic Maps of the area, published by the Central Mapping Authority (CMA), numbered AVON RIVER 9029-3-S and WOLLONGONG 9029-2-S. The proposed Longwalls 6 to 10 in Areas 3A and the maximum footprint for Areas 3A, 3B and 3C have been overlaid on extracts of these CMA maps, which are shown in Fig. 2.1.

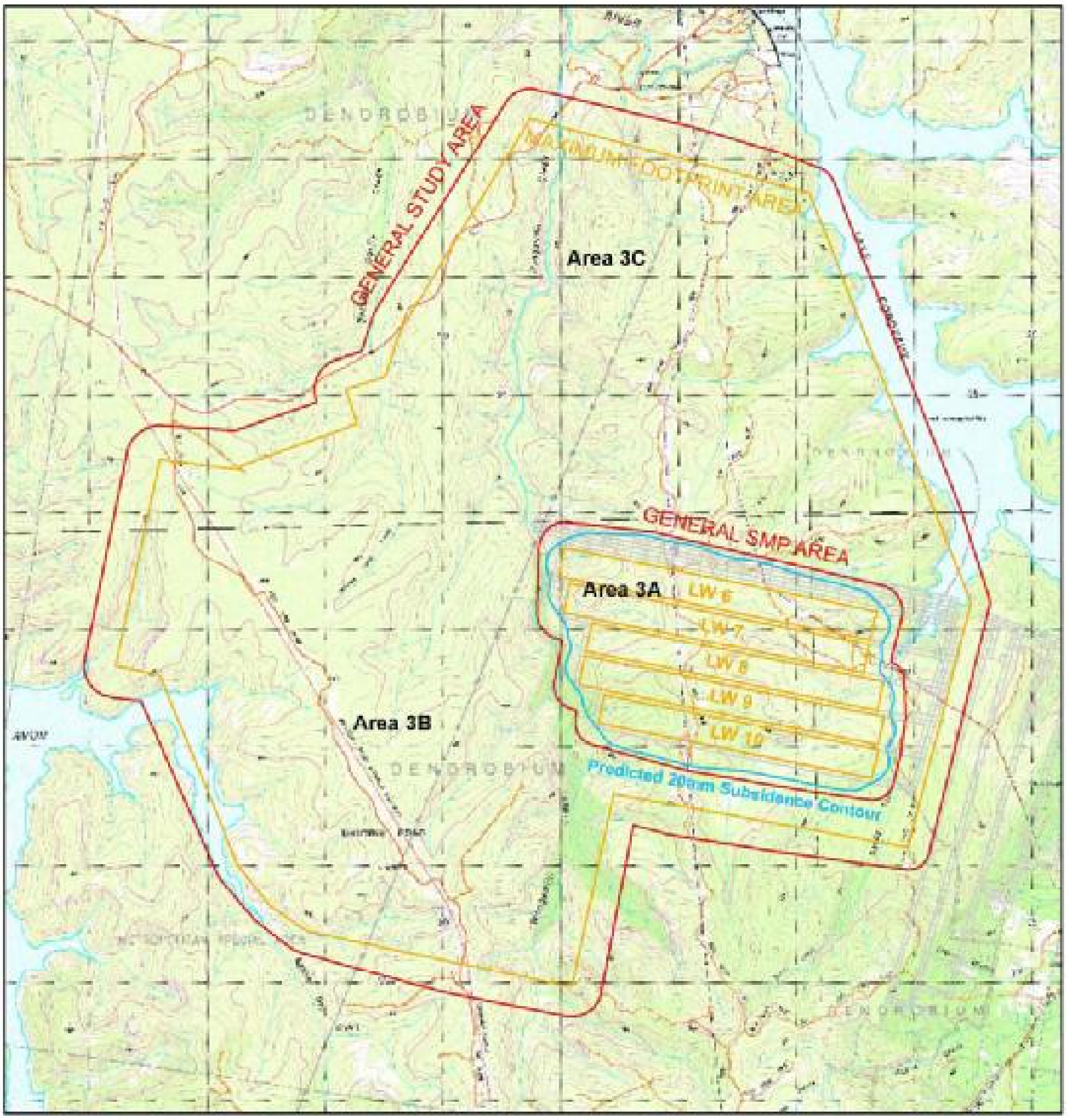


Fig. 2.1 Longwalls 6 to 10 and the Maximum Footprint Area Overlaid on Part CMA Maps Numbered Avon River 9029-3-S and Wollongong 9029-2-S

The following sections in this chapter identify and describe the major natural features and items of surface infrastructure that lie within the Study and SMP Areas. A summary of these features is provided in Table 2.1, which follows the list included in Appendix B of the DPI SMP Guideline 2003.

Further details identifying areas of environmental sensitivity, as defined in the DPI SMP Guideline, are provided in Section 2.3. The natural features and items of surface infrastructure within the Study and SMP Areas, which are further defined by specific studies, are illustrated in Drawings Nos. MSEC311-07 to MSEC311-14.

Table 2.1 Natural Features and Surface Infrastructure within the Study and SMP Areas

Item	Within Study Area	Within SMP Area	Environmentally Sensitive Area	Section Number Reference
NATURAL FEATURES				
Catchment Areas or Declared Special Areas	✓	✓	✓	2.4.1
Rivers or Creeks	✓	✓	✓	2.4.2 2.4.3
Aquifers or Known Groundwater Resources	✓	✓		2.4.4
Springs				
Sea or Lakes				
Shorelines				
Natural Dams				
Cliffs or Pagodas	✓	✓	✓	2.4.9
Steep Slopes	✓	✓		2.4.10
Escarpments				
Land Prone to Flooding or Inundation				
Swamps, Wetlands or Water Related Ecosystems	✓	✓		2.4.13
Threatened, Protected Species or Critical Habitats	✓	✓	✓	2.4.14
National Parks or Wilderness Areas				
State Recreational or Conservation Areas				
State Forests				
Natural Vegetation	✓	✓		2.4.18
Areas of Significant Geological Interest				
Any Other Natural Feature Considered Significant				
PUBLIC UTILITIES				
Railways	✓			2.5.1
Roads (All Types)	✓	✓		2.5.2
Bridges	✓			2.5.3
Tunnels				
Culverts				
Water, Gas or Sewerage Pipelines				
Liquid Fuel Pipelines				
Electricity Transmission Lines or Associated Plants	✓	✓	✓	2.5.7
Telecommunication Lines or Associated Plants				
Water Tanks, Water or Sewage Treatment Works				
Dams, Reservoirs or Associated Works	✓	✓	✓	2.5.9
Air Strips				
Any Other Public Utilities				
PUBLIC AMENITIES				
Hospitals				
Places of Worship				
Schools				
Shopping Centres				
Community Centres				
Office Buildings				
Swimming Pools				
Bowling Greens				
Ovals or Cricket Grounds				
Race Courses				
Golf Courses				
Tennis Courts				
Any Other Public Amenities				
FARM LAND AND FACILITIES				
Agricultural Utilisation, Agricultural Improvements or Agricultural Suitability of Farm Land				
Farm Buildings or Sheds				
Gas or Fuel Storages				
Poultry Sheds				
Glass Houses or Green Houses				
Hydroponic Systems				
Irrigation Systems				
Fences				
Farm Dams				
Wells or Bores				
Any Other Farm Features				
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS				
Factories				
Workshops				
Business or Commercial Establishments or Improvements				
Gas or Fuel Storages or Associated Plants				
Waste Storages and Associated Plants				
Buildings, Equipment or Operations that are Sensitive to Surface Movements				
Surface Mining (Open Cut) Voids and Rehabilitated Areas				
Mine Infrastructure Including Tailings Dams or Emplacement Areas	✓	✓		2.10
Any Other Industrial, Commercial or Business Features				
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	✓		2.11
ITEMS OF ARCHITECTURAL SIGNIFICANCE				
PERMANENT SURVEY CONTROL MARKS	✓	✓		2.14
RESIDENTIAL ESTABLISHMENTS				
Houses				
Flats or Units				
Caravan Parks				
Retirement or Aged Care Villages				
Associated Structures such as Workshops, Garages, On-Site Waste Water Systems, Water or Gas Tanks, Swimming Pools or Tennis Courts				
Any Other Residential Features				
ANY OTHER ITEM OF SIGNIFICANCE				

2.3. Areas of Environmental Sensitivity

This section provides a brief summary of features identified as "Areas of Environmental Sensitivity" within the Study and SMP Areas, as defined in Section 6.6.3 of the DPI SMP Guideline. Further details on each of these features are provided in subsequent sections of this report.

Table 2.2 Summary of Areas of Environmental Sensitivity within the Study and SMP Areas

No.	Description	Within Study Area	Within SMP Area	Details	Section No. Ref.
1	Land reserved as a State Conservation Area under the *National Parks and Wildlife Act 1974*	None	None		
2	Land declared as an Aboriginal Place under the *National Parks and Wildlife Act 1974*	None	None		
3	Land identified as *Wilderness* by the Director, National Parks and Wildlife under the *Wilderness Act 1987*	None	None		
4	Land subject to a 'conservation agreement' under the *National Parks and Wildlife Act 1974*	None	None		
5	Land acquired by the Minister for the Environment under Part 11 of the *National Parks and Wildlife Act 1974*	None	None		
6	Land within State forests mapped as Forestry Management Zone 1, 2 or 3	None	None		
7	Wetlands mapped under SEPP 14 – Coastal Wetlands	None	None		
8	Wetlands listed under the Ramsar Wetlands Convention	None	None		
9	Lands mapped under SEPP 26 – Coastal Rainforests	None	None		
10	Areas listed on the Register of the National Estate	None	None		
11	Areas listed under the *Heritage Act 1977* for which a plan of management has been prepared	None	None		
12	Land declared as critical habitat under the *Threatened Species Conservation Act 1995*	None	None		
13	Land within a restricted area prescribed by a controlling water authority	✓	✓	Metropolitan Catchment Area and the DSC Notification Areas	2.4.1
14	Land reserved or dedicated under the *Crown Lands Act 1989* for the preservation of flora, fauna, geological formations or other environmental protection purpose	None	None		
15	Significant surface watercourses and groundwater resources identified through consultation with relevant government agencies	✓	✓	Cordeaux River, Wongawilli, Sandy and Donalds Castle Creeks, Lake Cordeaux and Lake Avon	2.4.2 2.4.3 2.5.9
16	Lake foreshores and flood prone areas	✓	✓	Lake Cordeaux and Lake Avon	2.5.9
17	Cliffs, escarpments and other significant natural features	✓	✓	Cliffs	2.4.9
18	Areas containing significant ecological values	✓	✓	Flora and Fauna	2.4.14
19	Major surface infrastructure	✓	✓	330 kV Transmission Line, Cordeaux and Upper Cordeaux No. 2 Dam Walls	2.5.7 2.5.9
20	Surface features of community significance (including cultural, heritage or archaeological significance)	✓	✓	Archaeological Sites	2.11
21	Any other land identified by the Department to the titleholder	None	None		

2.4. Natural Features

2.4.1. Catchment Areas or Declared Special Areas

The Study Area lies entirely within the Metropolitan Catchment Area, which is a special declared area controlled by the Sydney Catchment Authority (SCA). The proposed Longwalls 6 to 10 in Area 3A are partly located within the Dams Safety Committee (DSC) Notification Area for the Cordeaux Reservoir, also known as Lake Cordeaux. The maximum footprints for the future longwalls in Areas 3B and 3C are partly located within the DSC Notification Areas for Lake Avon and Lake Cordeaux, respectively.

The water storages in the Metropolitan Catchment Area provide the sole water supply for the Macarthur and Illawarra regions and the townships of Campbelltown, Camden, Bargo, Picton, Thirlmere, Tahmoor, The Oaks, Buxton and Oakdale, and provide approximately 20 % of the supply to the Sydney Metropolitan Area, via the Prospect Reservoir.

The Metropolitan Catchment Area has been defined as an area of environmental sensitivity for the purposes of the SMP approval process.

2.4.2. Rivers

There are no rivers within the general Study Area. The Cordeaux River, downstream of the Cordeaux Dam, is located 470 metres north of the maximum footprint for Area 3C, at its closest point. The river is located approximately 4 kilometres north of the proposed Longwalls 6 to 10 in Area 3A, at its closest point.

The Cordeaux River could be subjected to valley related or far-field horizontal movements resulting from the extraction of the future longwalls in Area 3C and has, therefore, been included as part of the Study Area.

The Cordeaux River has been defined as an area of environmental sensitivity for the purposes of the SMP approval process.

2.4.3. Watercourses

The locations of the watercourses in Area 3 are shown in Drawing No. MSEC311-07.

The largest watercourse within the Study Area is **Wongawilli Creek** which is located between Areas 3A and 3B and crosses the western side of Area 3C. The creek is located 110 metres west of the commencing end of Longwall 6, at its closest point to the proposed longwalls in Area 3A. The creek generally flows in a northerly direction and drains into the Cordeaux River approximately 700 metres north of the maximum footprint for Area 3C. A photograph of Wongawilli Creek within the SMP Area is shown in Fig. 2.2.

The total length of Wongawilli Creek within the general Study Area is approximately 8.6 kilometres. The natural gradient of the creek within the Study Area, excluding the cascade in the south of Area 3B, varies between a minimum of less than 1 mm/m and a maximum of 200 mm/m, with an average natural gradient of approximately 10 mm/m. The natural gradient of Wongawilli Creek within the SMP Area varies between a minimum of less than 1 mm/m and a maximum of 25 mm/m, with an average natural gradient of approximately 4 mm/m.

Fig. 2.2 Wongawilli Creek

Sandy Creek is partly located within Area 3A and crosses the eastern sides of the general Study and general SMP Areas. The creek is located 85 metres east of the finishing ends of Longwalls 8, 9 and 10 at its closest point to the proposed longwalls in Area 3A. The creek generally flows in a northerly direction and drains into an arm of Lake Cordeaux at a waterfall site located 250 metres east of Longwall 7. A photograph of Sandy Creek is shown in Fig. 2.3.

The total length of Sandy Creek within the general Study Area is approximately 2 kilometres. The natural gradient of the creek within the Study Area, upstream of the waterfall, varies between a minimum of less than 1 mm/m and a maximum of 60 mm/m, with an average natural gradient of 10 mm/m. The natural gradient of Sandy Creek within the SMP Area varies between a minimum of less than 1 mm/m and a maximum of 30 mm/m, with an average natural gradient of approximately 10 mm/m.

Fig. 2.3 Sandy Creek

The upper reaches of **Donalds Castle Creek** are located in the northern part of Area 3B and in the western part of Area 3C. The creek is located 1.4 kilometres west of the commencing end of Longwall 6, at its closest point to the proposed longwalls in Area 3A. The creek generally flows in a northerly direction and drains into the Cordeaux River approximately 3.4 kilometres north of the general Study Area. A photograph of Donalds Castle Creek is shown in Fig. 2.4.

The total length of Donalds Castle Creek within the general Study Area is approximately 3.4 kilometres. The natural gradient of the creek within the Study Area varies between a minimum of 10 mm/m and a maximum of 150 mm/m, with an average natural gradient of 30 mm/m.

Fig. 2.4 Donalds Castle Creek

Wongawilli, Sandy and Donalds Castle Creeks are generally permanently flowing streams with small base flows and increased flows for short periods of time after each significant rain event. Pools in the streams are permanent and naturally develop at the creek rock bars and at the sediment and debris accumulations, the locations of which are shown in Drawings Nos. MSEC311-08 to MSEC311-10. The beds of the creeks are formed within the Bulgo Sandstone, which overlies the Stanwell Park Claystone, however, there are small sections of the creeks which are formed within the Hawkesbury Sandstone.

Wongawilli, Sandy and Donalds Castle Creeks have been defined as areas of environmental sensitivity for the purposes of the SMP approval process.

There are a number of other smaller drainage lines which have also been identified within the Study Area, which have also been shown in Drawing No. MSEC311-07.

2.4.4. Aquifers and Known Ground Water Resources

Shallow aquifers have been identified within the Study Area and these are associated with the drainage lines and upland swamps. The aquifers and groundwater resources within the Study Area have been investigated and are described in reports by GHD (2007) and Ecoengineers (2007).

2.4.5. Springs

There have been no natural springs identified within the Study Area, however, minor groundwater seeps have been identified within the Study Area.

2.4.6. Seas or Lakes

There are no natural lakes within the Study Area. There are, however, two artificial reservoirs which are partially located within the Study Area which are described in Section 2.5.9.

2.4.7. Shorelines

There are no shorelines within the Study Area, other than those associated with the reservoirs which are described in Section 2.5.9.

2.4.8. Natural Dams

There are no natural dams within the Study Area.

2.4.9. Cliffs and Natural Rock Formations

For the purposes of this report, a cliff has been defined as a continuous rockface having a minimum height of 10 metres and a minimum slope of 2 to 1, ie: having a minimum angle to the horizontal of 63°. The locations of the cliffs were determined from site inspections and from the 1 metre surface level contours which were generated from an aerial laser scan of the area.

Most of the cliffs within the Study Area have been identified within the valley of Wongawilli Creek, however, small isolated cliffs have also been identified elsewhere within the Study Area. There is a 25 metre high waterfall (Ref. DA3-CF6), which is located just outside the general SMP Area, where Sandy Creek flows into Lake Cordeaux, which has been included as part of the SMP Area.

The locations of the cliffs within the Study Area are shown in Drawing No. MSEC311-11. The details of the cliffs within the SMP Area are provided in Table 2.3. In addition to the cliffs, there are also numerous rock outcrops which are located across the Study Area. The rock outcrops are generally less than 5 metres in height.

Table 2.3 Details of the Cliffs within the SMP Area

Cliff ID	Overall Length (m)	Maximum Height (m)
DA3-CF2	15	15
DA3-CF3	20	15
DA3-CF6	85	25
DA3-CF7	25	15
DA3-CF8	25	10
DA3-CF13	100	10
DA3-CF14	300	15
DA3-CF15	100	15
DA3-CF16	70	10
DA3-CF17	280	10
DA3-CF18	180	15

The longer clifflines within the Study Area are made up of a number of separate cliffs, rather than being a single continuous cliffline. The cliffs have formed predominantly from Hawkesbury Sandstone, with the faces being at various stages of weathering and erosion. The cliffs have many overhangs and undercuts which are generally less than 6 metres of overhang. Cliff DA3-CF6 has the greatest overhang which is in the order of 20 metres. A photograph of Cliff DA3-CF6 is shown Fig. 2.5.

Fig. 2.5 Photograph of Cliff DA3-CF6 Overhang

The cliffs have been defined as areas of environmental sensitivity for the purposes of the SMP approval process.

2.4.10. Steep Slopes

A number of steep slopes have been identified within the Study Area. The reason for identifying steep slopes is to highlight areas in which existing ground slopes may be marginally stable. For the purposes of this report, a steep slope has been defined as an area of land having a natural gradient between 1 in 3 (ie: a grade of 33 %, or an angle to the horizontal of 18°) and 2 in 1 (ie: a grade of 200 %, or an angle to the horizontal of 63°).

The maximum slope of 2 to 1 represents the threshold adopted for defining a cliff. The minimum slope of 1 to 3 represents a slope that would generally be considered stable for slopes consisting of rocky soils or loose rock fragments. Clearly the stability of natural slopes varies depending on their soil or rock types, and in many cases, natural slopes are stable at much higher gradients than 1 to 3, for example talus slopes in Hawkesbury Sandstone.

The surface within the Study Area generally consists of soils derived from Hawkesbury Sandstone, as can be inferred from Fig. 1.3, which are in varying stages of weathering. The majority of the slopes are stabilised, to some extent, by the natural vegetation.

The steep slopes were identified from the 1 metre surface level contours which were generated from an aerial laser scan of the area, and the locations have been shown in Drawing No. MSEC311-11. The steepest slopes within the Study Area, not including the cliffs and rock outcrops, were identified within the valley of Wongawilli Creek, and have natural grades of up to 1 in 1.25, or angles to the horizontal of up to 40°. The steep slopes located directly above the proposed longwalls in Area 3A typically have natural grades of up to 1 in 2, or angles to the horizontal of up to 27°.

2.4.11. Escarpments

There are no escarpments within the Study Area. The Illawarra Escarpment is located more than 6 kilometres to the east of the general Study Area and, therefore, will not be subjected to any significant subsidence impacts resulting from the extraction of the proposed and future longwalls.

2.4.12. Land Prone to Flooding or Inundation

The catchment areas of the watercourses within the Study Area are relatively small and the land drains freely into Lake Cordeaux and Lake Avon. There are no major flood prone areas identified within the Study Area. The predicted changes in the levels of the watercourses, resulting from the extraction of the proposed and future longwalls, will have only a marginal effect on their natural gradients, and hence, on their discharge characteristics.

2.4.13. Wetlands and Swamps

There are a number of upland swamps within the Study Area, the locations of which are shown in Drawing No. MSEC311-07. The locations and extents of these upland swamps have been interpreted from detailed aerial photogrammetry.

A total of 24 upland swamps have been mapped within or partially within the general Study Area, of which five are located within or partially within the general SMP Area. Swamps 12 and 15b are located directly above proposed Longwalls 7 and 8 and Swamp 15a is partially located above proposed Longwalls 9 and 10 in Area 3A. Swamp 10 is located south of the proposed longwalls and Swamp 16 is located north of the proposed longwalls in Area 3A.

Detailed investigations of the swamps have been undertaken and are described in the report by Biosis (2007a), CFR (2007a, 2007b & 2007c) and Ecoengineers (2007).

2.4.14. Threatened, Protected Species or Critical Habitats

There are no lands within the Study Area that have been declared as critical habitat under the *Threatened Species Conservation Act 1995*. There are, however, threatened and protected species within the Study Area which are described in the report by Biosis (2007a).

2.4.15. National Parks or Wilderness Areas

There are no National Parks or any land identified as wilderness under the *Wilderness Act 1987* within the Study Area.

2.4.16. State Recreation Areas and State Conservation Areas

There are no State Recreation Areas or State Conservation Areas within the Study Area.

2.4.17. State Forests

There are no State Forests within the Study Area.

2.4.18. Natural Vegetation

The vegetation within the Study Area generally consists of undisturbed native bush. A detailed survey of the natural vegetation has been undertaken and is described in the report by Biosis (2007a).

2.4.19. Areas of Significant Geological Interest

There are no areas of significant geological interest within the Study Area. A description of the geology at Dendrobium Mine is provided in Section 1.4.

2.4.20. Any Other Natural Feature Considered Significant

There are no other significant natural features identified within the Study Area.

2.5. Public Utilities

2.5.1. Railways

There are no operating railways within the Study Area. The abandoned Maldon–Dombarton Railway Corridor crosses the Study Area, the location of which is shown in Drawing No. MSEC311-12. The railway corridor is located within Area 3B and is at a distance of 1.7 kilometres south-west of the general SMP Area, at its closest point. At the time of abandoning the work, the major earthworks had been completed, but no tracks or associated equipment had been installed. Any future plans for the corridor remain uncertain and are the subject of continuing debate.

2.5.2. Roads

There are no public roads within the Study Area. There are, however, unsealed fire trails and four wheel drive tracks within the Study Area, which are used by the Sydney Catchment Authority and other groups for fire fighting and other activities. The locations of the fire trails and four wheel drive tracks are shown in Drawing No. MSEC311-12.

2.5.3. Bridges

There is a steel truss bridge (Ref. B1) in Area 3A where Fire Road 6C crosses Sandy Creek, the location of which is shown in Drawing No. MSEC311-12. The bridge, which is owned by IC, is located 140 metres north-east of the commencing end of Longwall 8. A photograph of the bridge is Fig. 2.6.

Fig. 2.6 Bridge across Sandy Creek

There is a small timber bridge (Ref. DHS1) which crosses a drainage line within Area 3C, the location of which is shown in Drawing No. MSEC311-12. A photograph of the bridge is shown in Fig. 2.7 and further details are provided in the report by Biosis (2007b).

Fig. 2.7 Historic Bridge in Area 3C

There are also a number of small bridges, which are owned by IC, which cross small gullies to the east of Sandy Creek. These bridges are unlikely to be subjected to any significant systematic, valley related, or far-field horizontal movements as a result of the extraction of the proposed and future longwalls in Area 3 and have not, therefore, been included as part of the Study Area.

2.5.4. Tunnels

There are no tunnels within the Study Area.

2.5.5. Drainage Culverts

There are no drainage culverts within the Study Area.

2.5.6. Water, Gas or Sewerage Pipelines

There are no water, gas or sewerage pipelines within the Study Area.

2.5.7. Electrical Services

The electrical services within the Study Area comprise the 330 kV transmission line, which is owned by TransGrid, and the 33 kV powerline, which is owned by Integral Energy, the locations of which are shown in Drawing No. MSEC311-12.

The Sydney West – Dapto 330 kV Transmission line is located directly above the proposed Longwalls 6 to 10 in Area 3A and continues northward through Area 3C. The transmission line cables are supported by transmission towers and the locations and identification numbers of these towers are shown in Drawing No. MSEC311-12.

There is one tension tower located within the SMP Area, being Tower 44, which is located 40 metres north of Longwall 6. There are two additional tension towers located within Area 3C, being Towers 48 and 51. The remaining towers within the Study Area are suspension towers.

The 330 kV transmission line is a major item of surface infrastructure and has been defined as an area of environmental sensitivity for the purposes of the SMP approval process.

The 33 kV powerline is located directly above the proposed Longwalls 6 and 7 in Area 3A and continues northward through Area 3C. The powerline supplies the pumping stations at the Cordeaux Dam and the Upper Cordeaux No. 2 Dam. There is one tension pole within the SMP Area, identified as Pole 33T1, which is located adjacent to the tailgate of Longwall 6. There are three additional tension poles within Area 3C, which are identified as Poles 33T2 through 33T4.

There are no electrical substations within the Study Area.

2.5.8. Telecommunications Services

There are no telecommunications services within the Study Area.

2.5.9. Dams, Reservoirs and Associated Works

There are two reservoirs partially located within the Study Area, being Lake Cordeaux and Lake Avon, the locations of which are shown in Drawing No. MSEC311-07. The Dams Safety Committee (DSC) Notification Areas for Lake Cordeaux and Lake Avon are also partially located within the Study Area, which are also shown in Drawing No. MSEC311-07.

Lake Cordeaux is located 250 metres to the east of Longwall 7, at its nearest point to the proposed longwalls in Area 3A, when the lake is filled to the maximum storage level. The lake is located outside the general SMP Area, however, the lake has been included as part of the SMP Area since the proposed longwalls in Area 3A are partially located within the DSC Notification Area.

The lake is fed by the Cordeaux River and its many tributaries and the maximum supply level of the storage is 303.9 metres AHD. The width of the lake varies from 200 metres to 500 metres and the length of the lake is approximately 9 kilometres. The Lake Cordeaux water storage has a total operating capacity of approximately 94,000 ML.

Lake Avon is located 3 kilometres to the west of the proposed longwalls in Area 3A, at its nearest point, when the lake is filled to the maximum storage level. The lake and its notification area are, therefore, located well outside the general SMP Area for Longwalls 6 to 10 in Area 3A.

The lake is fed by the Avon River and its many tributaries and has a length of approximately 19 kilometres. The Lake Avon water storage has a total operating capacity of approximately 147,000 ML.

There are no dam walls or associated works within the general Study Area. The closest dam wall is the **Cordeaux Dam Wall**, which is located 980 metres north of the maximum footprint for Area 3C, at its closest point. The dam wall is located 4.4 kilometres north of Longwall 6, at its closest point to the proposed longwalls in Area 3A.

The Cordeaux Dam Wall, which was originally completed in 1926, is a curved dam built in cyclopean sandstone masonry with sandstone concrete facing on the downstream face and bluemetal concrete facing on the upstream face. The height of the dam wall above the base of the storage is approximately 50 metres and the total length of the dam wall at its crest, including the spillway, is approximately 540 metres.

The **Upper Cordeaux No. 2 Dam Wall** is located at a distance of approximately 2.6 kilometres south-east of the proposed Longwalls 6 to 10 in Area 3A. The dam wall is a curved concrete structure and is located between the Nebo workings and Longwalls 3 to 5A in Area 2 at Dendrobium Mine.

The locations of the Cordeaux Dam Wall and Upper Cordeaux No. 2 Dam Wall are shown in Drawings Nos. MSEC311-07 and MSEC311-01, respectively. The dam walls could be subjected to far-field horizontal movements resulting from the extraction of the proposed and future longwalls in Area 3 and have, therefore, been included as part of the Study and SMP Areas. The dam walls have been defined as areas of environmental sensitivity for the purposes of the SMP Approval process.

2.5.10. Any Other Public Utilities

There are no other public utilities within the Study Area.

2.6. Public Amenities

There are no public amenities within the Study Area.

2.7. Farm Land or Facilities

There is no farm land or farm facilities within the Study Area.

2.8. Industrial, Commercial or Business Establishments

There are no industrial, commercial or business establishments within the Study Area.

2.9. Known Proposed Developments

There are no known proposed developments within the Study Area. As described in Section 2.5.1, any future plans for the abandoned Maldon-Dombarton Railway corridor remain uncertain and are the subject of continuing debate.

2.10. Mine Infrastructure

There are a number of exploration bore holes within the Study Area, the locations of which are shown in Drawing No. MSEC311-13. The exploration bore holes are owned by IC and most contain piezometers or geophones.

2.11. Items of Archaeological Significance

A number of archaeological sites have been identified within the Study Area, the locations of which are shown in Drawing No. MSEC311-14. There are 14 archaeological sites which have been identified within the SMP Area for Longwalls 6 to 10 in Area 3A, a summary of which is provided in Table 2.4.

Site DM23 which is located just outside the general SMP Area has been included as part of the SMP Area. A further six archaeological sites have been identified in Area 3A, within the general Study Area but south of the general SMP Area. Summaries of these archaeological sites are provided in Table 2.5.

Table 2.4 Archaeological Sites within the SMP Area for Longwalls 6 to 10 in Area 3A

Recording Code	Site Name	Recording Type
52-2-0458	Browns Road Site 33	Shelter with art
52-2-1646	Browns Road Site 32	Shelter with art
52-2-1647	Browns Road Site 20	Shelter with artefacts only
52-2-2043	Sandy Creek Road 28	Isolated artefacts
52-2-3052	SCA Special Area Fire Trail 6C	Isolated artefacts
52-5-0273	Sandy Creek Road 21	Shelter with art
52-5-0274	Sandy Creek Road 22	Shelter with art
52-5-0277	Sandy Creek Road 25	Outcrop with art
52-5-0278	Sandy Creek Road 26	Outcrop with art
New Recording	DM13	Outcrop with artefacts only
New Recording	DM14	Isolated artefacts
New Recording	DM15	Shelter with art
New Recording	DM20	Shelter with art
New Recording	DM23	Shelter with artefacts only

Table 2.5 Additional Archaeological Sites within Area 3A (within the general Study Area but South of the general SMP Area)

Recording Code	Site Name	Recording Type
52-2-1643	Browns Road Site 29	Shelter with art
52-2-1644	Browns Road Site 30	Shelter with art
52-2-1645	Browns Road Site 31	Shelter with art
52-5-0271	Sandy Creek Road 19	Shelter with art
52-5-0272	Sandy Creek Road 20	Shelter with art
New Recording	DM12	Shelter with art

There are a further 24 archaeological sites which have been identified within or immediately adjacent to Area 3B and 18 archaeological sites which have been identified within or immediately adjacent to Area 3C. Summaries of these archaeological sites are provided in Table 2.6 and Table 2.7.

Table 2.6 Archaeological Sites within Area 3B

Recording Code	Site Name	Recording Type
52-2-1562	Donald Castle Creek 1	Shelter with art
52-2-1622	Browns Road Site 7	Shelter with artefacts only
52-2-1623	Browns Road Site 8	Shelter with artefacts only
52-2-1626	Browns Road Site 11	Shelter with art
52-2-1627	Browns Road Site 12	Shelter with art
52-2-1628	Browns Road Site 13	Shelter with art
52-2-1771	Upper Avon 35	Shelter with artefacts only
52-2-1772	Upper Avon 36	Outcrop with art
52-2-1773	Upper Avon 37	Shelter with artefacts only
52-2-1774	Upper Avon 38	Shelter with art
52-2-1775	Upper Avon 39	Shelter with artefacts only
52-2-1776	Upper Avon 40	Shelter with art
52-2-1777	Upper Avon 41	Shelter with artefacts only
52-2-2208	Dendrobium 1	Shelter with artefacts only
52-2-2209	Dendrobium 2	Shelter with art
52-2-2229	Site 1 – DB 1	Shelter with art
52-2-2246	Dendrobium 6	Isolated artefacts only
52-2-2248	Dendrobium 7	Shelter with art
52-2-3088	Dendrobium 8	Shelter with art
New Recording	DM2	Shelter with artefacts only
New Recording	DM16	Shelter with art
New Recording	DM17	Shelter with artefacts only
New Recording	DM21	Shelter with art
New Recording	DM22	Shelter with art

Table 2.7 Archaeological Sites within Area 3C

Recording Code	Site Name	Recording Type
52-2-0019 52-2-0544 52-2-0753	Sandy Creek Road 2	Shelter with art
52-2-0535	Sandy Creek Stone Arrangement	Isolated artefacts only
52-2-1563	Donald Castle Creek 2	Grinding grooves
52-2-1564	Donald Castle Creek 3	Grinding grooves
52-2-1591	Donalds Castle Creek 30	Shelter with Art
52-2-1632	Browns Road Site 17	Shelter with art
52-2-1633	Browns Road Site 18	Shelter with art
52-2-1634	Browns Road Site 19	Shelter with art
52-2-2219	Dendrobium 3	Shelter with art
52-3-0750	Sandy Creek Road 4	Shelter with art
52-3-0751	Sandy Creek Road 3	Shelter with art
52-5-0275	Sandy Creek Road 23	Outcrop with art
52-5-0276	Sandy Creek Road 24	Shelter with art
New Recording	DM1	Shelter with art
New Recording	DM9	Isolated artefacts only
New Recording	DM10	Shelter with artefacts only
New Recording	DM18	Shelter with art
New Recording	DM19	Shelter with art

Detailed descriptions of the archaeological sites within the Study Area are provided in the reports by Biosis (2007b) and Navin Officer (2000).

2.12. Items of Historical or Heritage Significance

Cordeaux Dam is listed on the NSW State Heritage Register and is described in Section 2.5.9 and in the report by Biosis (2007b). There are no other items of non-aboriginal heritage significance within the Study Area. There is also a small historic bridge (Ref. DHS1) located within Area 3C which is described in Section 2.5.3.

Sydney Water Corporation maintains its own heritage register entitled the Sydney Water Heritage Inventory. The features listed on this inventory under reference numbers SHI 4573713 or 4573714 include the Cordeaux Dam and the Upper Cordeaux No. 2 Dam, as well as a number of associated items of infrastructure.

Detailed descriptions of the historical and heritage sites within the Study Area are provided in the reports by Biosis (2007b) and Navin Officer (2000).

2.13. Items of Architectural Significance

There are no items of architectural significance within the Study Area.

2.14. Permanent Survey Control Marks

The locations of the survey control marks within the vicinity of the Study Area are shown in Drawing No. MSEC311-14. There are three survey control marks which are located within the general SMP Area for Longwalls 6 to 10 in Area 3A, details of which are provided in Table 2.8.

Table 2.8 Locations of the Survey Control Marks within the General SMP Area

Mark	Approximate MGA Easting	Approximate MGA Northing
S0704	292745	6193490
S1106	293905	6192600
S1343	292060	6193530

2.15. Residential Establishments

There are no residential structures within the Study Area.

CHAPTER 3. OVERVIEW OF LONGWALL MINING, THE DEVELOPMENT OF SUBSIDENCE AND THE METHODS USED TO PREDICT THE MINE SUBSIDENCE PARAMETERS FOR THE PROPOSED AND FUTURE LONGWALLS

3.1. Introduction

This chapter provides a brief overview of longwall mining, the development of mine subsidence and the methods that have been used to predict the mine subsidence movements resulting from the extraction of the proposed and future longwalls in Area 3. Further details on longwall mining, the development of subsidence and the methods used to predict mine subsidence movements are provided in the background reports entitled *Introduction to Longwall Mining and Subsidence* and *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

3.2. Overview of Longwall Mining

The coal at the project is proposed to be extracted using longwall mining techniques. A cross-section along the length of a typical longwall at the coal face is shown in Fig. 3.1.

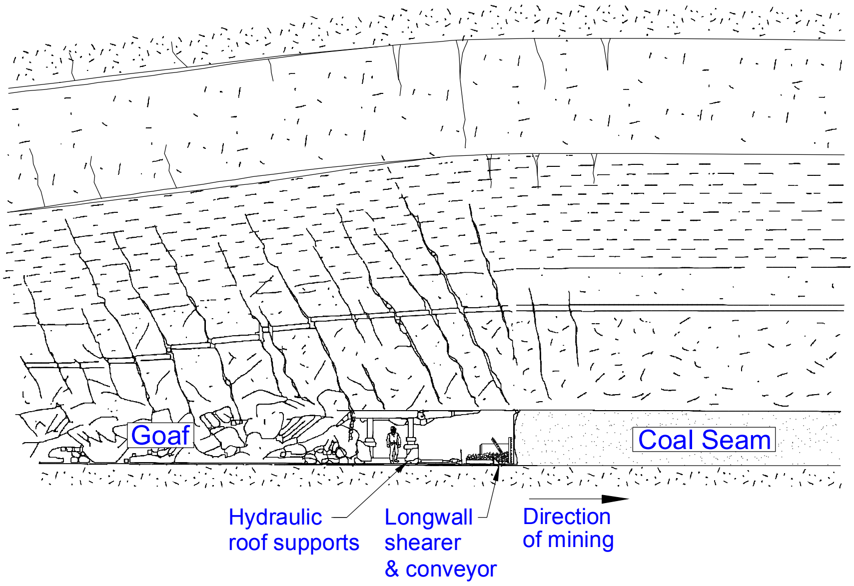


Fig. 3.1 Cross-section along the Length of a Typical Longwall at the Coal Face

The coal is removed by a shearer which cuts the coal from the coal face on each pass as it traverses the width of the longwall. The roof at the coal face is supported by a series of hydraulic roof supports, which temporarily hold up the roof strata and provides a working space at the coal face. The coal is then transported by a face conveyor belt which is located behind the shearer. As the coal is removed from each section of the coal face, the hydraulic supports are stepped forward and the coal face progresses (retreats) along the length of the longwall.

The strata directly behind the hydraulic supports, immediately above the coal seam, collapses into the void that is left as the coal face retreats. The collapsed zone comprises loose blocks and can contain large voids. Immediately above the collapsed zone, the strata remains relatively intact and bends into the void, resulting in new vertical factures, opening up of existing vertical fractures, and bed separation. The amount of strata sagging, fracturing and bed separation reduces towards the surface.

At the surface, the ground subsides vertically as well as moves horizontally towards the centre of the mined goaf area. The maximum subsidence at the surface varies, depends on a number of factors including longwall geometry, depth of cover, extracted seam thickness and geology. The maximum achievable subsidence in the Southern Coalfield is 65 % of the extracted seam thickness.

3.3. Overview of Systematic Subsidence Movements

The normal ground movements resulting from the extraction of longwalls are referred to as systematic subsidence movements. These movements are described by the following parameters:-

- **Subsidence** usually refers to vertical movement of a point, but subsidence of the ground actually includes both vertical and horizontal movement. These horizontal movements in some cases, where the subsidence is small, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.
- **Tilt** is the change in the slope of the ground as a result of differential subsidence and is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %.
- **Curvature** is the second derivative of subsidence, or the rate of change of tilt and is calculated as the change in tilt between two adjacent sections of the tilt profile divided by the average length of those sections. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (1/km)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*.
- **Strain** is calculated by the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distance between two points increases and **Compressive Strains** occur where the distance between two points decreases. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

A cross-section through a typical single longwall panel showing typical profiles of systematic subsidence, tilt, curvature and strain is provided in Fig. 3.2.

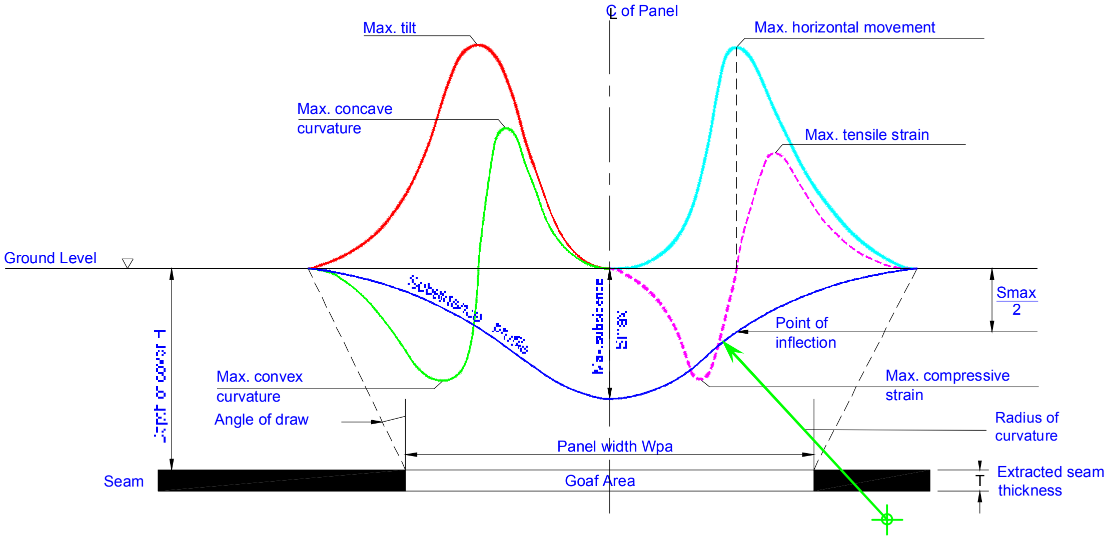


Fig. 3.2 Typical Profiles of Systematic Subsidence Parameter for a Single Longwall Panel

The definitions of incremental, cumulative, total and travelling subsidence parameters are defined as follows:-

- **Incremental** subsidence parameters provided in this report, are the additional subsidence, tilts, curvatures and strains which occur due to the extraction of a single longwall. Observed incremental subsidence profiles are determined by subtracting the observed subsidence profiles before from the observed subsidence profiles after the extraction of each longwall.
- **Cumulative** subsidence parameters provided in this report, are the accumulated subsidence, tilts, curvatures and strains which occur due the extraction of a number of longwalls within the series of longwalls.
- **Total** subsidence parameters provided in this report, are the accumulated subsidence, tilts, curvatures and strains which occur due to the extraction of all longwalls within the series of longwalls.
- **Travelling** subsidence parameters provided in this report, are the transient tilts, curvatures and strains which occur as the longwall extraction face mines directly beneath a point. The maximum travelling tilts, curvatures and strains are typically aligned along the longitudinal axes of the longwalls, with the maximum values typically occurring at the locations of maximum incremental subsidence for each longwall.

3.4. The Incremental Profile Method

The predicted systematic subsidence parameters for the proposed and future longwalls in Area 3 were determined using the Incremental Profile Method, which was developed by MSEC, formally known as Waddington Kay and Associates. The method is an empirical model based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales.

The database consists of detailed subsidence monitoring data from Collieries including: Angus Place, Appin, Baal Bone, Bellambi, Beltana, Bulli, Chain Valley, Clarence, Coalcliff, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Fernbrook, Glennies Creek, Gretly, Invincible, John Darling, Kemira, Lambton, Liddell, Metropolitan, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, South Bulga, South Bulli, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, West Cliff, West Wallsend and Wyee.

The database consists of the observed incremental subsidence profiles, which are the additional subsidence profiles resulting from the extraction of each longwall within a series of longwalls. It can be seen from the normalised incremental subsidence profiles within the database, that the observed shapes and magnitudes are reasonably consistent where the mining geometry and local geology are similar.

Subsidence predictions made using the Incremental Profile Method use the database of observed incremental subsidence profiles, the proposed longwall geometries, as well as local surface and seam information and geology. The method has a tendency to over-predict the systematic subsidence parameters (ie: is slightly conservative) where the proposed mining geometry and geology are within the range of the empirical database. The predictions can be further tailored to local conditions where observed monitoring data is available close to the proposed mining area.

Further details on the Incremental Profile Method are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*. The standard Southern Coalfield profiles from the database, based on monitoring data predominantly from the Bulli Seam, were used to predict the systematic subsidence, tilt, curvature and strain profiles for the proposed longwalls.

The model uses the surface level contours, seam floor contours and seam extraction height contours to make predictions. The surface level and seam floor contours were provided by IC and are shown in Drawings Nos. MSEC311-03 and MSEC311-04, respectively. The proposed longwalls will be mined using an extraction height of 3.9 metres. The identified geological structures at seam level are shown in Drawing No. MSEC311-06.

Predictions have been made at points on regular grids orientated north-south and east-west across the Study Area. A grid spacing of 5 metres in each direction was adopted, which provides sufficient resolution for the generation of subsidence, tilt and strain contours.

The maximum predicted systematic subsidence parameters resulting from the extraction of the proposed and future longwalls in Area 3 are provided in Chapter 4. The predicted subsidence parameters at the natural features and items of surface infrastructure in the Study Area are provided in Chapter 5.

3.5. Overview of Non-Systematic Subsidence Movements

Non-systematic subsidence movements include far-field horizontal movements, irregular subsidence movements and valley related movements. These movements are briefly described below and further details are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

3.5.1. Far-field Movements

In addition to the systematic horizontal movements which occur above and adjacent to extracted longwalls, far-field horizontal movements have been observed at considerable distances from extracted longwalls. Such movements are predictable and occur whenever significant excavations occur at the surface or underground.

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. These movements generally do not result in impact, except where they occur at large structures which are very sensitive to differential horizontal movements. Far-field horizontal movements and the method used to predict such movements are described in Section 5.21.2.

3.5.2. Irregular Subsidence Movements

Irregular subsidence movements can result from near surface geological structures, including faults, dykes and abrupt changes in geology. The presence of these features near the surface can result in a bump in the subsidence profile, which is accompanied by locally higher tilts and strains.

Irregular subsidence movements can also occur at shallow depths of cover, where the collapsed zone above the extracted longwalls extends near to the surface. In this situation, the resulting subsidence profile become very erratic, which is accompanied by higher tilts and strains.

The non-systematic tilts and strains resulting from irregular subsidence movements can be much greater than those resulting from the normal systematic subsidence movements. Irregular subsidence movements and the impacts resulting from such movements are described further in Section 5.21.4.

3.5.3. Valley Related Movements

The land within the Study Area will be subjected to valley related movements, which are commonly observed along river and creek alignments in the Southern Coalfield. Valley related movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.3.

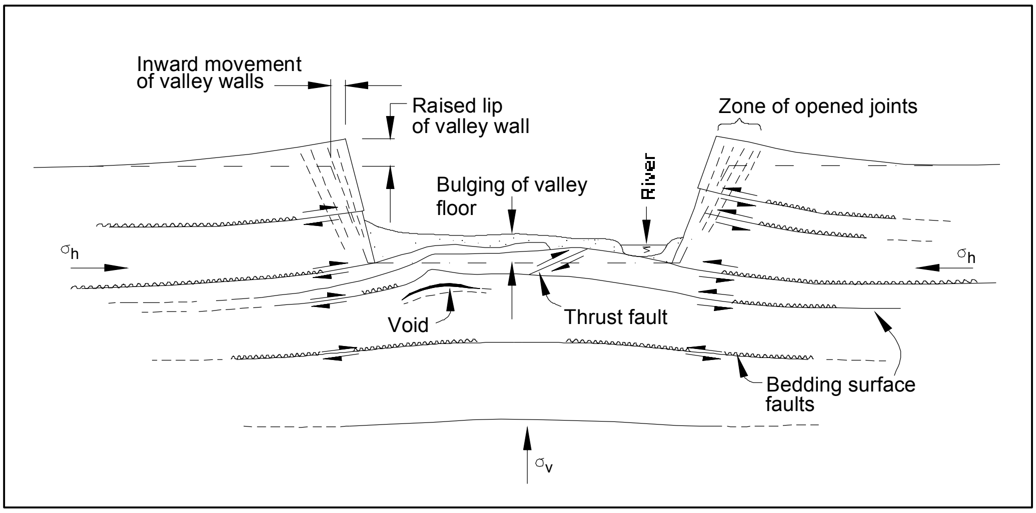


Fig. 3.3 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

Valley related movements can be accelerated by mine subsidence and are described by the following parameters:-

- **Upsidence** is the reduced subsidence, or the net uplift within the base of a valley and is typically expressed in units of *millimetres (mm)*. Upsidence results from the buckling of near surface strata in the base of the valley which results from the redistribution of the horizontal in situ stresses around the collapsed zones above extracted longwalls.
- **Closure** is the reduction in the horizontal distance between the valley sides and is expressed in units of *millimetres (mm)*. Closure also results from the redistribution of horizontal in situ stresses around the collapsed zones above extracted longwalls.
- **Compressive Strains** occur within the valley base as the result of valley closure movements and are calculated as the decrease in horizontal distance over a standard bay length, divided by the original bay length. **Tensile Strains** also occur adjacent to the valley as the result of valley closure movements and are calculated as the increase in horizontal distance over a standard bay length, divided by the original bay length. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20. Compressive and tensile strains due to valley closure movements are typically expressed in units of *millimetres per metre (mm/m)*.

The predicted valley related movements resulting from the extraction of the proposed and future longwalls at the project were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington 2004).

CHAPTER 4. MAXIMUM PREDICTED SYSTEMATIC SUBSIDENCE PARAMETERS FOR THE PROPOSED AND FUTURE LONGWALLS IN AREA 3

4.1. Introduction

The following sections provide the maximum predicted systematic subsidence parameters resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A and discuss the maximum predicted systematic subsidence parameters resulting from the future longwalls in Areas 3B and 3C. The predicted subsidence parameters and the impact assessments for the natural features and items of surface infrastructure located within the Study Area are provided in Chapter 5.

It should be noted that the predicted systematic subsidence parameters were obtained using the standard Incremental Profile Model for the Southern Coalfield, which is based on monitoring data predominantly from the Bulli Seam. The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report show the systematic movements, and do not include the valley related upsidence and closure movements, or the effects of faults and other geological structures. Such effects have been addressed separately in the impact assessments for each feature provided in Chapter 5.

4.2. Maximum Predicted Systematic Subsidence Parameters for Longwalls 6 to 10 in Area 3A

The locations of the proposed Longwalls 6 to 10 in Area 3A are shown in Drawing No. MSEC311-01 in Appendix F. The predicted cumulative systematic subsidence contours, after the extraction of each proposed longwall, are shown in Drawings Nos. MSEC311-16 to MSEC311-20. The predicted total systematic tilt, tensile strain and compressive strain contours, after the extraction of all proposed longwalls, are provided in Drawings Nos. MSEC311-21, MSEC311-22 and MSEC311-23, respectively.

A summary of the maximum predicted incremental systematic subsidence parameters, due to the extraction of each proposed longwall, is provided in Table 4.1. A summary of the maximum predicted cumulative systematic subsidence parameters, after the extraction of each proposed longwall, is provided in Table 4.2. A summary of the maximum predicted travelling tilts and strains, during the extraction of each proposed longwall, is provided in Table 4.3.

Table 4.1 Maximum Predicted Incremental Systematic Subsidence Parameters due to the Extraction of Each Proposed Longwall in Area 3A

Longwall	Maximum Predicted Incremental Subsidence (mm)	Maximum Predicted Incremental Tilt (mm/m)	Maximum Predicted Incremental Tensile Strain (mm/m)	Maximum Predicted Incremental Compressive Strain (mm/m)
Due to LW6	1520	13	2.0	4.5
Due to LW7	1880	19	4.0	10
Due to LW8	2075	21	4.0	11
Due to LW9	2010	20	3.5	12
Due to LW10	1945	20	3.5	11

Table 4.2 Maximum Predicted Cumulative Systematic Subsidence Parameters after the Extraction of Each Proposed Longwall in Area 3A

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
After LW6	1520	13	2.0	4.5
After LW7	1890	19	4.0	10
After LW8	2080	21	4.5	11
After LW9	2240	21	4.5	11
After LW10	2275	21	4.5	11

Table 4.3 Maximum Predicted Travelling Subsidence Parameters during the Extraction of Each Proposed Longwall in Area 3A

Longwall	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
During LW6	9	2.0	1.5
During LW7	12	3.0	2.5
During LW8	15	4.0	3.5
During LW9	14	4.0	3.0
During LW10	13	3.5	3.0

The maximum predicted cumulative systematic subsidence of 2275 mm occurs above the eastern end of Longwall 9, after the extraction of Longwall 10, where the depth of cover is around 280 metres. The maximum predicted cumulative systematic tilt of 21 mm/m (ie: 2.1 %), which represents a change in grade of 1 in 50, occurs above the maingate of Longwall 10. The maximum predicted travelling systematic tilt of 15 mm/m (ie: 1.5 %), which represents a change in grade of 1 in 65, occurs during the extraction of Longwall 8.

The minimum radii of curvatures associated with the maximum predicted cumulative systematic tensile and compressive strains of 4.5 mm/m and 11 mm/m, are 3.3 kilometres and 1.4 kilometres, respectively. The minimum radii of curvatures associated with the maximum predicted travelling tensile and compressive strains of 4.0 mm/m and 3.5 mm/m are 3.8 kilometres and 4.3 kilometres, respectively.

4.3. Maximum Predicted Systematic Subsidence Parameters for the Future Longwalls in Areas 3B and 3C

The future longwalls in Areas 3B and 3C will be located within the maximum footprint which is shown in Drawing No. MSEC311-01. The development of the final longwall layouts for these areas will progress as additional exploration data is gathered to better define the extractable resource. An application for SMP Approval will be developed for Areas 3B and 3C at a later date, which will be supported by detailed subsidence modelling of the future longwalls in these areas.

The maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts, in addition to the local variations in the depths of cover, extraction heights and geology in these areas. Where these factors for the future longwalls in Areas 3B and 3C are similar to those in Area 3A, it is expected that the maximum predicted subsidence parameters would be similar to those predicted for Longwalls 6 to 10.

Where these factors for the future longwalls in Areas 3B and 3C differ to those in Area 3A, the maximum predicted systematic subsidence parameters are expected to be greater or less than those predicted for Longwalls 6 to 10. A discussion on the effects of each of these factors on the maximum predicted systematic subsidence parameters for the future longwalls in Areas 3B and 3C are provided below.

Longwall Void Widths and Solid Chain Pillar Widths

The predicted systematic subsidence parameters resulting from longwall extractions are dependant on the longwall void widths and solid chain pillar widths. The maximum predicted systematic subsidence parameters generally increase as the longwall void widths increase or the solid chain pillar widths decrease, and visa versa.

Once longwalls have achieved supercritical condition, however, generally at width-to-depth ratios around 1.4, any increase in the void widths or decrease in the solid chain pillar widths do not result in any significant increase in the maximum predicted systematic subsidence parameters.

With all other factors being equal, the maximum predicted systematic subsidence parameters for the future longwalls in Areas 3B and 3C are expected to be similar to those predicted for Longwall 6 to 10 if the longwall void widths and solid chain pillar widths are similar to those adopted in Area 3A.

With all other factors being equal, the maximum predicted systematic subsidence parameters for the future longwalls in Areas 3B and 3C are expected to be greater than those predicted for Longwalls 6 to 10 if longwall void widths greater than 250 metres or solid chain pillar widths less than 40 metres were adopted. For example, if the future longwalls in Areas 3B and 3C were to have void widths of 300, 350 or 400 metres, the maximum predicted systematic subsidence parameters would be expected to be approximately 20, 30 or 35 % greater, respectively, than those predicted for Longwalls 6 to 10.

Depth of Cover

The predicted systematic subsidence parameters resulting from longwall extractions are dependant on the depth of cover above the longwalls. The maximum predicted systematic subsidence parameters generally increase as the depth of cover decreases and, conversely, the maximum predicted systematic subsidence parameters generally decrease as the depth of cover increases.

The depth of cover contours across Area 3 at Dendrobium Mine are shown in Drawing No. MSEC311-05. A summary of the ranges of the depths of cover within Areas 3A, 3B and 3C is provided in Table 4.4. The values provided in the table for Area 3A show the range of the depths of cover directly above Longwalls 6 to 10. The values provided in the table for Areas 3B and 3C show the ranges of the depths of cover within the maximum footprint.

Table 4.4 Ranges of Depths of Covers in Areas 3A, 3B and 3C at Dendrobium Mine

Location	Depth of Cover (m)		
	Minimum	Maximum	Average
Area 3A	255	400	320
Area 3B	225	425	360
Area 3C	215	425	350

The minimum depth of cover above the proposed longwalls in Area 3A of 255 metres occurs above the finishing (eastern) end of Longwall 10. The minimum depths of cover in Areas 3B and 3C of 225 metres and 215 metres, respectively, occur at the bases of Wongawilli Creek and Lake Cordeaux, respectively.

The maximum depth of cover above the proposed longwalls in Area 3A of 400 metres occurs above the tailgate of Longwall 6. The maximum depths of cover in Areas 3B and 3C both of 425 metres occurs along a ridgeline west of Wongawilli Creek, near the junction between Areas 3B and 3C.

It can be seen from the above table, that the ranges of the depths of cover in Areas 3B and 3C are similar to the range of the depths of cover above Longwalls 6 to 10 in Area 3A. It can also be seen from the above table, that the average depths of cover in Areas 3B and 3C are slightly greater than the average depth of cover above Longwalls 6 to 10 in Area 3A.

With all other factors being equal, therefore, the maximum predicted systematic subsidence parameters for the future longwalls in Areas 3B and 3C are expected to be similar to, or slightly less than those predicted for Longwalls 6 to 10, based on the ranges of the depths of cover in these areas.

Extraction Height

The predicted systematic subsidence parameters resulting from longwall extractions are dependant on extraction height. The maximum predicted systematic subsidence parameters generally increase or decrease at a similar proportion to that of extraction height, where the longwall chain pillars are relatively stable.

With all other factors being equal, therefore, the maximum predicted systematic subsidence parameters for the future longwalls in Areas 3B and 3C are expected to be greater than those predicted for Longwalls 6 to 10 if an extraction height greater than 3.9 metres were adopted and, conversely, are expected to be less than those predicted for Longwalls 6 to 10 if an extraction height less than 3.9 metres were adopted.

Geology

The predicted systematic subsidence parameters resulting from longwall extractions are dependant on geology, including the types and properties of the strata, the strengths and thicknesses of the strata beddings and local geological features including faults and dykes. The geology at Dendrobium Mine does not vary significantly between Areas 3A, 3B and 3C and, therefore, is unlikely to significantly affect the relative magnitudes of the maximum predicted systematic subsidence parameters between each area. There are, however, small local variations in geology and geological features located within Area 3 which could locally affect the predicted systematic subsidence parameters from place to place.

With all other factors being equal, however, the maximum predicted systematic subsidence parameters for the future longwalls in Areas 3B and 3C are expected to be similar to those predicted for Longwalls 6 to 10 based on the regional geology within Area 3.

Summary

The predictions and impact assessments for the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas. As described previously, detailed subsidence modelling based on the final longwall layouts in Areas 3B and 3C will be undertaken as part of the application for SMP Approval for these areas.

The impact assessments provided in this report for the natural features and items of infrastructure in Areas 3B and 3C have been based on the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas being similar to those resulting from the extraction of Longwalls 6 to 10 in Area 3A.

Impact assessments for the natural features and items of surface infrastructure that are located within Areas 3A, 3B and 3C have also been provided in this report based on the maximum predicted systematic subsidence parameters resulting from the extraction of the proposed and future longwalls in each area being greater than those resulting from the extraction of Longwalls 6 to 10 in Area 3A.

4.4. Maximum Predicted Systematic Subsidence Parameters along Prediction Line A

The predicted systematic subsidence parameters have been determined along Prediction Line A, the location of which is shown in Drawing No. MSEC311-15. The predicted profiles of systematic subsidence, tilt and strain along this prediction line are shown in Fig. E.01 in Appendix E. This figure illustrates the variations in the predicted systematic subsidence parameters above the proposed longwalls in Area 3A.

A summary of the maximum predicted cumulative systematic subsidence parameters along Prediction Line A, after the extraction of each proposed longwall, is provided in Table 4.5. The maximum predicted systematic subsidence parameters along this prediction line, which were determined using the Incremental Profile Method, are compared to those obtained using the Departments Method in Section 5.22.

Table 4.5 Maximum Predicted Cumulative Systematic Subsidence Parameters along Prediction Line A Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
After LW6	1210	9	1.0	2.5
After LW7	1495	14	2.5	6.0
After LW8	1665	15	3.0	6.5
After LW9	1925	14	3.0	6.5
After LW10	1950	17	3.0	8.0

CHAPTER 5. PREDICTED SUBSIDENCE PARAMETERS AND IMPACT ASSESSMENTS FOR THE NATURAL FEATURES AND ITEMS OF SURFACE INFRASTRUCTURE IN AREA 3

5.1. Introduction

The following sections provide the predicted subsidence parameters for the natural features and items of surface infrastructure within the Study Area. Impact assessments have been made for the natural features and items of surface infrastructure based on the predicted subsidence parameters. All significant natural features and items of surface infrastructure located outside the general Study Area, which may be subjected to far-field movements and may be sensitive to these movements, have also been included as part of these assessments.

It is possible for the actual subsidence parameters to be greater or less than those predicted for isolated features, depending on their relative position within the subsidence trough, so an additional factor of safety has been applied by taking the predicted maximum values of subsidence, tilt, curvature and strain within 20 metres of the perimeter of each feature. The predictions should, therefore, provide the best available indication of the overall subsidence parameters that are likely to be experienced by each feature.

5.2. The Cordeaux River

The location of the Cordeaux River, downstream of the Cordeaux Dam, is shown in Drawing No. MSEC311-07.

The Cordeaux River is located approximately 4 kilometres north of proposed Longwalls 6 to 10 in Area 3A and the future longwalls in Area 3B. It is unlikely, therefore, that the river would be subjected to any significant systematic subsidence, valley related, or far-field horizontal movements resulting from the extraction of the proposed and future longwalls in these areas.

The Cordeaux River is located 470 metres north of the maximum footprint for Area 3C, at its closest point. It is proposed that the future longwalls within Area 3C would be set back from the river such that it is assessed that no significant impacts on the river would occur. It is proposed that the methodology used to determine the required set back distances for Longwalls 6 to 10 in Area 3A from Wongawilli and Sandy Creeks would be adopted, which is outlined in Section 5.3.5.2.

The observations and monitoring data obtained during the extraction of Longwalls 6 to 10 in Area 3A will be used to further refine the impact assessment methodology and suitable set back distances for the future longwalls in Area 3C.

Based on the above, it is unlikely that there would be any significant impacts on the Cordeaux River, resulting from the extraction of the proposed and future longwalls in Areas 3A, 3B and 3C.

5.3. Wongawilli and Sandy Creeks

The locations of the watercourses within the Study Area are shown in Drawing No. MSEC311-07. The predictions and impact assessments for Wongawilli and Sandy Creeks are provided in the following sections. The predictions and impact assessments for Donalds Castle Creek and other drainage lines are provided in Sections 5.4 and 5.5, respectively.

5.3.1. Predictions for Wongawilli Creek due to Longwalls 6 to 10 in Area 3A

The predicted profiles of incremental and cumulative subsidence, upsidence and closure along Wongawilli Creek, after the extraction of each proposed longwall in Area 3A, are shown in Fig. E.02 in Appendix E. A summary of the maximum predicted values of cumulative subsidence, upsidence and closure anywhere along the creek, after the extraction of each proposed longwall in Area 3A, is provided in Table 5.1. The predicted contours of upsidence and horizontal movement due to valley closure along Wongawilli Creek, after the extraction of all proposed longwalls in Area 3A, are shown in Drawings Nos. MSEC311-24 and MSEC311-25, respectively.

Table 5.1 Maximum Predicted Cumulative Subsidence, Upsidence and Closure at Wongawilli Creek Resulting from the Extraction of Longwalls 6 to 10

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Upsidence (mm)	Maximum Predicted Cumulative Closure (mm)
After LW6	< 20	110	90
After LW7	< 20	145	160
After LW8	< 20	145	175
After LW9	< 20	165	180
After LW10	< 20	190	195

The profile of equivalent valley height that was used to determine the predicted valley related upsidence and closure movements along the creek is shown in Fig. E.02. The equivalent valley height is calculated by multiplying the measured overall valley depth by a factor which reflects the shape of the valley. The overall valley height is measured after examining the terrain across the valley within a radius of half the depth of cover. The factor varies from 1.0, for steeply sided valleys in flat terrain, to less than 0.5, for valleys of flatter profile in undulating terrain. An equivalent valley height factor of 0.7 was adopted for Wongawilli Creek.

The maximum predicted total systematic subsidence along Wongawilli Creek is less than 20 mm and, therefore, the maximum predicted total systematic tensile and compressive strains at the creek are both less than 0.1 mm/m. The maximum predicted closure movements across the valley of Wongawilli Creek are likely to result in elevated compressive strains in the base of the creek, which is discussed in Section 5.3.5.2.

The predicted changes in surface level along the alignment of the creek are illustrated by the predicted net vertical movement profiles that are shown in Fig. E.02, which have been determined by the addition of the subsidence and upsidence movements. A summary of the maximum predicted cumulative net vertical movements and the subsequent changes in grade along the alignment of the creek, after the extraction of each proposed longwall, is provided in Table 5.2.

Table 5.2 Maximum Predicted Cumulative Net Vertical Movements and Changes in Grade along the Alignment of Wongawilli Creek Resulting from the Extraction of Longwalls 6 to 10

Location	Maximum Predicted Cumulative Subsidence plus Upsidence (mm)		Maximum Predicted Cumulative Tilt due to Subsidence plus Upsidence (mm/m)	
	Net Subsidence (+ve)	Net Uplift (-ve)	Increase in Gradient (+ve)	Decrease in Gradient (-ve)
After LW6	< +20	-105	+1	-1
After LW7	< +20	-140	+1	-1
After LW8	< +20	-140	+1	-1
After LW9	< +20	-155	+1	-1.5
After LW10	< +20	-185	+1	-1.5

The locations of the rock bars and riffles along Wongawilli Creek are shown in Drawings Nos. MSEC311-08 and MSEC311-09 and in Fig. E.02. A summary of the maximum predicted total systematic subsidence and valley related movements at each of these features, resulting from the extraction of the proposed longwalls, is provided in Table 5.3.

Table 5.3 Maximum Predicted Total Systematic and Valley Related Movements at the Rock Bars and Riffles along Wongawilli Creek Resulting from the Extraction of Longwalls 6 to 10

Feature	Label	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Rock Bars	WC-RB30	< 20	< 20	< 20
	WC-RB31	< 20	70	105
	WC-RB32	< 20	25	25
	WC-RB33	< 20	25	25
Riffles	WC-RF8	< 20	< 20	< 20
	WC-RF9	< 20	75	120
	WC-RF10	< 20	120	145
	WC-RF11	< 20	100	160
	WC-RF12	< 20	125	175

5.3.2. Predictions for Wongawilli Creek due to the Future Longwalls in Areas 3B and 3C

Wongawilli Creek is located along the eastern side of Area 3B and crosses the western side of Area 3C. The maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas.

It is proposed that the future longwalls in Areas 3B and 3C would be set back from Wongawilli Creek such that it is assessed that no significant impacts on the creek would occur, such as significant fracturing and surface water diversions.

The methodology used to determine the required set back distances for proposed Longwalls 6 to 10 in Area 3A, which is outlined in Section 5.3.5.2, is proposed to be adopted for the future longwalls in Areas 3B and 3C. The observations and monitoring data obtained during the extraction of Longwalls 6 to 10 in Area 3A will be used to further refine the impact assessment methodology and suitable set back distances for the future longwalls in Areas 3B and 3C.

It is proposed that the future longwalls in Areas 3B and 3C would be set back from Wongawilli Creek such that the maximum predicted parameters along the creek, resulting from the extraction of all proposed and future longwalls in Areas 3A, 3B and 3C, would not result in significant impacts on the creek. It would still be possible, however, that some minor fracturing could occur along the creek, since this has been previously observed outside extracted longwall goaf edges in the Southern Coalfield.

5.3.3. Predictions for Sandy Creek due to Proposed Longwalls 6 to 10 in Area 3A

The predicted profiles of incremental and cumulative subsidence, upsidence and closure along Sandy Creek, after the extraction of each proposed longwall in Area 3A, are shown in Fig. E.03 in Appendix E. A summary of the maximum predicted values of cumulative subsidence, upsidence and closure anywhere along the creek, after the extraction of each proposed longwall, is provided in Table 5.4. The predicted contours of upsidence and horizontal movement due to valley closure along Sandy Creek, after the extraction of all proposed longwalls in Area 3A, are shown in Drawings Nos. MSEC311-24 and MSEC311-25, respectively.

Table 5.4 Maximum Predicted Cumulative Subsidence, Upsidence and Closure at Sandy Creek Resulting from the Extraction of Longwalls 6 to 10

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Upsidence (mm)	Maximum Predicted Cumulative Closure (mm)
After LW6	< 20	45	50
After LW7	< 20	75	110
After LW8	25	105	155
After LW9	25	120	170
After LW10	35	125	180

The profile of equivalent valley height that was used to determine the predicted valley related upsidence and closure movements along the creek is shown in Fig. E.03. An equivalent valley height factor of 0.7 was adopted for Sandy Creek.

The maximum predicted total systematic subsidence at Sandy Creek is 35 mm and the associated maximum predicted total systematic tensile and compressive strains along the alignment of the creek are both less than 0.1 mm/m. Sandy Creek is located at a minimum distance of 85 metres from the finishing ends of Longwalls 8 to 10 and the resulting maximum predicted total systematic tensile strain across the alignment of the creek is 0.3 mm/m. The maximum predicted closure movements across the valley of Sandy Creek are likely to result in elevated compressive strains in the base of the creek, which is discussed in Section 5.3.5.2.

The predicted changes in surface level along the alignment of the creek are illustrated by the predicted net vertical movement profiles that are shown in Fig. E.03, which have been determined by the addition of the subsidence and upsidence movements. A summary of the maximum predicted cumulative net vertical movements and the subsequent changes in grade along the alignment of the creek, after the extraction of each proposed longwall, is provided in Table 5.5.

Table 5.5 Maximum Predicted Cumulative Net Vertical Movements and Changes in Grade along the Alignment of Sandy Creek Resulting from the Extraction of Longwalls 6 to 10

Location	Maximum Predicted Cumulative Subsidence plus Upsidence (mm)		Maximum Predicted Cumulative Tilt due to Subsidence plus Upsidence (mm/m)	
	Net Subsidence (+ve)	Net Uplift (-ve)	Increase in Gradient (+ve)	Decrease in Gradient (-ve)
After LW6	< 20	-45	+0.5	-0.5
After LW7	< 20	-75	+0.5	-1.5
After LW8	< 20	-105	+0.5	-2
After LW9	< 20	-120	+1	-2.5
After LW10	< 20	-125	+1	-2.5

The location of the waterfall where Sandy Creek flows into Lake Cordeaux and the locations of the rock bars and riffles along the creek are shown in Drawing No. MSEC311-10 and in Fig. E.03. A summary of the maximum predicted systematic and valley related movements at the waterfall, rock bars and riffles, resulting from the extraction of the proposed longwalls, is provided in Table 5.6.

Table 5.6 Maximum Predicted Systematic and Valley Related Movements at the Waterfall, Rockfalls and Riffles along Sandy Creek Resulting from the Extraction of Longwalls 6 to 10

Feature	Label	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Waterfall	DM23	< 20	125	175
Rock Bars in Lake Cordeaux	SC-RB1 and SC-RB2	< 20	100	170
Rock Bars along Sandy Creek	SC-RB3 to SC-RB19	30	105	90
Riffles along Sandy Creek	SC-RF1 to SC-RF8	30	70	45

5.3.4. Predictions for Sandy Creek due to the Future Longwalls in Areas 3B and 3C

Sandy Creek is located at distances of 3000 metres and 700 metres from Areas 3B and 3C, respectively, at the nearest points. It is unlikely, therefore, that the creek would be subjected to any significant systematic, valley related, or far-field horizontal movements resulting from the extraction of the future longwalls in Areas 3B and 3C.

5.3.5. Impact Assessments for Wongawilli and Sandy Creeks

The impact assessments for Wongawilli and Sandy Creeks, based on the predicted systematic and valley related movements, are provided in the following sections. The findings in the following sections should be read in conjunction with the other relevant technical reports attached to the applications. The predictions and impact assessments for the arm of Lake Cordeaux, downstream of the waterfall at the end of Sandy Creek, are provided in Section 5.16.

5.3.5.1. The Potential for Increased Levels of Ponding, Flooding and Scouring

Wongawilli and Sandy Creeks are permanent streams with small flows, except for increased flows for short periods of time during and following significant rain events. The pools in the streams are permanent and naturally develop upstream of the rock bars and at the sediment and debris accumulations, the locations of which are shown in Drawings Nos. MSEC311-08 and MSEC311-10.

Mining can potentially result in increased levels of ponding and some minor flooding of the adjacent riparian areas in locations where the mining induced tilts oppose and are greater than the natural creek gradients that exist before mining. Mining can also potentially result in an increased likelihood of scouring of the creek banks in the locations where the mining induced tilts considerably increase the natural creek gradients that exist before mining.

The maximum predicted increasing tilts along the Wongawilli and Sandy Creeks, due to net vertical movements resulting from proposed Longwalls 6 to 10 in Area 3A, are both 1 mm/m (ie: 0.1 %), or a change in grade of 1 in 1000. The maximum predicted decreasing tilts along Wongawilli and Sandy Creeks, due to net vertical movements resulting from proposed Longwalls 6 to 10 in Area 3A, are 1.5 mm/m (ie: 0.2 %) and 2.5 mm/m (ie: 0.3 %), respectively, or changes in grade of 1 in 665 and 1 in 400, respectively.

It is proposed that the future longwalls in Areas 3B and 3C would be set back from Wongawilli Creek using the methodology that was adopted for Longwalls 6 to 10 in Area 3A. It is expected, therefore, that the maximum predicted systematic tilts along the creek, resulting from the extraction of the future longwalls in Areas 3B and 3C, would be similar to those predicted for Longwalls 6 to 10 in Area 3A.

The natural gradient of Wongawilli Creek within the Study Area, excluding the cascade in the south of Area 3B, varies between a minimum of less than 1 mm/m and a maximum of 200 mm/m, with an average natural gradient of approximately 10 mm/m. The natural gradient of Sandy Creek within the Study Area, upstream of the waterfall, varies between a minimum of less than 1 mm/m and a maximum of 60 mm/m, with an average natural gradient of approximately 10 mm/m.

Although the creeks have relatively shallow natural gradients, it is unlikely that there would be any significant increases in the levels of ponding, flooding, or scouring of the creek banks, as the maximum predicted changes in grade along the creeks are very small, being less than or equal to 0.3 %, or 1 in 400. It is possible, however, that there could be some very localised increased levels of ponding or flooding where the maximum predicted tilts coincide with existing pools, steps or cascades along the creeks, however, any changes are not expected to result in significant impacts.

5.3.5.2. The Potential for Fracturing of Bedrock and Surface Water Flow Diversions

Fractures and joints in bedrock and rock bars occur naturally from erosion and weathering processes and from natural valley bulging movements. Where longwall mining occurs in the vicinity of creeks and rivers, mine subsidence movements can result in additional fracturing or the reactivation of the existing joints. The precise causes of these mining-induced fractures are difficult to determine as the mechanisms are complex, although the main mining-related mechanisms are systematic subsidence and valley related upsidence and closure movements.

Diversions of surface water flows also occur naturally from erosion and weathering processes and from natural valley bulging movements. Mining-induced surface water flow diversions into near surface subterranean flows occur where there is an upwards thrust of bedrock, resulting in a redirection of some water flows into the dilated strata beneath the creek beds. The water generally reappears further downstream of the fractured zone as the water is only redirected below the creek bed for a certain distance.

Mining-induced surface water flow diversions due to rock bar leakage occur in a similar manner to the above mechanism, except that the rock bar is elevated above the rest of the creek bed and the near surface watertable. The rate of leakage is dependent, among other things, on the extent of horizontal fracturing over the depth of the rock bar and the water level. Rock bars leak at a higher rate when the pool is full, as there is access to all drainage paths and the water head is at its greatest. As the pool level falls, the drainage rate reduces as the water head falls and access is restricted to drainage paths near the base of the rock bar.

The types of surface water flow diversions mentioned above are illustrated in Fig. 5.1.

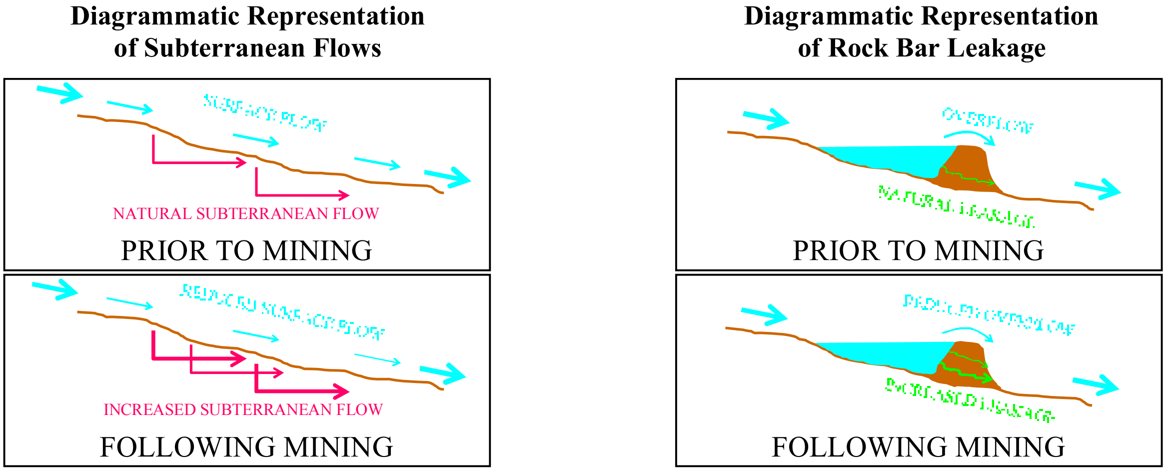


Fig. 5.1 Types of Surface Water Flow Diversions

The experience gained from previous longwall mining in the Southern Coalfield indicate that mining-induced fracturing in bedrock and rock bars are commonly found in sections of creeks and rivers that are located directly above extracted longwalls. However, minor fracturing has also been observed in isolated locations beyond extracted longwall goaf edges, the majority of which have been within the limit of systematic subsidence. In a few isolated cases, minor fracturing has been observed up to 400 metres outside extracted longwall goaf edges.

In times of extended drought, such as has recently occurred, the groundwater table can be lowered considerably. In these drought conditions, surface water flows can be naturally diverted through the existing natural joints into a lower groundwater aquifer and when and where mining induced fractures occur, additional water diversions can occur into the groundwater aquifer. Following periods of groundwater recharge rain events, the groundwater levels are expected to return to levels higher than the creeks.

The infiltration of surface water into groundwater is generally possible during periods of low rainfall when the groundwater table is below the surface water in the creeks. The surface water diverted into groundwater, however, is not drawn upon, utilised or lost from the region and, hence, the diverted surface water is not viewed as a loss of water from the system.

The diversion of surface water into subterranean flows and rock bar leakage do not result in the loss of water or upper groundwater systems and, with time, these subterranean flow channels and fractures can become blocked with debris and sediment. Hence, the diversion of surface water into subterranean flows can reduce over time.

The maximum predicted total systematic tensile strains at Wongawilli and Sandy Creeks, resulting from the extraction of the proposed longwalls in Area 3A, are less than 0.1 mm/m and 0.3 mm/m, respectively. The maximum predicted total systematic compressive strains at Wongawilli and Sandy Creeks, resulting from the extraction of the proposed longwalls in Area 3A, are both less than 0.1 mm/m.

The fracturing of sandstone due to systematic subsidence movements has generally not been observed in the Southern Coalfield where the systematic tensile and compressive strains are less than 0.5 mm/m and 2 mm/m, respectively. It is unlikely, therefore, that these maximum predicted systematic strains at Wongawilli and Sandy Creeks would result in any significant fracturing in the sandstone bedrock or result in any significant surface water diversions.

It is proposed that the future longwalls in Areas 3B and 3C would be set back from Wongawilli Creek such that the maximum predicted total systematic strains along the creek, resulting from the extraction of all proposed and future longwalls in Areas 3A, 3B and 3C, are such that it is assessed that it is unlikely that there would be any significant impacts on the creek, such as significant surface water flow diversions or loss of pool water.

Elevated compressive strains across the alignments of the creeks are likely to result from the valley related movements. The maximum predicted total upsidence movements along Wongawilli and Sandy Creeks, resulting from the extraction of the proposed longwalls in Area 3A, are 190 mm and 125 mm, respectively. The maximum predicted total closure movements across the valleys of Wongawilli and Sandy Creeks, resulting from the extraction of the proposed longwalls in Area 3A, are 195 mm and 180 mm, respectively.

It is proposed that the future longwalls in Areas 3B and 3C would be set back from Wongawilli Creek such that the maximum predicted valley related movements along the creek, resulting from the extraction of all proposed and future longwalls in Areas 3A, 3B and 3C, are such that it is assessed that it is unlikely that there would be any significant impacts on the creek, such as significant surface water flow diversions or loss of pool water.

The compressive strains resulting from valley related movements are more difficult to predict than systematic strains, especially where creeks and rivers are located above solid coal, ie: outside the areas located directly above extracted longwalls.

The potential for the fracturing of bedrock and, hence, the potential for surface water flow diversions along Wongawilli and Sandy Creeks, resulting from the predicted upsidence and closure movements have, therefore, been assessed by comparing the predicted movements along these creeks with the back-predicted movements along a number of creeks and rivers which have been affected by mining within the Southern Coalfield.

The selected case studies include the following:-

- Elouera Longwalls 1 to 10 which mined adjacent to and directly beneath Wongawilli Creek,
- Elouera Longwalls 1 to 10 which mined adjacent to and directly beneath Native Dog Creek,
- Dendrobium Area 1 – Longwalls 1 and 2 which mined adjacent to Kembla Creek,
- Appin Longwall 301 which mined adjacent to the Cataract River,
- West Cliff Longwalls 5A1 to 5A4 which mined adjacent to and directly beneath the Georges River,
- West Cliff Longwalls 29 and 31 which mined adjacent to the Georges River, and
- Tahmoor Longwalls 14 to 19 which mined adjacent to and directly beneath the Bargo River.

Descriptions and details of each case study are provided in Appendix C at the end of this report. The case studies include a range of longwall geometries, mining details, longwall offsets from creek and river valleys and heights and shapes of creek and river valleys.

To allow comparisons between the case studies and the proposed longwalls, the back-predicted upsidence and closure movements for the case studies were determined using the ACARP Method (Waddington 2004), which is the same method that was used to predict the upsidence and closure movements for Longwalls 6 to 10 in Area 3A.

Observed valley related movements were not used in these comparisons because the mining geometries and valley geometries for the case studies are different to those for the proposed longwalls. By using the ACARP Method of prediction for valley related movements, however, the mining geometries and valley geometries for the case studies are normalised and comparisons can be made with the predictions for Longwalls 6 to 10 in Area 3A.

The back-predicted total upsidence and closure movements and the observed impacts for each case study are shown in Fig. 5.2. Minor impacts, such as isolated fracturing, gas release and iron staining, are shown as circles in this figure. Significant impacts, including major fracturing and surface water flow diversions, are shown as crosses in this figure. The maximum predicted total upsidence and closure movements along Wongawilli and Sandy Creeks, resulting from the extraction of Longwalls 6 to 10 in Area 3A, are also shown in this figure for comparison.

The natural pools along Wongawilli and Sandy Creeks are controlled by the rock bars, sediment accumulations and riffles, the locations of which are shown in Drawings Nos. MSEC311-08 to MSEC311-10 and in Figs. E.02 and E.03. The maximum predicted total upsidence and closure movements at the rock bars along Wongawilli and Sandy Creeks, resulting from the extraction of Longwalls 6 to 10 in Area 3A, are compared with the back-predicted movements for the case studies in Fig. 5.3.

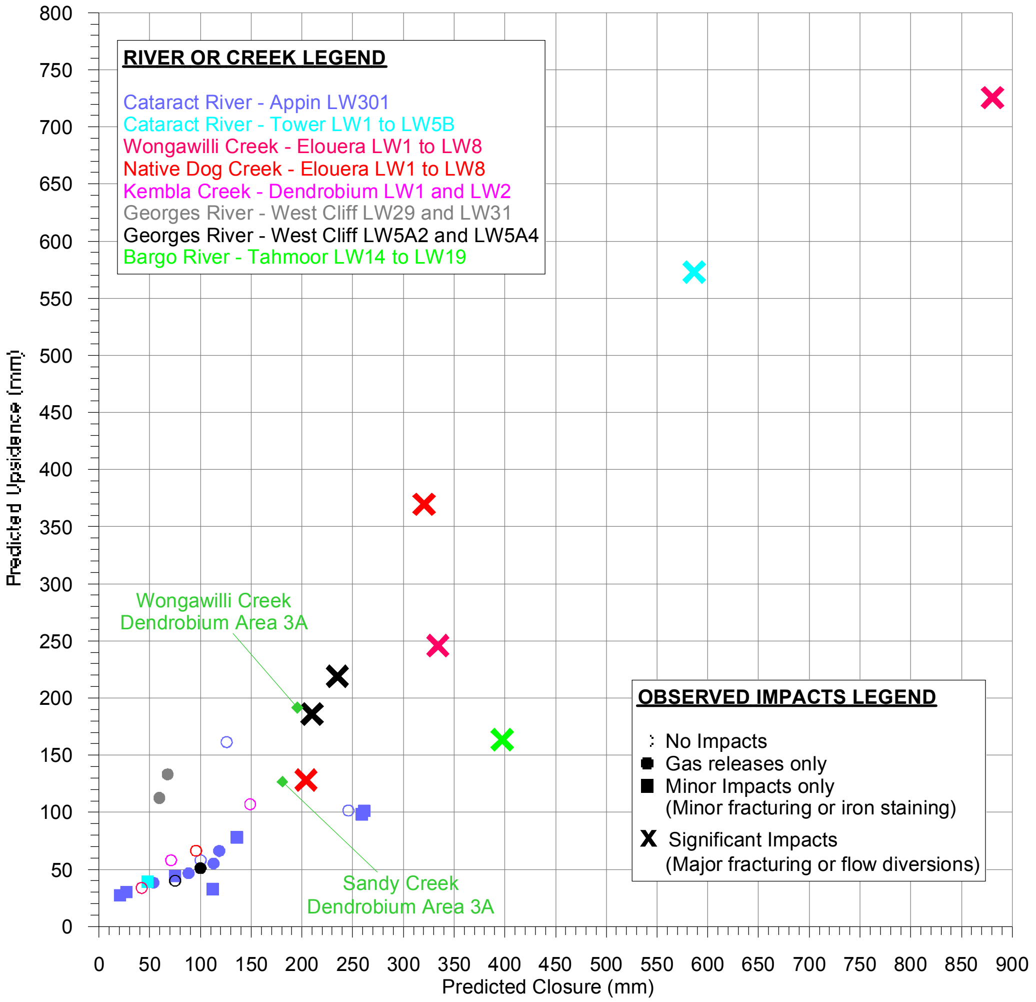


Fig. 5.2 Back-Predicted Upsidence and Closure and the Observed Impacts for the Case Studies

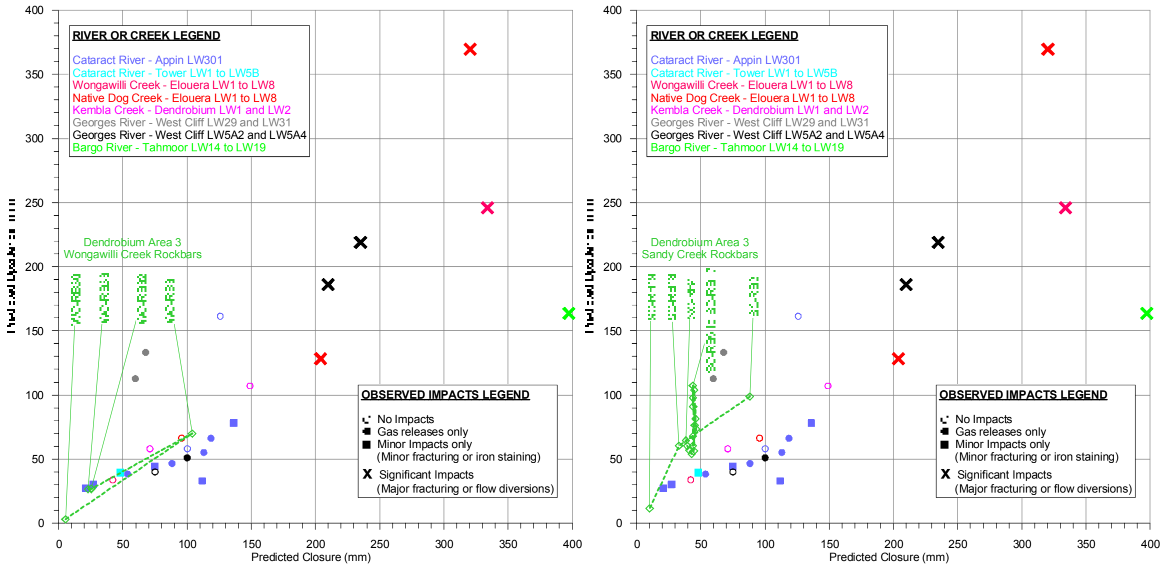


Fig. 5.3 Comparison of Predicted Upsidence and Closure at the Rock Bars along Wongawilli and Sandy Creeks with Back-Predicted Movements and Observed Impacts for the Case Studies

Where Wongawilli and Native Dog Creeks were previously mined beneath by Elouera Longwalls 1 to 10, substantial fracturing in the bedrock and rock bars occurred directly above the longwalls. Only isolated minor fractures were identified outside the extracted longwall goaf edges.

The last drained pool along Wongawilli Creek at Elouera Colliery was located 95 metres (to the rock bar) downstream of the maingate of Longwall 6 and the back-predicted upsidence and closure at this location were 245 mm and 335 mm, respectively. The first full pool along the creek was located 275 metres (to the rock bar) downstream of the edge of Longwall 7. The locations of these pools are shown in Fig. D.1 in Appendix D.

The last drained pool along Native Dog Creek at Elouera Colliery was located 75 metres (to the rock bar) downstream of the maingate of Longwall 7 and the back-predicted upsidence and closure at this point were 130 mm and 205 mm, respectively. The first full pool along the creek was located 105 metres (to the rock bar) downstream of the maingate of Longwall 7. The locations of these pools are shown in Fig. D.2 in Appendix D.

It can be seen from Fig. 5.2 that only minor impacts occurred where the back-predicted closure and upsidence for the case studies were typically less than 150 mm and 125 mm, respectively. It can also be seen from this figure that the commencement of significant impacts occurred where both the back-predicted closure and upsidence for the case studies were greater than 200 mm and 125 mm, respectively.

It should be noted that the predicted and back-predicted upsidence and closure movements made using the ACARP Method use conservative upperbound prediction curves. The observed valley related movements, therefore, are typically found to be much less than those predicted using this method. Comparisons between predicted and observed upsidence and closure movements in the valley related movements database are provided in Fig. 5.3 and Fig. 5.4.

It has been found, in the majority of cases, that the observed valley related movements are typically between 50 % and 100 % of those predicted and in some cases the observed movements are less than 25 % of those predicted. In rare cases, it has been found that the observed movements exceeded those predicted, which is generally the result of weak near surface geology.

While both upsidence and closure movements have been back-predicted, it is our opinion that the most relevant parameter for assessing the potential for significant impacts along the creeks is the predicted closure movements. This opinion is based on information that is currently available and is made for the following reasons:-

- Closure is the measure of macro valley movements and, therefore, there is less variation in the observed closure movements between adjacent cross-sections within a valley. As a result, there is less scatter in the observed closure movement data in the empirical database, which can be seen in Fig. 5.4.
- Upsidence is the measure of micro valley movements in the base of the valley, which can vary significantly between adjacent cross-sections due to variations in near surface geology, whether failure of the bedrock occurs and the nature of bedrock failure. As a result, there is greater scatter in the observed upsidence movement data in the empirical database, which can be seen in Fig. 5.3.
- The observed upsidence movements in the empirical database are also influenced by the placement of survey pegs, which can miss the point of maximum upsidence within the cross-section and measurements can vary significantly between adjacent cross-sections.

Based on the above points, the predicted closure movements are considered to be more reliable than the predicted upsidence movements. Although fracturing and dilation of underlying strata and, hence, the potential for surface water flow diversions result from upsidence movements, the correlation between closure and upsidence movements, which can be seen in Fig. 5.2, allows us to use the predicted closure movements to assess the potential for these impacts.

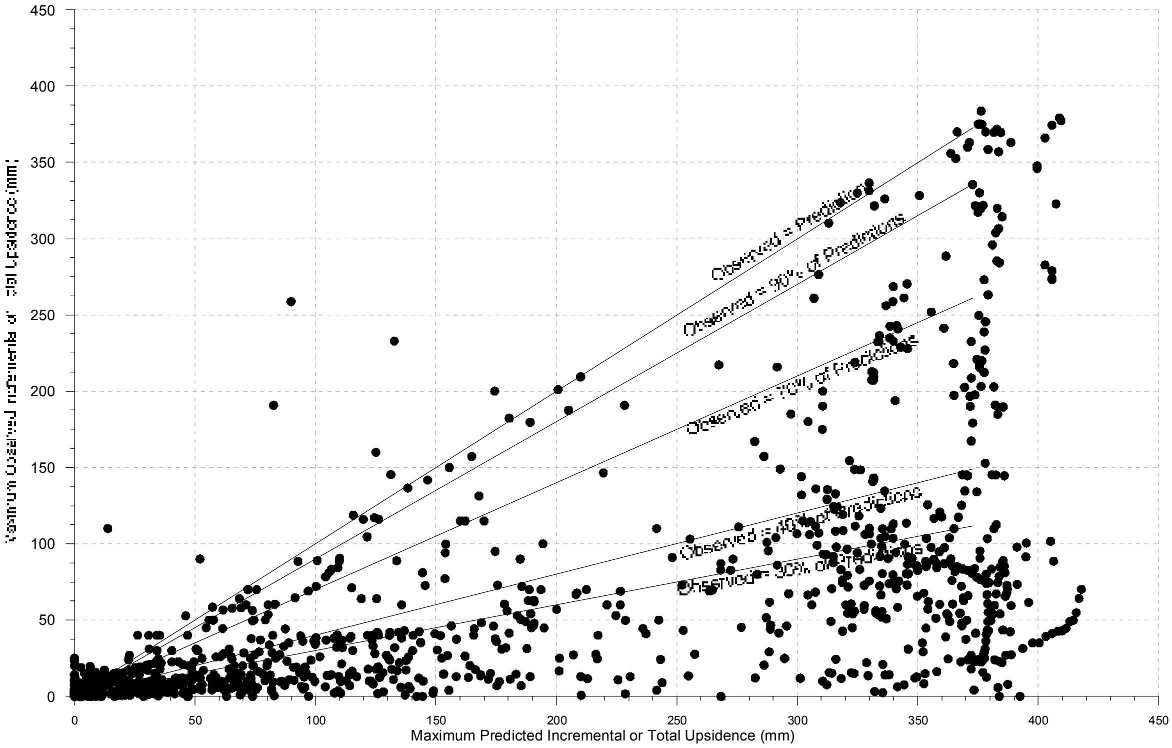


Fig. 5.4 Comparison of Predicted and Observed Upsidence Movements in Database

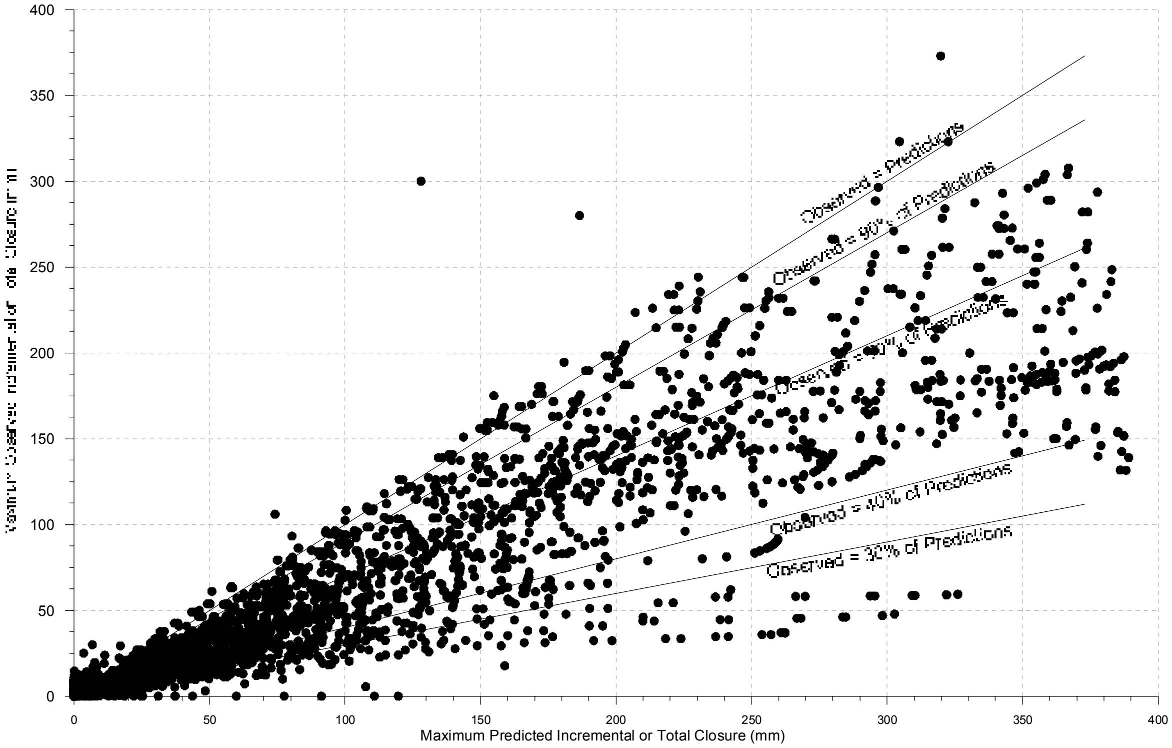


Fig. 5.5 Comparison of Predicted and Observed Closure Movements in Database

It can be seen from Fig. 5.2, that the maximum predicted closure along Wongawilli and Sandy Creeks, resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A, are less than those back-predicted for all case studies which had observed significant impacts. It can also be seen from Fig. 5.3, that the maximum predicted closure at the identified rock bars along Wongawilli and Sandy Creeks are considerably less than those back-predicted for all case studies which had observed significant impacts.

The maximum predicted upsidence along Sandy Creek, resulting from the extraction of the proposed longwalls in Area 3A, is less than those back-predicted for all case studies which had observed significant impacts. The maximum predicted upsidence along Wongawilli Creek, resulting from the extraction of the proposed longwalls in Area 3A, is less than those back-predicted for all but three case studies which had observed significant impacts. However, the following should be noted for these case studies:-

- The back-predicted upsidence of 130 mm along Native Dog Creek was accompanied by a back-predicted closure of greater than 200 mm. The impact associated with these movements was a single drained pool located at a distance of 75 metres from the longwalls,
- The back-predicted upsidence of 165 mm along the Bargo River was accompanied by a very large back-predicted closure of 400 mm, and
- The back-predicted upsidence of 185 mm along the Georges River was accompanied by a back-predicted closure of greater than 200 mm. The impact associated with these movements occurred at Marhnyes Hole which was directly mine beneath by the longwalls.

As described previously, predicted closure is considered to be the more reliable parameter for assessing impacts along creeks and rivers. The case studies, therefore, indicate that a maximum predicted closure of 200 mm is an appropriate limit for assessing the likelihood for significant impacts on the creeks. Similar case studies have also been assessed for creeks and rivers located over previously extracted longwalls at other Collieries within the Southern Coalfield and similar findings have been found.

It should be noted that the case studies occurred during a time of severe drought and the surface water and groundwater levels around the creeks and rivers are likely to have been at lower levels and, hence, the rate of surface water diversion would have been much greater than during normal periods. In this regard, the selected threshold for surface water diversions is considered to be conservative and represents significant protection against flow diversions, even in drought periods.

Wongawilli and Sandy Creeks are not directly mined beneath by proposed Longwalls 6 to 10 in Area 3A and are not proposed to be mined beneath by the future longwalls in Areas 3B and 3C. In addition to this, the maximum predicted total closure movements along these creeks, resulting from the extraction of the proposed longwalls in Area 3A, are less than 200 mm and the maximum predicted total closure movements at the rock bars along the creeks are considerably less than 200 mm. It has been assessed, therefore, that it is unlikely that significant fracturing or surface water flow diversions would occur along Wongawilli and Sandy Creeks as a result of the extraction of the proposed longwalls in Area 3A.

It is proposed that the future longwalls in Areas 3B and 3C would also be set back from Wongawilli Creek such that the maximum predicted total closure along the creek, resulting from the extraction of all proposed and future longwalls in Areas 3A, 3B and 3C, is such that it is assessed that it is unlikely to result in significant fracturing along the creek. Based on this, it would also be assessed that it would be unlikely that significant surface water flow diversions would occur along Wongawilli Creek as a result of the extraction of the future longwalls in Areas 3B and 3C.

It should be noted, however, that it is likely that minor fracturing in the beds of Wongawilli and Sandy Creeks could occur as a result of the extraction of the proposed and future longwalls in Area 3. Based on previously observed fractures in the beds of creeks and rivers adjacent to longwall mining in the Southern Coalfield, it is possible that minor fractures could occur in Wongawilli and Sandy Creeks, up to 400 metres from the proposed and future longwalls. Any fracturing that does occur in the beds of these creeks would be expected to be isolated and of a minor nature and not result in any significant surface water flow diversions.

5.3.5.3. The Potential Impacts on the Waterfall

The waterfall site, where Sandy Creek flows into an arm of Lake Cordeaux, is located 250 metres east of proposed Longwall 7 in Area 3A. The case studies described in the previous section can not be used to assess the potential for impacts on the waterfall itself, as the case studies are based on observed impacts in the bases of creek and river beds, rather than impacts on vertical and undercut rockfaces.

The waterfall is a 25 metre high concave cliff face having a maximum overhang in the order of 20 metres. The potential for rockfalls at the waterfall site is extremely difficult to assess due to the complex nature of mine subsidence movements and due to the numerous factors which are difficult to fully quantify, including jointing, inclusions, weaknesses within the rockmass, and water pressure and seepage flow behind the rockface. Even if these factors could be fully quantified, it would still be difficult to determine the extent to which each of these factors influence the stability of the site naturally, or when it is exposed to mine subsidence movements.

Previous experience in the Southern Coalfield indicates that very few rockfalls have occurred outside of extracted longwall goaf areas and only in extremely rare cases have rockfalls occurred more than half the depth of cover from extracted longwall goaf edges. In addition to this, all rockfalls observed in Area 1 at Dendrobium Mine occurred directly above the extracted longwalls and no rock falls were observed outside of the extracted longwall goaf areas. It is unlikely, therefore, that the extraction of the proposed and future longwalls in Area 3 would result in rockfalls at the waterfall, as the site is located more than half a depth of cover from the proposed and future longwalls.

The potential for loss of surface water flow at the waterfall is governed by the potential for surface water diversions in Sandy Creek immediately upstream of the site. As described in Section 5.3.5.2, it has been assessed that it is unlikely that surface water flow diversions would occur along Sandy Creek as a result of the extraction of the proposed and future longwalls in Area 3.

5.3.5.4. The Potential Impacts on Water Quality

Mine subsidence can potentially impact on the quality of water in the creeks due to leaching of minerals from freshly fractured bedrock and from increased inputs from groundwater to surface flow. Such impacts tend to be temporary, localised and associated with low flow conditions. An investigation into the potential impacts of mine subsidence on water quality in the creeks has been undertaken and described in the report by Ecoengineers (2007).

5.3.5.5. The Potential Impacts on Flora and Fauna

Mine subsidence can potentially impact on flora and fauna within the alignments of the creeks. Flora could be adversely affected by the emission of gas at the surface and habitats can be affected by the fracturing of bedrock and the cracking of soils. The potential impact of mine subsidence on flora and fauna are provided in the reports by The Ecology Lab (2007) and by Biosis (2007a).

5.3.6. Impacts on Wongawilli and Sandy Creeks Based on Increased Predictions

If the predicted systematic tilts along the creeks were increased by factors of up to 2 times, the maximum predicted changes in grade along the creeks would still be less than 1 %. It is possible that there could be small changes in the levels of ponding and flooding where the maximum predicted tilts coincide with any existing pools, steps, or cascades along the creeks, however, any impacts would still be expected to be minor and not significant.

If the predicted systematic strains at the creeks were increased by factors of up to 2 times, it is possible that minor fracturing in the bed of Sandy Creek would occur where the creek is located closest to the proposed longwalls in Area 3A. Any fracturing would still be expected to be of a minor nature and not result in any significant surface water flow diversions, as the maximum predicted tensile strain would only just be 0.5 mm/m.

Minor fracturing could occur along Wongawilli Creek within Areas 3B and 3C, where the maximum predicted tensile and compressive strains exceed 0.5 mm/m and 2 mm/m, respectively. It is proposed that the future longwalls in Areas 3B and 3C would be set back using the methodology adopted for proposed Longwalls 6 to 10 in Area 3A and it is likely, therefore, that the maximum predicted systematic tensile and compressive strains would not result in significant fracturing or surface water flow diversions.

Elsewhere within Area 3A, the maximum predicted systematic tensile and compressive strains would still be less than 0.5 mm/m and 2 mm/m, respectively, and unlikely, therefore, to result in any significant fracturing in the creek beds.

If the predicted valley related upsidence and closure movements were increased by factors of up to 2 times, it is likely that fracturing and dilation of the creek beds would occur, which could result in some surface water flow diversions. It should be noted, however, that the method used to predict the valley related movements adopts conservative upper-bound prediction curves and it is unlikely, therefore, that these movements would be exceeded by any more than 15 %.

5.3.7. Recommendations for Wongawilli and Sandy Creeks

It is recommended that Wongawilli and Sandy Creeks are monitored during the extraction of the proposed and future longwalls in Areas 3A, 3B and 3C. It is also recommended that management strategies are developed for the creeks, in consultation with the SCA, such that any impacts can be identified and remediated accordingly. With these strategies in place, it is unlikely that there would be any significant impact on the creeks resulting from the proposed mining.

5.4. Donalds Castle Creek

The upper reaches of Donalds Castle Creek are located in the northern part of Area 3B and in the western part of Area 3C. The location of the creek is shown in Drawing No. MSEC311-07.

Donalds Castle Creek is located 1.4 kilometres west of the commencing end of Longwall 6, at its closest point to the proposed longwalls in Area 3A. It is unlikely, therefore, that the creek would be subjected to any significant systematic, valley related, or far-field horizontal movements as a result of the extraction of the proposed longwalls in Area 3A, even if the predictions were increased by a factor of 5 times.

The future longwalls in Areas 3B and 3C could potentially mine directly beneath Donalds Castle Creek. The maximum predicted systematic subsidence and valley related movements along the creek, resulting from the extraction of these future longwalls, will depend on the final longwall layouts in these areas.

Based on the future longwalls in Areas 3B and 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas are expected to be similar to those predicted for Longwalls 6 to 10 in Area 3A.

The impact assessments provided below for Donalds Castle Creek have, therefore, been based on the maximum predicted systematic subsidence parameters provided in Table 4.2. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas.

The maximum predicted systematic tilt for the future longwalls in Areas 3B and 3C is 21 mm/m (ie: 2.1 %), or a change in grade of 1 in 50. The natural gradient of Donalds Castle Creek within the Study Area varies between a minimum of 10 mm/m and a maximum of 150 mm/m, with an average natural gradient of 30 mm/m.

If the future longwalls in Areas 3B and 3C were to be mined directly beneath the creek, therefore, it would be likely that increased levels of ponding would occur upstream of the longwall chain pillars and increased levels of scouring of the banks could occur downstream of the longwall chain pillars. The increased levels of ponding and scouring of the banks would be expected to be of a minor nature, however, as the maximum predicted change in grade is only 2 %.

The maximum predicted systematic tensile and compressive strains for the future longwalls in Area 3B and 3C are 4.5 mm/m and 11 mm/m, respectively. Fracturing of exposed bedrock has been observed in the Southern Coalfield in the past where the predicted systematic tensile and compressive strains have been greater than 0.5 mm/m and 2 mm/m, respectively.

If the future longwalls in Areas 3B and 3C were to be mined directly beneath the creek, therefore, it would be likely that fracturing of the bedrock would occur along the creek. In addition to this, it would be expected that the maximum predicted valley related movements would be of sufficient magnitude to result in fracturing, buckling and dilation of the topmost bedrock along the creek, which could result in surface water flow diversions. The impacts on the creek would be expected to be similar to that observed where the Elouera Colliery longwalls mined directly beneath Wongawilli and Native Dog Creeks.

As discussed previously, the predictions and impact assessments for Donalds Castle Creek will depend on the final longwall layouts in Areas 3B and 3C. Detailed subsidence modelling and a refined impact assessment for the creek will be undertaken as part of the application for SMP Approval for the future longwalls in these areas. Management strategies will need to be developed, in consultation with the SCA, based on the final longwall layouts and the refined impact assessments.

5.5. Drainage Lines

The locations of the drainage lines within the Study Area are shown in Drawing No. MSEC311-07. The predictions and impact assessments for the drainage lines are provided in the following sections.

5.5.1. Predictions for the Drainage Lines in Area 3A

The drainage lines are located across Area 3A and are likely, therefore, to be subjected to the full range of predicted systematic subsidence and valley related movements in this area. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the drainage lines, at any time during or after the extraction of Longwalls 6 to 10 in Area 3A, is provided in Table 5.7.

Table 5.7 Maximum Predicted Systematic Subsidence, Tilt and Strain at the Drainage Lines Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Location	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
Drainage Lines	2275	21	4.5	11

The drainage lines are also likely to experience valley related upsidence and closure movements, which are discussed in the impact assessments for the drainage lines in Section 5.5.4.

5.5.2. Predictions for the Drainage Lines in Areas 3B and 3C

The drainage lines are located across Areas 3B and 3C and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in these areas. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas.

Based on the future longwalls in Areas 3B and 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas are expected to be similar to those predicted for Longwalls 6 to 10.

The impact assessments provided in this report for the drainage lines in Areas 3B and 3C have, therefore, been based on the maximum predicted systematic subsidence parameters provided in Table 5.7. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas.

5.5.3. Predictions for Drainage Lines WC17(A) and SC10

Specific subsidence predictions have been made for two drainage lines, being WC17(A) and SC10, which illustrate the variations in the predicted subsidence parameters above the proposed longwalls in Area 3A. The locations of these drainage lines are shown in Drawing No. MSEC311-07.

The predicted profiles of incremental and cumulative subsidence, upsidence and closure along WC17(A) and SC10, resulting from the extraction of the proposed longwalls in Area 3A, are shown in Figs. E.04 and E.05, respectively, in Appendix E. It is unlikely that these drainage lines would be subjected to any significant subsidence, upsidence or closure movements resulting from the extraction of the future longwalls in Areas 3B and 3C.

A summary of the maximum predicted values of total subsidence, upsidence and closure movements at WC17(A) and SC10, after the extraction of the proposed longwalls in Area 3A, is provided in Table 5.8.

Table 5.8 Maximum Predicted Total Subsidence, Upsidence and Closure Movements at WC17(A) and SC10 Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Location	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
WC17(A)	1900	520	450
SC10	2260	320	250

A summary of the maximum predicted systematic tilt, systematic tensile strain and systematic compressive strain along WC17(A) and SC10, at anytime during or after the extraction of the proposed longwalls in Area 3A, is provided in Table 5.9.

Table 5.9 Maximum Predicted Systematic Tilt, Tensile Strain and Compressive Strain at WC17(A) and SC10 Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Location	Maximum Predicted Systematic Tilt (mm/m)	Maximum Predicted Systematic Tensile Strain (mm/m)	Maximum Predicted Systematic Compressive Strain (mm/m)
WC17/17A	10	3.2	3.8
SC10	18	4.5	9.4

The maximum predicted closure movements across the valleys of the drainage lines are likely to result in elevated compressive strains in the bases of the drainage lines, which is discussed in the impact assessments in the following section.

5.5.4. Impact Assessments for the Drainage Lines

The drainage lines are located across the Study Area and, therefore, will experience the full range of predicted systematic and valley related movements. The potential for impact is greatest where the drainage lines are located directly above the proposed and future longwalls and, in these cases, the impacts are expected to be similar to those described below for Drainage Lines WC17(A) and SC10.

The maximum predicted systematic tilts along WC17(A) and SC10 are 10 mm/m (ie: 1.0 %) and 18 mm/m (ie: 1.8 %), respectively, or changes in grade of 1 in 100 and 1 in 55, respectively. The natural grade of WC17(A) varies between a minimum of 20 mm/m and a maximum of 300 mm/m, with an average natural grade of 100 mm/m. The natural grade of SC10 varies between a minimum of 10 mm/m and a maximum of 150 mm/m, with an average natural grade of 25 mm/m.

The predicted systematic tilts along WC17(A) are small when compared to the existing natural grades and are unlikely, therefore, to result in any significant increase in the levels of ponding, flooding and scouring along the drainage line. The predicted systematic tilts along SC10 are a similar order of magnitude to the existing natural grades and could, therefore, result in increased levels of ponding and flooding adjacent to the longwall tailgates and increased levels of scouring adjacent to the longwall maingates. The surface levels along WC17(A) and SC10, before and after the extraction of Longwalls 6 to 10 in Area 3A, are shown in Fig. 5.6 and Fig. 5.7, respectively.

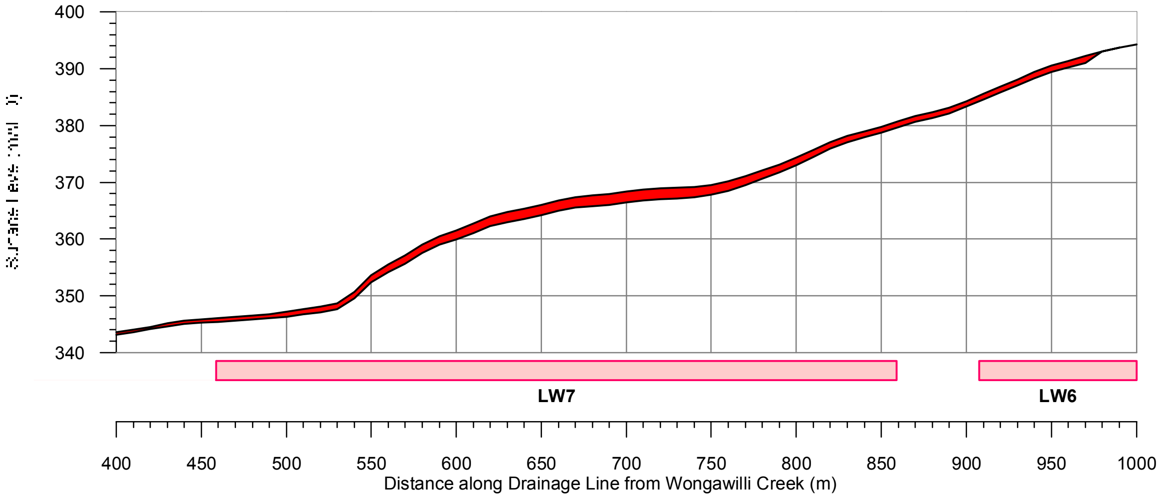


Fig. 5.6 Initial and Final Surface Levels along WC17(A)

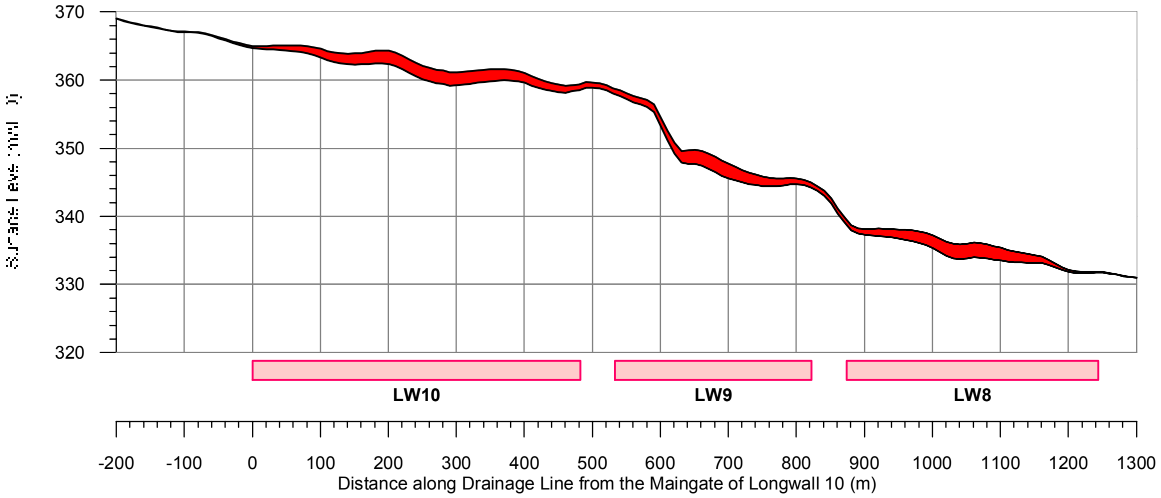


Fig. 5.7 Initial and Final Surface Levels along SC10

The drainage lines have some areas of alluvial beds and it is expected, therefore, that any ponding which occurs in these areas, as a result of the extraction of the proposed longwalls, would erode during subsequent rain events, especially during times of high flow. It would be expected over time, after a sufficient volume of water has flowed, that the gradients along the alluvial sections of the drainage lines would approach those which existed before mining. The level and extent of increased ponding in these areas along the drainage lines would, therefore, be expected to decrease with time.

The maximum predicted systematic tensile and compressive strains anywhere along these drainage lines are 4.5 mm/m and 9.4 mm/m, respectively. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are 3.3 kilometres and 1.6 kilometres, respectively. The maximum predicted valley related upsidence and closure movements anywhere along these drainage lines are also likely to result in elevated compressive strains in the bases of the drainage lines of greater than 10 mm/m.

Tensile strains greater than 0.5 mm/m may be of sufficient magnitude to result in fracturing in the topmost bedrock. Compressive strains greater than 2 mm/m may be of sufficient magnitude to result in the topmost bedrock buckling and fracturing. The maximum predicted systematic tensile and compressive strains at the drainage lines are likely, therefore, to be of sufficient magnitude to result in fracturing of the topmost bedrock, which could result in surface cracking where the depths of bedrock are shallow or where the bedrock is exposed.

Fracturing of exposed bedrock along the drainage lines could result in some diversion of surface water flows into the dilated strata beneath them and the draining of any pools which exist within the drainage lines. It is unlikely that there would be any net loss of water from the catchment, however, as the depth of dilation in rivers and creeks has generally been observed to be less than 15 metres in the past and, therefore, any diverted surface water is likely to re-emerge into the catchment further downstream.

The drainage lines are ephemeral and so water typically flows during and for periods of time after each rain event. In times of heavy rainfall, the majority of the runoff would flow over the beds and would not be diverted into the dilated strata below. In times of low flow, however, some of the water could be diverted into the dilated strata below the beds and this could affect the quality and quantity of the water flowing into the creeks. It is unlikely, however, that this would result in any significant impact on the overall quantity and quality of water harvested from the catchment.

Where Longwalls 1 and 2 in Area 1 at Dendrobium Mine were mined beneath six drainage lines, including their tributaries, fracturing was observed in only one of these drainage lines. The maximum predicted systematic tensile and compressive strains at the drainage lines within the Study Area are similar to those predicted at the drainage lines within Area 1. It is expected, therefore, that the proportion of drainage lines impacted by fracturing within the Study Area would be similar to that observed in Area 1, which was in the order of 15 % of the drainage lines which were directly mined beneath.

Where Longwalls 1 to 10 at Elouera Colliery were mined beneath Wongawilli and Native Dog Creeks, buckling of the bedrock in the bases of the valleys resulted in dilation of the strata and the creation of voids beneath the beds of the creeks. Fracturing of exposed bedrock allowed low flow surface water in the creeks to be redirected into the dilated strata. Pools in some sections of the creeks were drained due to the occurrence of the surface fractures at these locations.

It is recommended that remediation measures be implemented for the drainage lines, as required, after mining has been completed and, where necessary, any fracturing and dilation of the bedrock can be sealed by various methods, including grouting. With these measures in place, it is unlikely that there would be any significant impact on the drainage lines resulting from the extraction of the proposed and future longwalls in Area 3.

5.5.5. Impact Assessments for the Drainage Lines Based on Increased Predictions

If the predicted systematic tilts along the drainage lines were increased by factors of up to 2 times, the levels of ponding, flooding and scouring adjacent to the longwall chain pillars and goaf edges would increase accordingly, where the existing natural grades are small. An increased level of ponding, flooding or scouring could also occur where the predicted maximum tilts coincide with any existing pools, steps or cascades along the drainage lines.

If the predicted systematic strains at the drainage lines were increased by factors of up to 2 times, the likelihood and extent of cracking in the beds and the likelihood and extent of fracturing and dilation in the bedrock would increase accordingly directly above and immediately adjacent to the proposed and future longwalls.

It would still be expected, however, that any significant surface cracking could be remediated by infilling with alluvial or other suitable materials, or by locally regrading and recompacting the surface, and any significant fracturing in the exposed bedrock could be remediated by various methods, including grouting.

5.5.6. Recommendations for the Drainage Lines

It is recommended that the drainage lines are monitored as the proposed and future longwalls in Areas 3A, 3B and 3C mine beneath them. It is also recommended that management strategies are developed for the drainage lines, in consultation with the SCA, such that the impacts can be identified and remediated accordingly. With these strategies in place, it is unlikely that there would be any significant impact on the drainage lines resulting from the proposed mining.

5.6. Ground Water Resources

Shallow aquifers, associated with the drainage lines and upland swamps, and deep aquifers have been identified within the Study Area. Descriptions of these aquifers are provided in the reports by Ecoengineers (2007) and GHD (2007).

The aquifers within the Study Area are likely to be subjected to the full range of predicted systematic subsidence movements which were provided in Sections 4.2 and 4.3. The maximum predicted systematic tensile and compressive strains within the Study Area are 4.5 mm/m and 11 mm/m, respectively, and the associated minimum radii of curvatures are 3.3 kilometres and 1.4 kilometres, respectively.

Fracturing of the topmost bedrock has been observed in the Southern Coalfield in the past where tensile strains have been greater than 0.5 mm/m and compressive strains have been greater than 2 mm/m. It is likely, therefore, that the predicted maximum systematic strains are of sufficient magnitude to result in the fracturing of the strata above the proposed and future longwalls in Area 3. The predicted movements are also likely to result in the dilation and differential horizontal movements between strata layers at different horizons above the proposed and future longwalls in Area 3.

The fracturing of bedrock and the dilation and differential horizontal movement between strata layers is likely to result in an increased conductivity of water and gas in the strata above the longwalls. The movement of water and gas is likely to be inhibited by the known aquicludes and aquitards at different horizons, the most noteworthy being the Bald Hill Claystone.

The upper strata layers are also likely to be located within the “constrained zone” above the longwalls, which is described in Section 5.21.3. The constrained zone comprises confined rock strata which have sagged slightly but, because they are constrained, have absorbed most of the strain energy without suffering significant fracturing or alteration to the original physical properties. Some bed separation or slippage can be present, as well as discontinuous vertical cracks, usually on the underside of thick strong beds.

The potential impacts of the proposed and future longwalls in Area 3 on the groundwater resources within the Study Area are provided in the reports by GHD (2007) and Ecoengineers (2007).

5.7. Cliffs

The locations of the cliffs within the Study Area are shown in Drawing No. MSEC311-11. The predictions and impact assessments for the cliffs are provided in the following sections.

5.7.1. Predictions for the Cliffs in Area 3A

A summary of the maximum predicted values of systematic subsidence, tilt and strain at the cliffs in Area 3A, at any time during or after the extraction of proposed Longwalls 6 to 10, is provided in Table 5.10.

Table 5.10 Maximum Predicted Systematic Subsidence, Tilt and Strain at the Cliffs in Area 3A Resulting from the Extraction of Longwalls 6 to 10

Location	Maximum Predicted Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
DA3-CF2	25	0.4	< 0.1	< 0.1
DA3-CF3	40	0.7	0.1	< 0.1
DA3-CF6	< 20	< 0.1	< 0.1	< 0.1
DA3-CF7	1670	11	2.5	2.0
DA3-CF8	1315	11	2.5	1.6
DA3-CF13	45	0.8	0.2	< 0.1
DA3-CF14	60	1.0	0.2	< 0.1
DA3-CF15	< 20	0.2	< 0.1	< 0.1
DA3-CF16	70	1.1	0.2	0.2
DA3-CF17	240	3.5	1.4	0.3
DA3-CF18	160	2.7	0.7	0.4

The values provided in the above table are the maximum predicted parameters which occur within a 20 metre radius of the perimeter of each cliff.

5.7.2. Predictions for the Cliffs in Areas 3B and 3C

The cliffs in Areas 3B and 3C are typically located along the alignment of Wongawilli Creek. As described in Section 5.3, it is proposed that the future longwalls in Areas 3B and 3C will be offset from Wongawilli Creek such that it is assessed that no significant impacts would occur on the creek. It is unlikely, therefore, that the future longwalls in Areas 3B and 3C would be extracted directly beneath the majority of the cliffs along the alignment of Wongawilli Creek.

It is expected, therefore, that the cliffs along the alignment of Wongawilli Creek in Areas 3B and 3C would be subjected to systematic subsidence movements similar to the cliffs in Area 3A which are not directly mined beneath (ie: cliffs excluding DA3-CF7 and DA3-CF8), which are summarised in Table 5.10.

The remaining cliffs in Areas 3B and 3C could be directly mined beneath by the future longwalls and, therefore, could be subjected to the full range of predicted systematic subsidence movements. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas.

Based on the future longwalls in Areas 3B and 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas are expected to be similar to those predicted for Longwalls 6 to 10, which are summarised in Table 4.2.

The impact assessments for the cliffs along the alignment of Wongawilli Creek within Areas 3B and 3C are expected to be similar to the impact assessments for the cliffs in Area 3A which are not directly mined beneath, which is described in Section 5.7.3. The impact assessments for the remaining cliffs in Areas 3B and 3C are expected to be similar to the impact assessments for Cliffs DA3-CF7 and DA3-CF8, which is described in Section 5.7.3 and similar to the impact assessments for the rock outcrops, which is described in Section 5.8.3.

5.7.3. Impact Assessments for the Cliffs

The maximum predicted systematic subsidence parameters at the cliffs in Area 3A occur at Cliffs DA3-CF7 and DA3-CF8 which are directly mined beneath by Longwall 10. The maximum predicted systematic tilt at these cliffs is 11 mm/m (ie: 1.1 %), or a change in grade of 1 in 90. The cliffs in Areas 3B and 3C, away from Wongawilli Creek, could be subjected to the maximum predicted systematic tilt in these areas, which have been taken as 21 mm/m (ie: 2.1 %), or a change in grade of 1 in 50.

Tilt does not directly induce differential movements along cliffs, which is the main cause of cliff instabilities. Tilt, however, can increase the overturning moments in steep or overhanging cliffs which, if of sufficient magnitude, could result in toppling type failures. It is unlikely, however, that the maximum predicted tilt in this case would be of sufficient magnitude to directly result in topping type failures along these cliffs.

It is possible, however, that if the systematic strains were of sufficient magnitude, existing sections of rock could fracture along existing bedding planes or joints and become unstable, resulting in a sliding or toppling type failures along the cliffs.

The maximum predicted systematic tensile and compressive strains at Cliffs DA3-CF7 and DA3-CF8 are 2.5 mm/m and 2.0 mm/m, respectively. The minimum radii of curvatures associated with these maximum predicted systematic tensile and compressive strains are 6 kilometres and 7.5 kilometres, respectively. The cliffs in Areas 3B and 3C, away from Wongawilli Creek, could be subjected to the maximum predicted systematic tensile and compressive strains in these areas, which have been taken as 4.5 mm/m and 11 mm/m, respectively. The minimum radii of curvatures associated with these maximum predicted systematic tensile and compressive strains are 3.3 kilometres and 1.4 kilometres, respectively.

Fracturing of sandstone has been observed in the Southern Coalfield in the past where the predicted systematic tensile and compressive strains have been greater than 0.5 mm/m and 2 mm/m, respectively. It is likely, therefore, that the maximum predicted systematic strains at Cliffs DA3-CF7 and DA3-CF8 and the cliffs which are directly mined beneath in Areas 3B and 3C are of sufficient magnitude to result in the fracturing of sandstone and, hence, the potential for rockfalls.

The extent of disturbance at the cliffs which are directly mined beneath by the proposed and future longwalls in Area 3 is expected to be similar to that observed in Area 1, where Longwalls 1 and 2 mined directly beneath a ridgeline. Rockfalls were observed in eight locations in Area 1, all of which were located above Longwall 1, which are shown Fig. 5.8.

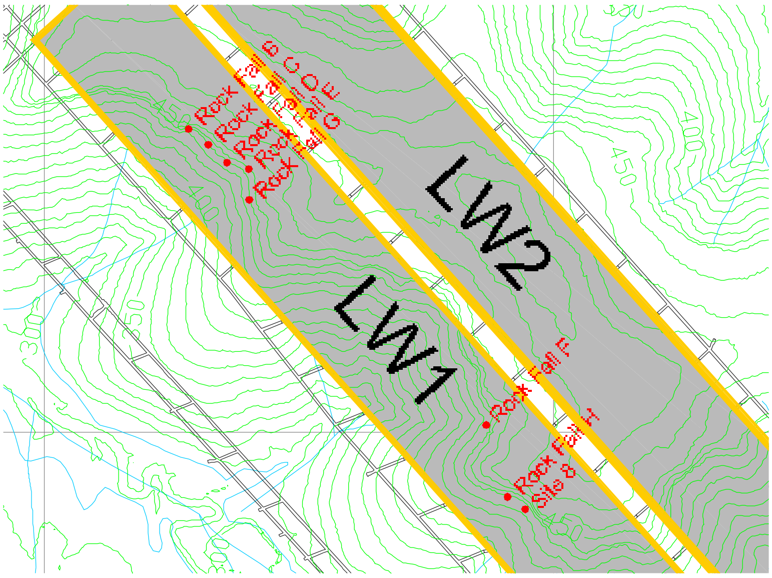


Fig. 5.8 Locations of Observed Rockfalls above Longwall 1 in Area 1 at Dendrobium Mine

Details of the observed rockfalls along the ridgeline above Longwall 1 in Area 1 at Dendrobium Mine are provided in Table 5.11.

Table 5.11 Observed Disturbances along the Ridgeline above Longwalls 1 and 2 in Area 1

Location	Approximate Width of Disturbance (m)	Approximate Height of Disturbance (m)	Total Height of Cliff (m)
Rock Fall B	35 ~ 45	5 ~ 15	20
Rock Fall C	10 ~ 15	6	13
Rock Fall D	10 ~ 15	4	18
Rock Fall E	15 ~ 20	5	5
Rock Fall F	50 ~ 60	10	10
Rock Fall G	5	3	7
Rock Fall H	10 ~ 15	6	20
Site 8	Rock fragments only		

The total width of disturbance resulting from the extraction of Longwalls 1 and 2 was approximately 135 to 175 metres. It should be noted, however, that the actual widths of the observed rockfalls at some of the sites were less than the overall widths of the disturbance recorded in Table 5.11. The total width of disturbance, therefore, provides a conservative estimate of the total width of observed rockfalls.

The total plan length of ridgeline located directly above the longwalls in Area 1 is approximately 1800 to 2000 metres. It should be noted that there are two levels of cliff in some locations and, therefore, the total length of cliffline is greater than the total plan length of the ridgeline.

The width of ridgeline disturbed as a result of the extraction of Longwalls 1 and 2 was, therefore, estimated to be between 7 and 10 % of the total plan length of ridgeline directly above the longwalls. The width of rockfalls which occurred as a result of the extraction of Longwalls 1 and 2 was, however, less than the width of disturbed ridgeline.

The percentage of cliffline disturbed along Cliffs DA3-CF7 and DA3-CF8 and the cliffs in Areas 3B and 3C which are directly mined beneath, resulting from the extraction of the proposed and future longwalls, is expected to be similar to that observed in Area 1.

The remaining cliffs in Area 3A are located outside of goaf areas of the proposed longwalls. The maximum predicted systematic tilt at the cliffs located outside the longwall goaf areas is 3.5 mm/m (ie: 0.4 %), or a change in grade of 1 in 285, which occurs at Cliff DA3-CF17. The cliffs along the alignment of Wongawilli Creek in Areas 3B and 3C, which are not directly mined beneath, are expected to be subjected to a similar magnitude of tilt. As discussed previously, it is unlikely that tilts of these magnitudes would have any significant impact on the cliffs.

The maximum predicted systematic tensile and compressive strains at the cliffs in Area 3A which are located outside the longwall goaf areas are 1.4 mm/m and 0.4 mm/m, respectively, which occur at Cliffs DA3-CF17 and DA3-CF18, respectively. The minimum radii of curvatures associated with these maximum predicted systematic tensile and compressive strains are 11 kilometres and 38 kilometres, respectively. The cliffs along the alignment of Wongawilli Creek in Areas 3B and 3C, which are not directly mined beneath, are expected to be subjected to similar magnitudes of systematic strain.

Previous experience in the Southern Coalfield indicates that very few rockfalls have occurred outside longwall goaf areas and none have occurred in the Dendrobium area. The width of disturbed cliffline at the cliffs located outside the longwall goaf areas is expected, therefore, to be much less than that observed in Area 1, where the cliffline was directly mined beneath.

Access to the land within the Study Area is restricted and there are no fire roads or four wheel drive tracks in the vicinity of the identified cliffs. It is unlikely, therefore, that there would be an impact on public safety as a result of potential rockfalls. It is recommended, however, that persons who enter the Study Area are made aware of the potential for rockfalls as a result of the proposed mining.

5.7.4. Impact Assessments for the Cliffs Based on Increased Predictions

If the predicted systematic tilts were increased by factors of up to 2 times, the likelihood and extent of rockfalls would not significantly increase, as the changes in grade would still be small compared to the existing slopes of the cliff faces.

If the predicted systematic strains were increased by factors of up to 2 times, the extent of fracturing and, hence, the potential for rockfalls at Cliffs DA3-CF7 and DA3-CF8 in Area 3A, the cliffs which are directly mined beneath in Areas 3B and 3C and, to a lesser extent Cliffs DA3-CF17 and DA3-CF18 in Area 3A, would increase accordingly, as the predicted tensile strains would be greater than 0.5 mm/m. Elsewhere, the predicted systematic tensile strains would still be less than 0.5 mm/m and, therefore, the potential for rockfalls would not significantly increase.

5.7.5. Recommendations for the Cliffs

It is recommended that persons who enter the Study Area are made aware of the potential for rockfalls resulting from the extraction of the proposed longwalls. The conditions of the cliffs should be monitored throughout the mining period until such time that the mine subsidence movements have ceased, as may be required.

In addition to this, it is recommended that appropriate management strategies are put in place to ensure the safety of people that may be within the vicinity of the cliffs during the mining period. With these measures in place, it is unlikely that there would be a significant impact associated with the cliffs resulting from the proposed mining.

5.8. The Rock Outcrops

The predictions and impact assessments for the rock outcrops are provided in the following sections.

5.8.1. Predictions for the Rock Outcrops in Area 3A

The rock outcrops are located across Area 3A and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the rock outcrops, at any time during or after the extraction of the proposed longwalls in Area 3A, is provided in Table 5.12.

Table 5.12 Maximum Predicted Systematic Subsidence, Tilt and Strain at the Rock Outcrops Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Location	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
Rock Outcrops	2275	21	4.5	11

5.8.2. Predictions for the Rock Outcrops in Areas 3B and 3C

The rock outcrops are located across Areas 3B and 3C and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in these areas. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas.

Based on the future longwalls in Areas 3B and 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas are expected to be similar to those predicted for Longwalls 6 to 10.

The impact assessments provided in this report for the rock outcrops in Areas 3B and 3C have, therefore, been based on the maximum predicted systematic subsidence parameters provided in Table 5.12. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas.

5.8.3. Impact Assessments for the Rock Outcrops

The maximum predicted systematic tilt at the rock outcrops, at any time during or after the extraction of the proposed and future longwalls, is 21 mm/m (ie: 2.1 %), or a change in grade of 1 in 50. As described in Section 5.7.3 for the cliffs, tilt does not directly result in differential movements and, hence, rock falls are more likely to occur as a result of systematic strain and curvatures.

The maximum predicted systematic tensile and compressive strains at the rock outcrops, at any time during or after the extraction of the proposed and future longwalls, are 4.5 mm/m and 11 mm/m, respectively. The minimum radii of curvatures associated with the maximum predicted tensile and compressive strains are 3.3 kilometres and 1.4 kilometres, respectively.

Fracturing of sandstone has been observed in the Southern Coalfield in the past where the predicted systematic tensile and compressive strains have been greater than 0.5 mm/m and 2 mm/m, respectively. It is likely, therefore, that the predicted maximum systematic strains are of sufficient magnitude to result in the fracturing of sandstone and, hence, the potential for rockfalls.

Previous experience in the Southern Coalfield indicates that the percentage of rock outcrops that are likely to be impacted by mining is small. Rockfalls are more likely to occur where rock outcrops are continuous, massive, overhanging and marginally stable. It is expected, therefore, that the extent of disturbance at the rock outcrops above the proposed Longwalls 6 to 10 in Area 3A and above the future longwalls in Areas 3B and 3C would be less than that observed along the ridgeline in Area 1, which is discussed in Section 5.7.3.

5.8.4. Impact Assessments for the Rock Outcrops Based on Increased Predictions

If the predicted systematic tilts were increased by factors of up to 2 times, the likelihood of rockfalls would not significantly increase, as the changes in grade would still be small compared to the existing slopes of the rock outcrops.

If the predicted systematic strains were increased by factors of up to 2 times, the extent of fracturing and, hence, the likelihood of rockfalls would increase accordingly. The extent of disturbance at the rock outcrops, however, would still be expected to be less than that observed along the ridgeline in Area 1.

5.8.5. Recommendations for the Rock Outcrops

It is recommended that persons who enter the Study Area are made aware of the potential for rockfalls resulting from the extraction of the proposed longwalls and future longwalls in Area 3. The conditions of the rock outcrops should be monitored throughout the mining period until such time that the mine subsidence movements have ceased, as may be required.

In addition to this, it is recommended that appropriate management strategies are put in place to ensure the safety of people that may be within the vicinity of the rock outcrops during the mining period. With these measures in place, it is unlikely that there would be a significant impact associated with the rock outcrops resulting from the proposed mining.

5.9. Steep Slopes

The locations of the steep slopes within the Study Area are shown in Drawing No. MSEC311-11. The predictions and impact assessments for the steep slopes are provided in the following sections.

5.9.1. Predictions for the Steep Slopes in Area 3A

The steep slopes are located across Area 3A and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in this area. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the steep slopes, at any time during or after the extraction of Longwalls 6 to 10 in Area 3A, is provided in Table 5.13.

Table 5.13 Maximum Predicted Systematic Subsidence, Tilt and Strain at the Steep Slopes Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Location	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
Steep Slopes	2275	21	4.5	11

5.9.2. Predictions for the Steeps Slopes in Areas 3B and 3C

The steep slopes are located across Areas 3B and 3C and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in these areas. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas.

Based on the future longwalls in Areas 3B and 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas are expected to be similar to those predicted for Longwalls 6 to 10.

The impact assessments provided in this report for the steep slopes in Areas 3B and 3C have, therefore, been based on the maximum predicted systematic subsidence parameters provided in Table 5.13. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas.

5.9.3. Impact Assessments for the Steep Slopes

The maximum predicted systematic tilt at the steep slopes, resulting from the extraction of the proposed and future longwalls, is 21 mm/m (ie: 0.2 %), or a change in grade of 1 in 50. The steep slopes are more likely to be impacted by the systematic strains, rather than tilt, as the maximum predicted tilt is small when compared to the existing surface gradients of the steep slopes.

The maximum predicted systematic tensile and compressive strains at the steep slopes, resulting from the extraction of the proposed and future longwalls, are 4.5 mm/m and 11 mm/m, respectively. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are 3.3 kilometres and 1.4 kilometres, respectively.

The predicted maximum systematic tensile strain at the steep slopes is likely to be of sufficient magnitude to result in surface cracking. The predicted maximum compressive strain at the steep slopes is likely to be of sufficient magnitude to result in the buckling of the topmost bedrock, which could in turn result in surface cracking, where the depths of the overlying soils are shallow.

It is also possible that the predicted maximum systematic strains would result in downhill slumping along the steep slopes, resulting in tension cracks at the tops of the slopes and compressive ridges at the bottoms of the slopes. It is unlikely that mine subsidence would result in any large-scale slope failure, since such failures have not been observed as the result of longwall mining in the Southern Coalfield. This includes the extraction of Longwalls 1 and 2 in Area 1 and Longwall 3 in Area 2 at the mine.

The natural grades of the steep slopes across Area 3 are generally less than the natural grades of the steep slopes in Areas 1 and 2. In addition to this, the depths of cover across Areas 3 are generally greater than the depths of cover in Areas 1 and 2. It is likely, therefore, that the maximum size and extent of surface cracking at the steep slopes within Area 3 will be less than that observed during the extraction of Longwalls 1 and 2 in Area 1 and during the extraction of Longwall 3 in Area 2, which is described in Sections 5.21.6 and 5.21.7, respectively.

If any significant cracking were left untreated, erosion channels could potentially develop. In this case, it is recommended that appropriate remediation measures are undertaken, including infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface. Similarly, where cracking restricts the passage of vehicles along roads and tracks that are required to be open to access, it is recommended that these cracks are treated in the same way. With these remediation measures in place, it is unlikely that there would be any significant impact on the environment.

5.9.4. Impact Assessments for the Steep Slopes Based on Increased Predictions

If the predicted systematic tilts were increased by factors of up to 2 times, the potential impacts on the steep slopes would not significantly increase, as the predicted tilts would still be much less than the natural surface gradients of the steep slopes in Area 3.

If the predicted systematic strains were increased by factors of up to 2 times, the extent of potential surface cracking and soil slippage would increase accordingly at the steep slopes located directly above the proposed and future longwalls. It is expected, however, that the surface cracking could still be remediated by infilling with soil or other suitable materials, or by locally regrading and compacting the surface. With these remediation measures in place, it is unlikely that there would be any significant impact on the environment.

5.9.5. Recommendations for the Steep Slopes

It is recommended that the steep slopes are monitored throughout the mining period and until any necessary rehabilitation measures are complete. In addition to this, it is recommended that any significant surface cracking which could result in increased erosion or restrict access to areas be remediated by infilling with soil or other suitable materials, or by locally regrading and compacting the surface. It is also recommended that management strategies are developed, in consultation with the SCA, to ensure that these measures are implemented. With appropriate management strategies in place, it is unlikely that there would be a significant impact on the steep slopes resulting from the proposed mining.

5.10. Upland Swamps

There are a number of upland swamps located within or partially within the Study Area, the locations of which are shown in Drawing No. MSEC311-07. The predictions and impact assessments for these swamps are provided in the following sections.

5.10.1. Predictions for the Upland Swamps in Area 3A

A summary of the maximum predicted values of systematic subsidence, tilt and strain at the swamps within the SMP Area for proposed Longwalls 6 to 10 in Area 3A, at any time during or after the extraction of each proposed longwall, is provided in Table 5.14.

Table 5.14 Maximum Predicted Systematic Subsidence, Tilt and Strain at the Swamps Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Swamp	Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
Swamp 12	After LW6	120	1.5	0.3	0.1
	After LW7	1730	17	2.9	7.1
	After LW8	1885	15	3.6	7.1
	After LW9	1900	17	4.0	7.1
	After LW10	1900	17	4.0	7.1
Swamp 15a	After LW6	< 20	< 0.1	< 0.1	< 0.1
	After LW7	< 20	< 0.1	< 0.1	< 0.1
	After LW8	< 20	0.4	0.1	< 0.1
	After LW9	2020	20	3.8	11
	After LW10	2275	21	3.8	11
Swamp 15b	After LW6	< 20	< 0.1	0.2	< 0.1
	After LW7	410	7.1	2.1	0.4
	After LW8	1920	15	4.5	7.1
	After LW9	2115	15	4.5	7.1
	After LW10	2115	15	4.5	7.1
Swamp 16	After LW6	70	1.0	0.3	0.1
	After LW7	70	1.1	0.3	0.1
	After LW8	70	1.1	0.3	0.1
	After LW9	70	1.1	0.3	0.1
	After LW10	70	1.1	0.3	0.1
Swamp 34	After LW6	< 20	< 0.1	< 0.1	< 0.1
	After LW7	< 20	< 0.1	< 0.1	< 0.1
	After LW8	< 20	< 0.1	< 0.1	< 0.1
	After LW9	< 20	< 0.1	< 0.1	< 0.1
	After LW10	40	0.5	0.1	< 0.1

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of the perimeter of each swamp. The predicted tilts and strains are the maximum values which occur during, or after the extraction of each proposed longwall, whichever is the greater.

Swamps 12, 15a, 15b and 16 are located within or partially within the valleys of drainage lines and could, therefore, be subjected to upsidence and closure movements as a result of the extraction of the proposed longwalls. Swamp 34 is located on the side of a valley and is unlikely, therefore, to be subjected to any significant upsidence or compressive strains due to closure movements. A summary of the maximum predicted values of total upsidence and closure at the swamps, after the extraction of the proposed longwalls in Area 3A, is provided in Table 5.15.

Table 5.15 Maximum Predicted Total Upsidence and Closure at the Swamps Resulting from the Extraction of Longwalls 6 to 10

Swamp	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Swamp 12	415	335
Swamp 15a	290	200
Swamp 15b	345	265
Swamp 16	30	30

An equivalent valley depth factor of 0.7 has been adopted for the swamps. The maximum predicted upsidence movements occur at the bases of the valleys in which the swamps have formed. The maximum predicted closure movements occur between the steepest sides of the valleys and, therefore, the total closure movements across the extents of the swamps are less than the values provided in the above table.

5.10.2. Predictions for the Upland Swamps in Areas 3B and 3C

The swamps are located across Areas 3B and 3C and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in these areas. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas.

Based on the future longwalls in Areas 3B and 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas are expected to be similar to those predicted for Longwalls 6 to 10.

The range of predicted systematic and valley related movements for the swamps in Areas 3B and 3C are, therefore, expected to be similar to the range of predicted movements for the swamps in Area 3A, which are summarised in Table 5.14 and in Table 5.15. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas.

5.10.3. Impact Assessments for the Upland Swamps

The maximum predicted total subsidence at the swamps is 2275 mm, which occurs at Swamp 15a after the extraction of proposed Longwall 10. The minimum predicted total subsidence at Swamp 15a is less than 20 mm, which occurs south of Longwall 10 and, therefore, the maximum predicted differential total subsidence across the extent of this swamp is 2275 mm. The differential total subsidence across the extent of Swamp 15a is illustrated in Fig. 5.9.

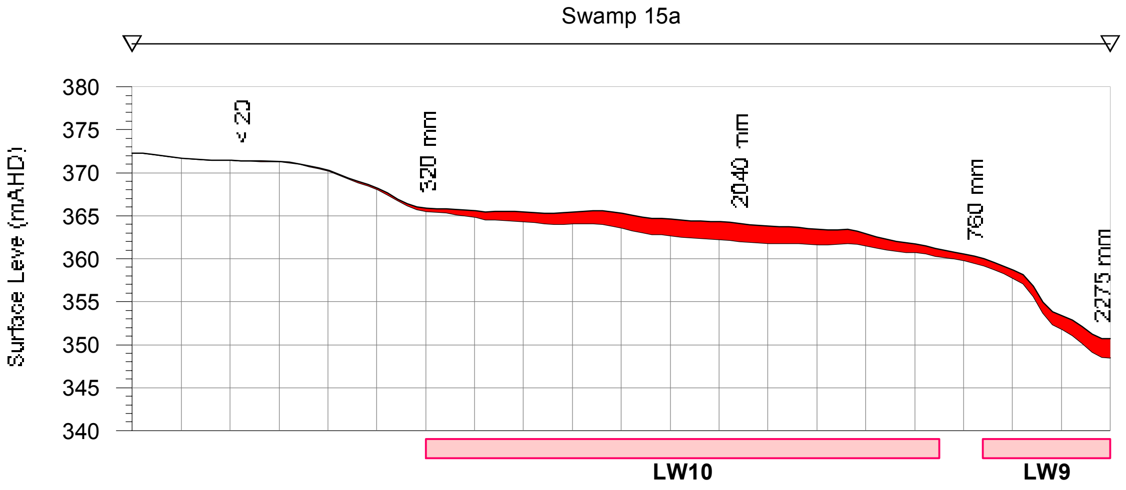


Fig. 5.9 **Cross-Section through Swamp 15a Showing the Profile of Total Predicted Subsidence**

The maximum predicted differential total subsidence at Swamp 15a above the centre of Longwall 10, relative to the total subsidence above the longwall goaf edges, is 1500 mm. The maximum predicted differential total subsidence at Swamp 15a above the centre of Longwall 9, relative to the total subsidence above the chain pillar is 1515 mm.

Similarly, the maximum predicted differential total subsidence at Swamps 12 and 15b above the centres of the longwalls, relative to the total subsidence above the longwall goaf edges, are 1625 mm and 1350 mm, respectively.

The maximum predicted total systematic tilt at the swamps, resulting from the differential subsidence within the swamps, is 21 mm/m (ie: 2.1 %), or a change in grade of 1 in 50, which occurs at Swamp 15a adjacent to the maingate of Longwall 10. The natural grade within the swamp varies from less than 5 mm/m to greater than 500 mm/m, with an average natural grade of approximately 50 mm/m at the location of maximum predicted tilt.

The maximum predicted total systematic tilts at Swamps 12 and 15b, resulting from the differential subsidence within the swamps, are 17 mm/m (ie: 1.7 %) and 15 mm/m (ie: 1.5 %), respectively, or changes in grade of 1 in 60 and 1 in 65, respectively, which both occur adjacent to the chain pillar between Longwalls 7 and 8. The natural grades of the surface within these swamps vary from less than 5 mm/m to greater than 200 mm/m.

The predicted differential total subsidence and total tilt within Swamps 12, 15a and 15b may result in increased water levels above the centrelines of the longwalls, and decreased water levels above the chain pillars and longwall goaf edges. It is possible that the changes in water level within the swamps could impact on the distribution of local vegetation within the swamps. Generally, however, the surfaces of the swamps are free draining, and it is not anticipated that significant changes in water levels would occur as a result of differential subsidence or tilt.

The maximum predicted systematic tensile and compressive strains at the swamps, at any time during or after the extraction of the proposed longwalls, are 4.5 mm/m and 11 mm/m, respectively, which occur at Swamps 15b and 15a, respectively. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are 3.3 kilometres and 1.4 kilometres, respectively.

Tensile strains greater than 0.5 mm/m may be of sufficient magnitude to result in fracturing in the topmost bedrock. Compressive strains greater than 2 mm/m may be of sufficient magnitude to result in the topmost bedrock fracturing, buckling and dilating. It is expected, therefore, that fracturing, buckling and dilation of the topmost bedrock would occur at the pre-existing natural joints and bedding planes beneath Swamps 12, 15a and 15b as a result of the extraction of the proposed longwalls.

The maximum predicted total upsidence at the swamps is 415 mm, which occurs at the base of the drainage line along the northern edge of Swamp 12. The maximum predicted total closure at the swamps is 335 mm, which occurs across the valley in which Swamp 12 has formed. The maximum predicted upsidence and closure movements at Swamps 12, 15a and 15b are likely to result in compressive strains of sufficient magnitude to dilate and buckle the topmost bedrock at the bases of the valleys in which these swamps have formed.

Studies of upland swamps indicate that the swamps are very resilient sediment storage features in the landscape. Two fundamental types of upland swamps have been identified:-

1. “Valley Infill” swamps lie along well defined drainage lines and are susceptible to scouring of the sandy substrates. Swamps 15a and 15b are valley infill swamps which lie within the valleys of Drainage Lines SC10 and SC10C, respectively, and
2. “Headwater” swamps lie within relatively low sloped areas of weathered Hawkesbury Sandstone in which confined hillslope aquifers exist. Swamps 12 and 34 are headwater swamps.

In both types of swamps, significant quantities of sediment are found above the bedrock which is highly fractured and weathered naturally. It is unlikely, therefore, that any additional fracturing in the bedrock, as a result of mine subsidence, would have a significant impact on the sediments, aquifers and, hence, the swamps. It should also be noted, that the reported incidence of impacts on upland swamps within the catchment areas of the Illawarra Escarpment, due to longwall mining, has been low. Where impacts have been observed, these impacts have generally been associated with natural events or non-mining disturbances.

A detailed discussion on upland swamps, the susceptibility of these swamps to impact, being natural or due to mining, and detailed assessments of these swamps based on the predicted levels of subsidence, upsidence and closure movements have been provided in a report by Ecoengineers (2007).

5.10.4. Impact Assessments for the Upland Swamps Based on Increased Predictions

If the predicted systematic subsidence at the swamps was increased by factors of up to 2 times, the differential subsidence and, hence, the potential for increased ponding at Swamps 12, 15a and 15b above the centrelines of the proposed longwalls in Area 3A, and at the swamps located directly above the future longwalls in Areas 3B and 3C, would increase accordingly. It should be noted, however, that the associated maximum predicted systematic tilt at the swamps of 42 mm/m, would still be less than the average natural grades within the swamps, which vary between approximately 50 and 100 mm/m.

If the predicted systematic strains or the predicted upsidence and closure movements at the swamps were increased by factors of up to 2 times, the likelihood and extent fracturing, buckling and dilation in the topmost bedrock would increase accordingly. As discussed previously, however, significant quantities of sediment are found above the bedrock at the swamps which is highly fractured and weathered naturally. It is unlikely, therefore, that any additional fracturing in the bedrock, as a result of mine subsidence, would have a significant impact on the sediments, aquifers and, hence, the swamps.

It should also be noted, that the method used to predict the valley related movements adopt conservative upper-bound prediction curves and it is unlikely, therefore, that these movements would be exceeded by any more than 15 %.

5.10.5. Recommendations for the Upland Swamps

It is recommended that the swamps are monitored during the extraction of the proposed and future longwalls in Area 3. It is also recommended that management strategies are developed, in consultation with the SCA. With appropriate management strategies in place, it is unlikely that there would be a significant impact on the swamps resulting from the proposed mining.

5.11. The Abandoned Maldon-Dombarton Railway Corridor

The abandoned Maldon–Dombarton Railway Corridor crosses Area 3B, the location of which is shown in Drawing No. MSEC311-12. At the time of abandoning the work, the major earthworks had been completed, but no tracks or associated equipment had been installed. The predictions and impact assessments for the corridor are provided in the following sections.

5.11.1. Predictions and Impact Assessments for the Corridor

The corridor is located at a distance of 1.9 kilometres from proposed Longwalls 6 to 10 in Area 3A, at its closest point. It is unlikely, therefore, that the corridor would be subjected to any significant systematic subsidence, valley related, or far-field horizontal movements resulting from the extraction of these longwalls.

The corridor crosses Area 3B and is likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in this area. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Area 3B will depend on the final longwall layouts in this area.

Based on the future longwalls in Area 3B having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in this area are expected to be similar to those predicted for Longwalls 6 to 10, which are summarised in Table 4.2. A refined impact assessment based on the final longwall layout in Area 3B will be provided as part of the application for SMP Approval for the future longwalls in this area.

It is likely that the rock cuttings would be impacted by the future longwalls in Area 3B, including the fracturing and mobilisation of joints in the rock faces and minor rock falls, similar to that observed where the Elouera Longwalls 10 and 11 mined directly beneath the corridor. A photograph of fracturing observed in the rock cuttings along the corridor at Elouera Colliery is shown in Fig. 5.10.

Fig. 5.10 Fracturing in the Rock Cuttings above the Previously Extracted Elouera Longwalls

It is expected that any fracturing and rock falls along the rock cuttings, resulting from the extraction of future longwalls in Area 3B, would be of a similar nature to that observed as a result of the extraction of Elouera Longwalls 10 and 11.

5.11.2. Recommendations for the Corridor

It is recommended that persons who enter the Study Area are made aware of the potential for rockfalls along the corridor resulting from the extraction of the future longwalls in Area 3B. The conditions of the rock faces should be monitored throughout the mining period until such time that the mine subsidence movements have ceased, as may be required. It is also recommended that management strategies are developed, in consultation with the SCA, to ensure that these measures are implemented. With the appropriate management strategies in place, it is unlikely that there would be any significant impacts on the corridor as a result of the proposed mining.

5.12. Fire Trails and Four Wheel Drive Tracks

The locations of the fire trails and four wheel drive tracks within the Study Area are shown in Drawing No. MSEC311-12. The predictions and impact assessments for the fire trails are provided in the following sections.

5.12.1. Predictions for the Fire Trails and Four Wheel Drive Tracks in Area 3A

The fire trails and four wheel drive tracks are located across Area 3A and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in this area. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the fire trails and four wheel drive tracks, at any time during or after the extraction of Longwalls 6 to 10 in Area 3A, is provided in Table 5.16.

Table 5.16 Maximum Predicted Systematic Subsidence, Tilt and Strain at the Fire Trails and Four Wheel Drive Tracks Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Location	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
Fire Trails and Four Wheel Drive Tracks	2275	21	4.5	11

The predicted profiles of incremental and cumulative systematic subsidence, tilt and strain have been shown along Fire Roads 6C and 6F in Figs. E.06 and E.07, respectively, in Appendix E. These figures illustrate the variations in the predicted systematic subsidence parameters along two typical fire trails above the proposed longwalls in Area 3A.

5.12.2. Predictions for the Fire Trails in Areas 3B and 3C

The fire trails and four wheel drive tracks are located across Areas 3B and 3C and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in these areas. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas.

Based on the future longwalls in Areas 3B and 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas are expected to be similar to those predicted for Longwalls 6 to 10.

The impact assessments provided in this report for the fire trails and four wheel drive tracks in Areas 3B and 3C have, therefore, been based on the maximum predicted systematic subsidence parameters provided in Table 5.16. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas.

5.12.3. Impact Assessments for the Fire Trails and Four Wheel Drive Tracks

The maximum predicted systematic tilt at the roads, at any time during or after the extraction of the proposed and future longwalls in Area 3, is 21 mm/m (ie: 2.1 %), or a change in grade of 1 in 50. It is unlikely that the predicted maximum tilts would result in any significant changes in the surface water drainage along roads, as the predicted maximum changes in grades are an order of magnitude smaller than the existing gradients along the roads, which are as high as 200 mm/m in the steepest sections.

The maximum predicted systematic tensile and compressive strains at the roads, at any time during or after the extraction of the proposed and future longwalls in Area 3, are 4.5 mm/m and 11 mm/m, respectively. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are 3.3 kilometres and 1.4 kilometres, respectively.

Tensile strains greater than 0.5 mm/m may be of sufficient magnitude to result in cracking in the unsealed surfaces of the roads. Compressive strains greater than 2 mm/m may be of sufficient magnitude to result in the topmost bedrock to buckle and fracture, which could induce cracking in the unsealed surfaces of the roads.

It is recommended that the roads are repaired using normal road maintenance techniques, by regrading and recompacting the unsealed road surfaces. With these remediation measures implemented, the roads can be maintained in a safe and serviceable condition throughout the mining period.

5.12.4. Impact Assessments for the Fire Trails and Four Wheel Drive Tracks Based on Increased Predictions

If the predicted systematic tilts were increased by factors of up to 2 times, the maximum predicted tilt at the roads would be 42 mm/m (ie: 4.2 %), or a change in grade of 1 in 25. The predicted maximum tilts would still be much smaller than the existing grades along the roads and unlikely, therefore, to have any significant impact on the serviceability of the roads.

If the predicted systematic strains were increased by factors of up to 2 times, the maximum predicted systematic tensile and compressive strains at the roads would be 9.0 mm/m and 22 mm/m, respectively. The likelihood and extent of surface tensile cracking and compressive rippling of the unsealed surfaces of the roads would increase accordingly.

It would be expected, however, that the roads could still be easily repaired using normal road maintenance techniques, by regrading and recompacting the unsealed road surfaces. With these remediation measures implemented, the roads can be maintained in a safe and serviceable condition throughout the mining period.

5.12.5. Recommendations for the Fire Trails and Four Wheel Drive Tracks

It is recommended that the fire trails and four wheel drive tracks are visually monitored as the proposed and future longwalls mine beneath them, so that any impacts can be identified and rectified accordingly. It is also recommended that management strategies are developed for the fire trails and four wheel drive tracks, in consultation with the SCA. With these strategies in place, it is likely that the fire trails and four wheel drive tracks can be maintained in a safe and serviceable condition throughout the mining period.

5.13. Bridges

The locations of the bridges within the Study Area are shown in Drawing No. MSEC311-12. The predictions and impact assessments for Bridges B1 and DHS1 are provided in the following sections.

5.13.1. Bridge B1

Bridge B1 is located where Fire Road 6C crosses Sandy Creek and is at a distance of 140 metres north-east of the commencing end of Longwall 8, at its closest point to the proposed longwalls in Area 3. The maximum predicted total subsidence at the bridge, resulting from the extraction of the proposed longwalls in Area 3A, is less than 20 mm and is unlikely, therefore, to result in any systematic subsidence impacts on the bridge.

The bridge is located a distances of approximately 3000 metres and 700 metres from Areas 3B and 3C, at their closest points, and it is unlikely, therefore, that the bridge would be subjected to any significant systematic subsidence, valley related, or far-field horizontal movements as a result of the future longwalls in these areas.

The bridge could be subjected to valley related movements resulting from the extraction of Longwalls 6 to 10 in Area 3A. The predicted profiles of upsidence and closure along Sandy Creek, resulting from the extraction of the proposed longwalls in Area 3A, are shown in Fig. E.03 in Appendix E. The maximum predicted values of total upsidence and closure at the bridge, resulting from the extraction of Longwalls 6 to 10, are 60 mm and 40 mm, respectively.

The upsidence movement could be transferred into the bridge structure via the central support, which is shown in Fig. 2.6, and the closure movement could be transferred into the bridge structure via the end supports. The maximum predicted upsidence of 60 mm could induce a hogging curvature into the bridge having a radius of approximately 1.9 kilometres. The maximum predicted closure of 40 mm could induce a compressive strain in the bridge having a magnitude of approximately 1.3 mm/m, if fully transferred into the structure.

The bridge is a double span steel truss structure, which has a flexible nature, and is unlikely to be impacted by the maximum predicted valley related movements. It is recommended, however, that the bridge is monitored, during the extraction of Longwall 6 to 10, so that any necessary remediation measures can be undertaken, as required.

5.13.2. Bridge DHS1

Bridge DHS1 is located 1.7 kilometres north of proposed Longwalls 6 to 10 in Area 3A and over 2 kilometres north-east of the future longwalls in Area 3B. It is unlikely, therefore, that the bridge would be subjected to any significant systematic subsidence, valley related, or far-field horizontal movements resulting from the extraction of the proposed and future longwalls in these areas.

The maximum predicted systematic subsidence and valley related movements at the bridge, resulting from the extraction of the future longwalls in Area 3C, will depend on the final longwall layout in this area. A refined impact assessment based on the final longwall layout in Area 3C will be provided as part of the application for SMP Approval for the future longwalls in this area.

The ends of the bridge rest on the banks of the gully and it is unlikely, therefore, that the systematic strains or the valley related upsidence and closure movements would be fully transferred into the timber bearers. The timber bridge is flexible and is likely to accommodate the maximum predicted systematic tensile and compressive strains within the Study Area of 4.5 mm/m and 11 mm/m, respectively.

The maximum predicted upsidence occurs in the base of the gully and is unlikely, therefore, to result in any impact on the bridge which spans the gully. The maximum predicted closure at the bridge is expected to be less than 50 mm, due to the small valley height of the gully, and is unlikely, therefore, to result in impact on the bridge.

5.14. 330 kV Transmission Line

The 330 kV transmission line crosses directly above proposed Longwalls 6 to 10 in Area 3A and then continues northward across Area 3C. The location of the transmission line within the Study Area is shown in Drawing No. MSEC311-12. The predictions and impact assessments for the transmission line are provided in the following sections.

5.14.1. Predictions for the 330 kV Transmission Line due to Proposed Longwalls 6 to 10 in Area 3A

The predicted profiles of incremental and cumulative systematic subsidence, tilt along and tilt across the alignment of the 330 kV transmission line, resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A, are shown in Fig. E.06 in Appendix E. The predicted profiles of incremental and cumulative systematic strain along the transmission line are similar to those along Fire Road 6F which are shown in Fig. E.07 in Appendix E.

A summary of the maximum predicted values of cumulative systematic subsidence, tilt along, tilt across, and strain at the transmission line, after the extraction of each proposed longwall in Area 3A, is provided in Table 5.17.

Table 5.17 Maximum Predicted Cumulative Systematic Subsidence, Tilt Along, Tilt Across and Strain at the 330 kV Transmission Line Resulting from the Extraction of Longwalls 6 to 10

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt Along Alignment (mm/m)	Maximum Predicted Cumulative Tilt Across Alignment (mm/m)	Maximum Predicted Cumulative Tensile Strain (mm/m)	Maximum Predicted Cumulative Compressive Strain (mm/m)
After LW6	1165	7.5	2.2	0.9	2.0
After LW7	1490	13	3.9	2.1	5.0
After LW8	1670	12	3.6	2.0	4.
After LW9	1690	14	3.8	2.3	5.2
After LW10	1790	16	4.3	2.6	6.5

The transmission line will also be subjected to travelling tilts and strains as the extraction face of each longwall passes beneath it. A summary of the maximum predicted travelling tilts and strains at the transmission line, during the extraction of each proposed longwall, is provided in Table 5.18.

Table 5.18 Maximum Predicted Travelling Tilts and Strains at the 330 kV Transmission Line during the Extraction of Longwalls 6 to 10

Longwall	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Tensile Strain (mm/m)	Maximum Predicted Travelling Compressive Strain (mm/m)
During LW6	5.8	1.2	0.9
During LW7	7.2	1.5	1.2
During LW8	6.8	1.4	1.1
During LW9	7.6	1.6	1.2
During LW10	8.9	2.0	1.6

There is one tension tower within the SMP Area, being Tower 44, which is located 40 metre north of the tailgate of Longwall 6. A summary of the maximum predicted values of total systematic subsidence, tilt along, tilt across and strain at the tension tower, after the extraction of the proposed longwalls, is provided in Table 5.19.

Table 5.19 Maximum Predicted Total Systematic Subsidence, Tilt Along, Tilt Across and Strain at Tension Tower 44 Resulting from the Extraction of Longwalls 6 to 10

Location	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt Along Alignment (mm/m)	Maximum Predicted Total Tilt Across Alignment (mm/m)	Maximum Predicted Total Tensile Strain (mm/m)	Maximum Predicted Total Compressive Strain (mm/m)
Tower 44	350	4.6	1.3	0.9	< 0.1

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of the centre of the tower.

5.14.2. Predictions for the 330 kV Transmission Line due to the Future Longwalls in Area 3C

The transmission line crosses Area 3C and is likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in this area. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Area 3C will depend on the final longwall layout in this area.

Based on the future longwalls in Area 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in this area are expected to be similar to those predicted for Longwalls 6 to 10.

The impact assessments provided in this report for the transmission line in Area 3C have, therefore, been based on the maximum predicted systematic subsidence parameters provided in Table 5.17 and Table 5.18. A refined impact assessment based on the final longwall layout in Area 3C will be provided as part of the application for SMP Approval for the future longwalls in this area.

5.14.3. Impact Assessments for the 330 kV Transmission Line

The cables along the 330 kV transmission line are not affected by ground strains, as they are supported by the towers above ground level. The cables can, however, be affected by the changes in bay lengths, ie: the distances between the towers at the level of the cables, which result from mining induced differential subsidence, horizontal ground movements and lateral movements at the tops of the towers due to tilting of the towers. The stabilities of the towers can also be affected by the mining induced tilts and ground strains at the location of each tower and by changes in the catenary profiles of the cables.

The maximum predicted systematic tilt anywhere along the alignment of the transmission line in Area 3A is 16 mm/m (ie: 1.6 %), or a change in gradient of 1 in 65, which occurs adjacent to the maingate of Longwall 10. There are no towers located in the vicinity of the maximum predicted tilt.

The maximum predicted systematic tilt within 20 metres of the tower locations in Area 3A is 6 mm/m which occurs at Tower 43 and is orientated along the alignment of the transmission line. The associated predicted systematic horizontal movement at the base of this tower is 90 mm. Based on a tower height of 50 metres, the maximum predicted systematic tilt and maximum predicted systematic horizontal movement at Tower 43 results in a maximum predicted horizontal movement of 400 mm at the top of the tower, which is orientated along the alignment of the transmission line.

The maximum predicted systematic tilt at the tower locations in Area 3C will depend on the final layout of the future longwalls in this area. It is expected, however, that the maximum predicted tilt anywhere along the transmission line within Area 3C would be similar to that in Area 3A, which is 16 mm/m. Based on a tower height of 50 metres, the maximum predicted systematic tilt and maximum predicted systematic horizontal movement in Area 3C would result in a maximum predicted horizontal movement of 1050 mm at the tops of the towers.

The predicted horizontal movements at the tops of the towers are expected to result in changes in the catenary profiles of the aerial cables, which in turn results in differential horizontal loads on the towers. If the towers are unable to support the differential cable loads, it may be necessary to install cable sheaves which could facilitate the predicted movements at the tops of the towers.

The maximum predicted systematic tilt within 20 metres of tension Tower 44 is 4.6 mm/m (ie: 0.5 %), or a change in gradient of 1 in 215. The associated predicted systematic horizontal movement at the base of this tower is 70 mm. Based on a tower height of 50 metres, the maximum predicted systematic tilt and maximum predicted systematic horizontal movement results in a maximum predicted horizontal movement of 300 mm at the top of the tower, which is orientated along the alignment of the transmission line. Cable sheaves cannot be installed on tension towers and, therefore, it may be necessary to adjust the cable catenaries either side of Tower 44, prior to the extraction of Longwall 6. The maximum predicted systematic tilts and maximum predicted systematic horizontal movements at the tension towers in Area 3C will depend on the final layout of the future longwalls in this area.

The maximum predicted systematic tensile and compressive strains anywhere along the alignment of the transmission line are 2.6 mm/m and 6.5 mm/m, respectively, which occur above Longwalls 9 and 10, respectively. There are no towers located in the vicinities of the maximum predicted systematic tensile and compressive strains.

The maximum predicted systematic tensile and compressive strains at the tower locations in Area 3A are 1.5 mm/m and less than 0.1 mm/m, respectively. The minimum radii of curvatures associated with the maximum predicted systematic tensile and compressive strains are 10 kilometres and greater than 150 kilometres, respectively.

The maximum predicted systematic tensile and compressive strains within 20 metres of the tower locations in Area 3C will depend on the final layout of the future longwalls in this area. It is expected, however, that the maximum predicted tensile and compressive strains along the alignment of the transmission line within Area 3C would be similar to that in Area 3A, which are 2.6 mm/m and 6.5 mm/m, respectively.

The maximum predicted systematic strains are likely to result in increased stresses within the tower members which could be of sufficient magnitude to result in the structure becoming overstressed. It may be necessary to strengthen some of the tower bases within the Study Area, which may include the installation of cruciform bases or additional structural members.

It is recommended that the predicted movements along the 330 kV transmission line are provided to TransGrid so that a detailed structural analysis of the towers can be undertaken. Suitable preventive measures should be established, in consultation with TransGrid, so that the transmission line can be maintained in a safe and serviceable condition throughout the mining period. With the implementation of these management strategies, it is unlikely that there would be a significant impact on the transmission line resulting from the proposed mining.

5.14.4. Impact Assessments for the 330 kV Transmission Line Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the maximum predicted systematic tilt anywhere along the transmission line would be 32 mm/m, which occurs adjacent to the maingate of Longwall 10. The maximum predicted systematic tilt within 20 metres of the tower locations within Area 3A would be 12 mm/m, which occurs at Tower 43, and the resulting maximum predicted horizontal movement at the top of the tower would be 800 mm, which is orientated along the alignment of the transmission line.

If the predicted strains were increased by factors of up to 2 times, the maximum predicted systematic tensile and compressive strains anywhere along the alignment of the transmission line would be 5.2 mm/m and 13 mm/m, respectively, which occur above Longwalls 9 and 10, respectively. The maximum predicted systematic tensile and compressive strains within 20 metres of the tower locations within Area 3A would be 3.0 mm/m and less than 0.1 mm/m, respectively.

It is recommended that appropriate factors of safety are applied in the detailed structural analysis of the transmission line undertaken by TransGrid. These factors of safety should be applied in the design of any preventive measures required for the towers. If these factors of safety are applied to any required mitigation measures, it would be unlikely that any impacts would occur on the transmission line as a result of mining the proposed longwalls, based on increased predictions.

5.14.5. Recommendations for the 330 kV Transmission Line

It is recommended that the predicted movements at the 330 kV transmission line are provided to TransGrid so that a detailed structural analysis can be undertaken. It is also recommended that the transmission line is inspected by a suitably qualified person prior to mining, to assess the existing condition. In addition to this, it is recommended that suitable preventive measures are undertaken, based on the findings from the detailed structural analysis and the site inspection, such that the transmission line is maintained in a safe and serviceable condition throughout the mining period.

It is recommended that 3D survey marks are established around each of the towers within the Study Area so that the subsidence movements can be monitored. It is also recommended that management strategies are developed for the 330 kV transmission line in consultation with TransGrid. With these strategies in place, it is likely that the transmission line can be maintained in a safe and serviceable condition throughout the mining period and that there would be no significant impact on the infrastructure.

5.15. 33 kV Powerline

The 33 kV powerline crosses directly above Longwalls 6 and 7 in Area 3A and then continues northward across Area 3C. The location of the powerline within the Study Area is shown in Drawing No. MSEC311-12. The predictions and impact assessments for the powerline are provided in the following sections.

5.15.1. Predictions for the 33 kV Powerline due to Proposed Longwalls 6 to 10 in Area 3A

The predicted profiles of incremental and cumulative systematic subsidence, tilt along and tilt across the alignment of the 33 kV powerline, resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A, are shown in Fig. E.07 in Appendix E. A summary of the maximum predicted values of cumulative systematic subsidence, tilt along and tilt across the alignment of the powerline, after the extraction of each proposed longwall in Area 3A, is provided in Table 5.20.

Table 5.20 Maximum Predicted Cumulative Systematic Subsidence, Tilt Along and Tilt Across the 33 kV Powerline Resulting from the Extraction of Longwalls 6 to 10

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Tilt Along Alignment (mm/m)	Maximum Predicted Cumulative Tilt Across Alignment (mm/m)
After LW6	1415	4.4	11
After LW7	1530	7.2	10
After LW8	1530	7.3	11
After LW9	1530	7.3	11
After LW10	1530	7.3	11

The powerline will also be subjected to travelling tilts as the extraction faces of Longwalls 6 and 7 pass beneath it. A summary of the maximum predicted travelling tilts, during the extraction of each proposed longwall, is provided in Table 5.21.

Table 5.21 Maximum Predicted Travelling Tilts at the 33 kV Powerline during the Extraction of Longwalls 6 and 7

Longwall	Maximum Predicted Travelling Tilt (mm/m)
During LW6	7.8
During LW7	4.5

The 33 kV powerline crosses Sandy Creek to the east of Longwall 7. A summary of the maximum predicted values of total upsidence and closure at the creek crossing, after the extraction of the proposed longwalls, is provided in Table 5.22.

Table 5.22 Maximum Predicted Total Upsidence and Closure at the Sandy Creek Crossing Resulting from the Extraction of Longwalls 6 to 10

Location	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)
Sandy Creek Crossing	60	40

There is one tension pole within the SMP Area for Longwalls 6 to 10 in Area 3A, identified as Pole 33T1, which is located adjacent to the tailgate of Longwall 6. A summary of the maximum predicted values of total systematic subsidence, tilt along and tilt across the tension pole, after the extraction of the proposed longwalls in Area 3A, is provided in Table 5.23.

Table 5.23 Maximum Predicted Total Systematic Subsidence, Tilt Along and Tilt Across Tension Pole 33T1 Resulting from the Extraction of Longwalls 6 to 10

Location	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt Along Alignment (mm/m)	Maximum Predicted Total Tilt Across Alignment (mm/m)
Pole 33T1	455	4.6	6.2

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of the pole.

5.15.2. Predictions for the 33 kV Powerline due to the Future Longwalls in Area 3C

The powerline crosses Area 3C and is likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in this area. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Area 3C will depend on the final longwall layout in this area.

Based on the future longwalls in Area 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in this area are expected to be similar to those predicted for Longwalls 6 to 10.

The impact assessments provided in this report for the powerline in Area 3C have, therefore, been based on the maximum predicted systematic subsidence parameters provided in Table 5.20 and Table 5.21. A refined impact assessment based on the final longwall layout in Area 3C will be provided as part of the application for SMP Approval for the future longwalls in this area.

5.15.3. Impact Assessments for the 33 kV Powerline

The cables along the 33 kV powerline are not affected by ground strains, as they are supported by the poles above ground level. The cables can, however, be affected by the changes in bay lengths, ie: the distances between the poles at the height of the cables, which result from mining induced differential subsidence, horizontal ground movements and lateral movements at the tops of the poles caused by tilting of the poles. The stabilities of the poles can also be affected by the tilting of the poles and the changes in the catenary profiles of the cables.

The maximum predicted total systematic subsidence along the powerline is 1530 mm, which occurs above Longwall 6, after the extraction of Longwall 7. Based on a typical bay length of 50 metres between power poles, the maximum predicted total differential subsidence between the poles is 340 mm, which equates to a change in bay length of less than 5 mm, or less than 0.1 % of the original bay length.

The maximum predicted systematic tilt at the powerline is 11 mm/m (ie: 1.1 %), or a change in gradient of 1 in 90, which occurs adjacent to the finishing end of Longwall 7. High tilts at the locations of the power poles could adversely impact on the cable catenaries or could result in stability problems in any tension poles that are supported by guy ropes. Overhead powerlines can typically tolerate tilts of up to 20 mm/m at the poles, without any significant impacts on the cables or poles.

It is unlikely, therefore, that the maximum predicted systematic tilt would result in any significant impacts on the powerline. It is possible, however, that the predicted tilts could result in significant impacts on the powerline if the poles have high existing tilts.

It is recommended, therefore, that the powerline is inspected by a suitably qualified person, to determine the existing condition and whether any preventive measures are required, such as the installation of cable sheaves and guy ropes. It is also recommended, on the basis of this assessment, that management strategies are developed to maintain the powerline in a safe and serviceable condition throughout the mining period. With any required preventive measures in place, it is unlikely that there would be any significant impact on the 33 kV powerline as a result of the proposed mining.

The maximum predicted total upsidence at the Sandy Creek crossing is 60 mm, which occurs in the base of the creek. The magnitude of upsidence is predicted to be less than 20 mm at the locations of the poles and is unlikely, therefore, to have any significant impact on the powerline. The maximum predicted total closure at the Sandy Creek crossing is 40 mm. Based on a typical bay length of 50 metres, the maximum predicted closure represents a change in bay length of less than 0.1 % and is unlikely, therefore, to have any significant impact on the powerline.

5.15.4. Impact Assessments for the 33 kV Powerline Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the maximum predicted tilt at the powerline would be 22 mm/m, which occurs adjacent to the finishing end of Longwall 7. As described previously, overhead powerlines can typically tolerate tilts of up to 20 mm/m at the poles, without any significant impacts on the cables or poles. It is possible, therefore, that some preventive or remediation measures would be required for the powerline if the predicted tilts were exceeded by factors of up to 2 times.

If the maximum predicted valley related movements at the creek crossings were increased by factors of up to 2 times, the maximum predicted upsidence and closure at the Sandy Creek crossing would be 120 mm and 80 mm, respectively. As described previously, the maximum predicted upsidence occurs in the base of the creek and the magnitude of upsidence predicted at the locations of the poles would still be less than 20 mm. The maximum predicted closure of 80 mm still represents a change in bay length of less than 0.1 % of the original bay length. It is unlikely, therefore, that the valley related upsidence and closure movements would have any significant impact on the powerline, even if the predictions were exceeded by factors of up to 2 times.

5.15.5. Recommendations for the 33 kV Powerline

It is recommended that the powerline is inspected by a suitably qualified person prior to mining, to determine the existing condition and whether any preventive measures are required. It is also recommended that the powerline is visually monitored as the proposed longwalls mine beneath it.

It is recommended that management strategies are developed for the 33 kV powerline in consultation with Integral Energy. With these strategies in place, it is likely that the powerline can be maintained in a safe and serviceable condition throughout the mining period and that there would be no significant impacts on the powerline.

5.16. Lake Cordeaux and Lake Avon

The locations of Lake Cordeaux and Lake Avon are shown in Drawing No. MSEC311-07. The predictions and impact assessments for the lakes are provided in the following sections. The predictions and impact assessments for the Cordeaux and Upper Cordeaux No. 2 Dam Walls are provided in Section 5.17.

5.16.1. Predictions for the Lakes due to Proposed Longwalls 6 to 10 in Area 3A

The predicted profiles of incremental and cumulative subsidence, upsidence and closure along the arm of Lake Cordeaux located directly east of proposed Longwalls 6 to 10 in Area 3A are shown in Fig. E.03 in Appendix E. A summary of the maximum predicted values of cumulative subsidence, upsidence and closure at Lake Cordeaux, after the extraction of each proposed longwall in Area 3A, is provided in Table 5.24.

Table 5.24 Maximum Predicted Cumulative Subsidence, Upsidence and Closure at Lake Cordeaux Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Longwall	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative Upsidence (mm)	Maximum Predicted Cumulative Closure (mm)
After LW6	< 20	20	50
After LW7	< 20	70	110
After LW8	< 20	100	155
After LW9	< 20	115	170
After LW10	< 20	120	180

Lake Avon is located 3 kilometres to the west of the proposed longwalls in Area 3A, at its nearest point, when the lake is filled to its maximum storage level. It is unlikely, therefore, that Lake Avon would be subjected to any significant systematic, valley related, or far-field horizontal movements resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A.

5.16.2. Predictions for the Lakes due to the Future Longwalls in Areas 3B and 3C

It is proposed that the future longwalls in Areas 3B and 3C would be set back from Lake Cordeaux and Lake Avon such that it is assessed that the impacts on the lakes would not be significant. The future longwalls would, therefore, be set back and not mined beneath the lakes.

A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas. As part of that approval process, it is required that the Dams Safety Committee endorse the mining of the future longwalls within the Notification Areas of the lakes.

5.16.3. Impact Assessments for the Lakes

The maximum predicted total systematic subsidence at Lake Cordeaux and Lake Avon, resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A, are both less than 20 mm and are unlikely, therefore, to result in any significant systematic subsidence impacts on the lakes.

The maximum predicted total upsidence and closure at Lake Cordeaux, resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A, are 120 mm and 180 mm, respectively, which occur where the lake is closest to the proposed longwalls. The maximum predicted upsidence and closure movements at Lake Avon, resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A, are both negligible and not significant.

The perimeter of Lake Cordeaux is located at a distance of 250 metres from Longwall 7, at its closest point to the proposed longwalls in Area 3A. As discussed in Section 5.3.5.2, minor isolated cracking has been observed within creek and river valleys at these magnitudes of predicted movements, at distances of up to 400 metres from extracted longwalls.

It is possible, therefore, that minor isolated cracking could occur in the bed of Lake Cordeaux as a result of the extraction of the proposed longwalls in Area 3A. It is also possible that minor isolated cracking could occur in the beds of Lake Avon and Lake Cordeaux as a result of the extraction of the future longwalls in Areas 3B and 3C, where the future longwalls are within 400 metres of the lakes.

It is proposed that the future longwalls in Areas 3B and 3C would be set back from the lakes such that it is assessed that no significant impacts would occur on the lakes. The observations and monitoring data obtained during the extraction of Longwalls 6 to 10 in Area 3A will be used to further refine the impact assessment methodology and suitable set back distances from the lakes.

It is unlikely that any minor isolated cracking that occurs in the beds of the lakes would result in any loss of water, as the depths of cracking resulting from valley related movements have typically been observed to be less than 15 metres in the past. Any minor isolated cracking in the beds of the lakes is also likely to be filled by the alluvial materials within the lakes.

Fracturing of bedrock submerged beneath the lakes stored waters or within the impounded areas is unlikely to have a significant impact on the lakes, as the fractures would be quickly filled with water and alluvial materials and not result in any water loss from the system. Furthermore, there is unlikely to be an impact on water quality in the lakes as a result of fracturing in the bedrock, as there would be no flow paths through these fractures

A cross-section through Lake Cordeaux and Longwall 7, where the lake is located closest to the proposed longwalls in Area 3A, is shown in Fig. 5.11. It can be seen from this figure that the maximum storage water level in the lake is located outside the 35 degree angle of draw line from the proposed longwalls in Area 3A.

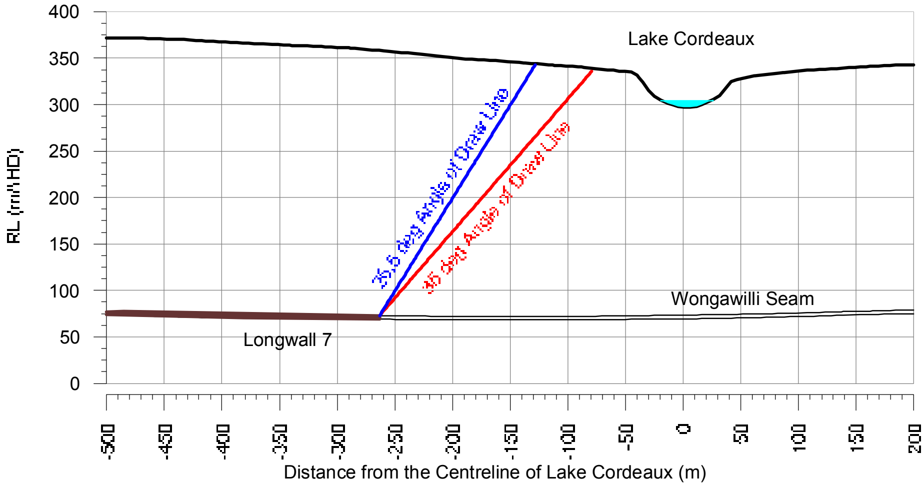


Fig. 5.11 Cross-Section through the Proposed Longwalls and Lake Cordeaux at its Closest Point

It is also likely that the future longwalls in Areas 3B and 3C would be located outside the 35 degree angle of draw lines from Lake Cordeaux and Lake Avon, based on the current methodology and understanding.

Directly above the proposed and future longwalls in Area 3, there is likely to be a significant increase in the conductivity of subsurface water in the strata within the collapsed zone and, to a lesser extent, within the fractured zone. These zones are located well inside the 26½ degree angle of draw lines from the goaf edges of the longwalls.

Outside the collapsed and fractured zones, there is unlikely to be a significant increase in the conductivity of subsurface water in the strata. It is unlikely, therefore, that there would be any loss of water from Lake Cordeaux or Lake Avon resulting from the proposed mining. A detailed assessment of the potential impact of the proposed mining on the conductivity of subsurface water is provided in a report by GHD (2007).

5.16.4. Impact Assessments for the Lakes Based on Increased Predictions

If the predicted systematic subsidence parameters at Lake Cordeaux and Lake Avon were increased by factors of up to 5 times, the maximum predicted subsidence resulting from the extraction of proposed Longwalls 6 to 10 in Area 3A would still be less than 20 mm and unlikely, therefore, to result in any significant impacts on the lakes. It is expected, based on the current methodology and understanding, that the future longwalls in Areas 3B and 3C would be located outside the 35 degree angle of draw lines from the lakes and it is likely, therefore, that the maximum predicted systematic tensile strains at the lakes would still be less than 0.5 mm/m, even if they were increased by factors up to 5 times.

If the predicted upsidence and closure movements were increased by factors of up to 2 times, it is possible that more significant cracking could occur within the beds of Lake Cordeaux and Lake Avon, within 400 metres of the proposed and future longwalls in Areas 3A, 3B and 3C. Any cracking resulting from the valley related movements would still be expected to be less than 15 metres in depth and unlikely, therefore, to result in loss of water from the lakes. It should be noted, however, that the method used to predict the valley related movements adopts conservative upper-bound prediction curves and it is unlikely, therefore, that these movements would be exceeded by any more than 15 %.

5.16.5. Recommendations for the Lakes

It is recommended that IC consult with the SCA and DSC in relation to management of any potential impacts on Lake Cordeaux and Lake Avon. In addition to this, appropriate management strategies should be developed and implemented to ensure that there is no unacceptable water loss from the lakes. With these management strategies in place, it is unlikely that there would be any significant impacts on the lakes resulting from the proposed mining.

5.17. Cordeaux and Upper Cordeaux No. 2 Dam Walls

Cordeaux and Upper Cordeaux No. 2 Dam Walls are located 4.4 kilometres north and 2.6 kilometres south-east of proposed Longwalls 6 to 10 in Area 3A, at their closest points. It is unlikely, therefore, that the dam walls would be subjected to any significant systematic or valley related movements resulting from the extraction of the proposed longwalls in this area.

Cordeaux Dam Wall is located 980 metres north of the maximum footprint for Area 3C and Upper Cordeaux No. 2 Dam Wall is located more than 3.5 kilometres south-east of the maximum footprints for Areas 3B and 3C. It is unlikely, therefore, that the dam walls would be subjected to any significant systematic or valley related movements resulting from the extraction of the future longwalls in these areas.

The dam walls could be subjected to very small far-field horizontal movements as a result of the extraction of the proposed and future longwalls in Area 3. Far-field horizontal movements have, in the past, been observed more than 1 kilometre from longwall extractions, however, these movements tend to be bodily movements associated with very low levels of strain.

The observed horizontal movements at the Upper Cordeaux No. 2 Dam Wall, resulting from the extraction of Longwalls 1 and 2 in Area 1, were less than 2 mm, which are within survey tolerance. The far-field horizontal movements at this dam wall resulting from the extraction of the proposed and future longwalls in Area 3, are expected to be less than those observed for Longwalls 1 and 2. The reason for this is that the proposed and future longwalls are located at a minimum distance of 2.5 kilometres from the dam wall, whereas Longwalls 1 and 2 are located at a minimum distance of less than 1.5 kilometres. In addition to this, Longwalls 3 to 5A in Area 2 are located between the proposed and future longwalls in Area 3 and the dam wall, which are likely to redistribute the horizontal in situ stresses in the strata in this area and, hence, the potential for further far-field horizontal movements.

Cordeaux Dam Wall is located at a distance of greater than 4 kilometres north Areas 3A and 3B and is unlikely, therefore, to be subjected to any significant far-field horizontal movements resulting from the extraction of the proposed and future longwalls in these areas. The dam wall could, however, be subjected to small far-field horizontal movements resulting from the extraction of the future longwalls in Area 3C.

A refined impact assessment for far-field horizontal movements at this dam wall, resulting from the extraction of the future longwalls in Area 3C, will be provided as part of the application for SMP Approval for the future longwalls in this area. It should also be noted, that this assessment will be based on monitoring data obtained during the extraction of the proposed and future longwalls in Areas 3A and 3B and can be further refined as the future longwall in Area 3C are mined closer towards to dam wall.

It is recommended that the Cordeaux and Upper Cordeaux No. 2 Dam Walls are monitored during the extraction of the proposed and future longwalls in Area 3. It is also recommended that management strategies are developed, in consultation with the SCA, to ensure that the dam walls remain in a safe and serviceable condition during and following the mining period. With these strategies in place, it is unlikely that there would be any significant impacts on the dam walls as a result of the proposed mining.

5.18. Exploration Bore Holes

The locations of the exploration bore holes within the Study Area are shown in Drawing No. MSEC311-13. The predictions and impact assessments for the exploration bore holes are provided in the following sections.

5.18.1. Predictions for the Exploration Bore Holes in Area 3A

The exploration bore holes are located across Area 3A and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in this area. A summary of the maximum predicted values of systematic subsidence, tilt and strain at the bores, at any time during or after the extraction of Longwalls 6 to 10 in Area 3A, is provided in Table 5.25.

Table 5.25 Maximum Predicted Systematic Subsidence, Tilt and Strain at the Exploration Bore Holes Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Location	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
Exploration Bore Holes	2275	21	4.5	11

5.18.2. Predictions for the Exploration Bores in Areas 3B and 3C

The exploration bore holes are located across Areas 3B and 3C and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in these areas. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas.

Based on the future longwalls in Areas 3B and 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas are expected to be similar to those predicted for Longwalls 6 to 10.

The impact assessments provided in this report for the exploration bore holes in Areas 3B and 3C have, therefore, been based on the maximum predicted systematic subsidence parameters provided in Table 5.25. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas.

5.18.3. Impact Assessments for the Exploration Bore Holes

Exploration bore holes can be impacted by mine subsidence due to the ground curvatures, which result in fracturing, opening of existing joints and spalling of strata in the walls of the bore holes, or by the differential horizontal movements between the strata layers at different horizons in the bore holes.

The maximum predicted systematic tensile and compressive strains in the Study Area are 4.5 mm/m and 11 mm/m, respectively, and the associated minimum radii of curvatures are 3.3 kilometres and 1.4 kilometres, respectively. The predicted maximum strains and curvatures are of sufficient magnitudes to result in the fracturing of sandstone and, hence, the potential for spalling within the bore holes.

The maximum predicted systematic tilt in the Study Area is 21 mm/m and the associated maximum predicted systematic horizontal movement at the surface is approximately 300 mm. The differential horizontal movements between the surface and seam, which result from longwall mining, are distributed between the strata layers at different horizons within the bore holes.

The exploration bore holes are owned by IC and most contain piezometers or geophones. Differential horizontal movements are likely to result in the shearing of the cables which connect the instrumentation with the surface. The differential movements between the strata layers could also result in fracturing and spalling of the strata within the bore holes, which could potentially result in the loss of water from aquifers, or the transmission of water or gas between strata at different horizons within the bore holes.

The majority of the exploration bore holes within the SMP Area are grouted and capped and are unlikely, therefore, to result in an increased conductivity of water and gas any greater than the surrounding strata, as a result of the extraction of the proposed longwalls in Area 3A. Similarly, the exploration bore holes which have been grouted and capped within the remainder of the Study Area are also unlikely to result in an increased conductivity of water and gas any greater than the surrounding strata, as a result of the extraction of the future longwalls in Areas 3B and 3C.

It is recommended that the open exploration bore holes within Areas 3A, 3B and 3C are grouted and capped prior to mining within each area. With these management strategies in place, it is unlikely that the exploration bore holes would result in any significant increase in the conductivity of water and gas between different strata horizons within the bore holes.

5.19. Archaeological Sites

A number of archaeological sites have been identified within the Study Area, the locations of which are shown in Drawing No. MSEC311-14. The predictions and impact assessments for the archaeological sites are provided in the following sections.

5.19.1. Predictions for the Archaeological Sites in Area 3A

A summary of the maximum predicted values of systematic subsidence, tilt and strain at the archaeological sites within the SMP Area, at any time during or after the extraction of the proposed longwalls in Area 3A, is provided in Table 5.26.

Table 5.26 Maximum Predicted Systematic Subsidence, Tilt and Strain at the Archaeological Sites Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Archaeological Site	Maximum Predicted Cumulative Subsidence (mm)	Maximum Predicted Cumulative or Travelling Tilt (mm/m)	Maximum Predicted Cumulative or Travelling Tensile Strain (mm/m)	Maximum Predicted Cumulative or Travelling Compressive Strain (mm/m)
52-2-0458	220	2.9	0.6	0.2
52-2-1646	150	3.9	0.8	0.3
52-2-1647	< 20	0.1	< 0.1	< 0.1
52-2-2043	< 20	0.1	< 0.1	< 0.1
52-2-3052	75	1.0	0.2	0.1
52-5-0273	1485	5.7	1.6	1.3
52-5-0274	235	4.6	1.9	0.5
52-5-0277	1540	7.4	1.8	3.6
52-5-0278	1540	7.6	1.8	3.6
DM13	1615	15	2.5	2.0
DM14	1400	10	1.4	2.5
DM15	1265	15	2.8	2.1
DM20	1660	6.0	1.4	1.1
DM23	< 20	< 0.1	< 0.1	< 0.1

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of each site. The predicted tilts and strains are the maximum values which occur during, or after the extraction of each proposed longwall, whichever is the greater.

The maximum predicted systematic subsidence parameters at the remainder of the archaeological sites in Area 3A, south of the SMP Area, are negligible and are unlikely, therefore, to result in any systematic subsidence impacts on these sites.

5.19.2. Predictions for the Archaeological Sites in Areas 3B and 3C

The archaeological sites are located across Areas 3B and 3C and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in these areas. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas.

Based on the future longwalls in Areas 3B and 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas are expected to be similar to those predicted for Longwalls 6 to 10.

The impact assessments provided in this report for the archaeological sites in Areas 3B and 3C have, therefore, been based on the maximum predicted systematic subsidence parameters provided in Table 4.2. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas.

5.19.3. Impact Assessments for the Archaeological Sites

There are three open sites with artefacts within the SMP Area, being Sites 52-2-2043, 52-2-3052 and DM14. There are also three open sites with artefacts within Areas 3B and 3C, being Sites 52-2-0535, 52-2-2246 and DM9. Open sites can potentially be affected by cracking of the surface soils as a result of mine subsidence movements. It is unlikely, however, that the scattered artefacts themselves would be impacted by surface cracking.

The maximum predicted systematic tensile strains at Sites 52-2-2043 and 52-2-3052, which are located outside the proposed longwall goaf edges, are less than 0.1 mm/m and 0.2 mm/m, respectively, and are unlikely, therefore, to be impacted by surface cracking. The maximum predicted systematic tensile strain at Site DM14, which is located above Longwall 6, is 1.4 mm/m and could potentially, therefore, be impacted by surface cracking.

Site DM14 is not located on a steep slope or adjacent to a cliff line and, therefore, the maximum predicted surface crack width in this area can be determined using Fig. 5.18. Based on a depth of cover of 350 metres at Site DM14, the maximum predicted surface crack width at the site is in the order of 40 mm. It is more likely, however, that a number of smaller cracks would develop in the vicinity of the site rather than a single large crack.

There are no grinding groove sites within the SMP Area or within Area 3B. There are two grinding groove sites within Area 3C, being Sites 52-2-1563 and 52-2-1564. It is possible that these sites could be impacted by the fracturing of exposed sandstone if the future longwalls were to be mined immediately adjacent to or directly beneath these sites. It should be noted, however, that the grinding groove sites are located on the western side of Area 3C and it is less likely, therefore, that the future longwalls would be mined directly beneath these sites.

Site DM23 comprises a large overhang with deposits, however, the overhang does not contain any art. The site is located 250 metres east of Longwall 7, at its closest point to the proposed longwalls in Area 3A. The maximum predicted systematic tensile and compressive strains at this site, resulting from the extraction of the proposed longwalls, are both less than 0.1 mm/m and are unlikely, therefore, to result in impact.

Site DM23 is located along Sandy Creek and could, therefore, be subjected to upsidence and closure movements resulting from the extraction of Longwall 6 to 10 in Area 3A. The predicted profiles of upsidence and closure along Sandy Creek are shown in Fig. E.03. The maximum predicted upsidence and closure movements at Site DM23, referred to as the waterfall in the figure, are 125 mm and 175 mm, respectively.

Previous experience in the Southern Coalfield indicates that very few rockfalls have occurred outside of extracted longwall goaf areas and only in extremely rare cases have rockfalls occurred more than half the depth of cover from extracted longwall goaf edges. In addition to this, all rockfalls observed in Area 1 at Dendrobium Mine occurred directly above the extracted longwalls and no rock falls were observed outside of the extracted longwall goaf areas. It is unlikely, therefore, that the extraction of the proposed and future longwalls in Area 3 would result in rockfalls at Site DM23, as the site is located more than half a depth of cover from the proposed and future longwalls.

The remaining archaeological sites within the Study Area consist of sandstone overhangs and outcrops with art or scattered artefacts. These types of sites can potentially be impacted by mine subsidence movements including the fracturing of sandstone, rock falls, or water seepage through joints which may affect artwork. The overhang and outcrop sites located directly above the proposed and future longwalls are more susceptible to mine subsidence movements than sites located over solid coal. There are seven overhang and outcrop sites that are located directly above the proposed longwalls in Area 3A.

The main mechanisms which can potentially result in impact on sandstone overhang and outcrop sites are the systematic strains and curvatures. The maximum predicted systematic tensile and compressive strains at these sites in Area 3A, resulting from the extraction of proposed Longwalls 6 to 10, are 2.8 mm/m and 3.6 mm/m, respectively. The minimum radii of curvatures associated with these maximum predicted systematic tensile and compressive strains are 5.4 kilometres and 4.2 kilometres, respectively.

The maximum predicted systematic strains at the overhang and outcrop sites in Areas 3B and 3C, resulting from the extraction of the future longwalls, depend on the final layouts of the future longwalls in these areas. The maximum predicted systematic tensile and compressive strains in Areas 3B and 3C are expected to be similar to those in Area 3A, which are 4.5 mm/m and 11 mm/m, respectively.

Tensile strains greater than 0.5 mm/m may be of a sufficient magnitude to result in the fracturing of sandstone. Compressive strains greater than 2 mm/m may be of a sufficient magnitude to result in the underlying strata buckling, which could result in the fracturing of the sandstone bedrock. It is likely, therefore, that the predicted maximum systematic tensile and compressive strains, resulting from the extraction of the proposed and future longwalls in Area 3, would result in the fracturing of the topmost bedrock. Where fracturing is coincident with an overhang or outcrop, it is possible that there could be an isolated rockfall as a result of the extraction of the proposed and future longwalls.

It has been reported that, where longwall mining has previously been carried out in the Southern Coalfield, beneath 52 shelters, that approximately 10 % of the shelters have been affected by fracturing of the strata or shear movements along bedding planes and that none of the shelters have collapsed (Sefton 2000). This suggests that the likelihood of any significant impacts on the overhang sites, resulting from the extraction of the proposed and future longwalls, is low. Also, as described in Section 5.8.3, it is expected that less than 7 to 10 % of the rock outcrops located directly above the proposed and future longwalls would be impacted by the extraction of these longwalls.

Further assessments of the potential impacts on the archaeological sites are provided in a report by Biosis (2007b).

5.19.4. Impact Assessments for the Archaeological Sites Based on Increased Predictions

If the predicted systematic strains were increased by factors of up to 2 times, the likelihood and extent of surface cracking and the fracturing of sandstone would increase accordingly. It should be noted, however, that the Incremental Profile Method generally provides conservative predictions, and that additional conservatism has been provided by taking the maximum subsidence parameters within a 20 metre radius of each archaeological sites. It is not expected, therefore, that the systematic subsidence parameters at the archaeological sites would be significantly exceeded.

5.19.5. Recommendations for the Archaeological Sites

It is recommended that a detailed survey of the archaeological sites is undertaken and a monitoring programme established to record the effects of mine subsidence on these sites.

5.20. Survey Control Marks

There are a number of survey control marks within the general Study Area, the locations of which are shown in Drawing No. MSEC311-14. The predictions and impact assessments for the survey control marks are provided in the following sections.

5.20.1. Predictions for the Survey Control Marks

There are three survey control marks located within the general SMP Area, being S0704, S1106 and S1343. A summary of the maximum predicted values of total systematic subsidence and horizontal movement at these survey control marks, after the extraction of the proposed longwalls in Area 3A, is provided in Table 5.27.

Table 5.27 Maximum Predicted Total Systematic Subsidence and Horizontal Movement at the Survey Control Marks Resulting from the Extraction of Longwalls 6 to 10 in Area 3A

Survey Mark	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Horizontal Movement (mm)
S0704	80	< 20
S1106	< 20	< 20
S1343	345	70

The values provided in the above table are the maximum predicted parameters within a 20 metre radius of each survey control mark.

The survey control marks are located across Areas 3B and 3C and are likely, therefore, to be subjected to the full range of predicted systematic subsidence movements in these areas. As discussed in Section 4.3, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in Areas 3B and 3C will depend on the final longwall layouts in these areas.

Based on the future longwalls in Areas 3B and 3C having similar void widths, chain pillar widths and extraction heights to those in Area 3A, the maximum predicted systematic subsidence parameters resulting from the extraction of the future longwalls in these areas are expected to be similar to those predicted for Longwalls 6 to 10, which are summarised in Table 4.2.

There are also a number of other survey control marks that are located in the vicinity of the Study Area which are likely to experience either small amounts of subsidence or small far-field horizontal movements as the proposed and future longwalls in Area 3 are mined. It is possible that other survey control marks outside the immediate area could also be affected by far-field horizontal movements, up to 3 kilometres outside the Study Area.

5.20.2. Impact Assessments for the Survey Control Marks

It will be necessary on the completion of the proposed and future longwalls in Area 3, when the ground has stabilised, to re-establish any survey control marks that are required for future use. Consultation between IC and the Department of Lands will be required throughout the mining period to ensure that these survey control marks are reinstated at the appropriate time, as required.

5.20.3. Impact Assessments for the Survey Control Marks Based on Increased Predictions

If the predicted systematic subsidence parameters were increased by factors of up to 5 times, the extent of the remediation measures would not significantly increase. If the predicted far-field horizontal movements were increased by factors up to 5 times, it is likely that additional survey control marks further afield would be affected and, therefore, could require re-establishment. It is anticipated that with appropriate remediation measures implemented, that there would be no significant impact on the survey marks as a result of the proposed mining.

5.20.4. Recommendations for the Survey Control Marks

It is recommended that management strategies are developed, in consultation with the Department of Lands, such that the survey control marks can be re-established, as required, at the appropriate time.

5.21. General Predictions and Other Potential Impacts

The following sections provide general predictions and discuss other potential impacts resulting from the extraction of the proposed and future longwalls in Area 3.

5.21.1. Predicted Horizontal Movements

Predicted horizontal movements over extracted longwalls are calculated by applying a factor to the predicted tilt values. In the Southern Coalfield a normal factor of 15 has been adopted, being the same factor as that used to determine strains from curvatures and this has been found to give a reasonable correlation with measured data. The factor will in fact vary and will be higher at low tilt values and lower at high tilt values. The application of this factor is likely, therefore, to lead to over-prediction of horizontal movements where the tilts are high and under-prediction of the movements where the tilts are low.

The maximum predicted systematic tilt within the SMP Area, resulting from the extraction of the proposed longwalls in Area 3A, is 21 mm/m which occurs adjacent to the maingate of Longwall 10. This area is predicted to experience the greatest horizontal movement towards the centre of the longwall. The maximum predicted tilts in Areas 3B and 3C have also been taken as 21 mm/m. Applying a factor of 15 to this predicted magnitude of tilt would provide a very conservative prediction of the horizontal movement, which is in the order of 300 mm.

Horizontal movements do not directly impact on natural features or items of surface infrastructure, rather impacts occur as the result of differential horizontal movements. Systematic strain is the rate of change of horizontal movement. The impacts of systematic strain on the natural features and items of surface infrastructure are addressed in the impact assessments for each feature in Sections 5.3 to 5.20.

5.21.2. Predicted Far-Field Horizontal Movements

In addition to the systematic movements that have been predicted above and adjacent to the proposed and future longwalls in Area 3 and the predicted valley related movements along the creeks and drainage lines, it is also likely that some far-field horizontal movements will also be experienced during the extraction of these longwalls.

Far-field horizontal movements result from the redistribution of horizontal in situ stress in the strata around the collapsed and fractured zones above longwall extractions. Such movements are, to some extent, predictable and occur whenever significant excavations occur at the surface or underground.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data primarily from the Southern Coalfield, from Collieries including Appin, Bellambi, Dendrobium, Douglas, Newstan, Tower and West Cliff. The far-field horizontal movements resulting from longwall mining were generally observed to be orientated towards the extracted longwalls. At very low levels of far-field horizontal movements, however, there was a high scatter in the orientations of the observed movements.

The observed incremental far-field horizontal movements resulting from the extraction of a single longwall, for all monitoring points within the database, is provided in Fig. 5.12. The observed incremental far-field horizontal movements resulting from the extraction of a single longwall, for monitoring points within the database only where there was solid coal between the longwalls and the monitoring points, is provided in Fig. 5.13.

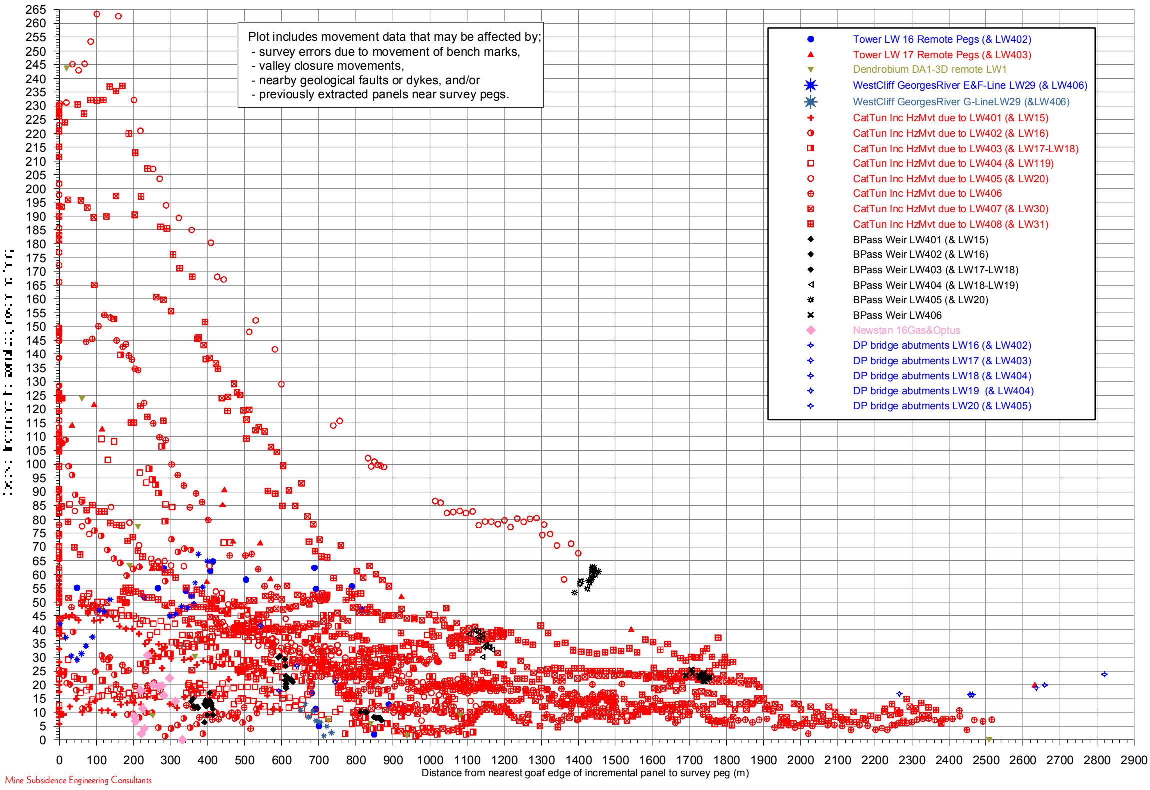


Fig. 5.12 Observed Incremental Far-Field Horizontal Movements

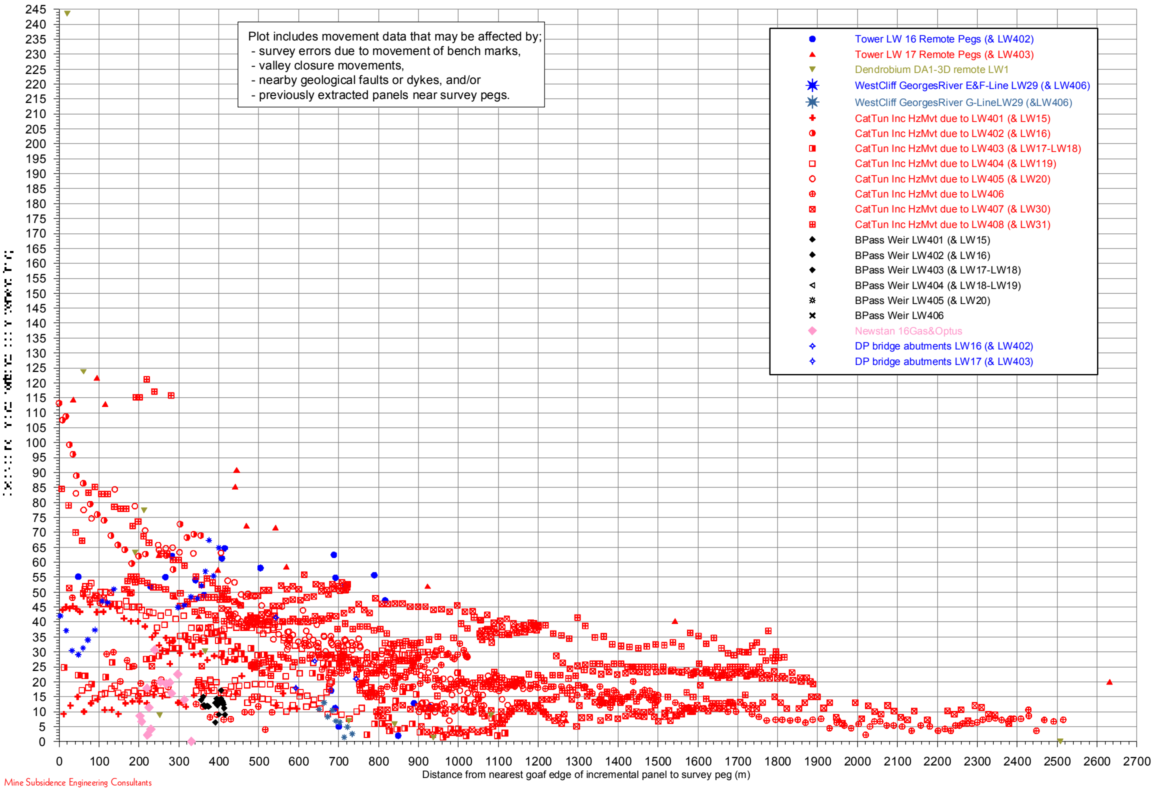


Fig. 5.13 Observed Incremental Far-Field Horizontal Movements with Solid Coal between the Monitoring Points and Extracted Longwall

It can be seen from these figures, that incremental far-field horizontal movements of up to 20 mm have been observed at distances of 2000 metres from extracted longwalls. It should be noted, however, that at these large distances from the longwall extractions, the measured movements contain larger proportions of survey error, in addition to valley related closure movements and movements along geological anomalies.

As successive longwalls within a series of longwalls are mined, the magnitudes of the incremental far-field horizontal movements decrease. This is possibly due to the fact that once the in situ stresses in the strata within the collapsed zones above the first few extracted longwalls has been redistributed, the potential for further movement is reduced. The total far-field horizontal movement resulting from the extraction of a series of longwalls is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

The far-field horizontal movements resulting from the extraction of the proposed and future longwalls in Area 3 are expected to be very small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain, which are generally less than 0.1 mm/m. The impacts of far-field horizontal movements on the natural features and items of surface infrastructure within the vicinity of the Study Area are expected to be insignificant.

5.21.3. Likely Height of the Fractured Zone above the Proposed Longwalls

The background to sub-surface strata movements is provided in the report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com* and the following conclusions should be read in that context.

The height of the fractured zone is dependent upon the angle of break (a), the width of the panel (W) and the spanning capacity of a competent stratum at the top of the fractured zone, span (w). These are illustrated in Fig. 5.14. From the mining geometry it can be shown that the height of the fractured zone equals the panel width (W) minus the span (w) divided by twice the tangent of the angle of break.

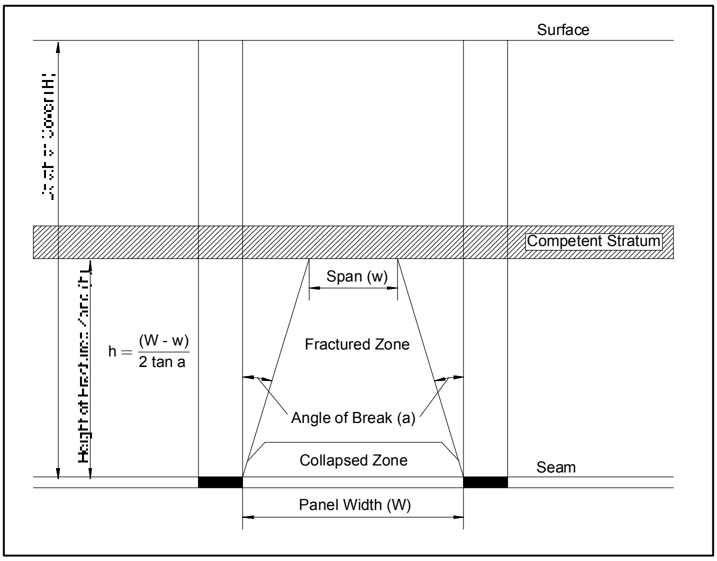


Fig. 5.14 Theoretical Model Illustrating the Development and Limit of the Fractured Zone

Using this relationship, the theoretical height of the fractured zone, as a proportion of the width of the extracted panel, has been determined for a range of panel width-to-depth ratios. These values have been plotted in the graph shown in Fig. 5.15, together with the values that have been reported in literature. The red data points are those which have been reported in literature whilst the theoretical values are shown in green, magenta and blue for angles of break of 17°, 20° and 23°, respectively.

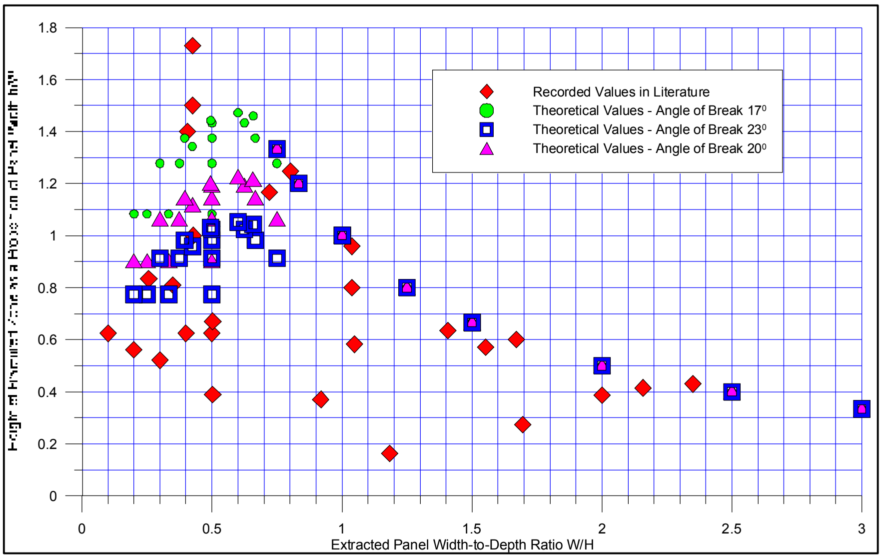


Fig. 5.15 Graph showing Height of Fractured Zone as a Proportion of Panel Width for different Width-to-Depth Ratios

It can be seen from the above figure that the height of the fractured zone in the database is reasonably well represented by the theoretical model using an angle of draw of 20°. Only three red data points appear above the magenta data points and these are the heights of the fractured zone over Longwall 2 at Ellalong Colliery and over Longwall 3 at Tahmoor Colliery, which were given by Holla (1986) and Holla and Buizen (1991).

In both of these cases, the apparent heights of the fractured zone were determined from extensometer readings which could have included horizontal shear as well as vertical dilation. The stated heights of the fractured zone at Tahmoor, which are the highest data points in the graph, are not supported by the measured vertical strains, which averaged only 0.6 mm/m in the top 160 metres of the overburden. A more realistic assessment is that the fractured zone extended only to the Bald Hill Claystone.

In some cases, it is likely that the upwards progression of the fractured zone was limited by the levels of vertical strain that could be developed, which is dependent upon the extracted seam thickness, the surface subsidence and the depth of cover.

The proposed Longwalls 6 to 10 in Area 3A have width-to-depth ratios varying between 0.6 to 1.0, which is well represented by the theoretical model using an angle of draw of 20°. It can be seen from Fig. 5.15, that there are no observed red data points above the predicted magenta data points for width-to-depth ratios greater than 0.6.

The upper limit of the fractured zone will be reached when the strata above that zone are sufficiently strong to span the goaf area without significant bending or shear strains being developed. In the Southern Coalfield, the upper layers of the overburden strata are relatively strong units in the Hawkesbury and Bulgo Sandstones which would be expected to be capable of spanning at least 30 metres.

The major claystone unit is the Bald Hill Claystone, which lies above the Bulgo Sandstone at the base of the Hawkesbury Sandstone. This claystone varies in thickness and is, in some places, more than 25 metres thick. Due to the nature of this claystone, which swells when it is wetted, it tends to act as an aquiclude.

A summary of the longwall void widths and predicted heights of the fractured zone above the proposed longwalls in Area 3A, determined using an average angle of break of 20° and a maximum strata span of 30 metres, is provided in Table 5.28.

Table 5.28 Predicted Height of Fractured Zone above Longwalls 6 to 10 in Area 3A

Longwall	Void Width (m)	Predicted Height of Fractured Zone (m)
Longwall 6 to 10	250	300

The predicted heights of the fractured zones above the future longwalls in Areas 3B and 3C will depend on the final voids widths of these longwalls. The predicted heights of the fractured zones for these longwalls are expected to be similar to those for Longwalls 6 to 10, if longwall void widths of 250 metres are also adopted.

The depth of cover contours within the Study Area are shown in Drawing No. MSEC311-05. A summary of the minimum, maximum and average depths of cover above the proposed longwalls in Area 3A is provided in Table 5.29.

Table 5.29 Depth of Cover above the Proposed Longwalls in Area 3A

Longwall	Minimum Depth of Cover Above Longwall (m)	Maximum Depth of Cover Above Longwall (m)	Average Depth of Cover Above Longwall (m)
Longwall 6	290	400	340
Longwall 7	285	385	330
Longwall 8	260	380	315
Longwall 9	270	375	320
Longwall 10	255	350	300

The depths of cover are generally greater than the predicted heights of the fractured zone above the central parts of the proposed longwalls in Area 3A. The depths of cover are, however, less than the predicted heights of the fractured zone above the commencing ends of Longwalls 6 and 10 and finishing ends Longwalls 7 to 10 and, to lesser extents, in small areas above the commencing ends of Longwalls 8 and 9 and in a small area above the finishing end of Longwall 6.

The depths of cover within Areas 3B and 3C vary between 215 and 425 metres. The depths of cover are, therefore, less than the predicted heights of the fractured zone beneath Wongawilli Creek and some of its tributaries.

It is probable, therefore, that the fractured zones could extend to the surface where the depths of cover are less than 300 metres, at the commencing and finishing ends of the proposed longwalls in Area 3A and beneath Wongawilli Creek and its tributaries within Areas 3B and 3C. This does not necessarily imply that there would be connectivity between the surface and the seam, however, since fractures caused by bed separation can increase horizontal permeability without necessarily increasing vertical permeability.

Where the depths of cover are greater than 300 metres, it is expected that a *Constrained Zone*, also called a *Continuous Deformation Zone*, would occur between the fractured zone and the surface, which is illustrated in Fig. 5.16 and Fig. 5.17.

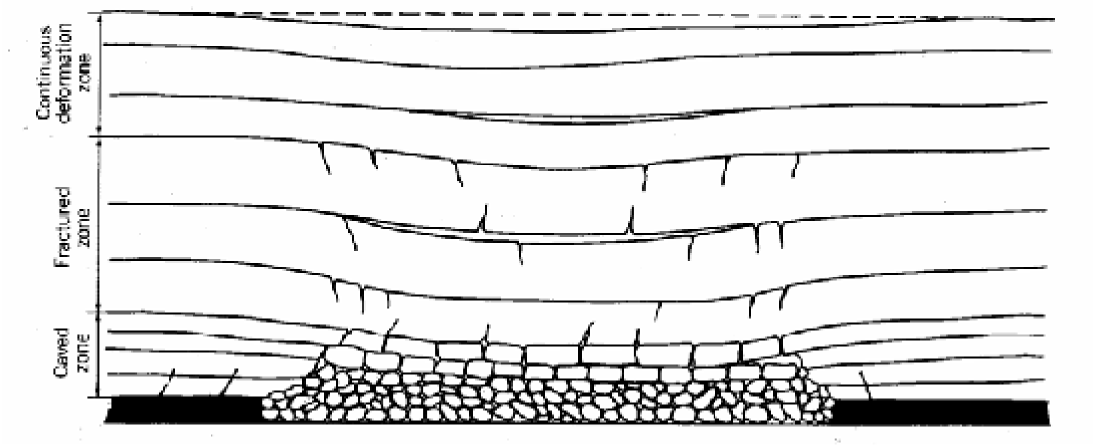


Fig. 5.16 Zones in the Overburden According to Peng and Chiang (1984)

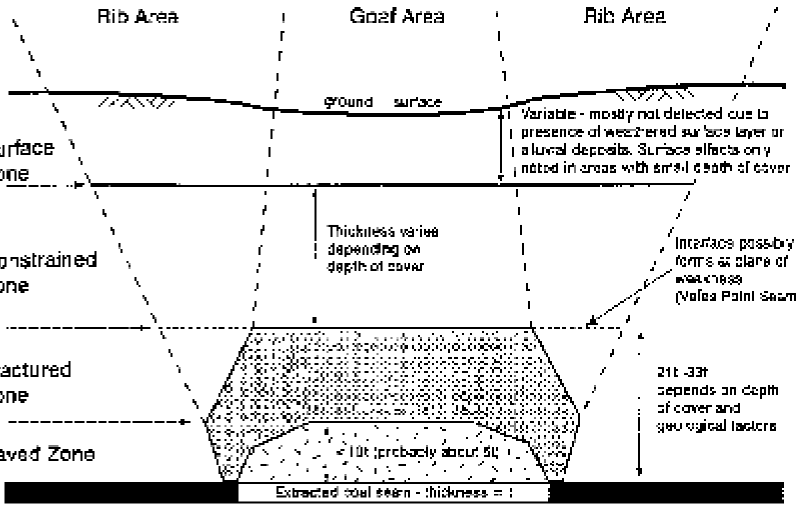


Fig. 5.17 Zones in the Overburden according to Forster (1995)

The constrained zone comprises confined rock strata which have sagged slightly but, because they are constrained, have absorbed most of the strain energy without suffering significant fracturing or alteration to the original physical properties. Some bed separation or slippage can be present, as well as discontinuous vertical cracks, usually on the underside of thick strong beds. Weak or soft beds in this zone may suffer plastic deformation.

Further details on sub-surface strata movements are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*. The potential impact of the proposed longwalls on groundwater resources within the Study Area is provided in the report by GHD (2007).

5.21.4. The Likelihood of Irregular Profiles

Wherever faults, dykes and abrupt changes in geology are present at the surface, it is possible that irregularities in the subsidence profiles could occur. Similarly, where surface rocks are thinly bedded, and where cross-bedded strata exist close to the surface, it is possible for surface buckling to occur, leading to irregular movements. By far the greatest number of irregularities in subsidence profiles, however, can be explained by the presence of surface incisions such as gorges, river valleys and creeks.

Several geological structures have been identified within the Study Area which are shown in Drawing No. MSEC311-06. The geological features identified at seam level include a fault which crosses near the finishing end of Longwall 10 and a dyke which crosses near the finishing ends of Longwalls 9 and 10. There are also a series of dykes which have been identified to the north of Longwall 6. These features have been identified at seam level and are unlikely, therefore, to result in an irregular subsidence profile at the surface.

The Nepheline Syenite is generally located south of the proposed longwalls in Area 3A and has intruded at the level of the Wongawilli Seam. It is unlikely, therefore, that this intrusion would affect the systematic subsidence movements, as the intrusion is not located within the collapsed or fractured zones above the proposed longwalls.

It is possible that anomalous movements could occur as a result of the extraction of the proposed and future longwalls in Area 3, as these have occurred in the past in the Southern Coalfield. Given the relatively low density of surface features within the Study Area, the probability of an anomalous movement coinciding with a surface feature is assessed as low. Further details on anomalous movements are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from *www.minesubsidence.com*.

Irregularities can also occur in shallow mining situations where the collapsed zone, above the extracted seam, extends all the way to the surface. This type of irregularity is generally only seen where the depth of cover is less than 100 metres, which does not occur above the proposed and future longwalls in Area 3.

Irregular profiles can also occur where longwall mining is carried out beneath previous workings such as bord and pillar extractions. In such situations, the stooks left in the upper seam can collapse, when mining occurs beneath them, leading to localised subsidence and irregular subsidence profiles. There are no earlier workings above the proposed and future longwalls in Area 3 and this kind of irregularity will not occur in this case.

5.21.5. The Likelihood of Surface Cracking in Soils and Fracturing of Bedrock

As subsidence occurs, surface cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the longwall perimeters. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the longwall perimeters. The cracks will generally be parallel to the longitudinal edges of the longwall.

It is also likely that cracks would occur above and parallel to the moving extraction face, i.e.: at right angles to the longitudinal edges of the longwall, as the subsidence trough develops. This cracking is, however likely to be transient, since the tensile phase, which causes the cracks to open up, is generally followed by a compressive phase, which partially re-closes them.

Surface tensile fracturing in near surface or exposed sandstone is likely to occur coincident with the maximum tensile strains, but open fractures could also occur due to buckling of surface beds that are subject to compressive strains.

Surface crack widths tend to increase as the depth of cover reduces and only minor fracturing would normally be expected above the proposed and future longwalls in Area 3 where the depths of cover are greater than 300 metres and where the terrain is relatively flat. It is possible, however, that significant surface cracking could occur above the proposed and future longwalls as a result of downhill slumping adjacent to the ridgelines and along the steep slopes, similar to that observed in Area 1, which is described in the following section.

The incidence of cracks on the surface due to mine subsidence, is dependent on the thickness and inherent plasticity of the soils that overlie the bedrock. Surface soils above the proposed and future longwalls in Area 3 are generally weathered to some degree. The widths and frequencies of the cracks are also dependent upon the pre-existing jointing patterns in the bedrock. Large joint spacing can lead to concentrations of strain and possibly the development of fissures at rockhead, which are not necessarily coincident with the joints.

A joint spacing of ten metres is not unusual for Hawkesbury Sandstone which generally is the underlying strata within the Study Area. The maximum predicted tensile strain resulting from the extraction of the proposed and future longwalls is 4.5 mm/m and, therefore, the fractures at the joints are expected to be in the order of 50 mm. If a reasonable thickness of surface soil exists, it is more likely that the surface soil would exhibit a number of cracks of lesser width rather than one large crack.

Fig. 5.18 shows the relationship between the depth of cover and the width of surface cracks in relatively flat terrain, based upon measured data in the NSW Coalfields and observations over mines in the United Kingdom. The line on the graph represents the upper bound limit of the data in relatively flat terrain.

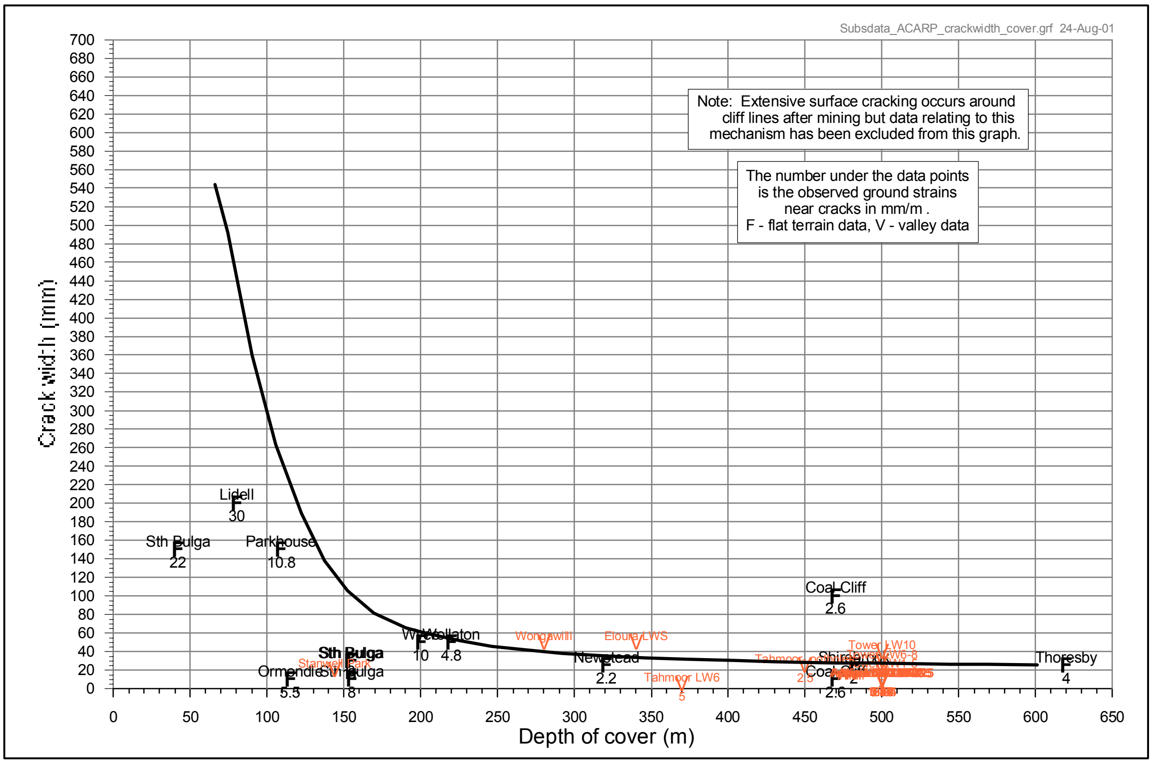


Fig. 5.18 Relationship between Crack Width and Depth of Cover

It can be seen that the maximum crack width at a depth of cover of 300 metres, due to normal subsidence movements, would generally be expected to be in the order of 40 to 50 mm where the terrain is relatively flat. Larger cracks are expected to occur adjacent to the ridgelines and along the steep slopes, however, similar to that observed in Areas 1 and 2, which are described in Sections 5.21.6 and 5.21.7.

Cracking is also often found in the beds of creek and river valleys due to the strains associated with upsidence and valley closure. As discussed in Sections 5.3 to 5.5, the predicted closure across the valleys of the creeks and drainage lines will result in elevated levels of compressive strain at the bases of the valleys. This could lead to localised fracturing and buckling of the bedrock at the bases of the creeks and drainage lines and tensile cracks at the tops of the valley sides.

Further discussion on surface cracking is provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

5.21.6. Observed Surface Cracking in Area 1 at Dendrobium Mine

During the extraction of Longwalls 1 and 2 in Area 1 at Dendrobium Mine, a number of surface cracks were observed along Fire Road 15C. The locations of Fire Road 15C and the observed surface cracks are shown in Fig. 5.19.

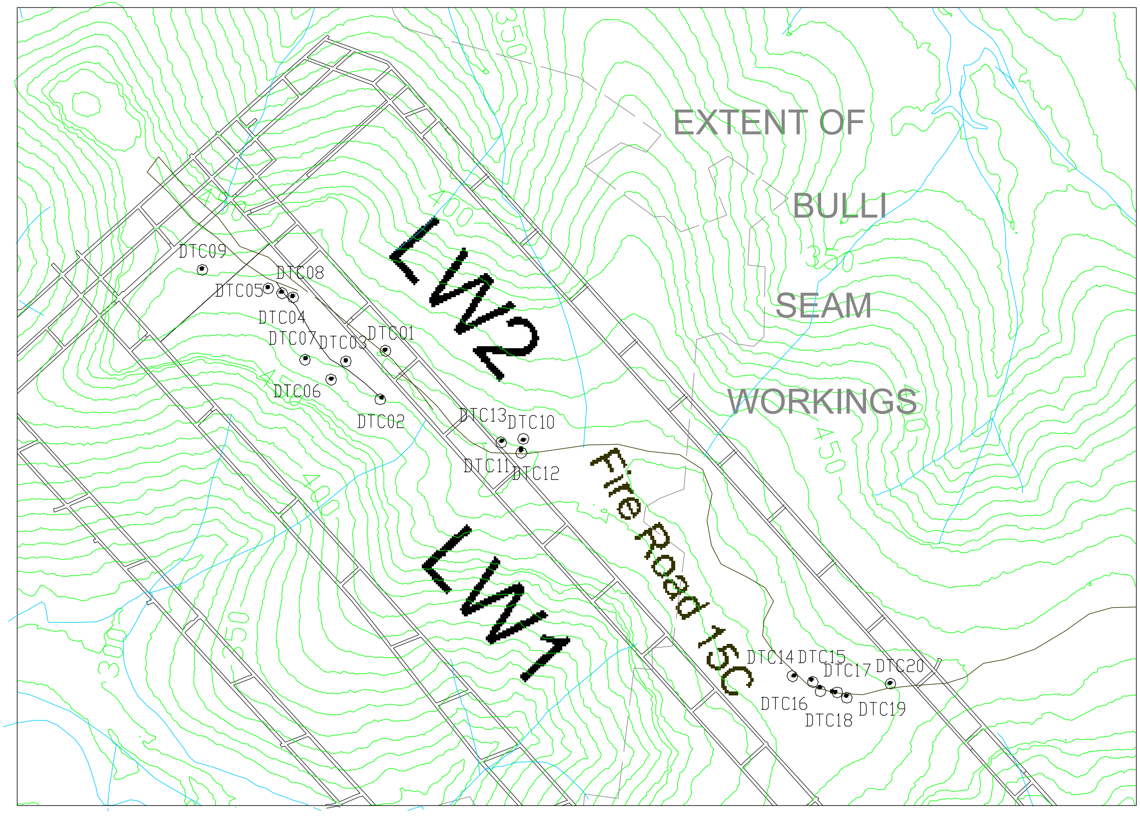


Fig. 5.19 Locations of Observed Surface Cracking above Longwall 1 in Area 1

The larger observed surface cracks in Area 1 were associated with the slippage of soils adjacent to the ridgeline and down the steep slopes, resulting in large tension cracks at the tops of the slopes and compressive ridges at the bottom of slopes. The widths of the observed surface cracks at the tops of the ridgeline and steep slopes varied up to 400 mm wide. Additional surface cracks, typically in the order of 100 mm to 150 mm in width, were also observed further down the ridgeline and steep slopes.

It is expected that the slippage of soils down the steep slopes above proposed Longwalls 6 to 10 in Area 3A and above the future longwalls in Areas 3B and 3C would also occur, resulting in surface cracks and openings similar to that observed above Longwalls 1 and 2 in Area 1. The depth of cover is greater and the terrain is flatter in Area 3 than in Area 1 and, therefore, it is expected that the maximum crack widths above the proposed and future longwalls in Area 3 would be less than that observed in Area 1.

5.21.7. Observed Surface Cracking in Area 2 at Dendrobium Mine

During the extraction of Longwall 3 in Area 2 at Dendrobium Mine, a number of large surface cracks were observed above the commencing end of the longwall. The locations of the observed surface cracks are shown in Fig. 5.20 and a photograph of a typical crack is shown in Fig. 5.21.

Fig. 5.20 Locations of Observed Surface Cracking above Longwall 3 in Area 2

Fig. 5.21 Photograph of an Observed Surface Crack above Longwall 3 in Area 2

The largest surface cracks above Longwall 3 occurred where the depth of cover is the shallowest, being a minimum of 145 metres above the commencing end of this longwall. As discussed in Section 5.21.5, the maximum width of surface cracking generally decreases as the depth of cover increases.

The depth of cover above the proposed Longwalls 6 to 10 in Area 3A varies between 255 metres and 400 metres, with the depth of cover generally being greater than 300 metres above the central sections of the longwalls. The depths of cover in Areas 3B and 3C vary between 215 metres and 425 metres, with the depths of cover also generally being greater than 300 metres. It is likely, therefore, that the maximum width of surface cracking resulting from the extraction of the proposed and future longwalls in Area 3 would be less than that observed above the commencing end of Longwall 3.

5.21.8. The Likelihood of Gas Emissions at the Surface

It is known that the mining of coal causes fracturing of the strata above the coal seam and this may result in the liberation of methane and other gases. Methane, being a lighter gas, tends to move upwards to fill the voids in the rock mass and diffuse towards the surface through any continuous cracks or fissures.

Some strata, however, have lower permeability and are able to act as barriers to water and gas movements. One such barrier is the Bald Hill Claystone, which separates the Hawkesbury and Bulgo Sandstones and impedes the movement of water and gas.

If the claystone were to be fractured by subsidence of the strata, it is possible that some gas and/or water could move upwards through the cracks. It is also possible that water could move downwards through the cracks, but the increase in moisture content of the claystone would cause it to swell and seal off the cracks, thus impeding further gas or water movements. An analysis of the bore hole geophysical testing in the IC exploration bore holes in Area 3A by Coalbed Geoscience (2005) indicates that there is negligible gas in the overburden.

Gas emissions at the surface have typically occurred within deep river valleys such as the Nepean, Cataract and Georges Rivers, although some gas emissions have also been observed in smaller creeks and in water bores. Analyses of gas compositions indicate that the coal seam is not the direct and major source of the gas and that the most likely source is the Hawkesbury Sandstone (APCRC, 1997).

Gas emissions from the beds of creeks and drainage lines will not have time to dissolve significantly into any surface water which is present. In addition to this, gas emissions as the result of mining comprises mainly of methane which is not significantly soluble in water. The gas emissions, therefore, are released into the atmosphere and are unlikely to have a significant impact on water quality.

It is possible, however, that substantial gas emissions at the surface could result in localised vegetation die back. This occurred at Tower Colliery over small areas in the base of the Cataract Gorge, as a result of gas emissions directly above Longwalls 10 and 14. These impacts were limited to small areas of vegetation, local to the points of emission where enhanced composting occurred. The gas emissions have declined and the affected areas have successfully recovered.

It should also be noted that the emission of gases at the surface tends to be short-lived temporary events and the consequences are generally minor and readily managed. There have been no reported cases of significant gas emissions from mining within the Wongawilli Seam that have resulted in the death of vegetation. It is unlikely that there would be any significant impact from gas releases to the surface as a result of the proposed mining.

Further discussions on the potential impact of gas emissions of flora and fauna are provided in the report by Biosis (2007a).

5.21.9. The Potential Impacts of Ground Vibration on Structures due to Mining

The settlement of the ground resulting from systematic subsidence is generally a gradual and progressive movement, the effect of which is not apparent to an observer at the surface. The major breakage and collapse of strata into the voids left by extraction of the seam occur in the layer immediately above the seam. Above that level, the breakage and collapse of the strata reduces to become a bending and sagging of the upper layers of rock with less sudden and much smaller movements occurring. In some instances, the movements can be concentrated at faults or other points of weakness in the strata with minor stepping at the surface.

Any major collapse below ground would result in some vibration in the layers of rock above it, which might be felt as a minor effect at the surface. This effect is generally only noticeable where the depth of cover is less than 100 metres, which does not occur above the proposed and future longwalls in Area 3.

It is possible, therefore, as the proposed and future longwalls in Area 3 are mined and the strata subsides, for some vibrations to be felt at the surface, though these are more likely to occur directly above or close to the longwalls. The levels of vibration would, however, generally be very low and would not be of sufficient amplitude to result in any significant impact on the natural features or items of infrastructure. The impact due to vibration resulting from the extraction of the proposed and future longwalls in Area 3 is predicted to be insignificant.

5.21.10.The Potential for Noise at the Surface due to Mining

It would be very unusual for noise to be noticed at the surface due to longwall mining at depths greater than 100 metres. As systematic subsidence occurs and the near surface rocks are affected by tensile and compressive strains, the rocks open up at joints and planes of weakness, and displace due to rotation and shear.

Generally the movements are gradual and cannot be detected by an observer at the surface. These movements are also generally shielded by the more plastic surface soils which tend to distribute the strains more evenly and insulate against any sounds from below.

In some cases, the stresses in the rock can build up to the point that the rock suddenly shears to form a new fracture and if the rock is exposed or has only a thin covering of surface soil, the noise resulting from the fracturing can be heard at the surface. Normally the background level of noise in the countryside is high enough to ensure that the sound is not noticed, although in the stillness of night, it might occasionally be noticed when it occurs in close proximity. The impact due to noise at the surface resulting from the extraction of the proposed and future longwalls in Area 3 is predicted to be insignificant.

5.22. Comparison of Predicted Subsidence Parameters Obtained using the Holla Series and Department's Handbook Methods

The maximum predicted systematic subsidence parameters along Prediction Line A, obtained using the Incremental Profile Method, were compared with the maximum subsidence parameters obtained using the Holla Series Method (Holla 1988) and the Department's Handbook Method (Holla 1985).

The Holla Series and the Department's Handbook Methods only allow the prediction of the maximum values of subsidence, tilt, curvature and strain, and do not precisely indicate where these maxima will occur. The comparisons were limited to, therefore, the maximum predicted values of each parameter over the proposed longwalls.

The overall void widths of Longwalls 6 to 10 in Area 3A are 250 metres and the solid chain pillars between each of the proposed longwalls are 40 metres. Along Prediction Line A, the depth of cover varies between 320 and 380 metres, with an average depth of cover of 350 metres. A seam thickness of 3.9 metres will be extracted for the proposed longwalls.

The maximum predicted systematic subsidence obtained using the Holla Series Method is determined from Figure 4 of a published paper which has been reproduced in Fig. 5.22. This figure provides the maximum predicted subsidence, as a ratio of the extracted seam thickness, for varying panel width-to-depth ratios and varying pillar width-to-depth ratios, based on critical extraction conditions.

Strictly speaking, the Department's Handbook Method is only applicable for a range of width-to-depth ratios between 0.23 and 0.45 and, therefore, does not apply to longwalls having a width-to-depth ratio outside this range.

Based on an individual panel width-to-depth ratio of 0.71 (i.e.: 250 metres / 350 metres) and pillar width-to-depth ratio of 0.11 (i.e.: 40 metres / 350 metres), the maximum predicted subsidence obtained using Fig. 5.22 is 0.49 times the extracted seam thickness, giving a total maximum predicted subsidence of 1900 mm. It should be noted that the maximum predicted subsidence obtained using the Holla Series Method is based on achieving critical extraction conditions.

The maximum predicted systematic tilts and strains can be obtained using the Department's Handbook Method by multiplying various factors by the maximum predicted subsidence in millimetres and dividing the result by the depth of cover in metres. The factors for tensile strain, compressive strain and tilt are given in Figures 14, 15 and 17, respectively, of the handbook. The curvatures are determined from the strains using Figure 18 of the handbook.

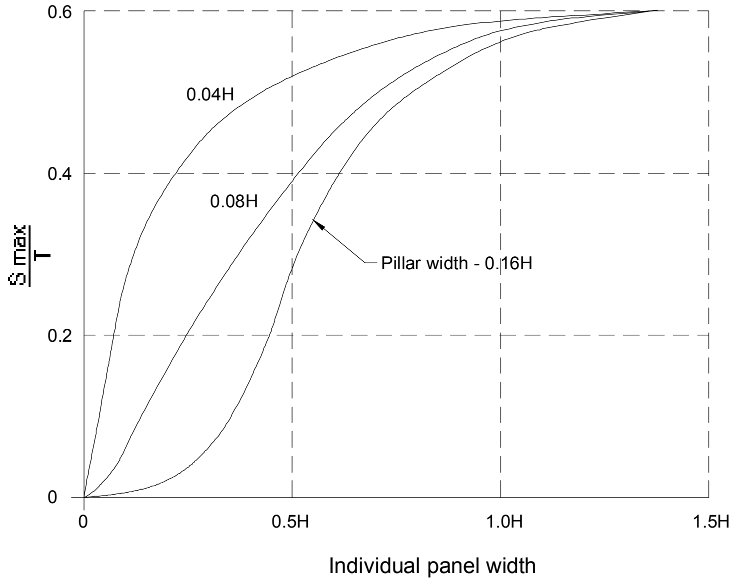


Fig. 5.22 Graph for the Prediction of Maximum Subsidence over a Series of Panels for Critical Extraction Conditions (after Holla 1988)

In the Department's Handbook Method, the tilt and strain factors are only applicable to single panels, but, based upon the definition of width, W, in the new handbook, it appears that the factors can be used to determine the tilts and strains over a series of longwall panels, using the overall width of the series to determine the width-to-depth ratio. For a series of panels with a width-to-depth ratio above 1.4, i.e.: for critical extraction conditions, the tilt factor is 3.0, the tensile strain factor is 0.4 and the compressive strain factor is 0.9.

The maximum predicted values of systematic subsidence, tilt, curvature and strain along Prediction Line A obtained using the Incremental Profile Method are compared to those obtained using the Holla Series and Department's Handbook Methods in Table 5.30.

Table 5.30 Comparison of Maximum Predicted Parameters Obtained using Alternative Methods

Predicted Parameter	Incremental Profile Method	Holla Series and the Departments Handbook Methods
Vertical Subsidence (mm)	1950	1900
Tilt (mm/m)	17	16
Hogging Curvature (1/km)	0.20	0.16
Sagging Curvature (1/km)	0.53	0.22
Tensile Strain (mm/m)	3.0	2.2
Compressive Strain (mm/m)	8.0	4.9

It can be seen from Table 5.30, that the maximum predicted systematic subsidence parameters obtained using the Incremental Profile Method are similar to, but slightly greater than those obtained using the Holla Series and Department's Handbook Methods.

5.23. Testing of the Incremental Profile Method against Measured Data at Dendrobium Mine

The following sections provide comparisons between the predicted and observed ground movements for Longwalls 1 and 2 in Area 1 and for Longwall 3 in Area 2 at Dendrobium Mine. The Incremental Profile Method was used to predict the systematic subsidence movements resulting from the extraction of these longwalls. The ground movements resulting from the extraction of these longwalls were monitored using a number of methods including:-

- aerial laser scans before and at the completion of mining,
- a number of 3D monitoring points over the surface at some roads and easily accessible locations that were used as a control for the aerial laser scans, and
- 2D monitoring points along the D1000 and D2000 monitoring lines which were measured both during and at the completion of mining.

5.23.1. Comparisons between the Predicted and Observed Movements for Longwall 1 in Area 1 at Dendrobium Mine

The location of Longwall 1 in Area 1 at Dendrobium Mine and the locations of the 3D monitoring points and the D1000 monitoring line are shown in Fig. 5.23. The predicted systematic subsidence contours, determined using the Incremental Profile Method, and the maximum observed subsidence at the 3D monitoring points resulting from the extraction of Longwall 1 are also shown in this figure.

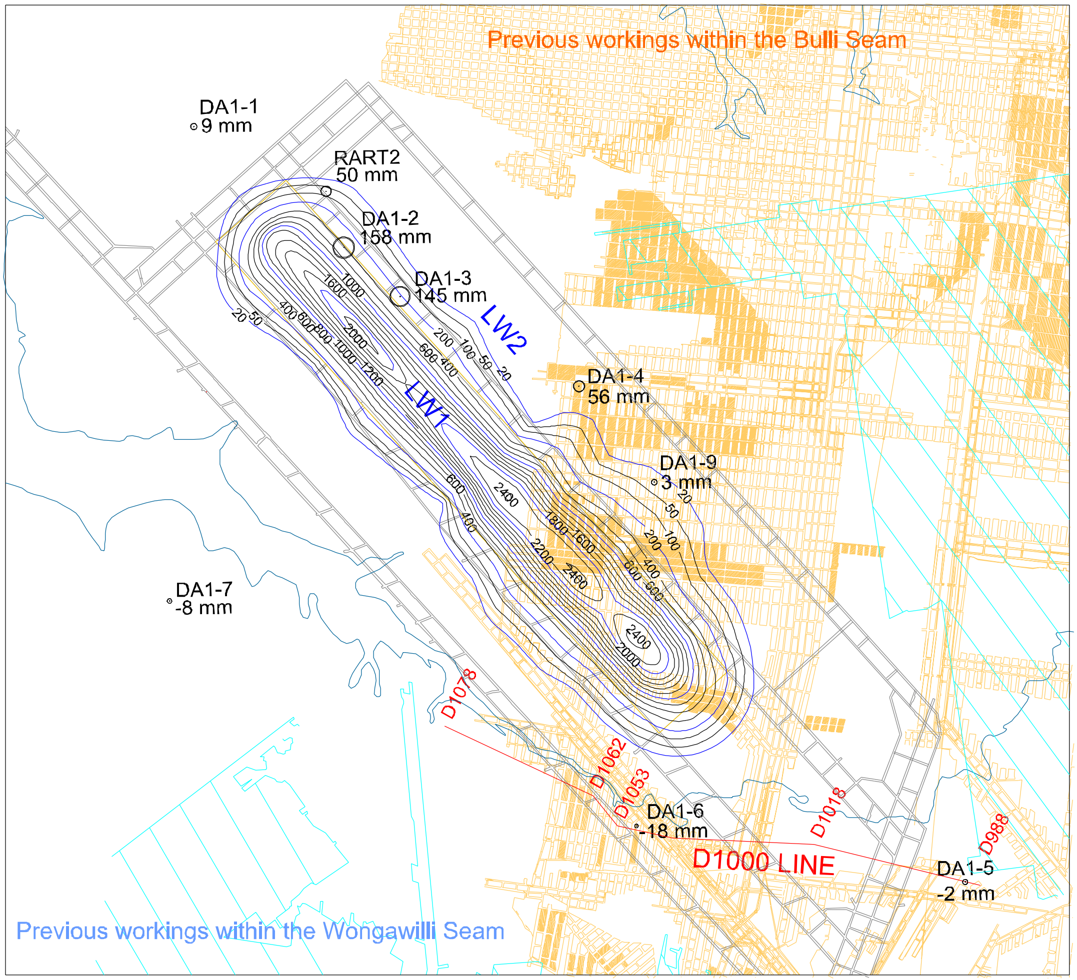


Fig. 5.23 Predicted Subsidence Contours and Observed Subsidence at the 3D Monitoring Points Resulting from the Extraction of Longwall 1 in Area 1

A comparison between the predicted systematic subsidence and the observed subsidence at the 3D monitoring points, at the completion of Longwall 1, is summarised in Table 5.31. This table shows both the predictions exactly at each monitoring point location and the predictions within 20 metres of each monitoring point location.

Table 5.31 Comparison between Predicted and Observed Subsidence after Longwall 1 in Area 1

Location	MGA Easting	MGA Northing	Predicted Subsidence at Monitoring Point (mm)	Predicted Subsidence within 20 metres of Monitoring Point (mm)	Observed Subsidence at Monitoring Point (mm)
DA1-1	296925	6192070	< 20	< 20	9
DA1-2	297320	6191750	425	600	158
DA1-3	297470	6191620	225	350	145
DA1-4	297945	6191380	< 20	< 20	56
DA1-5	298965	6190065	< 20	< 20	-2 (Upsidence)
DA1-6	298095	6190215	< 20	< 20	-18 (Upsidence)
DA1-7	296860	6190810	< 20	< 20	-8 (Upsidence)
DA1-8	299410	6190775	< 20	< 20	-1 (Upsidence)
DA1-9	298145	6191125	35	45	3
RART2	297275	6191900	75	125	50

It can be seen from the above table that the predicted systematic subsidence was greater than the observed subsidence in all locations, except at point DA1-4 which, as can be seen in Fig. 5.23, was located near previous pillar extraction areas in the Bulli Seam. It can also be seen from this table that four monitoring points experienced upsidence, being points DA1-5 to DA1-8, which are located along the creek alignments and within the valley of Lake Cordeaux. The observed subsidence at the monitoring points, due to the extraction of Longwall 1, indicates that the Incremental Profile Method has generally provided conservative subsidence predictions.

The D1000 monitoring line is located at a minimum distance of 240 metres from Longwall 1, as shown in Fig. 5.23, which is outside the 35 degree angle of draw line from the longwall. The maximum predicted systematic subsidence along the D1000 monitoring line was, therefore, less than 2 mm, and the maximum predicted systematic tilts and strains were less than 0.1 mm/m.

A number of survey pegs along the monitoring line were damaged prior to the completion of Longwall 1. The maximum observed subsidence along the D1000 line after the extraction of Longwall 1, excluding the damaged pegs, was 9 mm at peg D1068C, which is located 275 metres from Longwall 1. The maximum observed tilt and strain, excluding the damaged pegs, were 0.3 mm/m and was 0.2 mm/m, respectively, which are less than survey tolerance.

Although the maximum observed subsidence parameters are greater than the maximum predicted systematic subsidence parameters, the observed movements are extremely small and would be unlikely to result in any significant impacts at the location of the monitoring line. It is possible that the observed ground movements are the result of regional movements, or natural ground movements resulting from the lowering of the reservoir surface water and groundwater levels, or from local ground swelling due to moisture content, rather than from systematic subsidence movements.

The surface levels in Area 1 were determined by aerial laser scans before and at the completion of Longwall 1. The contours of observed changes in surface level were determined by taking the difference between the surface levels before and after mining and are shown in Fig. 5.24.

The accuracy of surface levels interpreted from the aerial laser scans are in the order of ±150 mm. The accuracy of the observed changes in surface level, which are the differences in heights between the two aerial laser scans are, therefore, in the order of ±300 mm. There is also a larger scatter in the observed surface levels from the aerial laser scans which result from heights being measured off natural features including trees, undergrowth and rocks. The scatter resulting from these features, however, can be smoothed to a certain extent.

It should also be noted that the contours of observed changes in surface level, developed from the aerial laser scans, show the changes in heights of points at fixed eastings and northings. This differs from the traditionally observed or predicted subsidence contours which include both vertical and horizontal components of the surface movements at fixed points on the surface. Horizontal movements are traditionally included in the subsidence profiles, as monitoring data is generally based on the movements of ground pegs, which are fixed in the ground.

The contours of observed changes in surface level, developed from the aerial laser scans, can be more difficult to interpret in locations of steep terrain, such as at cliffs, as the surface moves horizontally towards the centre of the goaf as the ground subsides, or can move down slope in steep terrain. Hence, the observed changes in surface level determined from the aerial laser scans, at fixed eastings and northings, can be dramatic and do not provide a realistic indication of the actual or “traditional” subsidence at a point, such as at survey pegs. Where the ground is reasonably level, however, the contours of observed changes in surface level should provide a good indication of the actual subsidence.

The observed changes in surface level resulting from the extraction of Longwall 1, determined from the aerial laser scans, are shown in Fig. 5.24. The profiles of observed changes in surface level and predicted systematic subsidence were compared along one longitudinal line and two transverse cross lines which are shown in Fig. 5.25. The locations of the longitudinal and transverse lines are shown in Fig. 5.24.

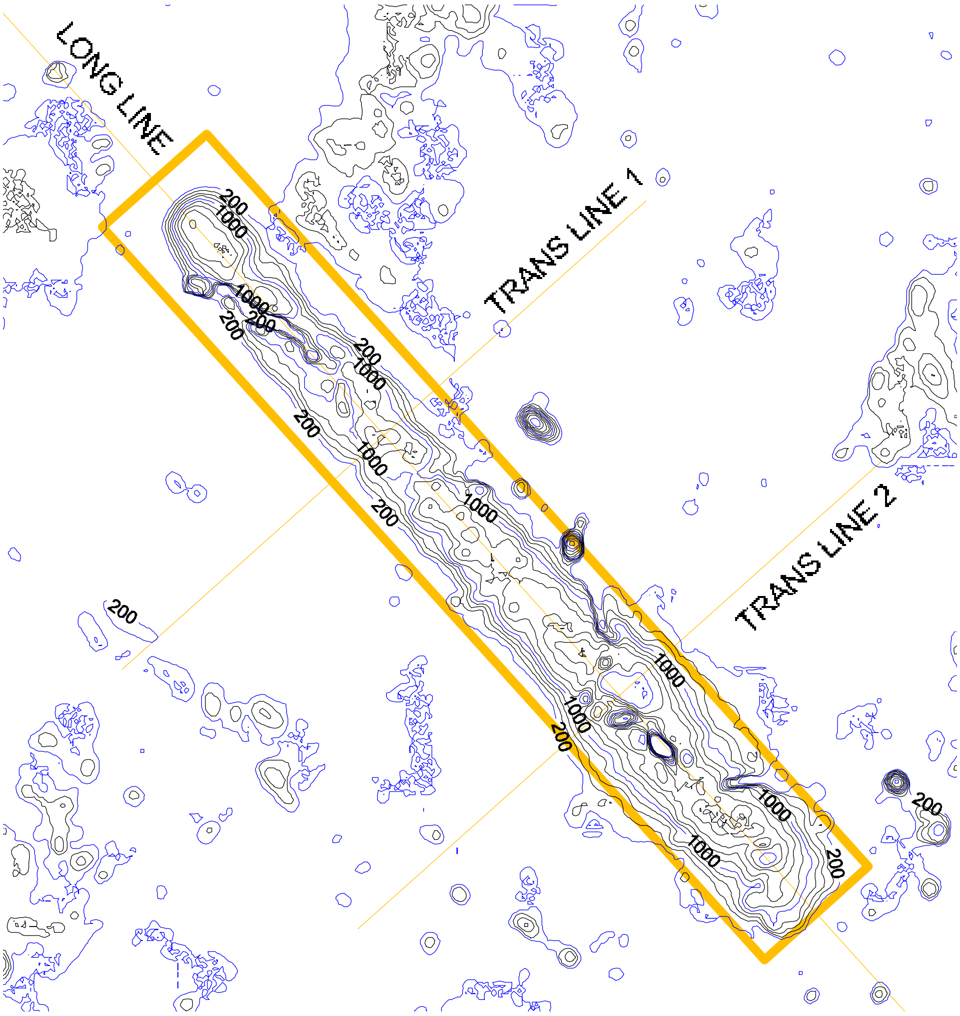


Fig. 5.24 Observed Change in Surface Level Contours after the Extraction of Longwall 1 in Area 1 based on the Aerial Laser Scans

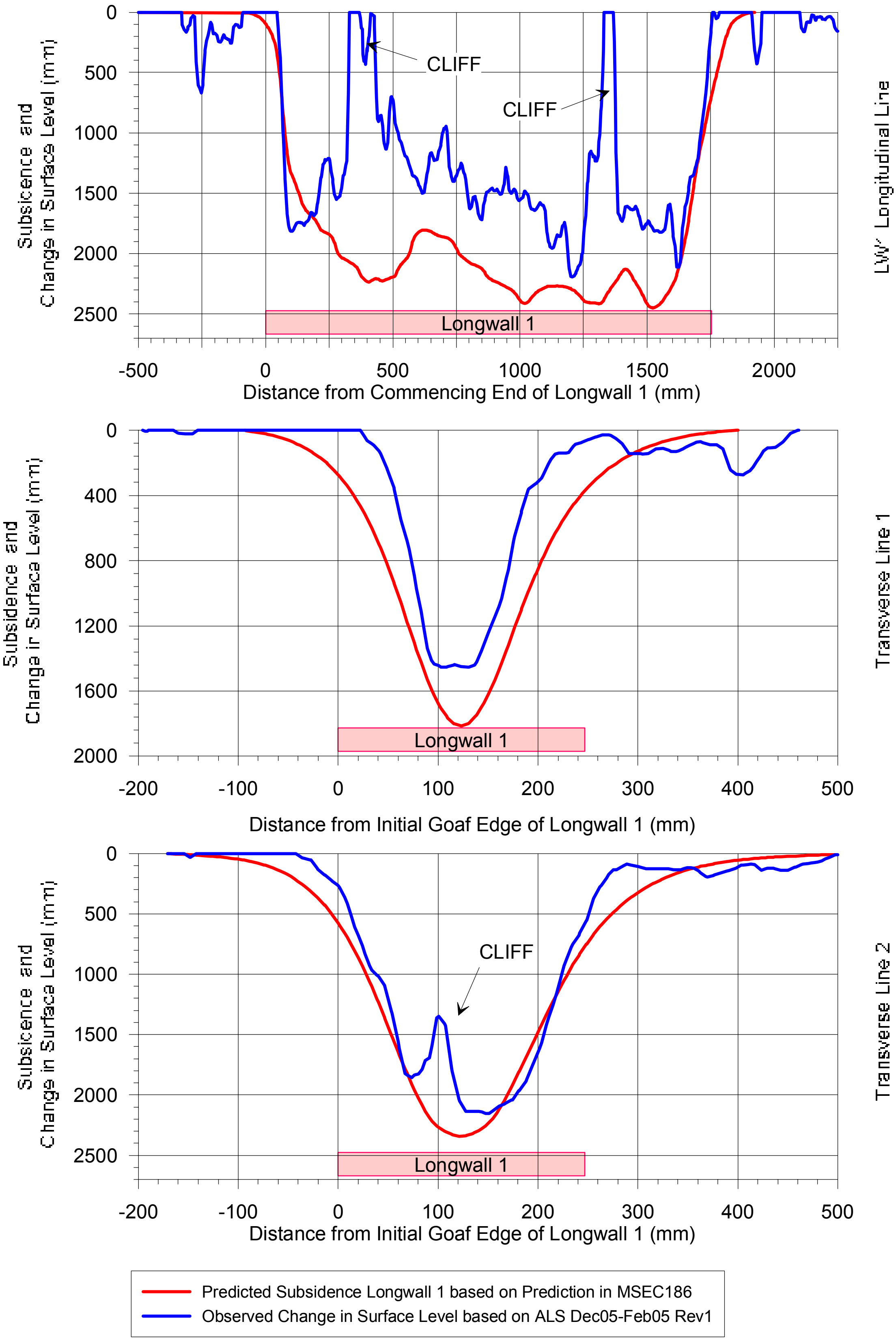


Fig. 5.25 Profiles of Observed Changes in Surface Level and Predicted Subsidence due to the Extraction of Longwall 1 in Area 1

It can be seen from the above figure, that the predicted subsidence is generally greater than the observed changes in surface level. The locations where the observed changes in surface level are greater than the predicted subsidence are generally adjacent to, or outside the goaf, and the differences are generally within the order of accuracy of the aerial laser scans. It can be concluded, therefore, that the Incremental Profile Method provided relatively good and generally conservative subsidence predictions for Longwall 1.

5.23.2. Comparisons between the Predicted and Observed Movements for Longwall 2 in Area 1 at Dendrobium Mine

The locations of Longwalls 1 and 2 at Dendrobium Mine and the locations of the 3D monitoring points and the D1000 monitoring line are shown in Fig. 5.26. The predicted systematic subsidence contours, determined using the Incremental Profile Method, and the maximum observed subsidence at the 3D monitoring points resulting from the extraction of Longwalls 1 and 2 are also shown in this figure.

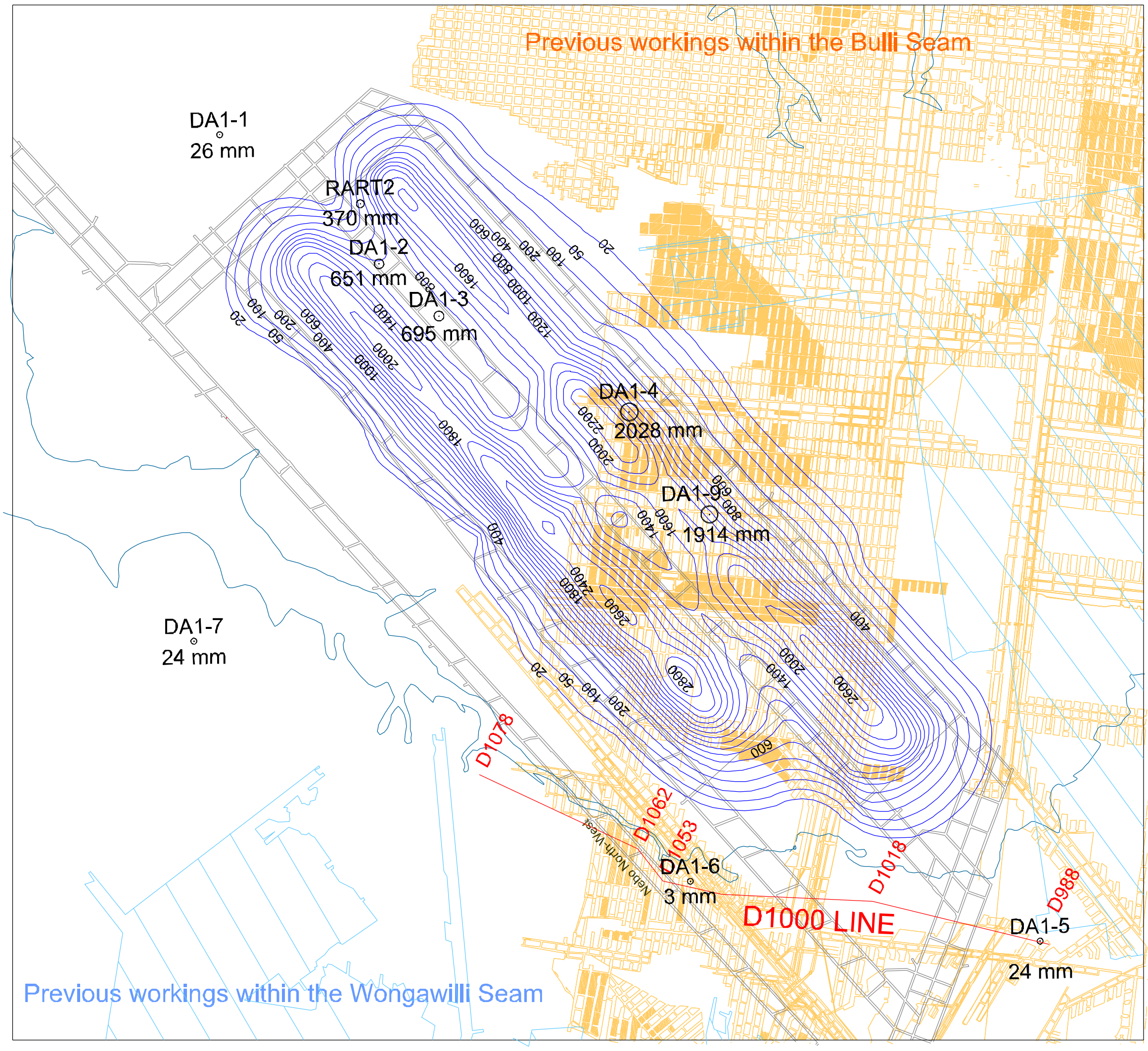


Fig. 5.26 Predicted Subsidence Contours and Observed Subsidence at the 3D Monitoring Points Resulting from the Extraction of Longwalls 1 and 2 in Area 1

A comparison between the predicted systematic subsidence and the observed subsidence at the 3D monitoring points, at the completion of Longwall 2, is summarised in Table 5.32. This table shows both the predictions exactly at each monitoring point location and the predictions within 20 metres of each monitoring point location.

Table 5.32 Comparison between Predicted and Observed Subsidence after Longwall 2 in Area 1

Location	MGA Easting	MGA Northing	Predicted Subsidence at Monitoring Point (mm)	Predicted Subsidence within 20 metres of Monitoring Point (mm)	Observed Subsidence at Monitoring Point (mm)
DA1-1	296925	6192070	< 20	< 20	26
DA1-2	297320	6191750	675	825	651
DA1-3	297470	6191620	700	700	695
DA1-4	297945	6191380	1750	2050	2028
DA1-5	298965	6190065	< 20	< 20	24
DA1-6	298095	6190215	< 20	< 20	3
DA1-7	296860	6190810	< 20	< 20	24
DA1-8	299410	6190775	< 20	< 20	-13 (Upsidence)
DA1-9	298145	6191125	1625	1750	1914
RART2	297275	6191900	125	300	370

It can be seen from the above table that there is a reasonably close match between the predicted and observed values, even in the locations having multi-seam conditions. The observed subsidence at Peg DA1-9 is the only case where the observed subsidence was greater than the predicted subsidence within 20 metres of the peg. It should be noted, that this peg is located over the previously extracted first workings in the Bulli Seam which is between the adjacent pillar extraction areas.

The profiles of observed subsidence, tilt and strain along the D1000 monitoring line, at the completion of Longwall 2, are shown in Fig. 5.27. As described previously, there were a number of survey pegs which were damaged along the monitoring line prior to the completion of Longwall 1. The observed subsidence, tilt and strain profiles along the monitoring line, excluding the damaged pegs, are shown as blue lines in this figure.

The predicted systematic subsidence, tilt and strain profiles along the monitoring line are shown as red lines in this figure. As described previously, the monitoring line is located outside the 35 degree angle of draw line from the longwalls and, therefore, the maximum predicted subsidence was less than 2 mm and the maximum predicted systematic tilts and strains were less than 0.1 mm/m.

The maximum observed subsidence along the monitoring line after the extraction of Longwall 2, excluding the damaged pegs, was 20 mm at peg D1067C, which is located 280 metres from Longwall 1. The maximum observed tilt and strain, excluding the damaged pegs, were 0.3 mm/m and was 0.6 mm/m, respectively.

As described previously, although the maximum observed subsidence parameters are greater than the maximum predicted systematic subsidence parameters, the observed movements are extremely small and would be unlikely to result in any significant impacts at the location of the monitoring line. It is possible that the observed ground movements are the result of regional movements, or natural ground movements resulting from the lowering of the reservoir surface water and groundwater levels, or from local ground swelling due to moisture content, rather than from systematic subsidence movements.

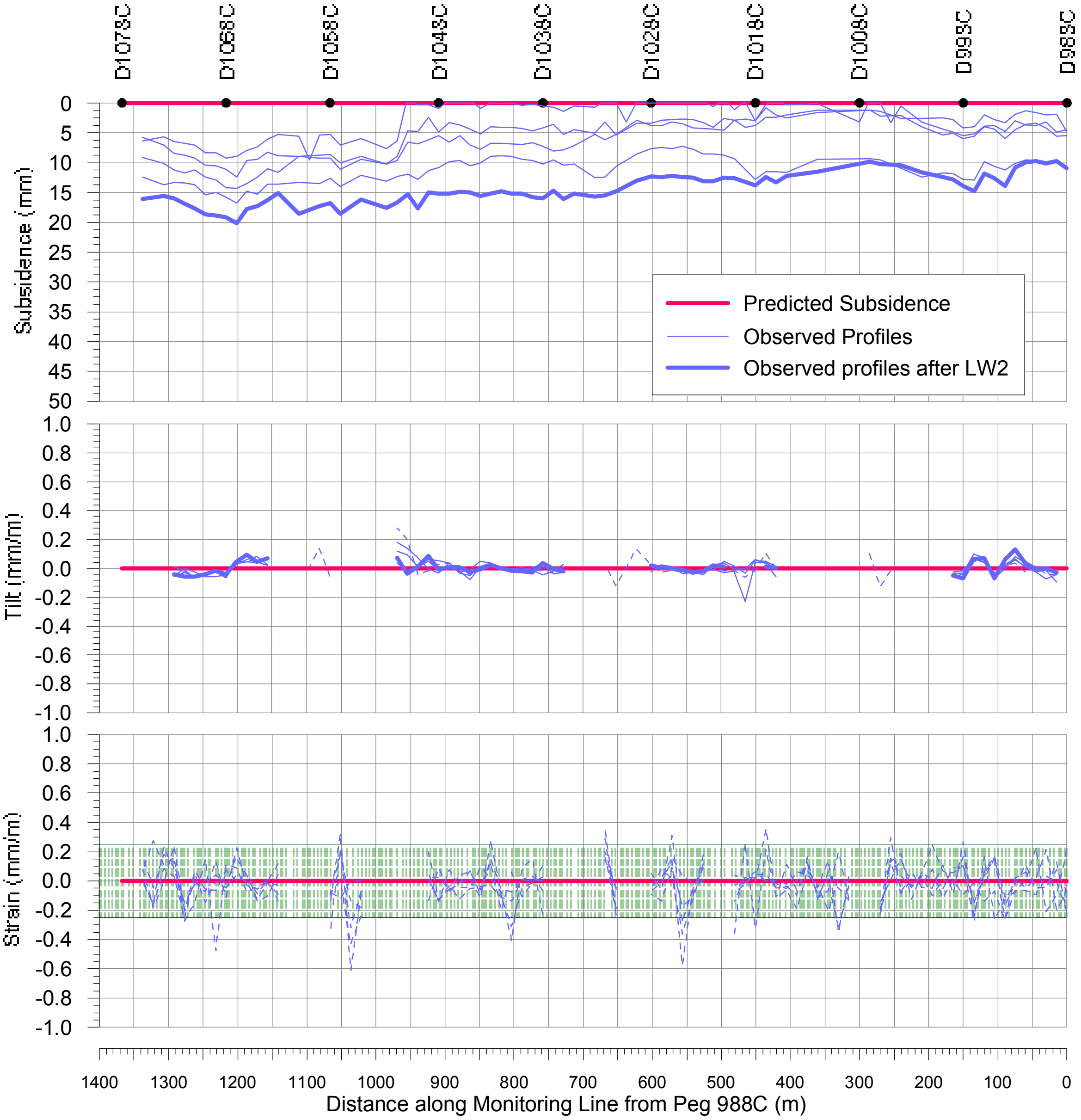


Fig. 5.27 Observed Subsidence Tilt and Strain along the D1000 Monitoring Line

The surface levels in Area 1 were determined by aerial laser scans before and at the completion of Longwall 2. The contours of observed changes in surface level were determined by taking the difference between the surface levels before and after mining and are shown in Fig. 5.28.

As described in Section 5.23.1, the accuracy of the observed changes in surface level, which are the differences in heights between the two aerial laser scans, are in the order of ±300 mm. There is also a larger scatter in the observed surface levels from the aerial laser scans which result from heights being measured off natural features including trees, undergrowth and rocks. The scatter resulting from these features, however, can be smoothed to a certain extent.

As described in Section 5.23.1, the observed changes in surface level, developed from the aerial laser scans, can differ from the traditionally observed or predicted subsidence contours which include both vertical and horizontal components of the surface movements at fixed points on the surface, such as at ground pegs.

The observed changes in surface level resulting from the extraction of Longwalls 1 and 2, determined from the aerial laser scans, are shown in Fig. 5.28. The profiles of observed changes in surface level and predicted systematic subsidence were compared along two longitudinal lines and two transverse cross lines which are shown in Fig. 5.29. The locations of the longitudinal and transverse lines are shown in Fig. 5.28.

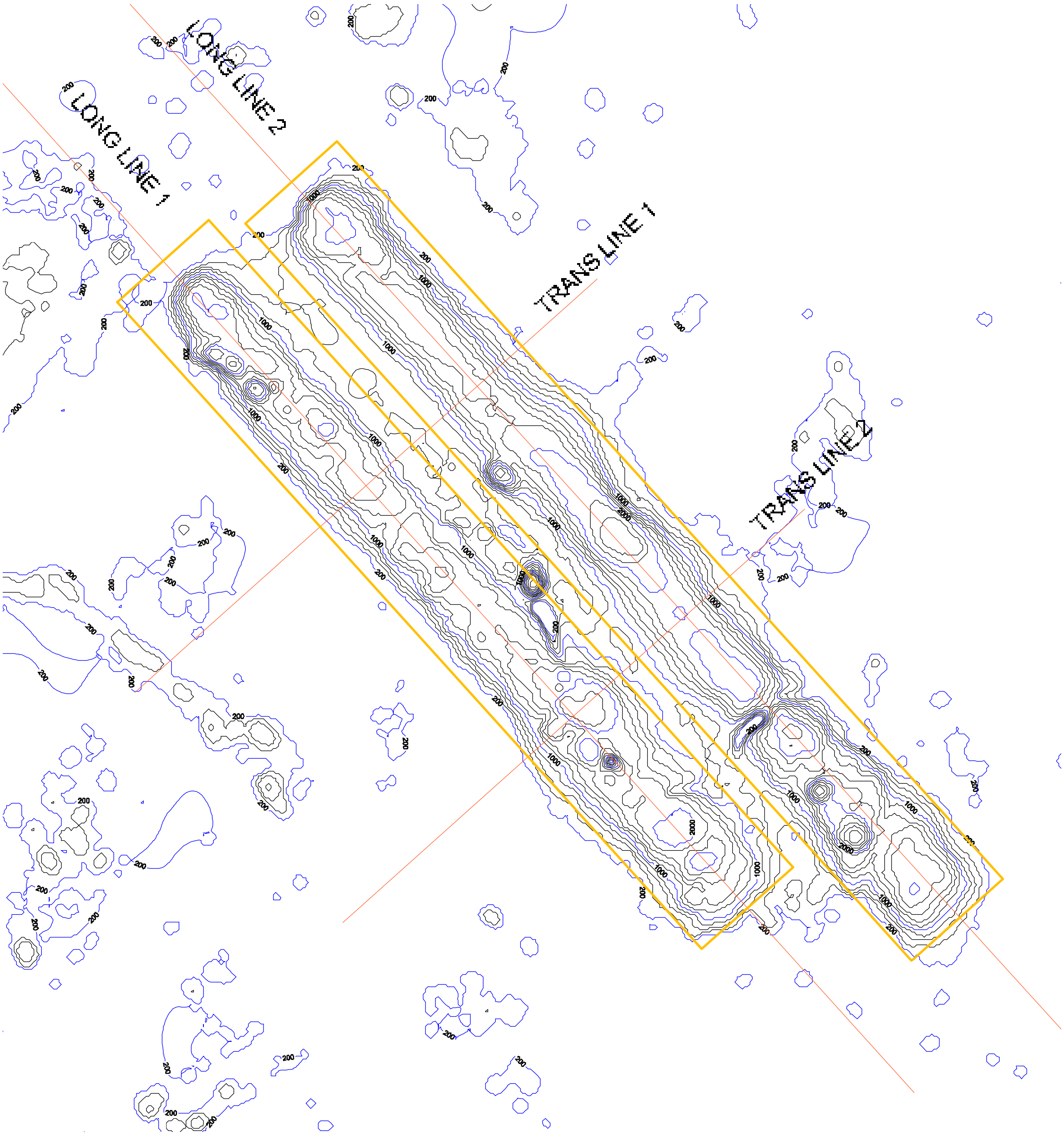


Fig. 5.28 Observed Changes in Surface Level Contours after the Extraction of Longwall 2 in Area 1 based on the Aerial Laser Scans

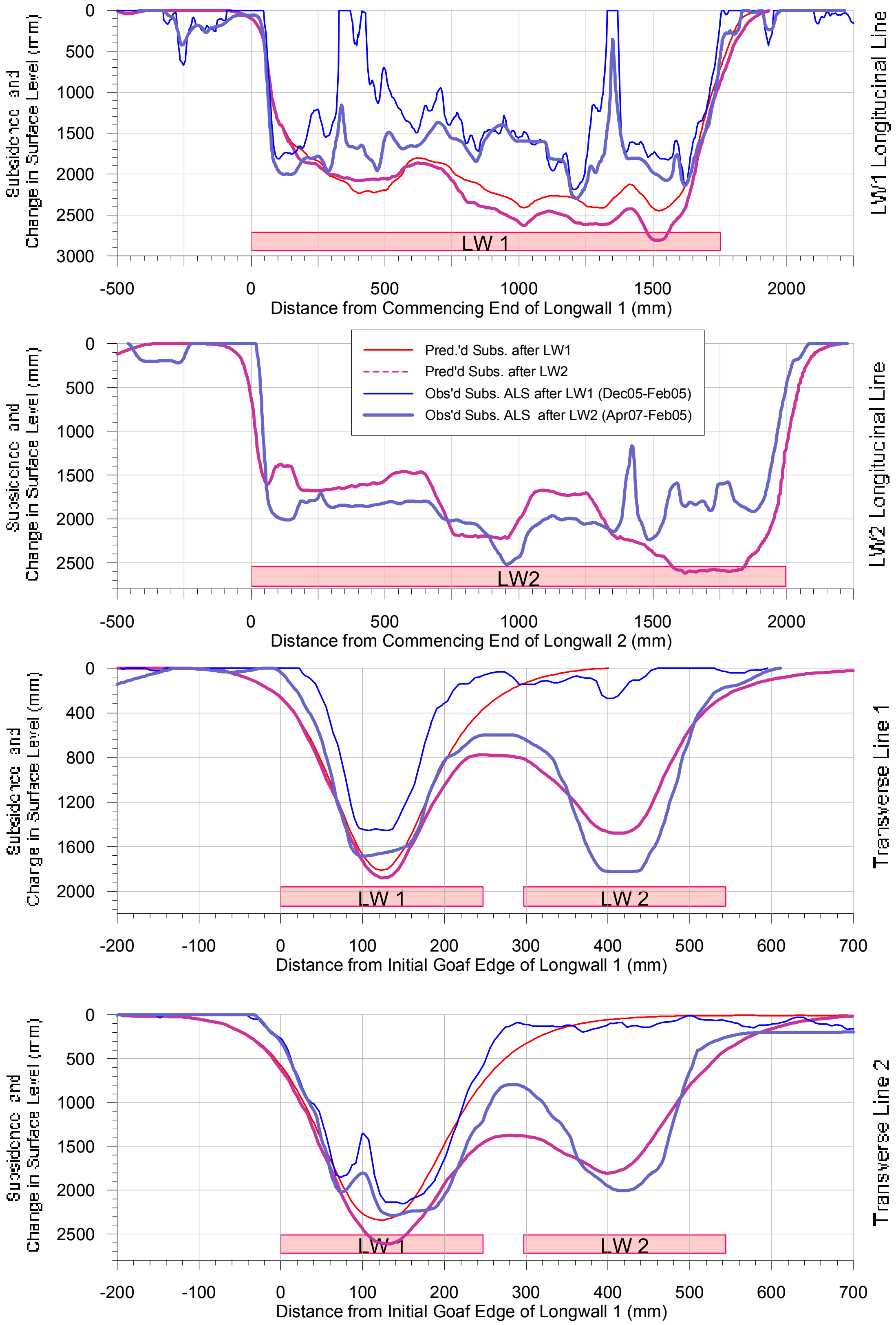


Fig. 5.29 Profiles of Observed Changes in Surface Level and Predicted Subsidence due to the Extraction of Longwalls 1 and 2 in Area 1

It can be seen from the above figure, that the predicted subsidence is generally greater than the observed changes in surface level above Longwall 1. Above Longwall 2, however, the predicted subsidence along Transverse Lines 1 and 2 are less than the observed changes in surface level. It can be seen from Longitudinal Line 2, however, that there are locations above Longwall 2 where the predicted subsidence is greater than the observed changes in surface level and other locations where the predicted subsidence is less than the observed changes in surface level. Overall, the predicted levels of movement above the extracted longwalls are similar to those observed, taking into account the order of accuracy of the aerial laser scans.

5.23.3. Comparisons between the Predicted and Observed Movements for Longwall 3 in Area 2 at Dendrobium Mine

The Incremental Profile Method was used to predict the systematic subsidence movements resulting from the extraction of Longwalls 3 to 5A in Area 2 at Dendrobium Mine. The predicted movements were provided in Report No. MSEC302 (Revision C).

At the time of this report, Longwall 3 had been extracted to approximately mid-length of the panel. The ground movements resulting from the extraction of Longwall 3 have been measured along the D2000 monitoring line. The observed ground movements will also be determined from aerial laser scans at the completion of each longwall in Area 2.

The observed subsidence, tilt and strain profiles along the D2000 monitoring line, taken at four survey dates during the extraction of Longwall 3, are shown in Fig. 5.30. The observed movements, excluding the damaged pegs, are shown as blue lines. The location of the D2000 monitoring line is also shown in this figure. The predicted systematic subsidence, tilt and strain profiles along the monitoring line are shown as red lines in this figure.

The maximum observed subsidence along the monitoring line during the extraction of Longwall 3 was 1004 mm at Peg D2001, which is located over the panel, 65 metres from the commencing end of Longwall 3. It can be seen from Fig. 5.30, that there is a good match between the predicted and observed subsidence profiles.

The maximum observed tilt and strain along the monitoring line, excluding the damaged pegs, were 38 mm/m and 31 mm/m, respectively. It can be seen from Fig. 5.30, that the predicted profiles of tilt and strain matched the observed profiles reasonably well, except in the last bay of the monitoring line, where these parameters were the greatest. It is difficult to compare the predicted and observed tilts and strains in this location, however, as the second last peg in the monitoring line was damaged. In addition to this, surface cracking occurred at the commencing end of Longwall 3, which is described in Section 5.21.7, and the magnitude of the observed strain, therefore, becomes meaningless as it becomes greatly dependant on the bay lengths along the monitoring line.

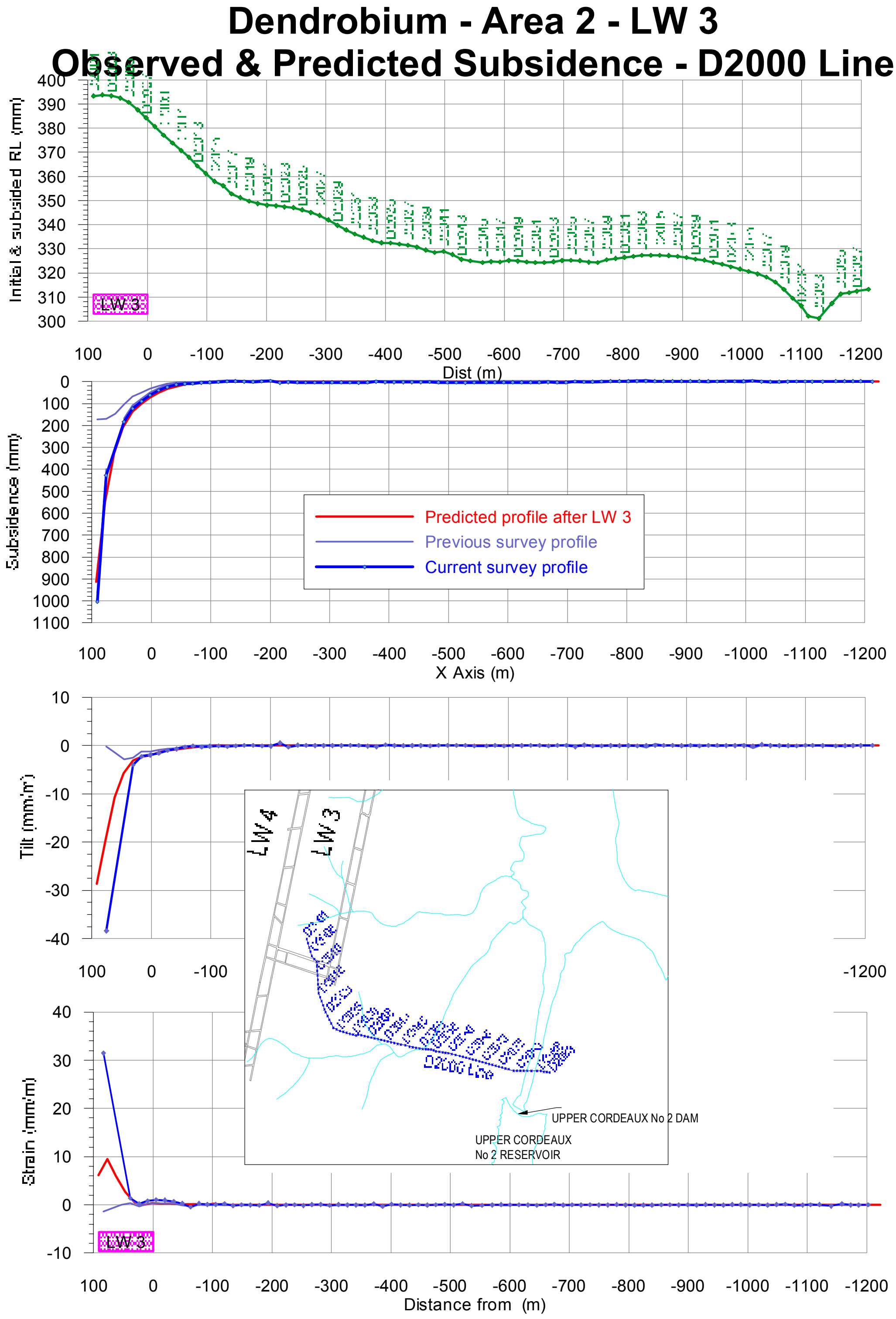


Fig. 5.30 Predicted and Observed Profiles of Subsidence, Tilt and Strain along the D2000 Line Resulting from the Extraction of Longwall 3 in Area 2

5.24. Testing of the Incremental Profile Method against Measured Profiles at Elouera Colliery

Using the Standard Incremental Profile Method for the Southern Coalfield, subsidence predictions were made along the Maldon-Dombarton Railway Survey Line, which crosses transversely over the longwalls at the nearby Elouera Colliery, as shown in Drawing No. MSEC311-27. This represents the only local data that is available outside of Dendrobium Mine.

The monitoring data only comprises of vertical subsidence movements. The predicted and observed subsidence, as well as the surface levels and depths of cover, along the survey line are plotted in Fig. E.10. This graph also shows the predicted total subsidence if a local geological factor of +20 % is applied.

It can be seen that there are differences between the predicted and observed subsidence profiles, though the shapes of the profiles show some similarities, and the profiles over the maingate sides of the longwalls are well represented. It appears from the shapes of the observed profiles over the tailgate sides of the longwalls, that they indicate some residual subsidence over the preceding panels.

The maximum observed incremental subsidence along the monitoring line for Longwall 10 of 540 mm is greater than the maximum predicted incremental subsidence of 415 mm. The shapes of the observed and predicted incremental subsidence profiles over the maingate of Longwall 10 are similar and, therefore, the tilts are well represented in this location. The observed incremental subsidence profile over the tailgate of Longwall 10 is wider and steeper than predicted.

The predicted subsidence profiles along the monitoring line were obtained using the standard Incremental Profile Method for the Southern Coalfield, which uses an empirical database based on monitoring data predominantly from the Bulli Seam. It is likely that the observed incremental subsidence above the tailgate of Longwall 10 is greater than predicted, as the longwall is subcritical and the chain pillar in the Wongawilli Seam is squashing more than an equivalent chain pillar within the Bulli Seam.

Borehole No. S1000 is located over Longwall 5 and the log of this borehole indicates that the strata immediately above the seam includes a high proportion of shale, together with Bulli Seam Coal. The shales in the immediate roof are overlain by thick beds of Bulgo and Hawkesbury Sandstone, which is a possible reason why part of the subsidence over each of the longwalls was delayed until the subsequent longwalls were mined. It should also be noted, that the survey line is located close to Wongawilli Creek and, therefore, was affected by varying degrees of upsidence and closure movements.

This type of phenomenon is unusual in the Southern Coalfield, but the shape of the profile over Longwall 4 at Elouera Colliery is similar to the shapes of the profiles over Longwalls 7, 9, 15 and 16 at Tahmoor Colliery and Longwalls 2 to 6 and 20 to 23 at West Wallsend Colliery. In each case the width-to-depth ratio of the longwalls was approximately 0.6. The most exaggerated shapes were those that were observed over Longwalls 20 to 23 at West Wallsend Colliery and Longwalls 5 and 6 at Elouera Colliery, where the pillar width-to-depth ratios were between 12 % and 17 %.

5.25. Estimation of the Reliability of the Subsidence Predictions

The Incremental Profile Method is based upon a large database of observed subsidence movements in the Southern Coalfield and has been found to give good, if rather conservative results in most cases. An additional factor of safety has been added to the predictions at isolated features as discussed in Section 5.1.

As indicated in Sections 5.23 and 5.24, the predicted subsidence movements obtained using the Incremental Profile Method for Longwalls 1 and 2 in Area 1 and for Longwall 3 in Area 2 at Dendrobium Mine and for the nearby longwalls at Elouera Colliery, have shown a reasonable correlation with the measured movements over those longwalls. It should also be noted, as discussed in Section 5.22, that the maximum predicted subsidence parameters obtained using the Incremental Profile Method are similar to, but slightly greater than those obtained using the Holla Series and Department's Handbook Methods.

The Incremental Profile Method should, therefore, provide realistic and possibly conservative predictions of subsidence, tilt, curvature and strain for the proposed and future longwalls in Area 3 at Dendrobium Mine. The predicted profiles obtained using this method also reflect the way in which each parameter varies over the mined area and indicate the movements that are likely to occur at any point on the surface.

It is likely, however, that the predicted systematic tilts, curvatures and strains will be exceeded at the creeks and drainage lines, as described in Sections 5.3 to 5.5. The predicted net vertical movements, due to the addition of subsidence and upsidence movements, and the compressive strains due to valley closure movements along the alignments of the creeks are provided and discussed in these sections.

It is possible that localised irregularities could occur elsewhere in the subsidence profiles and the likelihood of these are discussed in Section 5.21.4. Elsewhere, it is reasonable to assume that any significant irregularities or anomalies in the subsidence profiles would be relatively infrequent occurrences.

Empirical methods of subsidence prediction are generally accepted as providing predictions of maximum subsidence to an accuracy of −10 % to +15 %. It was indicated by Dr Lax Holla (1991), in his paper entitled, "Reliability of Subsidence Prediction Methods for use in Mining Decisions in New South Wales", that the accuracy of predictions of maximum subsidence, made using the Department's Empirical Method, generally ranged from +8 % to -11 %. Of the 14 examples, referred to in the paper, from longwalls at seven different collieries in the Southern and Newcastle Coalfields, the predicted maximum subsidence was less than the measured maximum subsidence in only four cases. Where empirical models have been calibrated to local data, even greater accuracies have been found to be possible in predicting the maximum values of the subsidence parameters.

The prediction of systematic subsidence parameters at a specific point is more difficult, but, based upon a large number of comparative analyses, it has been concluded that the vertical subsidence predictions for single seam extractions, obtained using the Incremental Profile Method, should generally be conservative where the geology is consistent and the model has been calibrated to local data. Where subsidence is predicted at points beyond the goaf edge, which are likely to experience very low values of subsidence, the predictions should generally be accurate to within 50 mm of subsidence.

In this case, however, the model has not been fully calibrated to local data, since little local data is available and, therefore, variations in the order of ±25 % are possible between the maximum predicted and maximum observed subsidence parameters for the proposed and future longwalls in Area 3.

The systematic tilts can be predicted to the same level of accuracy as subsidence, but the measured curvatures and strains can vary considerably from the predicted systematic values for the following reasons:-

- Variations in local geology can affect the way in which the near surface rocks are displaced as subsidence occurs. In the compression zone, the surface strata can buckle upwards or can fail by shearing and sliding over their neighbours. If localised cross bedding exists, this shearing can occur at relatively low values of stress. This can result in fluctuations in the local strains, which can range from tensile to compressive. In the tensile zone, existing joints can be opened up and new fractures can be formed at random, leading to localised concentrations of tensile strain.
- Where a thick surface layer of soil, clay or rock exists, the underlying movements in the bedrock are often transferred to the surface at reduced levels and the measured strains are, therefore, more evenly distributed and hence more systematic in nature than they would be if they were measured at rockhead.
- Strain measurements can sometimes give a false impression of the state of stress in the ground. For example:
    - buckling of the near-surface strata can result in localised cracking and apparent tensile strain in areas where overall, the ground is in fact being compressed, because the actual values of the measured strains are dependent on the locations of the survey pegs.
    - where joints open up or cracks develop in the tensile phase and fail to close in the compressive phase, as they sometimes do if they are subsequently filled, the ground can appear to be in tension when it is actually in compression.
- Sometimes, survey errors can also affect the measured strain values and these can result from movement in the benchmarks, inaccurate instrument readings, or disturbed survey pegs. In these circumstances it is not surprising that the predicted systematic strain at a point does not match the measured strain.
- In sandstone dominated environments, much of the earlier ground movements can be concentrated at the existing natural joints, which have been found to be at an average spacing of 7 to 15 metres.

It is also recognised that the ground movements above a longwall panel can be affected by the gradient of the coal seam, the direction of mining and the presence of faults and dykes within the panel, which can cause a lateral shift in the subsidence profile. The assessments at isolated features have, therefore, been based upon the highest values of subsidence, tilt, curvature and strain within a radius of 20 metres of each feature, rather than the values at the point.

A comparative analysis along the line of the Cataract Tunnel over Longwalls 401 to 403 at Appin Colliery revealed that the predicted strains at points along the surface over a length of 1.1 kilometres were exceeded in only eight locations. At six of these locations, the measured strain in a particular bay was immediately preceded or followed by a strain of equal amplitude, but of opposite sign, in the adjoining bay.

The two highest values of measured strain were 1.9 mm/m, tensile, and 2.1 mm/m, compressive, but all other strains were within the range 1.2 mm/m, tensile, to 1.4 mm/m, compressive. In five out of the eight locations, the measured strains exceeded the maximum predicted values. In many locations, the measured strains at particular points were less than predicted.

The prediction of strain at a point must be considered within an appropriate confidence interval, but the Incremental Profile Method approach does allow a more realistic assessment of the subsidence impacts to be made. An assessment based upon applying the maximum predicted strains at every point would be overly conservative and would yield an excessively overstated assessment of the potential subsidence impacts.

5.26. Estimation of the Reliability of Upsidence and Closure Predictions

It should be noted that the development of the predictive methods for upsidence and closure are the result of recent research and the methods do not, at this stage, have the same confidence level as systematic subsidence prediction techniques. As further case histories are studied, the method will be improved, but it can be used in the meantime, so long as suitable factors of safety are applied. This is particularly important where the predicted levels of movement are small, and the potential errors, expressed as percentages, can be higher.

Whilst the major factors that determine the levels of movement have been identified, there are some factors that are difficult to isolate. One factor that is thought to influence the upsidence and closure movements is the level of in-situ horizontal stress that exists within the strata. In-situ stresses are difficult to obtain and not regularly measured and the limited availability of data makes it difficult to be definitive about the influence of the in-situ stress on the upsidence and closure values. The methods are, however, based predominantly upon the measured data from Tower Colliery, where the in-situ stresses are high. The methods will, therefore, tend to over-predict the movements in areas of lower stress.

It should be noted, that the method used to predict the upsidence and closure movements in Area 3 was not adjusted for any local changes in the geology within the creek and river beds. The database for upsidence and closure is mainly based on creeks and rivers which predominantly have sandstone beds. It has been observed where creeks or rivers are founded on thinly bedded shales, the observed closure is higher and the observed upsidence is smaller than what would be predicted using the upsidence and closure model.

A review has been undertaken of all the available observed upsidence and closure movements at locations within the Georges River, Cataract River, Nepean River and the Bargo River against the predictions using the revised upsidence and closure prediction curves. Details are provided in the background report entitled *Estimation of the Reliability of Upsidence and Closure Predictions* which can be obtained from *www.minesubsidence.com*.

CHAPTER 6. MANAGEMENT OF SUBSIDENCE IMPACTS

6.1. Remediation Measures

It is likely that remediation measures will be required after the extraction of the proposed and future longwalls in Area 3. The impacts of subsidence will need to be monitored, as mining occurs, so that any unacceptable impacts can be addressed and appropriate remediation measures can be implemented. It is recommended that IC liaise closely with the SCA, the DSC, and all other regulatory authorities and owners of infrastructure to ensure that the impacts of subsidence are managed to an acceptable standard. The following items will need to be considered within the overall management strategy:-

- Wongawilli, Sandy and Donalds Castle Creeks,
- Drainage Lines,
- Cliffs and rock outcrops,
- Steep slopes,
- Swamps,
- Flora and fauna,
- Fire trails and four wheel drive tracks,
- TransGrid 330 kV transmission line,
- Integral Energy 33 kV powerline,
- Lake Cordeaux and Lake Avon, Cordeaux and Upper Cordeaux No. 2 Dam Walls,
- Archaeological sites, and
- Survey control marks.

The assessments provided in this report indicate that the levels of impact on the natural features and items of surface infrastructure are unlikely to be significant and can be managed by the preparation and implementation of management strategies. It should be noted, however, that more detailed assessments of some natural features and items of infrastructure have been undertaken by other consultants and the findings in this report should be read in conjunction with the findings in all other relevant reports.

6.2. Recommended Ground Monitoring

The objectives of a ground monitoring program are envisaged as follows:-

- Provide general information on the magnitude and extent of subsidence resulting from the extraction of the longwalls,
- Compare actual ground movements with predicted ground movements,
- Monitor ground movements at or near surface infrastructure at risk of impact from subsidence,
- Provide an indication of any non-systematic movements within the subsidence zone, however, given the low density of surface features above the longwalls, the risk of adverse impacts by non-systematic movements, ie: anomalies, is very low,
- Satisfy the objectives of the subsidence management strategies,
- Satisfy the objectives of agreed management plans, and
- Meet the expectations of the community with regard to the monitoring of subsidence.

The locations of the recommended ground monitoring in Area 3A are shown in Drawing No. MSEC311-26. The locations of the recommended ground monitoring in Areas 3B and 3C will be developed as the longwall layouts in these areas are finalised. The details of monitoring at the 330 kV transmission line and at the 33 kV powerline should be determined in consultation with TransGrid and Integral Energy. It is proposed that the changes in surface level resulting from the extraction of the proposed and future longwalls in Area 3 will be determined using aerial laser scans before and at the completion of the longwalls.

It should be noted that ground monitoring is only one part of an overall management strategy. Other forms of monitoring include visual monitoring and specific monitoring related to certain items of infrastructure. It has often been found that these other forms of monitoring are more effective in identifying impacts than traditional ground monitoring.

CHAPTER 7. EFFECTS OF CHANGES TO THE MINE LAYOUT

The subsidence predictions and impact assessments provided in this report for Longwalls 6 to 10 in Area 3A are based on the layout of the longwalls shown in Drawing No. MSEC311-01. The subsidence predictions and impact assessments for the future longwalls in Areas 3B and 3C are based on the maximum predicted subsidence parameters being similar to those for Longwalls 6 to 10. A refined impact assessment based on the final longwall layouts in Areas 3B and 3C will be provided as part of the application for SMP Approval for the future longwalls in these areas

It is recognised that mine layout refinements are continually being considered based on improved knowledge of both underground and surface features. These considerations result in mine plan amendments from time to time. These mine plan refinements may relate to changes in the length or width of longwall panels, changes in the width of chain pillars, shifting of the position of the mine layout, or changes in the height of extraction.

If the mine layout were amended, the predicted extent of subsidence movements would be different to that provided in this report. The predicted subsidence parameters at specific points on the surface would also be different in some areas. It is also possible that maximum predicted subsidence parameters resulting from the extraction of each longwall could change.

The impact assessments and recommendations for each natural feature and item of surface infrastructure may also change or could remain the same. This would depend on the type of feature, its proximity to the mine plan change and the nature of the change.

There are clearly an extensive number of possible amendments to mine layouts. However, general comments can be made for each potential scenario:-

- Increase in Length of Longwalls
  This will increase the extent or footprint of subsidence movements in line with the extension, but is unlikely to significantly change the magnitude of the maximum predicted systematic subsidence parameters for the mining area. While small changes are unlikely to affect the impact assessments provided in this report, it is recommended that all additional features within the revised footprint be re-assessed along with any of the features within the original footprint where a change to the original assessment is likely.

- Increase in Width of Longwalls
  This is likely to increase the extent and the magnitudes of the maximum predicted systematic subsidence parameters resulting from the extraction of this longwall. While small changes are unlikely to affect the impact assessments provided in this report, it is recommended that the impacts are re-assessed.

- Decrease in Length or Width of Longwalls
  This is likely to decrease the extent and the magnitudes of the maximum predicted systematic subsidence parameters resulting from the extraction of this longwall. While the maximum predicted parameters decrease, the maximum predicted parameters at some features could increase, depending on their relative position within the subsidence trough. It is recommended that the impact assessments for these features are re-assessed.

- Reduction in Width of Chain Pillars or Increase in Height of Seam Extraction
  This will, among other things, increase the magnitude of the maximum predicted systematic subsidence parameters. While small changes are unlikely to affect the impact assessments provided in this report, it is recommended that the impacts are re-assessed.

- Shifting the Position of the Mine Layout Outside the Currently Proposed Footprint
  This will, among other things, shift the extent of subsidence movements. While small changes are unlikely to affect the impact assessments provided in this report, it is recommended that the impacts are re-assessed.

APPENDIX A - GLOSSARY OF TERMS AND DEFINITIONS

Glossary of Terms and Definitions

Some of the more common mining terms used in the report are defined below:-

Angle of draw	The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).
Chain pillar	A block of coal left unmined between the longwall extraction panels.
Cover depth (H)	The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.
Critical area	The area of extraction at which the maximum possible subsidence of one point on the surface occurs.
Curvature	The change in tilt between two adjacent sections of the tilt profile divided by the average horizontal length of those sections.
Extracted seam	The thickness of coal that is extracted. The extracted seam thickness is thickness normally given as an average over the area of the panel.
Effective extracted seam thickness (T)	The extracted seam thickness modified to account for the percentage of coal left as pillars within the panel.
Face length	The width of the coalface measured across the longwall panel.
Goaf	The void created by the extraction of the coal into which the immediate roof layers collapse.
Goaf end factor	A factor applied to reduce the predicted incremental subsidence at points lying close to the commencing or finishing ribs of a panel.
Horizontal displacement	The horizontal movement of a point on the surface of the ground as it settles above an extracted panel.
Inflection point	The point on the subsidence profile where the profile changes from a convex curvature to a concave curvature. At this point the strain changes sign and subsidence is approximately one half of S max.
Incremental subsidence	The difference between the subsidence at a point before and after a panel is mined. It is therefore the additional subsidence at a point resulting from the excavation of a panel.
Maingate	The gate road typically located on the solid coal side of an active longwall panel which is used to provide access for workers and for the transportation of coal, materials and fresh air.
Overlap adjustment factor	A factor that defines the ratio between the maximum incremental subsidence of a panel and the maximum incremental subsidence of that panel if it were the first panel in a series.
Panel	The plan area of coal extraction.
Panel length (L)	The longitudinal distance along a panel measured in the direction of (mining from the commencing rib to the finishing rib.
Panel width (Wv)	The transverse distance across a panel, usually equal to the face length plus the widths of the roadways on each side.
Panel centre line	An imaginary line drawn down the middle of the panel.
Pillar	A block of coal left unmined.

Pillar width (Wpi)	The shortest dimension of a pillar measured from the vertical edges of the coal pillar, i.e. from rib to rib.
Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points.
Sub-critical area	An area of panel smaller than the critical area.
Subsidence	The vertical movement of a point on the surface of the ground as it settles above an extracted panel.
Super-critical area	An area of panel greater than the critical area.
Tailgate	The gate road typically located between an active longwall panel and the previously extracted longwall panel which is used for return air and as a secondary means of egress.
Tilt	The difference in subsidence between two points divided by the horizontal distance between the points.
Uplift	An increase in the level of a point relative to its original position.
Upsidence	A reduction in the expected subsidence at a point, being the difference between the predicted subsidence and the subsidence actually measured.

APPENDIX B - REFERENCES

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APPENDIX C. DEVELOPMENT OF LONGWALL LAYOUTS

C.1. Development of the Longwall Layout In Area 3A

A number of longwall layouts were considered in Area 3A as part of the development of the mining geometry. These layouts included variations in the numbers of longwalls and variations in the orientations, lengths and offsets of the longwalls from sensitive surface features.

The following sections provide three examples of the longwall layouts which were considered. Each example provides the predicted systematic subsidence, valley related movements and volume of sterilised coal for a range of longwall offsets from Wongawilli or Sandy Creeks.

C.1.1. Example 1 –Predicted Movements along Wongawilli Creek Based on An East-West Longwall Layout Having Varying Offsets

The first example adopts a series of five longwalls, orientated east-west, adjacent to Wongawilli Creek. The predicted movements along Wongawilli Creek were determined based on the creek being directly mined beneath and based on longwall offsets of 0, 100, 200, 300, 400 and 500 metres from the creek. The layout of the longwalls adopted in this option is shown in Fig. C. 1.

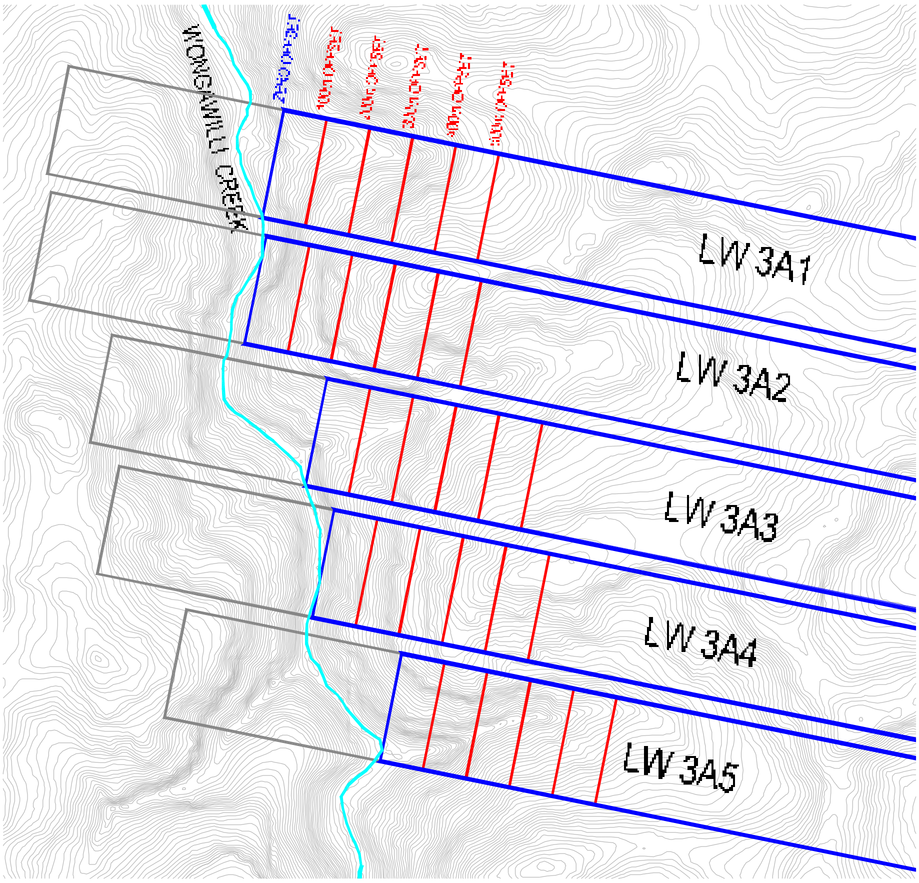


Fig. C. 1 Wongawilli Creek – East-West Longwall Layout Option Mining Directly Beneath the Creek and with Offsets Varying between 0 and 500 metres from the Creek

The predicted profiles of subsidence, upsidence and closure along Wongawilli Creek, based on each offset from the creek, are shown in Fig. C. 2. A summary of the maximum predicted upsidence and closure movements anywhere along the creek and the tonnage of sterilised coal for each offset are provided in Fig. C. 3.

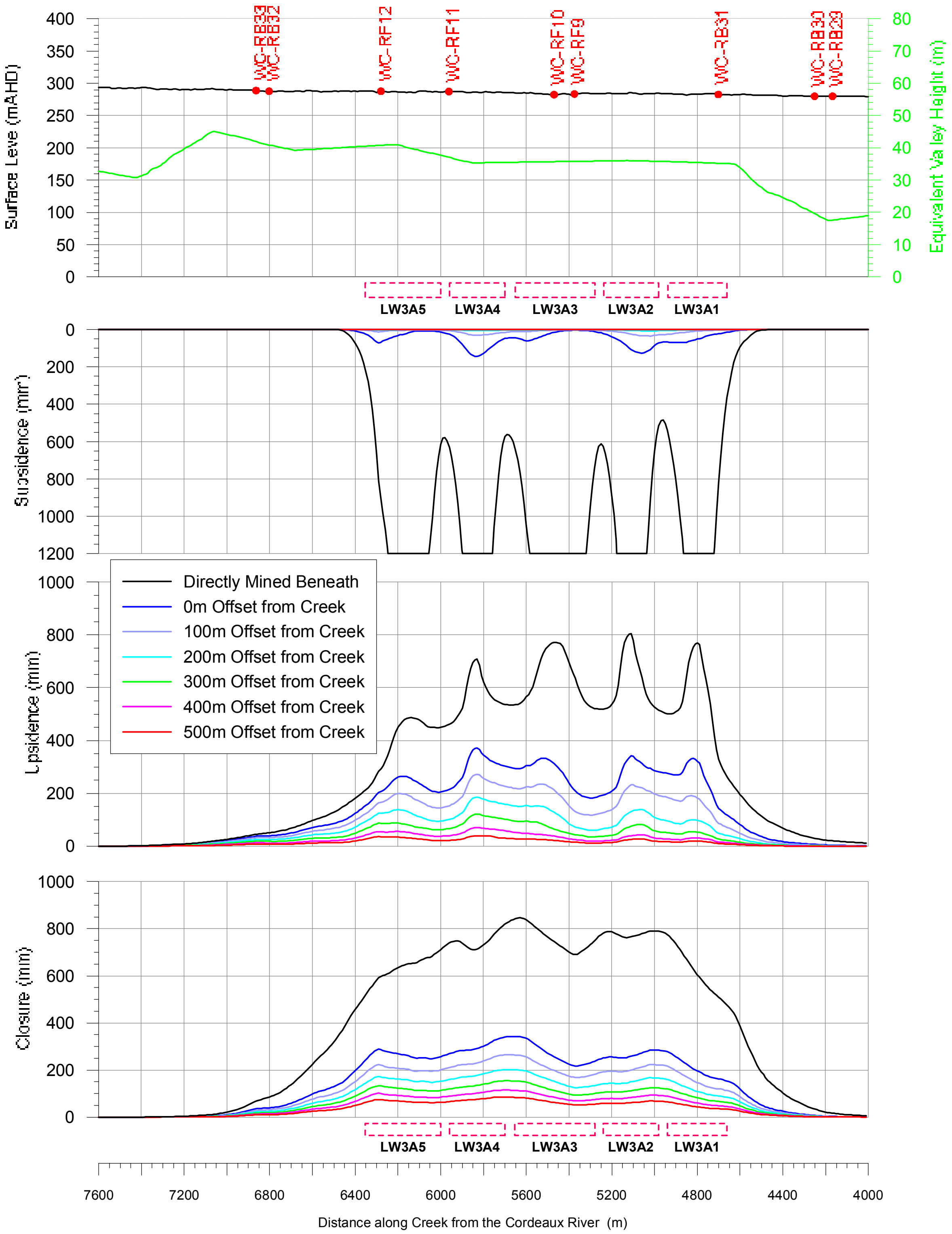


Fig. C. 2 Predicted Subsidence, Upsidence and Closure along Wongawilli Creek for Varying Offsets Based on an East-West Longwall Layout

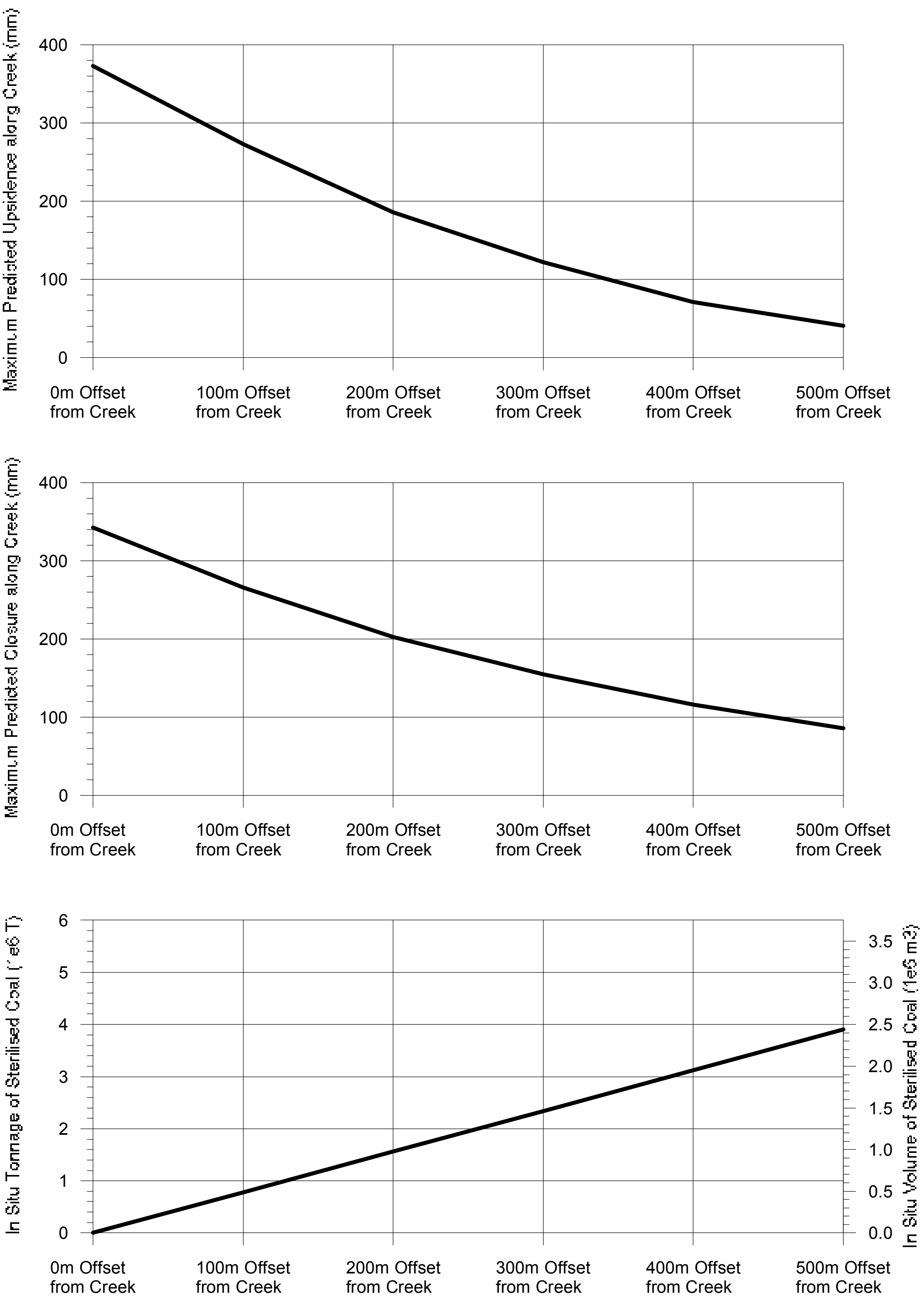


Fig. C. 3 Summary of Maximum Predicted Subsidence, Upsidence and Closure along Wongawilli Creek and Volume of Sterilised Coal for East-West Longwall Offset Option

C.1.2. Example 2 –Predicted Movements along Wongawilli Creek Based on A North-South Longwall Layout Having Varying Numbers of Longwalls

The second example adopts a series of nine longwalls, orientated north-south, adjacent to Wongawilli Creek. The predicted movements along Wongawilli Creek were determined as successive longwalls within the series were mined towards and then beneath the creek. The layout of the longwalls adopted in this option is shown in Fig. C. 4.

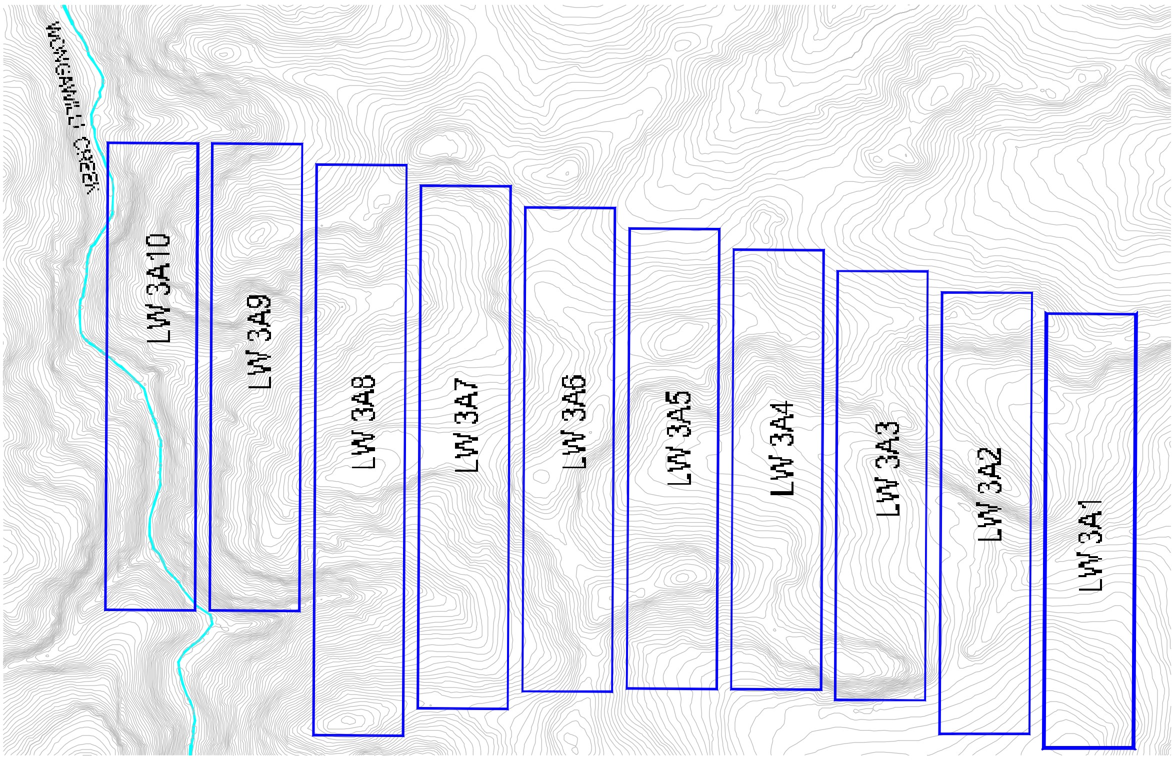


Fig. C. 4 Wongawilli Creek – North-South Longwall Layout adjacent to the Creek

The predicted profiles of subsidence, upsidence and closure along Wongawilli Creek, after each successive longwall within the series is mined towards and then beneath the creek, are provided in Fig. C. 5. A summary of the maximum predicted upsidence and closure movements anywhere along the creek and the tonnage of sterilised coal for each case are provided in Fig. C. 6.

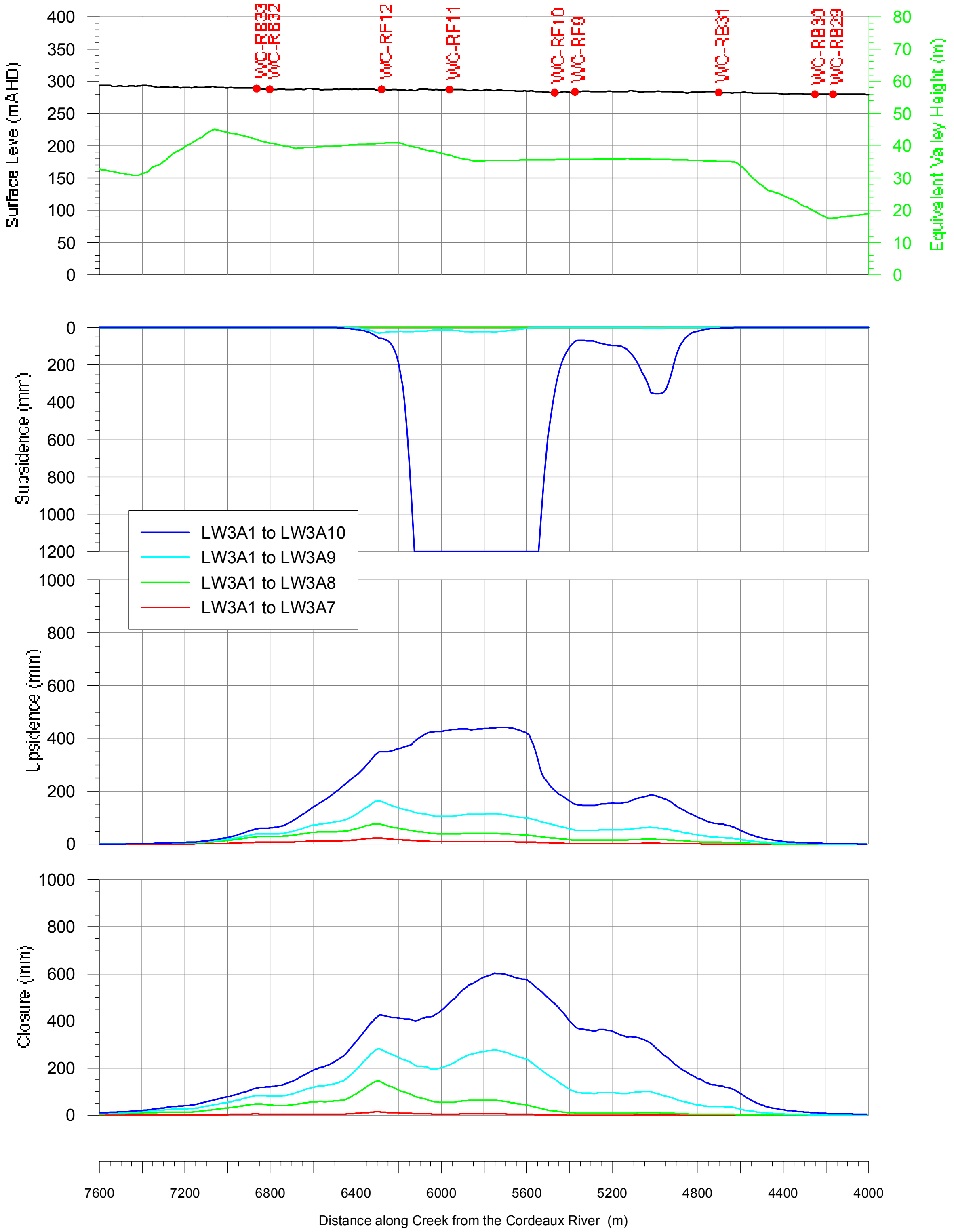


Fig. C. 5 Predicted Subsidence, Upsidence and Closure along Wongawilli Creek after the Extraction of Each Successive North-South Longwall within the Series

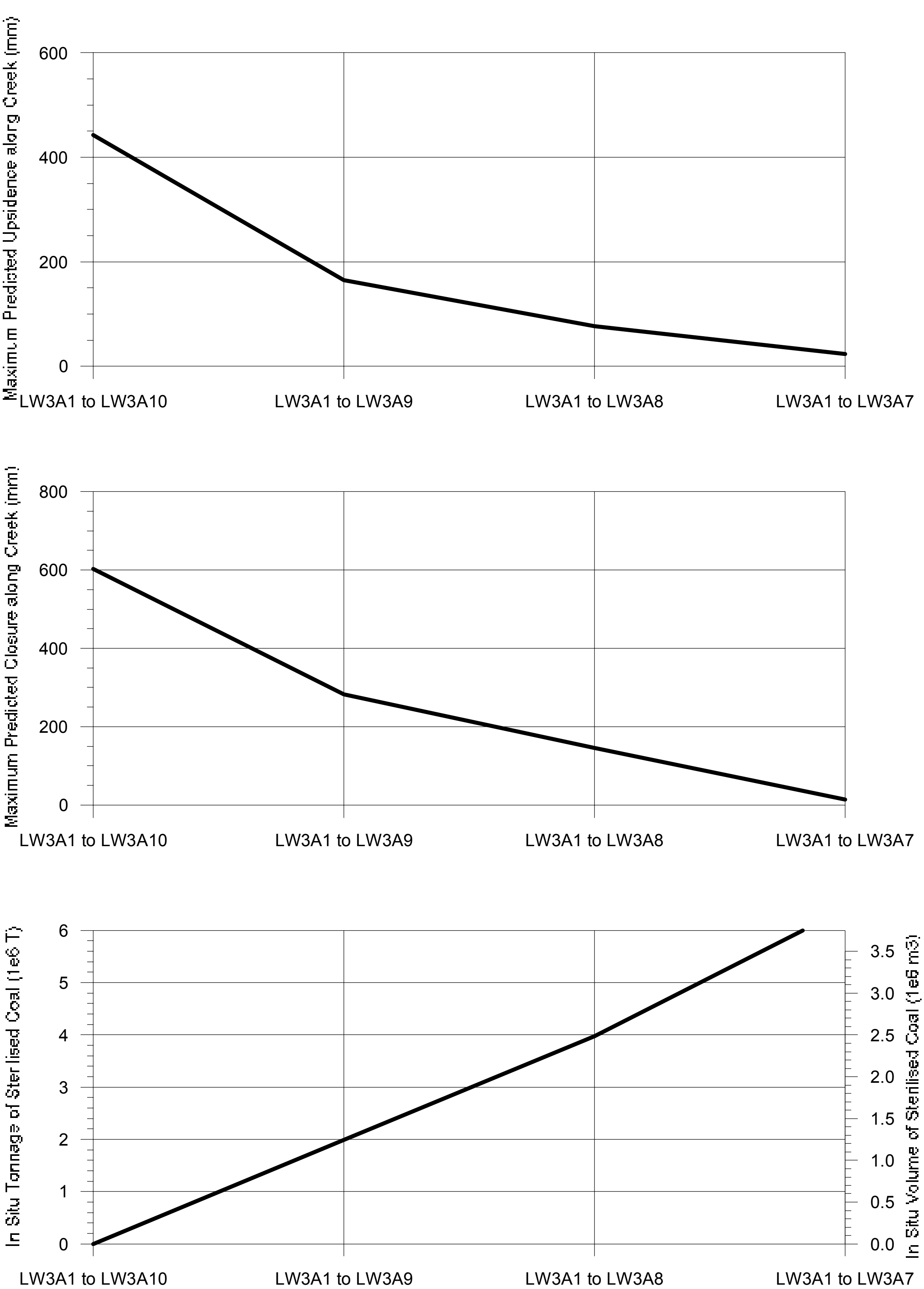


Fig. C. 6 Summary of Maximum Predicted Subsidence, Upsidence and Closure along Wongawilli Creek and Volume of Sterilised Coal for North-South Longwall Option

C.1.3. Example 3 –Predicted Movements along Sandy Creek Based on An East-West Longwall Layout Having Various Offsets

The third example adopts a series of five longwalls, orientated east-west, adjacent to Sandy Creek. The major feature along Sandy Creek is the waterfall where the creek flows into the arm of Lake Cordeaux. The layout of the longwalls and the waterfall site are shown in Fig. C. 7.

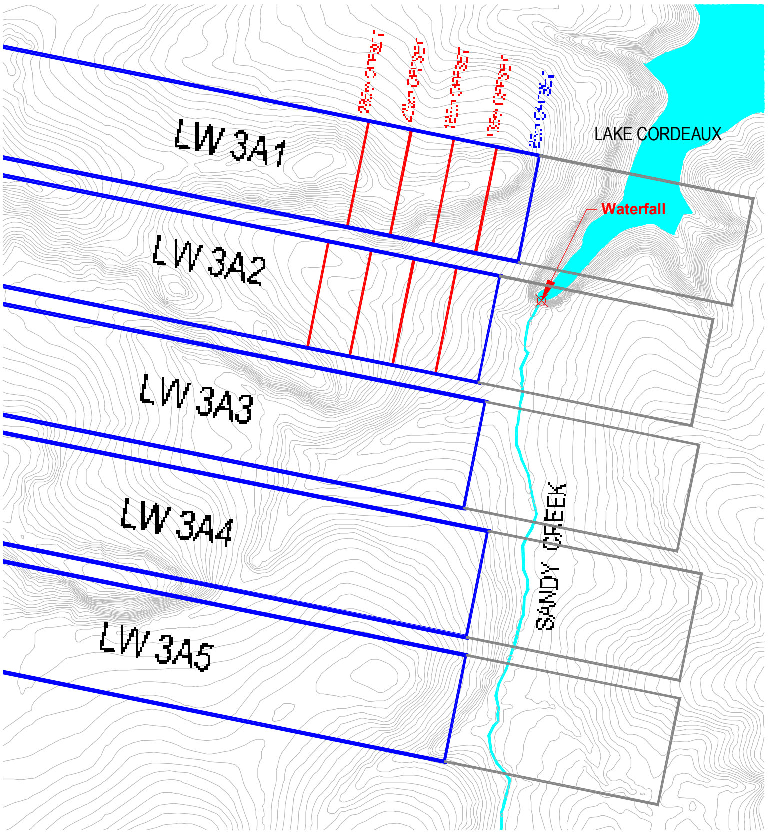


Fig. C. 7 Sandy Creek – East-West Longwall Layout Option Mining Directly Beneath the Creek and with Offsets Varying between 85 and 285 metres from the Creek

The greatest components of the predicted movements at the waterfall site are the result of the first two longwalls in the series, being LW3A1 and LW3A2. The offset of these longwalls from the creek were, therefore, governed by the predicted movements at the waterfall site. The predicted movements at the waterfall site resulting from the following longwalls, being LW3A3 to LW3A5, were relatively small in comparison and, therefore, the offsets of these longwalls were not governed by the predicted movements at the waterfall site.

The upper reaches of Sandy Creek has a relatively small equivalent valley height and, therefore, the minimum offsets of the final three longwalls in the series, being LW3A3 to LW3A5, were governed by the systematic movements rather than the valley related movements along this section of creek. A maximum tensile strain of 0.25 mm/m is predicted along Sandy Creek based on the longwalls having an offset of 85 metres from the creek.

The predicted movements along Sandy Creek were, therefore, determined based on the creek being directly mined beneath, based on all longwalls having an offset of 85 metres from the creek, as well as based on Longwalls 3A1 and 3A2 having offsets of 135, 185, 235 and 285 metres from the creek and, hence, from the waterfall site. The predicted profiles of subsidence, upsidence and closure along Sandy Creek based on each case are shown in Fig. C. 8. A summary of the maximum predicted upsidence and closure movements at the waterfall site and the tonnage of sterilised coal for each case are provided in Fig. C. 9.

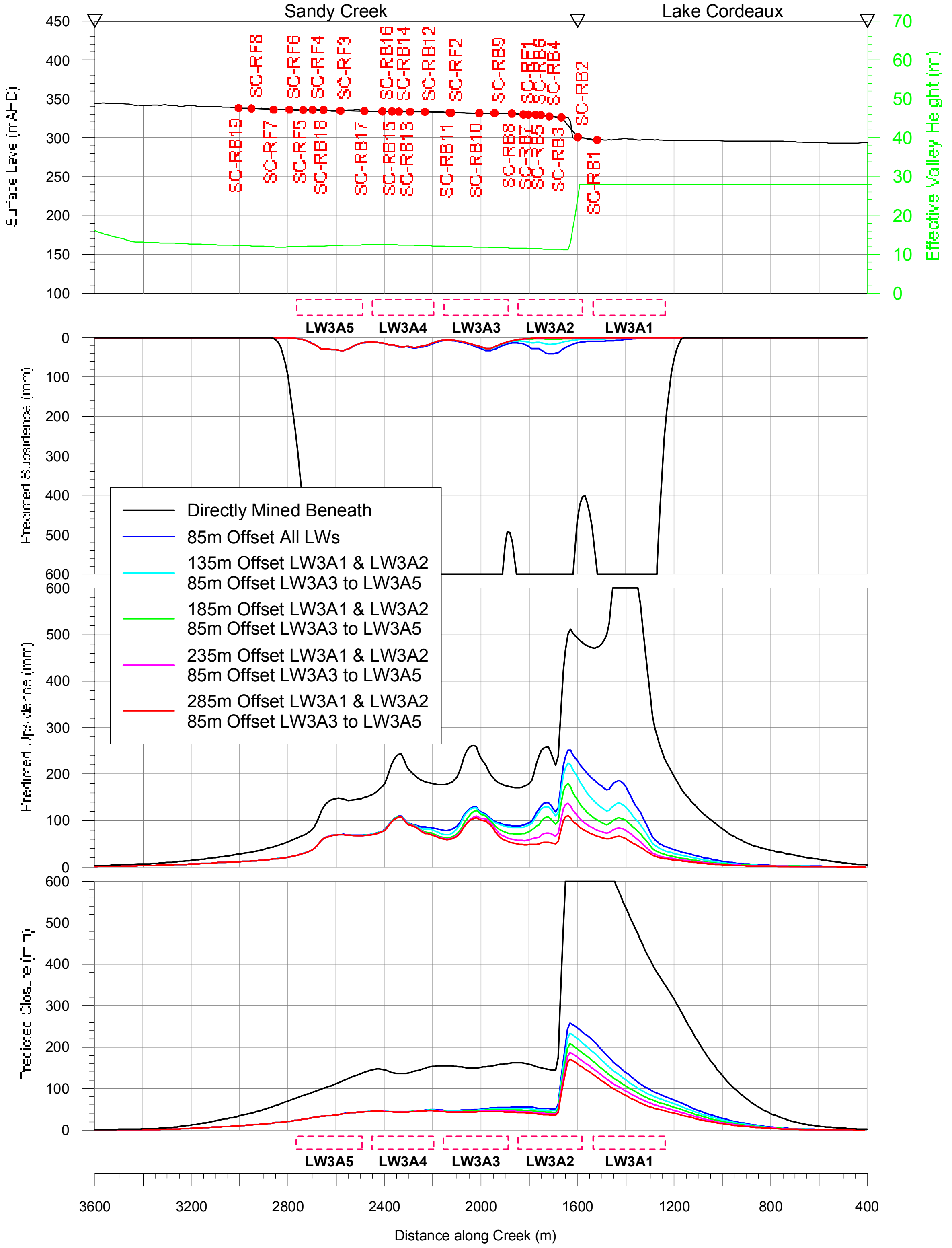


Fig. C. 8 **Predicted Subsidence, Upsidence and Closure along Sandy Creek for Varying Offsets Based on an East-West Longwall Option**

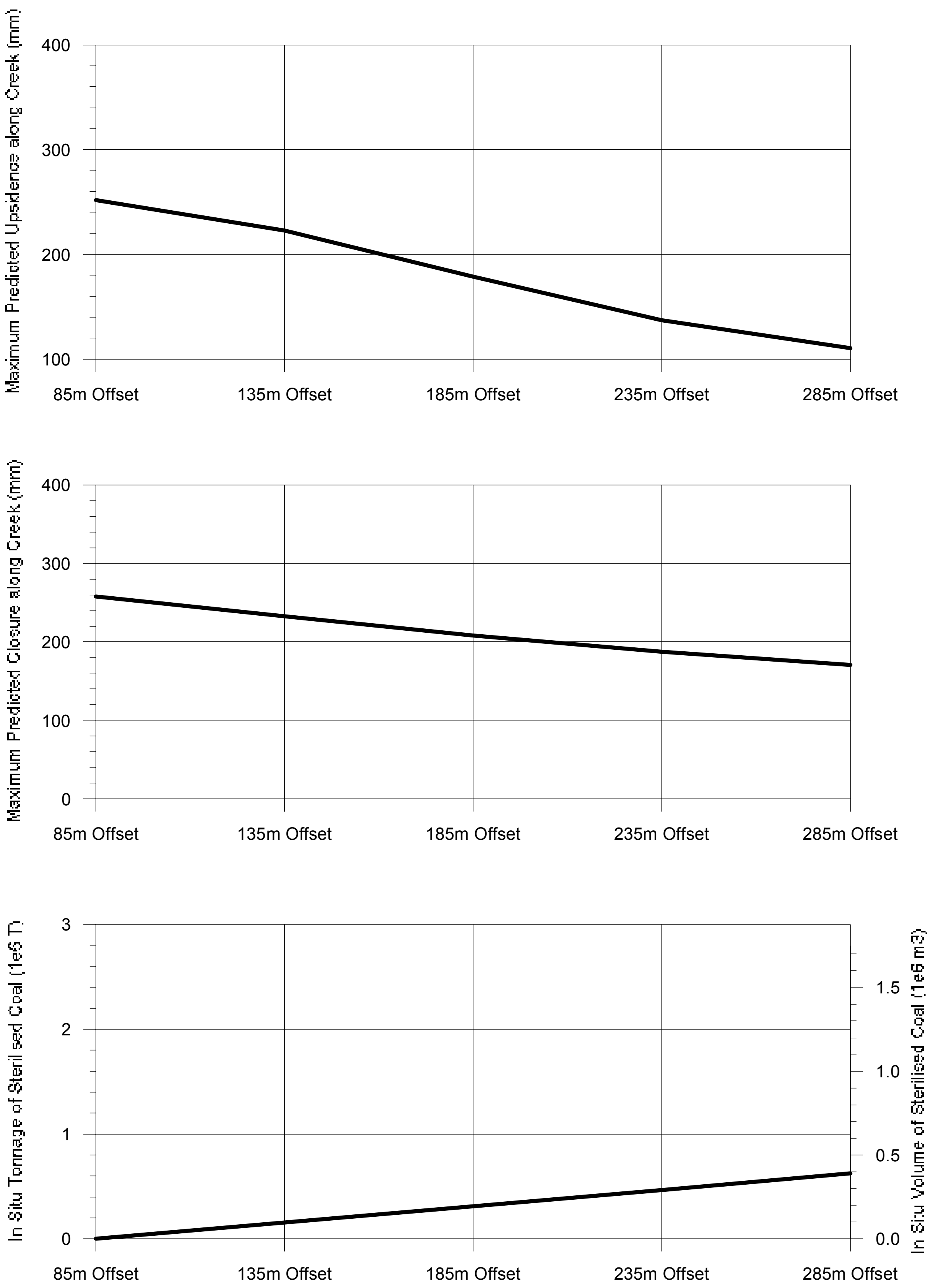


Fig. C. 9 Summary of Maximum Predicted Subsidence, Upsidence and Closure along Sandy Creek and Volume of Sterilised Coal for East-West Longwall Offset Option

C.2. Preliminary Concept Mining Domains for Areas 3B and 3C

The future development headings and longwalls in Areas 3B and 3C will be located within the maximum footprint area which is shown in Drawing No. MSEC311-01. The preliminary concept maximum longwall mining domains for the future longwalls in Areas 3B and 3C are shown in Fig. C. 10, which are based on limiting the maximum predicted systematic tensile and compressive strains at Wongawilli Creek, Lake Cordeaux and Lake Avon to less than 0.5 mm/m and 2 mm/m, respectively.

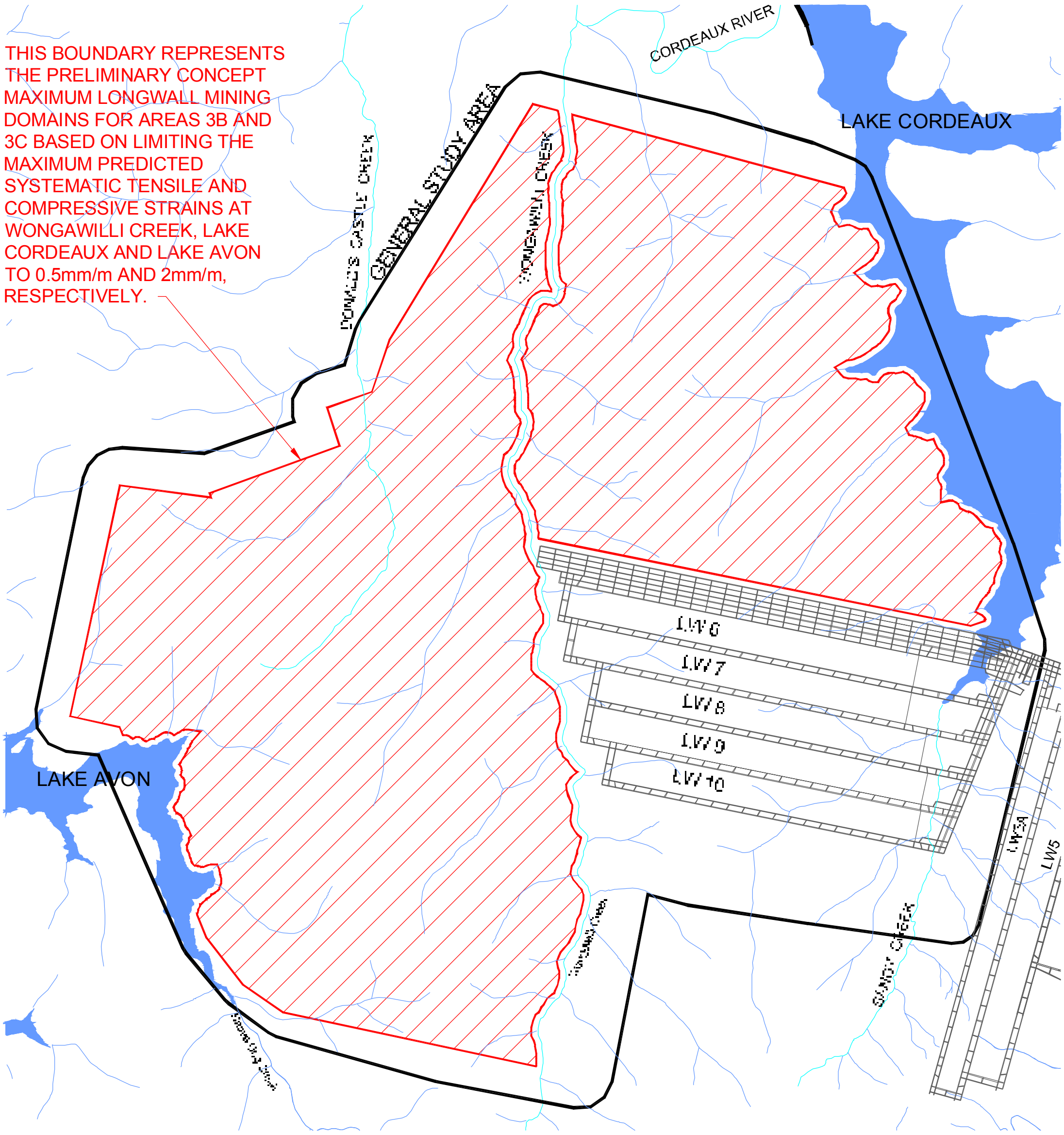
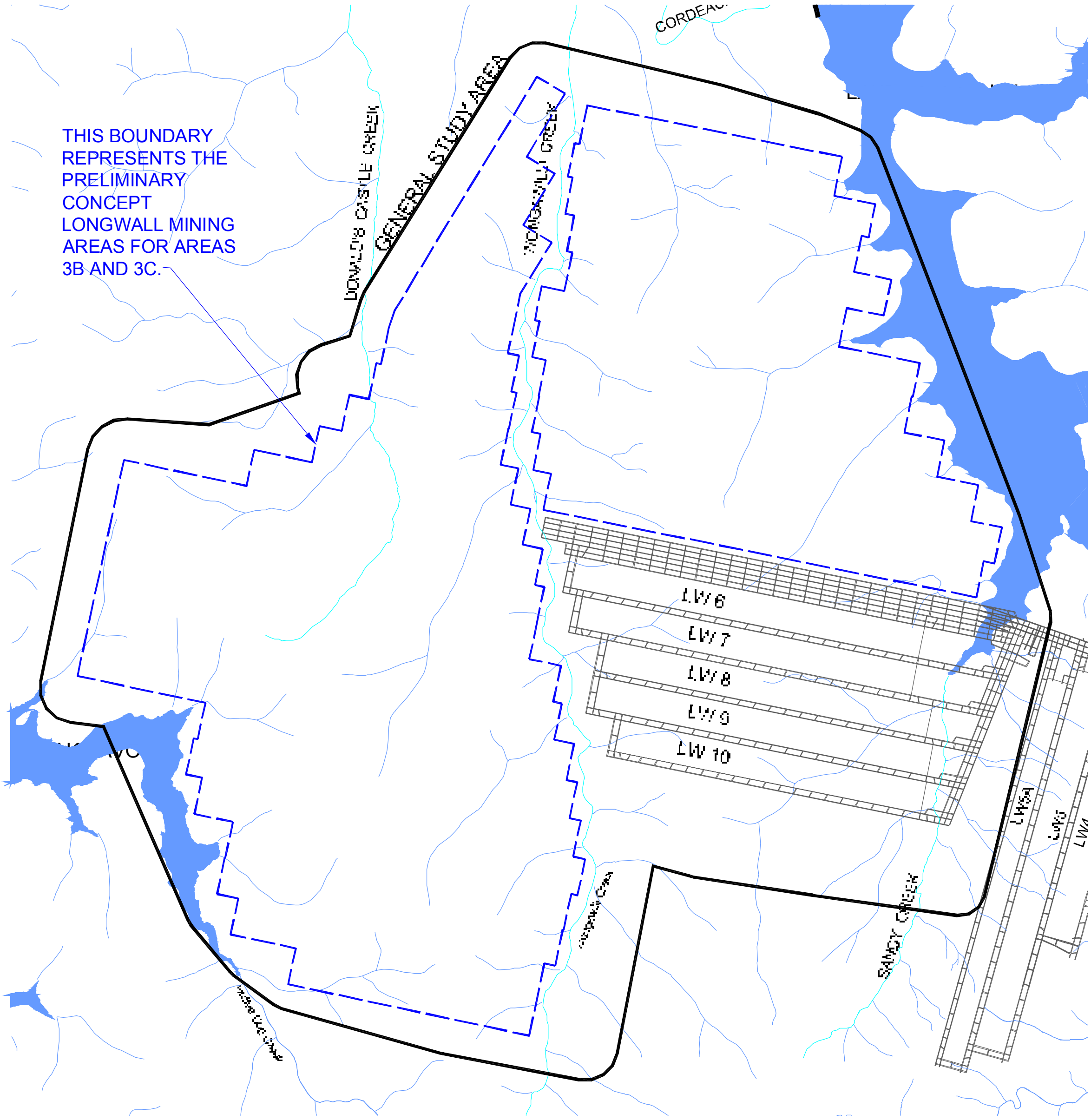


Fig. C. 10 Preliminary Concept Maximum Longwall Mining Domains for Areas 3B and 3C

The preliminary concept longwall mining areas for the future longwalls in Areas 3B and 3C are shown in Fig. C. 11, which are based on maintaining preliminary longwall mining areas within the preliminary concept maximum longwall mining domains shown in Fig. C. 10.



THIS BOUNDARY REPRESENTS THE PRELIMINARY CONCEPT LONGWALL MINING AREAS FOR AREAS 3B AND 3C.

Fig. C. 11 Preliminary Concept Longwall Mining Areas for Areas 3B and 3C

APPENDIX D. CASE STUDIES OF MINING NEAR CREEKS AND RIVERS IN THE SOUTHERN COALFIELD

D.1. Case Studies for Mining Near Creeks and Rivers in the Southern Coalfield

This appendix provides the background details for the selected case studies where longwalls have mined immediately adjacent to or directly beneath creeks and rivers within the Southern Coalfield. The case studies include:-

- Elouera Longwalls 1 to 10 which mined adjacent to and directly beneath Wongawilli Creek,
- Elouera Longwalls 1 to 10 which mined adjacent to and directly beneath Native Dog Creek,
- Dendrobium Area 1 – Longwalls 1 and 2 which mined adjacent to Kembla Creek,
- Appin Longwall 301 which mined adjacent to the Cataract River,
- West Cliff Longwalls 5A1 to 5A4 which mined adjacent to and directly beneath the Georges River,
- West Cliff Longwalls 29 and 31 which mined adjacent to the Georges River, and
- Tahmoor Longwalls 14 to 19 which mined adjacent to and directly beneath the Bargo River.

D.2. Elouera Longwalls 1 to 10 – Wongawilli Creek

Longwall Geometry:	Elouera Longwalls 1 to 8 150 ~ 185 metre void widths 40 metre solid chain pillars
Seam Information:	Wongawilli Seam 280 ~ 350 metre depth of cover 3 ~ 3.7 metre seam height
Creek Information:	Wongawilli Creek Permanent stream with small base flow Sandstone base rock bar controlled 10 ~ 100 mm/m (35 mm/m average) natural gradient 30 metre effective valley height

Back-predictions:

Location	Back-Predicted Subsidence (mm)	Back-Predicted Upsidence (mm)	Back-Predicted Closure (mm)
Directly above Longwalls	1400	725	880
Last Drained Pool	75	245	335
First Full Pool	< 20	35	40

Observed movements: No ground monitoring data along creek.

Observed Impacts: Majority of standing pools drained directly above longwalls.
Last drained pool 95 metres (to rock bar) downstream of Longwall 6, observed after completion of Longwall 6 (October 2001).
First full pool 275 metres (to rock bar) from edge of Longwall 7.

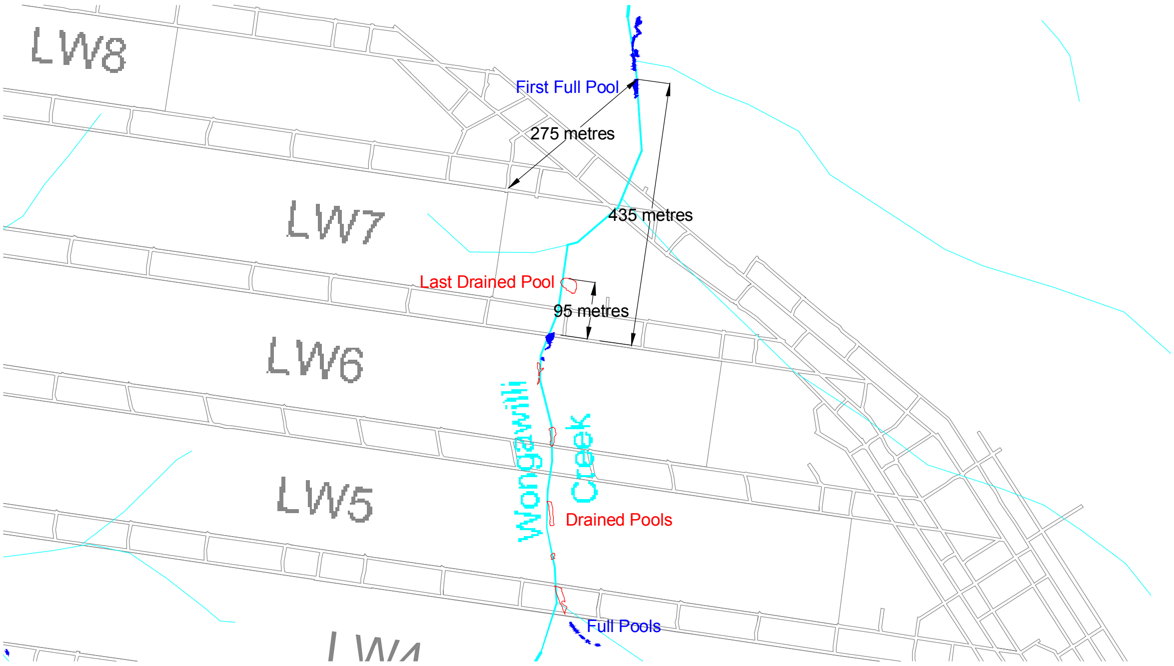


Fig. D.1 **Observed Impacts along Wongawilli Creek Resulting from the Extraction of Elouera Longwalls 1 to 10**

D.3. Elouera Longwalls 1 to 10 – Native Dog Creek

Longwall Geometry:	Elouera Longwalls 1 to 8 150 ~ 185 metre void widths 40 metre solid chain pillars
Seam Information:	Wongawilli Seam 280 ~ 350 metre depth of cover 3 ~ 3.7 metre seam height
Creek Information:	Native Dog Creek Ephemeral Sandstone base rock bar controlled 10 ~ 90 mm/m (35 mm/m average) natural gradient 15 ~ 20 metre effective valley height

Back-predictions:

Location	Back-Predicted Subsidence (mm)	Back-Predicted Upsidence (mm)	Back-Predicted Closure (mm)
Directly above Longwalls	1400	725	880
Last Drained Pool	75	130	205
First Full Pool	50	65	95

Observed movements:	No ground monitoring data along creek.
Observed Impacts:	Majority of standing pools drained directly above longwalls. Last drained pool 75 metres (to rock bar) downstream of Longwall 7, observed during the extraction of Longwall 7 (November 2001). First full pool 105 metres (to rock bar) downstream of Longwall 7.

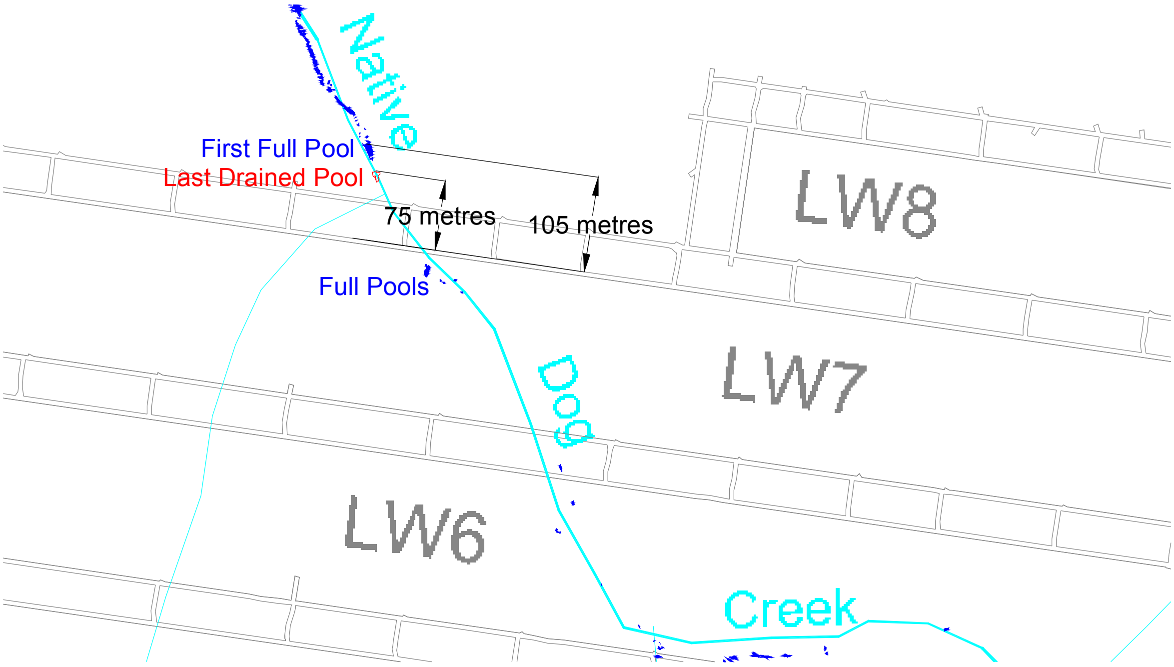


Fig. D.2 Observed Impacts along Native Dog Creek Resulting from the Extraction of Elouera Longwalls 1 to 10

D.4. Dendrobium Area 1 – Longwalls 1 and 2 – Kembla Creek

Longwall Geometry:
Dendrobium Longwalls 1 and 2
250 metre void widths
50 metre solid chain pillar

Seam Information:
Wongawilli Seam
170 ~ 320 metre depth of cover
3.2 ~ 3.4 metre seam height

Creek Information:
Kembla Creek
Ephemeral upstream of Lake Cordeaux
Sandstone base rock bar controlled
10 ~ 75 mm/m natural gradient
40 metre effective valley height

Back-predictions:

Location	Back-Predicted Subsidence (mm)	Back-Predicted Upsidence (mm)	Back-Predicted Closure (mm)
Directly above Longwalls	2850	-	-
Along creek	< 20	110	150

Observed movements: No ground monitoring data along creek

Observed Impacts: No observed fracturing or loss of water in pools after the completion of Longwall 1 (December 2005) or the completion of Longwall 2 (January 2007)

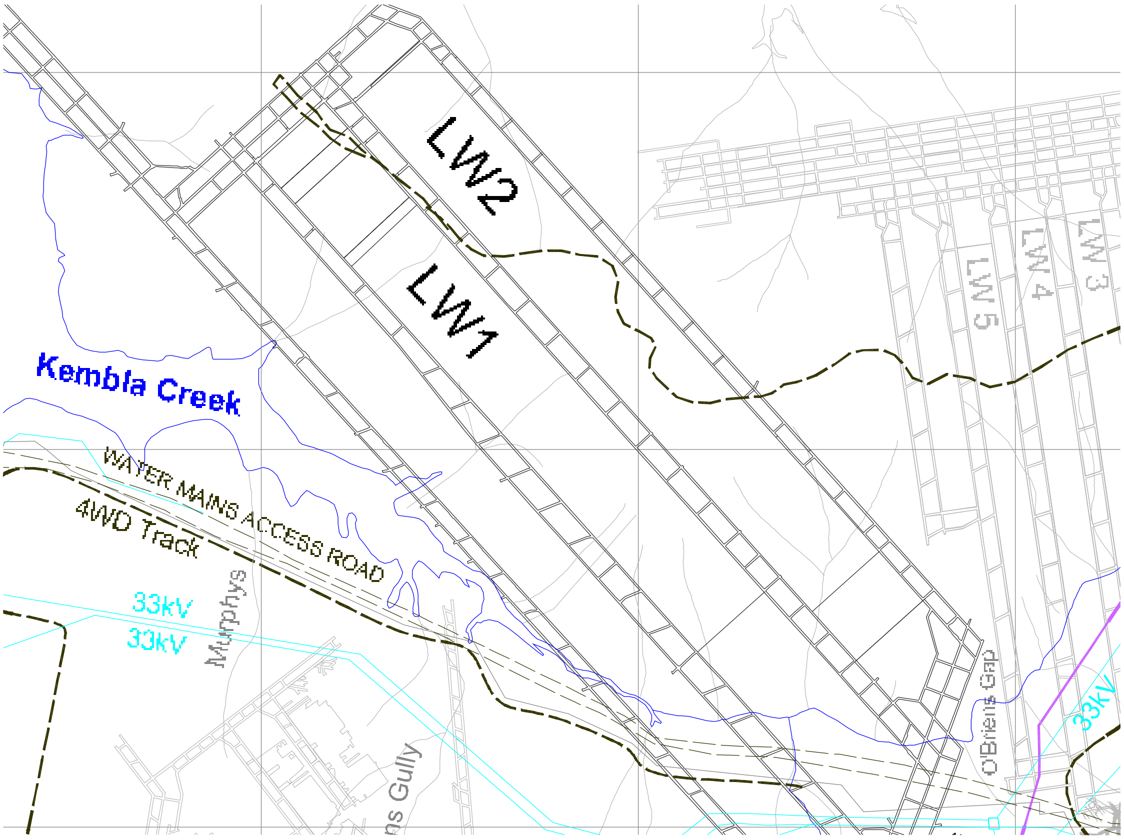
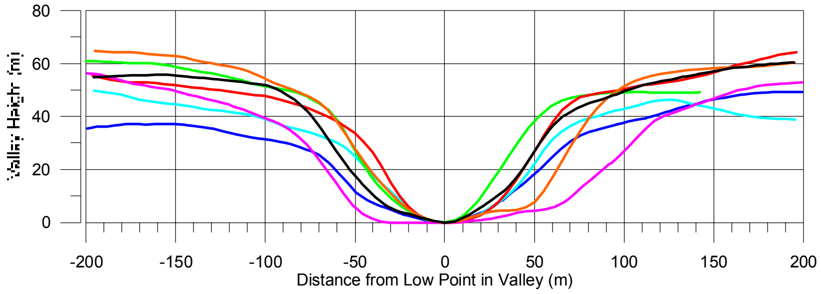


Fig. D. 3 Kembla Creek – Dendrobium Longwalls 1 and 2

D.5. Appin Longwalls 301 – Cataract River

Longwall Geometry:	Appin Longwall 301 260 metre void width First panel in the series
Seam Information:	Bulli Seam 500 metre depth of cover 2.8 ~ 3.0 metre seam height
Creek Information:	Cataract River Water flow controlled by the Cataract Dam (typically 0.5 ~ 100 ML/day) Sandstone base rock bar controlled 10 ~ 150 mm/m natural gradient 50 ~ 70 metre effective valley height



Back-predictions:

Location	Back-Predicted Subsidence (mm)	Back-Predicted Upsidence (mm)	Back-Predicted Closure (mm)
Directly above Longwall	420	-	-
Along river	25	165	260

Observed movements: 250 mm maximum upsidence along creek
165 mm maximum closure along creek

Impacts: No mining-induced flow diversions were observed during or after the extraction of Longwall 301, which was completed in April 2007. All pools that were observed to hold water at low flows prior to mining have continued to hold water, while releases from Cataract Dam have been 1 ML/day for periods of 19 and 28 consecutive days.

Table D. 1 Observed Impacts along the Cataract River Resulting from the Extraction of Appin Longwall 301

Impact	Locations
Fractures	Observed in eight locations, most of which have occurred to the side of Longwall 301, where the movements were the greatest. The furthest fracture was observed at Site SW4a at a distance of 375 metres from the longwall.
Gas Release	Observed in twelve locations. The furthest gas release site was observed near the A-Line at a distance of 600 metres from the longwall.
Iron Staining	Observed to source from four locations. The furthest iron stain site was observed near the A-Line at a distance of 525 metres from the longwall. Iron staining was observed downstream of Jordans Pass Weir during extended low flow periods.

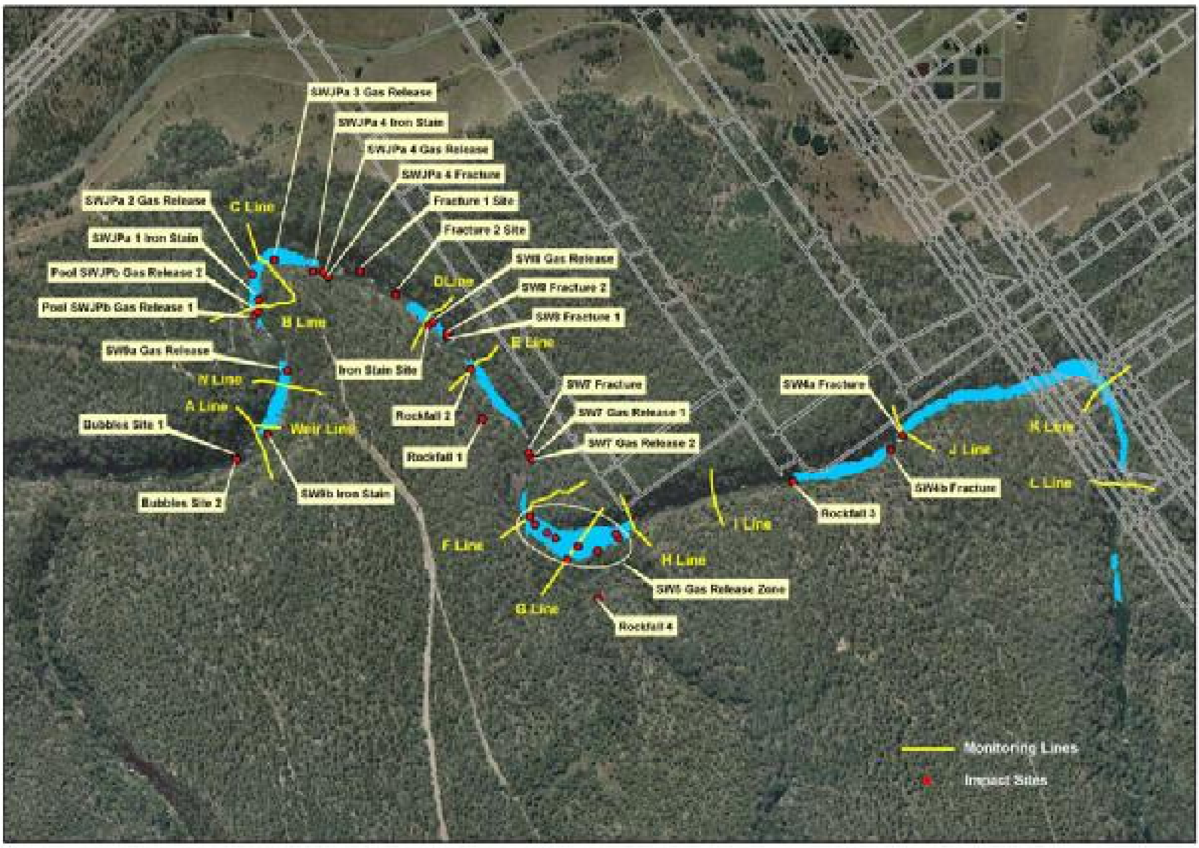


Fig. D. 4 Observed Impacts along the Cataract River Resulting from the Extraction of Appin Longwall 301

D.6. West Cliff Longwalls 5A1 to 5A4 – Georges River

Longwall Geometry:	West Cliff Longwalls 5A1 to 5A4 205 ~ 255 metre void widths 35 metre solid chain pillar
Seam Information:	Bulli Seam 450 ~ 500 metre depth of cover 3 metre seam height
Creek Information:	Georges River Perennial Sandstone base rock bar controlled 1 ~ 5 mm/m natural gradient upstream of Marhnyes Hole, and 50 mm/m natural gradient immediately downstream of Marhnyes Hole 10 ~ 20 metre effective valley height

Back-predictions:

Location	Back-Predicted Subsidence (mm)	Back-Predicted Upsidence (mm)	Back-Predicted Closure (mm)
Jutts Crossing	600	220	235
Marhnyes Hole	400	185	210

Observed movements:

Longwall	Observed Subsidence (mm)	Observed Upsidence (mm)	Observed Closure (mm)
Jutts Crossing	550	410	230
Marhnyes Hole	450	70	145

Observed Impacts: Loss of water in pools upstream of Jutts Crossing observed during the extraction of Longwall 5A2 in November 2000.

Loss of water in pools upstream of Marhnyes Hole first observed during the extraction of Longwall 5A4 in September 2002.

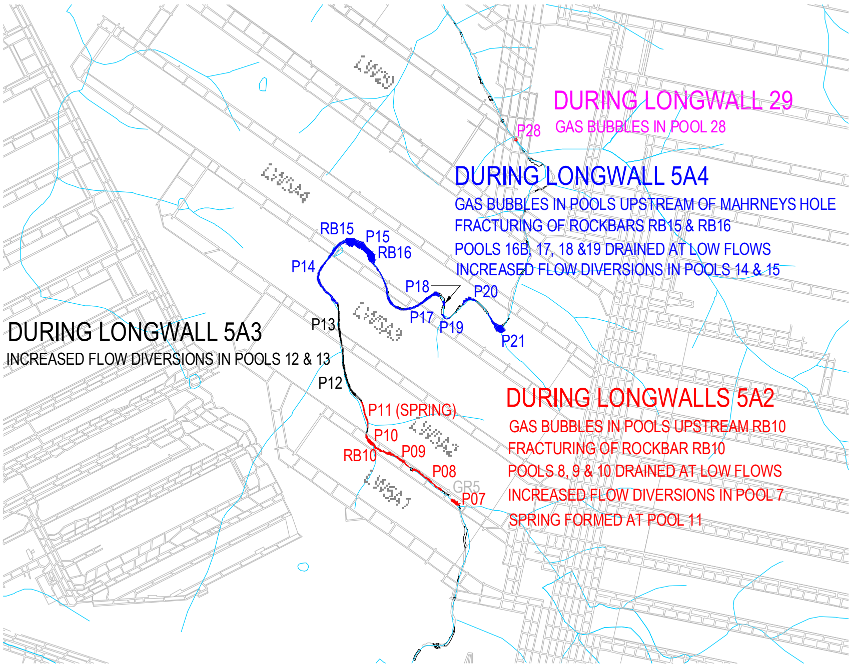


Fig. D. 5 Observed Impacts along the Georges River Resulting from the Extraction of West Cliff Longwalls 5A1 to 5A5

D.7. West Cliff Longwalls 29 and 31 – Georges River

Longwall Geometry:	West Cliff Longwalls 29 and 31 255 metre (LW29) and 200 metre (LW31) void widths 95 metre (LW29) and 140 metre (LW31) non-solid chain pillar widths
Seam Information:	Bulli Seam 475 ~ 525 metre depth of cover 2.7 metre seam height
Creek Information:	Georges River Perennial Sandstone base rock bar controlled 5 ~ 10 mm/m natural gradient 20 ~ 35 metre effective valley height

Back-predictions:

Longwall	Back-Predicted Subsidence (mm)	Back-Predicted Upsidence (mm)	Back-Predicted Closure (mm)
LW29	< 20	60	115
LW31	< 20	70	135

Observed movements:

Longwall	Observed Subsidence (mm)	Observed Upsidence* (mm)	Observed Closure (mm)
LW29	110	-	25
LW31	170	-	35

Note: No upsidence spike observed and lines too short to measure gaussian component.

Observed Impacts: Only minor gas release observed during the extraction of Longwall 29 (completed in August 2004) and during the extraction of Longwall 31 (completed December 2006).

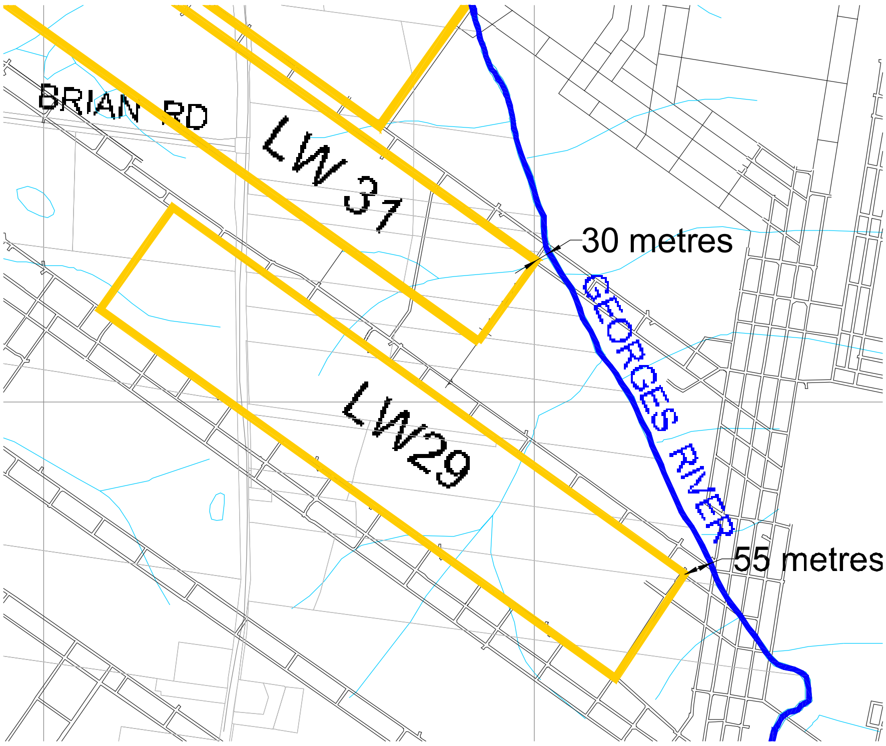
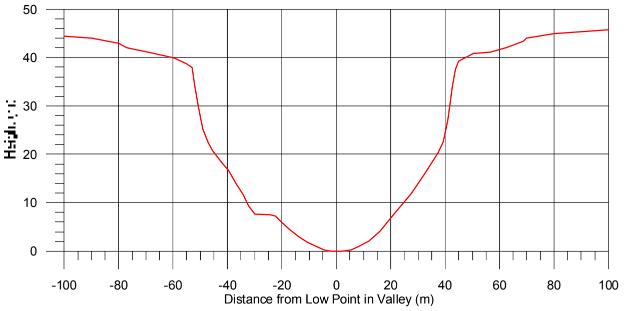


Fig. D. 6 Layout of West Cliff Longwalls 29 and 31 and the Georges River

D.8. Tahmoor Longwalls 14 to 19 - Bargo River



Longwall Geometry: Tahmoor Longwalls 14 to 19
340 metre void widths
40 metre solid chain pillars

Seam Information: Bulli Seam
400 metre depth of cover
2 metre seam height

River Information: Bargo River
Water flow controlled by the Picton Weir (typically 0 ~ 4 ML/day)
Sandstone base rock bar controlled
45 to 65 metre effective valley height

Back-predictions:

Location	Back-Predicted Subsidence (mm)	Back-Predicted Upsidence (mm)	Back-Predicted Closure (mm)
Directly above Longwalls	860	1000	1100
Flow Diversion 125 metres from Longwall 19	35	165	400

Observed movements:

Longwall	Observed Subsidence (mm)	Observed Upsidence (mm)	Observed Closure (mm)
Directly above Longwalls	830	400	610

Observed Impacts: Majority of standing ponds drained directly above longwalls.
No surface water flow 125 metres upstream of the maingate of Longwall 19, where the back- predicted upsidence is 165 mm and back-predicted closure is 400 mm, observed after the completion of Longwall 19 (July 2002).

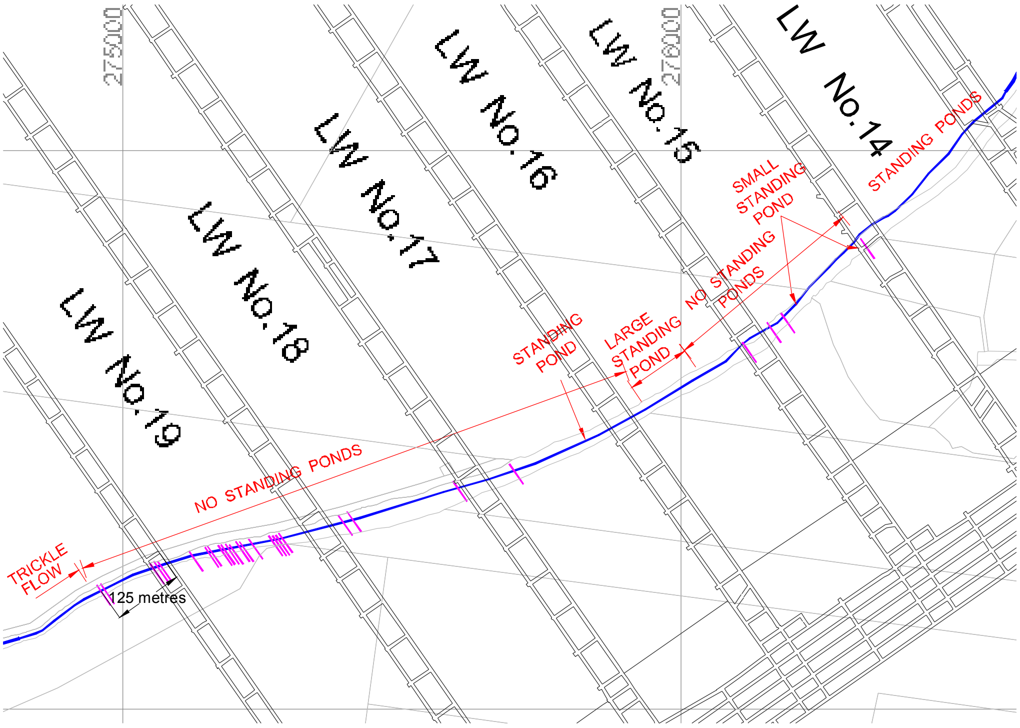


Fig. D. 7 Observed Impacts along the Bargo River Resulting from the Extraction of Tahmoor Longwalls 14 to 19

APPENDIX E.   FIGURES

Predicted Profiles of Systematic Subsidence, Tilt and Strain along Prediction Line A due to Longwalls 6 to 10 in Area 3A

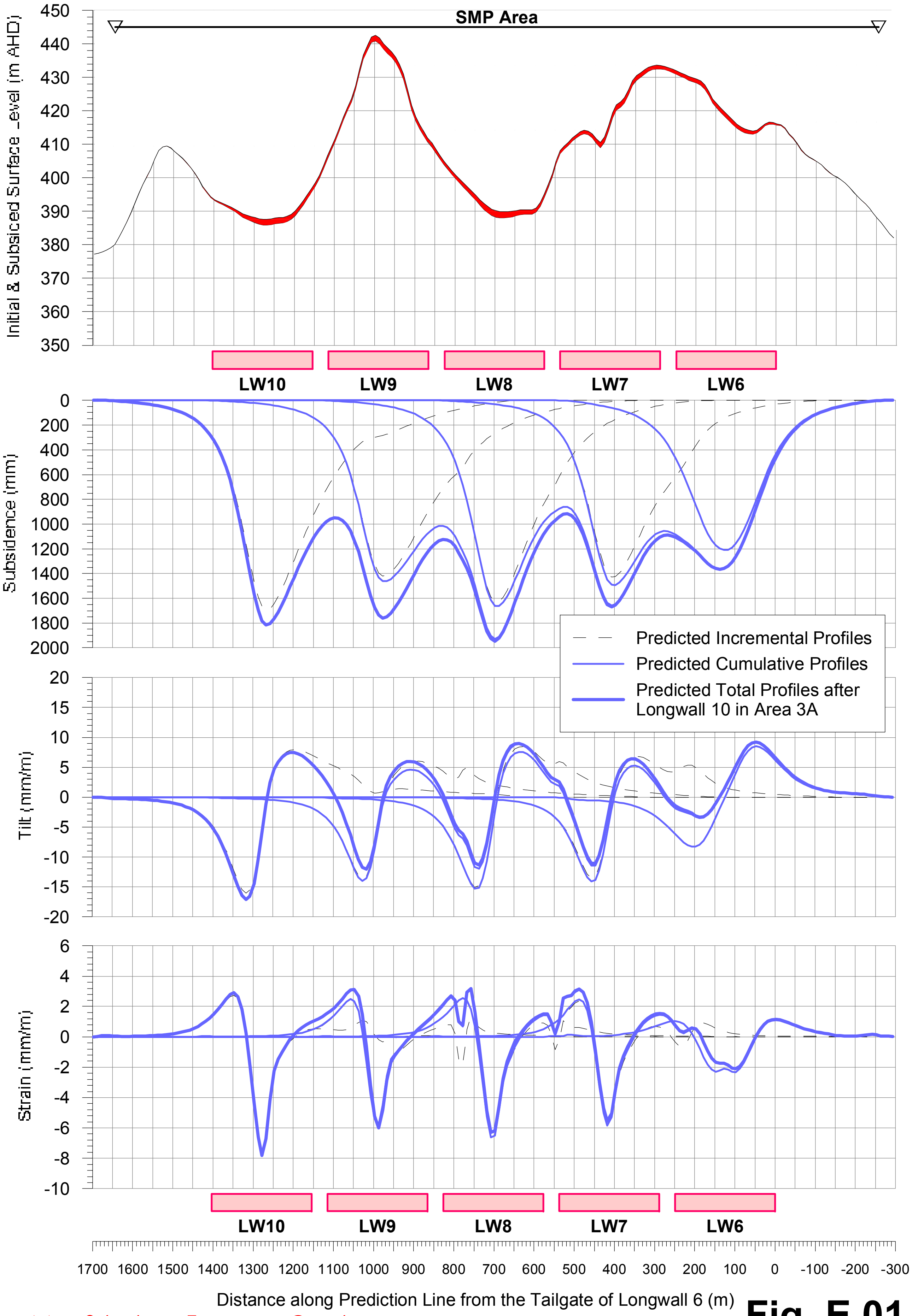


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Fig. E.01

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Dendrobium - Area 3A - Longwalls 6 to 10
Wongawilli Creek Long Section
Predicted Profiles of Subsidence, Upsidence and Closure

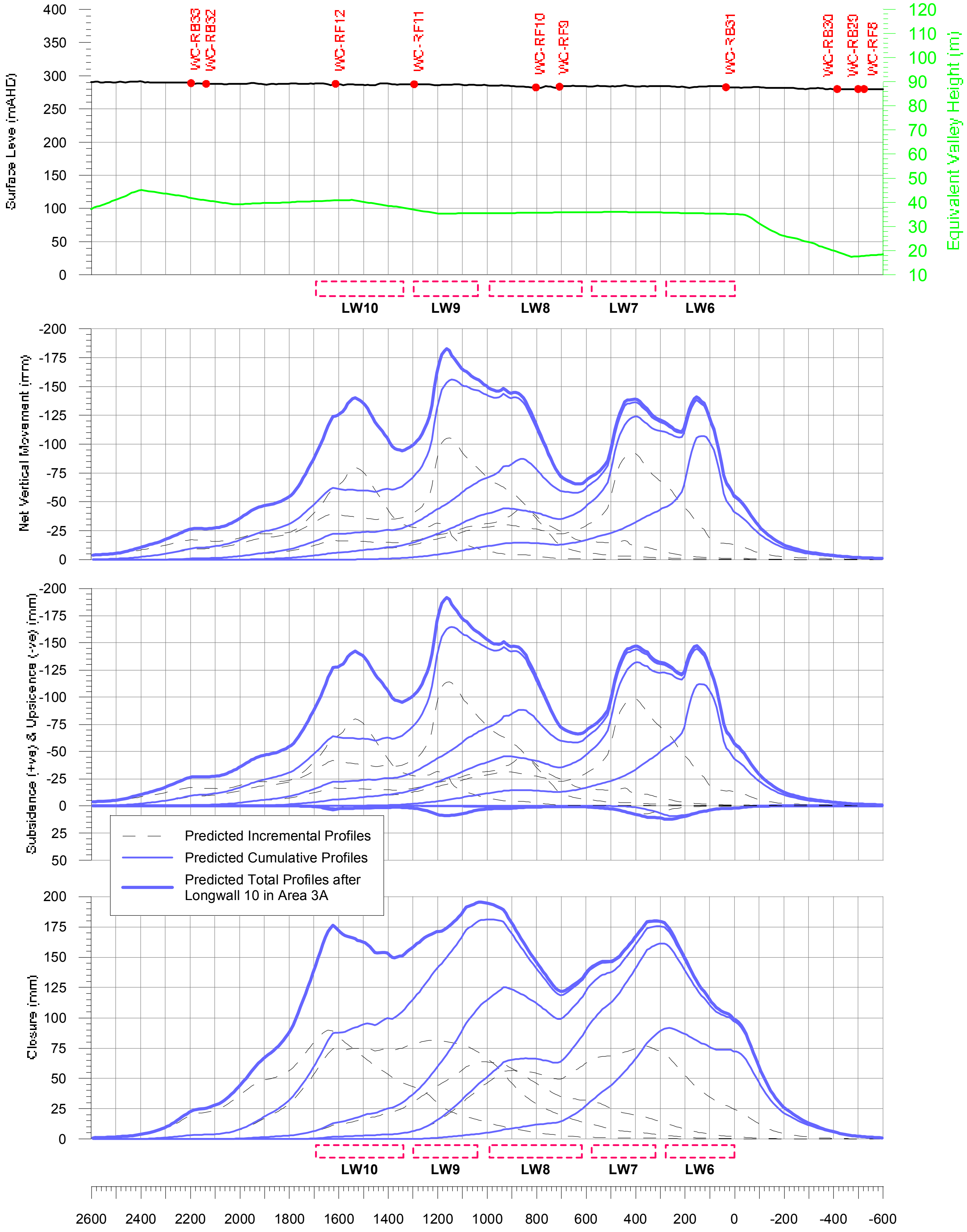

Fig. E.02

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Dendrobium - Area 3A - Longwalls 6 to 10
Sandy Creek Long Section
Predicted Profiles of Subsidence, Upsidence and Closure

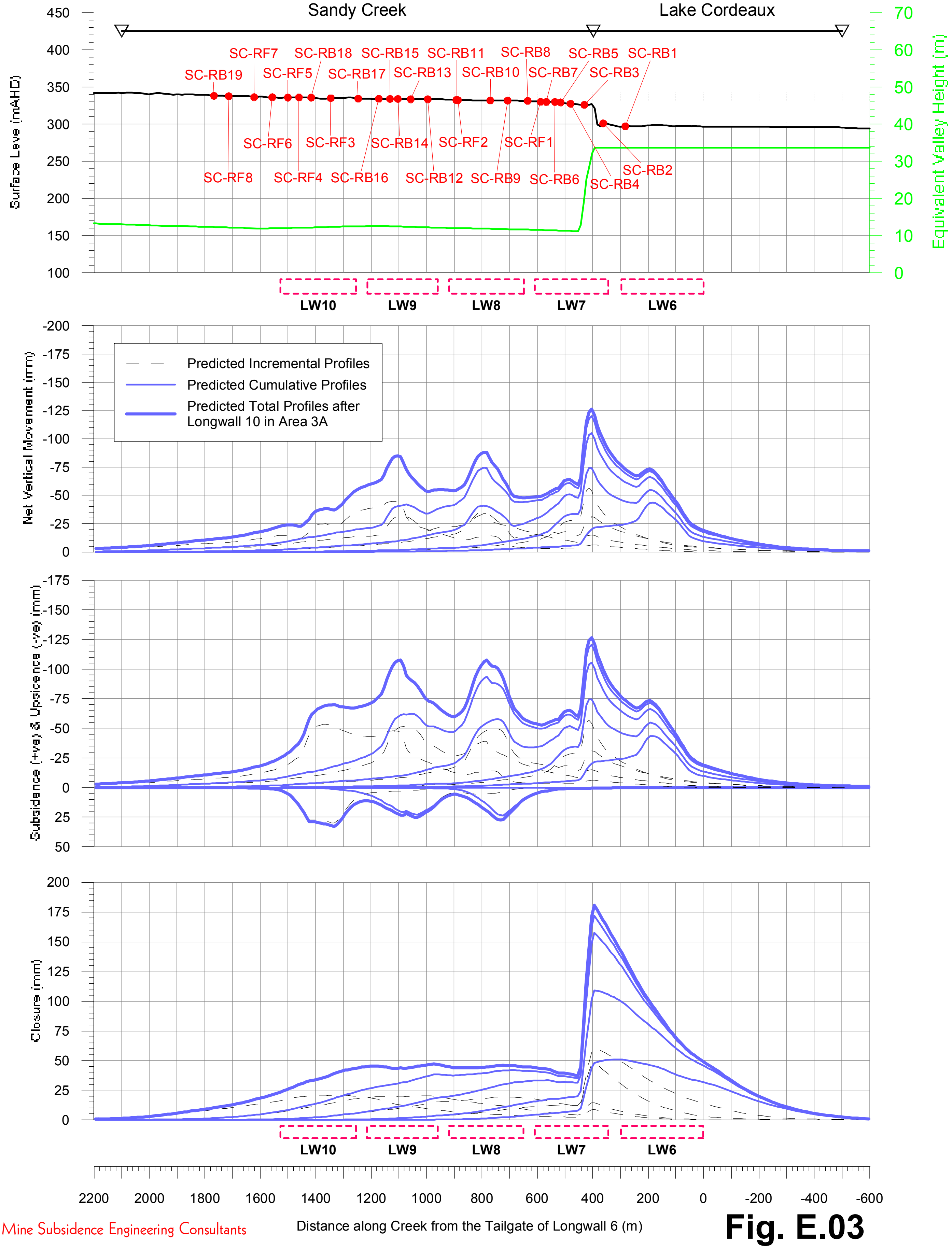

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Fig. E.03

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Dendrobium - Area 3A - Longwalls 6 to 10
Drainage Line WC17(A) (Tributary to Wongawilli Creek)
Predicted Profiles of Subsidence, Upsidence and Closure

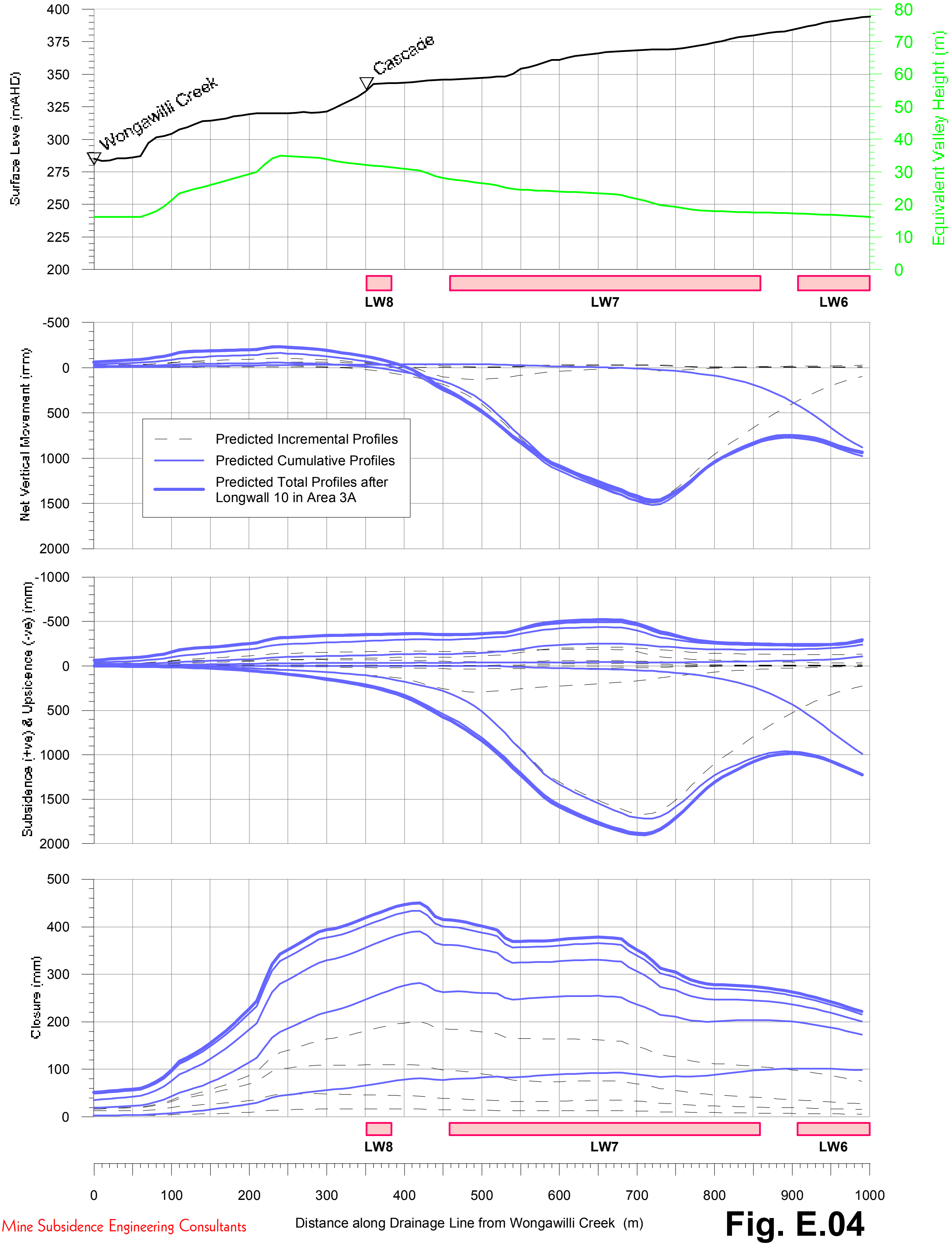

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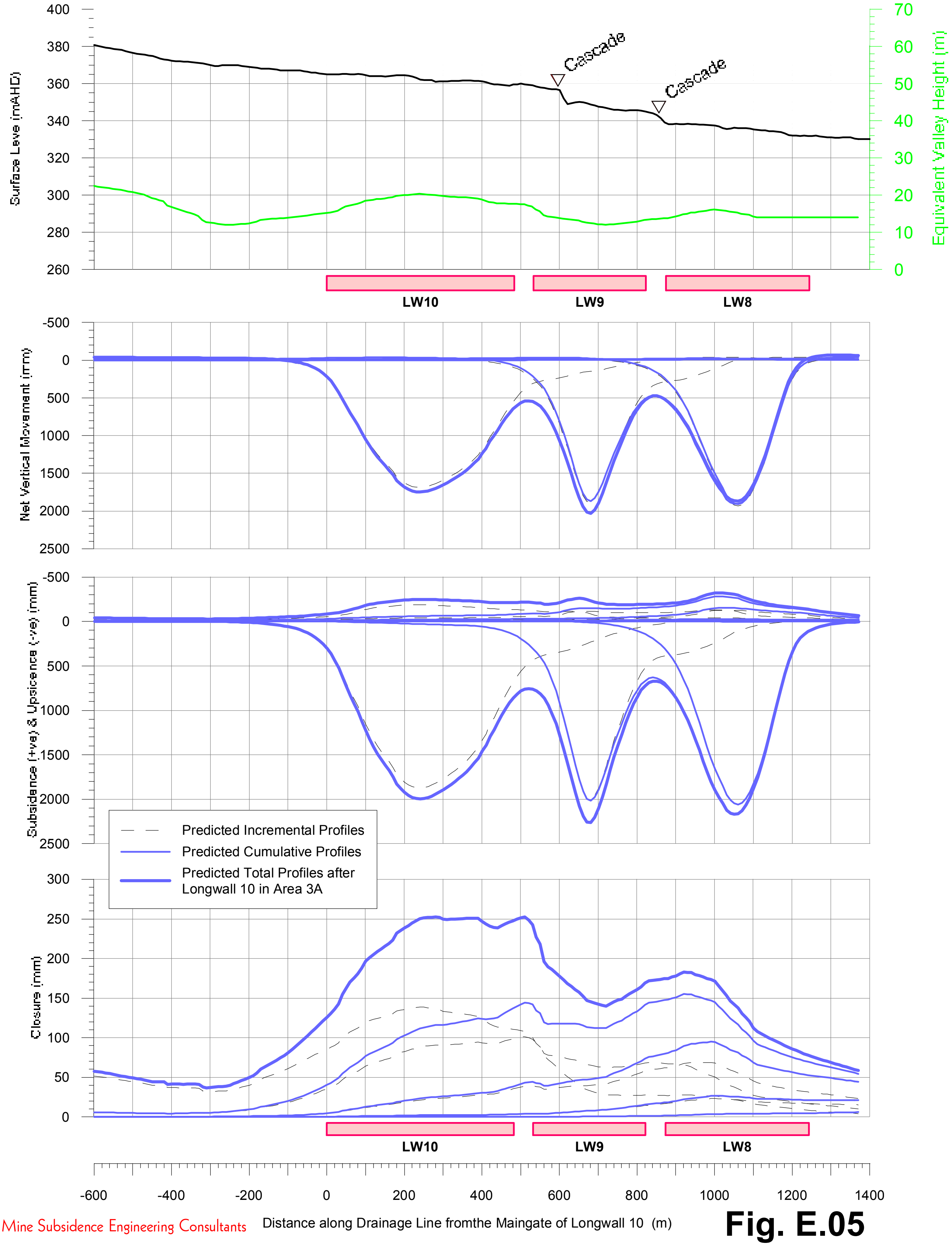
Fig. E.04

Dendrobium - Area 3A - Longwalls 6 to 10
Drainage Line SC10 (Tributary to Sandy Creek)
Predicted Profiles of Subsidence, Upsidence and Closure



Mine Subsidence Engineering Consultants

Fig. E.05

Predicted Profiles of Systematic Subsidence, Tilt and Strain along Fire Road 6C due to Longwalls 6 to 10 in Area 3A

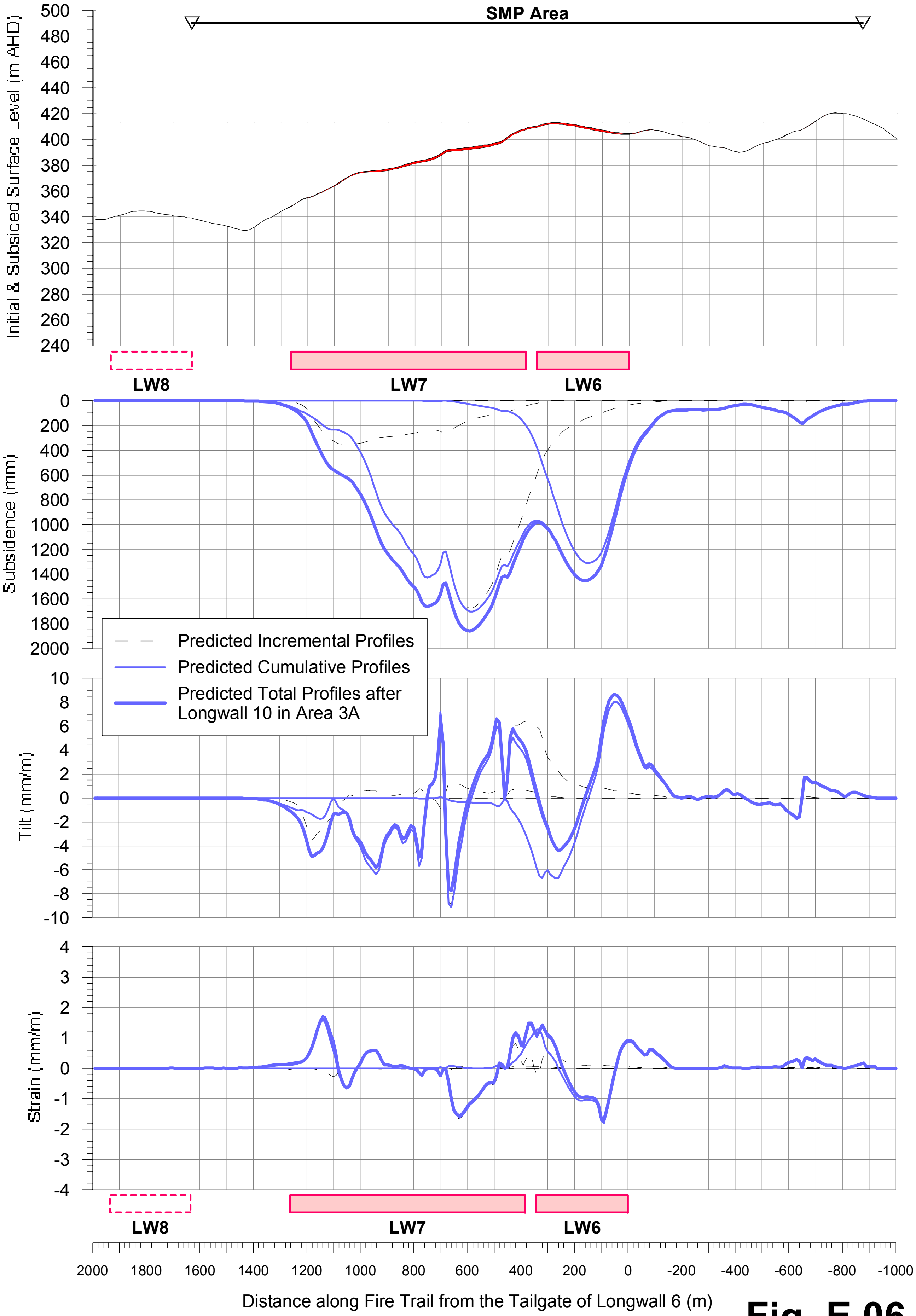


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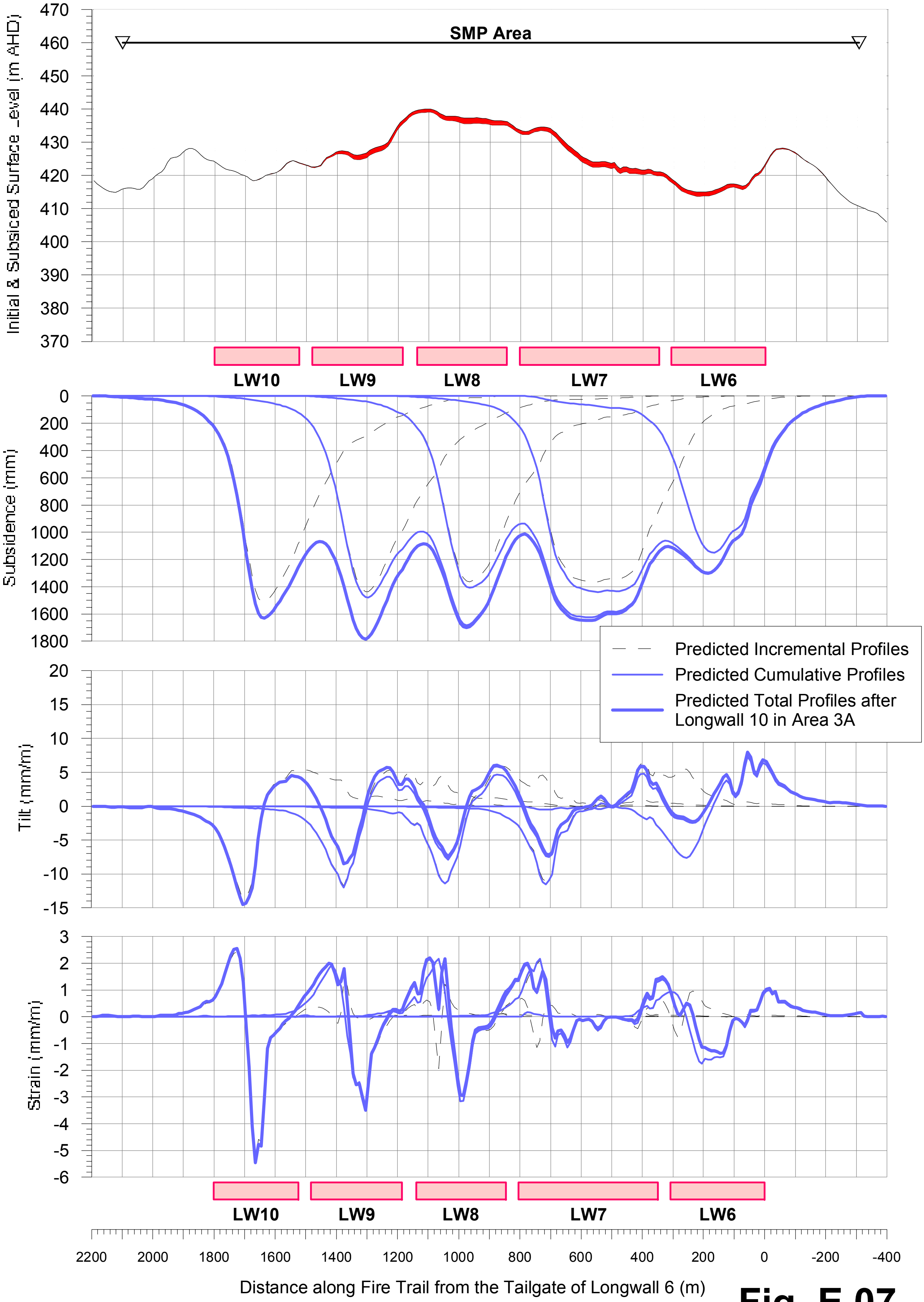
Fig. E.06

Predicted Profiles of Systematic Subsidence, Tilt and Strain along Fire Road 6F due to Longwalls 6 to 10 in Area 3A



Predicted Profiles of Systematic Subsidence, Tilt Along and Tilt Across the Alignment of the 330 kV Transmission Line in Area 3A

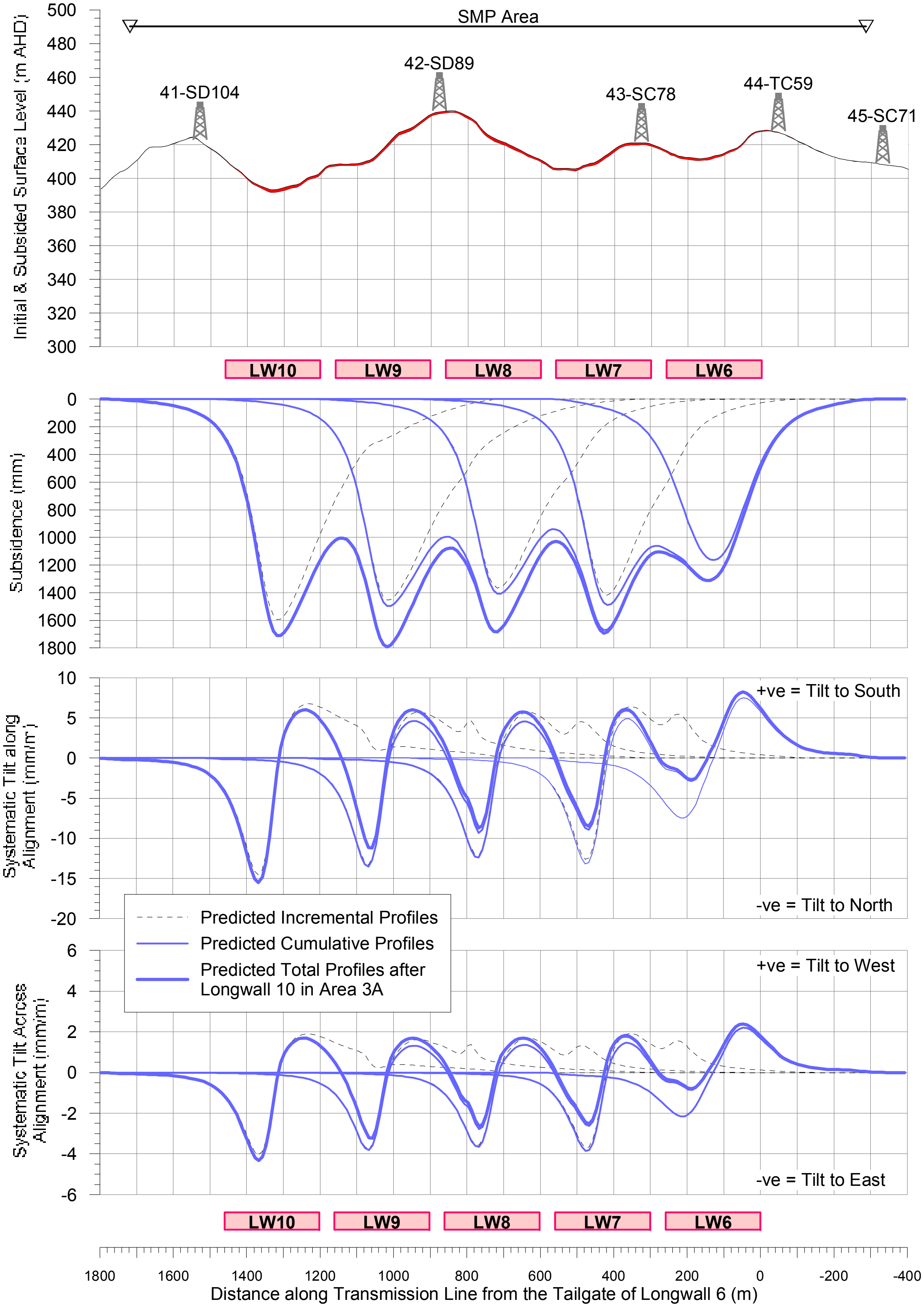
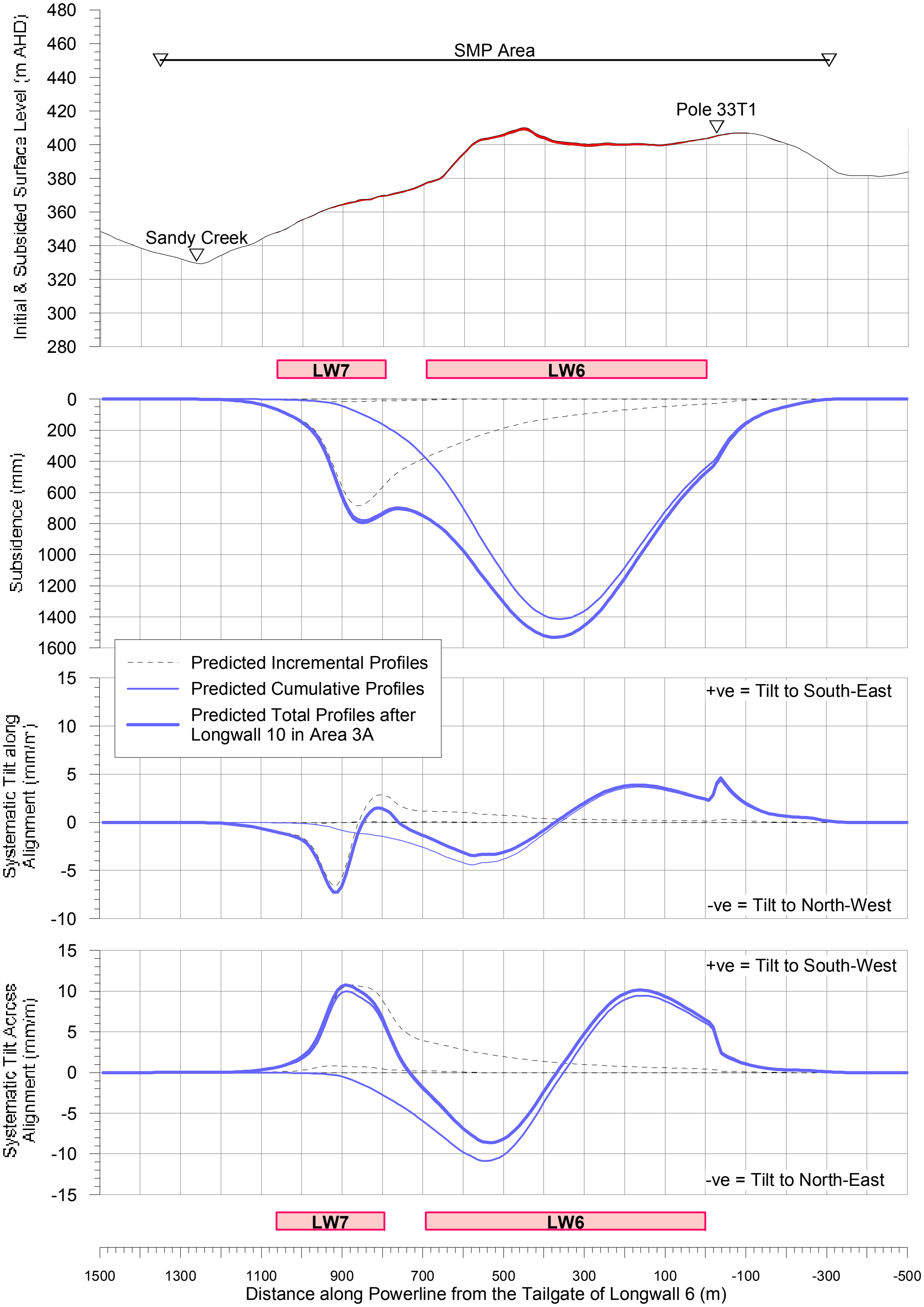


Fig. E.08

Predicted Profiles of Systematic Subsidence, Tilt Along and Tilt Across the Alignment of the 33 kV Powerline in Area 3A



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Elouera Colliery - Predicted and Observed Subsidence along the Maldon-Dombarton Monitoring Line

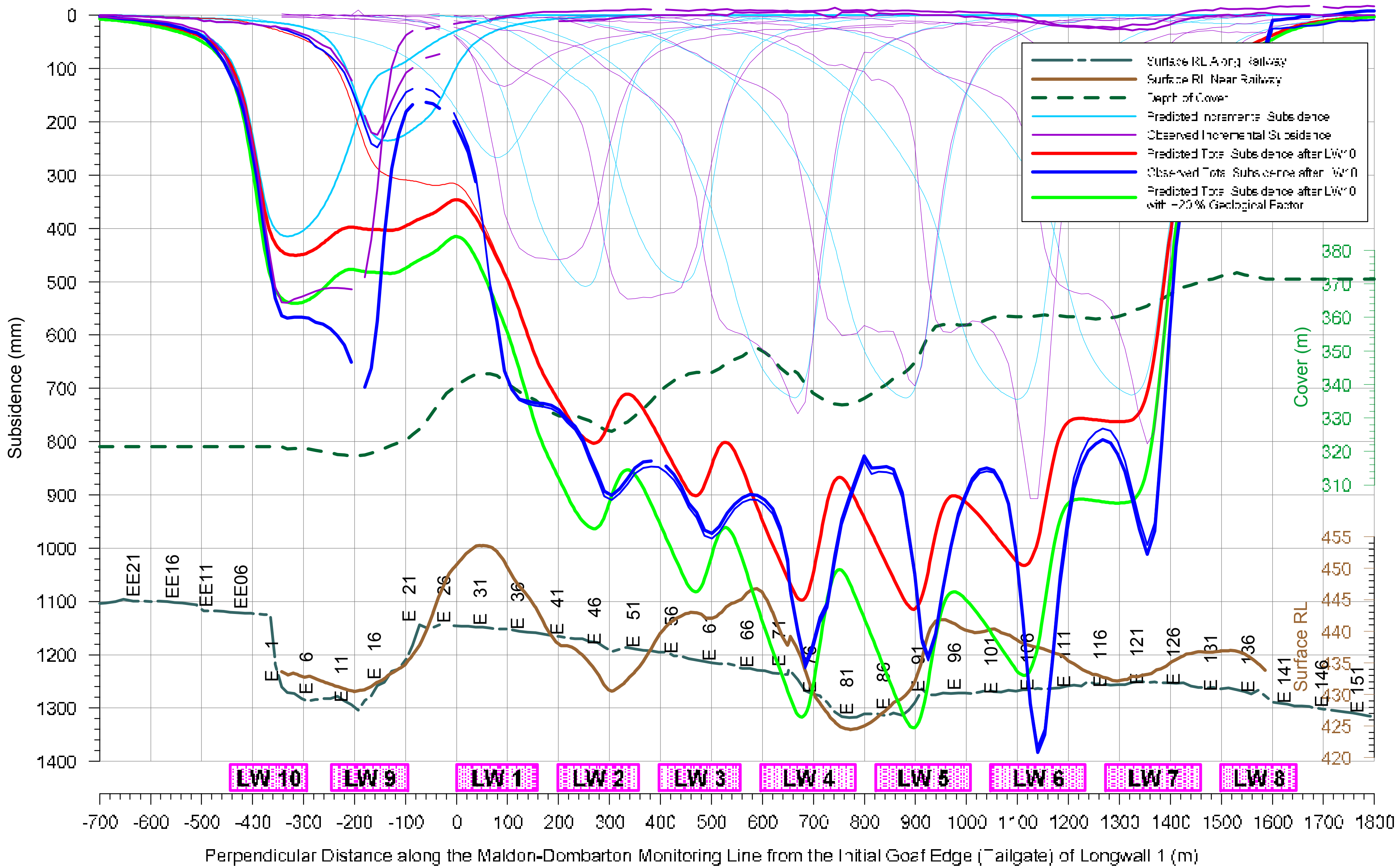

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Fig. E.10

APPENDIX F. DRAWINGS

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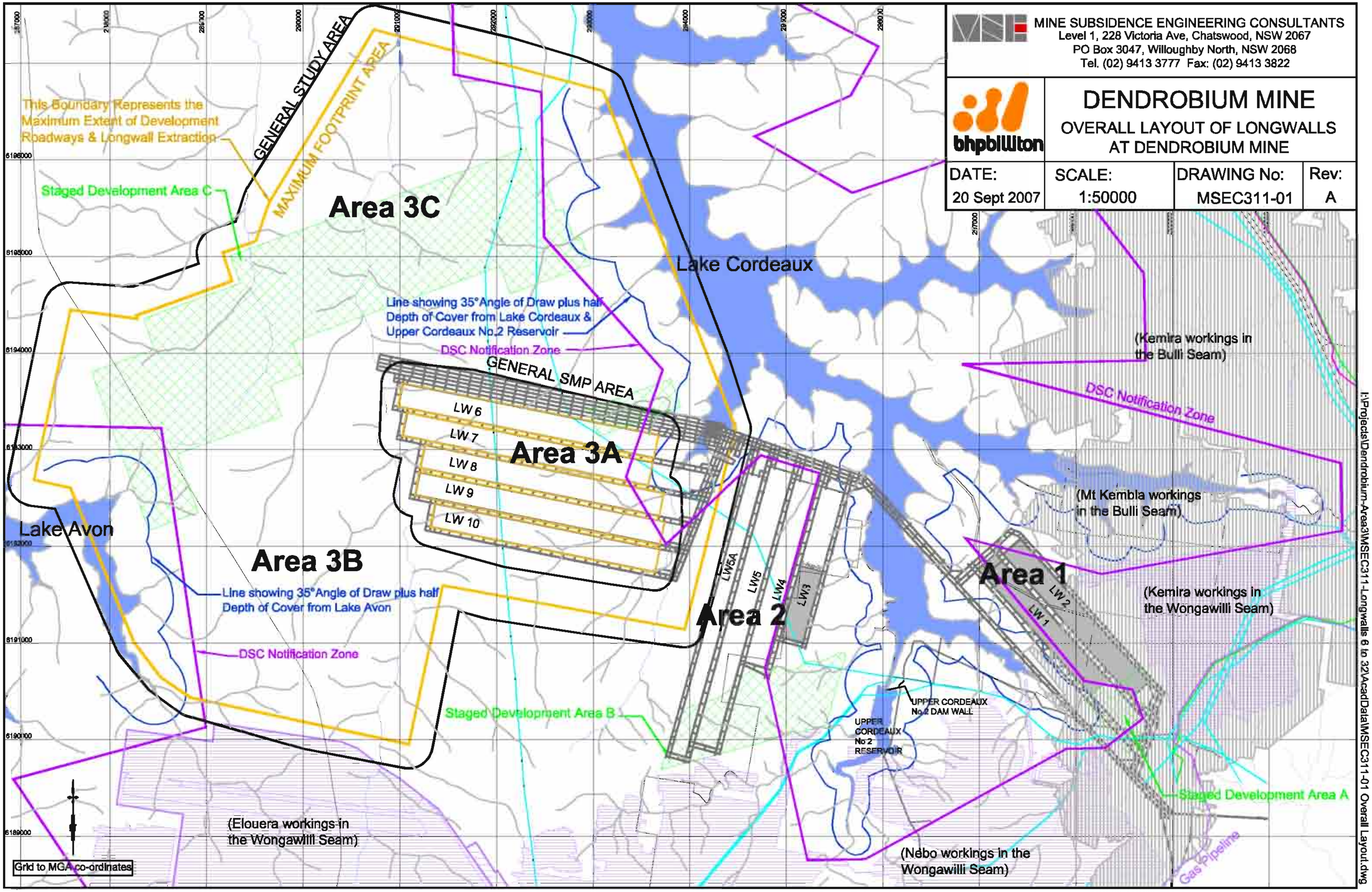
DENDROBIUM MINE

OVERALL LAYOUT OF LONGWALLS AT DENDROBIUM MINE

DATE:	SCALE:	DRAWING No:	Rev:
20 Sept 2007	1:50000	MSEC311-01	A



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DENDROBIUM MINE

COMPARISON BETWEEN PREVIOUS & CURRENT LONGWALL LAYOUT PROPOSALS

DATE:	SCALE:	DRAWING No:	Rev:
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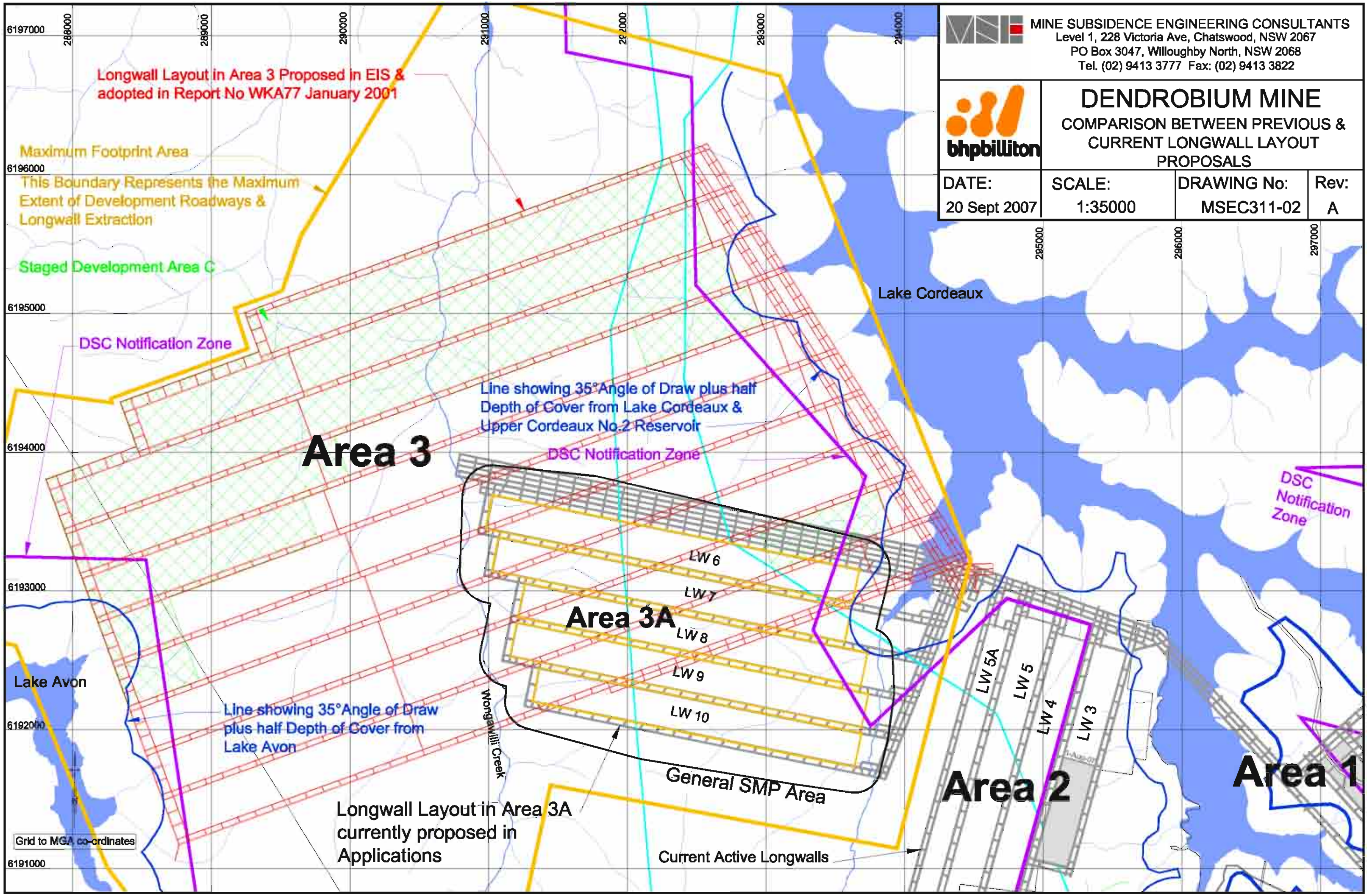

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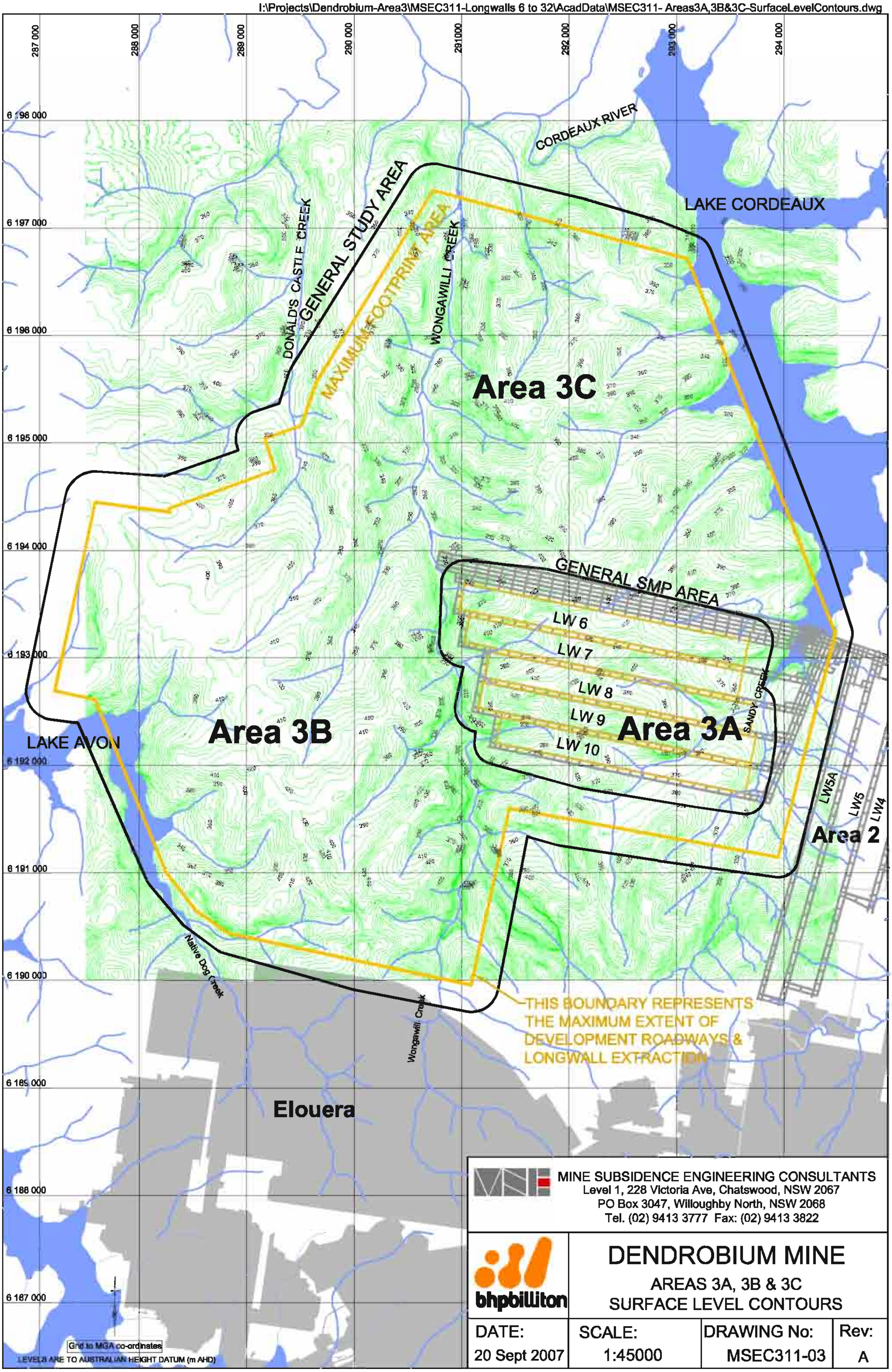

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DENDROBIUM MINE

AREAS 3A, 3B & 3C
SURFACE LEVEL CONTOURS

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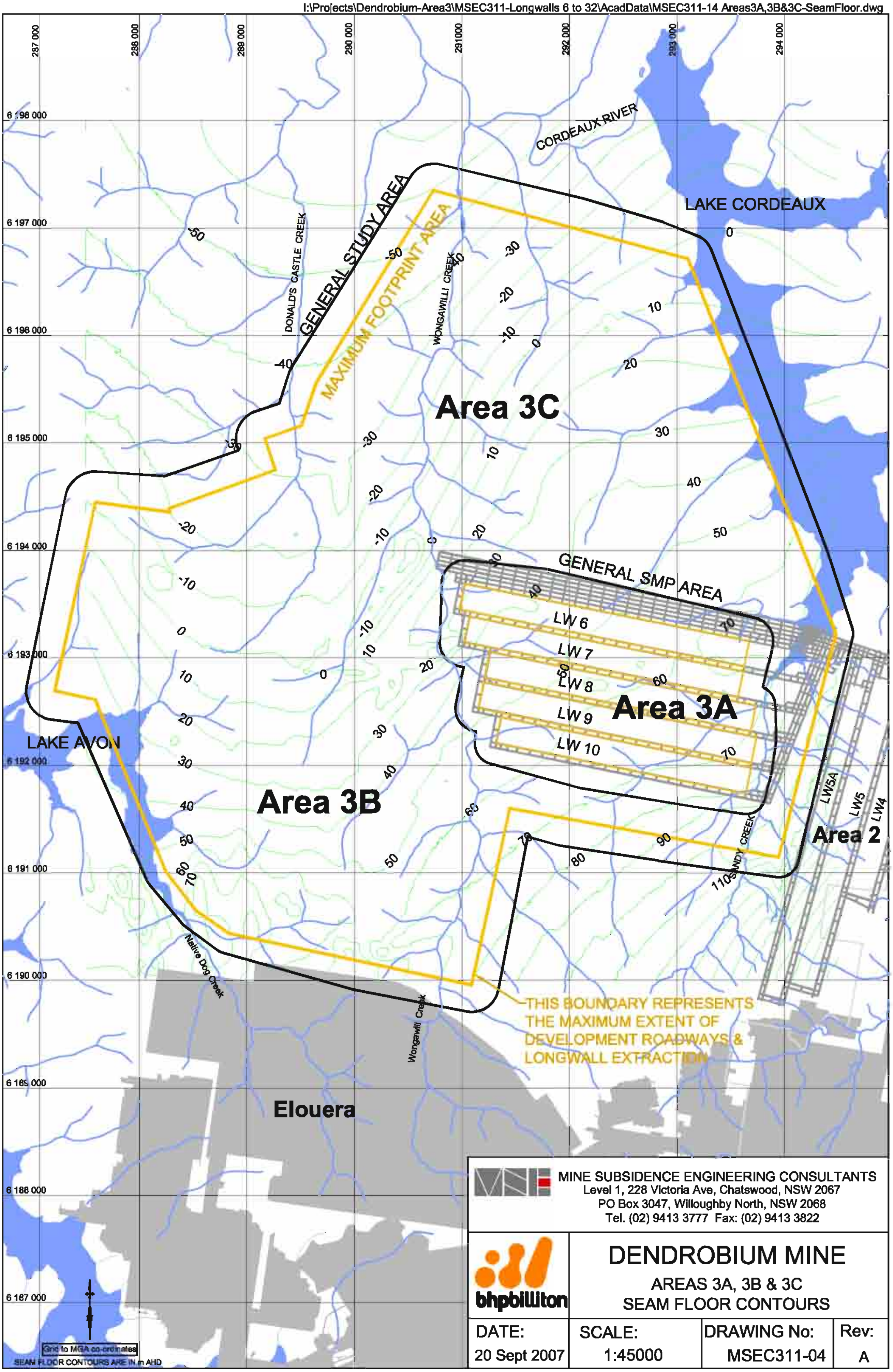

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DENDROBIUM MINE
AREAS 3A, 3B & 3C
SEAM FLOOR CONTOURS

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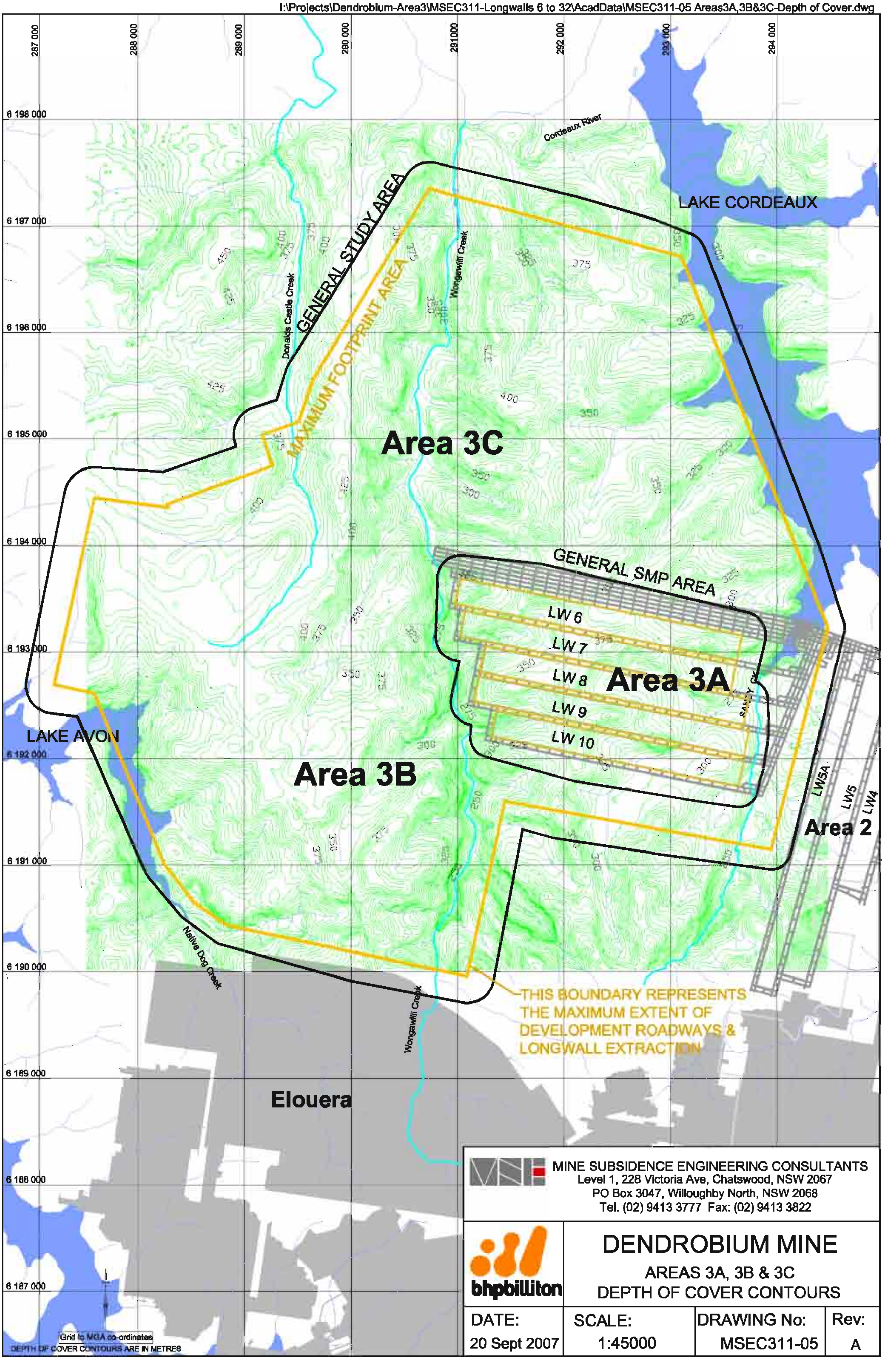

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DENDROBIUM MINE

AREAS 3A, 3B & 3C
DEPTH OF COVER CONTOURS

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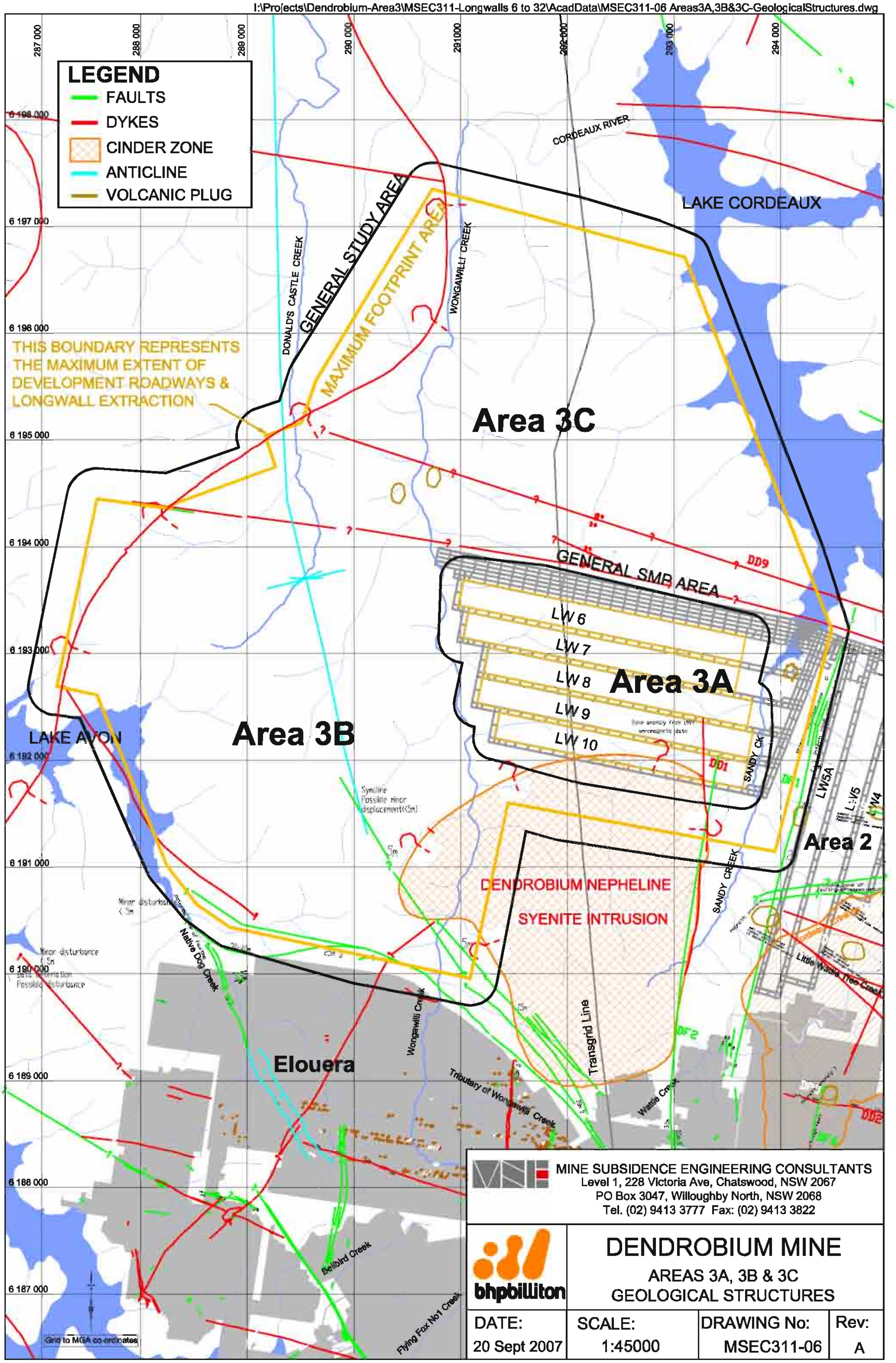

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AREAS 3A, 3B & 3C GEOLOGICAL STRUCTURES

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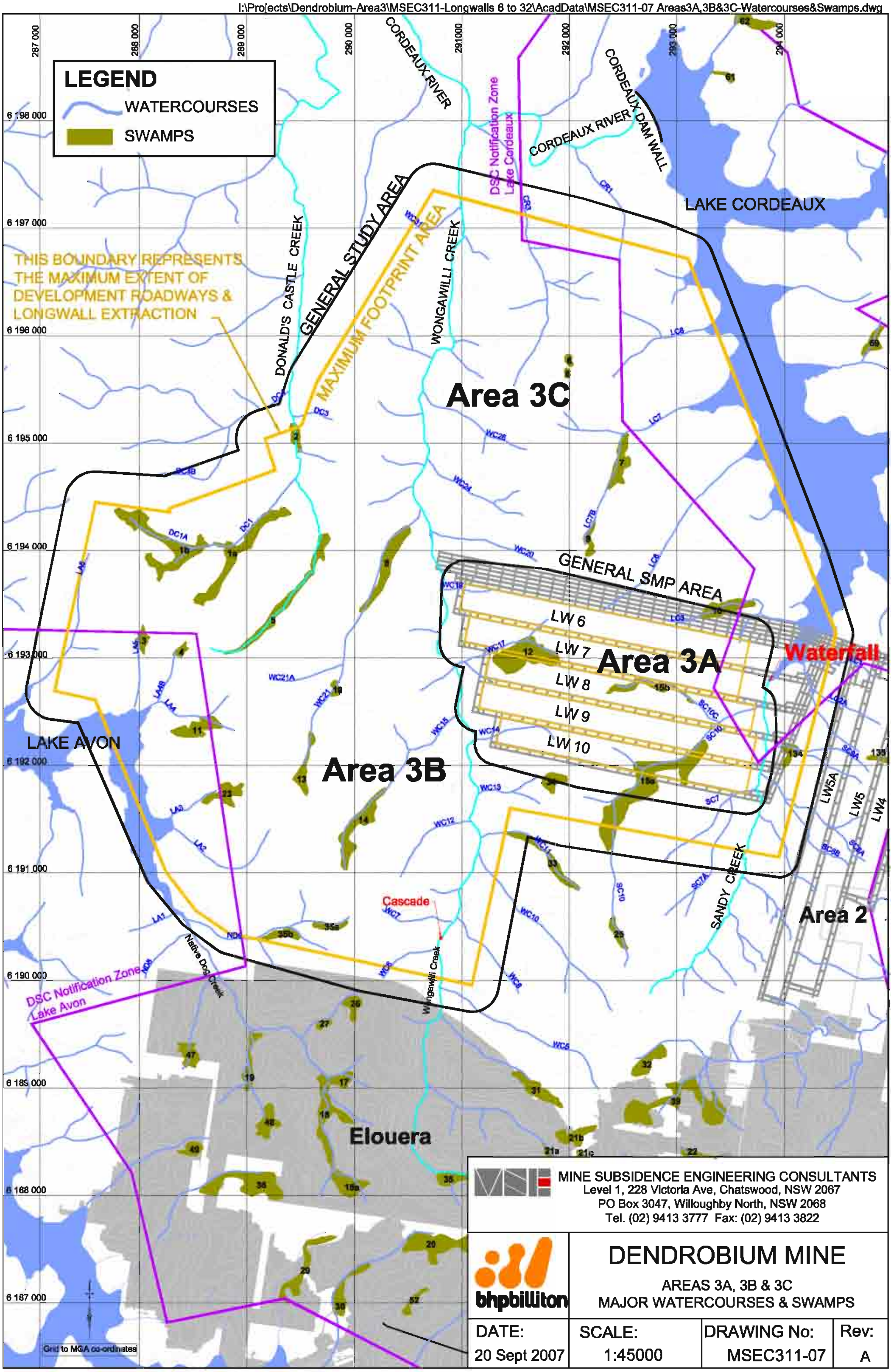

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DENDROBIUM MINE

AREAS 3A, 3B & 3C
MAJOR WATERCOURSES & SWAMPS

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DENDROBIUM MINE
STREAM FEATURES ALONG WONGAWILLI CREEK (SOUTH)

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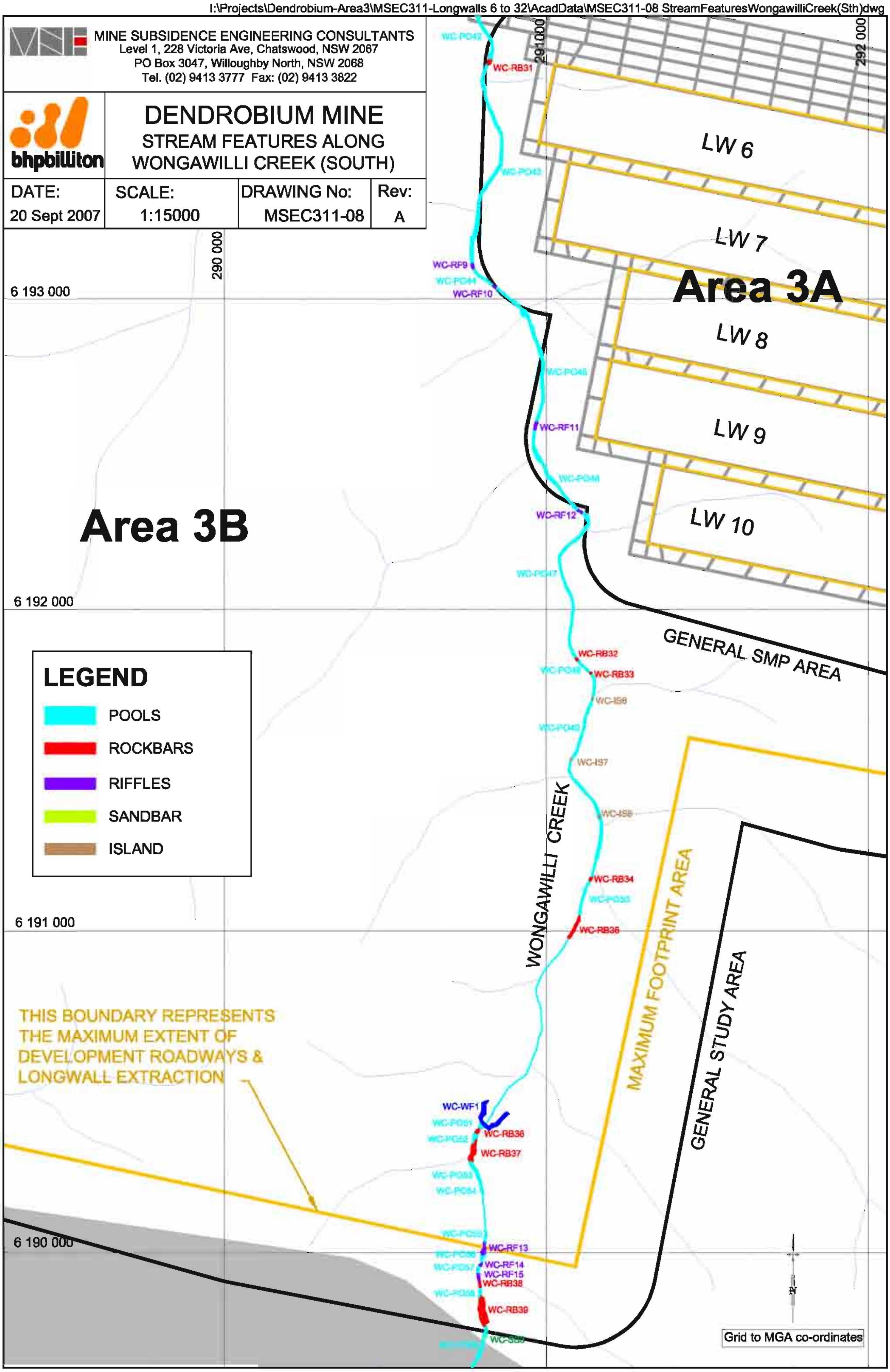

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DENDROBIUM MINE
STREAM FEATURES ALONG WONGAWILLI CREEK (NORTH)

DATE:	SCALE:	DRAWING No:	Rev:
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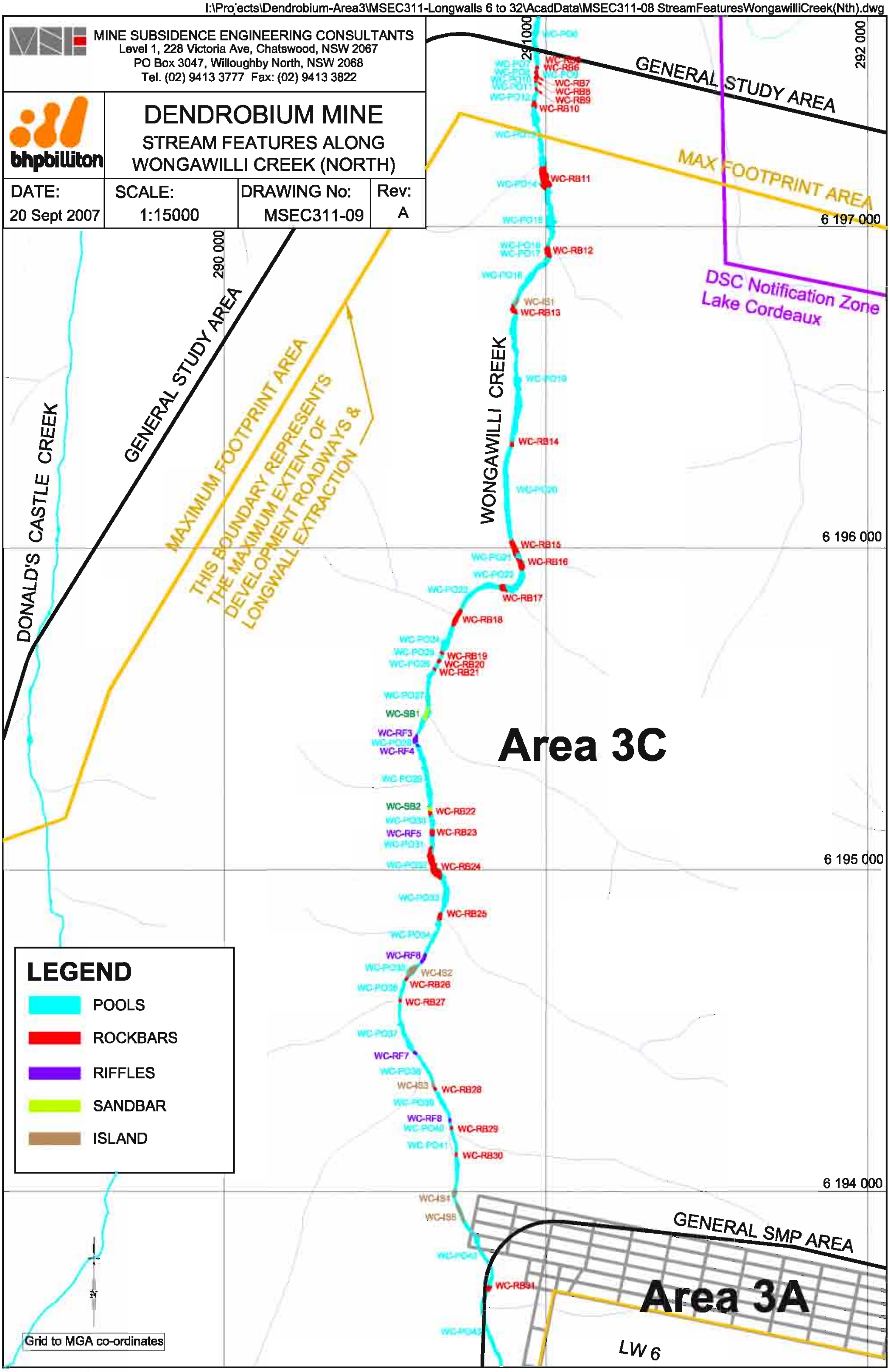

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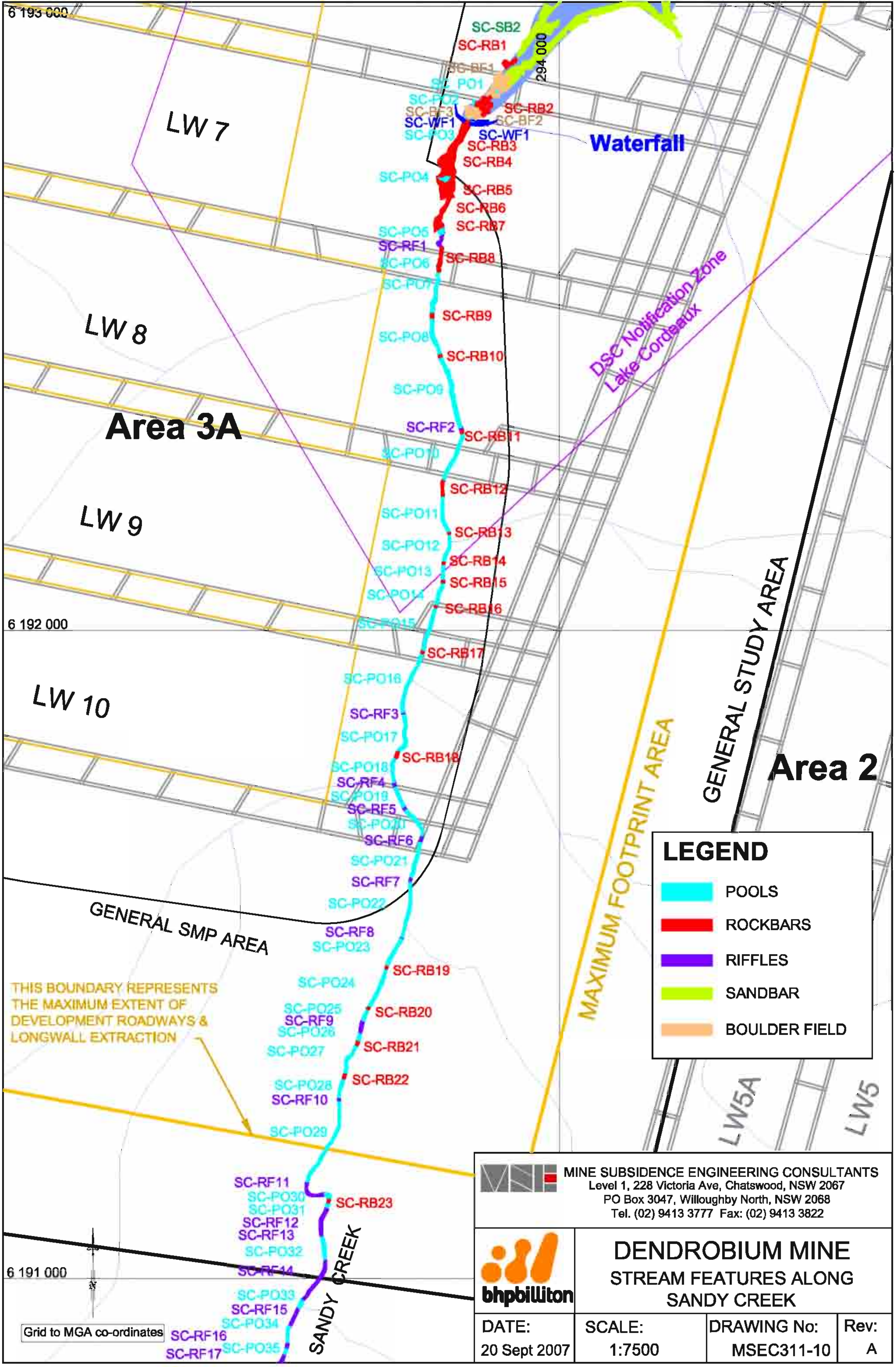

LEGEND

🟦	POOLS
🟥	ROCKBARS
🟪	RIFFLES
🟩	SANDBAR
🟧	BOULDER FIELD

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DENDROBIUM MINE
STREAM FEATURES ALONG
SANDY CREEK

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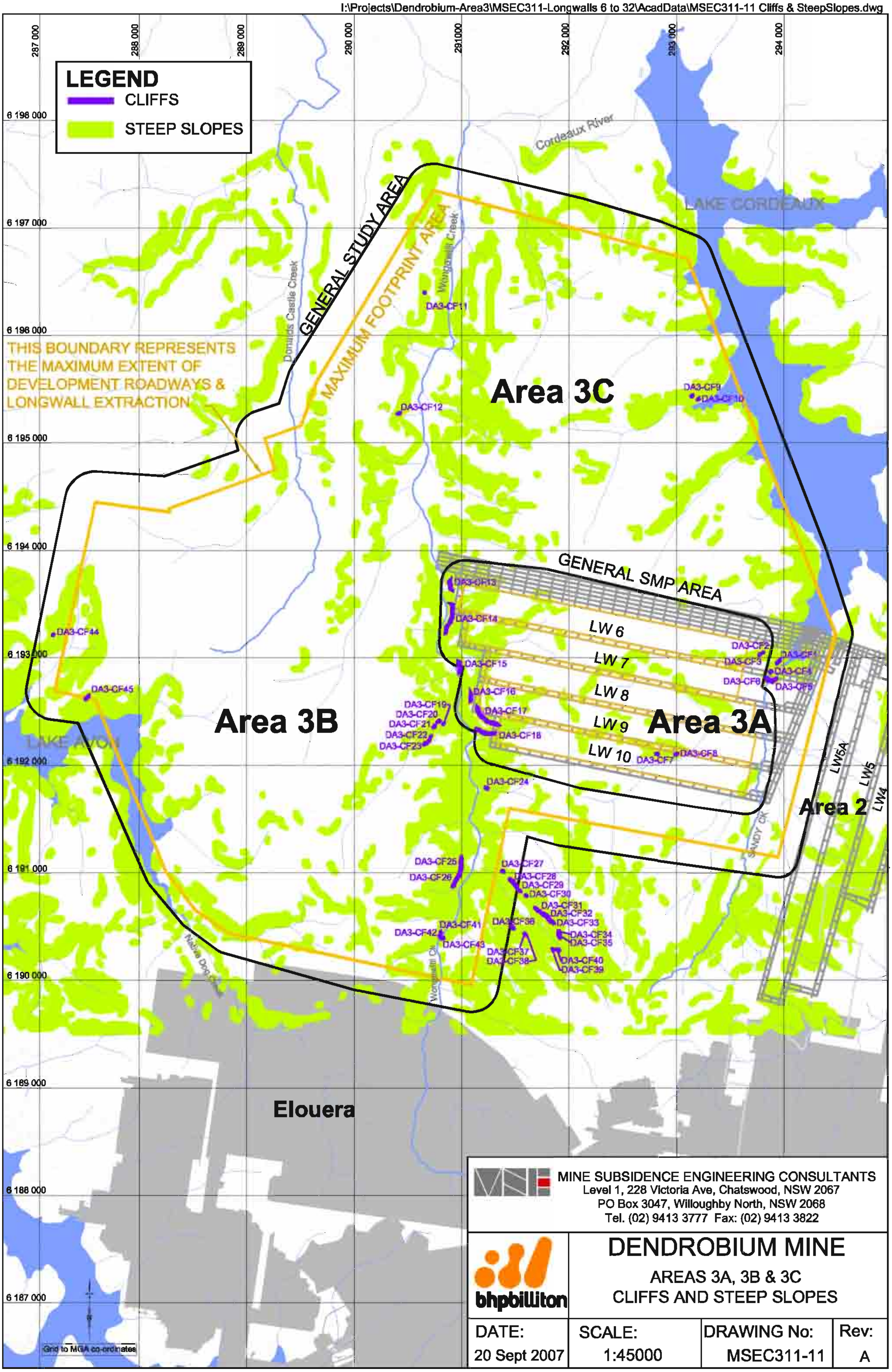

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DENDROBIUM MINE

AREAS 3A, 3B & 3C
CLIFFS AND STEEP SLOPES

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20 Sept 2007	1:45000	MSEC311-11	A

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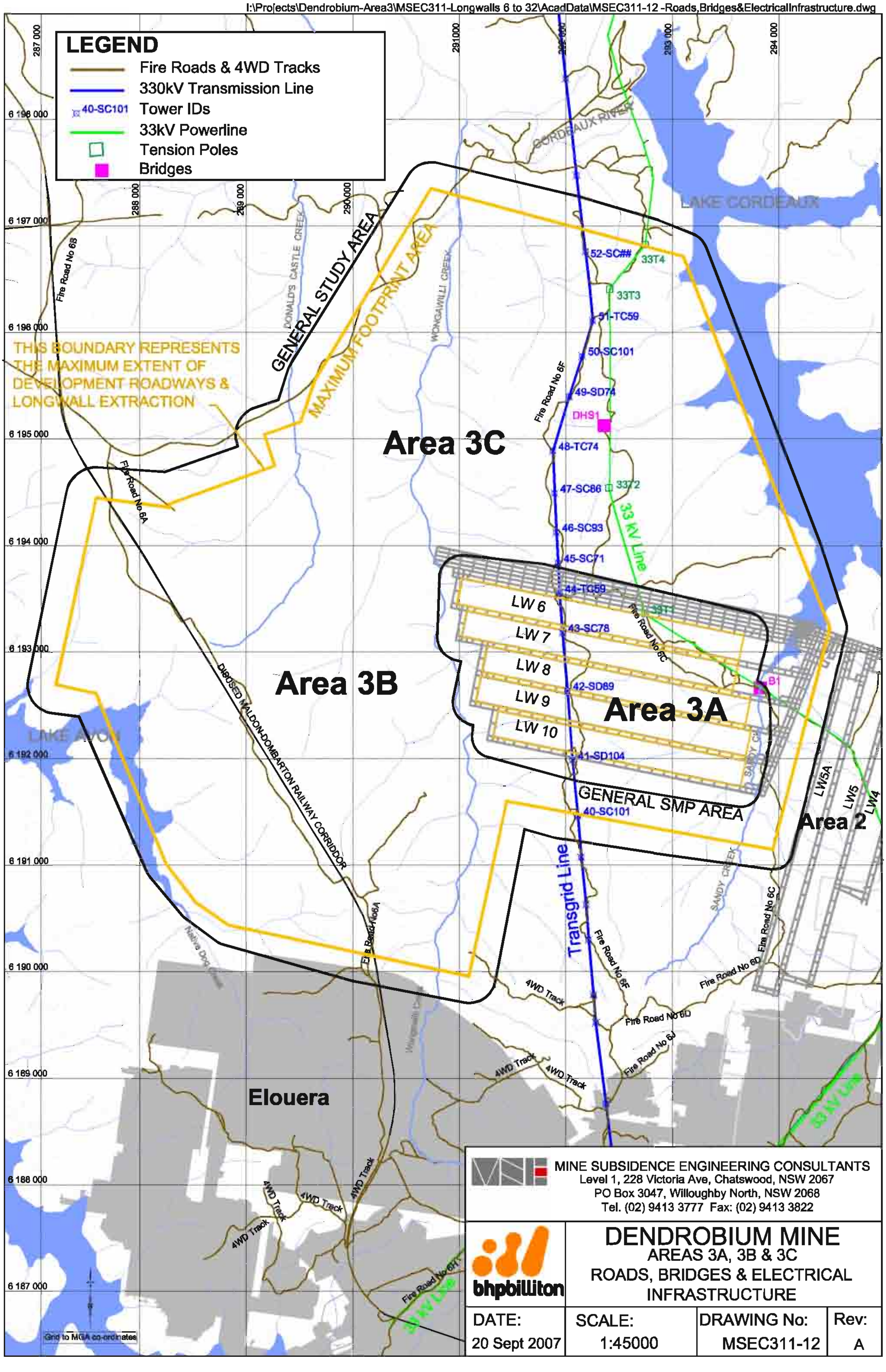

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DENDROBIUM MINE
AREAS 3A, 3B & 3C
ROADS, BRIDGES & ELECTRICAL INFRASTRUCTURE

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20 Sept 2007	1:45000	MSEC311-12	A

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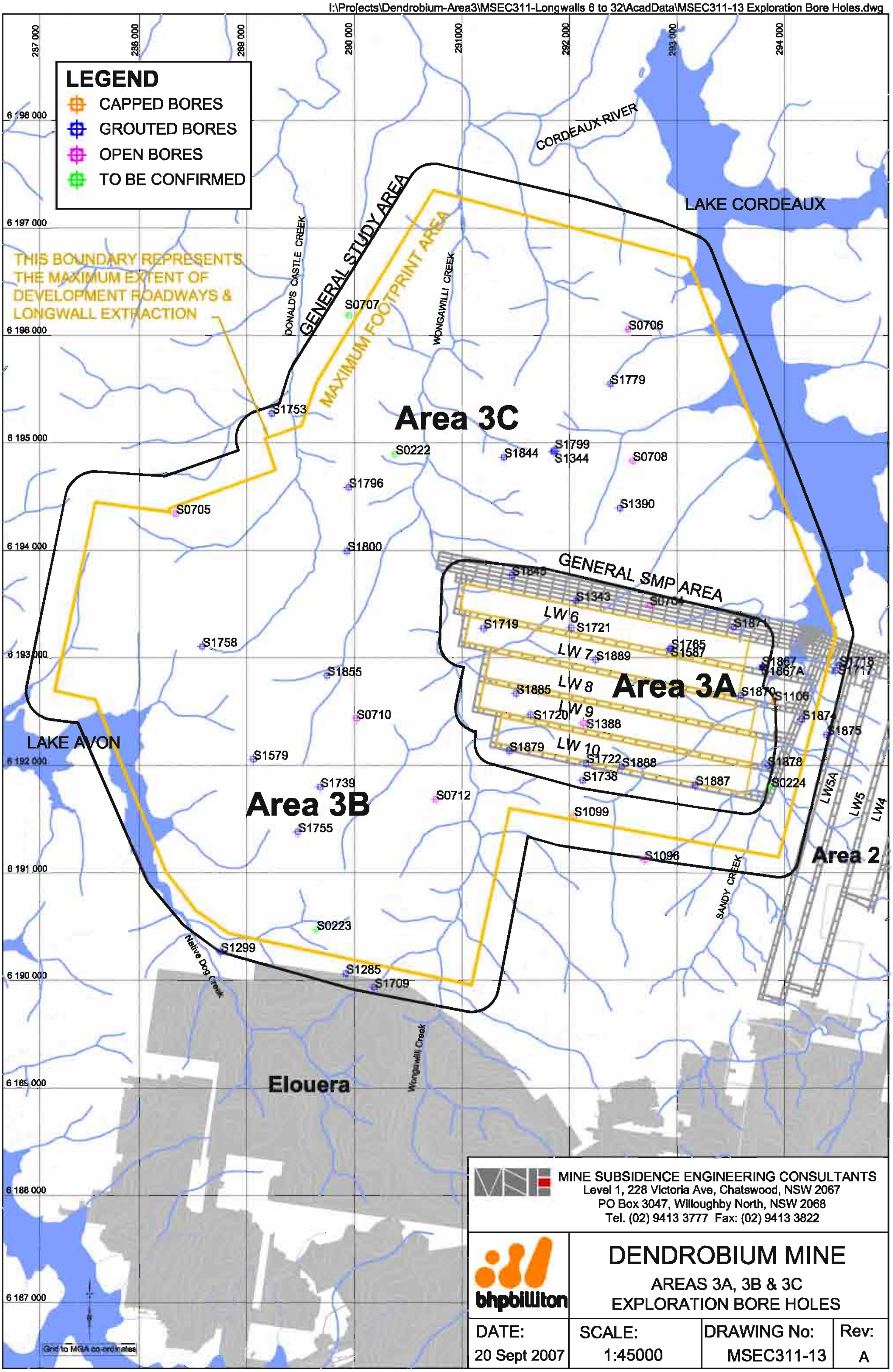

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DENDROBIUM MINE
AREAS 3A, 3B & 3C
EXPLORATION BORE HOLES

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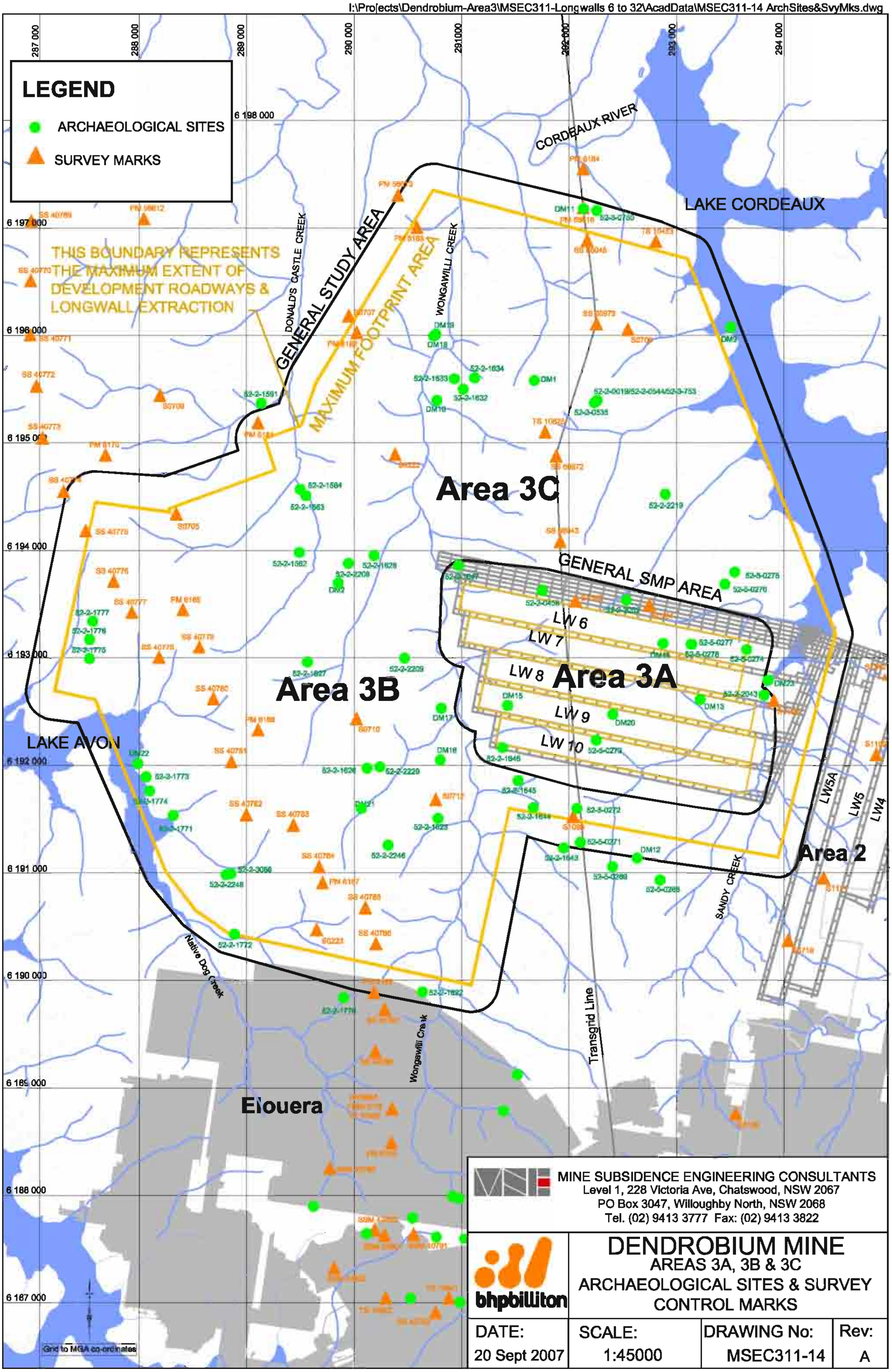

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DENDROBIUM MINE
AREAS 3A, 3B & 3C
ARCHAEOLOGICAL SITES & SURVEY CONTROL MARKS

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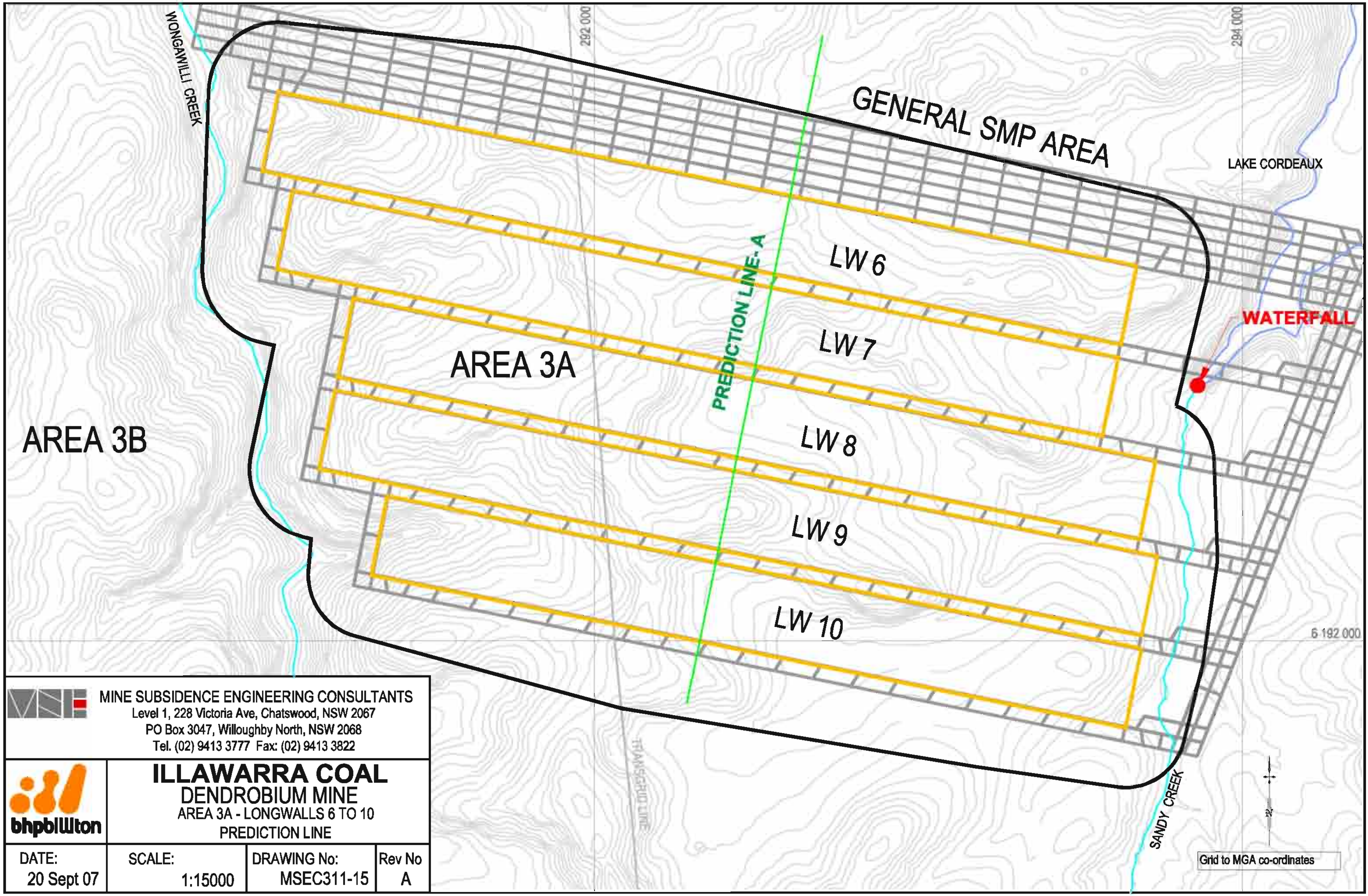

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ILLAWARRA COAL
DENDROBIUM MINE
AREA 3A - LONGWALLS 6 TO 10
PREDICTION LINE

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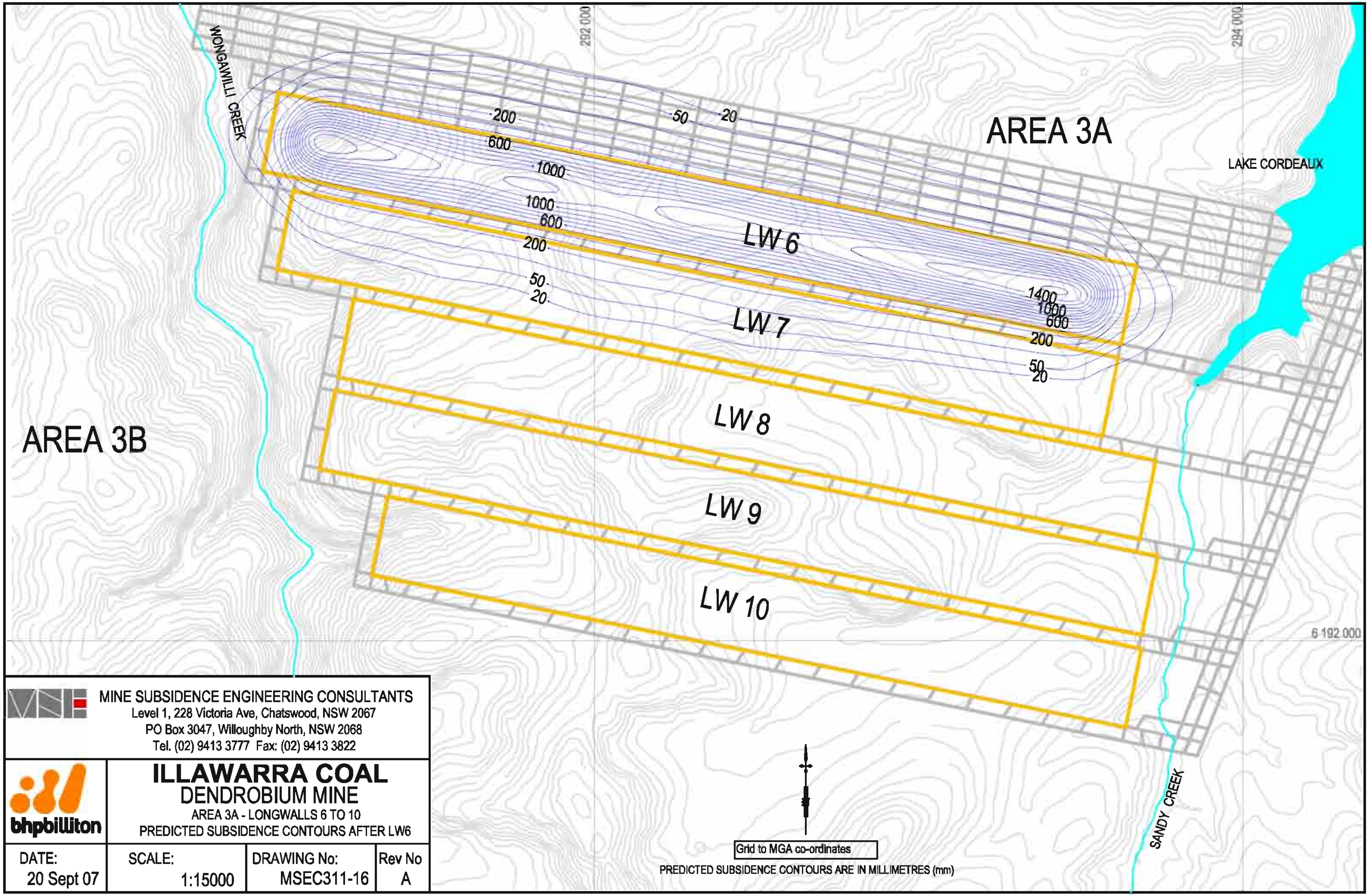

Grid to MGA co-ordinates

PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)

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DENDROBIUM MINE
AREA 3A - LONGWALLS 6 TO 10
PREDICTED SUBSIDENCE CONTOURS AFTER LW6

DATE:	SCALE:	DRAWING No:	Rev No
20 Sept 07	1:15000	MSEC311-16	A

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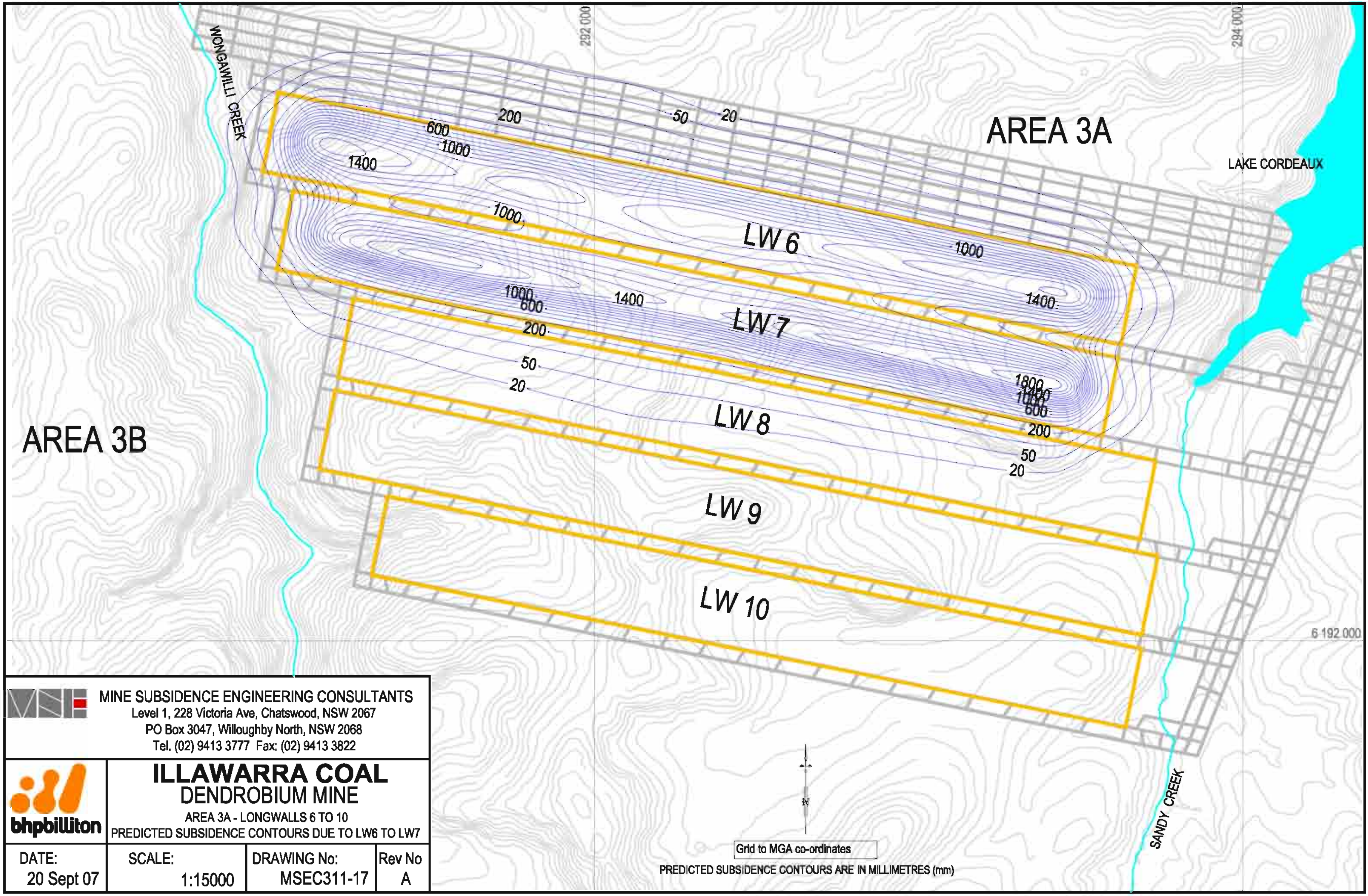

Grid to MGA co-ordinates

PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)

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AREA 3A - LONGWALLS 6 TO 10
PREDICTED SUBSIDENCE CONTOURS DUE TO LW6 TO LW7

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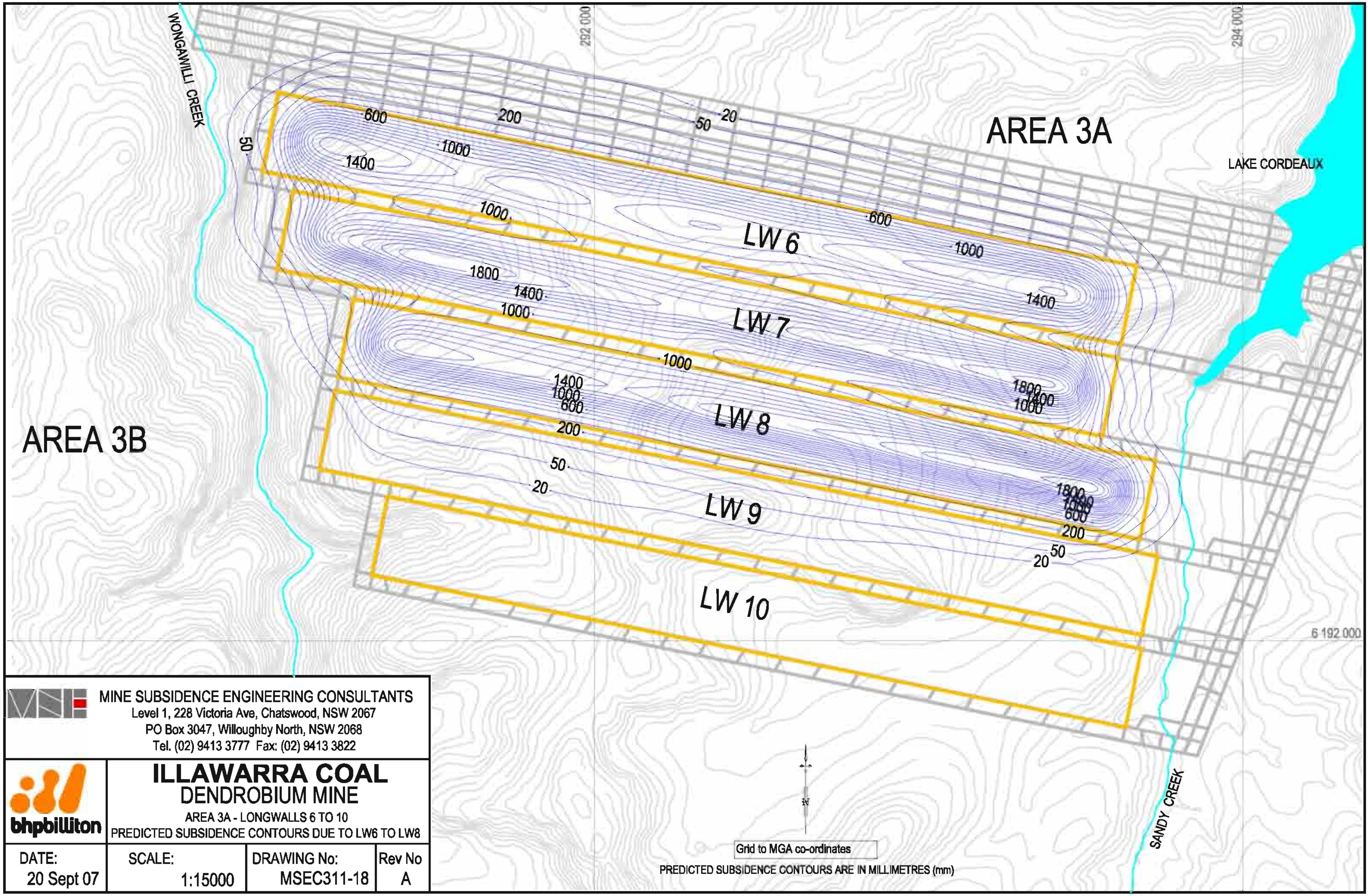

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PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)

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AREA 3A - LONGWALLS 6 TO 10
PREDICTED SUBSIDENCE CONTOURS DUE TO LW6 TO LW8

DATE:	SCALE:	DRAWING No:	Rev No
20 Sept 07	1:15000	MSEC311-18	A

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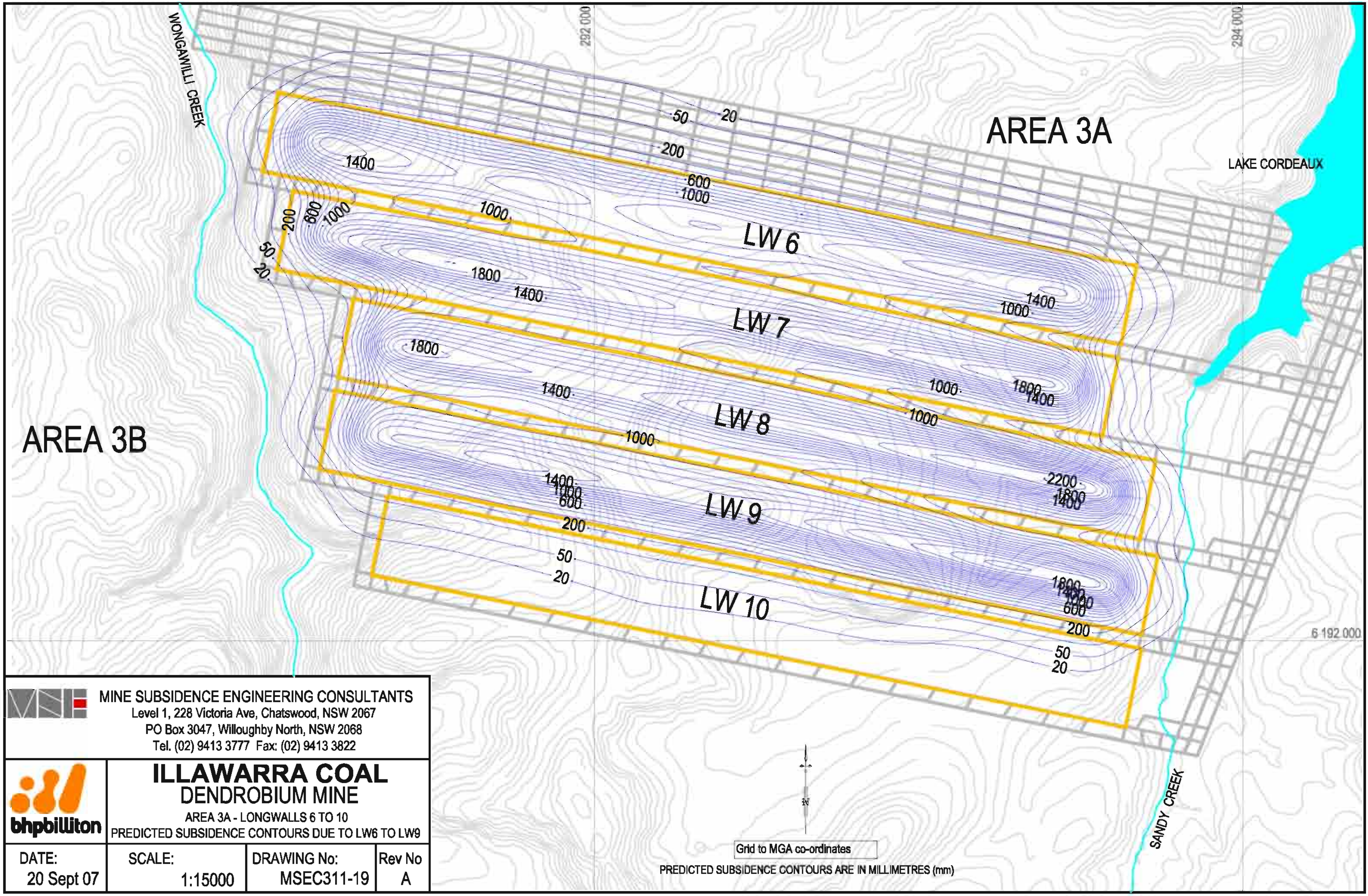

PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)

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ILLAWARRA COAL
DENDROBIUM MINE
AREA 3A - LONGWALLS 6 TO 10
PREDICTED SUBSIDENCE CONTOURS DUE TO LW6 TO LW9

DATE:	SCALE:	DRAWING No:	Rev No
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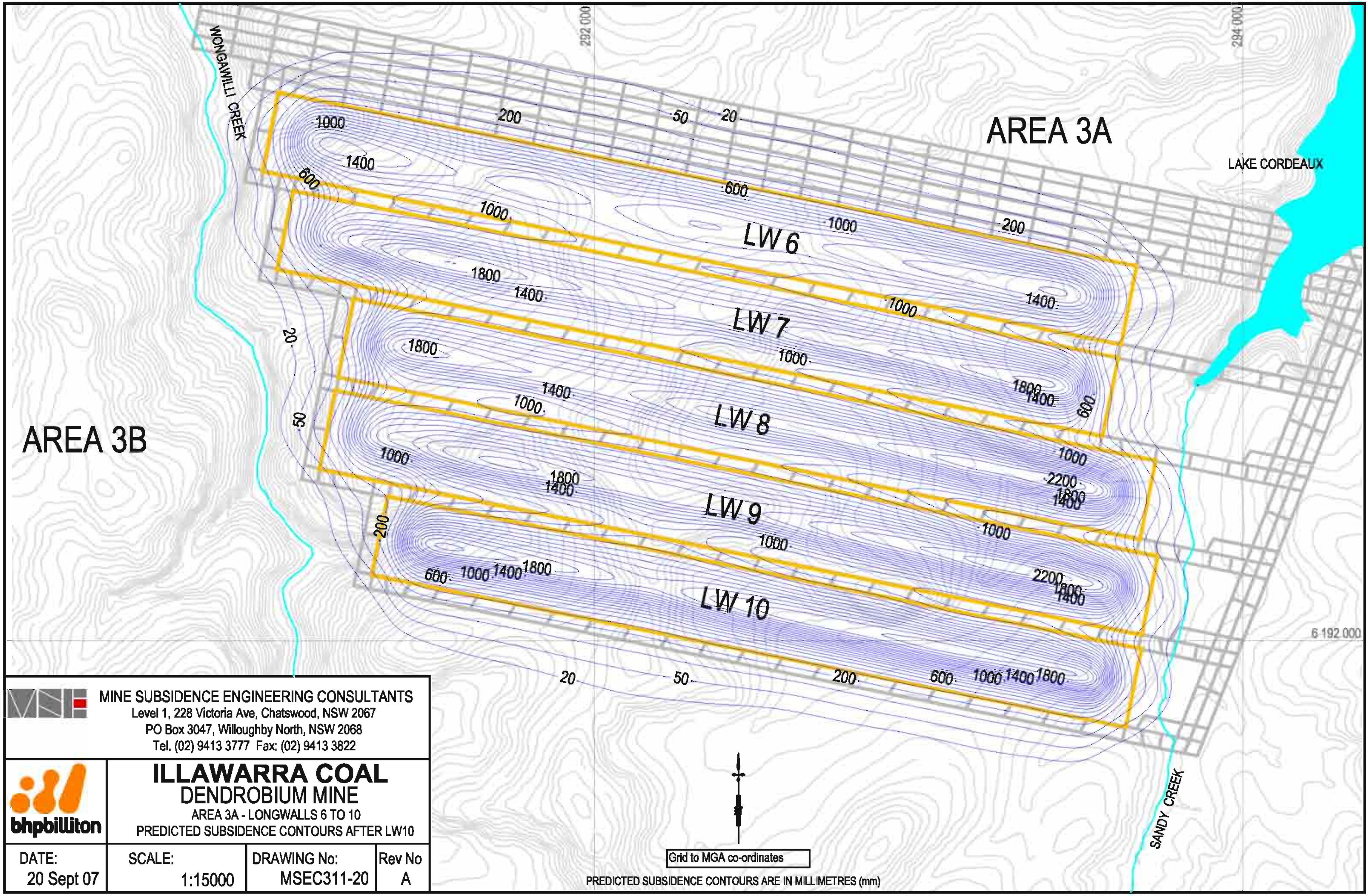

Grid to MGA co-ordinates

PREDICTED SUBSIDENCE CONTOURS ARE IN MILLIMETRES (mm)

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AREA 3A - LONGWALLS 6 TO 10
PREDICTED SUBSIDENCE CONTOURS AFTER LW10

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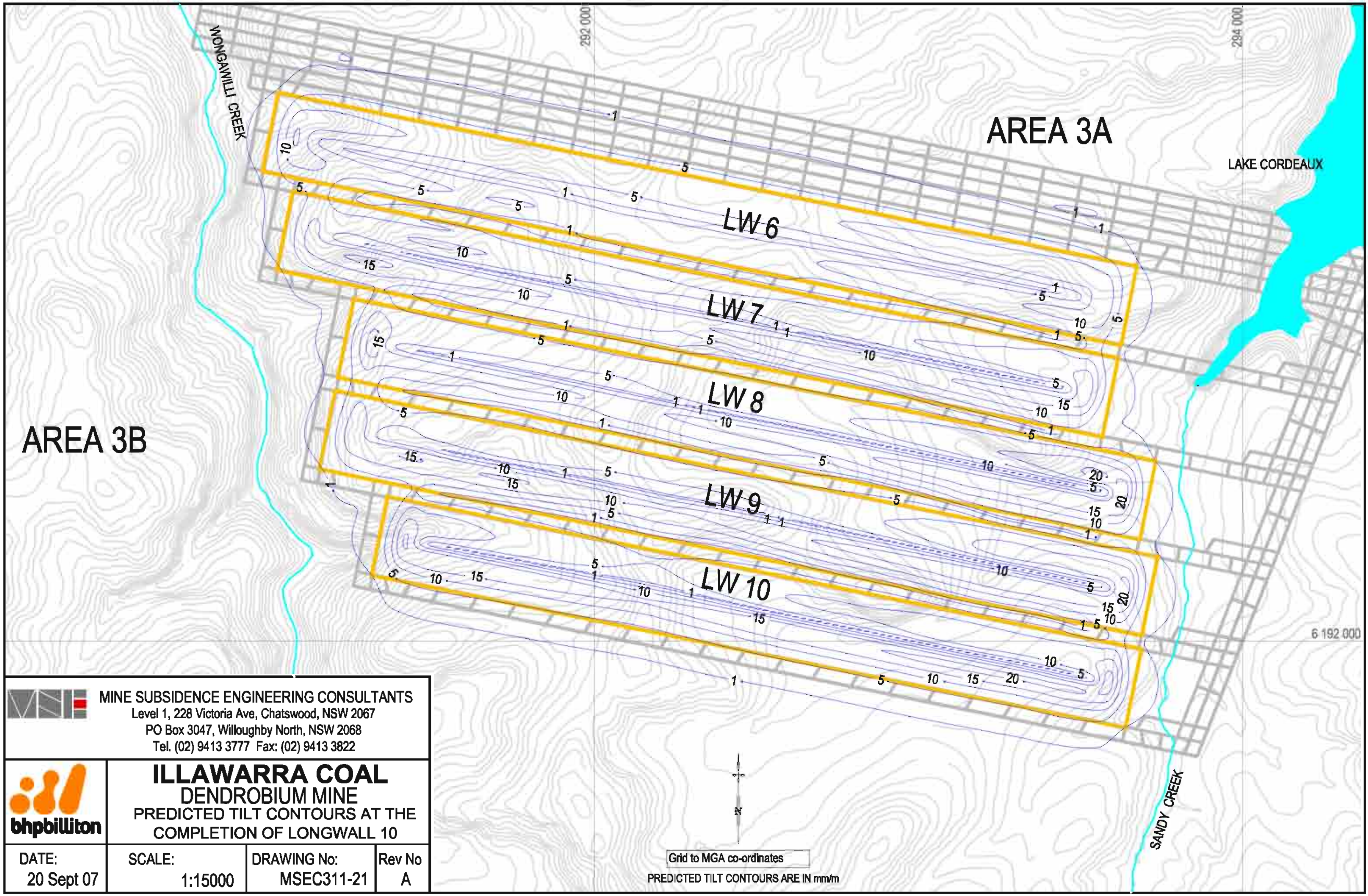

Grid to MGA co-ordinates

PREDICTED TILT CONTOURS ARE IN mm/m

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DENDROBIUM MINE
PREDICTED TILT CONTOURS AT THE COMPLETION OF LONGWALL 10

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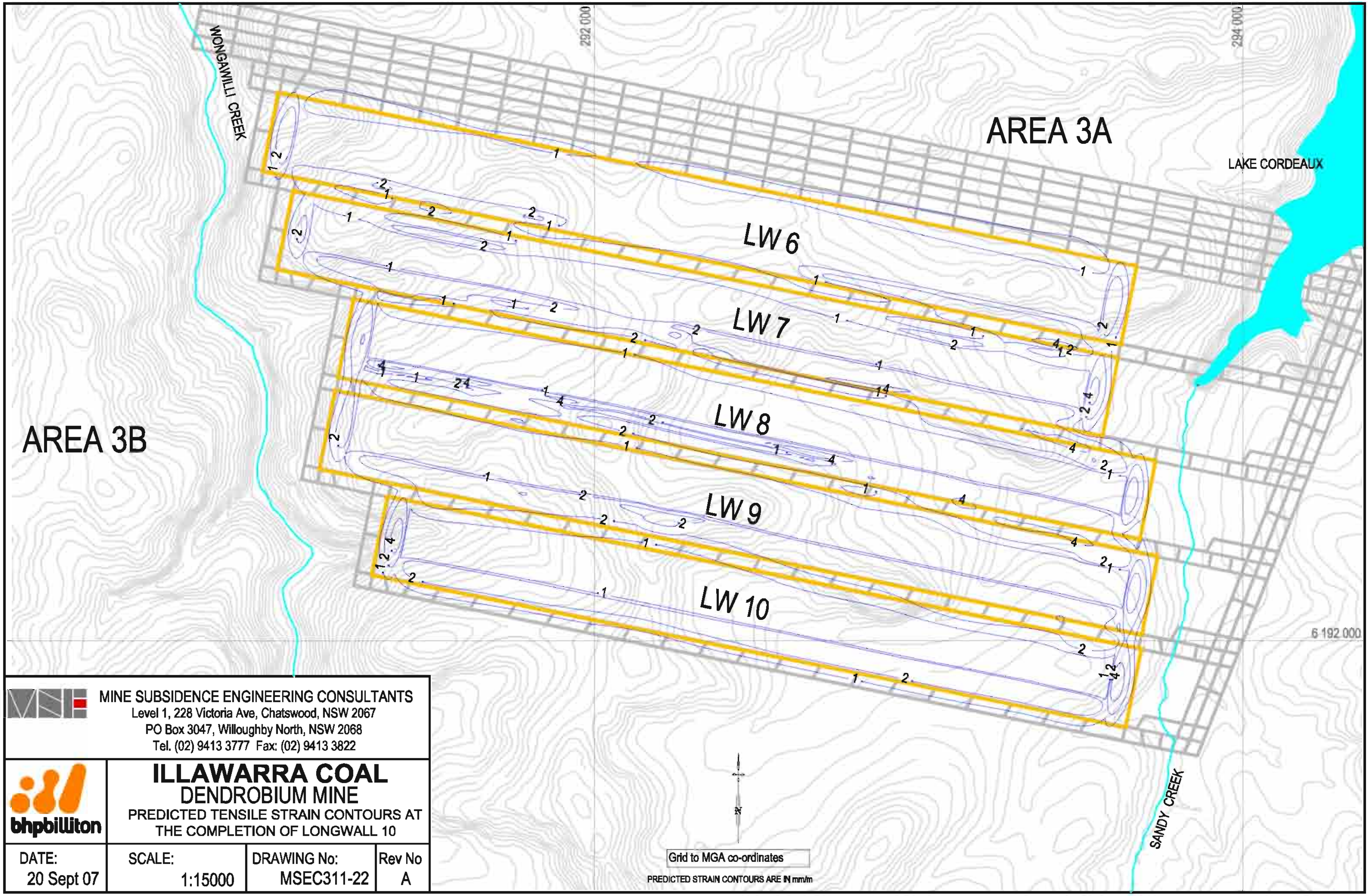

Grid to MGA co-ordinates

PREDICTED STRAIN CONTOURS ARE IN mm/m

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DENDROBIUM MINE
PREDICTED TENSILE STRAIN CONTOURS AT
THE COMPLETION OF LONGWALL 10

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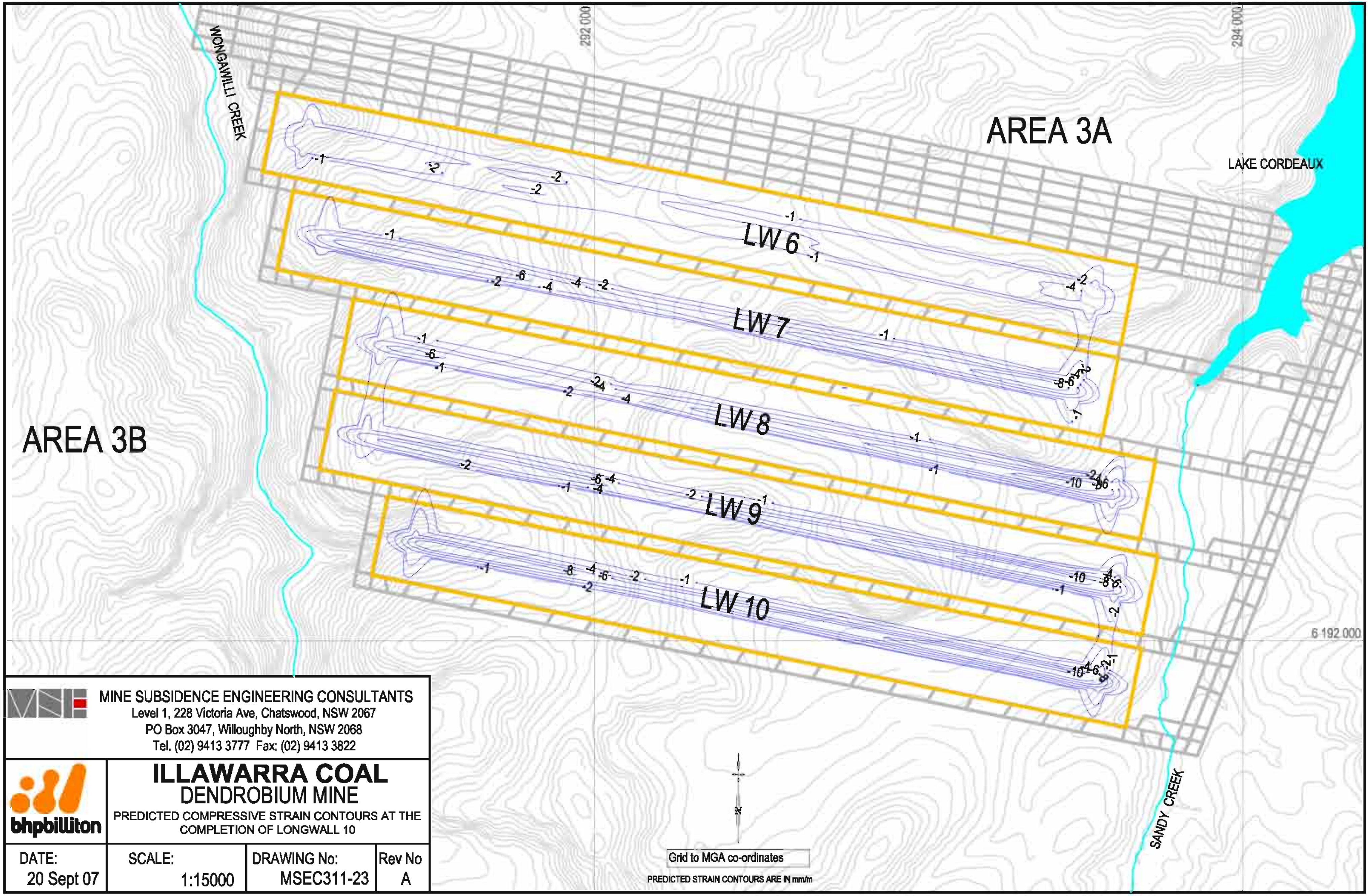

Grid to MGA co-ordinates

PREDICTED STRAIN CONTOURS ARE IN mm/m

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DENDROBIUM MINE
PREDICTED COMPRESSIVE STRAIN CONTOURS AT THE COMPLETION OF LONGWALL 10

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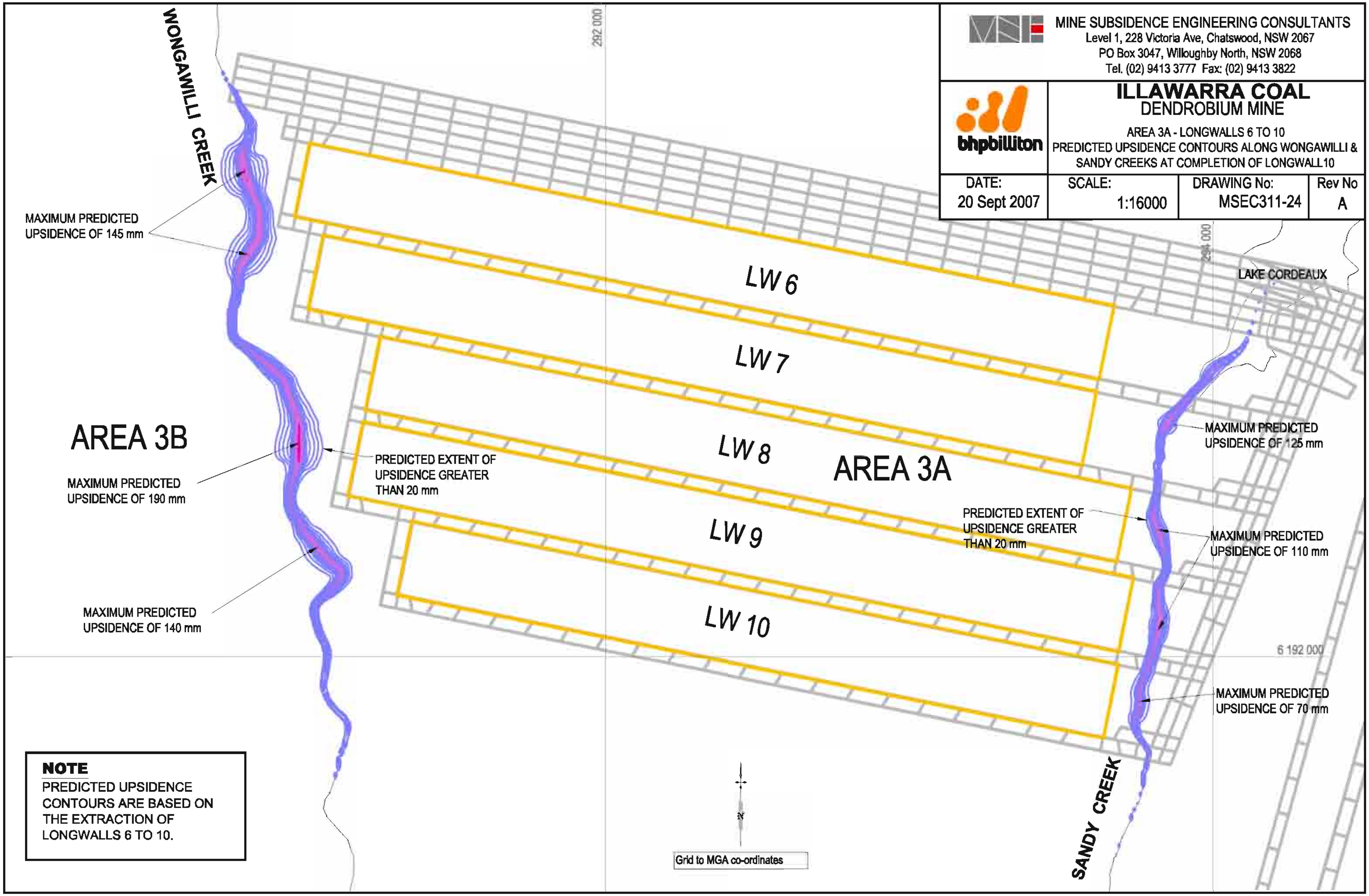

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ILLAWARRA COAL
DENDROBIUM MINE

AREA 3A - LONGWALLS 6 TO 10
PREDICTED UPSIDENCE CONTOURS ALONG WONGAWILLI & SANDY CREEKS AT COMPLETION OF LONGWALL 10

DATE:	SCALE:	DRAWING No:	Rev No
20 Sept 2007	1:16000	MSEC311-24	A

NOTE
PREDICTED UPSIDENCE CONTOURS ARE BASED ON THE EXTRACTION OF LONGWALLS 6 TO 10.

I:\Projects\Dendrobium\Area3\MSEC311-Area3-Longwalls6to10\AcadData\MSEC311-24 PredUpsCont along Wongawilli&SandyCks after LW10 .dwg

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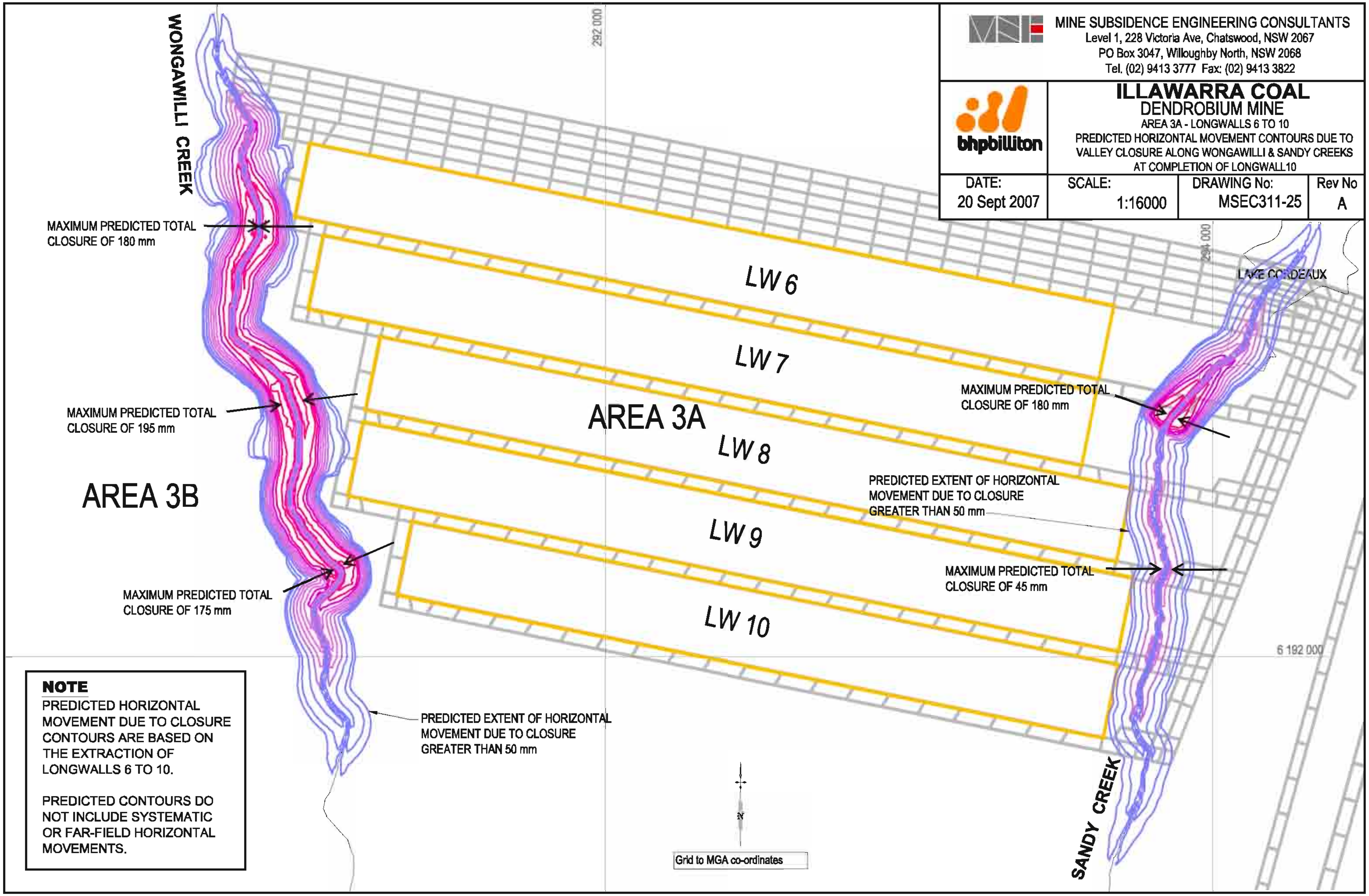
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

ILLAWARRA COAL
DENDROBIUM MINE
AREA 3A - LONGWALLS 6 TO 10
PREDICTED HORIZONTAL MOVEMENT CONTOURS DUE TO VALLEY CLOSURE ALONG WONGAWILLI & SANDY CREEKS AT COMPLETION OF LONGWALL10

DATE:	SCALE:	DRAWING No:	Rev No
20 Sept 2007	1:16000	MSEC311-25	A

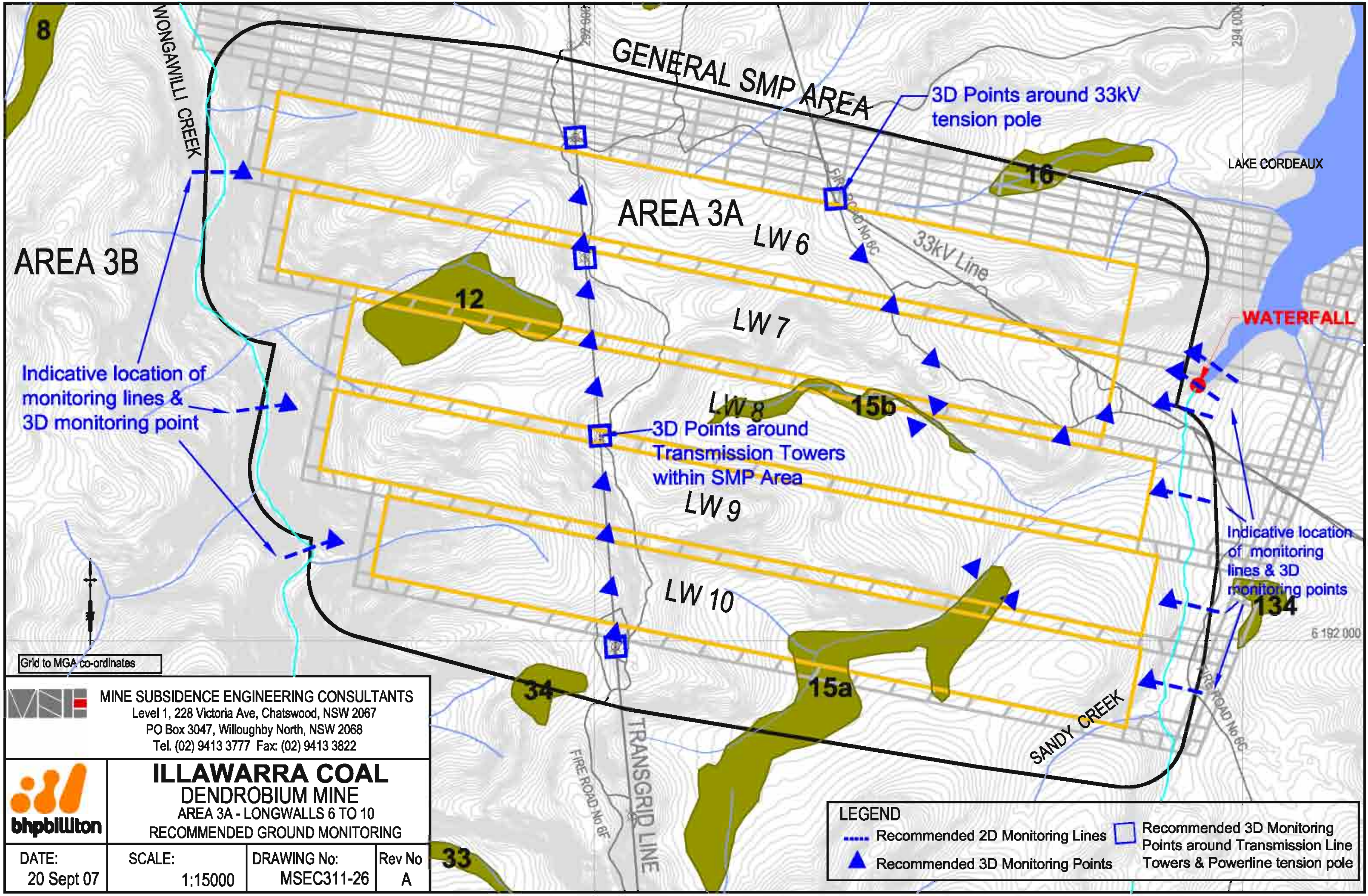


NOTE
PREDICTED HORIZONTAL MOVEMENT DUE TO CLOSURE CONTOURS ARE BASED ON THE EXTRACTION OF LONGWALLS 6 TO 10.

PREDICTED CONTOURS DO NOT INCLUDE SYSTEMATIC OR FAR-FIELD HORIZONTAL MOVEMENTS.

I:\Projects\Dendrobium\Area3\MSEC311-Area3-Longwalls6to10\AcadData\MSEC311-25 PredHzlMvtCont due to ValleyClosure.dwg

I:\Projects\Dendrobium\Area3\MSEC311-Area3-Longwalls6to10\AcadData\MSEC311-26 RecomendedGroundMonitoring .dwg



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bhpbilliton

ILLAWARRA COAL
DENDROBIUM MINE
AREA 3A - LONGWALLS 6 TO 10
RECOMMENDED GROUND MONITORING

DATE:	SCALE:	DRAWING No:	Rev No
20 Sept 07	1:15000	MSEC311-26	A

I:\Projects\Dendrobium\Area3\MSEC311-Area3A-Longwalls6to10\AcadData\MSEC311-27 Elouera Survey Line.dwg

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ELOUERA COLLIERY
LOCATION OF SURVEY LINE OVER LONGWALLS 1 TO 10

DATE:	SCALE:	DRAWING No:	Rev No
20 Sept 2007	1:20 000	MSEC311-27	A