ASSESSMENT OF MINE SUBSIDENCE IMPACTS ON THE NATURAL FEATURES AND SURFACE INFRASTRUCTURE FOR THE WALLARAH 2 COAL PROJECT IN SUPPORT OF THE PART 3A APPLICATION

Mine Subsidence Engineering Consultants
Level 1, 228 Victoria Avenue – Chatswood – NSW 2067
PO Box 3047 – Willoughby North – NSW 2068
Tel. (02) 9413 3777 Fax. (02) 9413 3822
Email: enquiries@minesubsidence.com
www.minesubsidence.com

Report Number MSEC428
Revision D
February 2010

DOCUMENT REGISTER

Revision	Description	Author(s)	Checker(s)	Date
A	Draft issue	DRK / JPB	AAW	2 Nov 09
B	Minor amendments	DRK / JPB	AAW	15-Nov-09
C	Minor amendments	DRK / JPB	DRK / JPB	19-Jan-10
D	Final report	DRK / JPB	DRK / JPB	04-Feb-10

Report produced to:- Support a Part 3A Environmental Assessment Application being submitted by the Wyong Areas Coal Joint Venture (WACJV) to the Department of Planning.

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

Introduction to Longwall Mining and Subsidence (Revision A)
General Discussion of Mine Subsidence Ground Movements (Revision A)
Mine Subsidence Damage to Building Structures (Revision A)

ACKNOWLEDGMENTS

Mine Subsidence Engineering Consultants would like to acknowledge the contribution towards the development of this report by the WACJV and its consultants; Minarco Asia Pacific, International Environmental Consultants, Environmental Resources Management Australia, Mackie Environmental Research, OzArk Environmental and Heritage Management and Strata Control Technologies.

Information relating to infrastructure has been provided by the infrastructure owners, including Telstra, TransGrid and the Wyong Shire Council. The Mine Subsidence Board has also provided valuable assistance with the provision of information relating to impacts on surface features and approved design parameters.

EXECUTIVE SUMMARY

Wyong Areas Coal Joint Venture (WACJV) is seeking approval under Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for the development of the proposed Wallarah 2 Coal Project (W2CP), including the development of an underground mine to extract coal from the coalesced Wallarah and Great Northern Seams using longwall mining techniques.

A detailed description of the Project is provided in the Main Environmental Assessment Report of the Part 3A Application.

Mine Subsidence Engineering Consultants (MSEC) has been commissioned by the WACJV to:-

- Study the current mining proposals,
- Identify the natural features and items of surface infrastructure within the Study Area,
- Provide subsidence predictions, based on numerical modelling advice from Strata Control Technologies (SCT) and undertake robust sensitivity analyses of these predictions,
- Provide impact assessments, in conjunction with other specialist consultants, for each of the identified natural features and items of surface infrastructure, and
- Provide a detailed description of the measures that would be implemented to avoid, minimise, remediate and/or offset the subsidence impacts of the project.

A separate detailed subsidence prediction report has been prepared by the WACJV to combine the subsidence prediction research and detailed prediction work undertaken by the WACJV, Strata Control Technologies (SCT) and Mine Subsidence Engineering Consultants. That subsidence prediction report is included in the W2CP Environmental Assessment Report of the Part 3A Application as Appendix B1, whilst this subsidence impact report, which is included in the Main Environmental Assessment Report of the Part 3A Application as Appendix B2, has been prepared to identify each of the natural and built features within the project area that could be affected by subsidence, to assess the likely impacts and consequences and to describe the measures that would be implemented to avoid, minimise, remediate and/or offset the subsidence impacts of the project.

The separate subsidence prediction report details the development of the subsidence prediction model and discusses mine planning options that were considered so that the predicted mine subsidence ground movements complied with required ground tilt levels and to reduce impacts. Numerous variations on the mine plan for the W2CP were considered by the WACJV team throughout the planning process. For example, the longwall panel widths and extraction heights were reduced in the Hue Hue Mine Subsidence District in order to comply with the Mine Subsidence Board requirement that final tilts at houses in the Hue Hue Mine Subsidence District did not exceed 4 mm/m. The mine plan was also amended to reduce possible impacts on surface water flows and alluvial contributions to water flow and to reduce flooding impacts.

The extents of the proposed mine plan are shown in Drawing No. MSEC428-01, which together with all other drawings is included in Appendix F of this report. Forty six (46) longwalls are planned to be extracted within the entire long term W2CP mining area. The longwalls are planned to be extracted within the coalesced Wallarah and Great Northern Coal Seams with panel void widths varying from 125 metres to 255 metres and chain pillar widths ranging from 45 metres to 75 metres. Depth of overburden cover above this combined coal seam ranges from 345 metres, over longwalls in the north-eastern area of the project, to 690 metres, below some heavily-timbered, steep-sided hills separating the Yarramalong and Dooralong Valleys.

The available seam thickness of the combined Wallarah and Great Northern Coal Seams ranges from 3.2 metres to 6.8 metres. A working section of 4.5 metres could have been extracted over virtually the entire W2CP extraction area. However, to limit ground movements in the north-east of the project area and in the Hue Hue Mine Subsidence District (MSD), it is proposed to limit the extracted seam thickness to 3.5 metres. To limit the ground movements in the Dooralong Valley (Jilliby Jilliby Creek) and in the Yarramalong Valley (Wyong River), it is proposed to limit the extracted seam thickness to 4.0 metres.

Under the coal seam lies the Warnervale Conglomerate and the Awaba Tuff, which are known to have extremely variable properties, ranging from very soft and weak to hard and competent. As there is only a limited amount of available mine subsidence monitoring data for areas with similar depths of cover, extracted seam thicknesses and geological conditions, a state of the art hybrid approach to subsidence prediction was adopted for the W2CP which involves integrating the MSEC empirical Incremental Prediction Method (IPM) with an advanced numerical model that was developed by SCT to simulate caving and to incorporate the appropriate geology. SCT ran this numerical model to provide results for a range of locations over the project area and these results were then used by MSEC to calibrate the IPM empirical model so that the IPM model then determined site specific predictions at each of the identified natural features and items of infrastructure.

The initial empirical mine subsidence predictions for these proposed longwalls did not allow for additional subsidence resulting from the weakening effects of the Awaba Tuff on the chain pillars. After consultation with SCT on the effects of the Awaba Tuff on the stability of the chain pillars and after the hybrid approach to predicting subsidence at the W2CP was developed, significantly increased levels of mine subsidence were adopted based on the SCT numerical model results.

The conservatively based hybrid study approach provides for subsidence parameters that are approximately double the values predicted if using conventional empirical formulae that are not modified to account for the weakening effect of the underlying Awaba Tuff and the relatively thick extracted seam thickness.

As discussed above, the outcomes of this hybrid mine subsidence prediction approach were also used to select the appropriate longwall panel widths, interpanel pillar widths and the seam mining height so that predicted subsidence parameters will be limited to the required pre-determined levels under sensitive surface features. For example, the proposed panel void widths beneath the north-eastern portion of the Hue Hue MSD range from 125 metres to 155 metres and the proposed panel widths beneath the 1 in 100 year flooding zones range from 155 metres, 175 metres and 205 metres, depending on depth of cover. Elsewhere, the panel void width is predominantly 255 metres.

The range of predicted subsidence ground movements varies across the mining area for a number of reasons according to the degree of surface constraint and the sensitivity which influenced the final mine design. The maximum predicted total conventional subsidence of 2600 mm occurs in the western forested hill zones where seam extraction height and panel width are greater than those that are being proposed in the floodplain and Hue Hue areas. Similarly, the maximum total conventional predicted tilt of 15 mm/m, the maximum predicted total conventional hogging curvature of 0.28 km^{-1} and the maximum predicted total conventional sagging curvature of 0.37 km^{-1} are also predicted to occur in parts of the western forested areas.

Even though a conservative approach has been adopted for the mine subsidence prediction and impact assessment methodology, the WACJV has committed itself to an adaptive and continuous improvement approach to the longwall panel design whereby the mining dimensions and limits of future mine workings will be continuously reviewed and modified as necessary, as experience is gained, to ensure the required subsidence parameters are observed at houses in the Hue Hue Mine Subsidence District and within the Dooralong and Yarramalong Valley floodplains.

The project and this subsidence prediction methodology was the subject of close scrutiny during the hearings of an Independent Strategic Inquiry into proposed coal mining activities at Wyong during August 2007. The Inquiry report was released in December 2008 and it acknowledged the advanced technical merit of the hybrid subsidence approach where it states, "*based on the information provided to the Panel, there does not appear to be any geological or other physical impediment to adopting this approach. This being the case, the issue becomes one of due diligence in preparing, implementing, monitoring and adapting the required SMP for the project.*"

In August 2009, the project was given the requirements of the Director General of the Department of Planning for the Environmental Assessment of the project. The Department advised that the Environmental Assessment of the project needs to comply with the Director-General's requirements, and provide an accurate and technically robust assessment of the potential impacts of the project.

The proposed mining activity will potentially affect a range of natural features and built infrastructure that has been identified within the Study Area.

Chapter 1 of this report provides a general introduction to the study and also includes a discussion on the proposed mining layouts and geological details of the proposed mining areas.

Chapter 2 provides an overview of key natural features and built infrastructure within the Study Area.

Chapter 3 of this report provides a brief overview of longwall mining and an overview of the development of the specific methods used to predict the mine subsidence parameters for this project to suit the specific geology and seam thicknesses to be extracted by the proposed longwalls.

Chapter 4 provides an overall summary of the maximum predicted subsidence parameters resulting from the extraction of the proposed longwalls.

Chapter 5 provides specific subsidence predictions and impact assessments for all identified natural features and built infrastructure within the Study Area.

The findings in this report should be read in conjunction with all other associated consultant reports.

It is recommended that the management of subsidence over the W2CP be controlled by the preparation and implementation of specific Subsidence Management Plans (or Extraction Plans). These management plans would be developed with the owners of infrastructure and should be approved by relevant government agencies.

Management measures generally include the recording of the condition and the value of surface natural and built features and the detailed monitoring of ground movements near these features. Mitigation measures and alternative mine layouts have been considered to mitigate or avoid the risk of serious consequences should impacts occur to some sensitive surface natural and built features.

The overall findings of the impact assessments undertaken by MSEC are that the levels of impact at all identified natural features and built infrastructure items are manageable and can be controlled by the preparation and implementation of Subsidence Management Plans (or Extraction Plans). The findings provided in this report should, however, be read in conjunction with the findings provided by all other consultants on the project.

CONTENTS

LIST OF TABLES, FIGURES AND DRAWINGS

Tables

Tables are prefaced by the number of the Chapter or letter of the Appendix in which they are presented.

Table No. Description

Figures

Figures are prefaced by the number of the Chapter or letter of the Appendix in which they are presented.

Figure No. Description

Drawings

Drawings referred to in this report are included in Appendix F at the end of the report.

Drawing No.	***Description***
MSEC428 – 01	General Layout
MSEC428 – 02	Surface Level Contours
MSEC428 – 03	Seam Floor Contours
MSEC428 – 04	Seam Thickness Contours and Proposed Extraction Heights
MSEC428 – 05	Depth of Cover Contours
MSEC428 – 06	Geological Structures at Seam Level
MSEC428 – 07	Extent and Thickness of the Warnervale Conglomerate
MSEC428 – 08	Watercourses
MSEC428 – 09	Steep Slopes
MSEC428 – 10	Mine Subsidence Districts
MSEC428 – 11	State Forests and Conservation Areas
MSEC428 – 12	Roads and Associated Infrastructure
MSEC428 – 13	Water and Gas Infrastructure
MSEC428 – 14	Electrical Infrastructure
MSEC428 – 15	Telecommunications Infrastructure
MSEC428 – 16	Archaeological and Heritage Sites
MSEC428 – 17	Groundwater and Exploration Bores
MSEC428 – 18	Survey Control Marks
MSEC428 – 19	Building Structures and Farm Dams – Key Plan
MSEC428 – 19A	Building Structures and Farm Dams – Map A
MSEC428 – 19B	Building Structures and Farm Dams – Map B
MSEC428 – 19C	Building Structures and Farm Dams – Map C
MSEC428 – 19D	Building Structures and Farm Dams – Map D
MSEC428 – 20	Public Utilities, Public Amenities, Industrial, Commercial and Business Establishments
MSEC428 – 21	Predicted Total Subsidence Contours

CHAPTER 1. INTRODUCTION

1.1. Background

Wyong Areas Coal Joint Venture (WACJV), is seeking approval under Part 3A of the NSW *Environmental Planning and Assessment Act 1979* (EP&A Act) for the development of the proposed Wallarah 2 Coal Project (W2CP), including the development of an underground mine to extract coal from the coalesced Wallarah and Great Northern Seams using longwall mining techniques.

A detailed description of the Project is provided in the Main Environmental Assessment Report of the Part 3A Application. The extents of the proposed mine plan are shown in Drawing No. MSEC428-01, which together with all other drawings is included in Appendix F of this report.

The project evolved following a tender in 1994 to the then Department of Mineral Resources for a new coal development north-west of Wyong. Exploration Licence 4911 was granted to the WACJV with conditions that subsidence would not be permitted east of the F3 Freeway nor under the Warnervale Airport and associated land. These conditions, including an expectation that coal mined from the WACJV licence areas would not be transported on public roads, appeared to be a tightening of those arising out of the 1988 Clough – Smith Report.

The project was also the subject of intense scrutiny during the hearings of the independent Strategic Inquiry into potential coal mining activities at Wyong during August 2007. Nevertheless, the Inquiry report dated July 2008 and released in December 2008, recognised the technical merit of the hybrid subsidence modelling approach and stated, "*based on the information provided to the Panel, there does not appear to be any geological or other physical impediment to adopting this approach. This being the case, the issue becomes one of due diligence in preparing, implementing, monitoring and adapting the required SMP for the project*."

In August 2009, the project was given the Director General of the Department of Planning's requirement for the environmental assessment of the project. The Department acknowledged the level of public interest in the project and noted the need for the environmental assessment of the project to adequately address the Director-General's requirements, and provide an accurate and technically robust assessment of the potential impacts of the project.

Mine Subsidence Engineering Consultants (MSEC) has been involved in subsidence studies and related integrated assessments at various stages throughout the project development. Having participated in the Wallarah 2 Coal Project's subsidence modelling study since 2006, MSEC was commissioned in September 2009 by the WACJV to:-

- Identify the natural features and items of surface infrastructure within the Study Area,
- Provide subsidence predictions at each natural feature and item of surface infrastructure, based on numerical modelling advice from Strata Control Technologies (SCT) and the mine subsidence prediction methodology that is described in a separate detailed subsidence prediction report (WACJV, 2008) and is included in the W2CP Environmental Assessment Report of the Part 3A Application as Appendix B1,
- Provide impact assessments, in conjunction with other specialist consultants, at each natural feature and item of surface infrastructure, and to
- Provide a detailed description of the measures that would be implemented to avoid, minimise, remediate and/or offset the subsidence impacts of the project.

Forty six (46) longwalls are planned to be extracted within the entire long term W2CP mining area, which is located to the northwest of Wyong and to the west of the F3 freeway. A number of natural features and items of surface infrastructure have been identified in the vicinity of the proposed longwalls, and these are described in Chapter 2 of this report. The proposed longwalls and the Study Area, which is defined in Section 2.2, have been overlaid on an orthophoto and topographic map of the area and these are shown in Fig. 1.1 and Fig. 2.1, respectively. The major natural features and items of surface infrastructure within the Study Area can also be seen in these figures.

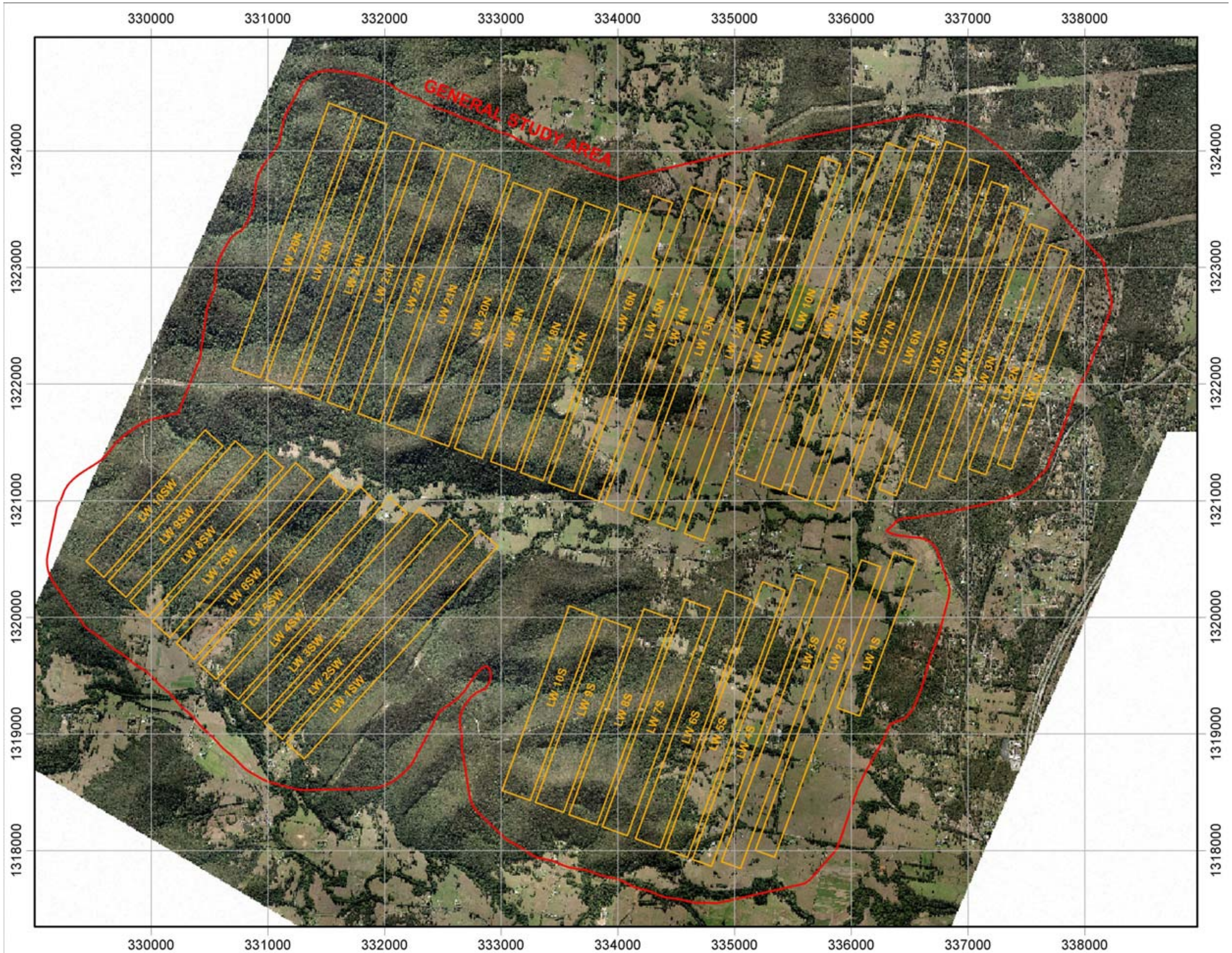


Fig. 1.1 Aerial Photograph showing the Proposed W2CP Longwalls and the Study Area

Chapter 3 of this report includes a brief overview of longwall mining, the development of mine subsidence and the specific method that has been used to predict the mine subsidence movements resulting from the extraction of the proposed longwalls. As discussed above, a separate detailed subsidence prediction report, which is included in the Main Environmental Assessment Report of the Part 3A Application as Appendix B1, has been prepared by the WACJV which combines the subsidence prediction research and detailed prediction work undertaken by the WACJV, Strata Control Technologies (SCT) and Mine Subsidence Engineering Consultants.

Chapter 4 provides a general overview of the maximum predicted conventional subsidence parameters resulting from the extraction of the proposed longwalls.

Chapter 5 provides the site-specific predicted subsidence parameters for each natural feature and item of surface infrastructure described in Chapter 2. The impact assessments and recommendations for each of these features have been made based on the predicted subsidence parameters.

1.2. Mining Geometry

The proposed longwall layout has been developed by the WACJV, based on the available information from the current exploration, the current mining technologies, the current subsidence prediction hybrid approach and the locations of significant features within the Study Area. Numerous variations on the mine plan for the W2CP were considered throughout the planning process, primarily to ensure that impacts were kept to an acceptable level. The final layout of the proposed longwalls is shown in Drawing No. MSEC428-01.

A summary of the dimensions of these longwalls is provided in Table 1.1. The proposed panel void widths vary from 125 metres to 255 metres and proposed chain pillar widths vary from 45 metres to 75 metres.

Table 1.1 Indicative Dimensions of the Proposed Longwalls in the Coalesced Wallarah and Great Northern Seams

Longwall Series	Longwalls	Overall Lengths (m)	Void Widths Including Headings (m)	Solid Chain Pillar Widths (m)
LW 1N to LW 26N	LW 1N	1815	125	-
	LW 2N to LW 5N	2040 to 2810	155	65
	LW 6N to LW 11N	2960 to 3435	175	65
	LW 12N	3260	175	75
	LW 13N to LW 14N	2950 to 3105	175	65
	LW 15N	2805	175	55
	LW 16N	2620	225	55
	LW 17N	2455	205	50
	LW 18N	2365	225	50
	LW 19N	2370	225	75
	LW 20N to LW 21N	2315 to 2370	255	50
	LW 22N	2370	205	65
	LW 23N	2370	205	75
	LW 24N	2370	205	65
	LW 25N	2415	225	65
	LW 26N	2415	225	50
LW 1S to LW 10S	LW 1S	1415	205	-
	LW 2S to LW 4S	2590 to 2675	175	65
	LW 5S	2440	205	45
	LW 6S	2255	205	45
	LW 7S to LW 10S	1685 to 1875	255	50
LW 1SW to LW 10SW	LW 1SW	2465	205	-
	LW 2SW to LW 6SW	1945 to 2360	205	50
	LW 7SW	1830	205	75
	LW 8SW to LW 10SW	1515 to 1725	205	50

Even though a conservative approach has been adopted for the mine subsidence prediction and impact assessment methodology, the WACJV has committed itself to an adaptive and continuous improvement approach to the longwall panel design whereby the mining dimensions and limits of future mine workings will be continuously reviewed and modified as necessary, as experience is gained, to ensure the required subsidence parameters occur at the houses in the Hue Hue Mine Subsidence District and within the Dooralong and Yarramalong Valley floodplains

It is likely that these longwall layouts will be further modified in the future as additional mining and subsidence data is gathered and reviewed during mining operations.

Any such modifications to the longwall layouts would be constrained within the Extents of the Longwall Mining Areas as shown in Drawing No. MSEC428-01. Discussions on the effects of changes in the longwall layouts on the predicted subsidence parameters are provided in the impact assessments for each feature provided in Chapter 5.

1.3. Geological Details

The Study Area lies within the north-eastern margin of the Sydney Basin and in the southern part of the Newcastle Coalfield. The economic coal resources are contained in the Wallarah and Great Northern Seams which are within the upper part of the Permian Newcastle Coal Measures. These strata outcrop to the far north and north-east of the region and dip gently to the south-west beneath the WACJV exploration area at grades of 1 in 30 to 1 in 50.

The WACJV undertook detailed exploration investigations and advised that the various available seams were subject to splitting and coalescence through the development of conglomerate filled fluvial channels. After the exploration programme was finished the WACJV advised that apart from the coalesced Wallarah and Great Northern Seams, all other seams occurred at depths and thicknesses that rendered them uneconomic.

A diagrammatic east-west cross section showing the available Permian Newcastle Coal Measures and the overlying Triassic Narrabeen Group strata layers is presented in Fig. 1.2. This diagram also shows the Proposed Mining Area. Below the coalesced Wallarah and Great Northern Coal Seams in this area lies the Awaba Tuff and the Warnervale Conglomerate. Above these coal seams lies the Dooralong Shale, Munmorah Conglomerate and other Narrabeen Group formations.

The Wallarah and Great Northern Coal Seams are in the upper part of the Newcastle Coal Measures and these seams were formed during the late Permian Period. They are overlain by the Triassic Narrabeen Group which outcrops across the WACJV exploration area. The lowermost strata of the Narrabeen Group comprise the Dooralong Shale which consists of between 50 metres and 70 metres of shales and laminites; this sequence coarsens upwards to contain beds of pebbly sandstone. The overlying Munmorah Conglomerate is generally 70 metres to 80 metres thick and consists of coarse and pebbly sandstones with occasional green-grey shales. Neither of these sequences outcrops in the proposed target mining area.

Outcropping in the north-east of the area is the Tuggerah Formation, a 200 metres thick sequence of sandstones with minor siltstones and rare conglomerates. Above this, the Patonga Claystone, which consists of 80 metres to 110 metres of interbedded grey-green and red-brown claystones and minor fine-grained sandstones, commonly outcrops in the lower, more undulating areas through (and immediately beneath) the Yarramalong and Dooralong Valleys. The uppermost strata of the Narrabeen Group in the area belong to the Terrigal Formation and consist of sandstones and minor siltstones. This sequence occurs through the more elevated zones of the south-western half of the project area, which is typically covered by State forests.

The geological structures which have been identified at seam level are shown in Drawing No. MSEC428-06. As shown in this drawing and based on an extensive drilling programme, there are no major geological structures identified at seam level within the project area. Outside the project area there are a series of dykes, sills, and other igneous structures, and a number of faults, but these are not expected to affect the proposed extraction of the W2CP coal resource.

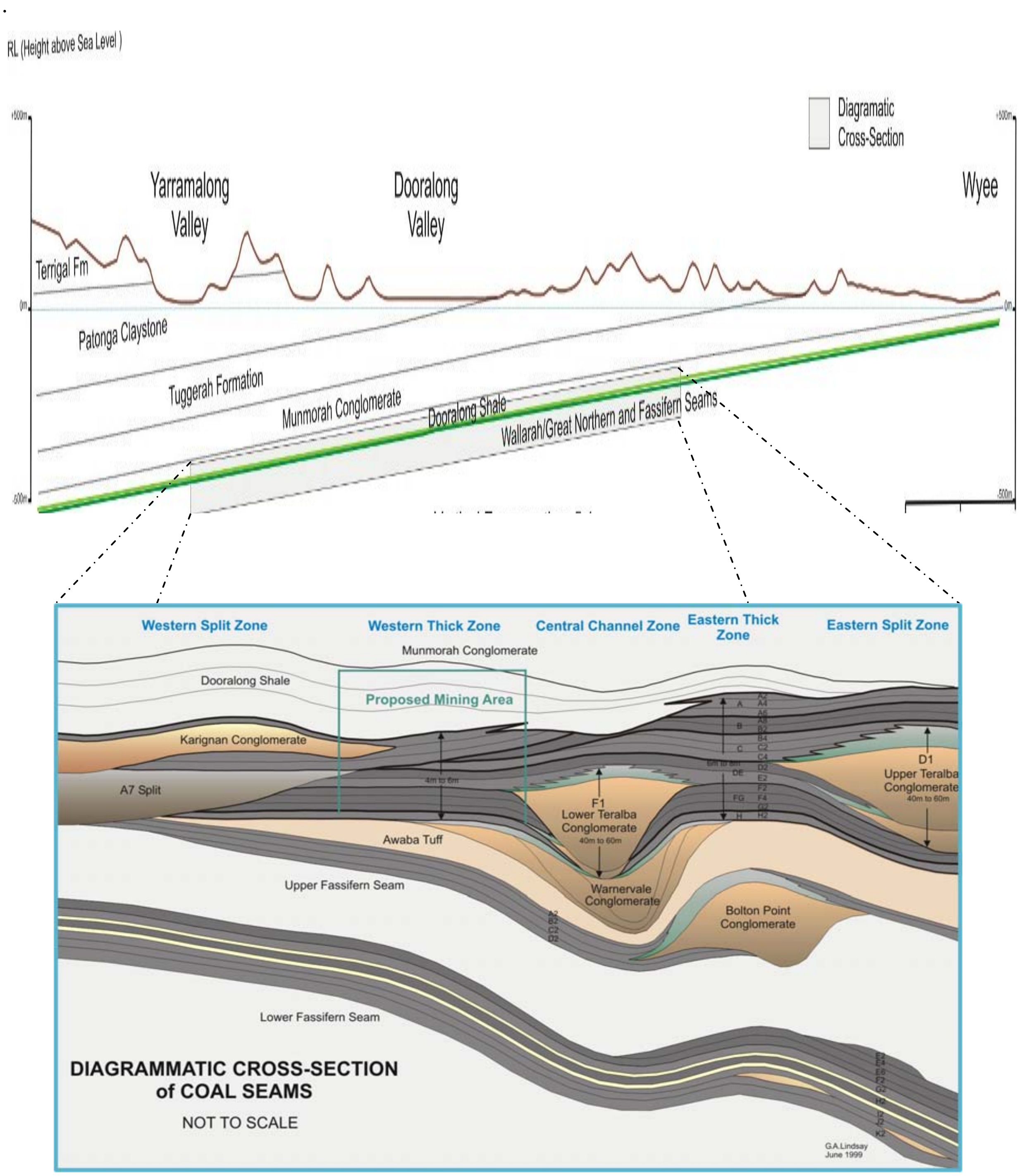


Fig. 1.2 Diagrammatic East – West Stratigraphic Cross Section across the Project Area with focus on the upper Permian Newcastle Coal Measures

The surface geology within the Study Area can be seen in Fig. 1.3, which shows the W2CP longwalls overlaid on a plan prepared by the WCAJV.

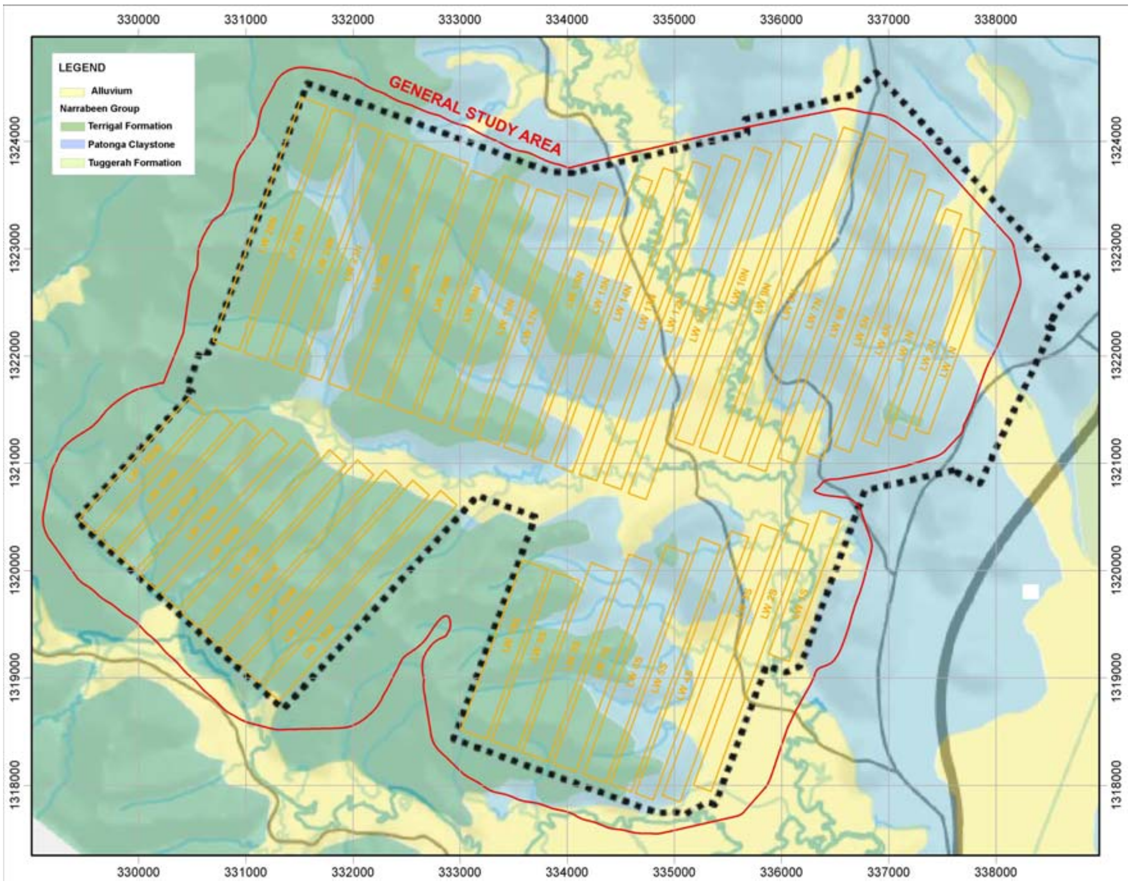


Fig. 1.3 Surface Geology within the Study Area

It can be seen from the above figure that the surface geology within the Study Area is comprised predominantly of areas derived from the Narrabeen Group and Quaternary deposits.

1.4. Surface and Seam Information

The surface level contours across the W2CP are shown in Drawing No. MSEC428-02. The surface levels within the study area range from RL 5 metres (AHD), along the Jilliby Jilliby Creek over the southern end of LW 1S, to RL 235 metres (AHD), within the Jilliby State Conservation Area over the northern end of LW 22N.

As shown in Fig. 1.2, within the proposed W2CP mining area the Wallarah and Great Northern Seams coalesce to form a single seam and, beyond the proposed mining area, the seams are subject to splitting by conglomerate filled fluvial channels. Within the proposed mining area, the available seam thickness of the combined Wallarah and Great Northern Seams ranges from 3.2 metres to 6.8 metres, as shown in Drawing No. MSEC428-04.

Accordingly, a working section of 4.5 metres could have been extracted over virtually the entire W2CP extraction area. However, as shown in Fig. 1.4, the proposed seam thicknesses to be extracted have been limited to 3.5 metres and 4.0 metres in various areas to limit ground movements in the north-east of the project area and in the Hue Hue Mine Subsidence District (MSD) and in the Dooralong Valley (Jilliby Jilliby Creek).

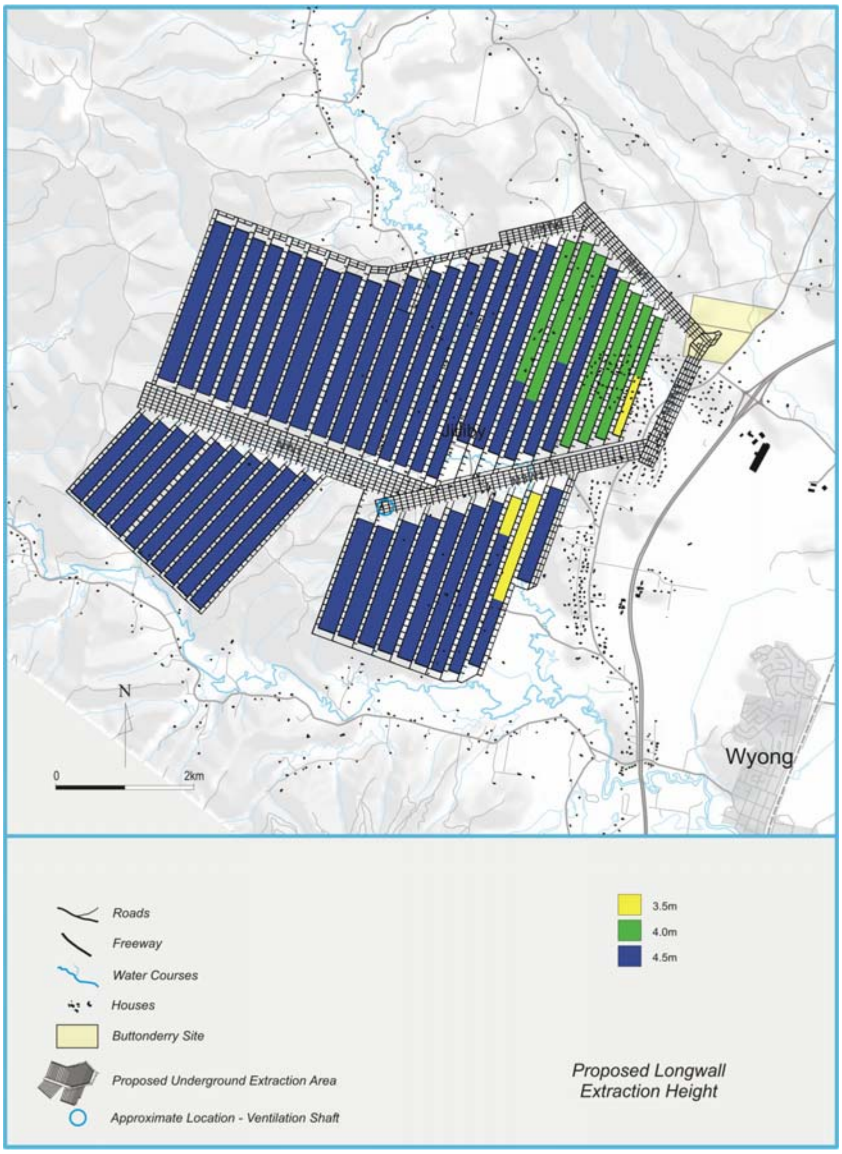


Fig. 1.4 Proposed Extracted Seam Thicknesses

A summary of the proposed extraction heights is provided in Table 1.2.

Table 1.2 Thicknesses of the Wallarah – Great Northern Seam

Longwalls	Proposed Extraction Heights (m)		
	Minimum	Maximum	Average
LW 1N to LW 5N	3.5	4.5	4.05
LW 6N to LW 10N	4.0	4.5	4.3
LW 11N to LW 15N	4.5	4.5	4.5
LW 16N to LW 20N	4.5	4.5	4.5
LW 21N to LW 26N	4.5	4.5	4.5
LW 1S to LW 5S	3.5	4.5	4.33
LW 6S to LW 10S	4.5	4.5	4.5
LW 1SW to LW 5SW	4.5	4.5	4.5
LW 6SW to LW 10SW	4.5	4.5	4.5

The seam floor contours, seam thickness contours and the depth of cover contours, for the combined Wallarah-Great Northern Seam, are shown in Drawings Nos. MSEC428-03, MSEC428-04 and MSEC428-05, respectively.

The seam floor levels of the Wallarah Seam within the project area vary from 322 metres below AHD, at the northern end of LW 6N, to 503 metres below AHD at the southern end of LW 7SW.

A summary of the depths of cover directly above the proposed longwalls in each mining domain is provided in Table 1.3.

Table 1.3 Depths of Cover to the Wallarah – Great Northern Seam

Longwalls	Depth of Cover (m)		
	Minimum	Maximum	Average
LW 1N to LW 5N	345	485	385
LW 6N to LW 10N	345	465	385
LW 11N to LW 15N	380	555	415
LW 16N to LW 20N	380	630	485
LW 21N to LW 26N	410	620	505
LW 1S to LW 5S	395	545	430
LW 6S to LW 10S	430	660	515
LW 1SW to LW 5SW	470	685	575
LW 6SW to LW 10SW	480	690	570

CHAPTER 2. IDENTIFICATION OF SURFACE FEATURES

2.1. Definition of the Extents of the Longwall Mining Areas

The *Extents of the Longwall Mining Areas* are defined as the maximum extents of the proposed longwalls (i.e. second workings) that are shown in Drawing No. MSEC428-01.

2.2. Definition of the Study Area

The initial W2CP *Project Area* extended beyond the extents of the proposed mining area. The proposed mine was designed by WCAJV to minimise its impact on the environment, geological constraints and the views of the community. The amount of coal to be extracted beneath the Hue Hue area has been reduced by WCAJV to limit surface movements to comply with the levels stipulated by the declared Mine Subsidence District. Similarly, reduced coal extraction has been planned by WCAJV beneath the Dooralong Valley and Yarramalong Valley flood plains to reduce the subsidence effects and to protect the shallow alluvial aquifers.

The *Study Area* has been defined as the surface area that is likely to be affected by the proposed mining of longwalls at the W2CP. The extent of the Study Area has been calculated by combining the areas bounded by the following limits:-

- The 26½ degree angle of draw line,
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour, and
- Features sensitive to far-field movements.

Given that the depth of cover above the proposed longwalls varies between 345 metres and 690 metres, the 26½ degree angle of draw line has been conservatively determined by drawing a line that is a horizontal distance varying between 173 metres and 345 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 calibrated Incremental Profile Method, which is dependent on many factors as described in further detail in Section 2.4. Sometimes the predicted total 20 mm subsidence contour extends further from the edge of the mined panel than the 26½ degree angle of draw line and at other places the 26½ degree angle of draw line extends further than the predicted total 20 mm subsidence contour.

A line has therefore been drawn defining the general Study Area, based upon either the 26½ degree angle of draw line or the predicted total 20 mm subsidence contour, whichever is further from the proposed longwalls, and this line is shown in Drawing No. MSEC428-01 to Drawing No. MSEC428-20.

There are areas that lie outside the general Study Area that are expected to experience either far-field horizontal movements, or valley related upsidence and closure movements. The surface features which are sensitive to such movements have been identified in this report and have been included as part of the Study Area. These features are listed below and details of these are provided in later sections of the report.

- Streams, within the predicted limit of 20 mm total upsidence and 20 mm total closure,
- Bridges along the Sydney-Newcastle Freeway,
- Proposed Mardi-Mangrove Transfer Main Pipeline
- Groundwater bores, and
- Survey control marks.

The predicted 20 mm conventional subsidence contour is shown in Drawing No. MSEC428-21. It can be seen on this drawing, that an area between the northern and south-eastern series of longwalls is predicted to experience less than 20 mm of conventional subsidence. It is possible that this area could experience slightly greater subsidence due to far-field vertical movements as the result of stress redistribution from the proposed mining on both sides of this area. It would not be expected, however, that this area would experience any significant tilts, curvatures or strains.

2.3. 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 9131-1-N and 9131-1-S. The proposed longwalls and the Study Area have been overlaid on an extract of these CMA maps, and are shown in Fig. 2.1.

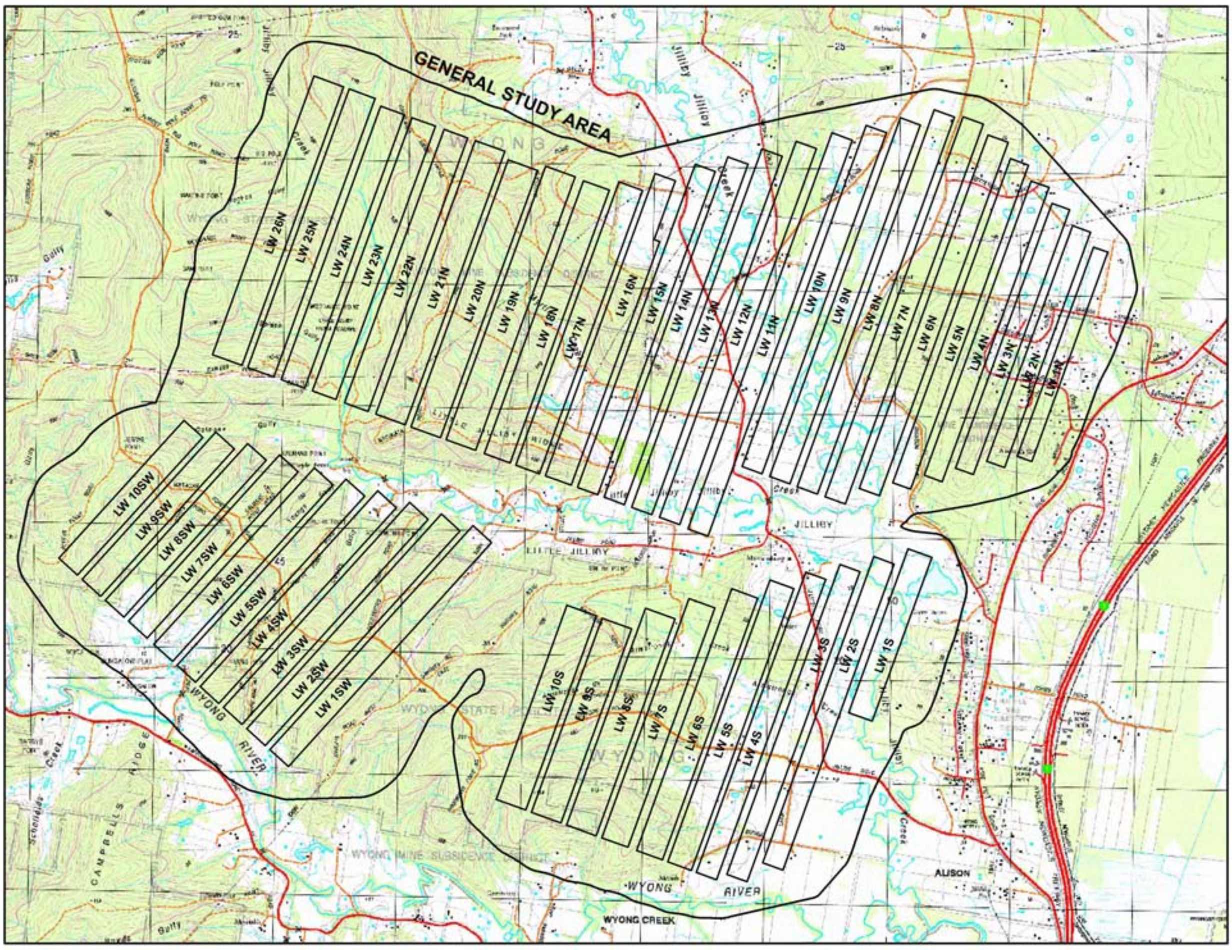


Fig. 2.1 The Proposed Longwalls and the Study Area Overlaid on CMA Maps Nos. 9131-1-N and 9131-1-S

The Director General of the Department of Planning required that the W2CP Environmental Assessment should identify the natural and built features (both surface and sub-surface) within the area that could be affected by the subsidence associated with the proposed mining operations.

The Director General also advised that the Environmental Assessment of the Project must take into account the Guideline for Application for Subsidence Management Approvals that was prepared by Department of Industry and Investment (DII, 2003). This Guideline provides a list of the natural features and items of surface infrastructure that should considered in applications and this list is included within the following Table 2.1. This table references the Section Numbers of this report where descriptions are provided for each natural feature or item of surface infrastructure that has been identified within the Study Area.

Table 2.1 Identification of Natural Features and Surface Infrastructure within the Study Area

Item	Within Study Area	Report Section Number Reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	✓	2.4.1
Rivers or Creeks	✓	2.4.2
Aquifers or Known Groundwater Resources	✓	2.4.3
Springs	✓	2.4.4
Sea or Lakes		
Shorelines		
Natural Dams		
Cliffs or Natural Rock Formations	✓	2.4.8
Steep Slopes	✓	2.4.9
Escarpments		
Land Prone to Flooding or Inundation	✓	2.4.11
Swamps, Wetlands or Water Related Ecosystems	✓	2.4.12
Threatened, Protected Species or Critical Habitats	✓	2.4.13
National Parks or Wilderness Areas		
State Recreational or Conservation Areas	✓	2.4.15
State Forests	✓	2.4.16
Natural Vegetation	✓	2.4.17
Areas of Significant Geological Interest		
Any Other Natural Feature Considered Significant		
PUBLIC UTILITIES		
Railways		
Roads (All Types)	✓	2.5.2
Bridges	✓	2.5.3
Tunnels		
Culverts	✓	2.5.5
Water, Gas or Sewerage Pipelines	✓	2.5.6
Liquid Fuel Pipelines		
Electricity Transmission Lines or Associated Plants	✓	2.5.8
Telecommunication Lines or Associated Plants	✓	2.5.9
Water Tanks, Water or Sewage Treatment Works	✓	2.5.10
Dams, Reservoirs or Associated Works	✓	2.5.11
Air Strips		
Any Other Public Utilities		
PUBLIC AMENITIES		
Hospitals		
Places of Worship		
Schools	✓	2.6.3
Shopping Centres		
Community Centres	✓	2.6.5
Office Buildings		
Swimming Pools		
Bowling Greens		
Ovals or Cricket Grounds		
Racecourses		
Golf Courses		
Tennis Courts		
Any Other Public Amenities		
FARM LAND AND FACILITIES		
Agricultural Utilisation, Agricultural Improvements or Agricultural Suitability of Farm Land	✓	2.7.1
Farm Buildings or Sheds	✓	2.7.2
Gas or Fuel Storages	✓	2.7.4
Poultry Sheds		
Glass Houses or Green Houses		
Hydroponic Systems		
Irrigation Systems	✓	2.7.8
Fences	✓	2.7.9
Farm Dams	✓	2.7.10
Wells or Bores	✓	2.7.11
Any Other Farm Features		
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS		
Factories		
Workshops		
Business or Commercial Establishments or Improvements	✓	2.8.3
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	✓	2.8.7
Mine Infrastructure Including Tailings Dams or Emplacement Areas		
Any Other Industrial, Commercial or Business Features		
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	2.9 & 2.10
PERMANENT SURVEY CONTROL MARKS	✓	2.12
RESIDENTIAL ESTABLISHMENTS		
Houses	✓	2.13.1
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	✓	2.13.5
Any Other Residential Features	✓	2.13.6
ANY OTHER ITEM OF SIGNIFICANCE		

2.4. Natural Features

2.4.1. Catchment Areas or Declared Special Areas

The Wyong Water Supply Catchment District was declared in Gazette 153 in 1950 under the Local Government Act of 1919 in connection with the Wyong Water Supply under the control of the Council of the Shire of Wyong.

The Study Area is located largely within the Wyong River Catchment and represents 5 % of the water supply catchment for the regional area, as described in the Environmental Assessment.

2.4.2. Streams

The locations of the streams within the Study Area are shown in Drawing No. MSEC428-08 and a summary of the major streams within the Study Area is provided in Table 2.2.

Table 2.2 Details of the Streams within the Study Area

Stream	Description	Location Relative to Longwalls
Wyong River	Flows into Tuggerah Lake at Rocky Point	Located at a minimum distance of 135 metres from proposed longwalls
Jilliby Jilliby Creek	Drains into the Wyong River	Located directly above LW11N to LW13N and LW22N to LW26N
Little Jilliby Jilliby Creek	Drains into Jilliby Jilliby Creek	Located directly above LW6N to LW15N, LW1S and LW2S
Myrtle Creek	Drains into Little Jilliby Jilliby Creek	Located directly above LW11N to LW21N
Armstrong Creek	Drains into Jilliby Jilliby Creek	Located directly above LW2S to LW10S
Youngs Gully	Drains into Little Jilliby Jilliby Creek	Located directly above LW5SW and LW6SW
Calmans Gully	Drains into Little Jilliby Jilliby Creek	Located directly above LW9SW and LW10SW
Splash Gully	Drains into Little Jilliby Jilliby Creek	Located directly above LW23N and LW26N
Hughes Gully	Drains into Little Jilliby Jilliby Creek	Located directly above LW26N
Hue Hue Creek	Drains to Porters Creek	Located directly above LW1N to 5N

There are also a number of tributaries within the Study Area, the locations of which are shown in Drawing No. MSEC428-08. The tributaries are located directly above and across the extents of the proposed longwalls.

2.4.3. Aquifers and Known Groundwater Resources

Details on the aquifers and groundwater resources within the Study Area are provided in the report by Mackie (2009).

Groundwater resources are occasionally exploited within the Study Area for water supply by bores and wells. The locations of these groundwater bores are shown in Drawing No. MSEC342-17 and details of these bores are provided in Section 2.7.11. Three principal groundwater systems have been identified within the region;

- the unconsolidated surface alluvial aquifers within the Yarramalong and Dooralong Valleys and within the valley of Hue Hue Creek,
- the shallow weathered rock zone, and
- the more regional Narrabeen Group of sedimentary rocks overlying the Wallarah-Great Northern (WGN) seam.

Other than the surface unconsolidated alluvium, the remaining strata are considered to be aquitards (very poor groundwater transmission characteristics) or aquicludes (impermeable).

The ground water that is available to meet all competing environmental and extractive needs for water varies year-to-year and day-to-day with climate conditions and river flows. As indicated in the report by Mackie (2009), the Central Coast Unregulated Water Sharing Plan commenced on 1st August 2009. The Plan includes rules for protecting the environment, extractions, managing licence holders' water accounts and water trading.

The report by Mackie (2009) discusses the potential environmental impacts and consequences on the aquifers and groundwater resources.

2.4.4. Springs

There are no specific springs identified within the Study Area, however, minor natural springs or seeps may occur at some interfaces of certain strata, particularly in the southern facing (down-dip) slopes of the valleys, as described in the Environmental Assessment.

2.4.5. Seas or Lakes

There are no seas or lakes within the Study Area.

2.4.6. Shorelines

There are no shorelines within the Study Area, other than the shorelines associated with the streams, which were described in Section 2.4.2.

2.4.7. Natural Dams

There are no natural dams within the Study Area. There are, however, a number of farm dams within the Study Area, which are described in Section 2.7.10.

2.4.8. 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, i.e. having a minimum angle to the horizontal of 63°. The locations of cliffs within the Study Area were determined from the 0.5 metre surface level contours which were generated from an airborne laser scan of the area.

There were no major cliff lines identified within the Study Area.

There were, however, some isolated cliffs identified within the Study Area, which were located up the sides of the Dooralong, Yarramalong and Little Jilliby Jilliby Creek Valleys. Rock outcrops were also identified across the Study Area, which are defined as rockfaces having heights of less than 10 metres or slopes of less than 2 to 1.

A quarry face has been identified within the Study Area, which is discussed in Section 2.8.3. This quarry is apparently disused though it is possible that it may become active during the mining period.

2.4.9. Steep Slopes

A number of areas containing steep slopes have been identified within the Study Area. The purpose for identifying steep slopes is to highlight areas where the 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 greater than 1 in 3, i.e. a grade of 33 %, or an angle to the horizontal of 18°.

The minimum grade of 1 to 3 represents a slope that would generally be considered stable for natural ground 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.

The areas of steep slopes were identified from the 0.5 metre surface level contours which were generated from an airborne laser scan of the area, and the locations have been shown in Drawing No. MSEC428-09.

It can be seen from this drawing, that there are steep slopes located on the sides of the Dooralong, Yarramalong and Little Jilliby Jilliby Creek Valleys which are located directly above the proposed longwalls.

Photographs of the Dooralong and Yarramalong Valleys are provided in Fig. 2.2 and Fig. 2.3, respectively.

Fig. 2.2 Photographs of the Dooralong Valley

Fig. 2.3 Photograph of the Yarramalong Valley

The steep slopes have natural grades typically between 1 in 3 and 1 in 1.5, with more localised areas having natural grades between 1 in 1.5 and 1 in 1. The distribution of the natural surface slopes within the Study Area is provided in Fig. 2.4.

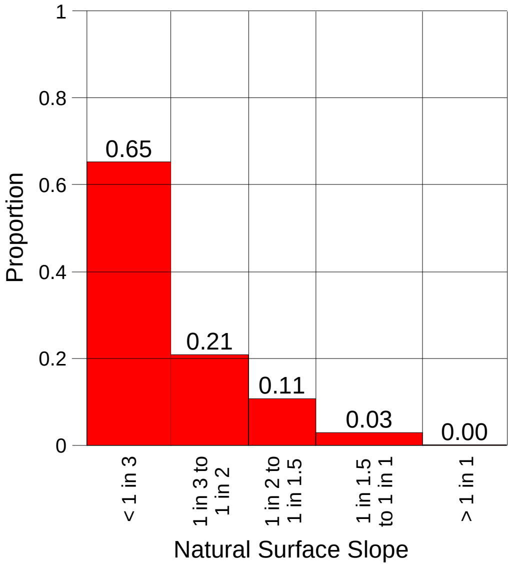


Fig. 2.4 Distribution of Natural Surface Slopes within the Study Area

The natural steep slopes within the Study Area are generally stabilised by the natural vegetation. The surface geology within the Study Area is discussed in Section 1.3.

2.4.10. Escarpments

There are no escarpments within the Study Area.

2.4.11. Land Prone to Flooding or Inundation

The land within the Study Area drains freely into the major streams within the Study Area.

The wide alluvial flats within the Dooralong Valley floodplain (containing the Jilliby Jilliby Creek, Little Jilliby Jilliby Creek and minor tributaries), the Yarramalong Valley floodplain (containing the Wyong River and tributaries) and the Hue Hue Creek floodplain are susceptible to inundation during major flood events (i.e. 1 in 100 year flood events).

The Yarramalong Valley floodplain is relatively narrow and the majority of it is classified as high hazard based on flood depths. The Dooralong Valley floodplain is wider and high hazard zones are mainly restricted to low lying areas adjacent to Jilliby Jilliby Creek and large farm dams. In the Hue Hue Creek floodplain flood depths are significantly less, as described in the Environmental Assessment.

For further information on flood prone land refer to the report by ERM (2009)

2.4.12. Wetlands, Swamps and Water Related Ecosystems

There are no swamps or wetlands that have been identified within the Study Area. There are, however, water-related ecosystems within the Study Area, in particular, along the streams where there is a permanent source of water. These have been investigated and are described in the report by OzArk (2010a).

2.4.13. 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 OzArk (2010a).

2.4.14. 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.

2.4.15. State Recreation Areas and State Conservation Areas

The north-western portion of the Study Area is located within the Jilliby State Conservation Area. This park was initially part of Wyong State Forest and was created in July 2003. It covers an area of 12,159 hectares. Approximately 10 % of the Jilliby State Conservation Area is located within the Study Area.

2.4.16. State Forests

A portion of the north-western part of the Study Area is located within Wyong State Forest. Approximately 640 hectares of native vegetation within the proposed subsidence area occurs occur within the Wyong State Forest (OzArk, 2010a).

2.4.17. Natural Vegetation

The sides of the Dooralong, Yarramalong and Little Jilliby Jilliby Creek Valleys have natural vegetation, which can be seen in Fig. 1.1. The land along the wide alluvial flats of the major streams has generally been cleared, as can also be seen in this figure.

The descriptions of the natural vegetation within the Study Area are provided in the report by OzArk (2010a).

2.4.18. Areas of Significant Geological Interest

There are no areas of significant geological interest within the Study Area.

2.4.19. Any Other Natural Feature Considered Significant

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

2.5. Public Utilities

2.5.1. Railways

There are no railways within the Study Area. The closest railway in the Main Northern Railway, which is located at a distance of over 4 kilometres east of the proposed longwalls. This railway is not expected to experience any significant subsidence movements resulting from the extraction of the proposed longwalls.

2.5.2. Roads

The locations of the major roads within the Study Area are shown in Drawing No. MSEC428-12. A summary of these roads are provided in Table 2.3.

Table 2.3 Details of the Major Local Roads within the Study Area

Road	Located Directly Above Longwalls
Brothers Road (fire trail)	LW6S to LW10S
Cottesloe Road	LW4N to LW7N
Dicksons Road	LW5N to LW8N
Durren Road	LW10N to LW13N
Jilliby Road	LW11N to LW15N & LW2S to LW4S
Little Jilliby Road	None
Maculata Road	LW15N and LW16N
Smiths Road	LW12N to LW13N

The local roads are managed by the Wyong Shire Council and typically have bitumen seals or asphaltic pavements. Some of the minor local roads, fire trails and privately owned roads within the Study Area are unsealed. Photographs of some of the major local roads are provided in Fig. 2.5 to Fig. 2.7.

Fig. 2.5 Photograph of Jilliby Road

Fig. 2.6 Photograph of Parkridge Drive

Fig. 2.7 Photograph of Brothers Road (fire trail within Jilliby State Conservation Area)

The Sydney-Newcastle Freeway is outside the general Study Area, as shown in Drawing No. MSEC428-12. The freeway is located at a distance of 1.1 kilometres south-east of Longwall 1N, at its closest point from the proposed longwalls.

The freeway could experience small far-field horizontal movements, resulting from the extraction of the proposed longwalls, however, it is unlikely that the freeway pavement itself would experience any adverse impacts as the result of the proposed mining. It is possible that the freeway bridges could be sensitive to the far-field horizontal movements, which are discussed in Section 2.5.3.

2.5.3. Bridges

There are a number of local road bridges that have been identified within the Study Area. The locations of these bridges are shown in Drawing No. MSEC428-12 and details are provided in Table 2.4.

Table 2.4 Details of the Local Road Bridges within the Study Area

Bridge Label	Crossing	Description
Bridge WR-B1	Boyds Lane over the Wyong River	Steel girder with timber deck
Bridge WR-B2	Private Road over the Wyong River	Steel girder with timber deck
Bridge LJ-B1	Jilliby Road over Little Jilliby Jilliby Creek	Concrete bridge
Bridge LJ-B2	Little Jilliby Road over Little Jilliby Jilliby Creek	Timber bridge (Heritage Site M)
Bridges LJ-B3 and LJ-B4	Little Jilliby Road over Little Jilliby Jilliby Creek	Timber bridge
Bridges JJ-B1 and JJ-B2	Durren Road over Jilliby Jilliby Creek	Concrete box culvert

Photographs of the local road bridges are provided in Fig. 2.8 to Fig. 2.10.

Fig. 2.8 Photographs of Bridge WR-B1 – Boyds Lane over the Wyong River

Fig. 2.9 Photograph of Bridge LJ-B1 – Jilliby Road Bridge over Little Jilliby Jilliby Creek

Fig. 2.10 Photographs of Bridge LJ-B2 (Heritage Site M) – Little Jilliby Road Bridge over Little Jilliby Jilliby Creek

The Sydney-Newcastle Freeway is located outside the general Study Area. The bridges along the freeway could, however, be sensitive to the far-field horizontal movements resulting from the extraction of the proposed longwalls. The freeway bridges in the vicinity of the proposed longwalls have been included as part of the overall Study Area.

The closest freeway bridge is that over a small drainage line, which is located approximately 1.1 kilometres south-east of Longwall 1N. Other nearby bridges include the St. Johns Road underpass, which is located approximately 1.3 kilometres east of Longwall 1S, and the Sparks Road overbridge, which is located approximately 1.4 kilometres east of Longwall 1N. Photographs of the Sparks Road Bridge are provided in Fig. 2.11.

Fig. 2.11 Photographs of Sparks Road Bridge over the Sydney-Newcastle Freeway

2.5.4. Tunnels

There are no tunnels within the Study Area.

The closest tunnel to the Study Area is Boomerang Creek Tunnel, which transfers water from Mangrove Creek Dam to Bunning Creek, and then into the Wyong River. The Boomerang Creek Tunnel is located at a distance of approximately 5.8 km from the general Study Area at its closest point and, therefore, is not expected to experience any adverse impacts as the result of the proposed mining.

2.5.5. Drainage Culverts

Drainage culverts have been installed where some of the local roads cross the drainage lines. The culverts vary from small circular culverts to large box culverts across the larger stream crossings.

The locations of the culverts within the Study Area were identified from the aerial photograph of the area and are shown in Drawing No. MSEC428-12. It is likely that there are other culverts within the Study Area, in addition to those shown in this drawing, including those on private land, or where the drainage lines were not visible on the aerial photograph.

2.5.6. Water, Gas or Sewerage Pipelines

The locations of the water and gas pipelines in the vicinity of the proposed longwalls are shown in Drawing No. MSEC428-13. The descriptions of these pipelines are provided below:-

Existing Water Pipelines

A short section of pipeline is located within the eastern extent of the Study Area, which carries water from the Jilliby Hue Hue Pipeline to Treelands Drive Reservoir.

The Jilliby Hue Hue Water Pipeline follows Hue Hue Road and is located to the east of the general Study Area. This pipeline could experience small far-field horizontal movements, resulting from the extraction of the proposed longwalls, however, it is unlikely that it would experience any adverse impacts as the result of the proposed mining.

The Hunter Water Corporation Pipeline follows the Sydney-Newcastle Freeway and Sparks Road and is located at a minimum distance of 1.7 kilometres east of Longwall 1N, at its closest point to the proposed longwalls. This pipeline could experience small far-field horizontal movements, resulting from the extraction of the proposed longwalls, however, it is unlikely that it would experience any adverse impacts as the result of the proposed mining.

Proposed Water Pipelines

The Mardi-Mangrove Link Project is a key element of WaterPlan 2050 which is the long term water supply strategy for the Central Coast. It will help to secure the region's town water supply over the next four decades by linking Wyong River and Ourimbah Creek to Mangrove Creek Dam, via Mardi Dam. The Project is an initiative of Gosford City and Wyong Shire Councils with Australian Government funding of $80.3 million from the Water Smart Australia Program.

The Mardi-Mangrove Link Project is the most significant water supply infrastructure project since the early-1980s when Mangrove Creek Dam was built. It will therefore take some time to carry out all the works necessary to meet community, government and construction requirements.

A general timeframe for the project currently includes:

- Call expressions of interest - July 2009 (complete)
- Call tenders for construction – October 2009 (complete)
- Award construction contracts - December 2009 (complete)
- Start construction - early 2010
- Complete construction & final commissioning – mid 2011

Two pipelines are proposed as part of this Link Project.

A new Mardi-Mangrove Transfer Main pipeline approximately 19 kilometres long and about 1000 mm diameter is proposed, linking Mardi Dam with the end of the existing Boomerang Creek Tunnel (which leads to Mangrove Creek Dam). The proposed route of the pipeline is shown in Drawing MSEC428-13 and a part of this route is located on the Study Area boundary, i.e. about 370 metres from the nearest proposed longwall edge. This rising main pipeline will permit water to flow in either direction according to operational needs. The majority of the pipeline would be in private property and constructed using open trenching. However, there would be sections of the route where construction would take place in the road reserve of the Yarramalong Road and there would be a number of river crossings.

Another pipeline, a new rising main water pipeline is proposed from Wyong River Pumping Station to Mardi Dam through Wyong Creek. This proposed pipeline is located outside the general Study Area, some 2.5 km to the south-east and, therefore, is not expected to experience any adverse impacts as the result of the proposed mining.

Oil and Gas Pipeline

There are no oil or gas pipelines located within the Study Area.

The Sydney to Newcastle Oil and Gas Pipeline is located on the eastern side of the Sydney-Newcastle Freeway and parallels the freeway in this area. The pipeline is located at a distance of 1.1 kilometres south-east of Longwall 1N, at its closest point from the proposed longwalls. The pipeline could experience small far-field horizontal movements, resulting from the extraction of the proposed longwalls, however, it is unlikely that it would experience any adverse impacts as the result of the proposed mining.

Sewerage Pipelines

There are no public sewerage pipelines in the Study Area.

2.5.7. Liquid Fuel Pipelines

There are no liquid fuel pipelines within the Study Area.

2.5.8. Electrical Services

There are two 330 kV transmission lines (Lines 21 and 22) which cross the Study Area, the locations of which are shown in Drawing No. MSEC428-14.

There are a total of 29 transmission towers within the Study, which are labelled in Drawing No. MSEC428-14, and the details of these towers are provided in Table 2.5.

Table 2.5 Details of the 330 kV Transmission Towers within the Study Area

Line	Tower ID	Type	Approximate Change in Angle (deg)	Approximate Surface Level (m AHD)	Approximate Span between Towers (m)
Line 21	21-53-T	Tension	5	132	-
	21-52-S	Suspension	-	167	267
	21-51-S	Suspension	-	194	413
	21-50-T	Tension	< 5	235	555
	21-49-T	Tension	< 5	143	387
	21-48-T	Tension	< 5	154	447
	21-47-T	Tension	5	180	1235
	21-46-T	Tension	5	215	1111
	21-45-T	Tension	10	43	903
	21-44-T	Tension	50	42	377
	21-43-S	Suspension	-	41	404
	21-42-S	Suspension	-	50	282
	21-41-S	Suspension	-	38	437
	21-40-S	Suspension	-	38	434
	21-39-S	Suspension	-	49	380
	21-38-T	Tension	20	68	331
	21-37-S	Suspension	-	54	430
	21-36-S	Suspension	-	41	496
Line 22	22-56-S	Suspension	-	233	-
	22-55-S	Suspension	-	216	327
	22-54-S	Suspension	-	219	284
	22-53-T	Tension	5	196	264
	22-52-T	Tension	40	231	1002
	22-51-T	Tension	< 5	216	668
	22-50-T	Tension	5	172	812
	22-49-T	Tension	10	93	474
	22-48-S	Suspension	-	54	557
	22-47-S	Suspension	-	56	260
	22-46-S	Suspension	-	43	457

Photographs of some of the towers along these transmission lines are presented in Fig. 2.12.

Fig. 2.12 Photographs of Transmission Towers within the Study Area

The towers are 330kV single circuit latticed steel towers that are approximately 30 metres high. A third transmission line (Line 25) is located just outside the Study Area and at a distance of 470 metres north of the commencing end of Longwall 1N, at its closest point to the proposed longwalls.

A 132 kV transmission line is located outside the Study Area at a distance of 950 metres east of Longwall 1N, at its closest point to the proposed longwalls.

There are also aerial powerlines within the Study Area, the locations of which are shown in Drawing No. MSEC428-14.

A local substation is located near the intersection of Jilliby and Little Jilliby Roads as shown in Drawing No. MSEC428-14. The substation is located between the northern and south-eastern series of longwalls and is 250 metres north of Longwall 5S, at its closest point to the proposed longwalls.

2.5.9. Telecommunications Services

The locations of the telecommunications infrastructure within and adjacent to the Study Area are shown in Drawing No. MSEC428-15. The telecommunications infrastructure includes direct buried optical fibre cables, direct buried and aerial copper cables and a Cellular Mobile Telephone Services (CMTS) site.

A Telstra optical fibre cable is located directly above the proposed longwalls and follows a similar alignment as Jilliby Road within the Study Area. The total length of cable located directly above the proposed longwalls is approximately 4.2 kilometres.

There is a Telstra optical fibre cable located immediately south of the Study Area which follows the alignment of Yarramalong Road. This cable is located at a minimum distance of 400 metres from the proposed longwalls.

There are Telstra and NextGen optical fibre cables located immediately east of the Study Area which follow the alignment of Hue Hue Road. There is also an Optus optical fibre cable further east which follows the alignment of the Sydney-Newcastle Freeway.

The Telstra CMTS site is located above the commencing end of Longwall 1N, which includes a GSM tower (Global System for Mobile) and a shed enclosure. An optical fibre cable connects this site with the main optical fibre cable along Hue Hue Road. A photograph of the CMTS site is provided in Fig. 2.13.

Fig. 2.13 Photograph of the CMTS Site

2.5.10. Water Tanks, Water and Sewerage Treatment Works

The rural properties within the Study Area have water storage tanks and on-site water systems. The locations of the above ground tanks within the Study Area are shown in Drawing No. MSEC428-19.

The Treelands Drive Reservoir tanks are located just inside the eastern extent of the general Study Area and are 300 metres east of the proposed Longwall 1S, at their closest point to the proposed longwalls. The locations of these tanks are shown in Drawing No. MSEC428-13.

2.5.11. Dams, Reservoirs and Associated Works

Apart from the abovementioned water tanks, there are no other public dams, reservoirs or associated works within the Study Area.

2.5.12. Air Strips

There are no air strips within the Study Area.

2.5.13. Any Other Public Utilities

There are no other public utilities within the Study Area.

2.6. Public Amenities

2.6.1. Hospitals

There are no hospitals within the Study Area.

2.6.2. Places of Worship

There are no places of worship within the Study Area.

2.6.3. Schools

The Jilliby Public School is located between the northern and south-eastern series of longwalls and is at a distance of 250 metres north of Longwall 5S, at its closest point to the proposed longwalls. The location of this school is shown in Drawing No. MSEC428-20.

2.6.4. Shopping Centres

There are no shopping centres within the Study Area.

2.6.5. Community Centres

A scout camp is located on the northern end of Brothers Road. This property is used for camping and has a covered all weather shelter on a concrete slab, a small area that can be locked in the shelter and outdoor toilets for the campers. The location of this site is shown in Drawing No. MSEC428-20.

2.6.6. Office Buildings

There are no office buildings within the Study Area.

2.6.7. Swimming Pools

There are no public swimming pools within the Study Area. There are, however, a number of privately owned swimming pools within the Study Area, which are described in Section 2.13.5.

2.6.8. Bowling Greens

There are no bowling greens within the Study Area.

2.6.9. Ovals or Cricket Grounds

There are no ovals or cricket grounds within the Study Area.

2.6.10. Racecourses

There are no racecourses within the Study Area.

2.6.11. Golf Courses

There are no golf courses within the Study Area.

2.6.12. Tennis Courts

There are no public tennis courts within the Study Area. There are, however, a number of privately owned tennis courts within the Study Area, which are described in Section 2.13.5.

2.6.13. Any Other Public Amenities

There are no other public amenities within the Study Area.

2.7. Farm Land or Facilities

2.7.1. Agriculture Utilisation and Agriculture Improvements

The land on the wide alluvial flats within the Study Area is predominantly cleared pasture, which is mainly used for agricultural and residential purposes.

The dominant agricultural activity in the valleys is intensive grazing, although turf farming is also common in the more fertile areas near the Wyong River and Jilliby Jilliby Creek. Over the last 20 years large holdings have been fragmented and converted to hobby farms, rural weekend retreats, market gardens, nurseries, horse studs and turf farms. As a result the character is rural rather than agricultural.

The features on the rural properties are described in the following sections.

2.7.2. Farm Buildings and Sheds

There are 680 rural building structures that have been identified within the Study Area, which includes sheds, garages, gazebos, pergolas, greenhouses, playhouses, shade structures and other non-residential building structures.

The locations of the rural building structures are shown in Drawing No. MSEC428-19 and details are provided in Table D.02 in Appendix D. The locations and sizes of the rural building structures were determined from the 2007 aerial photograph of the area. It is likely that additional rural building structures will be constructed prior to the commencement of mining.

2.7.3. Farm Tanks

There are privately owned water tanks on the rural properties within the Study Area, which are described in Section 2.13.5.

2.7.4. Farm Gas and Fuel Storages

There are privately owned gas and fuel storages on the rural properties within the Study Area.

2.7.5. Poultry Sheds

There are no large poultry sheds within the Study Area.

2.7.6. Farm Glass Houses

There are no large glasshouses within the Study Area. There are, however, some small greenhouses on the rural properties within the Study Area.

2.7.7. Hydroponic Systems

There are no known large hydroponic systems within the Study Area.

2.7.8. Farm Irrigation Systems

Some rural properties and turf businesses within the Study Area have irrigation systems consisting of pipes and sprinkler systems.

2.7.9. Farm Fences

There are a number of farm fences within the Study Area. The majority of fences mark property boundaries and have been constructed using timber or steel posts, with fencing wire or timber railings. There are other fences within the properties within the Study Area, around in-ground pools and enclosures that contain livestock and pets.

2.7.10. Farm Dams

There are 375 farm dams that have been identified within the Study Area. The locations of the farm dams are shown in Drawing No. MSEC428-19 and details are provided in Table D.03 in Appendix D. The locations and sizes of the farm dams were determined from the 2007 aerial photograph of the area. It is likely that additional farm dams will be constructed prior to the commencement of mining.

The dams are typically of earthen construction and have been established by localised cut and fill operations within the natural drainage lines. The distributions of the longest lengths and surface areas of the farm dams within the Study Area are shown in Fig. 2.14.

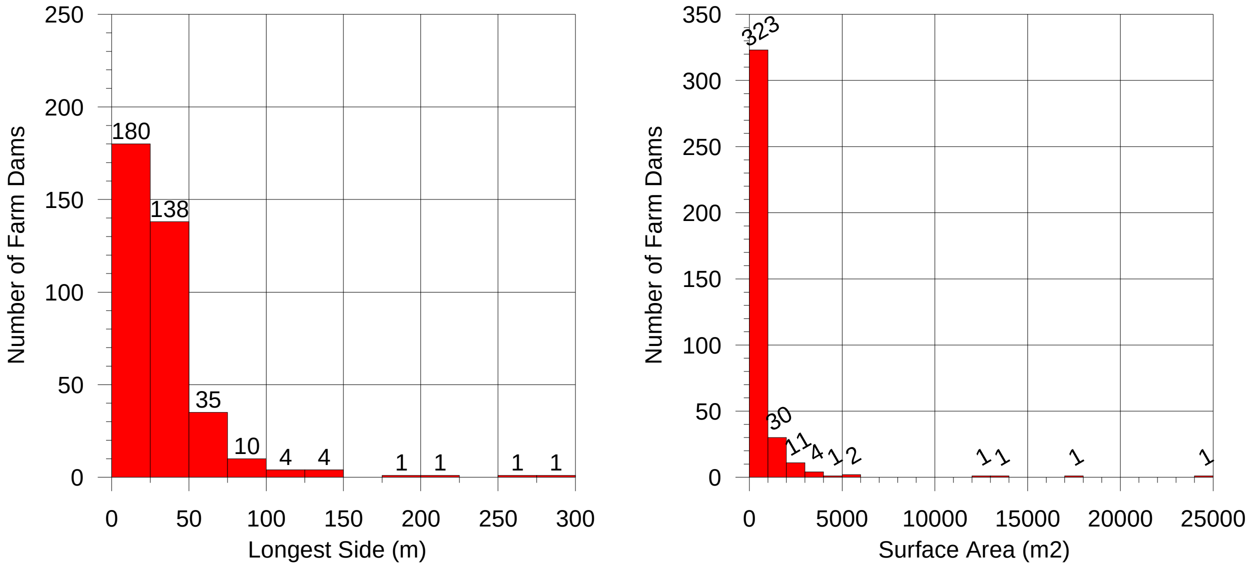


Fig. 2.14 Distributions of Longest Lengths and Surface Areas of the Farm Dams

2.7.11. Wells and Bores

There are 13 registered groundwater bores within the general Study Area. The locations of these bores are shown in Drawing No. MSEC428-17 and details are provided in Table 2.6.

Table 2.6 Registered Groundwater Bores within the General Study Area

Bore ID	Approximate ISG Easting (m)	Approximate ISG Northing (m)	Intended Purpose(s)
GW028035	335050	1318125	Farming
GW033297	335275	1320975	Domestic
GW051560	334550	1322800	Stock
GW056521	332050	1321125	Domestic stock
GW058390	331925	1320975	Domestic
GW058391	332075	1321150	Domestic
GW058392	332150	1321375	Domestic
GW059092	335400	1320475	Irrigation
GW078221	335325	1319125	Commercial
GW078609	335275	1323525	Domestic stock
GW080608	335875	1321125	Domestic stock
GW200211	329200	1320325	Domestic stock
GW200505	337275	1321850	Domestic stock

The locations and details of the registered ground water bores were obtained from the Department of Natural Resources using the *Natural Resource Atlas* website (NRAtlas, 2009). Further descriptions of the registered groundwater bores are provided in the report by Mackie (2009).

2.7.12. Any Other Farm Features

There are no other significant farm features within the Study Area.

2.8. Industrial, Commercial or Business Establishments

2.8.1. Factories

There are no factories within the Study Area.

2.8.2. Workshops

There are no workshops within the Study Area.

2.8.3. Business or Commercial Establishments or Improvements

One quarry site has been identified within the Study Area, above Longwalls 14N and 15N, the location of which is shown in Drawing No. MSEC428-20. This quarry currently appears to be disused, however, it is possible that this quarry could be used at some time in the future. A photograph of the quarry site is provided in Fig. 2.15.

Fig. 2.15 View of the Disused Quarry from Jilliby Road

A number of other commercial establishments have been identified within the Study Area, including:-

- Linton Park and Parkview Horse Studs,
- Moonpar Nursery,
- Highland Park Aviary, and
- Dooralong Valley Turf Farm.

The locations of these commercial establishments are shown in Drawing No. MSEC428-20.

2.8.4. Commercial Gas or Fuel Storages and Associated Plant

There are no commercial gas or fuel storages or associated plant within the Study Area.

2.8.5. Commercial Waste Storages and Associated Plant

There are no waste storages or associated plant within the Study Area.

2.8.6. Commercial Buildings, Equipment or Operations that are Sensitive to Surface Movements

There are no known commercial buildings, equipment or operations that are sensitive to surface movements (i.e. equipment that requires tight operational tolerances) within the Study Area.

2.8.7. Surface Mining (Open Cut) Voids and Rehabilitated Areas

One disused quarry site has been identified within the Study Area, which is discussed in Section 2.8.3. There are no other open cut mines or rehabilitation areas within the Study Area.

2.8.8. Mine Infrastructure Including Tailings Dams or Emplacement Areas

There is no mine infrastructure within the Study Area.

2.8.9. Any Other Industrial, Commercial or Business Features

There are no other identified industrial, commercial or business features within the Study Area.

2.9. Items of Archaeological Significance

There are no lands within the Study Area declared as an Aboriginal Place under the *National Parks and Wildlife Act 1974*.

The locations of the archaeological sites within the Study Area were identified by OzArk (2010b) using the Department of Environment and Climate Change Aboriginal Heritage Information Management System. A total of seven archaeological sites were identified, the locations of which are shown in Drawing No. MSEC428-16 and details are provided in Table 2.7.

Table 2.7 Archaeological Sites within the Study Area

Site ID	Site Type
45-3-3040	Axe Grinding Groove
45-3-3041	Axe Grinding Groove
45-3-3042	Axe Grinding Groove
WSF-AG1	Axe Grinding Groove
WSF-AG2	Axe Grinding Groove
WSF-AG3	Axe Grinding Groove
WSF-AG4	Axe Grinding Groove

It is noted, that Sites WSF-AG1 and WSF-AG2 are located north of the general Study Area. These sites are located along a creek line and could experience valley related movements and, therefore, have been included as part of the Study Area.

Further details are provided in OzArk (2010b).

2.10. Items of Historical or Heritage Significance

There are no items of heritage significance listed in the Australian Heritage Database that are located within the Study Area.

There are three heritage items listed in the Wyong Shire LEP 1991 (which includes all listings on the NSW Heritage Office inventory) that are located within the general Study Area. The locations of these items are shown in Drawing No. MSEC428-16 and details are provided Table 2.8.

Table 2.8 Heritage Sites within the Study Area

Site ID	Site Description	Level of Significance
Site 1	Brick and iron silo located south of Davenport Lane above Longwall 2S	Regional Significance
Site 3	The dwelling “Bangalow” which is located on the south-western corner of Longwall 5SW	Regional Significance
Site 11	Jilliby Public School, which is located between the northern and south-eastern series of longwalls	Local Significance

Further details on the Heritage Sites are provided in the report by OzArk (2010b).

OzArk (2010b) discussed some sites that were previously identified by ERM (2000) as additional items of Potential Heritage Significance within the Study Area. These items are shown in Drawing No. MSEC428-16 and details are provided in Table 2.9.

Table 2.9 Potential Heritage Sites within the Study Area

Site ID(s)	Site Description
Sites G, I, J, K, L, R and S	Dwellings
Site M	Little Jilliby Road Bridge
Site N	Bunya Pine
Site O	Keegan’s Silo
Site P	Pick fence on Durren Road
Site Q	Silos

Further details are provided in OzArk (2010b).

2.10.1. Items on the Register of the National Estate

There are no items on the *Register of National Estate* within the Study Area.

2.11. Items of Architectural Significance

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

2.12. Permanent Survey Control Marks

There are a number of survey control marks in the vicinity of the proposed longwalls, the locations of which are shown in Drawing No. MSEC428-18. There are 16 survey control marks have been identified within the general Study Area. The locations and details of the survey control marks were obtained from the *Land and Property Management Authority* using the *SCIMS Online* website (SCIMS, 2009).

2.13. Residential Establishments

2.13.1. Houses

There are 242 houses that have been identified within the Study Area. The locations of the houses are shown in Drawing No. MSEC428-19 and details are provided in Table D.01 in Appendix D. The locations and sizes of the houses were determined from the 2007 aerial photograph of the area. The types of construction of the houses were determined from kerb side inspections. It is likely that additional houses will be constructed prior to the commencement of mining.

The distribution of the maximum plan dimensions of the houses within the Study Area is provided in Fig. 2.16. The distributions of the wall and footing constructions of the houses within the Study Area are provided in Fig. 2.17. The distribution of the natural surface slope at the houses within the Study Area is provided in Fig. 2.18.

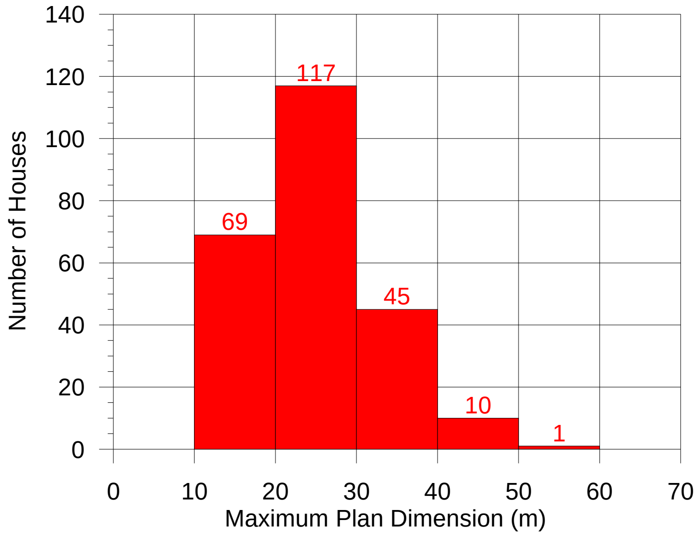


Fig. 2.16 Distribution of the Maximum Plan Dimension of Houses within the Study Area

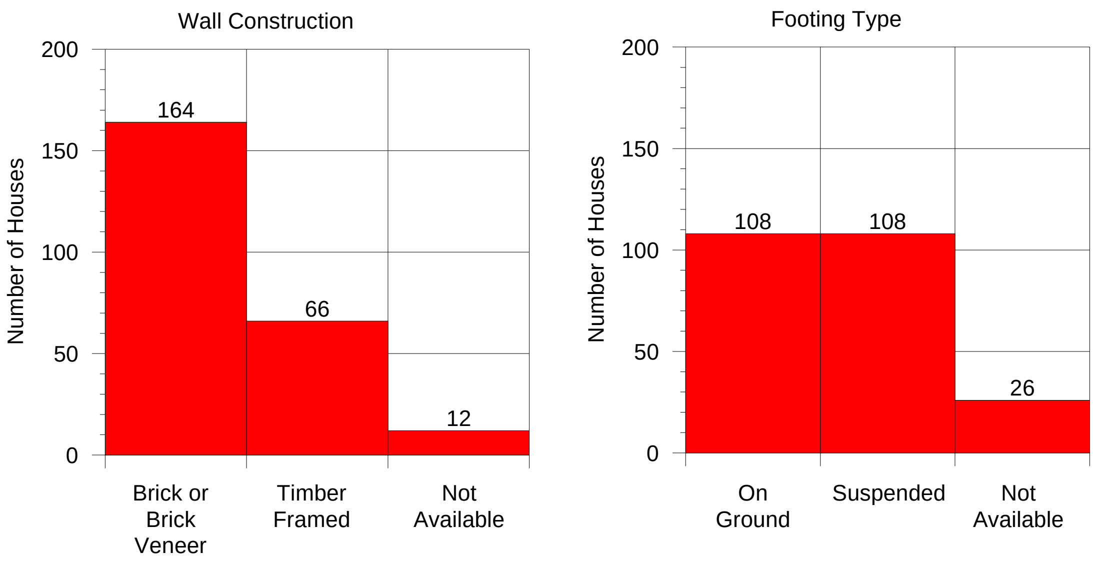


Fig. 2.17 Distributions of Wall and Footing Construction for Houses within the Study Area

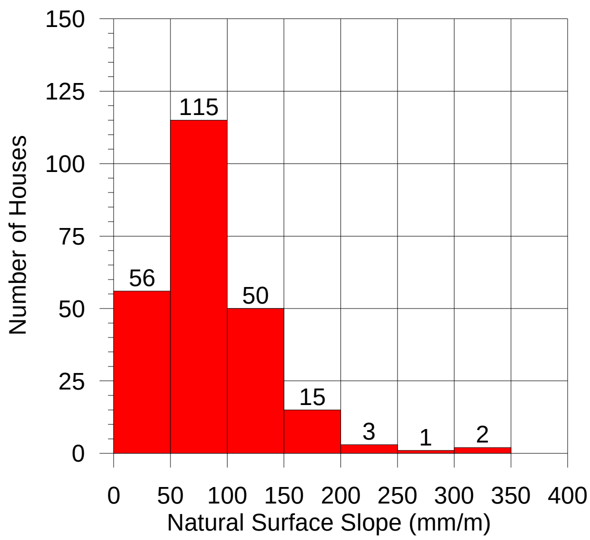


Fig. 2.18 Distribution of the Natural Surface Slope at the Houses within the Study Area

The houses within the Study Area are located within the *Hue Hue* and the *Wyong* Mine Subsidence Districts, which are shown in Drawing No. MSEC428-10. There are a total of 88 houses identified within the Hue Hue Mine Subsidence District, which was proclaimed on the 31st December 1985 and notified on the 31st January 1986. There are a total of 154 houses identified within the Wyong Mine Subsidence District, which was proclaimed on the 9th April 1997 and notified on the 18th April 1997.

2.13.2. Flats or Units

There are no flats or units within the Study Area.

2.13.3. Caravan Parks

There are no caravan parks within the Study Area.

2.13.4. Retirement or Aged Care Villages

There are no retirement or aged care villages within the Study Area.

2.13.5. Any Other Associated Structures

Descriptions of rural building structures and tanks are provided in Sections 2.7.2 and 2.7.3.

There are 467 water tanks that have been identified within the Study Area, the locations of which are shown in Drawing No. MSEC428-19. The locations and sizes of the tanks were determined from the 2007 aerial photograph of the area. It is likely that additional tanks will be constructed prior to the commencement of mining.

There are privately owned gas and fuel storages on the rural properties within the Study Area.

There are 98 privately owned swimming pools which have been identified within the Study Area, of which 91 are in-ground pools and 7 are above ground pools. There are also 10 privately owned tennis courts which have been identified within the Study Area. The locations of these features are shown in Drawing No. MSEC428-19, which were determined from the 2007 aerial photograph of the area. It is likely that additional swimming pools and tennis courts will be constructed prior to the commencement of mining.

The houses within the Study Area have on-site waste systems. Many of the houses within the Study Area also have concrete driveway pavements or footpaths.

2.13.6. Any Other Residential Feature

There are no other residential features identified within the Study Area.

2.14. Any Other Items

There are no other significant items within the Study Area.

2.15. Any Known Future Developments

The proposed Mardi-Mangrove Transfer Main pipeline is located just outside the Study Area, which is discussed in Section 2.5.6.

It is likely that there will be future development of houses and possible future development of residential subdivisions 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 LONGWALLS

3.1. Introduction

A separate detailed subsidence prediction report has been prepared by the WACJV to combine the subsidence prediction research work that was undertaken by the WACJV, Strata Control Technologies (SCT) and MSEC (WACJV, 2008). That WACJV report is included in the W2CP Environmental Assessment Report of the Part 3A Application as Appendix B1. This report, MSEC428, which was prepared to be included in the Main Environmental Assessment Report of the Part 3A Application as Appendix B2, has been prepared by MSEC to;

- identify the natural and built features within the project area that could be affected by subsidence,
- assess the likely impacts and consequences, and
- describe the measures that would be implemented to avoid, minimise, remediate and/or offset the subsidence impacts of the project.

This chapter provides a brief overview of longwall mining, the development of mine subsidence and describes the specific subsidence prediction methods that have been used to predict the mine subsidence movements at the W2CP.

The project and this subsidence prediction methodology was the subject of close public scrutiny during the hearings of an Independent Strategic Inquiry into proposed coal mining activities at Wyong during August 2007. The Inquiry report, which was titled "*Strategic Review of Impacts of Potential Underground Coal Mining in the Wyong Local Government Area",* was released in December 2008.

This report adopted some terms and definitions to draw a distinction between subsidence effects, subsidence impacts and the environmental consequences. These new terms and definitions were first published in the report of another Independent Inquiry that was published in July 2008 and this report was titled "*Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield".*

One of the terms of reference of this Southern Coalfield Inquiry was to provide advice on the best practice in regard to the assessment of subsidence impacts and, hence, the Inquiry report discussed the available subsidence prediction and impact assessment methods and used various terms and definitions to clarify the steps in the prediction and damage assessment processes. These terms and definitions are currently being reviewed and have been described as;

- ***Subsidence Effects:*** *the deformations of the ground mass surrounding a mine, sometimes referred to as 'components' or 'parameters' of mine subsidence induced ground movements including; vertical and horizontal displacements, tilts, curvatures, strains, upsidence and closure.*
- ***Subsidence Impacts:*** *the physical changes or damage to the fabric or structure of the ground, its surface and natural features, or man-made structures that are caused by the subsidence effects. These impacts considerations can include; tensile and shear cracking of the rock mass, localised buckling of strata bed separation, rock falls, collapse of overhangs, failure of pillars, failure of pillar floors, dilation, slumping and also include subsidence depressions or troughs.*
- ***Subsidence Consequences:*** *the knock-on results of subsidence impacts, i.e. any change in the amenity or function of a natural feature or man-made structure that arises from subsidence impacts. Consequence considerations include; public safety, loss of flows, reduction in water quality, damage to artwork, flooding, draining of aquifers, the environment, community, land use, loss of profits, surface improvements and infrastructure. Consequences related to natural features are referred to as* ***environmental consequences****.*

The Inquiry also reported;

> *The conventional or general model of surface subsidence is based on the presence of straight forward and uniform site conditions, including:*
>
> - *the surface topography is relatively flat;*
> - *the surrounding rock mass is relatively uniform and free of major geological disturbances or dissimilarities or previously mined panels; and*
> - *the surrounding rock mass does not contain any extremely strong or extremely weak strata.*
>
> *Where these conditions are not met, surface subsidence effects may vary from those that would be predicted using the conventional model. Such subsidence effects are generally known as 'non-conventional', although this is somewhat of a misnomer as what has varied are the site conditions in which they take place.*
>
> *The various* ***subsidence*** *parameters associated with this* ***conventional****, or general, model of subsidence behaviour are sometimes referred to as the* ***systematic components*** *of subsidence, whilst those associated with site-specific behaviours are referred to as* ***non-systematic****.*
>
> *This Inquiry has maintained the convention of treating subsidence outcomes based on the* ***conventional model*** *of subsidence behaviour as being the standard or norm, and then adapting these to take account of variations created by the effects of the presence of specific natural features.*
>
> ***Conventional*** *surface subsidence effects and their impacts are well understood and are readily and reasonably predictable by a variety of established methods. The understanding of* ***non-conventional*** *surface subsidence effects (far-field horizontal movements, valley closure, upsidence and other topographical effects) is not as advanced.*
>
> *Subsidence impact assessments in the Southern Coalfield have generally focused too much on the prediction of* ***subsidence effects****, rather than the accurate prediction of* ***subsidence impacts*** *and their* ***consequences****.*

This report follows the terminology suggested in these Inquiry reports. The predicted values of subsidence, tilt, curvature, strain, closure and upsidence, as discussed in Chapters 3 to 5, are the **subsidence effects** that are referred to in these Inquiry reports. Chapter 5 of this report assesses both the **subsidence impacts** and some of the **subsidence consequences** that are caused by the **subsidence impacts**. Other consultants' reports also provide further discussions on the **subsidence consequences** some of which are also called **environmental consequences**.

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

WACJV proposes to extract coal beneath the project area using conventional longwall mining techniques. A generic cross-section through the immediate roof strata and along the length of a typical longwall, at the coal face, is shown in Fig. 3.1.

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 provide a secure working space at the coal face. The coal is then transported by an armoured face conveyor belt which is located behind and beneath 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.

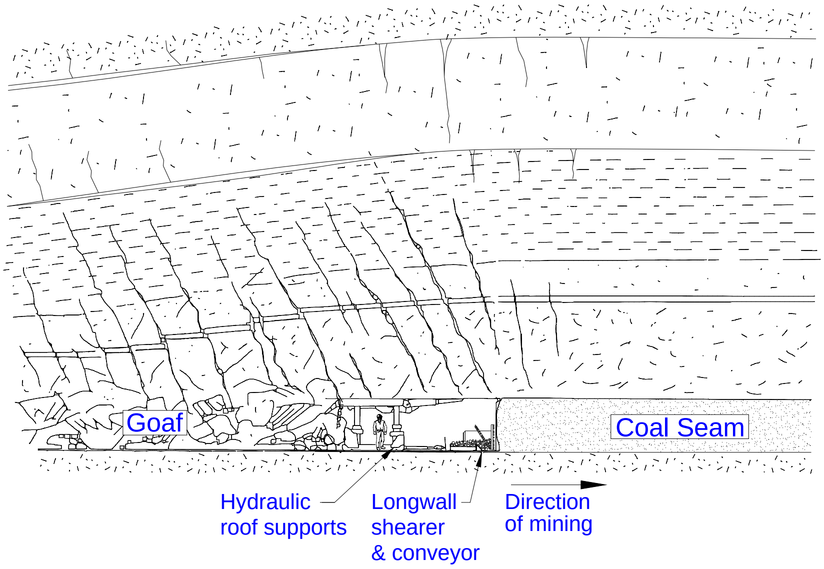


Fig. 3.1 Cross-section along the Length of a Typical Longwall at the Coal Face

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 generally contains 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 moving horizontally towards the centre of the mined goaf area. Some mining induced fractures can be observed on the surface.

The maximum subsidence at the surface varies, depending on a number of factors including longwall geometry, depth of cover, extracted seam thickness and overburden geology. Based on many years of subsidence monitoring over mined areas in the Sydney Basin, the maximum achievable subsidence in the NSW Coalfields is 65 % of the extracted seam thickness, for single-seam conditions.

3.3. Overview of Conventional Subsidence Movements

The normal or systematic or conventional mine subsidence ground movements resulting from the extraction of longwalls are typically described by the following parameters:-

- **Subsidence** usually refers to vertical movement of a point, but 'subsidence of the ground' actually includes both a vertical and horizontal movement components. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of *millimetres (mm)*. The horizontal component of subsidence can be measured as relative movements between adjacent pegs (2D surveys) or absolute movements from fixed datum points (3D surveys).

- **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 horizontal 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 %, or 1 in 1000.
- **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* (km^{-1}), 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 the relative differential horizontal displacement of the ground. Normal strain is calculated as the change in horizontal distance between two points on the ground, divided by the original horizontal distance between them, i.e. strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation. **Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases.

  Slope strains have occasionally been determined, but, they should not be confused with the horizontal strains that are usually discussed when comparing mine subsidence issues. In most subsidence literature strain is expressed in units of *millimetres per metre (mm/m)*. So that these mining induced 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.

  Whilst mining induced **normal strains** are measured **along** monitoring lines, ground **shearing** can also occur both vertically and horizontally **across** the directions of monitoring lines. Most of the published mine subsidence literature discusses the differential ground movements that are measured **along** subsidence monitoring lines, however, differential ground movements can also be measured **across** monitoring lines using 3D survey monitoring techniques.

  Transient horizontal ground movement patterns vary across and along longwalls as the travelling face approaches and passes beneath a point and predicting these movement patterns is extremely complex. Accordingly to the rigorous definitions, it is not possible to measure **horizontal shear strains** using 3D survey data from a straight line of survey points.

- **Horizontal shear deformations** across monitoring lines can be measured and these are described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. It is difficult to compare observed horizontal shear deformations for monitoring lines that were not installed in straight lines parallel or perpendicular to mined panels, as the initial orientations of the monitoring lines affect the magnitudes and directions of observed horizontal ground measurements. It is easier to compare measured ground deformations after they have been translated into movements parallel or movements perpendicular to the mined panel.

  High deformations along monitoring lines (i.e. normal strains) are generally measured where high deformations have been measured across the monitoring line (i.e. shear deformations). Conversely, high deformations across monitoring lines are also generally measured where high normal strains have been measured along the monitoring line.

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

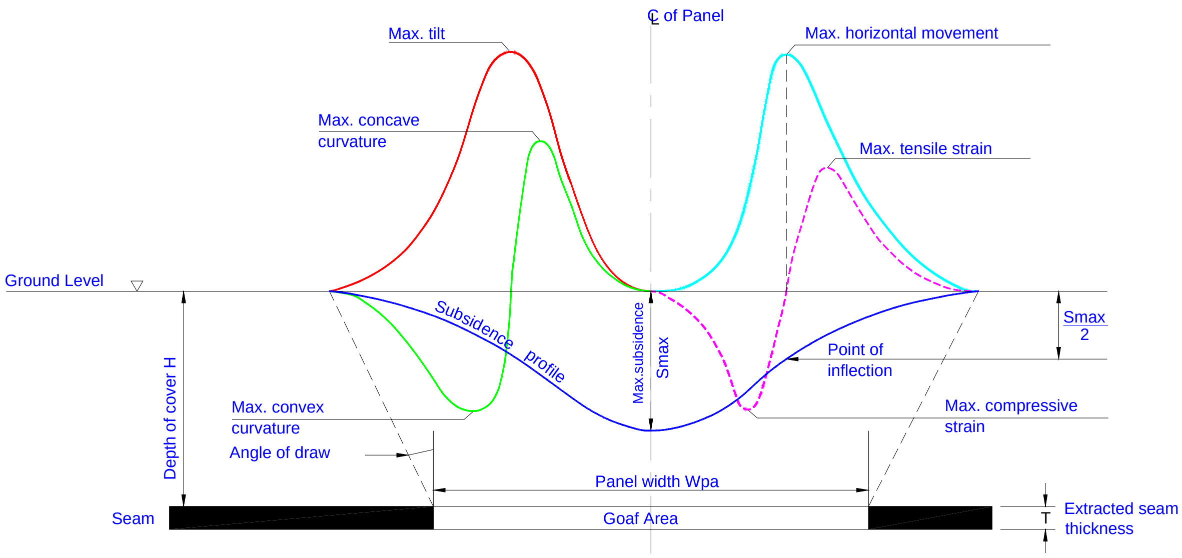


Fig. 3.2 Typical Profiles of Conventional Subsidence Parameters for a Single Longwall Panel

Where both vertical and horizontal movements of pegs are measured, usually, the vertical subsidence movement is greater than the horizontal movement for those pegs that are located over the extracted longwall panel. Where the vertical subsidence is very small, and particularly at those pegs that are located well beyond the panel edges and over solid unmined coal areas, the measured horizontal movement at the pegs can be much greater than the vertical movement.

The magnitude of the maximum subsidence at the surface varies, depends on a number of factors including the longwall panel and pillar widths, the chain pillar stability, depth of cover, extracted seam thickness, the geology of the strata layers between the surface and coal seam and on the geology of the strata layers in the floor below the seam. The maximum possible subsidence in the Newcastle Coalfield is typically between 55 % and 60 % of the extracted seam thickness for single seam extractions. For this project we have conservatively adopted a maximum possible subsidence of 65% of the extracted seam thickness.

The absolute horizontal component of mining induced subsidence can be predicted, though these predictions are prepared to a lesser degree of accuracy when compared to predictions of vertical subsidence. The magnitude of the absolute horizontal displacements can be determined from the predicted tilt profiles by applying a factor and these subsidence induced horizontal displacements are generally directed towards the centre of the mined longwall panel as shown in Fig. 3.3. This factor varies with depth of cover, see Holla and Barclay (2000).

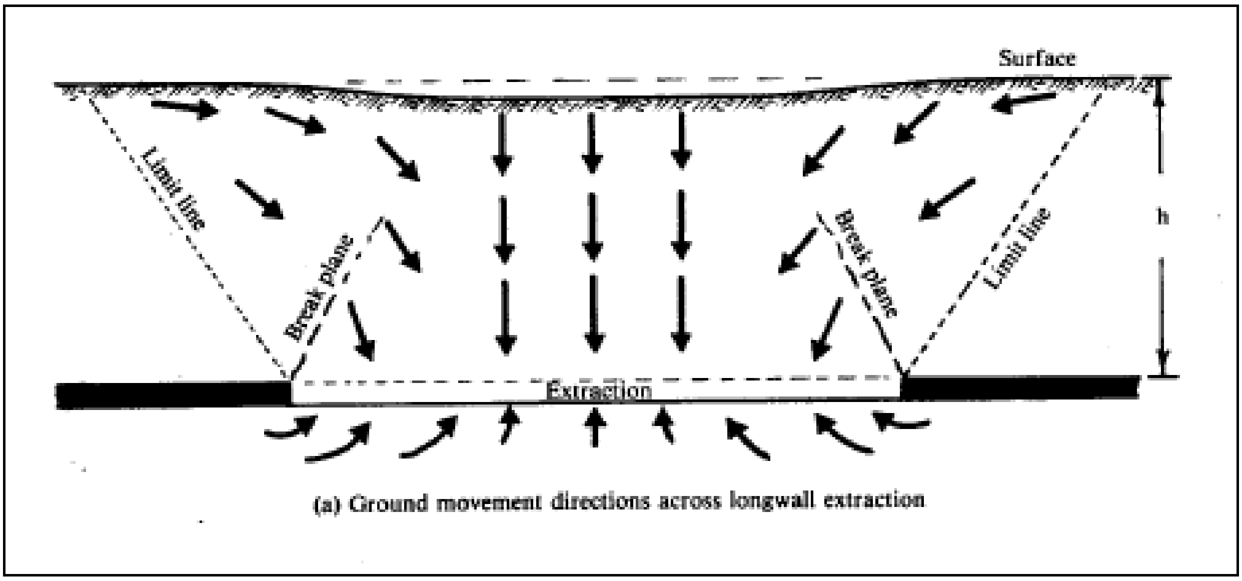


Fig. 3.3 Normal Mining Induced Movements above an Extracted Area (after Whittaker, Reddish and Fitzpatrick, 1985)

As a general rule for the proposed longwalls, a tilt-to-horizontal displacement factor of 15 can be used to predict the 'normal' absolute horizontal component of subsidence. If the predicted tilt at a point is 2 mm/m, for example, then the predicted absolute horizontal ground displacement will be approximately 30 mm, directed towards the centre of the mined goaf. This horizontal ground displacement prediction method is only approximate and, whilst it tends to be conservative where the tilts are high, it tends to underestimate the horizontal movements where the tilts are low. When comparing the predicted and observed horizontal movements over many longwalls, it becomes apparent that these approximate horizontal movement predictions are most accurate for simple mine layouts with consistent geological conditions and uniform extracted coal seam thicknesses under flat surface terrains.

Increased magnitudes of horizontal movements are generally observed where steep slopes or surface incisions exist, as these natural topographic features influence both the magnitude and the direction of horizontal ground movement patterns. Similarly, increased levels of observed horizontal movements are often measured around sudden changes in geology, or where blocks of coal are left between longwalls or near other previously extracted series of longwalls.

The observed far-field horizontal movements, i.e. beyond the normal vertical subsidence limits of the extracted panels, also tend to be higher than the predicted horizontal movements using the above approximate horizontal ground displacement prediction method.

With ongoing monitoring, analysis and research of subsidence induced ground movements, improved understanding of the influence of these factors is continually being developed. However, the current predictions of vertical subsidence movements are generally more accurate than the predictions of horizontal subsidence movements.

As described previously, normal strains are the differential horizontal movements of the ground. Average strains can, therefore, be estimated by multiplying the ground curvature by the same factor used to determine absolute horizontal movement from tilt. That is, for the proposed longwalls, the average strain can be estimated by applying a factor of 15 to the ground curvatures.

To allow for the variability in the predicted horizontal movements and strains, a statistical approach has been used to provide probabilities for strain, rather than providing a single predicted average strain. As discussed in Section 4.3, the range of potential strains resulting from the extraction of the proposed longwalls are provided with the probabilities of exceedance of the various strain ranges, based on monitoring data from previously extracted longwalls in the Newcastle Coalfield.

The angle at which the vertical subsidence spreads out towards the limit of subsidence, at the surface, is referred to as the angle of draw. The angle of draw depends upon the strength of the strata and the depth of cover to the coal seam and typically lies between 10 degrees and 35 degrees from the vertical, depending on how the limit of subsidence is defined.

It is generally accepted that vertical subsidence of less than 20 mm will have negligible effect on surface infrastructure and this is generally adopted as the cut-off point for determination of the angle of draw. In many locations, ground movements of more than 20 mm have been observed due to moisture and climatic conditions. In the Coalfields of NSW, if local data is not available, the cut-off-point or the limit of vertical subsidence is taken as a point on the surface defined by an angle of draw of 26.5 degrees from the edge of the extraction, i.e. a point on the surface at a distance of half the depth of cover from the longwall goaf edges. Where local data exists and it can be shown that the angle is generally less than 26.5 degrees, then, the lower angle of draw can be used.

3.4. Far-field Movements

As discussed above, the measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas are often much greater than the observed vertical movements at those pegs. An empirical database of observed horizontal movements has been developed which confirms this.

For example, at the location beyond the panel edges where the predicted conventional vertical subsidence value is 20 mm, i.e. at a distance of about half of the depth of cover from the panel edges, horizontal movements of up to 100 mm have been observed, with an average observed horizontal movement of approximately 40 mm. These horizontal movements are higher than the vertical movements beyond the longwall panel edges and over solid unmined coal due to a redistribution of the in-situ horizontal compressive stresses in the strata around the longwalls. Before mining these in-situ stresses, which are generally compressive in all directions, are in equilibrium or balance. When mining occurs, the equilibrium is disturbed and the stresses achieve a new balance by shearing through the weaker strata units allowing the strata to move or expand towards the goaf areas, where the confining stresses have been relieved.

When large horizontal displacements are measured outside the goaf area, they are more likely to be a result of far-field movements than a result of conventional mine subsidence mechanisms. 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.

The Southern Coalfield Inquiry includes far-field horizontal movements as non-conventional movements. The methods used to predict far-field horizontal movements have continued to develop in recent years using the current and available 3D monitoring data. The confidence levels in these predictions continue to improve and, for this reason, this report considers far-field horizontal movements to be conventional movements, rather than irregular or anomalous non-conventional movements.

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 impacts on natural features or built environments, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

In some cases increased higher levels of far-field horizontal movements are observed where steep slopes or surface incisions exist nearby, as these features influence both the magnitude and the direction of ground movement patterns. Similarly, increased observed horizontal movements are often observed around sudden changes in geology or where blocks of coal are left between longwalls or near other previously extracted series of longwalls.

Far-field horizontal movements and the method used to predict such movements are described further in Sections 3.4 and 4.5.

The predicted 20 mm conventional subsidence contour is shown in Drawing No. MSEC428-21. It can be seen on this drawing, that an area between the northern and south-eastern series of longwalls is predicted to experience less than 20 mm of conventional subsidence. It is possible that this area could experience slightly greater subsidence due to far-field vertical movements as the result of stress redistribution from the proposed mining on both sides of this area. It would not be expected, however, that this area would experience any significant tilts, curvatures or strains.

3.5. Overview of Non-Conventional Subsidence Movements and Irregular Subsidence Profiles

Conventional subsidence profiles are typically smooth in shape and can be explained by the expected caving mechanisms associated with overlying strata collapsing into a void. Normal conventional subsidence movements due to longwall extraction are easy to identify where longwalls are regular in shape, the extracted coal seams are relatively uniform in thickness, the geological conditions are consistent and surface topography is relatively flat.

As a general rule, the smoothness of the profile is governed by the depth of cover and lithology of the overburden, particularly the near surface strata layers. Where the depth of cover is greater than 400 metres, the observed subsidence profiles along monitored survey lines are generally smooth. Where the depth of cover is less than 100 metres, the observed subsidence profiles along monitoring lines are generally irregular. Very irregular subsidence movements are accompanied with much higher tilts and strains at very shallow depths of cover, where the collapsed zone above the extracted longwalls extends up to or near to the surface.

However, irregular subsidence movements are occasionally observed at the higher depths of cover along an otherwise smooth subsidence profile. The cause of these irregular subsidence movements can be associated with;

- issues related to the timing and the method of the installation of monitoring lines,
- sudden or abrupt changes in geological conditions,
- steep topography, and
- valley related mechanisms.

Approximate predictions of ground movements can be provided for non-conventional subsidence movements where the underlying geological or topographic conditions are known in advance.

3.5.1. Irregular Subsidence Movements caused by Changes in Geological Conditions

It is believed that most non-conventional ground movements are a result of the reaction of near surface strata to increased horizontal compressive stresses due to mining operations. Some of the geological conditions that are believed to influence these irregular subsidence movements are the blocky nature of near surface sedimentary strata layers and the possible presence of; unknown faults, dykes or other geological structures, cross bedded strata, thin and brittle near surface strata layers and pre-existing natural joints. The presence of these geological features near the surface can result in a bump in an otherwise smooth subsidence profile and these bumps are usually accompanied by locally increased tilts and strains. Buckling of surface soils can also occur.

Even though it may be possible to attribute a reason behind most observed non-conventional ground movements, there remain some observed irregular ground movements that still cannot be explained with the available geological information. The term "anomaly" is therefore reserved for those non-conventional ground movement cases that were not expected to occur and cannot be explained with by any of the above possible causes.

While the exact cause of an anomaly along an otherwise smooth subsidence profile may not yet be fully understood, it is expected that they will be better understood as the development of mine subsidence knowledge progresses. This may then allow these non-conventional movements to be predicted, so that surface features can be better protected in the future. At the moment these observed non-conventional ground movements are being included, statistically, in current predictions by basing predictions on the frequency of past occurrence of both the conventional and non-conventional observed ground movements. Such movements can be detected early by regular subsidence monitoring surveys and hence can be managed. Irregular subsidence movements and the impacts resulting from such movements are described further in Chapter 5.

3.5.2. Valley Related Movements

Mining induced valley related movements, called upsidence and valley closure, are commonly observed in monitored mine subsidence data across river and creek alignments within the Southern Coalfield. Occasionally mining induced valley related movements have also been observed in mine subsidence data monitored in the Western, Newcastle and Hunter Valley Coalfields.

These mining induced valley related movements are similar to the naturally occurring valley related movements that are often observed in areas where there are high in-situ horizontal stresses. These natural valley formation movements, coupled with erosion events, result in the ongoing development of valleys as is illustrated in Fig. 3.4.

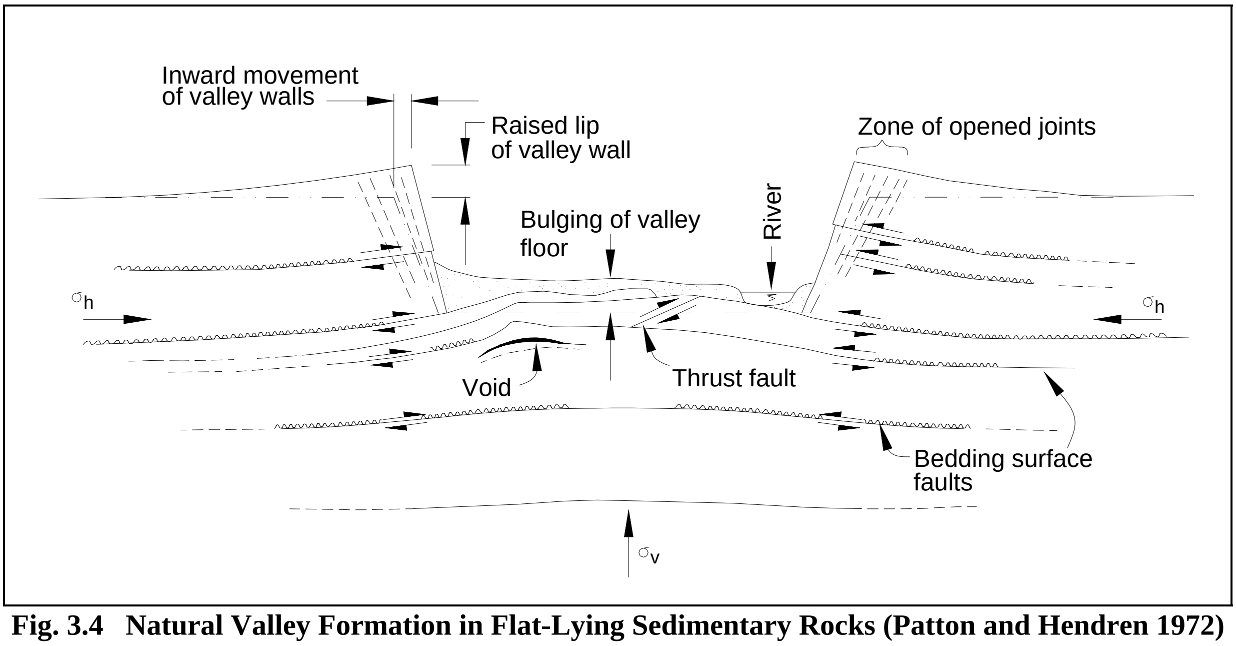


Fig. 3.4 Natural Valley Formation in Flat-Lying Sedimentary Rocks (Patton and Hendren 1972)

These natural valley formation movements can be accelerated by coal mining and mine subsidence. Mining induced valley movements have similar effects and consequences as the natural valley related movements. The mechanisms that are involved in both the natural and mining induced valley related movements are very complex and are thought to be influenced by a number of factors, including dilation and down slope movements, but, the principal factor appears to be associated with a redistribution of horizontal in-situ stresses.

Coal was formed when ancient ferns, plants and trees died, and sank to the bottom of vast swamps, initially forming peat. Accumulations of thousands of metres of sand and clay materials and sediments over the peat over millions of years squeezed the water out and produced sufficient heat and pressure to transform the peat layers into coal seams and the soft sediments into sandstones and shales.

Coal seams were therefore buried and formed at significantly greater depths than where they are found today and, at these depths, high vertical and horizontal stresses existed. As erosion has taken place over geologic time, the vertical (loading) stresses have been relieved but a component of the horizontal stress remains locked in the seams and surrounding strata. It is not uncommon in coalfield strata for the in-situ horizontal stresses to be up to three times greater than the vertical stress.

Steep, incised topography interrupts the transmission of horizontal stress, causing it to be redirected from the hills and into the floor of the valleys or gorges as discussed above and as is shown in Fig. 3.4. This can lead to overstressing of valley floors, with the near-surface rock strata uplifting under the effects of bending and buckling. The valley is deepened which, in turn, causes an increase in the horizontal stress redirected into the floor of the valley. This very slow, self perpetuating natural valley formation process is also referred to as valley bulging. Field investigations have revealed that this process can result in the creation of voids beneath water courses, often in the form of open bedding planes which may act as underground flow paths for groundwater and stream water (Patton and Hendren, 1972, Fell et al, 1992, Everett et al, 1998, Waddington Kay, 2002).

Mining causes further disruptions around valleys because it creates large voids at the coal seam and above the coal seam through which the horizontal stress can be released causing the surrounding rock mass to move horizontally towards the caved and fractured zones. The regional horizontal stress is redirected around the void and the valley floor as shown conceptually in Fig. 3.5, thereby increasing the stresses acting across the valley floor and resulting in the mining induced valley related movements.

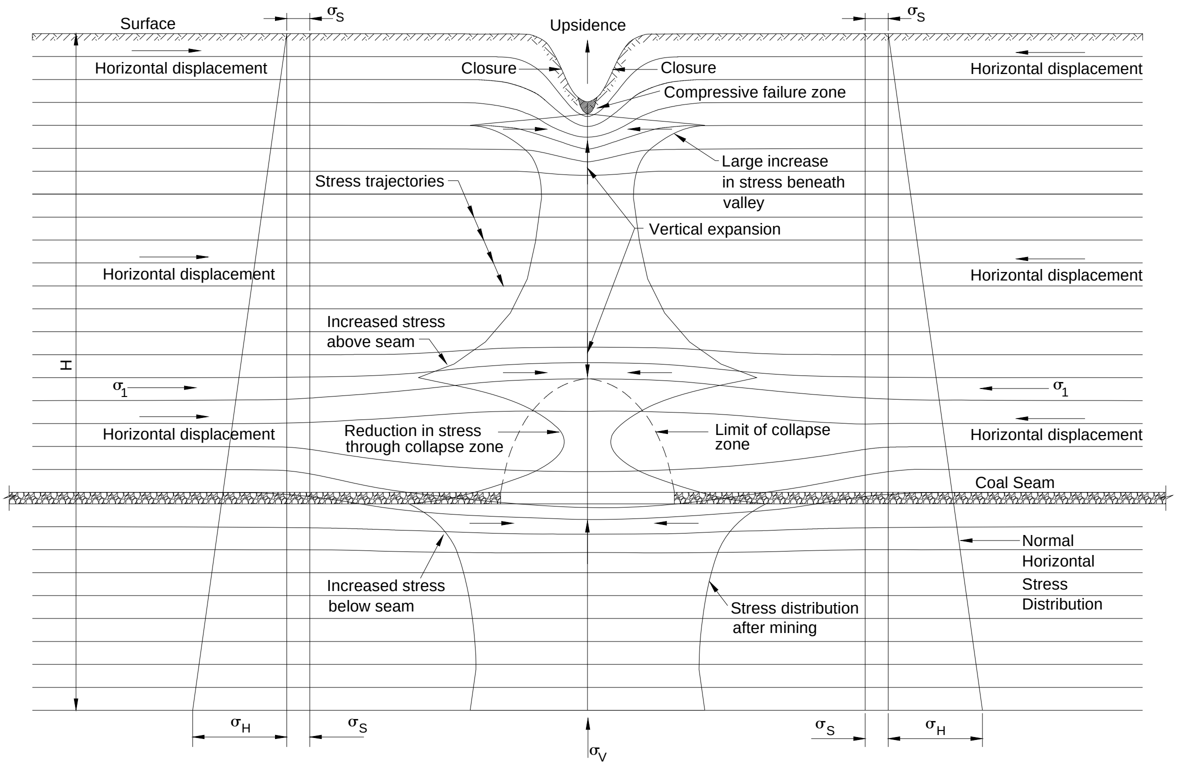


Fig. 3.5 Redistribution of in-situ horizontal stresses due to mining beneath a valley

Studies have shown that the observed upsidence and closure movements increase with increased mining induced subsidence, when the mined panel is directly underneath the valley, where the valleys are steep and incised and with increased valley depths.

The main watercourses within the Study Area are positioned within wide, alluvial-filled floodplains. This wide valley morphology, allied with bedrock being up to 40 metres deep below the alluvial sedimentary fill with very low in-situ horizontal stresses, is distinctly different to most valleys in the Southern Coalfields which feature sandstone rock based streams within deeply incised, narrow, steep-sided valleys. As a result far less mining induced valley related movements are anticipated within the Study Area than have been observed in the Southern Coalfields.

Nevertheless, the valley landscapes within the Study Area may be subjected to some mining induced valley related movements and these issues are discussed below.

Mining induced valley related movements are normally described by the following parameters:-

- **Upsidence** is the reduced subsidence, or the relative uplift within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.
- **Closure** is the reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill soil slumping and other possible strata mechanisms.
- **Compressive Strains** occur within the bases of valleys as a result of valley closure and the buckling or shearing of the near surface strata. **Tensile Strains** also occur at the tops of the valleys as the result of valley closure movements. The magnitudes of these strains, which are typically expressed in the units of *millimetres per metre (mm/m)*, are calculated as the changes in horizontal distance over a standard bay length, divided by the original bay length.

3.6. Definitions of Incremental, Cumulative, Total and Travelling Subsidence Parameters

For the purposes of this report, the definitions of incremental, cumulative, total and travelling subsidence parameters are as follows:-

- **Incremental** subsidence parameters are the additional movements 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 are the accumulated movements which occur due to the extraction of a number of longwalls within a series of longwalls.
- **Total** subsidence parameters are the accumulated movements which occur due to the extraction of all longwalls within a series of longwalls.
- **Travelling** subsidence parameters are the transient movements which occur as the longwall extraction faces mine 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.

3.7. Calibration of Subsidence, Tilt and Curvature Predictions for the W2CP

As discussed in the separate detailed subsidence prediction report, which has been prepared by the WACJV, there is only a limited amount of mine subsidence monitoring data available for areas with similar depths of cover, extracted seam thicknesses and geological conditions. Accordingly, a state of the art hybrid approach to subsidence prediction was adopted for the W2CP, which involved integrating the MSEC empirical Incremental Prediction Method (IPM) with an advanced numerical model that was developed by SCT to simulate caving and to incorporate the appropriate geology. As discussed in the subsidence prediction report, SCT ran this numerical model to provide results for a range of locations over the project area. MSEC then calibrated the IPM empirical model based on the output of the SCT numerical modelling at these specific locations.

MSEC then determined site specific subsidence, tilt and curvature predictions and prepared impact assessments resulting from the extraction of the proposed longwalls at each of the identified natural features and items of infrastructure based on changes in panel widths, pillar widths, seam extraction heights, seam levels, surface levels and depths of cover.

To make predictions of the site specific subsidence, tilts and curvatures, the IPM model uses the surface level contours, seam floor contours and seam thickness contours, which are shown in Drawings Nos. MSEC428-02, MSEC428-03 and MSEC428-04, respectively. The geological structures identified at seam level are shown in Drawing No. MSEC428-06. The surface and seam information shown in these drawings was provided by the WACJV.

The IPM model provides mine subsidence parameter predictions at points on a regular grid orientated north-south and east-west across the Study Area. A grid spacing of 10 metres in each direction was generally adopted, which provides sufficient resolution for the generation of subsidence, tilt and curvature contours.

The maximum predicted conventional subsidence parameters resulting from the extraction of the proposed longwalls are provided in Chapter 4. The method used to predicted strains for the proposed longwalls is described in Section 4.3.

The predicted subsidence parameters at the natural features and items of surface infrastructure within the Study Area are provided in Chapters 5.

3.8. The Standard Incremental Profile Method

The Incremental Profile Method has been successfully used to make subsidence predictions for many previously extracted longwalls in the coalfields of NSW.

The standard Incremental Profile Method has been used to make conventional subsidence predictions for many previously extracted longwalls in the Southern, Newcastle and Western Coalfields of NSW. The Incremental Profile Method was developed by MSEC, which was 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 in NSW 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, Gretley, Invincible, John Darling, Kemira, Lambton, Liddell, Mandalong, Metropolitan, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, South Bulga, South Bulli, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, 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. The maximum width of extracted longwalls in the database is 410 metres, and the maximum width of extracted panels in the database is more than 800 metres (continuous miner operations).

The extraction heights in the database varying from less than 2 metres and typically up to 5 metres, of which 7 % are for cases having seam extraction heights of less than 2 metres, 74 % are for cases having seam extraction heights between 2 and 3 metres, 15 % are for cases having seam extraction heights between 3 and 4 metres, and 4 % are for cases having seam extraction heights between 4 and 5 metres.

Subsidence predictions made using the Incremental Profile Method use the database of observed incremental subsidence profiles, the longwall geometries, local surface and seam information and geology. The method has a tendency to over-predict the conventional subsidence parameters (i.e. is slightly conservative) where the 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 mining area.

Further details on the standard 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*. Further details on the calibration of the Incremental Profile Method for the proposed longwalls is provided in Appendix B1 of the Environmental Assessment.

3.9. Reliability of the Predicted Subsidence, Tilt and Strain Parameters

Empirical methods of subsidence prediction are generally accepted as providing predictions of maximum subsidence to an accuracy of ±10 % to ±15 % where mining and geological conditions are similar.

However, the initial empirical mine subsidence predictions for these proposed longwalls did not allow for additional subsidence resulting from the weakening effects of the Awaba Tuff on the chain pillars. After consultation with SCT on the effects of the Awaba Tuff on the stability of the chain pillars and after the hybrid approach to predicting subsidence at the W2CP was developed, significantly increased levels of mine subsidence have been predicted across the Study Area based on the SCT numerical model results.

The conservatively based hybrid subsidence prediction approach now provides subsidence parameters that are approximately double the values predicted if conventional empirical formula are used to predict subsidence in the Newcastle Coalfields without modifications to account for weakening effect of the underlying Awaba Tuff and the relatively thick extracted seam thickness. The ground conditions modelled by SCT were selected from an extensive borehole drilling and geomechanical testing programme to represent a conservative assessment in order to ensure a worst-case scenario. This modelling included the full coal seam thickness, the weak seam floor and other geological factors to ensure the model simulated pillar floor collapses. Under these conditions, it is believed that the resulting conservatively based hybrid subsidence predictions are likely to be greater than the observed subsidence values and, in this case, are likely to be greater than the typical upper level of the accuracy of empirical predictions of +10 % to +15 %. All impact and consequence assessments have therefore been undertaken based on these conservative worst-case scenario assessments. Accordingly, it will be necessary to monitor the ground movements over the initial longwall panels at the W2CP, so that the management strategies can be re-assessed and modified, if and as needed, based on the actual ground movements that are observed over the previously extracted longwalls.

Even though a conservative approach has been adopted for the mine subsidence prediction and impact assessment methodology, the WACJV has committed itself to an adaptive and continuous improvement approach to the longwall panel design whereby the mining dimensions and limits of future mine workings will be continuously reviewed and modified as necessary as experience is gained to ensure the required subsidence parameters are observed at houses in the Hue Hue Mine Subsidence District and within the Dooralong and Yarramalong Valley floodplains. It will therefore be necessary to undertake detailed monitoring of the ground movements over the initial longwall panels at the W2CP. Whilst the current conservative approach is appropriate for the current mine planning study, the proposed monitoring and analysis of the actual subsidence measured during the initial mining will enable further verification of the model and enhance its future predictive capability and will allow appropriate subsidence management plans to be developed.

The comparison between predicted and observed tilts and conventional curvatures, for previous longwall mining, show that the Incremental Profile Method provides reasonable results. It is expected, in this case, that the calibrated Incremental Profile Method will generally provide conservative results for the proposed longwalls. It is likely, however, that the predicted conventional tilts and curvatures will be exceeded at the watercourses, as a result of valley related movements. A separate method of predicting valley closure, upsidence and strain is provided in this report and the reliability of the predictions is provided in Section 3.10.

Observations of strain show that there is a trend of increasing average tensile strain with increasing hogging curvature and an increasing average compressive strain with increasing sagging curvature. As discussed in more detail in Section 4.3, applying a linear relationship between curvature and strain provides a reasonable estimate for the average tensile and compressive strains. However, there is a considerable variability in strain observations. When expressed as a percentage, observed strains can be many times greater than the predicted average strain for low curvatures.

The predictions of strain provided in this report have therefore adopted a statistical approach to account for the variability, rather than providing a single predicted average strain. The variation in strain occurs 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 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 and the direction of mining, which can cause a lateral shift in the subsidence profile. While an adjustment for seam dip has been included in the predictions, the assessments at isolated features have, been based upon the highest predicted values of subsidence, tilt and curvature within a radius of 20 metres of each feature, rather than the predicted values at the points.

3.10. Reliability of Predictions of Upsidence and Closure Movements

The predicted valley related movements resulting from the extraction of the proposed longwalls were made using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002). Further details can be obtained from the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

The development of the predictive methods for upsidence and closure are the result of recent and ongoing research and the methods do not, at this stage, have the same confidence level as conventional 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 impossible 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 in the Southern Coalfield, where the in-situ stresses are high. The methods should, therefore, tend to over-predict the movements in areas of lower stress.

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.

Another factor that is thought to influence the movements is the characteristics of near surface geology, particularly in stream beds. Upsidence in particular is considered to be sensitive to the way in which the bedrock responds, since thin strata layers may respond differently to thicker ones. The location of the point of maximum upsidence is also considered to be strongly influenced by the characteristics of near surface geology.

Another factor that is thought to influence upsidence and closure movements is the presence of geomorphological features. Recent monitoring along a deeper and more incised valley has shown variable measurements around bends. There tended to be less movement at the apex of the bend than in the straight sections.

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.

Some upsidence and closure ground movements have been monitored in the Newcastle and Western Coalfields; however, these movements are not often observed outside the Southern Coalfields at locations where the depths of cover are shallower and where the levels of monitored systematic or conventional strains exceed the levels of the upsidence and closure ground movements. No upsidence and closure ground movements have been observed where there are thick alluvial beds over the bedrock.

Accordingly, as discussed above, it will therefore be necessary to undertake detailed monitoring of the ground movements over the initial longwall panels at the W2CP. Whilst the current conservative approach is appropriate for the current mine planning study, the proposed monitoring and analysis of the actual subsidence measured during the initial mining will enable further verification of the model and enhance its future predictive capability and will allow appropriate subsidence management plans to be developed.

CHAPTER 4. MAXIMUM PREDICTED CONVENTIONAL SUBSIDENCE PARAMETERS FOR THE PROPOSED LONGWALLS

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of the proposed longwalls. The predicted subsidence parameters and the impact assessments for the natural features and items of surface infrastructure within the Study Area are provided in Chapter 5.

4.2. Maximum Predicted Conventional Subsidence, Tilts and Curvatures

The predicted conventional subsidence parameters for the proposed longwalls were determined using the Incremental Profile Method, which was calibrated using an advanced numerical model that was developed by SCT to simulate caving and to incorporate the appropriate geology. The background on the method of calibration of the prediction model and discussions on the reliability of the predictions is provided in Chapter 3 and further details of the subsidence prediction methodology are described in a separate detailed subsidence prediction report (WACJV, 2008).

The predicted total conventional subsidence contours, resulting from the extraction of all the proposed longwalls, are shown in Drawing No. MSEC428-21. A summary of the maximum predicted values of total conventional subsidence, tilts and curvatures, resulting from the extraction of the proposed longwalls, is provided in Table 4.1.

Table 4.1 Maximum Predicted Total Conventional Subsidence, Tilts and Curvatures Resulting from the Extraction of the Proposed Longwalls

Longwalls	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt (mm/m)	Maximum Predicted Total Conventional Hogging Curvature (km^{-1})	Maximum Predicted Total Conventional Sagging Curvature (km^{-1})
LW1N to LW5N	1000	11	0.20	0.27
LW6N to LW26N	2500	15	0.28	0.37
LW1S to LW10S	2600	13	0.25	0.30
LW1SW to LW10SW	2550	12	0.11	0.19
Study Area	**2600**	**15**	**0.28**	**0.37**

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report show the conventional movements and do not include the valley related upsidence and closure movements, nor 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.

The maximum predicted conventional tilt within the Study Area is 15 mm/m (i.e. 1.5 %), which represents a change in grade of 1 in 65. The maximum predicted conventional curvatures within the Study Area are 0.28 km^{-1} hogging and 0.37 km^{-1} sagging, which represent minimum radii of curvature of approximately 4 kilometres and 3 kilometres, respectively.

The predicted conventional subsidence parameters vary across the Study Area as the result of, amongst other factors, variations in the depths of cover, longwall void widths, chain pillar widths and extraction heights. To illustrate this variation, the predicted profiles of conventional subsidence, tilt and curvature have been determined along four prediction lines, the locations of which are shown in Drawing No. MSEC428-21. The predicted profiles of conventional subsidence, tilt and curvature along Prediction Lines 1, 2, 3 and 4, resulting from the extraction of the proposed longwalls, are shown in Figs. E.01, E.02, E.03 and E.04, respectively, in Appendix E.

4.3. Predicted Strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. As discussed in Section 3.9, the reasons for this are that strain is affected by many factors, including ground curvature and horizontal movement, as well as local variations in the near surface geology, the locations of joints at bedrock, and the depth of bedrock. Survey tolerance also represents a substantial portion of the measured strain is some cases. The profiles of observed strain can, therefore, be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

In previous MSEC subsidence reports, predictions of conventional strain have been provided based on the best estimate of the average relationship between curvature and strain. Similar relationships have been proposed by other authors. The reliability of the strain predictions was highlighted in these reports, where it was stated that measured strains can vary considerably from the predicted conventional values.

Adopting a linear relationship between curvature and strain provides a reasonable estimate for the average tensile and compressive strains. There is, however, considerable variation from the average. When expressed as a percentage, observed strains can be many times greater than the predicted average strain for low curvatures. In this report, therefore, we have provided a statistical approach to account for the variability, instead of providing a single predicted average strain.

The range of potential strains resulting from the extraction of the proposed longwalls has been determined using monitoring data from previously extracted longwalls in the Newcastle Coalfield. The monitoring data was taken from nearby Collieries, where the regional geology is closest to that within the Study Area, for longwalls having similar width-to-depth (W/H) ratios and extraction heights as those that are planned for the proposed longwalls. A summary of the monitoring data used in the strain analysis is provided in Table 4.2.

Table 4.2 Monitoring Data used in the Strain Analysis

Colliery	Number of Monitoring Lines	Longwall W/H Ratio	Extraction Height (m)
Austar LWA1 & LWA2	3	0.3 ~ 0.6	≈ 5.5 m (LTCC[1])
Ellalong LWs SL1 to SL4 and LWs 1 to 13A	8	0.4 ~ 0.7	3.0 ~ 3.5
West Wallsend LW11 to LW18	1	0.5 ~ 0.8	2.5 ~ 4.8
Newstan LW8 to LW14	2	0.7 ~ 0.8	3.5 ~ 4.5
Teralba LW8 and LW9	4	0.5 ~ 0.8	2.5 ~ 4.8

[1] LTCC is Longwall Top Coal Caving

The width-to-depth ratios for the proposed longwalls vary between 0.3 and 0.5 and the proposed extraction heights vary between 3.5 and 4.5 metres. It can be seen from the above table, that the monitoring data used in the strain analysis include previously extracted longwalls with similar width-to-depth ratios and extraction heights as those that are planned for the proposed longwalls.

The range of strains measured during the extraction of the longwalls listed in Table 4.2 should, therefore, provide a reasonable indication of the range of potential strains for the proposed longwalls. The data used in the analysis included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley related movements, which are addressed separately in this report. The strains resulting from damaged or disturbed survey marks have also been excluded.

4.3.1. Analysis of Strains Measured in Survey Bays

For features that are in discrete locations, such as building structures, farm dams and archaeological sites, it is appropriate to assess the frequency of the observed maximum strains for individual survey bays.

The survey database has been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls shown in the Table 4.2, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls.

The frequency distribution of the maximum observed tensile and compressive strains measured in survey bays above goaf is provided in Fig. 4.1. A gamma probability distribution function has been fitted to the data which is also shown in this figure.

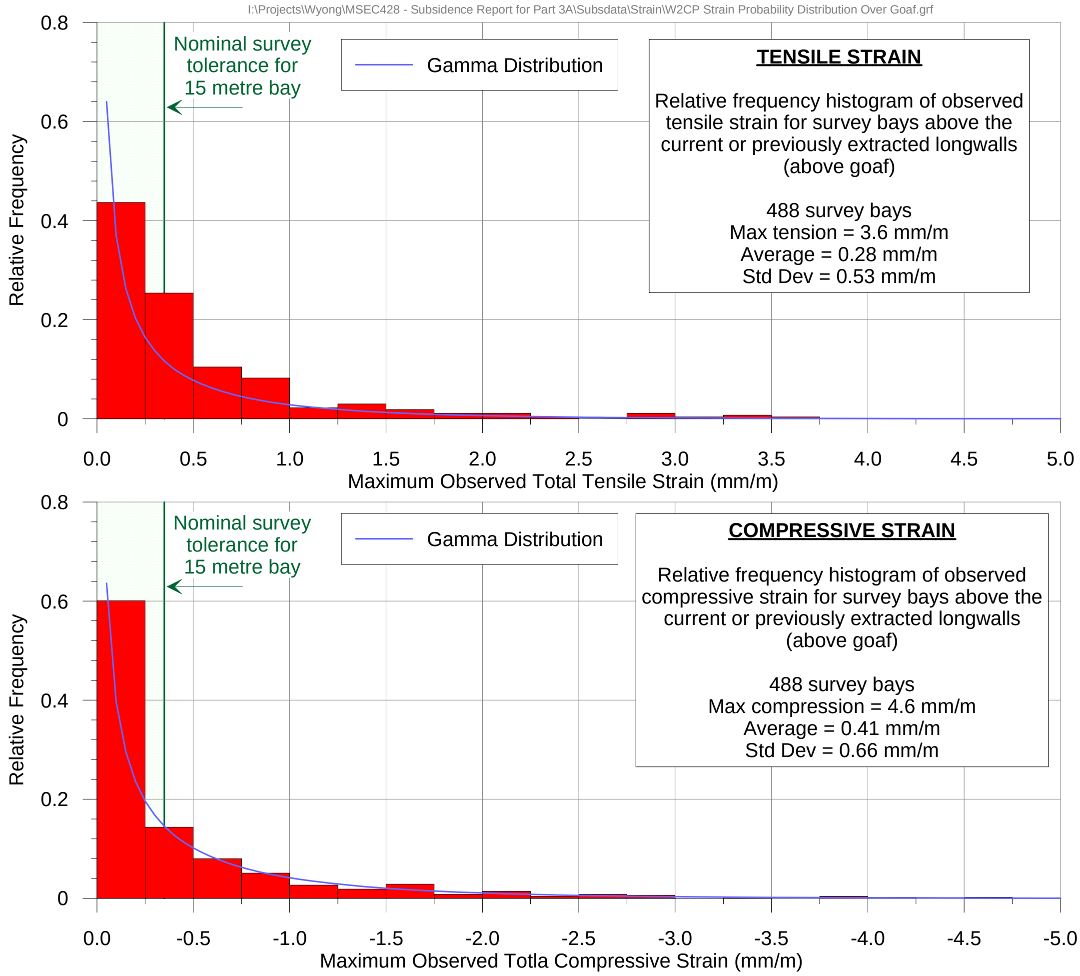


Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains at Any Time during the Extraction of Previous Longwalls for Survey Bays Located Above Goaf

A summary of the probabilities of exceedance for tensile and compressive strains for survey bays located above goaf, based on these gamma probability distributions, is provided in Table 4.3.

Table 4.3 Probabilities of Exceedance for Strain for Survey Bays above Goaf

Strain (mm/m)		Probability of Exceedance
Compression	-5.0	1 in 700
	-4.0	1 in 250
	-3.0	1 in 85
	-2.0	1 in 25
	-1.0	1 in 8
	-0.5	1 in 4
Tension	0.5	1 in 6
	1.0	1 in 15
	2.0	1 in 50
	3.0	1 in 175
	4.0	1 in 600
	5.0	1 in 1,800

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls shown in Table 4.2, for survey bays that were located directly above solid coal and within 200 metres of the nearest longwall goaf edge. Solid coal is defined as the coal that has not been extracted by longwalls.

The frequency distribution of the maximum observed tensile and compressive strains measured in survey bays above solid coal is provided in Fig. 4.2. A gamma probability distribution function has been fitted to the data which is also shown in this figure.

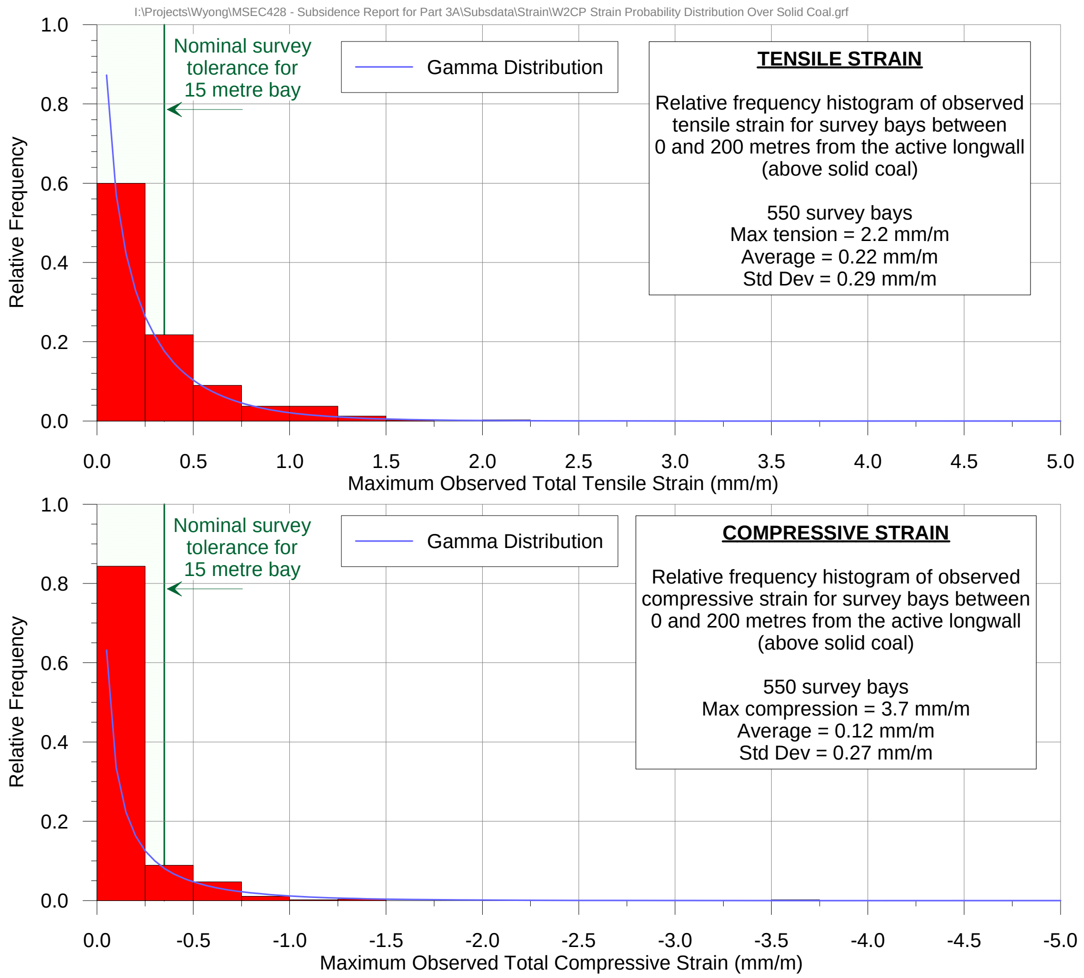


Fig. 4.2 Distributions of the Measured Maximum Tensile and Compressive Strains at Any Time during the Extraction of Previous Longwalls for Survey Bays Located Above Solid Coal

A summary of the probabilities of exceedance for tensile and compressive strains for survey bays above solid coal, based these gamma probability distributions, is provided in Table 4.4.

Table 4.4 Probabilities of Exceedance for Strain for Survey Bays above Solid Coal

Strain (mm/m)		Probability of Exceedance
Compression	-2.0	1 in 400
	-1.5	1 in 150
	-1.0	1 in 50
	-0.5	1 in 15
	-0.25	1 in 7
Tension	0.25	1 in 3
	0.5	1 in 8
	1.0	1 in 35
	1.5	1 in 150
	2.0	1 in 600

4.3.2. Analysis of Strains Measured Along Whole Monitoring Lines

For linear features such as roads, cables and pipelines, it is more appropriate to assess the frequency of observed maximum strains along whole monitoring lines, rather than for individual survey bays. That is, an analysis of the maximum strains anywhere along the monitoring lines, regardless of where the strain actually occurs.

The frequency distribution of maximum observed tensile and compressive strains measured anywhere along the monitoring lines, at any time during or after the extraction of the previous longwalls in the Newcastle Coalfield, is provided in Fig. 4.3.

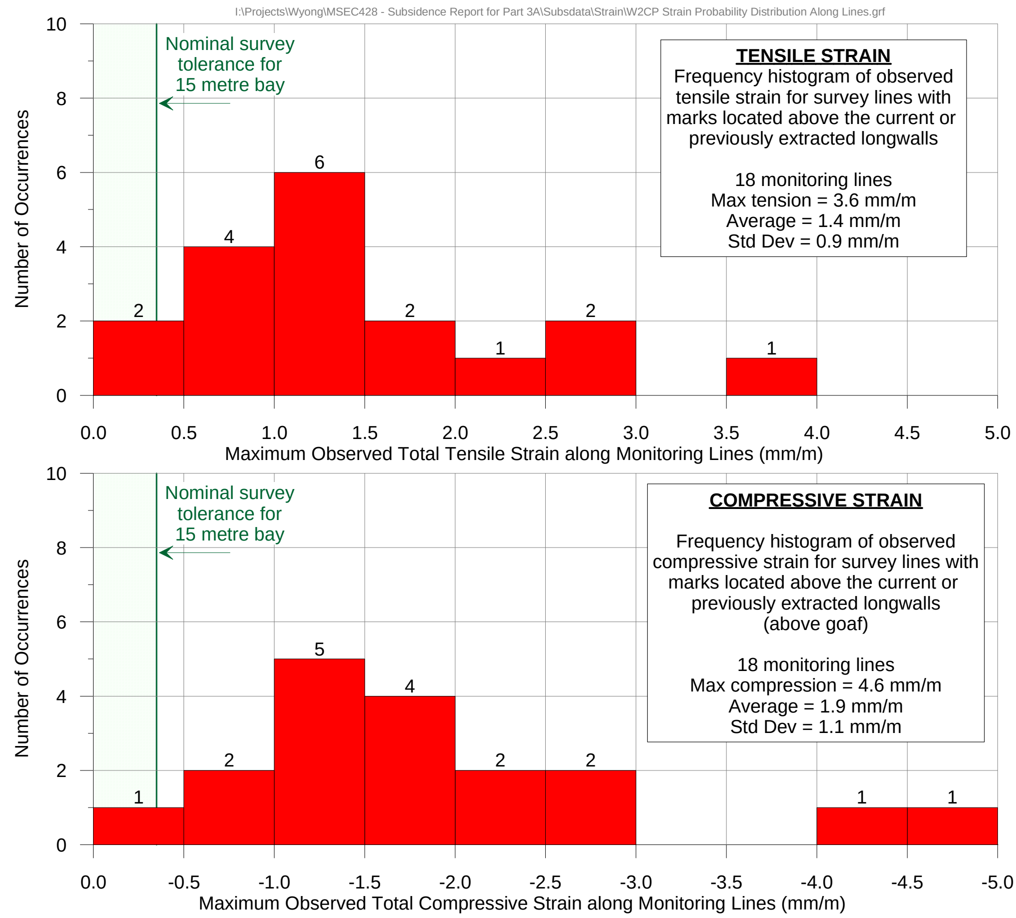


Fig. 4.3 Distributions of Measured Maximum Tensile and Compressive Strains along the Monitoring Lines at Any Time during the Extraction of Previous Longwalls

It can be seen from the above figure, that 14 of the 18 monitoring lines have recorded maximum total tensile strains of 2.0 mm/m or less, and that 12 of the 18 monitoring lines have recorded maximum total compressive strains of 2.0 mm/m or less. The maximum observed tensile strain was 3.6 mm/m and the maximum observed compressive strain was 4.6 mm/m.

4.3.3. Analysis of Shear Strains

As described in Section 3.3, ground strain comprises two components, being normal strain and shear strain, which can be interrelated using Mohr's Circle. The magnitudes of the normal strain and shear strain components are, therefore, dependant on the orientation in which they are measured. The maximum normal strains, referred to as the principal strains, are those in the direction where the corresponding shear strain is zero.

Normal strains along monitoring lines can be measured using 2D and 3D techniques, by taking the change in horizontal distance between two points on the ground and dividing by the original horizontal distance between them. This provides the magnitude of normal strain along the orientation of the monitoring line and, therefore, this strain may not necessarily be the maximum (i.e. principal) normal strain.

Shear deformations are more difficult to measure, as they are the relative horizontal movements perpendicular to the direction of measurement. However, 3D monitoring techniques now provide data on the direction and the absolute displacement of survey pegs and, therefore, the shear deformations perpendicular to the monitoring line can be determined. But, in accordance with rigorous definitions and the principles of continuum mechanics, (e.g. Jaeger, 1969), it is not possible to determine horizontal shear strains in any direction relative to the monitoring line using 3D monitoring data from a straight line of survey marks.

As described in Section 3.3, shear deformations perpendicular to monitoring lines can be quantified using a number of different parameters, including shear index, horizontal tilt, horizontal curvature and mid-ordinate deviation, each of which have their advantages and disadvantages. In this report, mid-ordinate deviation has been used as the measure for shear deformation, which is defined as the differential horizontal movement of each survey mark, perpendicular to a line drawn between two adjacent survey marks, as indicated in Fig. 4.7.

There is less 3D subsidence monitoring data than 2D subsidence monitoring data. For this study, therefore, an analysis of mid-ordinate deviation was undertaken for the available 3D monitoring lines in the NSW Coalfields, where the typical bay lengths were 20 metres and the depths of cover were greater than 350 metres, such as the case within the Study Area. As the typical bay length was 20 metres, the calculated mid-ordinate deviations were over a chord length of 40 metres.

The frequency distribution of the maximum mid-ordinate deviation measured at survey marks above goaf, for previously extracted longwalls where the depths of cover were greater than 350 metres, is provided in Fig. 4.4. A plot showing mid-ordinate deviation is presented in Fig. 4.7. A gamma probability distribution function has been fitted to the data which is also shown in this figure.

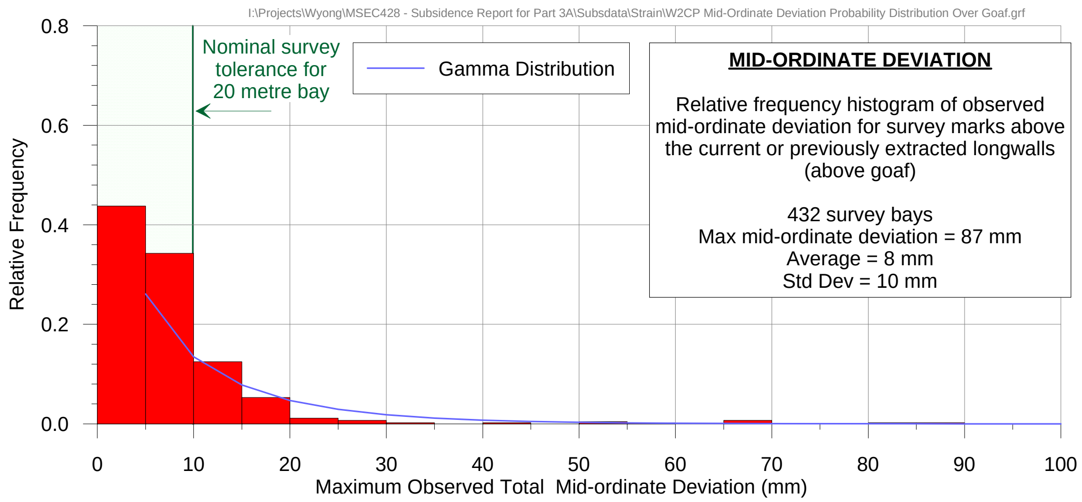


Fig. 4.4 Distribution of Measured Maximum Mid-ordinate Deviation at Any Time during the Extraction of Previous Longwalls for Marks Located Above Goaf

A summary of the probabilities of exceedance for mid-ordinate deviation, based the gamma probability distribution, is provided in Table 4.5.

Table 4.5 Probabilities of Exceedance for Mid-Ordinate Deviation for Survey Marks above Goaf at Depths of Cover Greater than 350 metres

Mid-ordinate Deviation over 40 m chord length (mm)		Probability of Exceedance
Mid-ordinate Deviation	10	1 in 4
	20	1 in 10
	30	1 in 25
	40	1 in 60
	50	1 in 140
	60	1 in 300
	70	1 in 700
	80	1 in 1,600

4.4. Predicted Horizontal Movements

The predicted conventional horizontal movements in flat terrain are calculated by applying a factor to the predicted conventional tilt values. In the Newcastle Coalfield a factor of 10 is generally adopted, being the same factor as that used to determine the average strain from curvature, and this has been found to give a reasonable correlation with measured data in flat terrain.

The calibration of the prediction model indicates that the shapes of the subsidence profiles for the proposed longwalls are expected to be closer to those observed in the Southern Coalfield, than those observed the Newcastle Coalfield, as described in the report entitled *Wallarah 2 Coal Project Subsidence Modelling Study*, which is included in Chapter B1 of the Environmental Assessment.

Monitoring data from the Southern Coalfield indicates that a factor of 15 provides a better correlation for prediction of conventional horizontal movements in flat terrain. This factor will in fact vary and will be higher at low tilt values and lower at high tilt values. The application of this factor will therefore 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 conventional tilt within the Study Area, resulting from the extraction of the proposed longwalls, is 15 mm/m. The maximum predicted conventional horizontal movement in flat terrain is, therefore, in the order of 225 mm, i.e. 15 mm/m multiplied by a factor of 15. The predicted conventional tilt and, hence, the predicted conventional horizontal movements vary across the Study Area, as illustrated by the predicted subsidence movements along Prediction Lines 1, 2, 3 and 4 shown in Figs. E.01, E.02, E.03 and E.04, respectively.

Larger horizontal movements are expected to occur as the result of downslope movements in steeply sided terrain and closure movements within the valleys. The predicted horizontal movements resulting from downslope and valley related movements are discussed in the impact assessments provided in Chapter 5.

Horizontal movements do not directly impact on natural features or items of surface infrastructure, rather impacts occur as the result of differential horizontal movements. Strain is the rate of change of horizontal movement. The impacts of strain on the natural features and items of surface infrastructure are addressed in impact assessments for each feature, which have been provided in Chapter 5.

4.5. Predicted Far-Field Horizontal Movements

In addition to the conventional movements that have been predicted above and adjacent to the longwalls and the predicted valley related movements along the rivers, creeks and drainage lines, it is also likely that far-field horizontal movements will 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 zones above the extracted voids. Such movements are, to some extent, predictable and occur whenever significant excavations occur at the surface or underground.

The Southern Coalfield Inquiry includes far-field horizontal movements as non-conventional movements. The methods used to predicted far-field horizontal movements have continued to develop in recent years using the current and available 3D monitoring data. The confidence levels in these predictions continue to improve and, for this reason, this report considers far-field horizontal movements to be conventional movements, rather than irregular or anomalous non-conventional movements.

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, 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 orientation of the observed movements due to the influences of survey tolerance and other mechanisms.

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. 4.5. 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. 4.6.

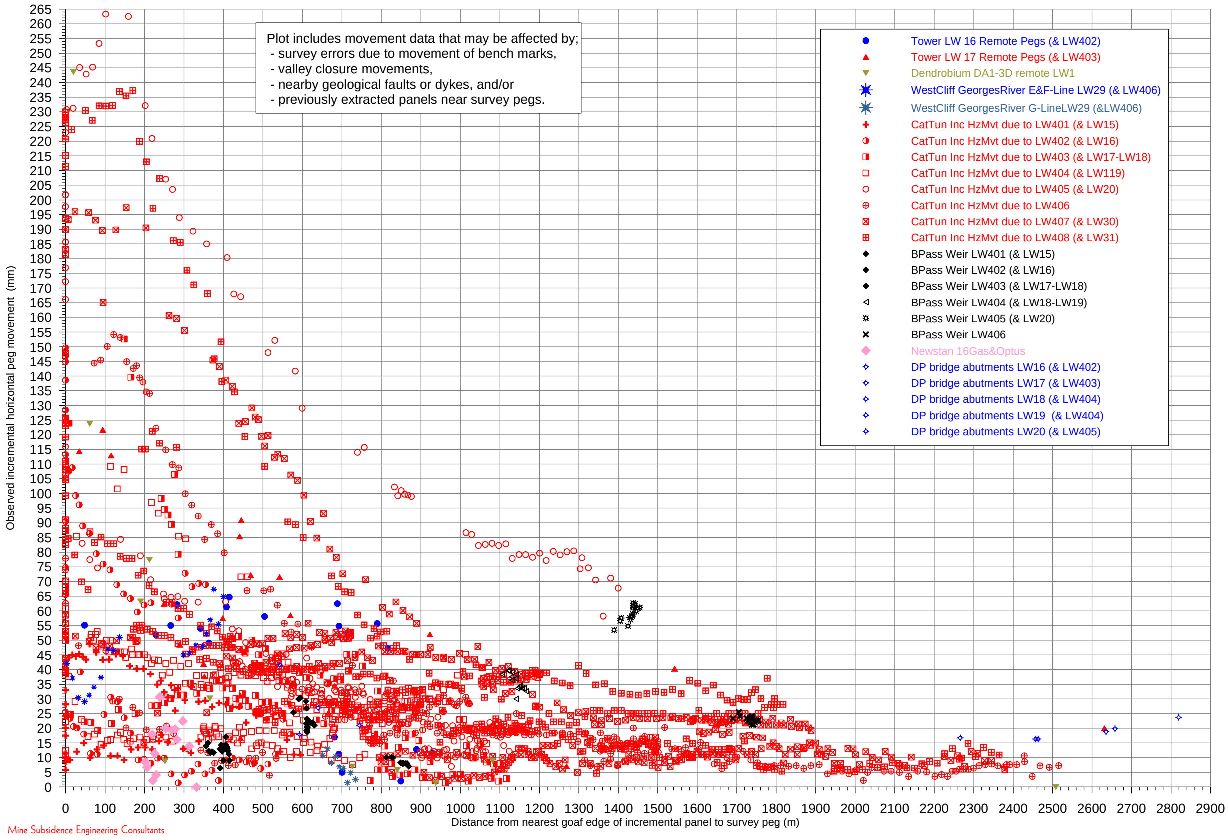


Fig. 4.5 Observed Incremental Far-Field Horizontal Movements

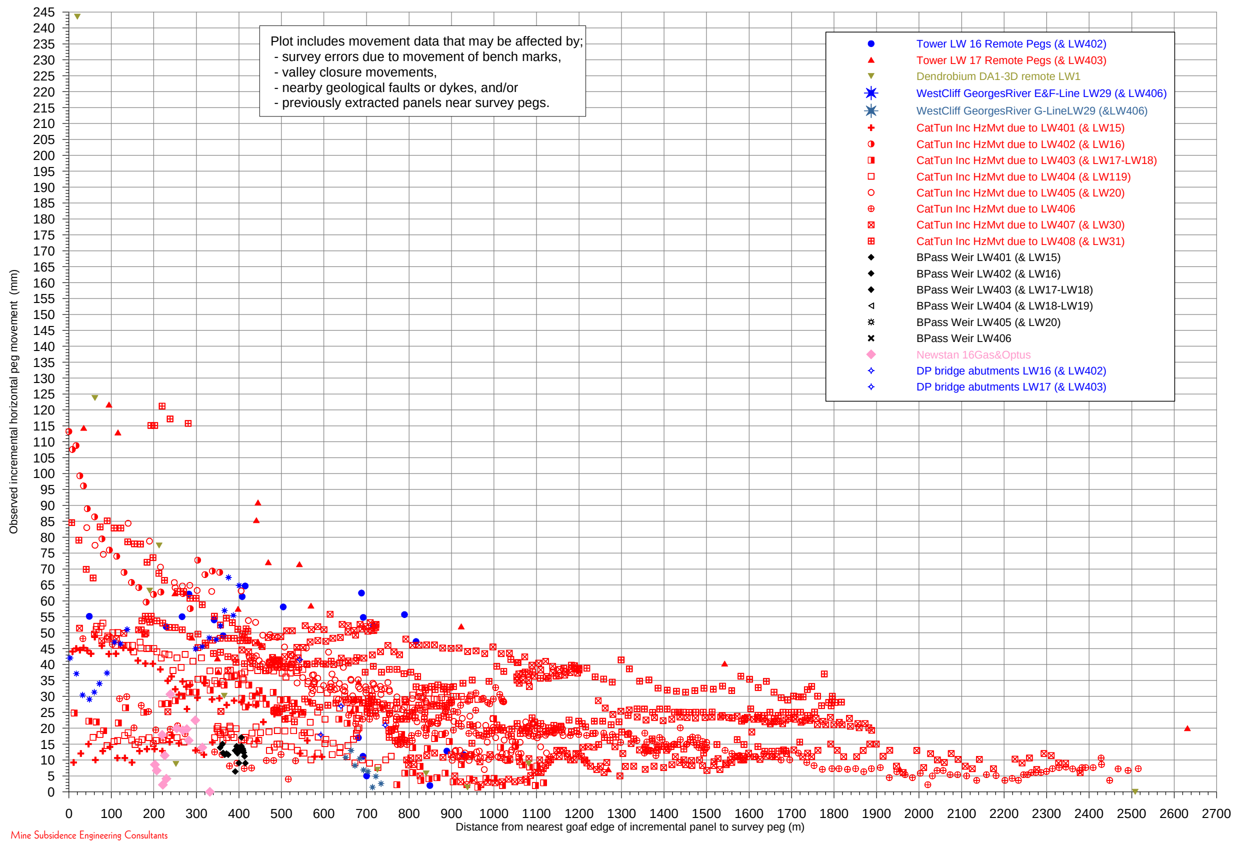


Fig. 4.6 Observed Incremental Far-Field Horizontal Movements with Solid Coal between the Monitoring Points and Mined Longwalls

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 the larger distances from the longwall extractions, the measured movements contain larger proportions of survey error, in addition to valley related closure movements and movements at 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 is not, therefore, the sum of the incremental far-field horizontal movements for the individual longwalls.

The predicted far-field horizontal movements resulting from the extraction of the proposed longwalls are 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. These levels of movement are generally not significant, except where they occur at large structures which are sensitive to small differential movements, which may include the bridges along the Sydney-Newcastle Freeway.

An additional method of assessment of expected far-field horizontal movements has been undertaken to better reflect the potential movements at the freeway bridges and to assess horizontal bending by calculating the mid-ordinate deviation between three survey pegs. The mid-ordinate deviation is the change in perpendicular horizontal distance from a point to a chord formed by joining points on either side. The mid-ordinate deviation was calculated for sets of survey results representing the increment of extraction of one longwall.

A schematic sketch showing the mid-ordinate deviation of a peg compared to its adjacent survey pegs between two survey epochs is provided in Fig. 4.7. This calculation was considered to be a better representation of the potential transverse movements across the freeway bridges.

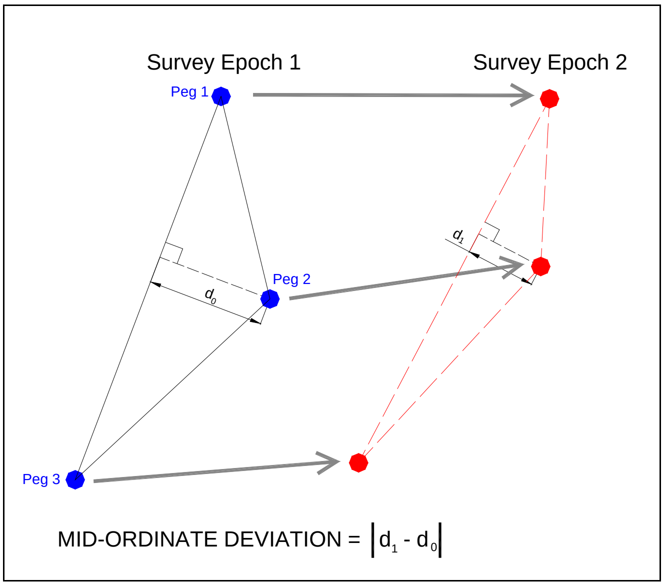


Fig. 4.7 Schematic Representation of Mid-Ordinate Deviation

A plot of the calculated mid-ordinate deviation for the current database of observed far-field horizontal movements that were used for this assessment is provided in the following Fig. 4.8.

The mid-ordinate deviation was calculated for marks with spacings of 20 metres ±10 metres, or an approximate spacing of 40 metres over the three marks since these distances represent the typical range of spacing between the bridge piers and abutments.

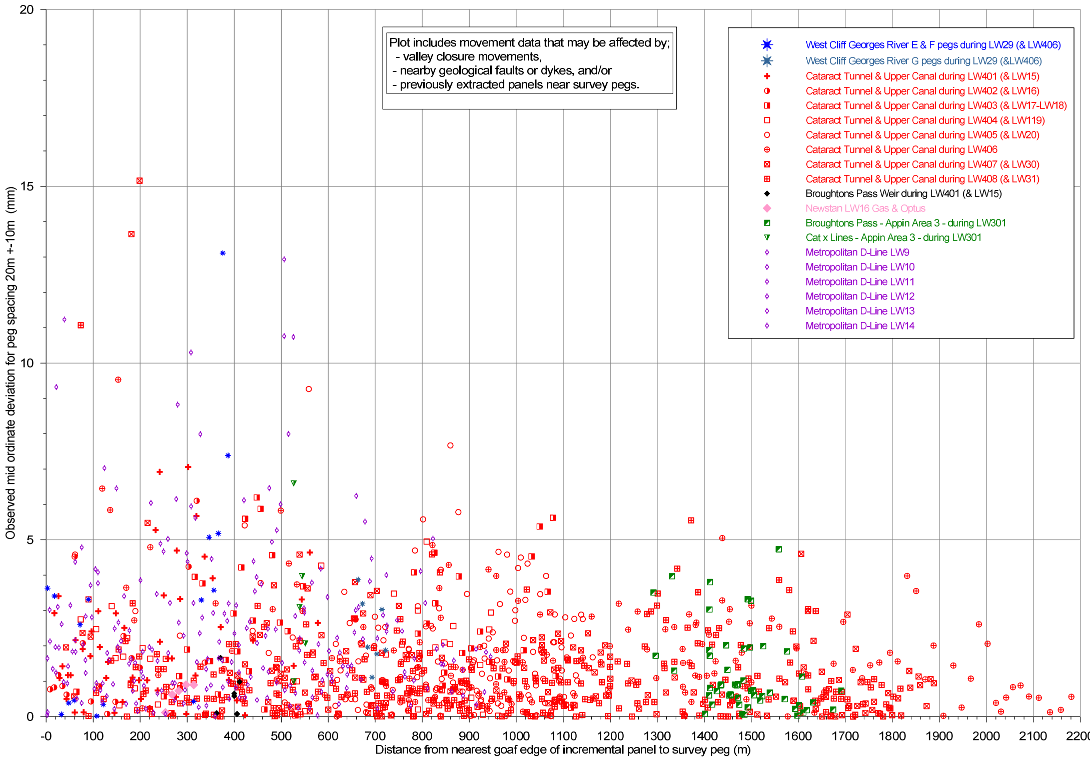


Fig. 4.8 Incremental Observed Mid-Ordinate Deviation due to the Extraction of Each Longwall (20m peg spacing ±10m) Only Pegs with Solid Coal Between Peg and Longwall

The potential impacts of far-field horizontal movements at the bridges along the Sydney-Newcastle Freeway are discussed in Section 5.11. The impacts of far-field horizontal movements on the natural features and the remaining items of surface infrastructure within the vicinity of the Study Area are not expected to be significant.

4.6. General Discussion on Mining Induced Cracking, Humping and Stepping

As discussed in Chapter 3, longwall mining results in mine subsidence and some surface fractures, cracking, heaving, buckling, humping and stepping of the ground surface have been observed. These types of mining induced deformations are more often observed over shallow mines but are occasionally observed over deep coal mines. However, their possible occurrence and extent over the W2CP are discussed below.

Fractures and joints in bedrock occur naturally during the both the formation of the strata and from subsequent erosion and weathering processes. Within the proposed W2CP Study Area the depths of cover are greater than 350 metres, there are few exposed rock platforms and alluvial deposits cover most of the valleys floors.

Mining induced fracture widths tend to decrease as the depth of cover increases and only minor fracturing is expected. Mining induced surface cracks at the W2CP will be limited to the opening of existing natural joints or an occasional tension crack located on steeply sloping terrain or a rare crack within exposed bedrock in valley floors. Few mining induced surface cracks are expected where deep soil or alluvial cover covers the bedrock.

The numerical modelling that was undertaken by SCT indicated that the caving related fracturing extends to approximately 200 metres above the seam, beyond which the disturbance to the strata will be limited to bedding plane shear and localised, non-continuous fracturing. The modelling showed that there would be some increased permeability in the near surface strata as a result of subsidence-related surface tension cracking. The modelling also showed no evidence of connectivity with the deeper, mining induced fracture systems and this is not unexpected since the two fracture systems will be vertically separated by 200 metres to 300 metres of strata.

Mining induced surface tensile fracturing in exposed bedrock 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 tensile cracking can also occur at the top of steep slopes, generally as a result of down slope soil movements. Steep slopes are further discussed in Section 5.5.

Elevated compressive strains could occur in the base of creeks due to valley closure movements. Fracturing of the exposed bedrock in valleys and along the creeks could occur, which is discussed in Chapter 3 and in the impact assessments for the streams in Chapter 5.

The incidence of mining induced surface cracks is additionally dependent on the thickness and inherent plasticity of the soils that overlie the bedrock. Surface soils above the proposed longwalls are generally weathered to a reasonable depth. 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 the rockhead, which are not necessarily coincident with the joints.

Localised ground buckling and shearing can occur wherever faults, dykes and abrupt changes in geology occur near the ground surface. No major faults, dykes or abrupt changes in surface geology have been identified above the proposed longwalls. The frequency of occurrence of these types of movements is generally uncommon but is still possible that they could be encountered at some time during the mining period.

A general guide as to the frequency, width and extent of such mining induced fractures on the steeply sloping areas can be obtained from the monitoring over longwall areas in the Southern Coalfield, where it is rare to observe any surface cracking except at locations of non-conventional movements, geological features, on the tops of steep slopes, or within bedrocks of valley floors.

Surface cracks are more readily observed in built infrastructure such as road pavements. In the majority of these cases no visible ground deformations can be seen in the natural ground adjacent to the cracks in the road pavements. In rare instances more noticeable ground deformations, such as humping or stepping of the ground can be observed at thrust faults.

Examples of these rarely observed ground deformations from the Southern Coalfield, where the depths of cover exceed 450 metres, are provided in the photographs in Fig. 4.9 to Fig. 4.14 below. No such thrust faults have been identified over the proposed longwalls. Further information on non-conventional subsidence movements are discussed in more detail in Section 3.5

The main impacts that may result from these potential surface fractures are associated with the disruption of surface aquifers and/or surface water regimes and further discussion on the potential impacts of surface cracking on groundwater water are provided in the report by Mackie (2009).

Fig. 4.9 Example of Surface Compression Humping along Outcropping of a Low Angle Thrust Fault

Fig. 4.10 Example of Surface Compression Humping along Outcropping of a Low Angle Thrust Fault

Fig. 4.11 Example of Surface Compression Buckling Observed in a Pavement

Fig. 4.12 Example of Surface Tension Cracking along the Top of a Steep Slope

Fig. 4.13 Example of Surface Tension Cracking along the Top of a Steep Slope

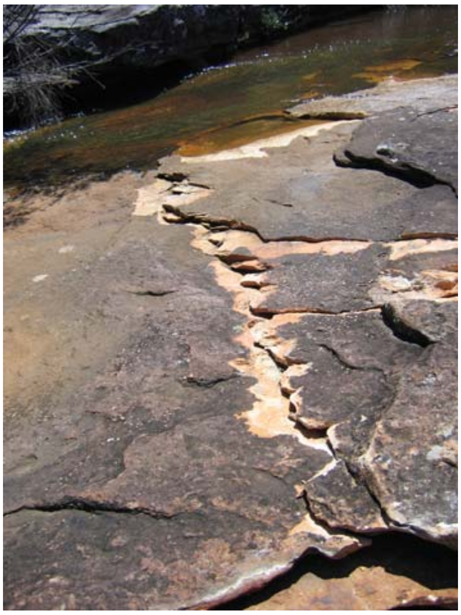


Fig. 4.14 Example of Sandstone Fracturing and Bedding Plane Slippage in Bedrock in the Base of a Stream in the Southern Coalfield
(NB: no significant bedrock lined streams occur in W2CP study area)

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

5.1. Introduction

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

The features in the following sections are presented in the same order as they were presented in Chapter 2. Table 5.1 references the Section Number of this report where the assessed impacts and consequences of mine subsidence are provided for each of the various major natural features and items of surface infrastructure that are located within the Study Area.

The depths of cover in the Study Area are similar to or greater than those in the Southern Coalfield. The experience of impacts and consequences resulting from previous longwall mining in the Southern Coalfield has been used in the impact assessments provided in this report. The hybrid subsidence modelling approach has provided maximum predicted subsidence parameters for the proposed longwalls that are greater than those typically experienced in the Southern Coalfield. Accordingly, the experience of mine subsidence impacts and consequences resulting from previously extracted longwalls in the Hunter and Newcastle Coalfields, where the depths of cover are similar to those in the Study Area, has also been used in the impact assessments provided in this report.

Table 5.1 Section Number References for Impact Assessments at Natural Features and Surface Infrastructure within the Study Area

Item	Within Study Area	Report Section Number Reference
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	✓	5.2
Rivers or Creeks	✓	5.3
Aquifers or Known Groundwater Resources	✓	5.3
Springs		
Sea or Lakes		
Shorelines		
Natural Dams		
Cliffs or Natural Rock Formations	✓	0
Steep Slopes	✓	5.5
Escarpments		
Land Prone to Flooding or Inundation	✓	5.3.2.1
Swamps, Wetlands or Water Related Ecosystems	✓	5.6
Threatened, Protected Species or Critical Habitats	✓	5.7
National Parks or Wilderness Areas		
State Recreational or Conservation Areas	✓	5.2
State Forests	✓	5.2
Natural Vegetation	✓	5.2
Areas of Significant Geological Interest		
Any Other Natural Feature Considered Significant		
PUBLIC UTILITIES		
Railways		
Roads (All Types)	✓	5.8 & 5.11
Bridges	✓	5.9 & 5.11
Tunnels		
Culverts	✓	5.10
Water, Gas or Sewerage Pipelines	✓	5.12
Liquid Fuel Pipelines		
Electricity Transmission Lines or Associated Plants	✓	5.13, 0, 5.15 & 5.16
Telecommunication Lines or Associated Plants	✓	5.17, 5.18, 5.19
Water Tanks, Water or Sewage Treatment Works	✓	5.12
Dams, Reservoirs or Associated Works		
Air Strips		
Any Other Public Utilities		
PUBLIC AMENITIES		
Hospitals		
Places of Worship		
Schools	✓	5.20.1
Shopping Centres		
Community Centres	✓	5.20.2
Office Buildings		
Swimming Pools		
Bowling Greens		
Ovals or Cricket Grounds		
Racecourses		
Golf Courses		
Tennis Courts		
Any Other Public Amenities		

Item	Within Study Area	Report Section Number Reference
FARM LAND AND FACILITIES		
Agricultural Utilisation, Agricultural Improvements or Agricultural Suitability of Farm Land	✓	5.21
Farm Buildings or Sheds	✓	5.23
Gas or Fuel Storages		
Poultry Sheds		
Glass Houses or Green Houses		
Hydroponic Systems		
Irrigation Systems		
Farm Fences	✓	5.24
Farm Dams	✓	5.25
Wells or Bores	✓	5.26
Any Other Farm Features		
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS		
Factories		
Workshops		
Business or Commercial Establishments or Improvements	✓	5.22
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	✓	5.22.1
Mine Infrastructure Including Tailings Dams or Emplacement Areas		
Any Other Industrial, Commercial or Business Features		
AREAS OF ARCHAEOLOGICAL OR HERITAGE SIGNIFICANCE	✓	5.27 & 5.28
PERMANENT SURVEY CONTROL MARKS	✓	5.29
RESIDENTIAL ESTABLISHMENTS		
Houses	✓	5.30
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	✓	5.31, 5.32, 5.33, 5.34, 5.35, 5.36 & 5.37
Any Other Residential Features	✓	
ANY OTHER ITEM OF SIGNIFICANCE		

5.2. Catchment Areas or Declared Special Areas

The potential impact of proposed underground mining on the surface water supply system was identified by the WACJV as a key area for detailed assessment and a rigorous analysis of potential effects was considered important since the proposed mining area represented 5% of the local water supply catchment area. Water quality was also considered very important because it can determine the usefulness of the supply for municipal and other purposes.

The proposed mining operations will not impact on the Gosford-Wyong Water Supply Scheme infrastructure. The proposed mine layout will, however, underlie parts of the catchment area.

Detailed assessments of the potential impacts and consequences of mine subsidence on the catchment areas, the near-surface alluvial aquifers and the aquifers found in the deeper hard rock are included in the report by Mackie (2009).

The Panel of independent experts that undertook the Strategic Review advised that the proposed longwalls will not have a significant impact or consequence on the region's catchment area or the existing or planned water supply infrastructure. The Panel also advised that the concerns raised by other interest groups, that the infrastructure would be damaged by the proposed longwalls, were also considered to be highly unlikely.

In recognition of the importance of protecting the water supply catchment, the WACJV has made public commitments regarding the safeguarding of the surface water supply catchment from mining impacts (refer to the Environmental Assessment Report). To further ensure that the project will not adversely affect the functions of the water supply catchment, the W2CP proposal includes a catchment environmental enhancement program designed to improve the water supply catchment (refer to the Environmental Assessment Report).

5.3. Streams

Table 2.2 provides a list of major streams within the Study Area and the locations of these streams are shown in Drawing No. MSEC428-08.

The major watercourses that are located within the Study Area, i.e. the Wyong River, Jilliby Jilliby Creek, Little Jilliby Jilliby Creek and Hue Hue Creek, are generally wide alluvial filled valleys. There are also many smaller tributaries of these major watercourses which generally flow over the steeper slopes of the Study Area.

The predictions and impact assessments for the major streams are provided in the following sections.

5.3.1. Predictions for the Streams

The streams are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements.

A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4. If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the maximum predicted subsidence parameters would be expected to be similar to those provided in Chapter 4.

Both the major watercourses and smaller tributaries of these major watercourses could also be subjected to valley related movements, which are commonly observed along streams in the Southern Coalfield, but less commonly observed in the Newcastle Coalfield, where the depths of cover are generally significantly shallower.

It is considered that valley related movements are less commonly observed in the Newcastle Coalfield because the conventional subsidence movements are typically much larger than those observed in the Southern Coalfield. These larger subsidence movements tend to mask any smaller valley related movements which may occur. The predicted valley related movements resulting from the extraction of the proposed longwalls were determined using the empirical method outlined in ACARP Research Project No. C9067 (Waddington and Kay, 2002).

This upsidence and closure prediction method is based on measured data from the Southern Coalfield, predominately from large and steeply incised valleys including the Cataract, Nepean, Bargo and Georges Rivers. The empirical prediction curves were conservatively drawn over the majority (i.e. more than 95 %) of the available upsidence and closure monitored data from the Southern Coalfield. The higher measured movements from the database are believed to be associated with brittle, thin and cross bedded bedrock layers and additional research is currently being undertaken for a current ACARP funded research project. Although there is very little upsidence and closure ground movement monitoring data available for wide alluvial filled valleys, such as those within the Study Area, the data that is available indicates that the ACARP method should provide a conservative indication of the overall level of valley related movements at bedrock level for the streams within the Study Area.

The predicted conventional subsidence and valley related movements vary across the Study Area as the result of, amongst other factors, variations in the depths of cover, longwall void widths, extraction heights and valley shapes and heights. To illustrate this variation, the predicted profiles of subsidence, upsidence and closure along the Wyong River, Jilliby Jilliby Creek and Little Jilliby Jilliby Creek, resulting from the extraction of the proposed longwalls, are provided in Figs. E.05, E.06 and E.07, respectively, in Appendix E.

A summary of the maximum predicted conventional subsidence, tilts and curvatures along the alignments of the Wyong River, Jilliby Jilliby Creek and Little Jilliby Jilliby Creek, resulting from the extraction of the proposed longwalls, is provided in Table 5.2. A summary of the maximum predicted valley related upsidence and closure movements along these streams is provided in and Table 5.3.

Table 5.2 Maximum Predicted Conventional Subsidence, Tilts and Curvatures along the Streams Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km-1)	Maximum Predicted Conventional Sagging Curvature (km-1)
Wyong River	175	1	0.01	0.01
Jilliby Jilliby Creek	1500	10	0.15	0.20
Little Jilliby Jilliby Creek	2000	12	0.20	0.25

Table 5.3 Maximum Predicted Valley Related Upsidence and Closure Movements along the Streams Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Wyong River	150	100
Jilliby Jilliby Creek	150	75
Little Jilliby Jilliby Creek	650	775

5.3.2. Impact Assessments for the Streams

The WACJV recognised that mine subsidence has the potential to increase the impacts of flooding and consequently a number of mine layouts were modelled to determine the sensitivity of flood impacts to vertical subsidence. The output from the hybrid subsidence modelling was a direct input into the flood modelling which assessed the impacts of mine subsidence on the 100 year flood extent line, relative flood levels and various inundation issues in the Yarramalong Valley, Dooralong Valley and Hue Hue Creek areas. The detailed results of these studies are contained within the flood study report (ERM, 2009).

The predicted subsidence ground movements are based on a worst case assessment of the geological conditions within the Study Area and, hence, it is believed that conservative levels of predicted ground movements have been provided for this flood study. It should be noted that the sequencing of the longwall extractions will allow the mining layout to be adjusted near the streams, depending on the subsidence observations during the mining of the earlier longwalls. After detailed subsidence monitoring data has been gathered and analysed during the mining process, further reviews will be undertaken of the subsidence predictions and of the assessed flood impacts.

The impact assessments for the streams within the Study Area are provided in the following sections. The findings in this report should be read in conjunction with the detailed findings from:-

- The flood model studies which are provided in the report by ERM (2009), and
- The groundwater studies which are provided in the report by Mackie (2009).

These reports are also appended to the main Environmental Assessment Report.

Streams can experience a number of potential impacts as a result of mining and these impacts are discussed below:-

- Increased levels of ponding, flooding or scouring,
- Changes to stream alignment,
- Fracturing of the bedrock in the floors of valleys,
- Surface water flow diversions to the shallow sub-strata,
- Changes to water quality,
- Release of strata gas, and
- Impacts on terrestrial and aquatic flora and fauna.

Mining has occurred under many streams and other bodies of surface water, including streams located in the Southern Coalfield, where the depths of cover are greater than 350 metres, such as the case within the Study Area. It should be noted that the geomorphology of the streams over the W2CP is significantly different to those in the Southern Coalfield. Many of the mine subsidence impacts on the streams in the Southern Coalfield were very noticeable because the surface water levels in the series of pools in these streams were controlled by a series of exposed rock bars and the groundwater levels around these perched pools were generally below the water levels in the pools.

It is relevant to note then that the streams in the alluvial filled wide valley floors above the proposed longwalls have water levels that are generally above the surrounding groundwater levels and the water levels in these streams are not controlled by series of exposed rock bars. This important distinction means that mine subsidence movements, resulting from the extraction of the proposed longwalls, is expected to have less impact over W2CP than have been experienced in the Southern Coalfield. Nevertheless, a general discussion is presented below of all the possible impacts on streams in order to provide a clearer understanding of the likely impacts and consequences over the W2CP.

Increased levels of ponding, flooding, scouring and changes to stream alignments can occur and the assessments of these potential impacts and the consequences of the predicted subsidence ground movements on the water levels in the streams are contained within the flood study report (ERM, 2009). The flood study will act as a key element in the preparation of future Coal Extraction Plans or Subsidence Management Plans.

Surface water flow diversions are the most visible and well known impacts associated with mining beneath streams in the Southern Coalfield, however, these are less likely to occur within the Study Area because the major watercourses have deep alluvial deposits covering the bedrock and there are few rock bars or exposed bedrock areas within the smaller tributaries to these major water courses.

Changes to water quality and, to a lesser extent, impacts to flora and fauna are largely dependent on the severity of these physical impacts and are discussed in detail in the reports by International Environmental Consultants (IEC, 2009). The impacts and consequences of mine subsidence ground movements on terrestrial and aquatic flora and fauna are discussed in detail in the report by OzArk (2010a).

The extent, severity and manner of impacts vary between different streams and different coal mines because each situation is different. Each stream is unique in terms of its characteristics, which include flow conditions, water quality, gradients, valley depths and degree of incision, sediment and nutrient load, ecosystems, bedrock mineralogy and geomorphology. The nature and extent of mining beneath or near these streams also varies considerably in terms of the proximity of the extraction to the stream, the size of the extraction and the depth of cover.

The complexity of factors requires impact assessments for mining applications near streams to be undertaken on a case by case basis. There are, however, a number of common themes that can be found in each case and these are discussed below.

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

Longwall mining can result in increased levels of flooding or scouring of the stream banks in the locations where the mining induced tilts considerably increase the natural stream gradients. Longwall mining can also result in increased levels of ponding in the locations where the mining induced tilts considerably decrease the natural stream gradients. The potential for these impacts are dependent on the magnitudes and locations of the mining induced tilts, the natural stream bed gradients, as well as the depth, velocity and rate of surface water flows.

The maximum predicted conventional tilt along the Wyong River, resulting from the extraction of the proposed longwalls, is 1 mm/m (i.e. 0.1 %), which represents a change in grade of 1 in 1000. The predicted maximum change in grade along the river is very small and is unlikely, therefore, to result in any significant changes in the levels of ponding, flooding and scouring.

The maximum predicted conventional tilts along Jilliby Jilliby Creek and Little Jilliby Jilliby Creek, resulting from the extraction of the proposed longwalls, are 10 mm/m (i.e. 1 %) and 12 mm/m (i.e. 1.2 %), respectively, which represent changes in grade of 1 in 100 and 1 in 85, respectively. The maximum predicted conventional tilt for the remaining streams within the Study Area, resulting from the extraction of the proposed longwalls, is 15 mm/m (i.e. 1.5 %), which represents a change in grade of 1 in 65.

A detailed flood model of the streams has been developed by ERM (2009) using the results of the hybrid subsidence prediction models. The potential for increased levels of ponding and flooding along the streams have been assessed in the flood model and are discussed in that report.

Flood prone land is defined as land which may become inundated during a 1 in 100 year flood event. The majority of flood prone houses are located outside the proposed mine plan. Baseline flood studies undertaken by ERM have demonstrated that the Yarramalong and Dooralong Valleys are currently flood prone. The floodplains are subject to regular inundation. Some bridges and culverts are cut off during relatively small floods.

Large sections of the main roads into both valleys are flood affected and many of the access roads pass through the floodplain. The Hue Hue Creek floodplain is different as flood depths are significantly less and the majority of flood prone land is located in rural or public open space areas of the catchment rather than in rural residential areas.

Within the Study Area, there are many dwellings in the Yarramalong and Dooralong Valleys and in the Hue Hue Creek floodplain. Subsidence can result in a change in floodplain storage and a change in hydraulic gradients within the floodplain. This will alter flooding behaviour depending on the timing of longwall extraction and their influence on subsided topography. Such effects can have both adverse and beneficial impacts on flooding within the subsided area and in areas upstream and downstream, depending on the provisions made for flood management. The report by ERM (2009) also discusses the envisaged mining induced changes in the level of flood waters, the changes in the depths of flood waters, the changes in the extent and frequencies of flooded areas and proposes mitigation and preventative works that can be undertaken.

The findings and recommendations of the report by the independent expert panel for the Strategic Inquiry into coal mining potential in the Wyong LGA, in respect to the effects of mine subsidence on the flooding of these valleys, have been reviewed by W2CJV and its consultants. These findings and conclusions have been found to be consistent with the conclusions and proposed commitments set out in the flood impact assessment study by ERM (2009).

It is considered that potential impacts resulting from increased ponding or flooding can be managed by increasing embankment heights for any affected roads, tracks or driveways and by regrading small sections of stream, if required.

It is recommended that WACJV develop management plans, in consultation with Wyong Shire Council and private landowners, to manage the potential impacts of increased ponding or flooding.

Although the major streams within the Study Area have relatively shallow natural gradients, it is unlikely that there would be any significant increases in the levels of scouring of the stream banks, as the maximum predicted changes in grade along the streams are very small, being in the order of 1 %. Some very localised areas of increased scouring could occur, in the locations of maximum increasing tilt, however, the levels of impact would be expected to be small when compared to natural scouring which occurs during natural flooding events.

The impacts and consequences of mine subsidence ground movements on flooding within the Study Area are discussed in detail in the reports by ERM (2009).

5.3.2.2. The Potential for Changes in Stream Alignment

Longwall mining can result in changes in stream alignment as the result of mining induced cross-bed tilts. The potential for mining-induced changes in the stream alignment depends upon the magnitudes and locations of the mining induced cross-bed tilts, the natural stream cross-bed gradients, as well as the depth, velocity and rate of surface water flows. Changes in stream alignment can potentially impact upon riparian vegetation, or result in increased scouring of the stream banks.

The WACJV was aware of this potential and iteratively amended the mine plan on several occasions so as to minimise the potential changes in stream alignment, refer to the WACJV (2008).

The maximum predicted conventional tilt across the alignment of the Wyong River, resulting from the extraction of the proposed longwalls, is less than 1 mm/m (i.e. < 0.1 %), which represents a change in cross-grade of less than 1 in 1000. The predicted maximum change in cross-grade for the river is very small and is unlikely, therefore, to result in any significant changes in stream alignment.

The maximum predicted conventional tilts across the alignments of Jilliby Jilliby Creek and Little Jilliby Jilliby Creek, resulting from the extraction of the proposed longwalls, are 10 mm/m (i.e. 1 %) and 12 mm/m (i.e. 1.2 %), respectively, which represent changes in cross-grade of 1 in 100 and 1 in 85, respectively. The maximum predicted conventional cross-tilt for the remaining streams within the Study Area, resulting from the extraction of the proposed longwalls, is 15 mm/m (i.e. 1.5 %), which represents a change in cross-grade of 1 in 65.

The predicted changes in the cross-bed gradients are small and are expected to be an order of magnitude less than the natural stream cross-bed gradients. The potential impacts associated with changes in the stream alignment, resulting from the extraction of the proposed longwalls are, therefore, not expected to be significant.

The potential impacts of the changes in stream alignment are expected to be minor when compared to the changes in the surface water flow depths and widths that occur during natural flooding events. In the locations where the stream beds comprise sediments and deposited debris, rainfall events can result in changes in the stream alignment. In a big storm event, even rocks and vegetation can be carried away downstream. The increased flow velocities in such events are likely to be an order of magnitude greater than those resulting from mining induced changes to bed gradients.

The impacts and consequences of mine subsidence ground movements on the changes in stream alignment within the Study Area are discussed in detail in the report by ERM (2009).

5.3.2.3. The Potential for Fracturing of Bedrock in the Floors of Valleys

Fractures and joints in bedrock occur naturally during the formation of the strata and from erosion and weathering processes, which include natural valley bulging movements.

When longwall mining occurs in the vicinity of streams, mine subsidence movements can result in additional fracturing or reactivation of existing joints. A number of factors are thought to contribute to the likelihood of mining-induced fracturing and these are listed below:-

- Mining-related factors, which affect the level of mining-induced ground movements in the valley. These include, amongst other things, the depth of cover and proximity of the mining to the stream, panel width and extracted thickness, and geology of the overburden.
- Topographic factors associated with the stream valley, which include valley depth, valley width and the shape and steepness of the valley sides.

- Local, near-surface geological factors, which include alluvial deposit thickness, bedrock lithology such as rock strength, thickness of beds within the strata, orientation and dip of strata, degree of cross-bedding and existing jointing.
- In-situ horizontal stresses in the bedrock.
- Presence of deep alluvial deposits covering the bedrock.

Monitoring of stream beds affected by longwall mining indicates that mining-induced fractures in bedrock are greatest in size and number directly above the extracted longwalls. Fewer fractures have developed above narrow longwalls than above wider longwalls. Where mining occurred close to but not directly beneath streams, a smaller number of mining-induced fractures were observed in the bedrock. These fractures may only be visible when the bedrock is exposed. The level of pre-existing stress in the valley bedrock varies depending on its position in the natural erosive cycle and the level of regional stress that has been imposed on it. The bedrock strength varies along the streams depending on the type of rock, its layer thickness and extent of natural joints and fractures.

In the cases of the major streams within the Study Area, exploration drilling indicates the presence of alluvial deposits up to 40 metres deep and, therefore, it is unlikely that any fracturing of the bedrock would be visible at the surface. The bedrock beneath these saturated stream beds may fracture, buckle, or uplift due to the valley closure and upsidence movements, creating a small zone of increased permeability in the upper few metres of rockhead. While these effects can cause noticeable impacts in rockbar controlled streams, this condition does not occur for the major watercourses within the Study Area, which are within these broad alluvium filled valleys.

Fracturing, shearing, buckling may occur at rock head in these valleys, but, since this will occur beneath the saturated alluvial deposits, the fracture zone will fill as it develops with little or no effect to the surface water level. Similarly, since this increased permeability zone will develop quite gradually, and its volume will be small compared to the volume of the overlying saturated alluvium, the impact on the alluvial and the overall surface stream flow is not expected to be significant.

It is possible, that compressive buckling in the bedrock could occur directly above and within say 250 metres of the proposed longwalls. In the smaller streams located up the sides of the alluvial filled valleys, where the bedrock is exposed, some fracturing may be visible at the surface.

It has been observed in the past, that the depth of buckling and dilation of the uppermost bedrock, resulting from valley related movements, is generally less than 10 to 15 metres. However this has only been noticed where there are extensive exposed rock platforms in the beds of valleys, where the strata are relatively thin and brittle, and these conditions have not been identified over the W2CP. If surface cracking were to occur within the stream alignments, it would be expected that, in times of heavy rainfall, any dilated bedrock beneath the stream beds would become water charged, and the surface water would flow over any surface cracks. Surface water that is diverted into the dilated bedrock beneath the streams, during times of rainfall, is unlikely to significantly affect the overall quality or quantity of the surface water flow, as the cross-sectional area of dilated bedrock is very small when compared to the cross-sectional area of the stream channels.

Any surface cracking would tend to be naturally filled with alluvial materials during subsequent flow events, especially during times of heavy rainfall. If any surface cracks were found not to heal naturally, some remediation measures may be required at the completion of mining. Where necessary, any significant surface cracks in the stream beds could be remediated by infilling with alluvial or other suitable materials, or by locally regrading and recompacting the surface.

The impacts and consequences of mine subsidence ground movements on groundwater resources are discussed in detail in the report by Mackie (2009).

5.3.2.4. The Potential for Surface Water Flow Diversions

The mining geometry, overburden geology, stream bed geology and stream flow conditions in the Study Area are different to the conditions in the Southern Coalfield. The potential mine subsidence related impacts on the streams over the W2CP will, therefore, be different to those experienced in the Southern Coalfield. Nevertheless, community concerns have been raised that there may be potential surface water flows impacts at the W2CP similar to those reported in the Southern Coalfield. Accordingly a brief review is required to explain the observed ground movements and the reported impacts on streams in the Southern Coalfield, so that comparisons can be made with the predicted and assessed impacts and the consequences expected over the W2CP.

The mine subsidence related impacts on surface water flows in the Southern Coalfield are primarily concerned with the diversion of surface water in the following ways:-

- Infiltration into the groundwater system, particularly where the groundwater table is lower than the surface water level of the stream, or where a flow path is established to a lower groundwater aquifer,
- Direct connectivity between the surface and the mine, and
- Diversion of surface water flows into subterranean flows and rockbar leakages, where surface water has been observed to flow via fractures and joints in the bedrock and via near-surface dilated strata and bedding plan separations within the bedrock. This water is generally observed to resurface downstream of the affected area. These diversions of surface water can also occur naturally, but mine subsidence ground movements have been observed to increase the quantity of water that can flow beneath the surface through these leakage paths.

Infiltration of surface water into deeper groundwater cannot result unless a conduit already exists or is established for flow through to a deeper permeable horizon. The potential for this type of impact within the Study Area is discussed in the report by Mackie (2009).

Where the depth of cover is shallow, connectivity between the surface and underground mine workings can result in a direct path from the surface to the mine. This has not been observed in the areas where the depths of cover are greater than 350 metres, such as the case within the Study Area. Following careful mine planning and rigorous assessments and approvals by the Dams Safety Committee, the Sydney Catchment Authority and the Department of Industry and Investment, mining has successfully occurred beneath various stored waters at such depths in the Newcastle and Southern Coalfields.

Intensive monitoring of mining beneath or near various water storage areas indicated that negligible impacts have occurred with appropriately designed mine layouts (Reid, 1991). Similar observations have been made with respect to mining beneath the Nepean River between the Douglas Park and Menangle Weirs. Monitoring in the river confirmed that the river bed and banks subsided similar to the predicted ground movements, while the water level remained unchanged. It is likely that the bedrock in this river experienced fracturing and uplift, as observed in other streams. However, the consequences of these small increased zones of increased permeability were not noticeable on the surface, as the fracturing and uplift was submerged below the permanent water level and often below impounded sediments.

A discussion on the likely height of the fractured zone above the longwalls, which was based on the numerical modelling by SCT, is included in the report on subsidence modelling by the WACJV (2008). The impacts and consequences of mine subsidence ground movements on groundwater resources are discussed in detail in the report by Mackie (2009).

Mining-induced surface flow diversion into subterranean flows occur where there is an upwards thrust of bedrock (measured as upsidence), resulting in fracturing of bedrock and redirection of surface water through the dilated strata beneath it, and this is illustrated in Fig. 5.1.

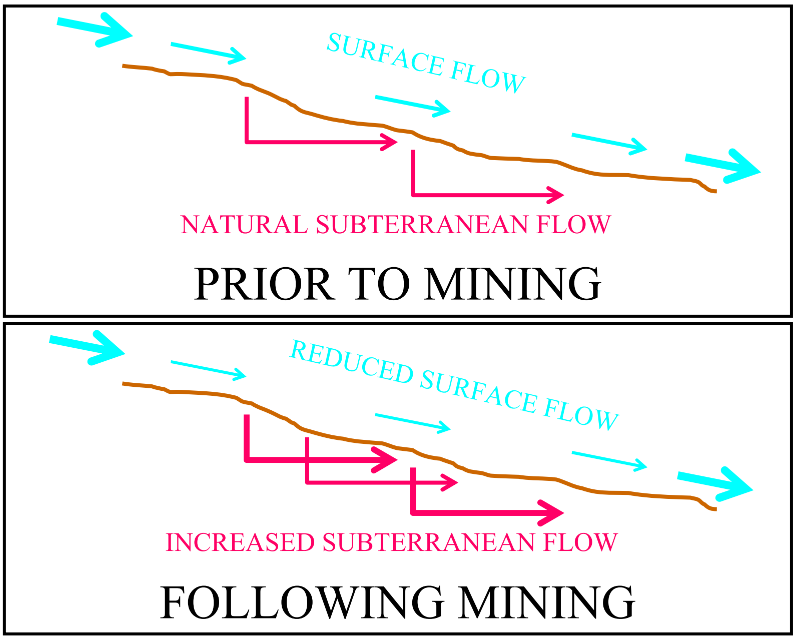


Fig. 5.1 Diagrammatic Representation of Subterranean Flows for Certain Rock-Lined Streams in the Southern Coalfield

While fractures in bedrock can provide a conduit through which water can travel beneath the surface, it does not necessarily follow that every fracture will result in surface flow diversion. Some minor fractures may not provide a continuous flow path to allow water to flow under the bedrock, and these types of fracture do not significantly impact surface water flows.

The most dramatic outcome of surface water flow diversion occurs when the stream bed becomes completely dry. The potential for noticeable or complete surface water flow diversions is not only dependent on the amount of fracturing and bed dilation, but also the magnitude of flow in the stream. Where the surface water flow is greater than the rate of leakage into subterranean flow or through a controlling feature, such as a rockbar, then surface water will still flow, at a reduced rate, through the impacted section of stream. The stream will only become completely dry where the upstream flow is less than the rate of leakage into subterranean flow or rockbar leakage.

The main concern of mine subsidence impacts on streams in the Southern Coalfield therefore relates to mining induced surface flow diversion into subterranean flows within deeply incised valleys where the surface water flows are small between pools is controlled by a series of rockbars. These rockbars in the Southern Coalfield are formed within the Hawkesbury Sandstones which commonly comprise thin bands of strong and brittle sandstone, occasional natural vertical joints and occasional cross bedding. There are many cases where the natural erosion and weathering processes have led to natural surface water diversions through and beneath these rock bars.

However this process is not expected to be significant over the W2CP because;

- The major streams are wide valleys with deep alluvial deposits and, therefore, any fracturing of the bedrock is unlikely to be visible at the surface and any dilation of the bedrock is likely to become water charged and not result in increased subterranean flows,
- There are few exposed rock platforms over the steep slopes and along the smaller streams that are located up the sides of the alluvial valleys,
- There are no exposed rock bars along the streams, and
- There are no thin, brittle or cross bedded strata layers exposed in the stream beds.

Accordingly water flow diversions are not anticipated over the W2CP.

5.3.2.5. *The Potential Consequences to Water Quality*

Impacts on water quality are highly influenced by the amount of surface water flow within the affected stream. Where there are low surface water flows, water quality can be noticeably degraded, for example increased iron oxide precipitation and reduced dissolved oxygen. Where there are high surface water flows, the impacts on water quality are less noticeable.

A description of potential impacts on water quality is presented in the report by Mackie (2009).

5.3.2.6. *The Potential for Gas Emissions*

It is known that mining results in fracturing of the strata above and adjacent to the extraction area and this may result in the liberation of methane and other gases. Gas emissions have been observed at other mines in streams and in groundwater bores. Emissions are most noticeable in the form of bubbles in water and, in some cases, emissions are concentrated enough to support a flame if lit.

Substantial studies have been undertaken into the properties of gas within rock strata. Gas is found in most rocks, and can exist in three different states – free gas, dissolved gas in water and adsorbed gas (Moelle et al, 1995). Analyses of gas compositions indicate that the near surface strata are the direct and major source of the gas rather than the extracted resource, particularly where mining occurs at significant depths. As rocks in the near surface strata experience compression in response to mining movements, free or adsorbed gas can be released, typically releasing at existing or new fractures and joints.

Gas emissions typically occur in isolated locations and the majority of gas emissions occur in areas that are directly mined beneath. These emissions are also typically the most vigorous. However, gas emissions do also occur in areas that have not been directly mined beneath.

Gas released into water quickly rises to the water surface where it is released to the atmosphere ensuring that is has very limited time to dissolve into the water body. The gas released is predominately methane, which is not particularly soluble in water. It is unlikely, therefore, to have an adverse impact on water quality within the stream.

It is possible, if substantial gas emissions occur at the surface, that these could cause localised vegetation dieback. Such vegetation dieback is rare and has only been recorded in one location in the Southern Coalfield. These impacts were limited to small areas of vegetation and local to the points of emission. The gas emissions have declined and the affected areas have successfully recovered. Vegetation dieback has not been observed in areas that have not been directly mined beneath.

5.3.3. Impact Assessments for the Streams Based on Increased Predictions

As discussed in Section 3.9, a hybrid approach was developed for predicting subsidence at the W2CP and significantly increased levels of mine subsidence have been predicted across the Study Area when compared to normal subsidence predictions at similar depths of cover within the Newcastle Coalfield. These higher levels were predicted based on the SCT numerical model results that accounted for the weakening effect on chain pillars of the underlying Awaba Tuff and the relatively thick extracted seam thickness. The ground conditions modelled by SCT were selected from an extensive borehole drilling and geomechanical testing programme to represent a conservative assessment, in order to ensure a worst-case scenario.

It is therefore believed that the predicted subsidence ground movements are realistic, but the observed movements are likely to be lower than these predicted values. Whilst the current conservative approach is considered appropriate for the current mine planning study, the proposed monitoring and analysis of the actual subsidence measured during the initial mining will enable further verification of the model and adjustments to the subsidence management strategies.

Should it be found that the actual observed subsidence is substantially different to the predicted subsidence, the mine layout can be adjusted prior to mining near or beneath the streams.

5.3.4. Recommendations for the Streams

The WACJV has committed to an adaptive and continuous improvement approach to the longwall panel design whereby the mining dimensions and limits of future mine workings will be continuously reviewed and modified as necessary as experience is gained to ensure the required subsidence parameters are observed within the various streams and floodplains.

The affects of mine subsidence movements on flooding and surface drainage were identified as an important environmental issue to be assessed. ERM (2009) was originally commissioned by the WACJV in 1999 to investigate and assess the potential impacts of the mine subsidence movements on flooding within the Dooralong and Yarramalong Valleys and within the Hue Hue Creek catchment.

The flood model also became an integral component in the finalisation of the mine plan and has been developed in conjunction with subsidence and groundwater assessments. The process has been iterative with several modifications being made to the mine plan in order to achieve the best outcome for flood affected properties within the mining area and to minimise the extent and severity of potential flood impacts. Assessments were made in 2000, 2003, 2006 and 2007 for previous mine plans and have been fundamental in the development of the current mine plan. Several changes were made between 2006 and 2009 in order to further minimise potential impacts on existing river channels.

Of particular note were the benefits of adjusting the mine plan to eliminate flood impacts for almost all of the Yarramalong Valley, to reduce the risk of changes to the alignment of Little Jilliby Jilliby Creek, as well as reduce the overall impacts in the Dooralong Valley and Hue Hue Creek.

The changes made to the mine plan have included variations to the longwall panel layout, the locations of the main roadways within Little Jilliby Jilliby Creek valley and the protection of its confluence with Jilliby Jilliby Creek, the reduction in longwall extraction height and panel width within the valley area and the restriction of mining activity near the Wyong River and the Yarramalong Valley.

Suitable Management Plans can be developed to manage the potential impacts on streams during the mining of the proposed longwalls. These plans typically cover five to ten longwalls and have been approved in the past up to a maximum of seven years. The management plans include monitoring and triggered response plans to mitigate impacts as they are observed. They also include monitoring of pre-mining conditions and data collection during mining. Monitoring typically continues for a period following mining and to determine the success of any rehabilitation requirements.

5.4. Rock Outcrops and Isolated Cliffs

There are rock outcrops and some isolated small cliffs within the Study Area, located primarily along the sides of the Dooralong, Yarramalong and Little Jilliby Jilliby Creek Valleys, as discussed in Section 2.4.8. The predictions and impact assessments for these rock formations are provided in the following sections.

5.4.1. Predictions for the Rock Formations

The rock formations are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. These features occur along the sides of the valleys, where the depths of cover are greater and, therefore, the maximum predicted parameters in these locations are less than the maxima provided in Chapter 4.

A summary of the maximum predicted conventional subsidence, tilts and curvatures for the rock formations within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table 5.4. The ranges of the depths of cover are also shown in this table for comparison.

Table 5.4 Maximum Predicted Conventional Subsidence, Tilts and Curvatures for the Rock Formations within the Study Area Resulting from the Extraction of the Proposed Longwalls

Location	Depth of Cover (m)	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
Rock Formations above LW1N to LW8N	400 ~ 490	1250	8.5	0.15	0.20
Rock Formations above LW12N to LW26N	400 ~ 610	2525	15	0.20	0.30
Rock Formations above LW1S to LW10S	470 ~ 660	2575	14	0.20	0.25
Rock Formations above LW1SW to LW10SW	500 ~ 690	2525	12	0.10	0.20

The parameters provided in the above table are the maximum predicted values at any time during or after the extraction of the proposed longwalls.

If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the individual rock formations would be predicted to experience greater or lesser movements, depending on their locations relative to the longwalls, but the overall levels of movement at the rock formations across the Study Area would not be expected to change significantly.

The rock formations are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements and downslope movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.4.2. Impact Assessments for the Rock Formations

Tilt can increase the overturning moments in steep or overhanging rock formations which, if of sufficient magnitude, could result in toppling type failures. The predicted maximum tilts for the rock formations are small in comparison to the natural slopes of the rock faces and are unlikely, therefore, to result in topping type failures in these cases.

The maximum predicted ground curvatures for the rock formations above Longwalls 1N to 8N and above Longwalls 1SW to 10SW are 0.15 km^{-1} hogging and 0.20 km^{-1} sagging, which represent minimum radii of curvature of 7 kilometres and 5 kilometres, respectively. The maximum predicted ground curvatures for these rock formations are similar to those typically experienced in the Southern Coalfield. The potential impacts on the rock formations above Longwalls 1N to 8N and above Longwalls 1SW to 10SW, therefore, are expected to be similar to those previously observed in the Southern Coalfield.

The maximum predicted ground curvatures for the rock formations above Longwalls 12N to 26N and above Longwalls 1S to 10S are 0.20 km^{-1} hogging and 0.30 km^{-1} sagging, which represent minimum radii of curvature of 5 kilometres and 3 kilometres, respectively. The maximum predicted curvatures for these rock formations are greater than those typically experienced in the Southern Coalfield. The depths of cover above Longwalls 12N to 26N and above Longwalls 1S to 10S are similar to or greater than those in the Southern Coalfield and, therefore, the observations from the Southern Coalfield should still provide a reasonable guide to the potential level of impact for these rock formations.

There is extensive experience of mining beneath rock formations in the Southern Coalfield. These include large cliffs and rock outcrops along the Cataract, Nepean, Bargo and Georges Rivers. One of the most important observations was that small isolated rock formations experienced far less instabilities than high cliffs or the longer wide cliff formations. Based on this experience, it is considered that there is a moderate to likely probability that rock falls will occur somewhere within the Study Area, affecting less than 5% of the rock formations which are directly mined beneath by the proposed longwalls.

It will be necessary to manage the potential risks of rockfalls to people and infrastructure downslope of the rock formations, which include the:-

- Roads and fire trails,
- CMTS site, and
- Houses.

5.4.3. Impact Assessments for the Rock Formations Based on Increased Predictions

If the predicted conventional tilts were increased by factors of up to 2 times, the potential impacts on the rock formations would not significantly increase, as the predicted tilts would still be much less than the natural slopes of the rock faces within the Study Area.

If the predicted curvatures and strains were increased by factors of up to 2 times, the incidence of rock falls would increase accordingly, however, the impacts would still be expected to represent a very small percentage of the rock formations.

5.4.4. Recommendations for the Rock Formations

It is recommended that management strategies are developed to minimise the risk of rock falls, which may include:-

- Identification of all features and items of infrastructure that are located downslope of the rock formations which are directly mined beneath,
- The provision of signage warning of the potential for rock falls, and
- Periodic visual inspections of the rock formations deemed to be at greatest risk during the active subsidence period.

5.5. Steep Slopes

The locations of the steep slopes within the Study Area are shown in Drawing No. MSEC428-09. The predictions and impact assessments for the steep slopes are provided in the following sections.

5.5.1. Predictions for the Steep Slopes

The steep slopes are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. The steep slopes occur along the sides of the valleys, where the depths of cover are higher and, therefore, the maximum predicted parameters in these locations are less than the maxima provided in Chapter 4.

A summary of the maximum predicted conventional subsidence, tilts and curvatures for the steep slopes within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table 5.5. The ranges of the depths of cover are also shown in this table for comparison.

Table 5.5 Maximum Predicted Conventional Subsidence, Tilts and Curvatures for the Steep Slopes within the Study Area Resulting from the Extraction of the Proposed Longwalls

Location	Depth of Cover (m)	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
Steep Slopes above LW1N to LW8N	400 ~ 490	1250	8.5	0.15	0.20
Steep Slopes above LW12N to LW26N	400 ~ 610	2525	15	0.20	0.30
Steep Slopes above LW1S to LW10S	470 ~ 660	2575	14	0.20	0.25
Steep Slopes above LW1SW to LW10SW	500 ~ 690	2525	12	0.10	0.20

The parameters provided in the above table are the maximum predicted values at any time during or after the extraction of the proposed longwalls. If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the maximum predicted subsidence parameters would be expected to be similar to those provided in the above table.

The steep slopes are planar features and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines from previous longwall mining. The analysis of strains measured along monitoring lines during the mining of previous longwalls in the Newcastle Coalfield is provided in Section 4.3.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements and downslope movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.5.2. Impact Assessments for the Steep Slopes

The maximum predicted tilt for the steep slopes, resulting from the extraction of the proposed longwalls, is 15 mm/m (i.e. 1.5 %), which represents a change in grade of 1 in 65. The predicted changes in grade are small when compared to the natural grades of the steep slopes, which are greater than 1 in 3 and, therefore, unlikely to result in any significant impact on the stability of the steep slopes.

The steep slopes are more likely to be impacted by ground curvatures and strains. The potential impacts would generally result from the down slope movement of soils, causing tension cracks to appear at the tops of the slopes and compression ridges to form at the bottoms of the slopes.

The maximum predicted ground curvatures for the steep slopes above Longwalls 1N to 8N and above Longwalls 1SW to 10SW are 0.15 km^{-1} hogging and 0.20 km^{-1} sagging, which represent minimum radii of curvature of 7 kilometres and 5 kilometres, respectively. The maximum predicted ground curvatures at these steep slopes are similar to those typically experienced in the Southern Coalfield. The potential impacts on the steep slopes above Longwalls 1N to 8N and above Longwalls 1SW to 10SW, therefore, are expected to be similar to those previously observed in the Southern Coalfield.

The maximum predicted ground curvatures for the steep slopes above Longwalls 12N to 26N and above Longwalls 1S to 10S are 0.20 km^{-1} hogging and 0.30 km^{-1} sagging, which represent minimum radii of curvature of 5 kilometres and 3 kilometres, respectively. The maximum predicted curvatures at these steep slopes are greater than those typically experienced in the Southern Coalfield. The depths of cover above Longwalls 12N to 26N and above Longwalls 1S to 10S are similar to or greater than those in the Southern Coalfield and, therefore, the observations from the Southern Coalfield should still provide a reasonable guide to the potential level of impact for these steep slopes.

There is extensive experience of mining beneath steep slopes in the Southern Coalfield. These include steep slopes along the Cataract, Nepean, Bargo and Georges Rivers. No large-scale slope failures have been observed along these slopes, even where longwalls have been mined directly beneath them. Although no large-scale slope failures have been observed in the Southern Coalfield, tension cracking has been observed at the tops of steep slopes as the result of downslope movements.

Cracking from downslope movements at depths of cover greater than 350 metres, such as the case in the Study Area, is generally isolated and small, typically having maximum crack widths in the order of 50 mm. Larger cracking has been observed at the tops of very steep slopes and adjacent to large rock formations, where maximum crack widths in the order of 100 to 150 mm have been observed.

If tension cracks were to develop, as the result of the extraction of the proposed longwalls, it is possible that soil erosion could occur if these cracks were left untreated. It is possible, therefore, that some remediation might be required, including infilling of surface cracks with soil or other suitable materials, or by locally regrading and recompacting the surface. In some cases, erosion protection measures may be needed, such as the planting of additional vegetation in order to stabilise the slopes in the longer term.

While in most cases, impacts on steep slopes are likely to consist of surface cracking, there remains a low probability of large-scale downslope movements. Experience indicates that the probability of mining induced large-scale slippages is extremely low due to the significant depth of cover within the Study Area.

While the risk is extremely low, some risk remains and attention must therefore be paid to any features or items of infrastructure that are located in the vicinity of steep slopes which are directly mined beneath, which include the:-

- Houses,
- Roads and fire trails,
- Transmission Towers 21-46-T to 21-53-T and 22-49T to 22-56-S,
- CMTS site and optical fibre cable, and
- Survey control marks.

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

If the predicted conventional 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 within the Study Area.

If the predicted ground curvatures and strains were increased by factors of up to 2 times, the extent of potential surface cracking would increase accordingly at the steep slopes located directly above the proposed longwalls. It is expected, however, that any surface cracking could still be remediated by infilling with soil or other suitable materials, or by locally regrading and compacting the surface.

5.5.4. Recommendations for the Steep Slopes

It is recommended that the steep slopes are periodically visually monitored during the mining period and until any necessary remediation measures are completed. It is also recommended that management strategies be developed to ensure that these measures are implemented. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the environment resulting from the extraction of the proposed longwalls.

It is recommended that management strategies are developed to ensure that the infrastructure on the steep slopes is maintained in safe and serviceable conditions throughout the mining period. The strategies may include:-

- Identification of all features that are located in the vicinity of steep slopes which are directly mined beneath,
- Site investigation and landslide risk assessment by a qualified geotechnical engineer for the critical features in the vicinity of the steep slopes which are directly mined beneath,

- Site investigation and structural assessment of structures where recommended by the geotechnical engineer. This may include recommendations to mitigate against potential impacts,
- Monitoring, including ground survey and visual inspections of critical features, and
- Remediation, where required, of any significant surface cracking or slippage.

5.6. Water Related Ecosystems

There are water-related ecosystems within the Study Area, particularly along the alignments of the streams and tributaries. The potential impacts on the streams, resulting from the extraction of the proposed longwalls, are discussed in Section 5.2 and in the report by ERM (2009). The potential impacts on the water-related ecosystems within the Study Area are discussed in the reports by OzArk (2010a).

5.7. Threatened, Protected Species or Critical Habitats

The greatest potential for impacts on fauna and their habitats will occur where the disturbance of the soils and near surface strata are the greatest. This is more likely to occur where the levels of curvature and ground strain are the highest. The most important changes in the surface relating to subsidence will be changes in the surface water conditions. The potential impacts on fauna and their habitats, resulting from the extraction of the proposed longwalls, are discussed in the report by OzArk (2010a)

5.8. The Local Roads

The locations of the local roads within the Study Area are shown in Drawing No. MSEC428-12. The predictions and impact assessments for roads are provided in the following sections.

5.8.1. Predictions for the Local Roads

A summary of the maximum predicted values of conventional subsidence, tilts and curvatures for the main (i.e. sealed) local roads within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table 5.6. The predicted subsidence parameters along Jilliby Road are also illustrated in Fig. E.08 in Appendix E

Table 5.6 Maximum Predicted Conventional Subsidence, Tilts and Curvatures for the Main Local Roads Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
Dickson Road	1350	9.0	0.12	0.17
Durren Road	1400	6.5	0.08	0.10
Jilliby Road	1750	7.5	0.09	0.09
Little Jilliby Road	175	1.0	0.01	0.01
Parkridge Drive Crestwood Road Sandra Street	1050	7.0	0.11	0.15

The tilts provided in the above table are the maximum predicted values at the completion of any or all proposed longwalls. The curvatures provided in the above table are the maximum predicted values which occur at any time during or after the extraction of the proposed longwalls.

The unsealed roads are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4. If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the maximum predicted subsidence parameters would still be expected to be similar to those provided in Chapter 4.

The roads cross a number of streams within and immediately adjacent to the Study Area, the locations of which are shown in Drawing No MSEC428-12. The predictions and impact assessments for the bridges and culverts at the stream crossings are provided in Sections 5.9 and 5.10, respectively.

The roads are linear features and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines from previous longwall mining. The analysis of strains measured along monitoring lines during the mining of previous longwalls in the Newcastle Coalfield is provided in Section 4.3.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements and downslope movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.8.2. Impact Assessments for the Local Roads

The maximum predicted tilt for the main local roads, resulting from the extraction of the proposed longwalls, is 9 mm/m (i.e. 0.9 %), which represents a change in grade of 1 in 110. The maximum predicted tilt for the unsealed local roads anywhere within the Study Area, resulting from the extraction of the proposed longwalls, is 15 mm/m (i.e. 1.5 %), which represents a change in grade of 1 in 65.

The predicted changes in grade are small, in the order of 1 to 2 % and are unlikely, therefore, to result in any significant impacts on the surface water drainage or serviceability of these roads. If any additional ponding or adverse changes in surface water drainage were to occur as the result of mining, the roads could be remediated using normal road maintenance techniques.

The maximum predicted ground curvatures for the main local roads are 0.12 km^{-1} hogging and 0.17 km^{-1} sagging, which represent minimum radii of curvature of 8 kilometres and 6 kilometres, respectively. The maximum predicted ground curvatures at these roads are similar to those typically experienced in the Southern Coalfield. The potential impacts on the main local roads in the Study Area, therefore, are expected to be similar to those previously observed in the Southern Coalfield.

The most extensive experience has come from the extraction of Tahmoor Longwalls 22 to 24A, where these longwalls have mined directly beneath approximately 10 kilometres of local roads. A total of 12 impacts have been observed, which equates to an average of one impact for every 860 metres of pavement. The impacts were minor and did not present a public safety risk.

Of these impact sites, one was substantially greater than the other observed impact sites, and this is shown in Fig. 5.2. Two additional sites with substantially greater impacts were recently observed during the mining of Tahmoor Longwall 25. One of the sites was located at a roundabout and a photograph is shown in Fig. 5.2. Photographs of other cracking and the buckling of a kerb and gutter are shown in Fig. 5.3.

More frequent impacts have been observed to concrete kerbs and gutters. The impacts are most commonly focussed around driveway laybacks and involve cracking, spalling or buckling. A typical buckling impact of a kerb is shown in Fig. 5.3.

A total of 5 drainage pits have been damaged during the mining of Tahmoor Longwalls 24A and 25. Investigations are currently underway to determine whether impacts have occurred to stormwater pipes in these areas.

Fig. 5.2 Cracking and Bump at Roundabout at Tahmoor

Fig. 5.3 Cracking and Buckling of Kerb at Tahmoor

It would be expected that any impacts on the main local roads within the Study Area could be remediated using normal road maintenance techniques. With the necessary remediation measures implemented, it would be expected that the main local roads could be maintained in safe and serviceable conditions throughout the mining period.

The maximum predicted ground curvatures for the unsealed roads, resulting from the extraction of the proposed longwalls, are 0.28 km^{-1} hogging and 0.37 km^{-1} sagging, which represent minimum radii of curvature of 4 kilometres and 3 kilometres, respectively. The potential impacts on the unsealed roads within the Study Area include cracking and heaving of the unseal road surfaces. It would be expected that any impacts on the unsealed roads could be remediated by infilling the cracks, or by regrading and recompacting the surface.

5.8.3. Impact Assessments for the Local Roads Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the maximum predicted changes in grade at the local roads within the Study Area would be in the order of 1 to 3 %. It would still be expected that any additional ponding or adverse changes in surface water drainage could still be remediated using normal road maintenance techniques.

If the maximum predicted curvatures or ground strains were increased by factors of up to 2 times, the likelihood and extent of cracking and heaving of the local road surfaces would increase accordingly. It would still be expected that any impacts could be repaired using normal road maintenance techniques.

5.8.4. Recommendations for the Local Roads

It is recommended that management strategies are developed, in consultation with the Wyong Shire Council, such that the roads can be maintained in a safe and serviceable condition throughout the mining period.

5.9. Local Road Bridges

The locations of the local road bridges which have been identified within the Study Area are shown in Drawing No. MSEC428-12. The following sections provide the predictions and impact assessments for these bridges.

5.9.1. Predictions for the Local Road Bridges

A summary of the maximum predicted values of conventional subsidence, tilts and curvatures for the local road bridges within the Study Area, at any time during or after the extraction of the proposed longwalls, is provided in Table 5.7.

Table 5.7 Maximum Predicted Conventional Subsidence, Tilts and Curvatures for the Local Bridges Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
JJ-B1 & B2	1350	2.0	0.05	0.04
LJ-B1	75	0.5	< 0.01	< 0.01
LJ-B2	75	0.8	< 0.01	< 0.01
LJ-B3	75	0.2	< 0.01	< 0.01
LJ-B4	100	0.8	< 0.01	< 0.01
WR-B1	150	1.2	< 0.01	< 0.01
WR-B2	75	0.7	< 0.01	< 0.01

The values provided in the above table are the maximum predicted parameters within 20 metres of the centre of each bridge, at any time during or after the extraction of the proposed longwalls.

The local bridges cross streams and, therefore, could also experience valley related movements. A summary of the maximum predicted upsidence and closure movements for the local bridges, resulting from the extraction of the proposed longwalls, is provided in Table 5.8.

Table 5.8 Maximum Predicted Upsidence and Closure Movements for the Local Bridges Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
JJ-B1 & B2	25	25
LJ-B1	25	< 20
LJ-B2	50	50
LJ-B3	75	75
LJ-B4	75	100
WR-B1	100	75
WR-B2	25	50

The local road bridges are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, valley related upsidence and closure movements and anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements. The strains resulting from valley related movements are discussed separately in the following sections.

5.9.2. Impact Assessments for the Local Road Bridges

The maximum predicted tilts for the local road bridges, resulting from the extraction of the proposed longwalls, vary between 0.2 mm/m (i.e. < 0.1 %) and 2 mm/m (i.e. 0.2 %), which represent changes in grades varying from less than 1 in 5000 to 1 in 500, respectively. The predicted changes in grade are small, less than 1 % and are unlikely, therefore, to result in any significant impacts on the surface water drainage or serviceability of these road bridges.

The maximum predicted ground curvatures for Bridges JJ-B1 & B2 are 0.05 km^{-1} hogging and 0.04 km^{-1} sagging, which represent minimum radii of curvature of 20 kilometres and 25 kilometres, respectively. The maximum predicted ground curvatures for the remaining bridges are less than 0.01 km^{-1}, which represents a minimum radius of curvature of greater than 100 kilometres. The maximum predicted ground curvatures at the bridges are small and, therefore, are unlikely to result in adverse impacts on these bridges.

The maximum predicted upsidence for the local road bridges vary between 25 mm and 100 mm and the maximum predicted closure for the local bridges also vary between 25 mm and 100 mm. The greatest upsidence and compressive strain due to closure movements are expected to occur near the bases of the streams. The greatest closure movements could occur at the bridge abutments.

Bridges JJ-B1 & B2 are concrete box culvert bridges and Bridge LJ-B1 is a single span concrete bridge. As these bridges span the streams, the predicted upsidence and compressive strain due to valley closure are unlikely to be transferred into the bridge structures. The predicted closure could be transferred into the bridge structures if the movement joints do not have sufficient capacity to accommodate these movements. It is recommended that structural inspections of these bridges are undertaken, to assess the movement tolerances of these bridges and, if necessary, to develop the necessary preventive measures.

The remaining bridges are single or double span timber bridges or steel girder with timber deck bridges. Timber and steel bridges are flexible structures which would be expected to accommodate the magnitudes of the predicted valley related movements. Some minor impacts could occur at these bridges, if the full predicted valley related movements were transferred into the structures, but it would be expected that preventive measures could be undertaken to accommodate these movements. It is recommended that structural inspections of these bridges are undertaken, to assess the movement tolerances of these bridges and, if necessary, to develop the necessary preventive measures.

5.9.3. Impact Assessments for the Local Road Bridges Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the maximum predicted changes in grade at the local road bridges would still be less than 1 % and are unlikely, therefore, to result in any significant impacts on the surface water drainage or serviceability of these road bridges.

If the maximum predicted curvatures were increased by factors of up to 2 times, the maximum predicted curvatures would be 0.10 km^{-1} hogging and 0.08 km^{-1} sagging, which represent minimum radii of curvature of 10 kilometres and 13 kilometres, respectively. The maximum predicted ground curvatures are still small and are likely to be accommodated by the bridge movement joints.

If the predicted valley related movements were increased by factors of up to 2 times, the potential for impact would increase if the concrete bridge movement joints did not have sufficient capacity to accommodate the closure movements, or the full valley related movements were transferred into the timber or steel bridge structures.

5.9.4. Recommendations for the Local Road Bridges

It is recommended that management strategies are developed, in consultation with the Wyong Shire Council, such that the local road bridges are maintained in safe and serviceable conditions throughout the mining period. The strategies may include:-

- Structural inspection of the bridges to determine the existing movement allowance of the bridges,
- Adjustment of the movement joints, if necessary, to accommodate the predicted closure movements, and
- Visual inspections of the bridges during the active subsidence period.

5.10. Drainage Culverts

The locations of the identified drainage culverts along the local roads within the Study Area are shown in Drawing No. MSEC428-12. It is likely that there are other culverts within the Study Area, in addition to those shown in this drawing, including those on private land, or where the drainage lines were not visible on the aerial photograph. The following sections provide the predictions and impact assessments for the drainage culverts.

5.10.1. Predictions for the Drainage Culverts

The drainage culverts are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4. If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the maximum predicted subsidence parameters would be expected to be similar to those provided in Chapter 4.

The culverts are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, valley related upsidence and closure movements and anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements. The strains resulting from valley related movements are discussed separately in the following sections.

5.10.2. Impact Assessments for the Drainage Culverts

The maximum predicted tilt within the Study Area is 15 mm/m (i.e. 1.5 %), which represents a change in grade of 1 in 65. It is expected that the culverts will generally experience tilts less than this maximum, as the result of the variations in the predicted tilts across the Study Area and the orientations of the culverts relative to the subsidence troughs.

The predicted changes in grade are small, in the order of 1 % and, therefore, are unlikely to result in any significant impacts on the serviceability of the culverts. If the flow of water through any culverts were to be adversely affected, as the result of the extraction of the proposed longwalls, this could be remediated by relevelling the affected culverts.

The maximum predicted ground curvatures within the Study Area, resulting from the extraction of the proposed longwalls, are 0.28 km^{-1} hogging and 0.37 km^{-1} sagging, which represent minimum radii of curvature of 4 kilometres and 3 kilometres, respectively. It is expected that the culverts will generally experience curvatures less than these maxima, as the result of variations in the predicted curvatures across the Study Area and the orientations of the culverts relative to the subsidence trough.

The drainage culverts are located along drainage lines and could, therefore, experience valley related upsidence and closure movements. The drainage culverts are orientated along the alignments of the drainage lines and, therefore, the upsidence and closure movements are orientated perpendicular the main axes of the culverts and unlikely to result in any significant impacts.

Drainage culverts have been mined beneath by previously extracted longwalls throughout the NSW Coalfields. The incidence of impacts is low and is generally limited to cracking in the concrete headwalls which can be readily remediated. In some cases, cracking in the culvert pipes occurred which required the culverts to be replaced. Visual inspections and more detailed analysis should be undertaken to review the potential impacts on the larger box culverts within the Study Area. In some cases, it may be necessary to provide some preventive measures to the larger concrete box culverts within the Study Area.

With the preventive or remediation measures implemented, it is expected that the drainage culverts within the Study Area can be maintained in serviceable conditions throughout the mining period.

5.10.3. Impact Assessments for the Drainage Culverts Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the maximum predicted change in grade at the culverts would be 3 %. If the flow of water through any culverts were to be adversely affected, this could be easily remediated by relevelling the affected culverts.

If the predicted curvatures or ground strains were increased by factors of up to 2 times, the likelihood of impacts would increase accordingly, however, the incidence of impact would still be expected to be relative low. Any culvert impacted by mining could be repaired or, if required, replaced.

5.10.4. Recommendations for the Drainage Culverts

The potential impacts on the drainage culverts within the Study Area can be managed by visual monitoring and the implementation of any necessary preventive or remediation measures. The ground movements will occur gradually as mining progresses, which will provide adequate time to remediate the culverts at the appropriate time, should these works be required. With these remediation measures in place, it is unlikely that there would be any significant impacts on the serviceability of the culverts.

5.11. The Sydney-Newcastle Freeway

The Sydney-Newcastle Freeway is located at a distance of 1.1 kilometres south-east of Longwall 1N, at its closest point from the proposed longwalls. At this distance, it is unlikely that the freeway pavement would experience any significant conventional subsidence movements resulting from the extraction of the proposed longwalls.

The freeway could be subjected to small far-field horizontal movements as a result of the extraction of the proposed longwalls. Far-field horizontal movements and the methods used to predict such movements are described further in Sections 3.4 and 4.5.

Far-field horizontal movements have, in the past, been observed at similar distances as the freeway is from the proposed longwalls, however, these movements tend to be bodily movements associated with very low levels of strain. It is unlikely, therefore, that the freeway pavement itself would be impacted by far-field horizontal movements resulting from the extraction of the proposed longwalls.

The freeway bridges, however, could be sensitive to far-field horizontal movements, if the differential movements at the bridge movement joints were greater than the tolerances provided for thermal movements. Mid-ordinate deviation is a measure for differential movement along monitoring lines, which is defined as the differential horizontal movement of each survey mark, perpendicular to the monitoring line, relative to the two adjacent survey marks, as illustrated in Fig. 4.7.

The mid-ordinate deviations measured along survey lines in the Southern Coalfield, for survey marks spaced nominally 20 metres apart, is provided in Fig. 4.8. It can be seen from this figure, at distances greater than 1 kilometre from extracted longwalls, such as the freeway bridges near the proposed longwalls, that mid-ordinate deviations of up to 5 mm have been observed. It should be noted, that survey tolerance is likely to represent a large proportion of these measurements.

It is recommended that the predicted mine subsidence movements, resulting from the extraction of the proposed longwalls, are provided to the RTA, so that a structural assessment of the bridges can be undertaken based on the predicted far-field horizontal movements. It may be necessary to undertake some preventive measures, if the bridge movement joints and bearings were not able to tolerate the predicted differential movements.

It is also recommended that management strategies are developed, in consultation with the RTA, which could include the:-

- Implementation of preventive measures, if required, to provide the necessary capacity at the bridge movement joints and bearings,
- Installation of a monitoring system, which could include, amongst other things, the monitoring of ground movements, structure movements, bridge joint displacements and visual inspections,
- Implementation of a response plan, where actions are triggered by monitoring results, and
- Implementation of a reporting and communication plan.

5.12. Water Infrastructure

The locations of the water infrastructure within the Study Area are shown in Drawing No. MSEC428-13. The predictions and impact assessments for the water infrastructure are provided in the following sections.

5.12.1. Treelands Drive Reservoir

The Treelands Drive Reservoir is located just inside the eastern extent of the general Study Area and is at a distance of 300 metres east of the proposed Longwall 1S, at its closest point to the proposed longwalls. The locations of the reservoir tanks are shown in Drawing No. MSEC428-13.

At this distance, the reservoir is predicted to experience less than 50 mm of subsidence. While it is possible that the reservoir could experience subsidence slightly greater than 50 mm, as the result of far-field vertical movements, it would not be expected to experience any significant tilts, curvatures or strains.

It is unlikely, therefore, that the Treelands Drive Reservoir would experience any significant impacts resulting from the extraction of the proposed longwalls, even if the predictions were increased by factors of up to 2 times.

5.12.2. The Proposed Mardi to Mangrove Creek Dam Pipeline

The proposed Mardi to Mangrove Creek Dam pipeline route touches the general Study Area, south-west of Longwalls 1SW and 2SW, but otherwise is located outside the general Study Area. The location of the proposed pipeline route is shown in Drawing No. MSEC428-13.

At this distance, the proposed pipeline is predicted to experience less than 20 mm of subsidence. While it is possible that the pipeline could experience subsidence slightly greater than 20 mm, as the result of far-field vertical movements, the pipeline would not be expected to experience any significant conventional tilts, curvatures or strains.

It is unlikely, therefore, that the proposed pipeline would experience any significant impacts, resulting from the conventional subsidence movements, even if the predictions were increased by factors of up to 2 times.

The pipeline is located within the valley of the Wyong River and, therefore, could experience valley related upsidence and closure movements. The predicted profiles of subsidence, upsidence, horizontal movement along and horizontal movement across the proposed pipeline route, resulting from the extraction of the proposed longwalls, are provided in Fig. 5.4.

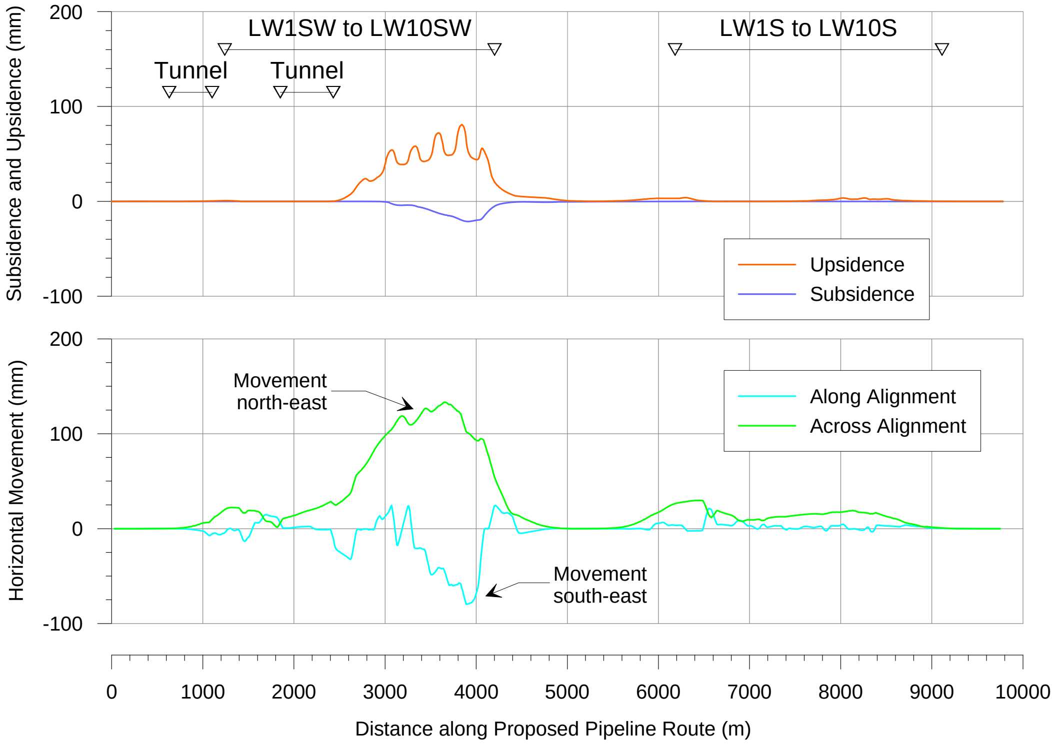


Fig. 5.4 Predicted Profiles of Subsidence, Upsidence, Horizontal Movement Along and Horizontal Movement Across the Alignment of the Proposed Pipeline Route

The predicted movements along the proposed route have been provided to the designers of the pipeline. It has been advised that the current design of the pipeline can accommodate the predicted movements resulting from the extraction of the proposed longwalls. It is unlikely, therefore, that the pipeline would experience any adverse impacts from the proposed mining, provided that it is constructed in accordance with the design which accommodates these predicted movements.

5.12.3. Other Water Pipelines

There are a number of other water pipelines located immediately to the east of the Study Area, the locations of which are shown in Drawing No. MSEC428-13.

At these distances, the pipelines are predicted to experience less than 20 mm of subsidence. While it is possible that the pipelines could experience subsidence slightly greater than 20 mm, as the result of far-field vertical movements, the pipelines would not be expected to experience any significant conventional tilts, curvatures or strains.

It is unlikely, therefore, that the water pipelines would experience any significant impacts, resulting from the extraction of the proposed longwalls, even if the predictions were increased by factors of up to 2 times

The pipelines located immediately to the east of the Study Area do not cross any significant valleys and, therefore, are unlikely to experience any significant valley related movements. It is unlikely, therefore, that these pipelines would experience any adverse impacts resulting from the extraction of the proposed longwalls.

5.13. 330 kV Transmission Lines

The locations of the 330 kV transmission lines within the Study Area are shown in Drawing No. MSEC428-14. The predictions and impact assessments for these transmission lines are provided in the following sections.

5.13.1. Predictions for the 330 kV Transmission Lines

The predicted profiles of incremental and cumulative conventional subsidence, tilt along and tilt across the alignments of the Transmission Lines 21 and 22, resulting from the extraction of the proposed longwalls, are shown in Figs. E.09 and E.10, respectively, in Appendix E.

A summary of the maximum predicted values of conventional subsidence, tilts along the alignments, tilts across the alignments and curvatures for the transmission lines, resulting from the extraction of the proposed longwalls, is provided in Table 5.9. The values provided in this table are the maximum predicted parameters anywhere along the alignments of the transmission lines, at any time during or after the extraction of the proposed longwalls.

Table 5.9 Maximum Predicted Conventional Subsidence, Tilts Along, Tilts Across and Curvatures for the 330 kV Transmission Lines Resulting from the Extraction of the Proposed Longwalls

Line	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt Along Alignment (mm/m)	Maximum Predicted Conventional Tilt Across Alignment (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
Line 21	2100	11	13	0.30	0.30
Line 22	2500	12	13	0.15	0.30

If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the maximum predicted subsidence parameters at the transmission lines would be expected to be similar to those provided in the above table.

A summary of the maximum predicted values of conventional subsidence, tilts and curvatures for the transmission towers within the Study Area, at any time during or after the extraction of the proposed longwalls, is provided in Table 5.10. The 330kV transmission lines are single circuit steel towers and the top earth wires are connected to the towers at a height of approximately 28 metres above ground level. A summary of the maximum predicted horizontal movements at the tops of the towers, resulting from the extractions of the proposed longwalls is also provided in Table 5.10.

The values provided in the above table are the maximum predicted parameters within 20 metres of the centre of each tower, at any time during or after the extraction of the proposed longwalls.

If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the individual towers would be predicted to experience greater or lesser movements, depending on their locations relative to the longwalls, but the overall levels of movement at the towers across the Study Area would not be expected to change significantly.

The transmission towers are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, downslope movements or anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The 330 kV Transmission Line No. 25 is predicted to experience less than 20 mm of subsidence. While it is possible that this transmission line could experience subsidence slightly greater than 20 mm, as the result of far-field vertical movements, it would not be expected to experience any significant tilts, curvatures or strains. It is also likely that Transmission Line 25 would experience far-field horizontal movements, resulting from the extraction of the proposed longwalls, which are discussed in Sections 3.4 and 4.5.

Table 5.10 Maximum Predicted Conventional Subsidence, Tilts and Curvatures for the Tension Towers within the Study Area Resulting from the Extraction of the Proposed Longwalls

Line	Tower ID	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})	Maximum Predicted Conventional Horizontal Movement at Top of tower (mm)
Line 21	21-36-S	20	< 0.5	< 0.01	< 0.01	< 20
	21-37-S	925	4.5	0.12	0.03	200
	21-38-T	1175	8.5	0.14	0.19	375
	21-39-S	1150	4.0	0.09	0.04	175
	21-40-S	1400	8.5	0.06	0.27	375
	21-41-S	1400	4.5	0.06	0.04	200
	21-42-S	1125	3.5	0.06	0.03	150
	21-43-S	1275	4.0	0.05	0.03	175
	21-44-T	1225	10	0.15	0.03	425
	21-45-T	1425	9.5	0.05	0.22	400
	21-46-T	2050	5.0	0.03	0.16	200
	21-47-T	1850	5.5	0.04	0.05	225
	21-48-T	400	3.0	0.03	0.01	125
	21-49-T	350	2.0	0.02	< 0.01	100
	21-50-T	250	1.5	0.01	< 0.01	50
	21-51-S	175	1.0	0.01	< 0.01	50
	21-52-S	100	0.5	0.01	< 0.01	25
	21-53-T	35	0.5	< 0.01	< 0.01	20
Line 22	22-46-S	< 20	< 0.5	< 0.01	< 0.01	< 20
	22-47-S	150	1.5	0.01	0.01	75
	22-48-S	425	5.0	0.08	0.03	225
	22-49-T	2175	5.5	0.06	0.05	250
	22-50-T	1875	4.0	0.05	0.03	175
	22-51-T	2425	5.0	0.04	0.08	200
	22-52-T	2125	9.5	0.03	0.19	400
	22-53-T	575	6.0	0.06	< 0.01	250
	22-54-S	300	2.5	0.03	< 0.01	100
	22-55-S	100	1.0	0.01	0.01	50
	22-56-S	< 20	< 0.5	< 0.01	< 0.01	< 20

5.13.2. Impact Assessments for the 330 kV Transmission Lines

The transmission towers can be impacted by the mining induced horizontal loads due to the changes in bay lengths, i.e. 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 curvatures and strains at the bases of each tower.

The maximum predicted tilt at the transmission towers is 10 mm/m (i.e. 1 %), which represents a change in verticality of 1 in 100. The predicted horizontal ground movement associated with the maximum predicted tilt is 150 mm. The maximum predicted horizontal movement at the tops of the towers, based on a height of approximately 28 metres, therefore, is 425 mm.

Where the horizontally movements at adjacent towers are of similar magnitude and in similar directions, there will only be small changes in the catenary profiles of the aerial cables. Where there are large differential horizontal movements at the levels of the cables, the changes in the catenary profiles of the aerial cables result in differential horizontal loads on the towers. The maximum predicted change in baylength between adjacent towers is 485 mm, which occurs over a span of 339 metres and, therefore, equates to an overall strain of approximately 1.4 mm/m.

The maximum predicted hogging and sagging curvatures at transmission lines, resulting from the extraction of the proposed longwalls, are both 0.30 km^{-1}, which equates to minimum radius of curvature of 3 kilometres. The maximum predicted curvatures and ground strains could result in increased stresses within the tower structural members.

Predictions of subsidence, tilt and strain at each tower and the predicted changes in bay lengths between the towers were issued to and discussed with TransGrid in 2006, 2007, 2008 and 2009. As the proposed mine layout and the predicted levels of the mine subsidence movements at the transmission lines and towers have not changed significantly since January 2007.

TransGrid has already reviewed the potential impacts of mining on the transmission lines and towers and these potential impacts have been discussed in the various meetings between WACJV and TransGrid. The main potential impacts that have been identified include:-

1. Increased conductor tensions which could overload the towers,
2. Ground strains and curvature which could deform the tower bases, and
3. Reduced cable heights which do not maintain the statutory minimum clearances.

Subsequent to one of these meetings, TransGrid advised the WACJV on 29th August 2008 by letter;

"In relation to the impact of the proposed mining of TransGrid assets the following is advised;

- *The magnitude of the possible strains that will be imposed on the towers is such that they would require the installation of some protective measures. These measures may include the installation of cruciform footings on suspension structures. Protective measures for tension structures are less well developed and may not be available for those structures with large deviation angles.*
- *The predicted tilts and translations can cause major tension changes to the conductors and earth wires that may adversely affect the safety and security of the transmission lines. The installation of sheaves on the conductors and/or earth wires would assist in alleviating the impact on suspension structures. However, this is generally not feasible for tension structures.*
- *The levels of subsidence may result in the clearance between the conductors and ground under maximum operating conditions being reduced to less than the required levels. If this occurs, protective measures would be required to protect the safety of the general public and the security of the lines."*

"While the above concerns can generally be addressed through protective measures for the suspension structures, the protection of tension structures is more problematic and measures for such towers are more limited. This is particularly, the case for structures 22-52-T and 21-44-T which both have large deviation angles. Protection of tension towers may require sterilisation of coal or variation of the mine layout to limit the strains and tilts to an acceptable level."

The assessments of the transmission lines that have been undertaken by TransGrid, to date, indicate that it is likely that the stability of the suspension towers (Potential Impacts 1 and 2) and the reduction of cable clearances (Potential Impact 3) could be managed by the implementation of suitable management strategies. These management strategies could include:-

- Installation of cable sheaves on the suspension towers where the mining induced horizontal movements could adversely affect the structural integrity of these towers,
- Fencing off the easement where the cable clearances are less than the minimum requirements until adjustments have been made to reinstate the clearances,
- Groundwork within the easement to increased the existing cable clearances, and
- Installation of cruciform bases for the suspension towers where the ground movements could adversely affect the structural integrity or the stability of these towers.

The required preventive measures will be developed as part of the ongoing discussions between WACJV and TransGrid. The preventive measures will be designed to ensure the safe operations of the transmission lines at all the towers within the Study Area.

As described in Table 2.1 and Table 5.10, there are 29 transmission towers located within the Study Area, of which 14 are tension towers and 15 are suspension towers. The assessments of the transmission lines undertaken by TransGrid also indicate that it is more difficult to provide preventive measures for the tension towers, especially Towers 22-52-T and 21-44-T.

Some of the tension towers were built because of the wide spans across the larger valleys and many of these only have very small changes in angle of the transmission line. The two tension towers with the greatest angled changes of the transmission line directions are labelled Tower 21-44-T and Tower 22-52-T. Tower 21-44-T is located at Dooralong in the floor of the valley, whilst Tower 22-52-T is located on top of a steep hill within the Jilliby Conservation Area.

Preventive measures such as cable sheaves and cruciform bases may not be able to be used at some of the tension towers, due to the permanent lateral load resulting from the change in direction of the cables. Detailed structural assessments of the towers will need to be undertaken to determine which, if any, tension towers are suitable for these types of preventive measures.

Where tension towers are found to be unable to tolerate the predicted mine subsidence movements and are not suitable for traditional preventive measures, as described above, other strategies would need to be considered, including the:-

- Strengthening of the tension towers,
- Installation of additional temporary towers or poles, although it is accepted that this may be difficult to achieve within the existing easement,
- Realignment or re-routing of the transmission lines, but this may be difficult based on the surrounding land use,
- Direct burying the transmission line cables, providing approvals can be obtained from the land owners and that the engineering and safety constraints can be overcome, or
- Providing coal barriers beneath the tension towers.

Based on preliminary assessments of the towers using the predicted curvatures and strains, it is believed that mitigation works can be undertaken to allow the safe operations at all the towers within the Study Area, except the two high angle tension towers, being 21-44-T and Tower 22-52-T. As indicated by the above quoted TransGrid letter dated 29th August 2008, cruciform footings will be required under many towers and coal sterilisation may be required under the two high angled tension towers labelled 21-44-T and Tower 22-52-T.

An assessment has been undertaken to determine the quantity of coal that would be required to be sterilised to protect these two towers. Fig. 5.5 shows a modification to the current mine plan by stopping the longwalls short of these towers and then re-commencing extraction beyond the towers. The volume of coal required to be sterilised to reduce predicted subsidence ground movements to acceptable levels is approximately 1,000,000 cubic meters. If this coal could be mined and if it is sold at $150/tonne the sale price would be $ 225,000,000.

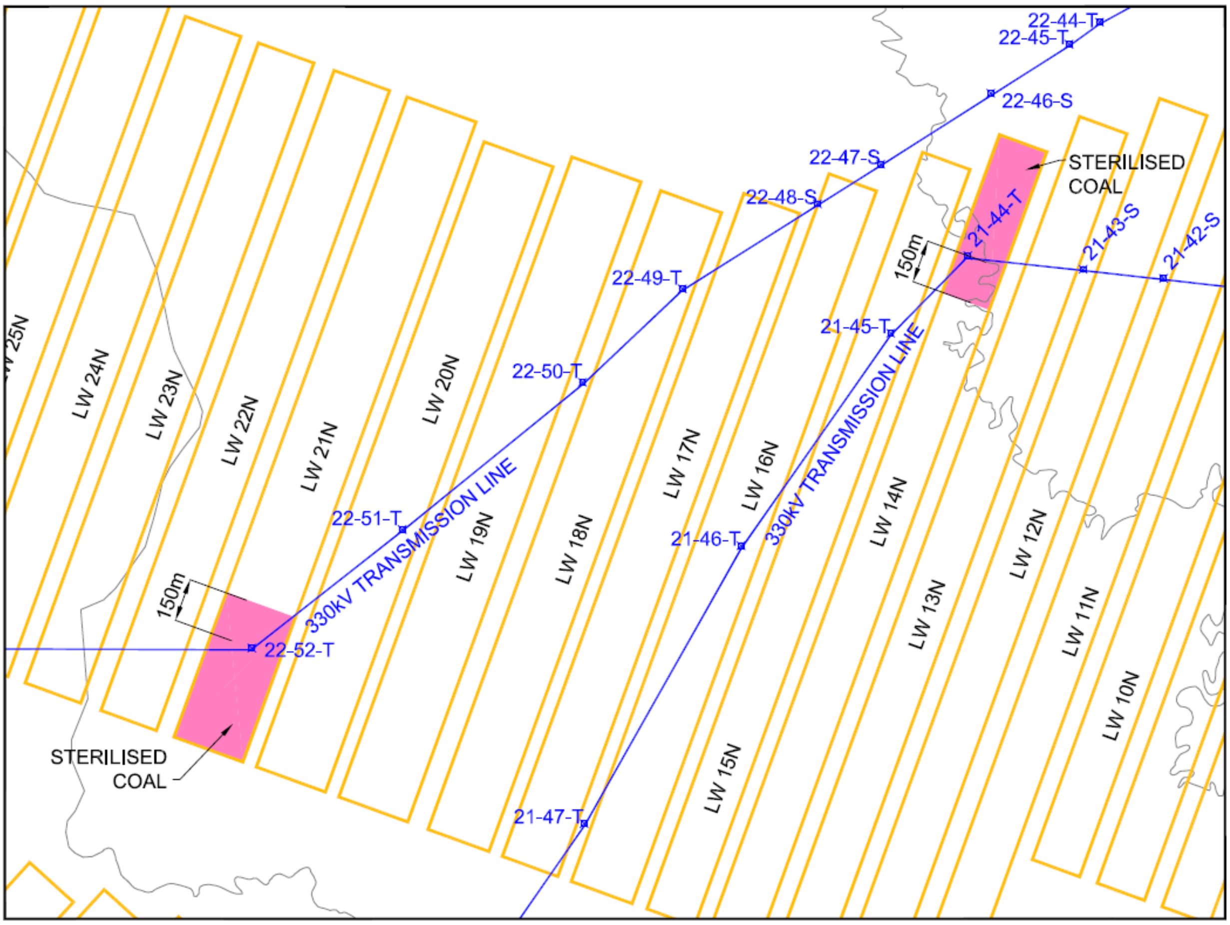


Fig. 5.5 Plan showing potential coal sterilisation if no preventative works are undertaken at the two high angled tension towers labelled Tower 21-44-T and Tower 22-52-T

Since the two high angled tension towers labelled Tower 21-44-T and Tower 22-52-T are not planned to be undermined within the first twenty years of the life of the project, it is recommended that a subsidence management committee be established, with officers from the WACJV, TransGrid and the Mine Subsidence Board, with the view to avoid sterilising coal in the cases where cruciform solutions would not work. As subsidence-resistant tension towers have been constructed in many countries overseas, it is expected that replacement towers could be installed to support these transmission lines.

The research programme would need to consider new solutions to overcome this subsidence problem and the study would include further literature reviews, detailed analysis and possibly building some trial towers over active longwalls to help analyse, observe and monitor the performance of various alternative towers that may allow the safe operation of the transmission lines and may avoid coal sterilisation. This research would only proceed with this option if TransGrid, MSB and the WACJV all agreed to work on this potential research project.

It will be necessary to monitor the ground movements, so that the management strategies can be assessed based on actual ground movements.

5.13.3. Impact Assessments for the 330 kV Transmission Lines Based on Increased Predictions

It is recommended that appropriate factors of safety are applied in the detailed structural analysis of the transmission lines undertaken by TransGrid. These factors of safety should be applied in the design of any necessary preventive measures required for the towers.

5.13.4. Recommendations for the 330 kV Transmission Lines

It is recommended that the discussions between WACJV and TransGrid should continue so that preventive measures can be developed by investigating each of the possible options that provide for the continued safe operation of the transmission lines and avoid the sterilisation of such large quantities of coal resources. It is also recommended that a subsidence management committee be established, with officers from the WACJV, TransGrid and the Mine Subsidence Board, so that the appropriate management strategies can be developed.

It is recommended that the ground movements are monitored so that the subsidence predictions can be reviewed and, if necessary, revised base on the latest available monitoring data. The first tension tower is located above Longwall 5N and monitoring data will be available from the first four longwalls prior to this tower being directly mined beneath. By this stage, at least twenty years of monitoring data will be available before longwall extraction approaches the first high angled tension tower and at that time appropriate management strategies can be developed by the envisaged subsidence management committee.

5.14. 132 kV Transmission Line

The 132 kV transmission line is predicted to experience less than 20 mm of subsidence. While it is possible that this transmission line could experience subsidence slightly greater than 20 mm, as the result of far-field vertical movements, it would not be expected to experience any significant tilts, curvatures or strains.

The 132 kV transmission could be subjected to small far-field horizontal movements as the result of the extraction of the proposed longwalls. Far-field horizontal movements have, in the past, been observed at similar distances as the transmission line is from the proposed longwalls, however, these movements tend to be bodily movements associated with very low levels of strain.

It is unlikely, therefore, that the 132 kV Transmission Line would experience any significant impacts resulting from the extraction of the proposed longwalls, even if the predictions were increased by factors of up to 2 times.

5.15. Powerlines

The locations of the powerlines within the Study Area are shown in Drawing No. MSEC428-14. The predictions and impact assessments for powerlines are provided in the following sections.

5.15.1. Predictions for the Powerlines

The powerlines are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4. If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the maximum predicted subsidence parameters would be expected to be similar to those provided in Chapter 4.

The predicted subsidence parameters vary across the Study Area as the result of, amongst other factors, variations in the depths of cover, longwall void widths and extraction heights. The variations in the predicted conventional subsidence parameters are illustrated along Prediction Lines 1, 2, 3 and 4 which are provided in Fig. E.01, E.02, E.03 and E.04, respectively, in Appendix E.

The powerlines are linear features and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines from previous longwall mining. The analysis of strains measured along monitoring lines during the mining of previous longwalls in the Newcastle Coalfield is provided in Section 4.3.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The aerial powerlines are not affected by ground strains, as they are supported by the poles above ground level. The aerial cables can, however, be affected by the changes in bay lengths, i.e. the distances between the poles at the levels of the cables, which result from mining induced differential subsidence, horizontal ground movements and lateral movements at the tops of the poles due to tilting of the poles. The stabilities of the poles can also be affected by mining induced tilts and by changes in the catenary profiles of the cables.

The maximum predicted conventional tilt within the Study Area is 15 mm/m (i.e. 1.5 %), which represents a change in verticality of 1 in 65. The predicted horizontal ground movement associated with the maximum predicted conventional tilt is in the order of 200 mm. The maximum predicted horizontal movement at the tops of the poles, based on a height of 12 metres is, therefore, approximately 400 mm.

A number of powerlines have been mined directly beneath by longwalls previously extracted in the NSW Coalfields, some of which have been summarised in Table 5.11.

Table 5.11 Previous Experience of Mining Beneath Powerlines in the NSW Coalfields

Colliery and LWs	Length of Powerlines Directly Mined Beneath (km)	Observed Maximum Movements at Powerlines	Observed Impacts
Beltana Why LW1 to LW11	Longwalls have mined beneath 2 km of 66 kV powerlines	1500 mm Subsidence 50 mm/m Tilt (Measured Charlton Rd)	No significant impacts after installation of preventive measures including roller sheaves and intermediate poles
Dendrobium LW3 and LW4	Longwalls have mined beneath 0.8 km of 33 kV powerlines	1100 mm Subsidence 40 mm/m Tilt (Measured D2000-Line)	No significant impacts
South Bulga Why LW1 to LW6	Longwalls have mined beneath 4 km of 11 kV and 4 km of 66 kV powerlines	1800 mm Subsidence 40 mm/m Tilt (Measured Broke Rd)	No significant impacts after installation of preventive measures including roller sheaves and intermediate poles
Tahmoor LW22 to LW24A	Longwalls have mined beneath approx. 17 km of powerlines and 380 power poles	1200 mm Subsidence 6 mm/m Tilt (Extensive street monitoring)	Some minor adjustments to cable catenaries, pole tilts and consumer cables required.

It can be seen from the above table, that there have been only minor impacts on powerlines which have been directly mined beneath by previously extracted longwalls in the NSW Coalfields. In some cases preventive measures were required, including the installation of roller sheaves and additional poles, and in other cases remedial measures were required, including adjustments to the cable catenaries, pole tilts and consumer cables which connect between the powerlines and the houses. The incidence of these impacts were, however, relatively infrequent and were readily repaired.

Based on this experience, it is likely that the extraction of the proposed longwalls would only result in relatively minor impacts on the powerlines within the Study Area. It is possible that some remedial measures would be required, including some adjustments of the cable catenaries, pole tilts and the consumer cables, as has been undertaken in the past, and that any impacts are expected to be relatively infrequent and readily repaired.

5.15.2. Impact Assessments for the Powerlines Based on Increased Predictions

If the predicted conventional tilts were increased by factors of up to 2 times, the maximum predicted tilt within the Study Area would be 30 mm/m (i.e. 3 %), which represents a change in verticality of 1 in 35. As shown Table 5.11, longwalls have been successfully mined beneath powerlines in the NSW Coalfields, where the tilts were greater than 30 mm/m, after the implementation of the necessary preventive measures, such as the installation of roller sheaves and additional poles.

In this case, it would be expected that some remedial measures would be required, including the adjustments of the cable catenaries, pole tilts and the consumer cables, as has been undertaken in the past, but any impacts would still be expected to be relatively infrequent and readily repaired.

5.15.3. Recommendations for the Powerlines

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

It is recommended that management strategies are developed, in consultation with Energy Australia, such that the powerlines can be maintained in safe and serviceable conditions throughout the mining period.

5.16. Local Substation

The local substation is located between the northern and south-eastern series of longwalls and is at a distance of 250 metres north of Longwall 5S, at its closest point to the proposed longwalls.

At this distance, the substation is predicted to experience less than 20 mm of subsidence. While it is possible that the substation could experience subsidence slightly greater than 20 mm, as the result of far-field vertical movements, it would not be expected to experience any significant tilts, curvatures or strains.

It is unlikely, therefore, that the substation would experience any significant impacts resulting from the extraction of the proposed longwalls, even if the predictions were increased by factors of up to 2 times.

5.17. Copper Telecommunications Cables

The locations of the copper telecommunications cables within the Study Area are shown in Drawing No. MSEC428-15. The predictions and impact assessments for these cables are provided in the following sections.

5.17.1. Predictions for the Copper Telecommunications Cables

The copper telecommunications cables are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4. If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the maximum predicted subsidence parameters would be expected to be similar to those provided in Chapter 4.

The predicted subsidence parameters vary across the Study Area as the result of, amongst other factors, variations in the depths of cover, longwall void widths and extraction heights. The variations in the predicted conventional subsidence parameters are illustrated along Prediction Lines 1, 2, 3 and 4 which are provided in Fig. E.01, E.02, E.03 and E.04, respectively, in Appendix E.

The cables are linear features and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines from previous longwall mining. The analysis of strains measured along monitoring lines during the mining of previous longwalls in the Newcastle Coalfield is provided in Section 4.3.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, valley related upsidence and closure movements and anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements. The strains resulting from valley related movements are discussed separately in the following sections.

5.17.2. Impact Assessments for the Copper Telecommunications Cables

The direct buried copper telecommunications cables are unlikely to be impacted by tilt. The cables are also unlikely to be impacted by curvature, as the cables are flexible and would be expected to tolerate the minimum predicted radius of curvature within the Study Area of 3 kilometres.

The direct buried copper cables could, however, be affected by the ground strains resulting from the extraction of the proposed longwalls. The cables are more likely to be impacted by tensile strains rather than compressive strains.

It is possible, that the direct buried cables could experience higher tensile strains where they are anchored to the ground by associated infrastructure, or by tree roots. The cables could also experience higher compressive strains at the creek crossings as the result of valley related movements.

The aerial copper telecommunications cables are not affected by ground strains, as they are supported by the poles above ground level. The aerial cables can, however, be affected by the changes in bay lengths, i.e. the distances between the poles at the levels of the cables, which result from mining induced differential subsidence, horizontal ground movements and lateral movements at the tops of the poles due to tilting of the poles. The stabilities of the poles can also be affected by mining induced tilts and by changes in the catenary profiles of the cables.

The maximum predicted conventional tilt within the Study Area is 15 mm/m (i.e. 1.5 %), which represents a change in verticality of 1 in 65. The predicted horizontal ground movement associated with the maximum predicted conventional tilt is in the order of 200 mm. The maximum predicted horizontal movement at the tops of the poles, based on a height of 12 metres is, therefore, approximately 400 mm.

A number of direct buried and aerial copper telecommunications cables have been mined directly beneath by previously extracted longwalls in the NSW Coalfields, some of which have been summarised in Table 5.12.

Table 5.12 Previous Experience of Mining Beneath Copper Telecommunications Cables in the NSW Coalfields

Colliery and LWs	Copper Cables	Observed Maximum Movements at the Copper Cables	Observed Impacts
Appin LW401 to LW408	Longwalls have mined beneath 4 km of underground cables and 0.8 km of aerial cables	700 mm Subsidence 5 mm/m Tilt 1 mm/m Tensile Strain 2 mm/m Comp. Strain (Measured A6000-Line)	No significant impacts
Tahmoor LW22 to LW24A	Longwalls have mined beneath 19 km of underground cables and 2.5 km of aerial cables	1200 mm Subsidence 6 mm/m Tilt 1.5 mm Tensile Strain 2.0 mm (typ.) and up to 5.0 mm/m Comp. Strain (Extensive street monitoring)	No significant impacts to underground cables. Some pole tilts and cable catenaries adjusted. Some consumer cables were re-tensioned as a precautionary measure
West Cliff LW29 to LW33	Longwalls have mined beneath 13 km of underground cables	950 mm Subsidence 1 mm/m Tensile Strain 5.5 mm/m Comp. Strain (Measured B-Line)	No significant impacts

It can be seen from the above table, that there were no reported impacts on the direct buried copper telecommunications cables in the above examples. It is also understood, that there have been no significant impacts on direct buried copper telecommunications cables elsewhere in the NSW Coalfields, where the depths of cover were greater than 350 metres, such as the case for the proposed longwalls.

It can also be seen from the above table, that there have been only minor impacts on the aerial copper telecommunications cables in the above examples. Some remedial measures were required, which included adjustments to cable catenaries, pole tilts and consumer cables which connect between the poles and houses. The incidence of these impacts was very low.

Based on this experience, it is unlikely that the extraction of the proposed longwalls would result in any significant impacts on the direct buried or aerial copper telecommunications cables within the Study Area. Any impacts on these cables would be expected to be relatively infrequent and readily repaired.

5.17.3. Impact Assessments for the Copper Telecommunications Cables Based on Increased Predictions

If the predicted conventional strains were increased by factors of up to 2 times, the magnitudes of strains would be less than the range of strains experienced at Collieries with much shallower depths of cover, such as Beltana and South Bulga. As shown Table 5.12, longwalls have been successfully mined beneath direct buried copper telecommunications cables where the measured strains were up to 5.5 mm/m.

If the predicted conventional tilts were increased by factors of up to 2 times, the maximum predicted tilt within the Study Area would be 30 mm/m (i.e. 3 %), which represents a change in verticality of 1 in 35. As shown Table 5.12, longwalls have been successfully mined beneath aerial copper telecommunications cables in the NSW Coalfields where the measured tilts were greater than 6 mm/m and only on minor impacts have been observed.

5.17.4. Recommendations for the Copper Telecommunications Cables

It is recommended that management strategies are developed, in consultation with Telstra, such that the copper telecommunications cables can be maintained in serviceable conditions throughout the mining period.

5.18. Optical Fibre Cables

The locations of the optical fibre cables within the Study Area are shown in Drawing No. MSEC428-15. The predictions and impact assessments for the cables are provided in the following sections.

5.18.1. Predictions for the Optical Fibre Cables

A Telstra optical fibre cable crosses directly above Longwalls 11N to 15N and Longwalls 1S to 5S. The predicted profiles of conventional subsidence, tilt and curvature along this cable, resulting from the extraction of the proposed longwalls, is provided in Fig. E.11 in Appendix E. A summary of the maximum predicted values of conventional subsidence movements for this cable is provided in Table 5.13.

Table 5.13 Maximum Predicted Conventional Subsidence, Tilt and Curvatures for the Telstra Optical Fibre Cable Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
Telstra Optical Fibre Cable	2150	10	0.13	0.19

A second Telstra optical fibre cable services the CMTS site, which is located above the commencing (south-western) end of Longwall 1N. The maximum predicted conventional subsidence parameters for this cable are the same as those for CMTS site, which are summarised in Section 5.19.

The Telstra optical fibre cable located south of the Study Area is at a minimum distance of 400 metres from the proposed longwalls. The optical fibre cables along Hue Hue Road and the Sydney-Newcastle Freeway are located at minimum distances of 285 metres and 1.1 kilometres, respectively, from the proposed longwalls. It is not expected that these cables will be subjected to any significant conventional subsidence movements resulting from the extraction of the proposed longwalls.

The optical fibre cables are linear features and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines from previous longwall mining. The analysis of strains measured along monitoring lines during the mining of previous longwalls in the Newcastle Coalfield is provided in Section 4.3.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, valley upsidence and closure movements and anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The optical fibre cables cross a number of streams within and immediately adjacent to the Study Area, the locations of which are shown in Drawing No MSEC428-15. A summary of the maximum predicted valley related upsidence and closure movements at the major stream crossings, resulting from the extraction of the proposed longwalls, is provided in Table 5.14.

Table 5.14 Maximum Predicted Valley Related Upsidence and Closure Movements at the Major Stream Crossings Resulting from the Extraction of the Proposed Longwalls

Location	Description	Maximum Predicted Upsidence (mm)	Maximum Predicted Closure (mm)
Crossing 1	Tributary 1 to Jilliby Jilliby Creek	< 20	< 20
Crossing 2	Tributary 2 to Jilliby Jilliby Creek	100	70
Crossing 3	Little Jilliby Jilliby Creek	30	25
Crossing 4	Tributary 3 to Jilliby Jilliby Creek	200	175
Crossing 5	Jilliby Jilliby Creek	40	25
Crossing 6	Jilliby Jilliby Creek	< 20	< 20
Crossing 7	Jilliby Jilliby Creek	< 20	< 20
Crossing 8	Hue Hue Creek	< 20	< 20

5.18.2. Impact Assessments for the Optical Fibre Cables

The optical fibre cables are direct buried and, therefore, could potentially be impacted by ground strains. The greatest potential for impacts will occur as the result of localised ground strains due to non-conventional movements or valley related movements.

The tensile strains in the optical fibre cables could be higher than predicted, where the cables connect to the support structures, which may act as anchor points, preventing any differential movements that may have been allowed to occur in the ground. Tree roots have also been known to anchor cables to the ground. The extent to which the anchor points affect the ability of the cables to tolerate the mine subsidence movements depends on the cable size, type, age, installation method and ground conditions.

In addition to this, optical fibre cables contain additional fibre lengths over the sheath lengths, where the individual fibres are loosely contained within tubes. Compression of the sheaths can transfer to the loose tubes and fibres and result in “micro-bending” of the fibres constrained within the tubes, leading to higher attenuation of the transmitted signal. If the maximum predicted compressive strains were to be fully transferred into the optical fibre cables, the strains could be of sufficient magnitude to result in the reduction in capacities of the cables or transmission loss.

The strains transferred into the optical fibre cables can be monitored using Optical Time Domain Reflectometer (OTDR), which can be used to notify the infrastructure owners of strain concentrations due to anomalous or valley related movements.

A number of optical fibre cables have been mined directly beneath by previously extracted longwalls in the Coalfields of New South Wales. A summary of some of the optical fibre cables which have been directly mined beneath is provided in Table 5.15.

Table 5.15 Previous Experience of Mining Beneath Optical Fibre Cables

Colliery and LWs	Length of Optical Fibre Cables Directly Mined Beneath (km)	Observed Maximum Movements at Optical Fibre Cables	Pre-Mining Mitigation, Monitoring and Observed Impacts
Appin LW301 and LW302	0.8	650 mm Subsidence 0.7 mm/m Tensile Strain 2.8 mm/m Comp. Strain	600 metre aerial cable on standby. Ground survey, visual, OTDR. No reported impacts.
Beltana LW1 to LW10 and South Bulga LW1, LW4 to LW6 and LWE1	7.4	1685 mm Subsidence 15 mm/m Tensile Strain 8 mm/m Comp. Strain	Installed in conduit at Beltana and partial cut over at South Bulga. Ground survey, visual, OTDR. None at Beltana and loss of 2dB at South Bulga
Tahmoor LW22 to LW24A	1.2	775 mm Subsidence 0.8 mm/m Tensile Strain 1.9 mm/m Comp. Strain	Ground survey, visual, OTDR, SBS. No reported impacts.
Tower LW1 to LW10	1.7	400 mm Subsidence 3 mm/m Tilt 0.5 mm/m Tensile Strain 1.0 mm/m Comp. Strain	No reported impacts
West Cliff LW5A3, LW5A4 and LW29 to LW32	2.3	930 mm Subsidence 1.2 mm/m Tensile Strain 5.0 mm/m Comp. Strain	Survey, visual, OTDR, SBS. No reported impacts.
West Wallsend LW27	0.2	350 mm Subsidence 1.3 mm/m Tensile Strain 1.7 mm/m Comp. Strain	Cut over clear of Longwall 27. Ground survey, visual, OTDR. No reported impacts.

It can be seen from the above table, that optical fibre cables have been successfully mined directly beneath by previously extracted longwalls in the Coalfields of New South Wales, with the implementation of suitable management strategies. It is recommended that the predicted movements are reviewed by the infrastructure owners, to assess the potential impacts and to develop the appropriate management strategies.

5.18.3. Impact Assessments for the Optical Fibre Cables Based on Increase Predictions

If the predicted strains were increased by factors of up to 2 times, the maximum predicted strains for the optical fibre cables within the Study Area would be less than the range of strains experienced at Collieries with much shallower depths of cover, such as Beltana and South Bulga. As shown Table 5.15, longwalls have been successfully mined beneath optical fibre cables where the measured strains were up to 15 mm/m, with the implementation of suitable management strategies.

5.18.4. Recommendations for the Optical Fibre Cables

It is recommended that the optical fibre cables are monitored during the extraction of the proposed longwalls using optical fibre sensing techniques, such as OTDR monitoring. Mitigation measures can be undertaken, such as excavating and exposing the cables, if strain concentrations are detected during the mining period. With the required mitigation measures in place, it is expected that the optical fibre cables can be maintained in serviceable conditions throughout the mining period.

It is recommended that management strategies are developed, in consultation with the infrastructure owners, such that the cables can be maintained in serviceable conditions throughout the mining period.

5.19. Cellular Mobile Telephone Services Sites

There is one Cellular Mobile Telephone Services (CMTS) site identified within the Study Area, the location of which is shown in Drawing No. MSEC428-15. The predictions and impact assessments for this site are provided in the following sections.

5.19.1. Predictions for the CMTS Site

A summary of the maximum predicted values of conventional subsidence, tilt and curvatures for the CMTS site, at any time during or after the extraction of the proposed longwalls, is provided in Table 5.16.

Table 5.16 Maximum Predicted Conventional Subsidence, Tilt and Curvatures for the CMTS Site Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
CMTS Site	250	2.5	0.02	< 0.01

The values provided in the above table are the maximum predicted parameters within 20 metres of the centre of the site, at any time during or after the extraction of the proposed longwalls.

The CMTS site is at a discrete location above goaf and, therefore, the most relevant distribution of strain is the maximum strains measured in individual survey bays above goaf from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.19.2. Impact Assessments for the CMTS Site

The maximum predicted tilt for the CMTS site, resulting from the extraction of the proposed longwalls, is 2.5 mm/m (i.e. 0.3 %), which represents a change in grade of 1 in 400. The maximum predicted tilt is small, less than 1 % and unlikely, therefore, to affect the structural integrity or serviceability of the shed structures containing the telecommunications equipment.

It is possible, however, that predicted tilt could affect the performance of the tower mounted panels or microwave dishes, as these antennae can be sensitive to angular deviations. The maximum predicted tilt represents an angular deviation of approximately 0.1° and, therefore, it is expected that this could be managed by making any necessary adjustments to the lines of sight during the active subsidence period.

The maximum predicted ground curvatures for the CMTS site are 0.02 km^{-1} hogging and less than 0.01 km^{-1} sagging, which represent minimum radii of curvature of 50 kilometres and less than 100 kilometres, respectively. The shed structures containing the telecommunications equipment are small and of light-weight construction and, therefore, would not be expected to be impacted by the predicted curvatures and ground strains.

It is recommended that the predicted movements for the CMTS site are provided to Telstra so that detailed structural analyses of the towers and associated infrastructure can be undertaken. Suitable preventive measures should be established, in consultation with Telstra, so that the towers and associated infrastructure can be maintained in safe and serviceable conditions throughout the mining period.

5.19.3. Impact Assessments for the CMTS Site Based on Increased Predictions

If the predicted conventional tilts were increased by factors of up to 2 times, the maximum predicted tilt for the CMTS would still be less than 1 % and unlikely, therefore, to affect the structural integrity or serviceability of the shed structures containing the telecommunications equipment. It would still be expected that the serviceability of the antennae could be managed by making any necessary adjustments to the lines of sight during the active subsidence period.

If the predicted conventional curvatures were increased by factors of up to 2 times, the minimum radius of curvature would be 25 kilometres and unlikely, therefore, to result in any impacts on the small and light-weight sheds containing the telecommunications equipment.

It is recommended that that detailed structural analyses of the towers and associated infrastructure include the appropriate factors of safety. In this way, the towers and associated infrastructure can be maintained in safe and serviceable conditions throughout the mining period.

5.19.4. Recommendations for the CMTS Site

It is recommended that the predicted movements for the CMTS site are provided to Telstra so that detailed structural analyses of the towers and associated infrastructure can be undertaken. Suitable preventive measures should be established, in consultation with Telstra, so that the towers and associated infrastructure can be maintained in safe and serviceable conditions throughout the mining period.

It is also recommended that strategies to developed to manage the potential risks of rockfalls from the rock face that is adjacent to the site. It is recommended that periodic visual inspections of the rock face are undertaken during the active subsidence period.

5.20. Public Amenities

The locations of the public amenities within the Study Area are shown in Drawing No. MSEC428-20. The predictions and impact assessments for these features are provided in the following sections.

5.20.1. Jilliby Public School

The Jilliby Public School is located between the northern and south-eastern series of longwalls and is at a distance of 250 metres north-west of Longwall 4S, at its closest point to the proposed longwalls.

At this distance, the school is predicted to experience less than 20 mm of subsidence. While it is possible that the school could experience subsidence slightly greater than 20 mm, as the result of far-field vertical movements, it would not be expected to experience any significant tilts, curvatures or strains.

It is unlikely, therefore, that the school would experience any significant impacts resulting from the extraction of the proposed longwalls, even if the predictions were increased by factors up to 2 times.

5.20.2. Scout Camp

The scout camp is located between the northern and south-eastern series of longwalls and is at a distance of 325 metres north-west of Longwall 7S, at its closest point to the proposed longwalls.

At this distance, the scout camp is predicted to experience less than 20 mm of subsidence. While it is possible that the school could experience subsidence slightly greater than 20 mm, as the result of far-field vertical movements, it would not be expected to experience any significant tilts, curvatures or strains.

It is unlikely, therefore, that the scout camp would experience any significant impacts resulting from the extraction of the proposed longwalls, even if the predictions were increased by factors up to 2 times.

5.21. Agriculture and Farm Lands

As farming could be affected by changes in the groundwater regime resulting from the extraction of the proposed longwalls, detailed studies on the potential impacts and consequences of subsidence have been undertaken and the results are presented in the report by Mackie (2009).

It is recommended that the WACJV develop management strategies, in consultation with the owners, to manage the potential for impacts to these agricultural businesses.

5.22. Commercial Sites

The locations of the commercial sites within the Study Area are shown in Drawing No. MSEC428-20. The predictions and impact assessments for these sites are provided in the following sections.

5.22.1. Disused Quarry Site

The disused quarry site is located above the proposed Longwalls 14N and 15N. It is possible that the quarry could become operational by the time longwall mining occurs beneath this site.

The mine subsidence movements resulting from the extraction of the proposed longwalls could dislodge marginally stable rocks or loose boulders on the quarry faces. The potential for rock falls poses a safety risk for people beneath the quarry faces.

It is recommended that access should be restricted from beneath the quarry faces as the proposed longwalls are mined beneath the site. If the quarry site is operational, then it is also recommended that the quarry faces should be visually monitored by a geotechnical engineer on a regular basis during the active subsidence period.

It is recommended that management strategies are developed, in consultation with the owners, so that the potential for rock falls can be managed throughout the mining period.

5.22.2. Horse Studs

The Linton Park and the Parkview horse studs are generally located between the northern and south-eastern series of longwalls. The northern boundary of Linton Park is located above the southern ends of Longwalls 7N to 9N and the southern boundary of Parkview is located above the northern ends of Longwalls 3S and 4S.

The main potential impact at these sites is considered to be surface cracking. The depth of cover in the locations of these horse studs is 400 metres and, therefore, only minor and isolated surface cracking would be expected directly above the proposed longwalls. Surface cracking can be identified by visual inspections and can be easily repaired so as to manage any hazards to horses. Further discussions on the potential for surface cracking are provided in Section 4.6. The potential impacts on the building structures, farm dams and associated infrastructure on these sites are provided in Sections 5.23 to 5.25.

5.22.3. Nursery

The Moonpar Nursery is located above Longwall 3S. The nursery could experience the full range of predicted subsidence movements from this longwall. A summary of the maximum predicted conventional subsidence movements above Longwalls 1S to 10S is provided in Chapter 4.

It is possible, that the in-ground plants could be affected by changes in the groundwater regime resulting from the extraction of the proposed longwalls. Discussions on the groundwater model and potential impacts on the groundwater regime are provided in the report by Mackie (2009). The potential impacts on the building structures and associated infrastructure on this site are provided in Sections 5.23 to 5.25.

5.22.4. Aviary

The Highland Park Aviary is located above Longwalls 6N and 7N. The aviary could experience the full range of predicted subsidence movements from these longwalls. A summary of the maximum predicted conventional subsidence movements above Longwalls 6N to 26N is provided in Chapter 4. The potential impacts on the building structures and associated infrastructure on this site are provided in Sections 5.23 to 5.25.

5.22.5. Turf Farm

The DooralongValley Turf farm is located above Longwall 12N. The farm could experience the full range of predicted subsidence movements from this longwall. A summary of the maximum predicted conventional subsidence movements above Longwalls 6N to 26N is provided in Chapter 4.

Planted turf activities require soil moisture management involving substantial irrigated water application and is influenced by natural rainfall and groundwater conditions. Discussions on the groundwater model and potential impacts on the groundwater regime are provided in the report by Mackie (2009). The potential impacts on the building structures and associated infrastructure on this site are provided in Sections 5.23 to 5.25.

5.23. Rural Buildings Structures

The locations of the rural building structures within the Study Area are shown in Drawing No. MSEC428-19. The predictions and impact assessments for these structures are provided in the following sections.

5.23.1. Predictions for the Rural Building Structures

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

A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each rural building structure within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table D.02 in Appendix D.

If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the individual rural building structures would be predicted to experience greater or lesser movements, depending on their locations relative to the longwalls, but the overall levels of movement for the rural building structures across the Study Area would not be expected to change significantly.

The distributions of the maximum predicted conventional subsidence, tilt and curvature for the rural building structures within the Study Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 5.6 and Fig. 5.7.

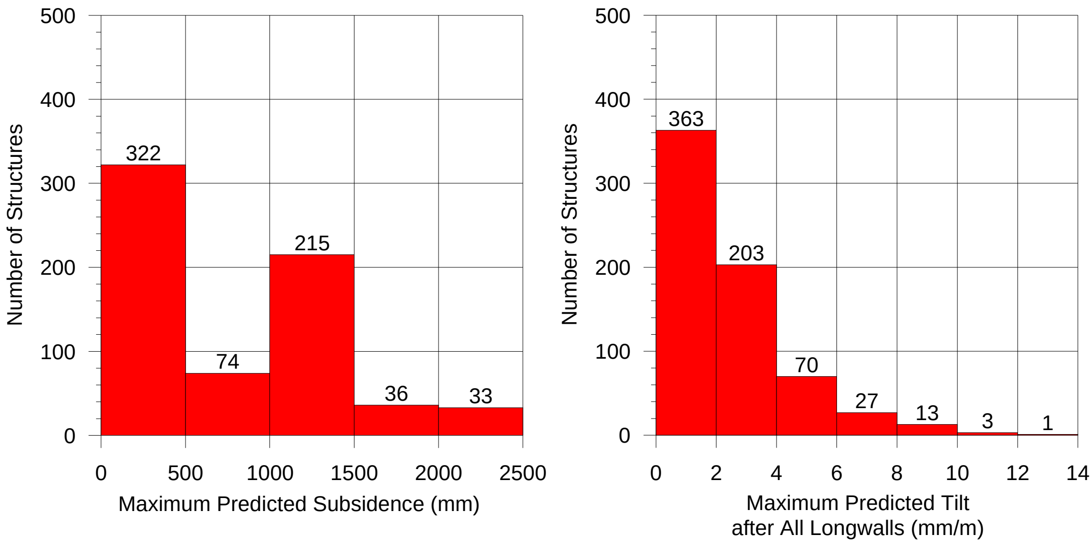


Fig. 5.6 Maximum Predicted Conventional Subsidence and Tilt for the Rural Building Structures within the Study Area Resulting from the Extraction of the Proposed Longwalls

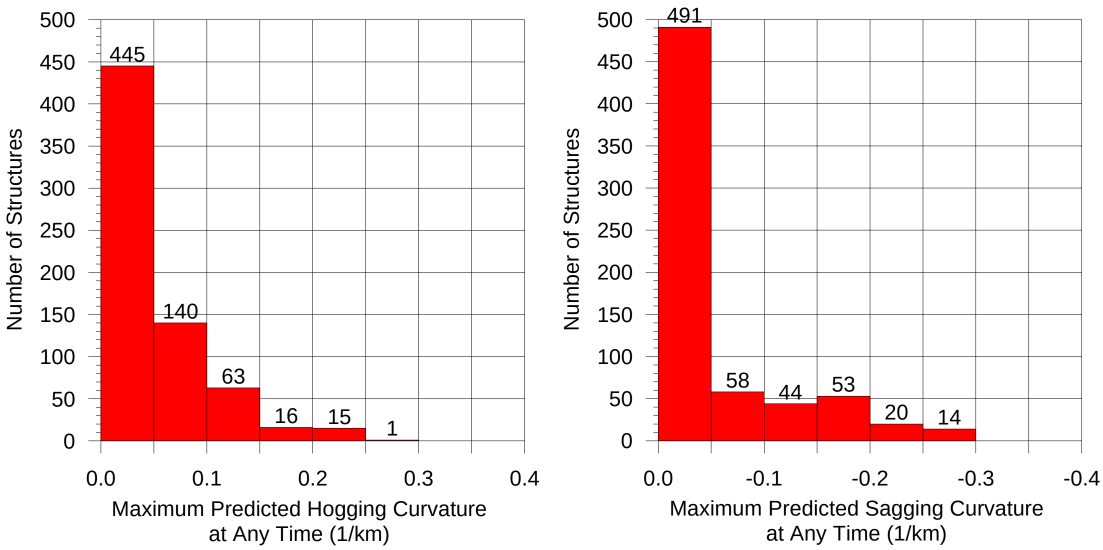


Fig. 5.7 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Rural Structures Resulting from the Extraction of the Proposed Longwalls

The rural building structures are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.23.2. Impact Assessments for the Rural Building Structures

The predicted maximum tilts are less than 7 mm/m at 653 structures (i.e. 96 %), between 7 mm/m and 10 mm/m at 23 structures (i.e. 3 %) and greater than 10 mm/m at four structures (i.e. 1 %) at the completion of mining. The maximum predicted conventional tilt for the rural building structures within the Study Area, at the completion of mining, is 13 mm/m (i.e. 1.3 %), which represents a change in grade of 1 in 75.

The majority of the rural building structures within the Study Area are of lightweight construction. It has been found from past longwall mining experience, that tilts of the magnitudes predicted within the Study Area generally do not result in any significant impacts on rural building structures. Some minor serviceability impacts could occur at the higher levels of predicted tilt, including door swings and issues with roof and pavement drainage, all of which can be remediated using normal building maintenance techniques.

It can be seen from Table D.02, that 526 of the 680 rural structures within the Study Area (i.e. 77 %) are predicted to experience hogging curvatures no greater than 0.10 km^{-1} and sagging curvatures no greater than 0.15 km^{-1}, which represent minimum radii of curvature of 10 kilometres and 7 kilometres, respectively. The range of predicted curvatures at these rural building structures, therefore, is similar to that typically experienced in the Southern Coalfield.

The remaining 154 of the 680 rural building structures within the Study Area (i.e. 23 %) are predicted to experience hogging curvatures up to 0.25 km^{-1} and sagging curvatures up to 0.29 km^{-1}, which represent minimum radii of curvature of 4 kilometres and 3 kilometres, respectively. The maximum predicted curvatures at these rural building structures are greater than those typically experienced in the Southern Coalfield. The depths of cover in these locations are, however, similar to or greater than those in the Southern Coalfield.

As 77 % of the rural building structures within the Study Area are predicted to experience curvatures similar to those experienced in the Southern Coalfield, the observed levels of impact on the rural building structures in the Southern Coalfield should provide a reasonable guide to the overall levels of impact on the rural building structures within the Study Area. A number of rural building structures have been mined directly beneath by previously extracted longwalls in the Southern Coalfield, some of which have been summarised in Table 5.17.

Table 5.17 Previous Experience of Mining Beneath Rural Building Structures in the Southern Coalfield

Colliery and LWs	Rural Building Structures	Maximum Predicted Movements at the Structures	Observed Impacts
Appin LW301 and LW302	4	770 mm Subsidence 6 mm/m Tilt 0.7 mm/m Tensile Strain 1.6 mm/m Comp. Strain	No reported impacts
Appin LW401 to LW408	75	1200 mm Subsidence 5 mm/m Tilt 1.2 mm/m Tensile Strain 2.2 mm/m Comp. Strain	No reported impacts
Appin LW701 and LW702	12	1300 mm Subsidence 5 mm/m Tilt 1.6 mm/m Tensile Strain 2.0 mm/m Comp. Strain	No reported impacts
Tahmoor LW22 to LW24A	79	850 mm Subsidence 5 mm/m Tilt 0.8 mm/m Tensile Strain 1.7 mm/m Comp. Strain	Impacts reported at three rural building structures
West Cliff LW29 to LW33	184	1200 mm Subsidence 6 mm/m Tilt 1.4 mm/m Tensile Strain 1.8 mm/m Comp. Strain	Impacts to four large chicken sheds due to non-conventional movements.

There is extensive experience of mining directly beneath rural building structures in the Southern Coalfield which indicates that the incidence of impacts on these structures is very low. This is not surprising as rural building structures are generally small in size and of light-weight construction, which makes them less susceptible to impact than houses which are typically more rigid. In all cases, the rural building structures remained in safe and serviceable conditions.

It is expected, therefore, that all the rural building structures within the Study Area would remain safe, serviceable and repairable during the mining period, provided that they are in sound existing condition. The risk of impact is clearly greater if the structures are in poor condition, though the chances of there being a public safety risk remains very low. A number of rural building structures which were in poor existing conditions have been directly mined beneath and these structures have not experienced impacts during mining.

Any impacts on the rural building structures that occur as the result of the extraction of the proposed longwalls are expected to be remediated using well established building techniques. With these remediation measures available, it is unlikely that there would be any significant long term impacts on rural building structures resulting from the extraction of the proposed longwalls.

5.23.3. Impact Assessments for the Rural Building Structures Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the incidence of serviceability impacts, such as door swings and issues with gutter and pavement drainage, would increase accordingly. It would still be unlikely that stabilities of these rural building structures would be affected by tilts of these magnitudes.

If the predicted curvatures and strains were increased by factors of up to 2 times, the incidence of impacts on the rural building structures would increase accordingly. Since rural building structures are generally small in size and of light-weight construction, they would still be expected to remain safe, serviceable and repairable using normal building maintenance techniques. With the implementation of any necessary remediation measures, it is unlikely that there would be any significant long term impacts on the rural building structures.

5.23.4. Recommendations for the Rural Building Structures

The assessed impacts on the rural building structures within the Study Area, resulting from the extraction of the proposed longwalls, could be managed with the implementation of suitable management strategies.

It is recommended that the rural building structures located above the proposed longwalls should be inspected, prior to being mined beneath, to assess the existing conditions and whether any preventive measures may be required. It is also recommended that the rural building structures are visually monitored during the extraction of the proposed longwalls. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the rural building structures.

5.24. Farm Fences

The fences are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The fences are linear features and, therefore, the most relevant distribution of strain is the maximum strains measured along whole monitoring lines from previous longwall mining. The analysis of strains measured along monitoring lines during the mining of previous longwalls in the Newcastle Coalfield is provided in Section 4.3.2.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The fences within the Study Area are constructed in a variety of ways, generally using either timber or metal materials.

Wire fences can be affected by tilting of the fence posts and by changes of tension in the fence wires due to strain as mining occurs. These types of fences are generally flexible in construction and can usually tolerate tilts of up to 10 mm/m and strains of up to 5 mm/m without significant impacts. It is likely, therefore, that some of the wire fences within the Study Area would be impacted as the result of the extraction of the proposed longwalls. Any impacts on the wire fences are likely to be of a minor nature and relatively easy to remediate by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

Colorbond and timber paling fences are more rigid than wire fences and, therefore, are more susceptible to impacts resulting from mine subsidence movements. It is possible that these types of fences could be impacted as the result of the extraction of the proposed longwalls. Any impacts on Colorbond or timber paling fences can be remediated or, where necessary, affected sections of the fences replaced.

5.25. Farm Dams

The locations of the farm dams identified within the Study Area are shown in Drawing No. MSEC428-19. The predictions and impact assessments for these features are provided in the following sections.

5.25.1. Predictions for the Farm Dams

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and around the perimeters of each farm dam. A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each farm dam within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table D.03 in Appendix D.

If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the individual farm dams would be predicted to experience greater or lesser movements, depending on their locations relative to the longwalls, but the overall levels of movement for the farm dams across the Study Area would not be expected to change significantly.

The distributions of the maximum predicted conventional subsidence, tilt and curvature for the farm dams within the Study Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 5.8, Fig. 5.9 and Fig. 5.10.

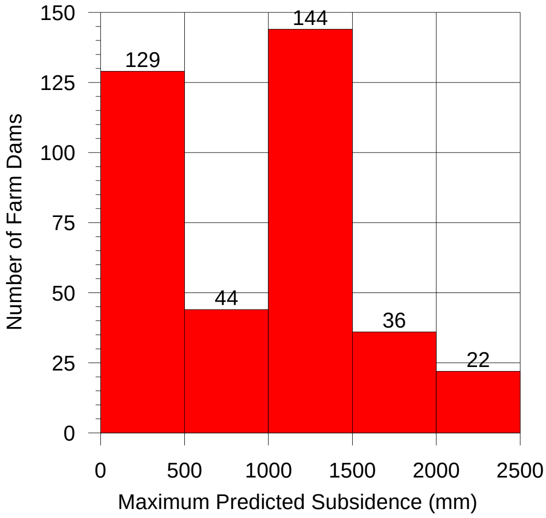


Fig. 5.8 Maximum Predicted Conventional Subsidence for the Farm Dams within the Study Area Resulting from the Extraction of the Proposed Longwalls

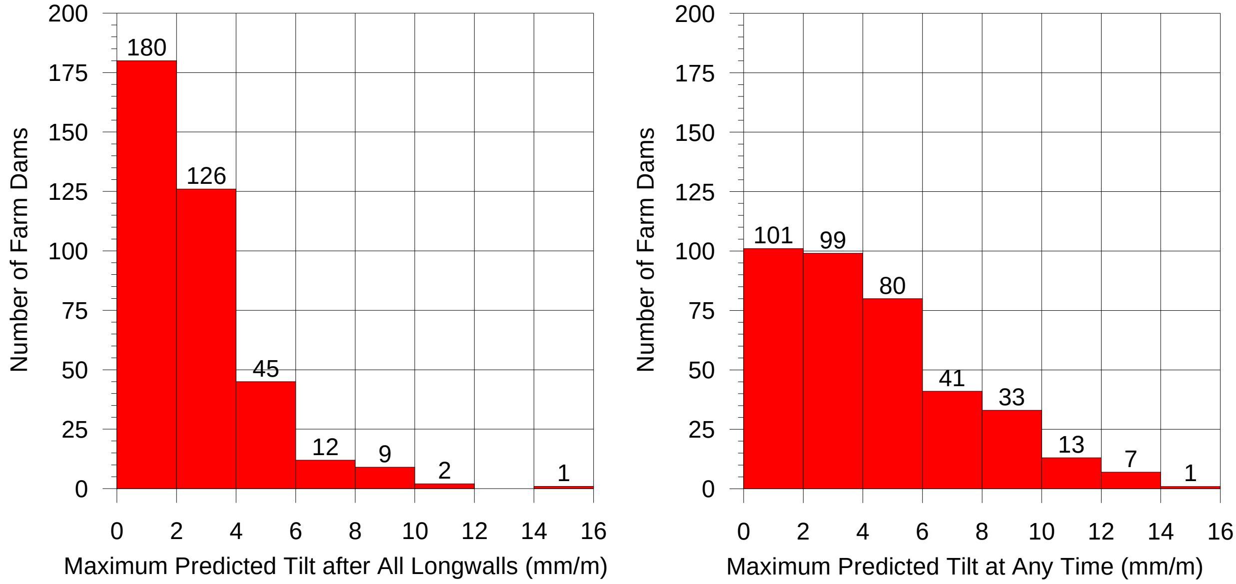


Fig. 5.9 Maximum Predicted Conventional Final and Transient Tilts for the Farm Dams within the Study Area Resulting from the Extraction of the Proposed Longwalls

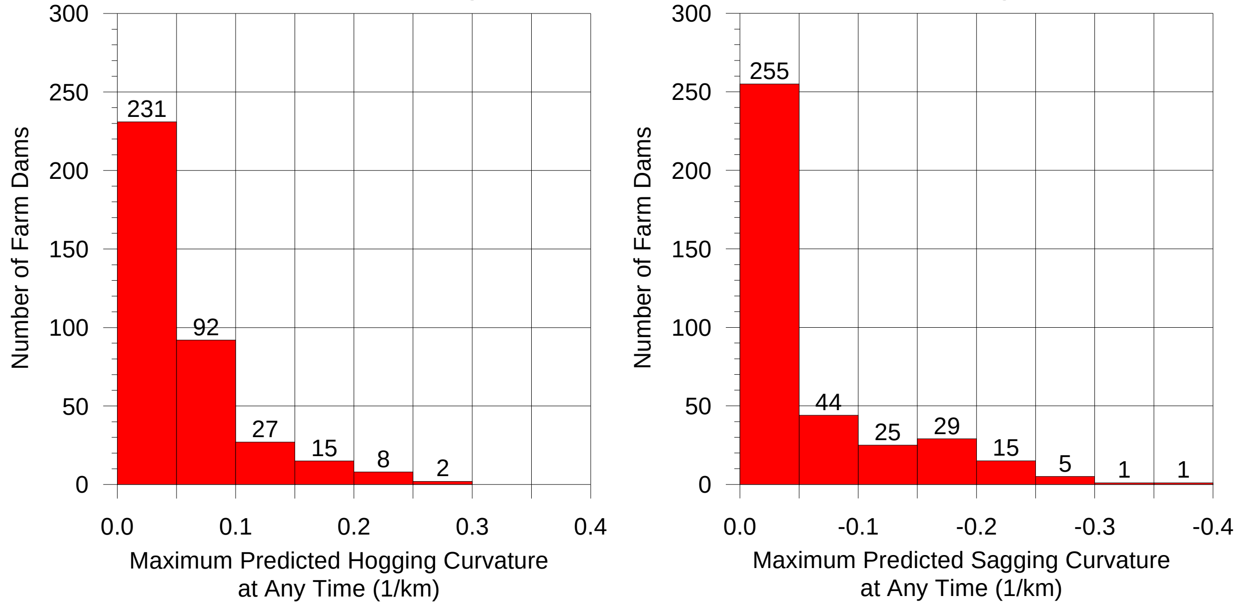


Fig. 5.10 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Farm Dams Resulting from the Extraction of the Proposed Longwalls

The dams have typically been constructed within the drainage lines and, therefore, may be subjected to valley related movements resulting from the extraction of the proposed longwalls. The equivalent valley heights at the dams are very small and it is expected that the predicted valley related upsidence and closure movements at the dam walls would be much less than the predicted conventional subsidence movements and, therefore, are not significant.

The farm dams are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, valley related upsidence and closure movements and anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements. The strains resulting from valley related movements are discussed separately in the following sections.

5.25.2. Impact Assessments for the Farm Dams

The maximum predicted tilt for the farm dams within the Study Area, at the completion of mining, is 14 mm/m (i.e. 1.4 %), which represents a change in grade of 1 in 70. The maximum predicted tilt for the farm dams within the Study Area, at any time during the extraction of the proposed longwalls, is 15 mm/m (i.e. 1.5 %), which represents a change in grade of 1 in 65.

Mining induced tilts can affect the water levels around the perimeters of farm dams, with the freeboard increasing on one side, and decreasing on the other. Tilt can potentially reduce the storage capacity of farm dams, by causing them to overflow, or can affect the stability of the dam walls.

The predicted changes in freeboard at the farm dams within the Study Area were determined by taking the difference between the maximum predicted subsidence and the minimum predicted subsidence anywhere around the perimeter of each farm dam. The predicted maximum changes in freeboard at the farm dams within the Study Area, after the completion of the proposed longwalls, are provided in Table D.03 in Appendix D and is illustrated in Fig. 5.11.

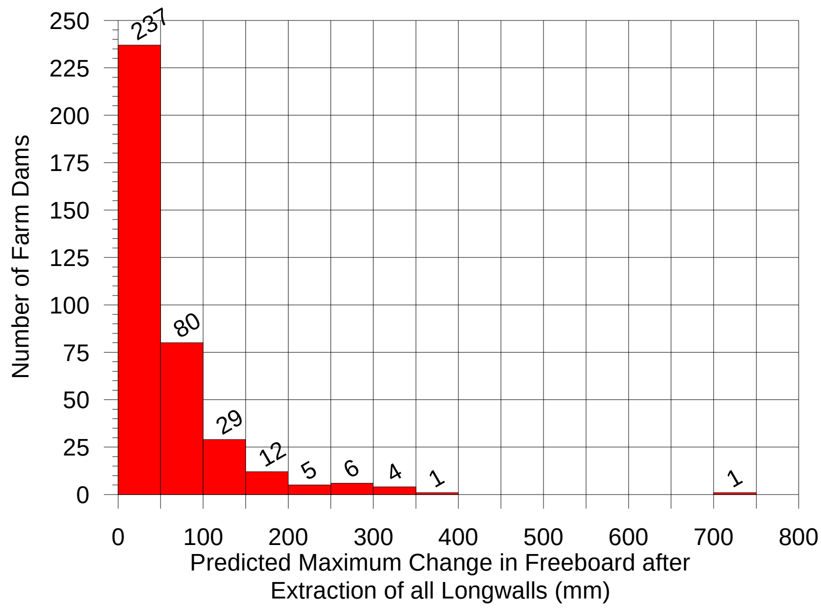


Fig. 5.11 Predicted Changes in Freeboards for the Farm Dams within the Study Area

The maximum predicted change in freeboard is 700 mm, which occurs at a dam near the finishing (north-eastern) end of Longwall 1N. This dam is located above the longwall tailgate and the direction of tilt is predicted to reduce the water level at the dam wall and, hence, is unlikely to affect the stability of the dam wall. The maximum predicted change in freeboard could, however, reduce the storage capacity of the dam and it may be necessary to remediate the dam, if required, to restore the storage capacity of this dam.

The predicted maximum changes in freeboard at the remaining farm dams within the Study Area are all less than 400 mm and are unlikely, therefore, to have a significant impact on the stability of the dam walls or the storage capacities of the farm dams.

It can be seen from Table D.03, that 282 of the 375 farm dams within the Study Area (i.e. 75 %) are predicted to experience hogging curvatures no greater than 0.10 km^{-1} and experience sagging curvatures no greater than 0.15 km^{-1}. The range of predicted curvatures at these dams, therefore, is similar to that typically experienced in the Southern Coalfield.

The remaining 93 of the 375 farm dams within the Study Area (i.e. 25 %) are predicted to experience hogging curvatures up to 0.25 km^{-1} and sagging curvatures up to 0.37 km^{-1}, which represent minimum radii of curvature of 4 kilometres and 3 kilometres, respectively. The maximum predicted curvatures at these farm dams are greater than those typically experienced in the Southern Coalfield. The depths of cover in these locations are, however, similar to or greater than those in the Southern Coalfield.

As 75 % of the farm dams within the Study Area are predicted to experience curvatures similar to those experienced in the Southern Coalfield, the observed levels of impact on the farm dams in the Southern Coalfield should provide a reasonable guide to the overall levels of impact on the farm dams within the Study Area. A number of farm dams have been mined directly beneath by previously extracted longwalls in the Southern Coalfield, some of which have been summarised in Table 5.18.

Table 5.18 Previous Experience of Mining Beneath Farm Dams in the Southern Coalfield

Colliery and LWs	Number of Farm Dams Directly Mined Beneath	Predicted Maximum Movements at Dams	Observed Impacts
Appin LW301 and LW302	3	750 mm Subsidence 6 mm/m Tilt 0.7 mm/m Tensile Strain 1.8 mm/m Comp. Strain	No reported impacts
Appin LW401 to LW408	49	1200 mm Subsidence 5 mm/m Tilt 1.2 mm/m Tensile Strain 2.2 mm/m Comp. Strain	No reported impacts
Appin LW701 and LW702	11	1100 mm Subsidence 4 mm/m Tilt 0.6 mm/m Tensile Strain 1.4 mm/m Comp. Strain	One farm dam reported to drain
Tahmoor LW22 to LW24A	16	850 mm Subsidence 5 mm/m Tilt 1.0 mm/m Tensile Strain 1.7 mm/m Comp. Strain	No reported impacts
West Cliff LW29 to LW33	42	1100 mm Subsidence 6 mm/m Tilt 1.2 mm/m Tensile Strain 2.0 mm/m Comp. Strain	No reported impacts

It can be seen from the above table, that the incidence of impacts on farm dams in the Southern Coalfield is extremely low. The farm dam reported to drain during the extraction of Appin Longwall 702 was of poor, shallow construction and seepage was observed at the base of the dam wall prior to mining. While no impacts were observed on the dam wall itself, the dam was observed to drain following mining of Appin Longwall 702.

It is expected, therefore, that the incidence of impacts on the farm dams within the Study Area, resulting from the extraction of the proposed longwalls, will be extremely low. If cracking or leakage of water were to occur in the farm dam walls, it is expected that this could be easily identified and repaired as required. It is not expected that any significant loss of water will occur from the farm dams, and any loss that did occur would flow into the tributary in which the dam was formed.

5.25.3. Impact Assessments for the Farm Dams Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the predicted changes in freeboard would still be typically less than 1 metre, with the maximum predicted change in freeboard being about 1.5 metres. These levels of movement could reduce the capacities of some dams below acceptable levels and, in these cases, it may be necessary to reinstate the capacities at the completion of mining.

If the predicted curvatures and strains were increased by factors of up to 2 times, the incidence of cracking in the farm dams would increase accordingly. Any surface cracking would still be expected to be of a minor nature and could be readily repaired. With any necessary remediation measures implemented, it is unlikely that any significant impact on the farm dams would occur resulting from the extraction of the proposed longwalls.

5.25.4. Recommendations for the Farm Dams

The assessed impacts on the farm dams, resulting from the extraction of the proposed longwalls, can be managed with the implementation of suitable management strategies. It is recommended that all water retaining structures be visually monitored during the extraction of the proposed longwalls, to ensure that they remain in safe and serviceable conditions. With these management strategies in place, it is unlikely that there would be any significant long term impacts on the farm dams.

5.26. Wells and Bores

There are a total of 13 registered groundwater bores within the general Study Area, the locations of which are shown in Drawing No. MSEC428-17.

The bores are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The bores are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

It is likely that the groundwater bores will experience some impacts as the result of mining of the longwalls, particularly those directly above the proposed longwalls. Impacts may include temporary lowering of the piezometric surface, blockage of the bore due to differential horizontal displacements at different horizons within the strata and changes to groundwater quality. Such impacts on the groundwater bores can be readily managed.

Further discussions on the potential impacts on the groundwater regime, resulting from the extraction of the proposed longwalls, are provided in the report by Mackie (2009).

5.27. Archaeological Sites

An indigenous heritage assessment has being undertaken by OzArk Environmental and Heritage Management. The following sections provide discussions on the potential impacts on the archaeological sites within the Study Area, which should be read in conjunction with the report by OzArk (2010b).

5.27.1. Predictions for the Archaeological Sites

The locations of the seven archaeological sites identified within and immediately adjacent to the Study Area are shown in Drawing No. MSEC428-16. A summary of the maximum predicted values of conventional subsidence, tilts and curvatures for these archaeological sites, at any time during or after the extraction of the proposed longwalls, is provided in Table 5.19.

Table 5.19 Maximum Predicted Conventional Subsidence, Tilts and Curvatures for the Identified Archaeological Sites Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
45-3-3040	2400	5.5	0.06	0.05
45-3-3041	2500	13.5	0.08	0.24
45-3-3042	2100	7.5	0.12	0.03
WSF-AG1	< 20	< 0.2	< 0.01	< 0.01
WSF-AG2	< 20	< 0.2	< 0.01	< 0.01
WSF-AG3	25	0.3	< 0.01	< 0.01
WSF-AG4	25	< 0.2	< 0.01	< 0.01

The values provided in the above table are the maximum predicted parameters within 20 metres of the centre of each archaeological site, at any time during or after the extraction of the proposed longwalls. The predictions are based on the co-ordinates of the sites which were obtained from the AHIMS search.

There are likely to be other archaeological sites within the Study Area in addition to those which have been identified. It is possible that these archaeological sites could be located across the Study Area and, therefore, could experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The archaeological sites are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, valley related upsidence and closure movements and anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements. The strains resulting from valley related movements are discussed separately in the following sections.

5.27.2. Impact Assessments for the Open Sites and PAD Sites

Open Sites and Potential Archaeological Deposit (PAD) Sites can potentially be affected by cracking in the surface soils as the result of mine subsidence movements. It is unlikely, however, that the scattered artefacts or isolated finds themselves would be impacted by surface cracking, as the likelihood of surface cracking being coincident with the precise location of the artefacts is considered low.

Surface cracking in soils as the result of conventional subsidence movements is generally of a minor nature at depths of cover greater than 350 metres, such as the case above the proposed longwalls. Larger cracking or soil heaving has been observed as the result of down slope movements along steep slopes, or in locations of non-conventional movements resulting from near surface geological structures. Further discussions on the surface cracking and are provided in Section 4.6.

Whilst it is unlikely that the scattered artefacts or isolated finds themselves would be impacted by mine subsidence, it is possible that if remediation of surface was required after mining, that these works could potentially impact on the archaeological sites.

It will be necessary to develop the appropriate surface remediation strategies, in the locations of the Open Sites and PAD Sites, such that these sites are not adversely affected by any necessary remediation measures.

Further discussions are provided in the report by OzArk (2010b).

5.27.3. Impact Assessments for the Shelters

Shelters can potentially be impacted by mine subsidence movements including the fracturing of the bedrock and the overhangs, rock falls, or water seepage through joints which may affect any artwork. The main mechanisms which could potentially result in impacts on sandstone shelters are the curvatures and ground strains.

Some shelters could also experience valley related movements, as the result of the extraction of the proposed longwalls, where they are located along the streams within the Study Area. The greatest upsidence and compressive strains due to the closure movements are expected to occur near the bases of the valleys and, therefore, are not expected to be significant in the locations of the shelters, which are generally located along the valley sides.

Although the maximum predicted conventional subsidence parameters within the Study Area are greater than those typically observed in the Southern Coalfield, the depths of cover within the Study Area are similar to or greater than those in the Southern Coalfield. The observed levels of impact on shelters in the Southern Coalfield should, therefore, provide a reasonable guide to the overall levels of impact on the shelters within the Study Area.

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 significant impacts on the shelters, resulting from the extraction of the longwalls, is low. There have been no reported impacts on shelters that have been located outside the extents of previously extracted longwalls in the NSW Coalfields.

Further discussions are provided in the report by OzArk (2010b).

5.27.4. Impact Assessments for Grinding Groove Sites

Grinding Groove Sites can potentially be impacted by fracturing of the bedrock. The main mechanisms which could potentially result in impacts on grinding groove sites are the curvatures, strains and valley related upsidence and closure movements.

The maximum predicted curvatures, strains and valley closure movements are of sufficient magnitude to result in fracturing in the bedrock. Experience in the NSW Coalfields indicates that fracturing of bedrock at depths of cover greater than 350 metres, such as the case within the Study Area, generally occurs in isolated locations and the likelihood that fracturing would be coincident with the grinding groove sites would be considered relatively low.

Preventive measures could be implemented at the grinding groove sites, where required, including slotting of the bedrock around the sites to isolate them from the ground movements. It is possible, however, that the preventive measures could result in greater impacts on the sites than those which would have occurred as the result of mine subsidence movements.

Further discussions are provided in the report by OzArk (2010b).

5.27.5. Impact Assessments for Scarred Trees

Scarred Trees can potentially be impacted by large ground deformations, however, this type of impact has only been observed at very shallow depths of cover. Based on the experience of previous longwall mining in the NSW Coalfields, it has been observed that trees are not impacted by mine subsidence movements at depths of cover greater than 350 metres, such as the case within the Study Area. It is unlikely, therefore, that the scarred trees would be impacted as the result of the extraction of the proposed longwalls.

Further discussions are provided in the report by OzArk (2010b).

5.28. Heritage Sites

The locations of the Heritage Sites and the Potential Heritage Sites within the Study Area are shown in Drawing No. MSEC428-16. The predictions and impact assessments for these sites are provided in the following sections.

5.28.1. Predictions for the Heritage Sites

A summary of the maximum predicted values of conventional subsidence, tilts and curvatures for the Heritage Sites, at any time during or after the extraction of the proposed longwalls, is provided in Table 5.20. A summary of the maximum predicted values of conventional subsidence, tilts and curvatures for the Potential Heritage Sites within the Study Area, at any time during or after the extraction of the proposed longwalls, is provided in Table 5.21.

Table 5.20 Maximum Predicted Conventional Subsidence, Tilts and Curvatures for the Heritage Sites Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
Site 1	850	7.5	0.09	0.04
Site 3	650	7.5	0.08	< 0.01
Site 11	< 20	< 0.2	< 0.01	< 0.01

Table 5.21 Maximum Predicted Conventional Subsidence, Tilt and Curvatures for the Potential Heritage Sites Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
Site G	25	0.4	< 0.01	< 0.01
Site I	25	0.2	< 0.01	< 0.01
Site J	50	0.4	< 0.01	< 0.01
Site K	150	1.5	0.02	< 0.01
Site L	< 20	< 0.2	< 0.01	< 0.01
Site M	75	0.8	< 0.01	< 0.01
Site N	50	0.3	< 0.01	< 0.01
Site O	1250	8.5	0.13	0.15
Site P	1350	8.0	0.06	0.25
Site Q	25	0.4	< 0.01	< 0.01
Site R	1200	4.0	0.05	0.04
Site S	850	11	0.17	0.02

The values provided in the above tables are the maximum predicted parameters within 20 metres of the centre of each site, at any time during or after the extraction of the proposed longwalls.

The Heritage Sites and the Potential Heritage Sites are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.28.2. Impact Assessments for Heritage Site 1 – Brick and Iron Silo

The maximum predicted tilt for the brick and iron silo, at the completion of the proposed longwalls, is 7.5 mm/m (i.e. 0.8 %), which represents a change in grade of 1 in 135. The structure comprises full masonry walls and, therefore, it is unlikely that a tilt of this magnitude would adversely affect the stability of this structure.

The maximum predicted curvatures for the brick and iron silo, resulting from the extraction of the proposed longwalls, are 0.09 km^{-1} hogging and 0.04 km^{-1} sagging, which represent minimum radii of curvature of 11 kilometres and 25 kilometres, respectively.

The Australian Standard AS 2870 (1996) provides guidance on the allowable deflection ratios for various types of structures. The allowable deflection ratio for full masonry structures with non-load bearing walls is 1:1500, which represents an allowable radius of curvature of approximately 3 kilometres based on the structure length of 15 metres.

It is possible, therefore, that the extraction of the proposed longwalls could result in cracking in the masonry walls. Any cracking would be expected to occur in the corners around the openings, possibly limited to the mortar, due to the robust construction of the structure. It would be expected that any cracking could be repaired using normal building maintenance techniques, however, any remediation works on the structure may need to be reviewed by a heritage consultant.

It is recommended that a study is undertaken to assess the potential impacts on the structure. The study may require input from a structural engineer, a subsidence engineer and a heritage consultant. Management strategies should be developed such that the heritage significance of the structure is not adversely affected by mining and to establish the appropriate remediation measures.

5.28.3. Impact Assessments for Heritage Site 3 – Dwelling "Bangalow"

The maximum predicted tilt for the dwelling "Bangalow", at the completion of the proposed longwalls, is 8 mm/m (i.e. 0.8 %), which represents a change in grade of 1 in 125. As described in Section 5.30.2, tilts of around 7 mm/m can result in some minor serviceability impacts on houses, including door swings and issues with roof gutter and wet area drainage, all of which can be remediated using normal building maintenance techniques.

In this case, the predicted tilt is slightly greater than 7 mm/m and it is possible, therefore, that some more substantial remediation measures may be required, including the relevelling of some wet areas. Any remediation works on the structure may need to be reviewed by a heritage consultant.

The maximum predicted curvatures for the dwelling "Bangalow", resulting from the extraction of the proposed longwalls, are 0.08 km^{-1} hogging and less than 0.01 km^{-1} sagging, which represent minimum radii of curvature of 13 kilometres and greater than 100 kilometres, respectively. The impact assessment for the structure has been made in accordance with the method described in Section 5.30.2 and Appendix C and the results are summarised in Table 5.22.

Table 5.22 Assessed Impact for Heritage Site 3

Location	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
Site 3	84 %	12 %	4 %	< 0.5 %

The repair categories R0 to R5 are described in Table C.4 in Appendix C.

The impact assessment indicates that there is a probability of approximately 95 % that none or only minor impacts (i.e. R0, R1, R2) will occur as the result of the extraction of the proposed longwalls. There is a small probability, approximately 5 %, that more substantial impacts could occur (i.e. R3 or greater) as the result of the extraction of the proposed longwalls.

It is recommended that a study is undertaken to assess the potential impacts on the dwelling "Bangalow". The study may require input from a structural engineer, a subsidence engineer and a heritage consultant. Management strategies should be developed such that the heritage significance of the structure is not adversely affected by mining and to establish the appropriate remediation measures.

5.28.4. Impact Assessments for Heritage Site 11 – Jilliby Public School

The Jilliby Public School is located between the northern and south-eastern series of longwalls and is at a distance of 250 metres north-west of Longwall 4S, at its closest point to the proposed longwalls. The impact assessments for this school are provided in Section 5.20.1.

5.28.5. Impact Assessments for the Potential Heritage Sites G, I, J, K, L, R and S – Dwellings

The Potential Heritage Sites G, I, J, K, L, R and S comprise dwellings which are located across the Study Area. The maximum predicted tilts for these sites, at the completion of the proposed longwalls, vary from less than 0.2 mm/m (i.e. < 0.1 %) to 11 mm/m (i.e. 1.1 %), which represent changes in grade varying from less than 1 in 5000 to1 in 90.

As described in Section 5.30.2, that tilts of less than 7 mm/m generally do not result in any significant impacts on houses. Some minor serviceability impacts can occur at these levels of tilt, including door swings and issues with roof gutter and wet area drainage, all of which can be remediated using normal building maintenance techniques. Tilts greater than 7 mm/m can result in greater serviceability impacts which may require more substantial remediation measures, including the relevelling of wet areas or, in some cases, the relevelling of the building structure.

The maximum predicted curvatures for the Potential Heritage Sites G, I, J, K, L, R and S, resulting from the extraction of the proposed longwalls, vary from less than 0.01 km^{-1} to 0.17 km^{-1} hogging curvature and vary from less than 0.01 km^{-1} to 0.04 km^{-1} sagging curvature. The impact assessments for these structures have been made in accordance with the method described in Section 5.30.2 and Appendix C and the results are summarised in Table 5.23.

Table 5.23 Assessed Impacts for the Potential Heritage Sites G, I, J, K, L, R and S

Location	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
Site G	94 %	5 %	1 %	< 0.1 %
Site I	94 %	5 %	1 %	< 0.1 %
Site J	94 %	5 %	1 %	< 0.1 %
Site K	90 %	9 %	1 %	< 0.1 %
Site L	93 %	6 %	1 %	< 0.1 %
Site R	73 %	19 %	8 %	< 0.5 %
Site S	81 %	14 %	5 %	< 0.5 %

The repair categories R0 to R5 are described in Table C.4 in Appendix C.

The impact assessments indicate that each dwelling has a probability between approximately 92 % and 99 % that none or only minor impacts (i.e. R0, R1, R2) will occur as the result of the extraction of the proposed longwalls. There is a small probability for each of these dwellings, between 1 and 8 %, that more substantial impacts could occur (i.e. R3 or greater) as the result of the extraction of the proposed longwalls.

It is recommended that a study is undertaken to assess the potential impacts on the Potential Heritage Sites G, I, J, K, L, R and S. The study may require input from a structural engineer, a subsidence engineer and a heritage consultant. Management strategies should be developed such that these structures are not adversely affected by mining and to establish the appropriate remediation measures.

5.28.6. Impact Assessments for the Potential Heritage Site M – Little Jilliby Bridge

The timber bridge over Little Jilliby Jilliby Creek is located approximately 200 metres south of the proposed Longwall 16N, at its closest point to the proposed longwalls. The impact assessments for this bridge are provided in Section 5.9, where it is referred to as Bridge LJ-B2.

It is recommended that a study is undertaken to assess the potential impacts on the bridge structure. The study may require input from a structural engineer, a subsidence engineer and a heritage consultant. Management strategies should be developed such that the bridge is not adversely affected by mining.

5.28.7. Impact Assessments for the Potential Heritage Site N – Bunya Pine

The Bunya Pine is located between the northern and south-western series of longwalls and is at a distance of approximately 300 metres north-east of the proposed Longwall 1SW, at its closest point to the proposed longwalls.

At this distance, the Bunya Pine is predicted to experience around 50 mm of subsidence. While it is possible that the pine could experience subsidence slightly greater than 50 mm, as the result of far-field vertical movements, it would not be expected to experience any significant tilts, curvatures or strains.

It is unlikely, therefore, that the Bunya Pine would experience any significant impacts resulting from the extraction of the proposed longwalls, even if the predictions were increased by factors up to 2 times.

5.28.8. Impact Assessments for the Potential Heritage Site O – Keegan's Silo

The Keegan's Silo is located above Longwall 12N. The maximum predicted tilt for this site, at the completion of the proposed longwalls, is 8.5 mm/m (i.e. 0.9 %), which represents a change in grade of 1 in 115. The structure is of light-weight construction with metal cladding and, therefore, it is unlikely that a tilt of this magnitude would adversely affect the stability of this structure.

The maximum predicted curvatures for the Keegan's Silo, resulting from the extraction of the proposed longwalls, are 0.13 km^{-1} hogging and 0.15 km^{-1} sagging, which represent minimum radii of curvature of 8 kilometres and 9 kilometres, respectively. The structure is of light-weight construction and, therefore, would be expected to tolerance curvatures of these magnitudes without any adverse impacts.

It is recommended that a study is undertaken to assess the potential impacts on the structure. The study may require input from a structural engineer, a subsidence engineer and a heritage consultant. Management strategies should be developed such that the structure is not adversely affected by mining.

5.28.9. Impact Assessments for the Potential Heritage Site P – Picket Fence

The picket fence is located above Longwall 10N. Timber fences are generally flexible in construction and it is likely, therefore, that this fence would experience any adverse impacts resulting from the extraction of the proposed longwalls.

Adverse impacts could occur, however, if significant irregular movements were to occur in this location. These types of movements develop slowly, which would allow the implementation of the necessary preventive measures if required.

5.28.10. Impact Assessments for the Potential Heritage Site Q – Silos

The Silos are located approximately 300 metres east of the proposed Longwall 1S, at its closest point to the proposed longwalls.

At this distance, the Silos are predicted to experience around 25 mm of subsidence. While it is possible that the Silos could experience subsidence slightly greater than 25 mm, as the result of far-field vertical movements, it would not be expected to experience any significant tilts, curvatures or strains.

It is unlikely, therefore, that the Silos would experience any significant impacts resulting from the extraction of the proposed longwalls, even if the predictions were increased by factors up to 2 times.

5.29. Survey Control Marks

The locations of the survey control marks within and immediately adjacent to the Study Area are shown in Drawing No. MSEC428-18.

The survey control marks are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4. If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the maximum predicted subsidence parameters would be expected to be similar to those provided in Chapter 4.

The survey control marks located outside and in the vicinity of the Study Area are also expected to experience small amounts of subsidence and small far-field horizontal movements. 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. Far-field horizontal movements and the methods used to predict such movements are described further in Sections 3.4 and 4.5.

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

5.30. Houses

The locations of the houses within the Study Area are shown in Drawing No. MSEC428-19. The predictions and impact assessments for these structures are provided in the following sections.

5.30.1. Predictions for the Houses

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

A summary of the maximum predicted values of conventional subsidence, tilt and curvature for each house within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table D.01 in Appendix D.

If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the individual houses would be predicted to experience greater or lesser movements, depending on their locations relative to the longwalls, but the overall levels of movement for the houses across the Study Area would not be expected to change significantly.

The distribution of the predicted conventional subsidence parameters for the houses within the Study Area are illustrated in Fig. 5.12, Fig. 5.13 and Fig. 5.14 below.

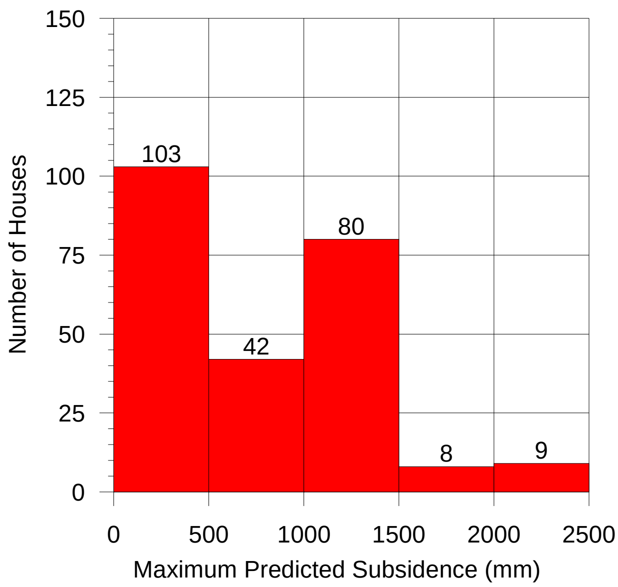


Fig. 5.12 Maximum Predicted Conventional Subsidence for the Houses within the Study Area Resulting from the Extraction of the Proposed Longwalls

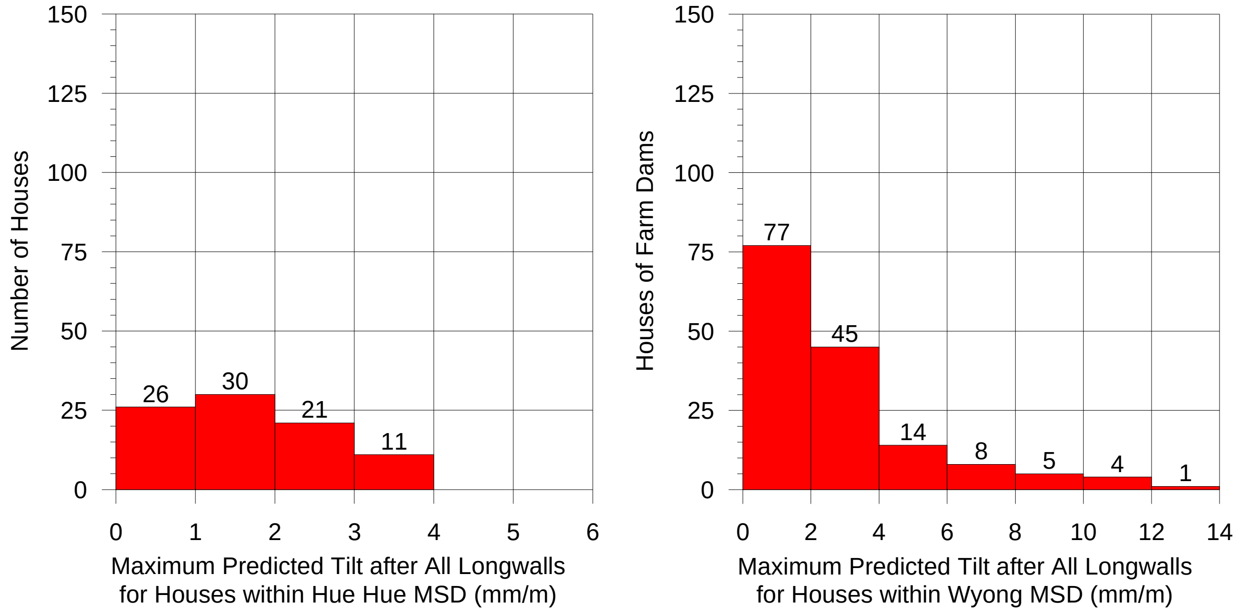


Fig. 5.13 Maximum Predicted Conventional Final Tilts for the Houses within the Hue Hue MSD (Left) and the Wyong MSD (Right) Resulting from the Extraction of the Proposed Longwalls

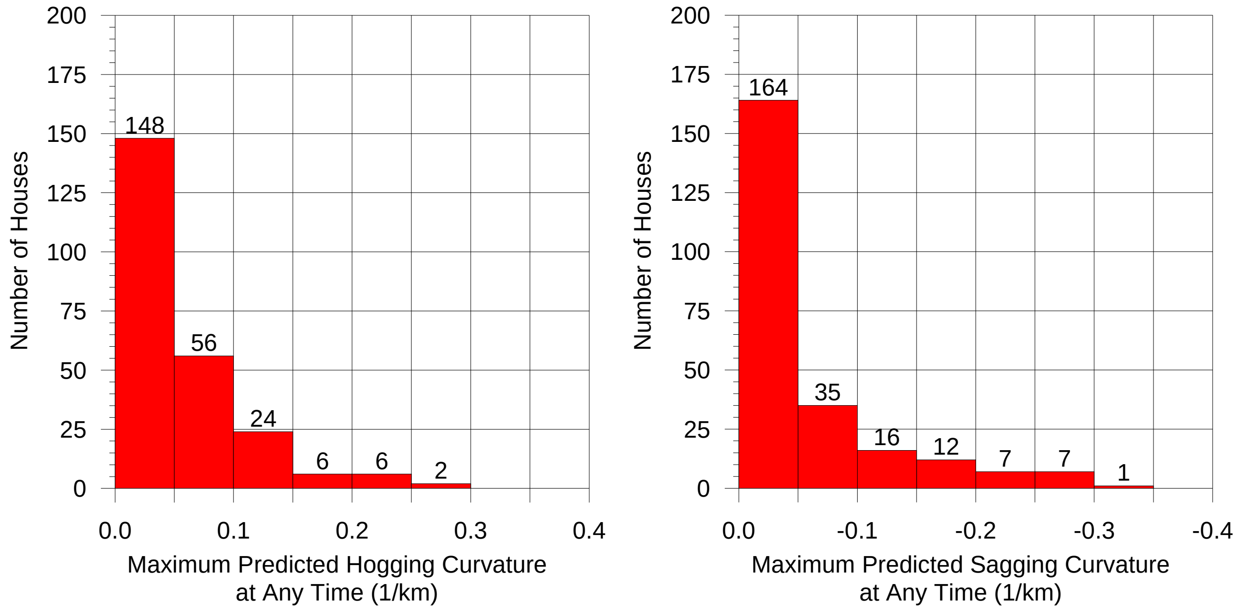


Fig. 5.14 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses Resulting from the Extraction of the Proposed Longwalls

The houses are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.30.2. Impact Assessments for the Houses

The following sections provide the impact assessments for the houses within the Study Area.

Potential Impacts Resulting from Vertical Subsidence

Vertical subsidence does not directly affect the stability or serviceability of houses. The potential for impacts on houses are affected by differential subsidence, which includes tilt, curvature and ground strain, and the impact assessments based on these parameters are described in the following sections.

Vertical subsidence in this case, however, can affect the heights of the houses above the flood level. The potential impacts on the houses resulting from the changes in flood level from the proposed mining has been assessed as part of the flood model, which is described in the report by ERM (2009).

Potential Impacts Resulting from Tilt

It has been found from past longwall mining experience that tilts of less than 7 mm/m generally do not result in any significant impacts on houses. Some minor serviceability impacts can occur at these levels of tilt, including door swings and issues with roof gutter and wet area drainage, all of which can be remediated using normal building maintenance techniques. Tilts greater than 7 mm/m can result in greater serviceability impacts which may require more substantial remediation measures, including the relevelling of wet areas or, in some cases, the relevelling of the building structure.

There are 88 houses identified within the Hue Hue Mine Subsidence District. It can be seen from Fig. 5.13, that the predicted maximum tilts for all these houses are less than 4 mm/m at the completion of mining. It is expected, therefore, that only minor serviceability impacts would occur at these houses, as the result of tilt, which could be remediated using normal building techniques.

There are 154 houses identified within the Wyong Mine Subsidence District. The predicted maximum tilts are less than 7 mm/m at 141 of these houses (i.e. 92 %) at the completion of mining. It is expected that only minor serviceability impacts would occur at these houses, as the result of tilt, which could be remediated using normal building techniques.

The predicted maximum tilts are between 7 mm/m and 10 mm/m at eight houses (i.e. 5 %) and are greater than 10 mm/m at five houses (i.e. 3 %) within the Wyong Mine Subsidence District at the completion of mining. The potential for serviceability impacts is greater for these houses than for the other houses within the Study Area. In some cases, more substantial remediation measures may be required, such as relevelling of the building structure.

It is expected, in all cases, that the houses within the Study Area will remain in safe conditions as the result of the mining induced tilts.

Potential Impacts Resulting from Curvature and Strain

The methods for predicting and assessing impacts on building structures have developed over time as knowledge and experience has grown. MSEC has provided predictions and impact assessments for the houses within the Study Area using the latest methods available at the time.

Background to the Method of Impact Assessment for Houses

Building structures have been directly mined beneath at a number of Collieries throughout the NSW Coalfields. The experience gained has provided substantial information that has been used to continually development of the methods of impact assessment for houses. The assessments provided in this report are based on the latest research, which is summarised in Appendix C. The discussions and the method of assessment provided in this report are based on the experience of mining at depths of cover generally greater than 350 metres, such as the case within the Study Area.

The most extensive data has come from the extraction of Tahmoor Longwalls 22 to 25, where over 1000 residential and significant civil structures have experienced mine subsidence movements. The impacts to houses at Tahmoor Colliery were last analysed in detail following the completion of Longwall 24A. A summary of the observed frequency of impacts for all structures located within the 26½ degree angle of draw line from the extents of mining at that time is provided in Table 5.24.

Table 5.24 Observed Frequency of Impacts for Building Structures Resulting from the Extraction of Tahmoor Longwalls 22 to 24A

Group	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
All buildings (total of 1099)	967 (88.0 %)	92 (8.4 %)	37 (3.4 %)	3 (0.3 %)
Buildings directly above goaf (total of 669)	546 (81.6 %)	84 (12.6 %)	36 (5.4 %)	3 (0.4 %)
Buildings directly above solid coal (total of 430)	421 (97.9 %)	8 (1.9 %)	1 (0.2 %)	0 (0.0 %)

The repair categories R0 to R5 are described in Table C.4 in Appendix C.

The distributions of the maximum predicted conventional hogging and sagging curvatures for the houses, resulting from the extraction of Tahmoor Longwalls 22 to 24A, are provided in Fig. 5.15. It can be seen from this figure, that the houses were predicted to have experienced conventional hogging curvatures of up to 0.10 km^{-1} and conventional sagging curvatures of up to 0.15 km^{-1}.

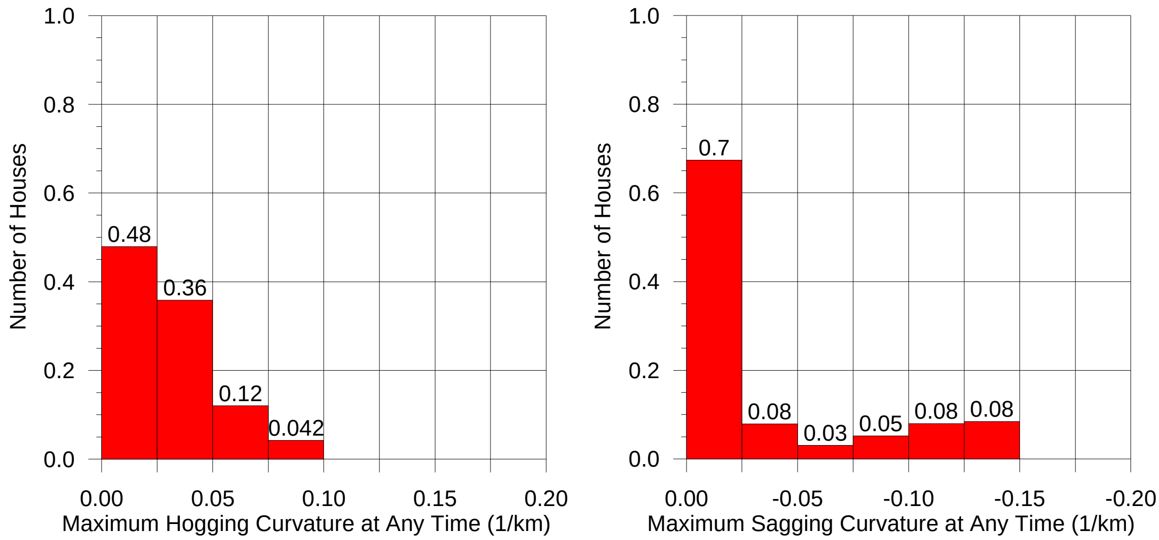


Fig. 5.15 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses Located Above Tahmoor Longwalls 22 to 24A

Extensive data has also come from the extraction of Teralba Longwalls 9 and 10, West Cliff Longwalls 5A1 to 5A4 and West Wallsend Longwalls 1 to 10, where approximately 500 houses have experienced mine subsidence movements. A summary of the observed frequency of impacts for the houses located within the 26½ degree angle of draw lines from the extents of mining at these Collieries is provided in Table 5.25.

Table 5.25 Observed Frequency of Impacts for Houses Resulting from the Extraction of Teralba Longwalls 9 and 10, West Cliff Longwalls 5A1 to 5A4 and West Wallsend Longwalls 1 to 10

Group	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
All houses (total of 494)	415 (84.0 %)	51 (10.3 %)	26 (5.3 %)	2 (0.4 %)

The repair categories R0 to R5 are described in Table C.4 in Appendix C.

The distributions of the maximum predicted conventional hogging and sagging curvatures for the houses, resulting from the extraction of Teralba Longwalls 9 and 10, West Cliff Longwalls 5A1 to 5A4 and West Wallsend Longwalls 1 to 10, are provided in Fig. 5.16. It can be seen from this figure, that the houses were predicted to have experienced conventional hogging curvatures of up to 0.20 km^{-1} and conventional sagging curvatures of up to 0.25 km^{-1}.

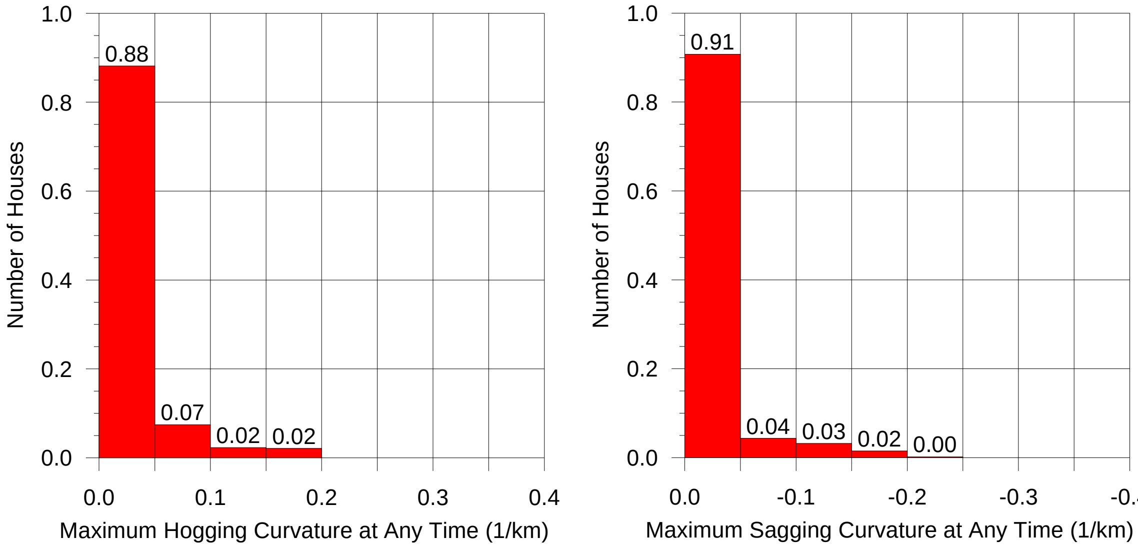


Fig. 5.16 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Houses at Teralba, West Cliff and West Wallsend

The experiences at Tahmoor, Teralba, West Cliff and West Wallsend Collieries indicate that the majority of observed impacts relate to minor effects that are relatively simple to repair, such as sticky doors or windows and cracks to plasterboard linings. In about 5 % of cases, however, substantial or more extensive repairs were required. In less than 1 % of cases, the houses experienced severe impacts, where the Mine Subsidence Board, in consultation with the owners, elected to rebuild the structure as the cost of repair exceeded the cost of replacement.

In all these cases, the residents were not exposed to any immediate and sudden safety hazards as the result of impacts that occurred due to mine subsidence movements. Emphasis is placed on the words “immediate and sudden” as, in rare cases, some structures have experienced severe impacts, but these impacts did not present an immediate risk to public safety as they developed gradually with ample time to relocate residents.

As part of ACARP Research Project C12015, a detailed analysis was undertaken to identify the trends that linked the frequency and severity of impacts with ground strain, ground curvature, type of construction and structure size. A method for assessment was developed for houses, using the primary parameters of ground curvature and type of construction, and further details of this method are provided in Appendix C. The method of assessment developed as part of the ACARP research project has been used to assess the potential impacts on the houses within the Study Area which is provided below.

Impact Assessment for Houses within the Study Area

It can be seen from Table D.01, that 193 of the 242 houses within the Study Area (i.e. 80 %) are predicted to experience hogging curvatures no greater than 0.10 km^{-1} and experience sagging curvatures no greater than 0.15 km^{-1}, which represent minimum radii of curvature of 10 kilometres and 7 kilometres, respectively. The range of predicted curvatures at these houses, therefore, is similar to that predicted to have occurred for the houses above Tahmoor Longwalls 22 to 24A, which is illustrated in Fig. 5.15.

It can also be seen from Table D.01, that 223 of the 242 houses within the Study Area (i.e. 92 %) are predicted to experience hogging curvatures no greater than 0.15 km^{-1} and experience sagging curvatures no greater than 0.25 km^{-1}, which represent minimum radii of curvature of 7 kilometres and 4 kilometres, respectively. The range of predicted curvatures at these houses, therefore, is similar to that predicted to have occurred for the houses above Teralba Longwalls 9 and 10, West Cliff Longwalls 5A1 to 5A4 and West Wallsend Longwalls 1 to 10, which is illustrated in Fig. 5.16.

The overall levels of movement predicted for the houses within the Study Area are greater than those predicted to have occurred for the houses at Tahmoor, Teralba, West Cliff and West Wallsend Collieries. It is expected, therefore, that the proportion of houses within the Study Area which experience impacts would be greater than those experienced at Tahmoor, Teralba, West Cliff and West Wallsend Collieries.

The higher proportion of impacts, however, would be expected to occur primarily at the lower end of the range, i.e. R0, R1 and R2, rather than at the higher end of the range, i.e. R3, R4 and R5. The reason for this is that experience suggests that, where the depth of cover is greater than 350 metres, such as the case within the Study Area, moderate and severe impacts are generally the result of non-conventional movements resulting from near-surface geological features. The potential for impacts resulting from non-conventional movements is dependent on the incidence of the geological features with the houses, rather than the magnitudes of the conventional subsidence movements.

As 80 % of the houses within the Study Area are predicted to experience curvatures similar to those experienced at Tahmoor Colliery and 92 % of houses within the Study Area are predicted to experience curvatures similar to those experienced at Teralba, West Cliff and West Wallsend Collieries, the observed levels of impact on the houses at these Collieries should provide a reasonable guide to the overall levels of impact on the houses within the Study Area.

The probabilities of impacts for each house within the Study Area have been assessed using the method developed as part of ACARP Research Project C12015, which is described in Appendix C. This method uses the primary parameters of ground curvature and type of construction. A summary of the predicted movements and the assessed impacts for each house within the Study Area is provided in Table D.01 in Appendix D. The overall distribution of the assessed impacts for the houses within the Study Area is provided in Table 5.26.

Table 5.26 Assessed Impacts for the Houses within the Study Area

Group	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
All houses (total of 242)	200 (83 %)	29 (12 %)	12 (5 %)	≈ 1 (< 0.5 %)

Trend analyses following the mining of Tahmoor Longwalls 22 to 24A indicate that the chance of impact is higher for the following houses:-

- Houses predicted to experience higher strains and curvatures,
- Houses with masonry walls,
- Masonry walled houses that are constructed on strip footings,
- Larger houses, and
- Houses with variable foundations, such as those with extensions added.

The primary risk associated with mining beneath houses is public safety. Residents have not been exposed to immediate and sudden safety hazards as a result of impacts that occur due to mine subsidence movements in the NSW Coalfields, where the depths of cover were greater than 350 metres, such as the case above the proposed longwalls. This includes the recent experience at Tahmoor Colliery, which has affected more than 1000 houses, and the experiences at Teralba, West Cliff and West Wallsend Collieries, which have affected around 500 houses.

Emphasis is placed on the words “immediate and sudden” as in rare cases, some structures have experienced severe impacts, but the impacts did not present an immediate risk to public safety as they developed gradually with ample time to relocate residents.

All houses within the Study Area are expected to remain safe, serviceable and repairable throughout the mining period, provided that they are in sound structural condition prior to mining. It should be noted, however, that the assessments indicate that the impact to approximately one house within the Study Area may be such that the cost of repair may exceeded the cost of replacement.

Potential Impacts Resulting from Downslope Movements

Longwall mining can result in downslope movements, in the locations where the natural surface grades are high, which can result in the increased potential for impacts on houses. The natural surface slopes at each house within the Study Area are provided in Table D.01 in Appendix D and is illustrated in Fig. 2.18.

It can be seen from this table and figure, that the natural surface slopes in the locations of the houses are generally less than 200 mm/m (i.e. 20 %), which represents a natural grade of 1 in 5. The maximum natural surface slope at the houses identified within the Study Area is 300 mm/m (i.e. 30 %), which represents a natural grade of 1 in 3.

As described in Section 2.4.9, natural slopes of less than 1 in 3 would not normally be considered steep. In many cases, natural slopes much greater than 1 in 3 would be considered stable. It is unlikely, therefore, that there would be any significant increase in the potential for impacts on the houses within the Study Area resulting from downslope movements.

The method of assessment for houses developed as part of ACARP Research Project C12015 included the experience of mining beneath houses having a similar range of natural surface slopes. The range of natural surface slopes within the Study Area is unlikely, therefore, to affect the probabilities of impact for the houses which have been obtained using this method.

5.30.3. Impact Assessments for the Houses Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the predicted maximum tilts would be less than 7 mm/m at 193 of the houses (i.e. 80 %) at the completion of mining. It would still be expected that only minor serviceability impacts would occur at these houses, as the result of tilt, which could be remediated using normal building techniques.

The predicted maximum tilts would be between 7 mm/m and 10 mm/m at 24 houses (i.e. 10 %) and would be greater than 10 mm/m at 25 houses (i.e. 10 %) at the completion of mining. It would be expected that greater serviceability impacts would occur at these houses which would require more substantial remediation measures including, in some cases, relevelling of the building structures.

It is expected, in all cases, that the houses within the Study Area would remain in safe conditions as the result of the mining induced tilts.

If the predicted curvatures and strains were increased by factors of up to 2 times, 129 of the 242 houses within the Study Area (i.e. 53 %) would be predicted to experience hogging curvatures no greater than 0.10 km^{-1} and experience sagging curvatures no greater than 0.15 km^{-1}. The range of predicted curvatures at these houses, therefore, would still be similar to that predicted to have occurred for the houses above Tahmoor Longwalls 22 to 24A.

Similarly, 165 of the 242 houses within the Study Area (i.e. 68 %) would be predicted to experience hogging curvatures no greater than 0.15 km^{-1} and experience sagging curvatures no greater than 0.25 km^{-1}. The range of predicted curvatures at these houses, therefore, would still be similar to that predicted to have occurred for the houses above Teralba Longwalls 9 and 10, West Cliff Longwalls 5A1 to 5A4 and West Wallsend Longwalls 1 to 10.

The increased curvatures and strains would result in a greater proportion of houses being impacted and greater levels of impact. Based on previous experience, it would still be expected that the houses would remain in safe conditions. The impacts would develop slowly, allowing preventive measures to be undertaken and, where required, relocation of residence if any structures were deemed to become unsafe.

5.30.4. Recommendations for the Houses

It is recommended that management strategies are developed as part of Property Subsidence Management Plans or the Extraction Plans, to manage the potential impacts on the residential and non-residential building structures. The management strategies should include the following where access is provided to the property:-

- Identification of structures and their forms of construction prior to mining,
- Identification by a suitably qualified building inspector of any structures or structural elements that may be potentially unstable prior to mining,
- Consideration of implementing any mitigation measures, where necessary to address specific identified risks to public safety,
- Consideration of undertaking detailed monitoring of ground movements at or around structures, where necessary to address specific identified risks to public safety,
- Periodic inspections of structures that are considered to be at higher risk. These may include:-
    - Structures in close proximity to steep slopes where recommended by a geotechnical or subsidence engineer,
    - Structures identified as being potentially unstable where recommended by a structural or subsidence engineer, and
    - Pool fences.
- Co-ordination and communication with landowners and the Mine Subsidence Board during mining.

It is recommended that the houses are visually monitored during the extraction of the proposed longwalls. With these strategies in place, it is expected that the houses would remain in safe conditions throughout the mining period.

5.31. Tanks

The locations of the water tanks within the Study Area are shown in Drawing No. MSEC428-19. The predictions and impact assessments for the tanks are provided in the following sections.

5.31.1. Predictions for the Tanks

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at points located around the perimeter of each tank, as well as at points located at a distance of 20 metres from the perimeter of each tank.

A summary of the maximum predicted values of conventional subsidence, tilt and curvatures for the tanks within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table 5.27.

Table 5.27 Maximum Predicted Conventional Subsidence, Tilt and Curvatures for the Tanks within the Study Area Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
Tanks	2350	11	0.25	0.30

The subsidence and tilt provided in the above table are the maximum predicted values at the completion of the proposed longwalls. The curvatures provided in the above table are the maximum predicted values which occur at any time during or after the extraction of the proposed longwalls.

The distributions of the maximum predicted conventional subsidence, tilt and curvature for the tanks within the Study Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 5.17 and Fig. 5.18.

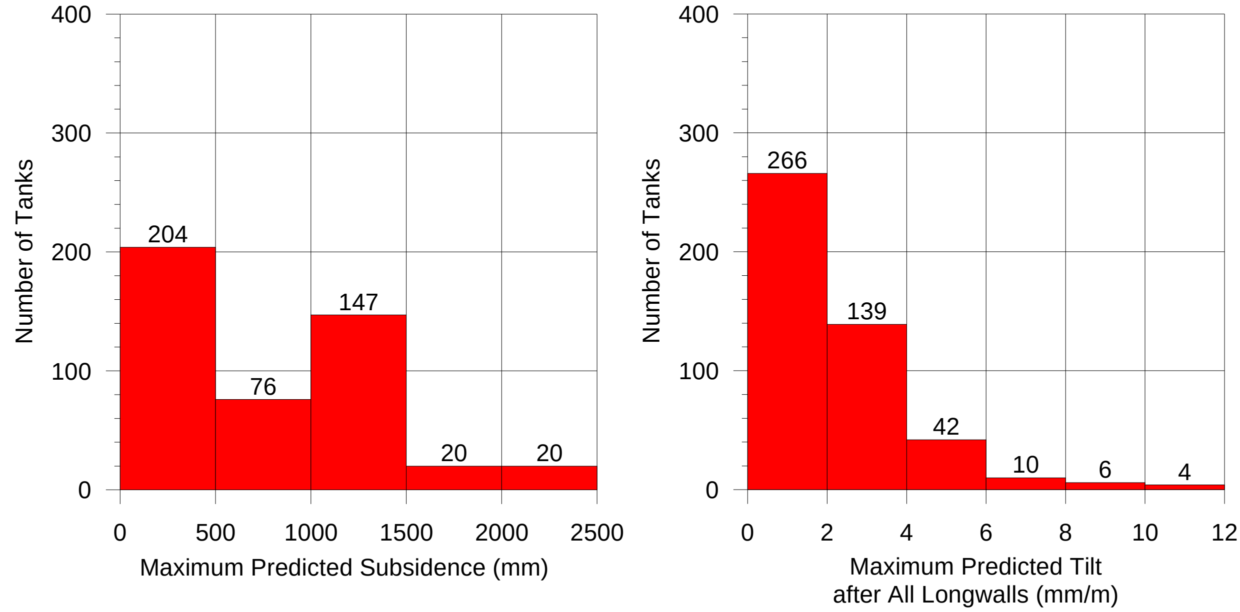


Fig. 5.17 Maximum Predicted Conventional Subsidence and Tilt for the Tanks within the Study Area Resulting from the Extraction of the Proposed Longwalls

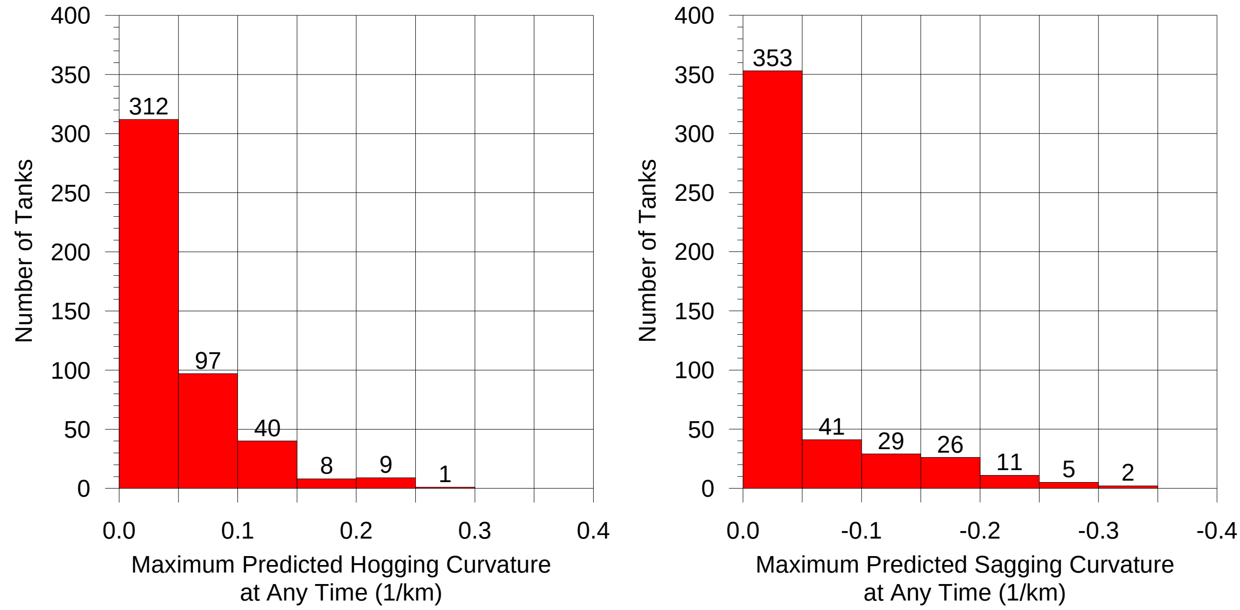


Fig. 5.18 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Tanks Resulting from the Extraction of the Proposed Longwalls

If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the individual tanks would be predicted to experience greater or lesser movements, depending on their locations relative to the longwalls, but the overall levels of movement for the tanks across the Study Area would not be expected to change significantly.

The tanks are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.31.2. Impact Assessments for the Tanks

Tilt can potentially affect the serviceability of tanks by altering the water levels in the tanks, which can in turn affect the minimum level of water which can be released from the outlets. The maximum predicted conventional tilt for the tanks within the Study Area is 11 mm/m (i.e. 1.1 %), which represents a change in grade of 1 in 90. The predicted changes in grade are small, in the order of 1 % and unlikely, therefore, to result in any significant impacts on the serviceability of the tanks.

The tanks structures are typically constructed above ground level and, therefore, are unlikely to experience the curvatures and ground strains resulting from the extraction of the proposed longwalls. It is possible, that any buried water pipelines associated with the tanks within the Study Area could be impacted by the ground strains, if they are anchored by the tanks, or by other structures in the ground.

Any impacts are expected to be of a minor nature, including leaking pipe joints, and could be easily repaired. With these remediation measures in place, it would be unlikely that there would be any significant impacts on the pipelines associated with the tanks.

5.31.3. Impact Assessments for the Tanks Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the incidences of serviceability impacts, such as changes in the minimum water levels which can be released from the outlets, would increase accordingly. Any such impacts would be expected to be easily remediated by relevelling the tanks.

If the predicted curvatures and ground strains were increased by factors of up to 2 times, the incidence of impacts on the tank structures would not be expected to change significantly, as they are not expected to experience these ground movements. The incidence of impacts on the buried pipelines would, however, be expected to increase accordingly. Any impacts would still be expected to be of a minor nature which could be easily repaired. With these remediation measures in place, it would be unlikely that there would be any significant long term impacts on the pipelines associated with the tanks.

5.31.4. Recommendations for the Tanks

The assessed impacts on the tanks and associated infrastructure resulting from the extraction of the proposed longwalls are not significant. It is recommended that the tanks are visually monitored during the mining period.

5.32. Gas and Fuel Storages

There are domestic gas and fuel storages on the rural properties across the Study Area which are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The storage tanks are generally elevated above ground level and, therefore, are not susceptible to mine subsidence movements. It is possible, however, that any buried gas pipelines associated with the storage tanks within the Study Area could be impacted by the ground strains, if they are anchored by the storage tanks, or by other structures in the ground.

Any impacts are expected to be of a minor nature, including minor gas leaks, which could be easily repaired. It is unlikely that there would be any significant impacts on the pipelines associated with the gas and fuel storage tanks, even if the predictions were increased by factors of up to 2 times.

5.33. Swimming Pools

The locations of the swimming pools within the Study Area are shown in Drawing No. MSEC428-19. The predictions and impact assessments for the pools are provided in the following sections.

5.33.1. Predictions for the Swimming Pools

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at points located around the perimeter of each pool, as well as at points located at a distance of 20 metres from the perimeter of each pool.

A summary of the maximum predicted values of conventional subsidence, tilt and curvatures for the pools within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table 5.28.

Table 5.28 Maximum Predicted Conventional Subsidence, Tilt and Curvatures for the Pools within the Study Area Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
Pools	2350	11	0.25	0.30

The subsidence and tilt provided in the above table are the maximum predicted values at the completion of the proposed longwalls. The curvatures provided in the above table are the maximum predicted values which occur at any time during or after the extraction of the proposed longwalls.

The distributions of the maximum predicted conventional subsidence, tilt and curvature for the pools within the Study Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 5.19 and Fig. 5.20.

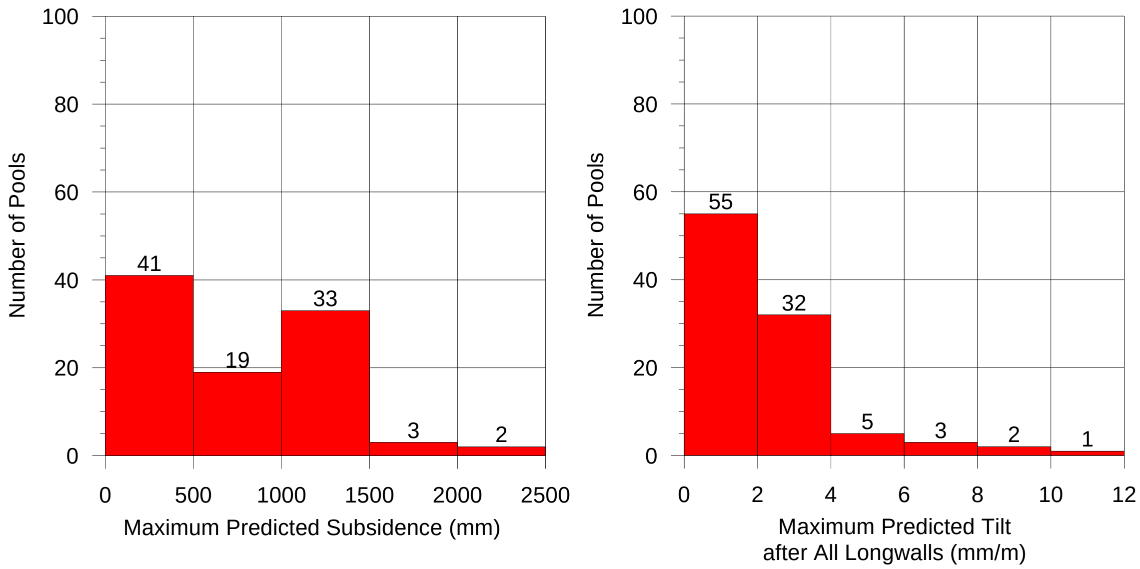


Fig. 5.19 Maximum Predicted Conventional Subsidence and Tilt for the Pools within the Study Area Resulting from the Extraction of the Proposed Longwalls

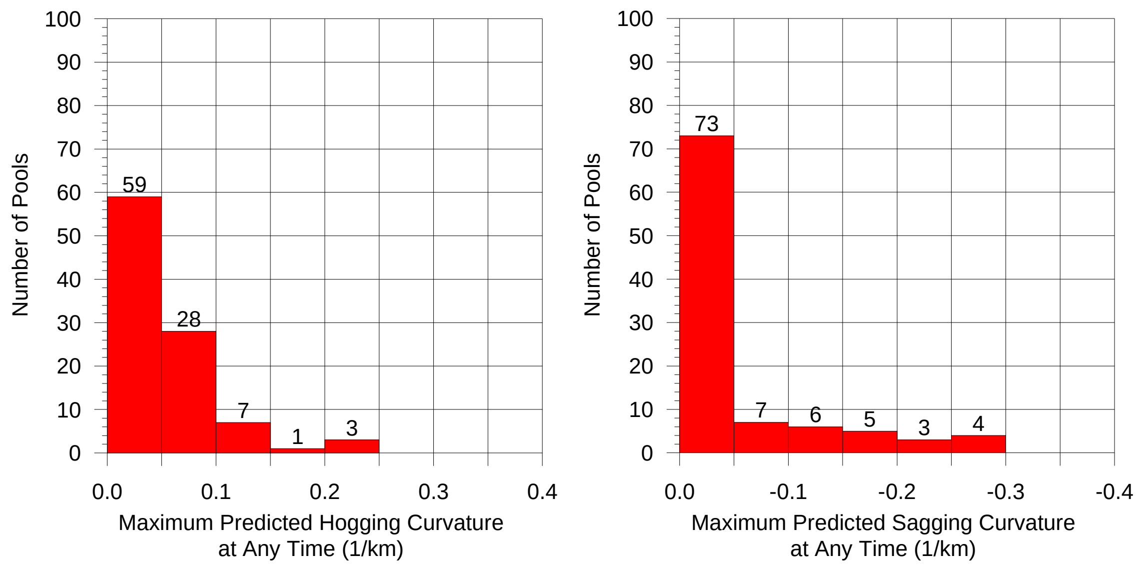


Fig. 5.20 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Pools Resulting from the Extraction of the Proposed Longwalls

If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the individual pools would be predicted to experience greater or lesser movements, depending on their locations relative to the longwalls, but the overall levels of movement for the pools across the Study Area would not be expected to change significantly.

The pools are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.33.2. Impact Assessments for the Swimming Pools

Mining-induced tilts are more noticeable in pools than other structures due to the presence of the water line and the small gap to the edge coping, particularly when the pool lining has been tiled. Skimmer boxes are also susceptible of being lifted above the water line due to mining tilt.

The Australian Standard AS2783-1992 (Use of reinforced concrete for small swimming pools) requires that pools be constructed level ± 15 mm from one end to the other. This represents a tilt of approximately 3.3 mm/m for pools that are 10 metres in length. Australian Standard AS/NZS 1839:1994 (Swimming pools – Pre-moulded fibre-reinforced plastics – Installation) also requires that pools be constructed with a tilt of 3 mm/m or less.

It can be seen from Fig. 5.19, that 74 of the 98 of the pools within the Study Area (i.e. 76 %) are predicted to experience tilts of less than 3 mm/m, at the completion of the proposed longwalls, which is similar to or less than the Australian Standard. The remaining 24 pools within the Study Area (i.e. 24 %) are predicted to experience tilts greater than 3 mm/m, at the completion of the proposed longwalls, which may require some remediation of the pool copings.

It can be seen from Fig. 5.20, that 79 of the 98 of the pools within the Study Area (i.e. 81 %) are predicted to experience hogging curvatures no greater than 0.10 km^{-1} and experience sagging curvatures no greater than 0.15 km^{-1}. The range of predicted curvatures at these pools, therefore, is similar to that predicted to have occurred for the houses and, hence, the pools above Tahmoor Longwalls 22 to 24A, which is illustrated in Fig. 5.15.

Observations during the mining of Tahmoor Colliery Longwalls 22 to 25 have shown that pools, particularly in-ground pools, are more susceptible to severe impacts than houses and other structures. Pools cannot be easily repaired and most of the impacted pools need to be replaced in order to restore them to pre-mining condition or better.

As of May 2009, a total of 108 pools have experienced mine subsidence movements during the mining of Tahmoor Colliery Longwalls 22 to 25, of which 80 were located directly above the extracted longwalls. A total of 14 pools have reported impacts, all of which were located directly above the extracted longwalls. This represents an impact rate of approximately 18 %. A higher proportion of impacts have been observed for in-ground pools, particularly fibreglass pools. The majority of the impacts related to tilt or cracking, though in a small number of cases the impacts were limited to damage to skimmer boxes or the edge coping.

The maximum predicted subsidence parameters for the pools within the Study Area are greater than the maxima predicted at Tahmoor Colliery. The incidence and levels of impacts on the pools in the Study Area, therefore, are expected to be greater than those experienced at Tahmoor Colliery. As 81 % of the pools within the Study Area are predicted to experience curvatures similar to the pools at Tahmoor Colliery, the observed levels of impact on the pools at Tahmoor should provide a reasonable guide to the potential levels of impact on the pools within the Study Area.

5.33.3. Impact Assessments for the Swimming Pools Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, 41 of the 98 of the pools within the Study Area (i.e. 42 %) would still be predicted to experience tilts of less than 3 mm/m, at the completion of the proposed longwalls, which is similar to or less than the Australian Standard. The remaining 57 pools within the Study Area (i.e. 58 %) would be predicted to experience tilts greater than 3 mm/m, at the completion of the proposed longwalls, and may require some remediation of the pool copings

If the predicted curvatures and strains were increased by factors of up to 2 times, 53 of the 98 pools within the Study Area (i.e. 54 %) would still be predicted to experience hogging curvatures no greater than 0.10 km^{-1} and experience sagging curvatures no greater than 0.15 km^{-1}. The range of predicted curvatures at these pools, therefore, would still be similar to that predicted to have occurred for the pools above Tahmoor Longwalls 22 to 24A. The remaining pools would be predicted to experience hogging curvatures greater than those predicted to have occurred for the pools at Tahmoor.

The increased curvatures would result in a greater proportion of pools being impacted and greater levels of impact when compared to the previous experience at Tahmoor Colliery.

5.33.4. Recommendations for the Swimming Pools

While not strictly related to the pool structure, a number of pool gates have been impacted as the result of the previous extraction of longwalls beneath pools. While the gates can be easily repaired, the consequence of breaching pool fence integrity is considered to be severe. As a result, it is recommended that regular inspections of the integrity of pool fences during the active subsidence period be included in the development of any Management Plan for properties that have pools or are planning to construct a pool during the mining period.

5.34. Tennis Courts

The locations of the tennis courts within the Study Area are shown in Drawing No. MSEC428-19. The predictions and impact assessments for the tennis courts are provided in the following sections.

5.34.1. Predictions for the Tennis Courts

Predictions of conventional subsidence, tilt and curvature have been made at the centroid and at points located around the perimeter of each tennis court, as well as at points located at a distance of 20 metres from the perimeter of each tennis court.

A summary of the maximum predicted values of conventional subsidence, tilt and curvatures for the tennis courts within the Study Area, resulting from the extraction of the proposed longwalls, is provided in Table 5.29.

Table 5.29 Maximum Predicted Conventional Subsidence, Tilt and Curvatures for the Pools within the Study Area Resulting from the Extraction of the Proposed Longwalls

Location	Maximum Predicted Conventional Subsidence (mm)	Maximum Predicted Conventional Tilt (mm/m)	Maximum Predicted Conventional Hogging Curvature (km^{-1})	Maximum Predicted Conventional Sagging Curvature (km^{-1})
Tennis Courts	1650	9	0.15	0.20

The subsidence and tilt provided in the above table are the maximum predicted values at the completion of the proposed longwalls. The curvatures provided in the above table are the maximum predicted values which occur at any time during or after the extraction of the proposed longwalls.

The distributions of the maximum predicted conventional subsidence, tilt and curvature for the pools within the Study Area, resulting from the extraction of the proposed longwalls, are illustrated in Fig. 5.21 and Fig. 5.22.

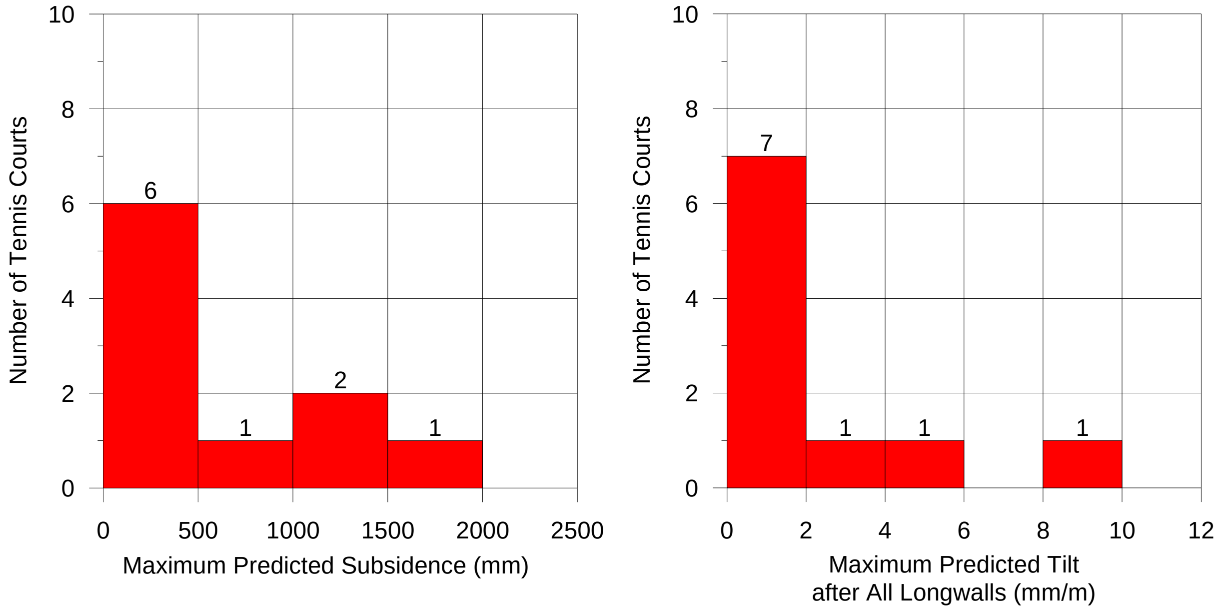


Fig. 5.21 Maximum Predicted Conventional Subsidence and Tilt for the Tennis Courts within the Study Area Resulting from the Extraction of the Proposed Longwalls

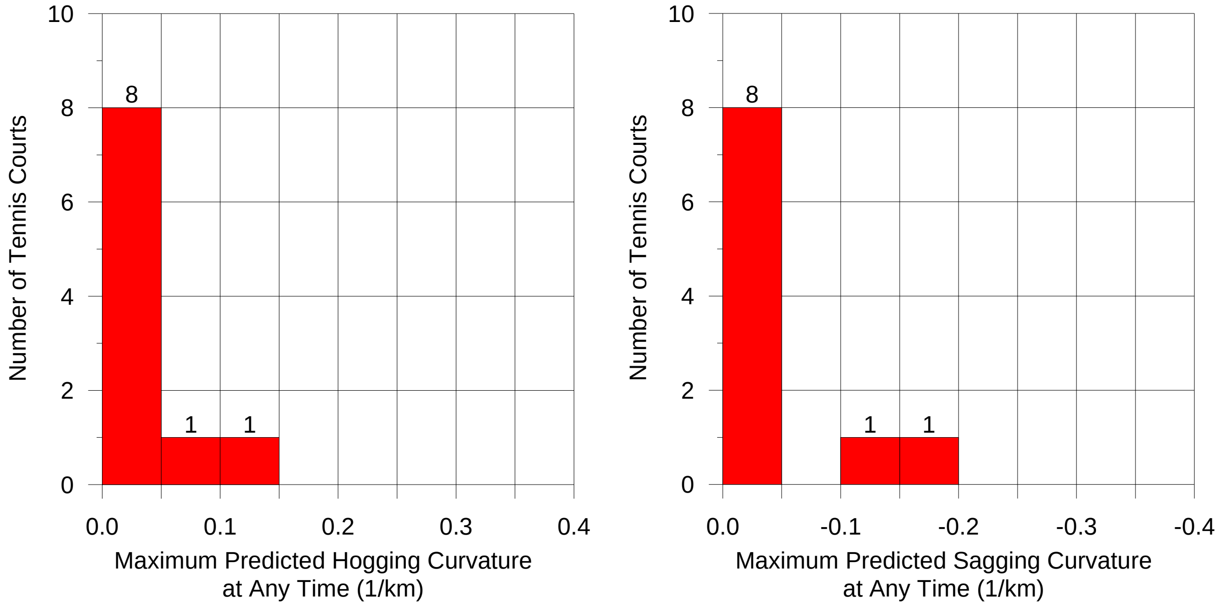


Fig. 5.22 Maximum Predicted Conventional Hogging Curvature (Left) and Sagging Curvature (Right) for the Tennis Courts Resulting from the Extraction of the Proposed Longwalls

If the longwalls were to be shifted or reoriented within the Extents of the Longwall Mining Areas, the individual tennis courts would be predicted to experience greater or lesser movements, depending on their locations relative to the longwalls, but the overall levels of movement for the tennis courts across the Study Area would not be expected to change significantly.

The tennis courts are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

5.34.2. Impact Assessments for the Tennis Courts

The maximum predicted tilt for the tennis courts, resulting from the extraction of the proposed longwalls, is 9 mm/m (i.e. 0.9 %), which represents a change in grade of 1 in 110. The predicted tilts are small, less than 1 % and unlikely, therefore, to result in any significant impacts on the serviceability of the tennis courts.

The maximum predicted curvatures for the tennis courts, resulting from the extraction of the proposed longwalls, are 0.15 km^{-1} hogging and 0.20 km^{-1} sagging, which represent minimum radii of curvature of 7 kilometres and 5 kilometres, respectively. The maximum predicted ground curvatures are similar to or slightly greater than those typically experienced in the Southern Coalfield.

It is possible that the maximum predicted curvatures and ground strains could result in minor cracking in the tennis courts with grass or clay surfaces, however, any cracking would be expected to be minor and readily repairable. It is expected, that the predicted ground strains would arch around the concrete tennis courts and would not be fully transferred into the pavements. It is possible, that some minor surface cracking could occur in the concrete surfaces, but any cracking would be expected to be of a minor nature and readily repairable.

5.34.3. Impact Assessments for the Tennis Courts Based on Increased Predictions

If the predicted tilts were increased by factors of up to 2 times, the maximum change in grade at the tennis courts would be 18 mm/m (i.e. 1.8 %), which is still reasonably small and unlikely to result any significant impacts on the serviceability of the tennis courts.

If the predicted curvatures and strains were increased by factors of up to 2 times, 7 of the 10 tennis courts within the Study Area (i.e. 70 %) would still be predicted to experience hogging curvatures no greater than 0.15 km^{-1} and experience sagging curvatures no greater than 0.20 km^{-1}. The maximum predicted ground curvatures for these tennis courts, therefore, would still be similar to or slightly greater than those typically experienced in the Southern Coalfield. The increased curvatures would result in a greater incidence of cracking in the tennis court surfaces. Any impacts would still be expected to be of a minor natural which could be readily repaired

5.34.4. Recommendations for the Tennis Courts

It is recommended that periodic visual inspections of the tennis courts are undertaken during the active subsidence period.

5.35. On-Site Waste Water Systems

The residences on the rural properties within the Study Area have on-site waste water systems.

The on-site waste systems are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence movements within the Study Area is provided in Chapter 4.

The on-site waste systems are at discrete locations and, therefore, the most relevant distributions of strain are the maximum strains measured in individual survey bays from previous longwall mining. The analysis of strains measured in survey bays during the mining of previous longwalls in the Newcastle Coalfield is discussed in Section 4.3.1. The results for survey bays above goaf are provided in Fig. 4.1 and Table 4.3. The results for survey bays above solid coal are provided in Fig. 4.2 and Table 4.4.

Non-conventional movements can also occur and have occurred in the NSW Coalfields as a result of, amongst other things, anomalous movements. The analysis of strains provided in Chapter 4 includes those resulting from both conventional and non-conventional anomalous movements.

The maximum predicted change in grade for the on-site waste water systems within the Study Area are in the order of 1 % to 2 %. It is unlikely, therefore, that the maximum predicted tilts would result in any significant impacts on the tank systems. The maximum predicted conventional tilts could, however, be of sufficient magnitude to affect the serviceability of the buried pipes between the houses and the on-site waste water systems, if the existing grades of these pipes are very small, say less than 1 %.

The on-site waste water system tanks are generally small, typically less than 3 metres in diameter, are constructed from reinforced concrete, and are usually bedded in sand and backfilled. It is unlikely, therefore, that the maximum predicted curvatures and ground strains would be fully transferred into the tank structures.

It is possible, however, that the buried pipelines associated with the on-site waste water tanks could be impacted by the ground strains if they are anchored by the tanks or other structures in the ground. Any impacts are expected to be of a minor nature, including leaking pipe joints, and could be easily repaired. With the implementation of these remediation measures, it would be unlikely that there would be any significant impacts on the pipelines associated with the on-site waste water systems, even if the predictions were increased by factors of up to 2 times.

5.36. Rigid External Pavements

Adverse impacts on rigid external pavements are often reported to the Mine Subsidence Board in the NSW Coalfields. This is because pavements are typically thin relative to their length and width. The design of external pavements is also not regulated by Council or the Mine Subsidence Board.

A study by MSEC of 120 properties at Tahmoor and Thirlmere indicated that 98 % of the properties with external concrete pavements demonstrated some form of cracking prior to mining. These cracks are sometimes difficult to distinguish from cracks caused by mine subsidence. It is therefore uncertain how many claims for damage can be genuinely attributed to mine subsidence impacts.

Residential concrete pavements are typically constructed with tooled joints which do not have the capacity to absorb compressive movements. It is possible that some of the smaller concrete footpaths or pavements within the Study Area, in the locations of the larger compressive ground strains, could buckle upwards if there are insufficient movement joints in the pavements. It is expected, however, that the buckling of footpaths and pavements would not be common, given the magnitudes of the predicted ground strains, and could be easily repaired.

5.37. Fences

The predictions and impact assessments for fences are provided in Section 5.24.

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.
Closure	**T**he reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill soil slumping and other possible strata mechanisms.
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, i.e. curvature is the second derivative of subsidence. Curvature is usually expressed as the inverse of the **Radius of Curvature** with the units of *1/kilometres (km-1)*, but the value of curvature can be inverted, if required, to obtain the radius of curvature, which is usually expressed in *kilometres (km)*. Curvature can be either **hogging** (i.e. convex) or **sagging** (i.e. concave).
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.
Far-field movements	**T**he measured horizontal movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas. Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain.
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.

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.
Shear deformations	The horizontal displacements that are measured across monitoring lines and these can be described by various parameters including; horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index.
Strain	The change in the horizontal distance between two points divided by the original horizontal distance between the points, i.e. strain is the relative differential displacement of the ground along or across a subsidence monitoring line. Strain is dimensionless and can be expressed as a decimal, a percentage or in parts per notation. **Tensile Strains** are measured where the distance between two points or survey pegs increases and **Compressive Strains** where the distance between two points decreases. Whilst mining induced **strains** are measured **along** monitoring lines, ground **shearing** can occur both vertically, and horizontally **across** the directions of the monitoring lines.
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, but, 'subsidence of the ground' in some references can include both a vertical and horizontal movement component. The vertical component of subsidence is measured by determining the change in surface level of a peg that is fixed in the ground before mining commenced and this vertical subsidence is usually expressed in units of *millimetres (mm)*. Sometimes the horizontal component of a peg's movement is not measured, but in these cases, the horizontal distances between a particular peg and the adjacent pegs are measured.
Subsidence Effects	The deformations of the ground mass surrounding a mine, sometimes referred to as 'components' or 'parameters' of mine subsidence induced ground movements including; vertical and horizontal displacements, tilts, curvatures, strains, upsidence and closure

Subsidence Impacts	The physical changes or damage to the fabric or structure of the ground, its surface and natural features, or man-made structures that are caused by the subsidence effects. These impacts considerations can include; tensile and shear cracking of the rock mass, localised buckling of strata bed separation, rock falls, collapse of overhangs, failure of pillars, failure of pillar floors, dilation, slumping and also include subsidence depressions or troughs.
Subsidence Consequences	The knock-on results of subsidence impacts, i.e. any change in the amenity or function of a natural feature or man-made structure that arises from subsidence impacts. Consequence considerations include; public safety, loss of flows, reduction in water quality, damage to artwork, flooding, draining of aquifers, the environment, community, land use, loss of profits, surface improvements and infrastructure. Consequences related to natural features are referred to as environmental consequences.
Super-critical area	An area of panel greater than the critical area.
Tilt	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 horizontal 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 %, or 1 in 1000.
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. Where upsidence exceeds subsidence a relative uplift of the valley floor can be observed. Upsidence results from the dilation or buckling of near surface strata at or near the base of the valley. The magnitude of upsidence, which is typically expressed in the units of *millimetres (mm)*, is the difference between the observed subsidence profile within the valley and the conventional subsidence profile which would have otherwise been expected in flat terrain.

APPENDIX B - REFERENCES

References

DII (2003). *Guideline for Application for Subsidence Management Approvals.* Department of Industry and Investment 2003.

ERM, (2009). *Wallarah 2 Coal Project Flood Impact Assessment for Wyong Areas Coal Joint Venture.* Environmental Resources Management Australia Pty Ltd 2009.

Forster, I.R., (1995). *Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW.* Engineering Geology of the Newcastle-Gosford Region. Australian Geomechanics Society. Newcastle, February 1995.

Holla, L. and Armstrong, M., (1986). *Measurement of Sub-Surface Strata Movement by Multi-wire Borehole Instrumentation*. Proc. Australian Institute of Mining and Metallurgy, 291, pp. 65-72.

Holla, L., (1991). *Reliability of Subsidence Prediction Methods for Use in Mining Decisions in New South Wales.* Conference on Reliability, Production and Control in Coal Mines, Wollongong.

Holla, L. and Barclay, E., (2000). *Mine Subsidence in the Southern Coalfield, NSW, Australia.* Published by the Department of Mineral Resources, NSW.

Holla, L. & Buizen, M., (1991). *The Ground Movement, Strata Fracturing and Changes in Permeability Due to Deep Longwall Mining*. Int. J. Rock Mech. Min. Sci. & Geomech. Abstr. Vol 28, No. 2/3, pp.207-217, 1991.

Independent Expert Panel, (2008). *Impacts of Potential Underground Coal Mining in the Wyong Local Government Area Strategic Review*. State of New South Wales through the Department of Planning, 2008

Kratzsch, H., (1983). *Mining Subsidence Engineering*, Published by Springer - Verlag Berlin Heidelberg New York.

Mackie, (2009). *Wallarah 2 Coal Project Groundwater Management Studies*. Mackie Environmental Research 2009

Moelle, K.H.R., Li, G., Dean-Jones, G.L., Philips, R.N., (1995). *On mechanical aspects of coal outbursts in underground coal mines.* Proceedings of the International Symposium on Management and Control of High Gas Emissions and Outbursts in Underground Coal Mines, Wollongong Australia, pp 593-601

McNally, G.H., Willey, P.L. and Creech, M., (1996). *Geological Factors influencing Longwall-Induced Subsidence*. Symposium on Geology in Longwall mining, 12-13 November 1996, Eds G.H. McNally and C.R. Ward, pp 257-267.

NRAtlas, (2009). *Natural Resource Atlas* website, viewed 22nd October 2009. The Department of Natural Resources. http://nratlas.nsw.gov.au/

OzArk, (2010a). *Proposed Wallarah 2 Coal Project Ecology Assessment of the Proposed Mining Area, Wyong, NSW.* OzArk Environmental and Heritage Management 2010.

OzArk, (2010b). *Indigenous & Non Indigenous Heritage Review Subsidence Area Wallarah 2 Coal Project, Wyong, NSW.* OzArk Environmental and Heritage Management 2010.

Patton F.D. & Hendron A.J., (1972). *General Report on Mass Movements,* Proc. 2nd Intl. Congress of International Association of Engineering Geology, V-GR1-V-GR57.

Peng S.S. & Chiang H.S., (1984). *Longwall Mining,* Wiley, New York, pg 708.

Reid, P.K., (1991). *Coal Mining Beneath Dams in NSW Australia*. 1991 ADSO Annual Conference, September 1991, San Diego, USA, pp 240-245.

SCIMS (2009). *SCIMS Online* website, viewed 14th October 2009. The Land and Property Management Authority. http://www.lands.nsw.gov.au/survey_maps/scims_online

Sefton, (2000). *Overview of the Monitoring of Sandstone Overhangs for the Effects of Mining Subsidence Illawarra Coal Measures, for Illawarra Coal.* C.E. Sefton Pty Ltd, 2000.

Report No. BHC2404C, SCT, December 2003.

Singh, M.M. & F.D. Kendorski, 1981. *Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments,* Proc. First Conference on Ground Control in Mining, West Virginia University, PP 76-89.

Trotter T, Frazier P, (2009) *Monitoring the effect of longwall mining on agricultural environments-Interim report.* ACARP Project C15013

Waddington, A.A. and Kay, D.R., (2002). *Management Information Handbook on the Undermining of Cliffs, Gorges and River Systems*. ACARP Research Projects Nos. C8005 and C9067, September 2002.

Whittaker, B.N. Reddish, D.J. and Fitzpatrick, D.J., (1985). *Ground fractures due to longwall mining subsidence*. Proc. I.M.W.A. Second Int. Congress on Mine Water, Granada, Spain, 1057-1072 2002.

WACJV (2008), *Wallarah 2 Coal Project Subsidence Modelling Study*. Wyong Areas Coal Joint Venture. John Edwards. 2008

APPENDIX C. METHOD OF IMPACT ASSESSMENTS FOR HOUSES

APPENDIX C METHOD OF IMPACT ASSESSMENT FOR HOUSES

C.1. Introduction

The methods for predicting and assessing impacts on building structures have developed over time as knowledge and experience has grown. MSEC has provided predictions and impact assessments for the building structures within the Study Area using the latest methods available at the time.

Building structures have been directly mined beneath at a number of Collieries in the Southern Coalfield, including Appin, West Cliff, Tower and Tahmoor Collieries. The most extensive data has come from extraction of Tahmoor Longwalls 22 to 24A, where over 1000 residential and significant civil structures have experienced subsidence movements and impacts have been observed to over 150 houses. The experiences gained during the mining of these longwalls, as well as longwalls at other Collieries in the Southern Coalfield, have provided substantial additional information that can be used for further development of the methods.

The information collected during the mining of Tahmoor Longwalls 22 to 24A has been reviewed in two parallel studies, one as part of a funded ACARP Research Project C12015, and the other at the request of the Department of Industry and Investment (DII).

The outcomes of these studies include:-

- Review of the performance of the previous method,
- Recommendations for improving the method of Impact Classification, and
- Recommendations for improving the method of Impact Assessment.

A summary is provided in the following sections.

C.2. Review of the performance of the previous method

The previous method of impact assessment for houses was used to support ICHPL SMP Applications for the extraction of Appin Longwalls 401 to 409, Appin Longwalls 301 and 302, Appin Longwalls 701 to 704 and West Cliff Longwalls 29 to 36. The previous method was also used to support Tahmoor Colliery's SMP Application for Longwalls 24 to 26.

The most extensive data on house impacts has come from extraction of Tahmoor Longwalls 22 to 25 and a comparison between predicted and observed impacts is provided in Table C.1. The comparison is based on pre-mining predictions that were provided in SMP Applications for these longwalls and the observations of impacts using the previous method of impact classification. The comparison is based on information up to 30 November 2008. At this point in time, the length of extraction of Longwall 25 was 611 metres.

A total of 1037 houses and civil structures were affected by subsidence due to the mining of Tahmoor Longwalls 22 to 25 at this time. A total of 175 claims have been received by the Mine Subsidence Board (not including claims that have been refused) of which 14 claims do not relate to the main residence or civil structure.

Table C.1 Summary of Comparison between Observed and Predicted Impacts for each Structure

Strain Impact Category	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 0	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 1	Total No. of Observed Impacts for Structures predicted to be Strain Impact Category 2	Total
No impact	483	373	20	**876**
Cat 0	31	70	6	**107**
Cat 1	8	9	1	**18**
Cat 2	7	11	2	**20**
Cat 3	2	2	0	**4**
Cat 4	3	5	0	**8**
Cat 5	3	1	0	**4**
Total	**537**	**471**	**29**	**1037**
% claim	**10 %**	**21 %**	**31 %**	**16 %**
% Obs > Pred	**4 %**	**4 %**	**0 %**	-
% Obs <= Pred	**96 %**	**96 %**	**100 %**	-

Note: Predicted impacts due to conventional subsidence only, as described in the SMP Application.

Given that observed impacts are less than or equal to predicted impacts in 96 % of cases, it is considered that the previous methods are generally conservative even though non-conventional movements were not taken into account in the predictions and assessments. However, when compared on a house by house basis, the predictions have been substantially exceeded in a small proportion of cases.

The majority, if not all, of the houses that have experienced Category 3, 4 or 5 impacts are considered to have experienced substantial non-conventional subsidence movements. The consideration is based on nearby ground survey results, where upsidence bumps are observed in subsidence profiles and high localised strain is observed. The potential for impact from non-conventional movements were discussed generally and not included in the specific impact assessments for each structure.

The inability to specify the number or probability of impacts due to the potential for non-conventional movements is a shortcoming of the previous method. It is considered that there is significant room for improvement in this area and recommendations are provided later in this report.

The comparison shows a favourable observation that the overall proportion of claims increased for increasing predicted impact categories. This suggests that the main parameters currently used to make impact assessments (namely predicted conventional curvature and maximum plan dimension of each structure) are credible. Please note that we have stated predicted conventional curvature rather than strain, as predictions of strain were directly based on predictions of conventional curvature.

A significant over-prediction is observed at the low end of the spectrum of impacts (Category 0 and 1). A number of causes and/or possible causes for the deviations have been identified:

- Construction methods and standards may mitigate against small differential ground movements.
- The impacts may have occurred but the residents have not made a claim for the following reasons:-
  - All structures contain some existing, pre-mining defects. A pre-mining field investigation of 119 structures showed that it is very rare for all elements of a building to be free of cracks. Cracks up to 3 mm in width are commonly found in buildings. Cracks up to 1 mm in width are very common. There is a higher incidence of cracking in brittle forms of construction such as masonry walls and tiled surfaces.
  - In light of the above, additional very slight Category 0 and 1 impacts may not have been noticed by residents. A forensic investigation of all structures before or after mining may reveal that the number of actual impacts is greater than currently known.
  - Similarly, impacts have been noticed but some residents may consider them to be too trivial to make a claim. While difficult to prove statistically, it is considered that the frequency of claims from tenanted properties is less than the frequency of claims from owner-occupied properties.
- The impacts have been noticed but some residents are yet to make a claim at this stage. It has been observed that there is a noticeable time lag between the moment of impact and the moment of making a claim. More claims are therefore expected to be received in the future within areas that have already been directly mined beneath.
- The predictive method is deliberately conservative in a number of ways.
  - Predicted subsidence movements for each structure are based on the maximum predicted subsidence movements within 20 metres of the structure.
  - An additional 0.2 mm/m of strain was added
  - Maximum strains were applied to the maximum plan dimension, regardless of the maximum predicted strain orientation.
  - The method of impact assessment does not provide for "nil impacts". The minimum assessed level of impact is Category 0.
  - The impact data was based on double-storey full masonry structures in the UK.

Finally, it is considered that the previous method impact classification has masked the true nature and extent of impacts. It is recommended that an improved method of classification be adopted before embarking on any further analysis. This is discussed in the next chapter of this report.

C.3. Method of Impact Classification

C.3.1. Previous Method

The impacts to structures were previously classified in accordance with Table C1 of Australian Standard 2870-1996, but the Table has been extended by the addition of Category 5 and is reproduced below.

Table C.2 Classification of Damage with Reference to Strain

Impact Category	Description of typical damage to walls and required repair	Approximate crack width limit
0	Hairline cracks.	< 0.1 mm
1	Fine cracks which do not need repair.	0.1 mm to 1.0 mm
2	Cracks noticeable but easily filled. Doors and windows stick slightly	1 mm to 5 mm
3	Cracks can be repaired and possibly a small amount of wall will need to be replaced. Doors and windows stick. Service pipes can fracture. Weather-tightness often impaired	5 mm to 15 mm, or a number of cracks 3 mm to 5 mm in one group
4	Extensive repair work involving breaking-out and replacing sections of walls, especially over doors and windows. Window or door frames distort. Walls lean or bulge noticeably. Some loss of bearing in beams. Service pipes disrupted.	15 mm to 25 mm but also depends on number of cracks
5	As above but worse, and requiring partial or complete rebuilding. Roof and floor beams lose bearing and need shoring up. Windows broken with distortion. If compressive damage, severe buckling and bulging of the roof and walls.	> 25 mm

Note 1 of Table C1 states that *"Crack width is the main factor by which damage to walls is categorized. The width may be supplemented by other factors, including serviceability, in assessing category of damage.*

Impacts relating to tilt were classified according to matching impacts with the description in Table C.3, not the observed actual tilt. This is because many houses that have experience tilts greater than 5 mm have not made a claim to the MSB.

Table C.3 Classification of Damage with Reference to Tilt

Impact Category	Tilt (mm/m)	Description
A	< 5	Unlikely that remedial work will be required.
B	5 to 7	Adjustment to roof drainage and wet area floors might be required.
C	7 to 10	Minor structural work might be required to rectify tilt. Adjustments to roof drainage and wet area floors will probably be required and remedial work to surface water drainage and sewerage systems might be necessary.
D	> 10	Considerable structural work might be required to rectify tilt. Jacking to level or rebuilding could be necessary in the worst cases. Remedial work to surface water drainage and sewerage systems might be necessary.

C.3.2. Need for Improvement to the Previous Method of Impact Classification

It is very difficult to design a method of impact classification that covers all possible scenarios and permutations. The application of any method is likely to find some instances that do not quite fit within the classification criteria.

Exposure to a large number of affected structures has allowed the mining industry to appreciate where improvements can be made to all aspects including the identification of areas for improvement in the previous method of impact classification.

A number of difficulties have been experienced with the previous method during the mining period. The difficulty centres on the use of crack width as the main classifying factor, as specified in Table C1 of Australian Standard 2870-1996.

A benefit of using crack width as the main factor is that it provides a clear objective measure by which to classify impact. However, experience has shown that crack width is a poor measure of the overall impact and extent of repair to a structure. The previous method of impact classification may be useful for assessing impact to newly built structures in a non-subsidence environment but further improvement and clarification is recommended before it can be effectively applied to houses impacted by mine subsidence.

The following aspects highlight areas where the previous classification system could be improved.-

- *Slippage on Damp Proof Course*

  Approximately 30 houses have experienced slippage along the damp proof course in Tahmoor. Slippage on some houses is relatively small (less than 10 mm) though substantial slippage has been observed in a number of cases, such as shown in Fig. C.1 below.

Fig. C.1 Example of slippage on damp proof course

  Under the previous classification method, the "crack" width of the slippage may be very small (Category 1) but the distortion in the brickwork is substantial. Moreover, the extent of work required to repair the impact is substantial as it usually involves re-lining the whole external skin of the structure. Such impacts would be considered Category 4 based on extent of repair but only Category 1 or 2 based on maximum crack width.

  There is no reference to slippage of damp proof course in the previous method of impact classification. However, if the extent of repair was used instead of using crack width as the main factor, the impact category would be properly classified as either Category 4 or Category 5.

  It was recommended that slippage of damp proof courses be added to the previous impact classification table.

- *Cracks to brickwork*

  In some cases, cracks are observed in mortar only. For example, movement joints in some structures have been improperly filled with mortar instead of a flexible sealant, as shown in Fig. C.2. In these situations, the measured crack width may be significant but the impact is relatively simple to repair regardless of the crack width.

Fig. C.2 Example of crack in mortar only

  In other cases, a small number of isolated bricks have been observed to crack or become loose. This is usually straightforward to repair. Under the previous impact classification method, a completely loose brick could be strictly classified as Category 5 as the crack width is infinitely large. This is clearly not the intention of the previous method but clarification is recommended to avoid confusion.

  If a panel of brickwork is cracked, the method of repair is the same regardless of the width. While it is considered reasonable to classify large and severe cracks by its width, it is recommended that cracks less than 5 mm in width be treated the same rather than spread across Categories 0, 1 and 2.

If a brick lined structure contains many cracks of width less than 3 mm, the impact would be classified as no more than Category 2 under the previous method of impact classification. The extent of repair may be substantially more than a house that has experienced only one single 5 mm crack. However, it is recognised that it is very difficult to develop a simple method of classifying impacts based on multiple cracks in wall panels. How many cracks are needed to justify an increase in impact category?

- *Structures without masonry walls*

  Timber framed structures with lightweight external linings such weatherboard panels and fibro sheeting are not referenced in the previous classification table. If crack widths were strictly adopted to classify impacts, it may be possible to classify movement in external wall linings beyond Category 3 when in reality the repairs are usually minor.

  It was recommended that the impact classification table be extended to include structures with other types of external linings.

- *Minor impacts such as door swings*

  Experience has shown that one of the earliest signs of impact is the report of a sticking door. In some instances, the only observed impact is one or two sticking doors. It takes less than half an hour to repair a sticking door and impact is considered negligible.

  Such an impact would be rightly classified as Category 0 based on the previous method of impact classification as there is no observed crack. However, the previous classification table suggests that sticking doors and windows occur when Category 2 crack widths develop. It was recommended that the impact classification table be amended in this respect.

C.3.3. Broad recommendations for improvement of previous method of impact classification

It was recommended that crack width no longer be used as the main factor for classifying impacts. This does not mean that the use of crack width should be abandoned altogether. Crack width remains a good indicator of the severity of impacts and should be used to assist classification, particularly for impacts that are moderate or greater.

By focussing on crack width, the previous impact classification table appears to be classifying impacts from a structural stability perspective. It was recommended that a revised impact classification table be more closely aligned with all aspects of a building, including its finishes and services. Residents who are affected by impacts are concerned as much about impacts to internal linings, finishes and services as they are about cracks to their external walls and a revised impact classification method should reflect this.

With crack width no longer used as the main factor, it was recommended that the wording of the descriptions of impact in the classification table be extended to cover impacts to more elements of buildings. In keeping with the previous method of assessment, the level of impact should distinguish between cosmetic, serviceability and stability related impacts:-

- Low impact levels should relate to cosmetic impacts that do affect the structural integrity of the building and are relatively straight-forward to repair,
- Mid-level impact categories should relate to impacts to serviceability and minor structural issues, and
- High level impacts should be reserved for structural stability issues and impacts requiring extensive repairs.

C.3.4. Revised Method of Impact Classification

The following revised method of impact classification has been developed.

Table C.4 Revised Classification based on the Extent of Repairs

Repair Category	Extent of Repairs
Nil	No repairs required
R0 **Adjustment**	One or more of the following, where the damage does not require the removal or replacement of any external or internal claddings or linings:- - **Door** or **window** jams or swings, or - Movement of **cornices**, or - Movement at external or internal **expansion joints**.
R1 **Very Minor Repair**	One or more of the following, where the damage can be repaired by filling, patching or painting without the removal or replacement of any external or internal brickwork, claddings or linings:- - Cracks in **brick mortar** only, or isolated cracked, broken, or loose **bricks** in the external façade, or - Cracks or movement < 5 mm in width in any external or internal wall **claddings**, **linings**, or **finish**, or - Isolated cracked, loose, or drummy floor or wall **tiles**, or - Minor repairs to any **services** or **gutters**.
R2 **Minor Repair**	One or more of the following, where the damage affects a small proportion of external or internal claddings or linings, but does not affect the integrity of external brickwork or structural elements:- - Continuous cracking in **bricks** < 5 mm in width in one or more locations in the total external façade, or - Slippage along the **damp proof course** of 2 to 5 mm anywhere in the total external façade, or - Cracks or movement ≥ 5 mm in width in any external or internal wall **claddings**, **linings**, **finish**, or - Several cracked, loose or drummy floor or wall **tiles**, or - Replacement of any **services**.
R3 **Substantial Repair**	One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or affects the stability of isolated structural elements:- - Continuous cracking in **bricks** of 5 to 15 mm in width in one or more locations in the total external façade, or - Slippage along the **damp proof course** of 5 to 15 mm anywhere in the total external façade, or - Loss of bearing to isolated walls, piers, columns, or other load-bearing elements, or - Loss of stability of isolated structural elements.
R4 **Extensive Repair**	One or more of the following, where the damage requires the removal or replacement of a large proportion of external brickwork, or the replacement or repair of several structural elements:- - Continuous cracking in **bricks** > 15 mm in width in one or more locations in the total external façade, or - Slippage along the damp proof course of 15 mm or greater anywhere in the total external façade, or - Relevelling of building, or - Loss of stability of several structural elements.
R5 **Re-build**	Extensive damage to house where the MSB and the owner have agreed to rebuild as the cost of repair is greater than the cost of replacement.

As discussed at the start of this chapter, it is very difficult to design a method of impact classification that covers all possible scenarios and permutations. While the method has been floated among some members of the mining industry, it is recommended that this table be reviewed broadly.

The recommended method has attempted to follow the current Australian Standard in terms of the number of impact categories and crack widths for Categories 3 and 4. The method is based on the extent of repairs required to repair the physical damage that has occurred, and does not include additional work that is occasionally required because replacement finishes cannot match existing damaged ones. It is therefore likely that the actual cost of repairs will vary greatly between houses depending on the nature of the existing level and type of finishes used.

The impacts experienced at Tahmoor Colliery have been classified in accordance with the revised method of classification with good results. The method allowed clearer trends to be found when undertaking statistical analyses.

A comparison between the previous and revised methods is shown in Fig. C.3.

I:\Projects\ACARP\Subsdata\Post Mining Tilts and Impacts.grf

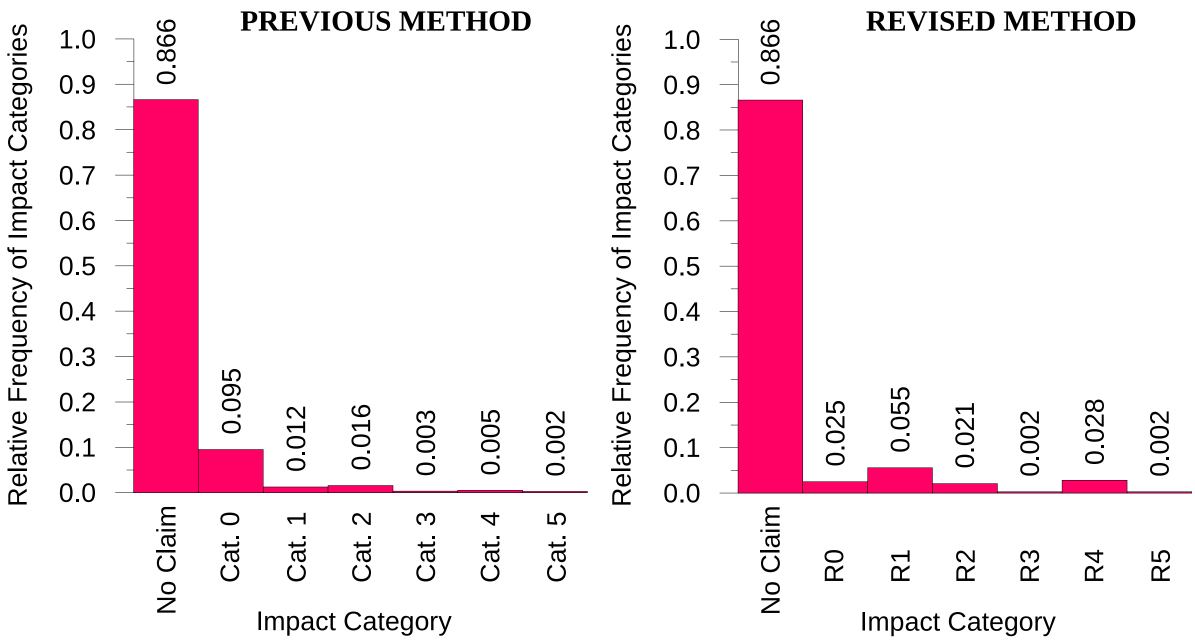


Fig. C.3 Comparison between Previous and Revised Methods of Impact Classification

It can be seen that there was an increased proportion in the higher impact categories using the revised method. This is brought about mainly by the recorded slippage on damp proof courses, which are classified as either Category 3 or Category 4 when they were previously classified as Category 1 or 2.

There was also a noticeable reduction in proportion of Category 0 impacts and noticeable increase in proportion of Category 1 impacts using the revised method. This is because the revised method reserves Category 0 impacts for impacts that did not result in cracking any linings, while the previous method allows hairline cracking to occur.

The consistent low proportion of Category 3 impacts under both the previous and current methods raises questions as to whether this category should be merged with Category 4.

C.4. Method of Impact Assessment

C.4.1. Need for improvement of the previous method

The previous method of impact assessment provided specific quantitative predictions based on predicted conventional subsidence movements and general qualitative statements concerning the potential for impacts due to non-conventional movements. These non-conventional movements are additional to the predicted conventional movements.

This message was quite complex and created the potential for confusion and misunderstanding among members of the community who may easily focus on numbers and letters in a table that deal specifically with their house and misunderstand the message contained in the accompanying words of caution about the low level of reliability concerning predictions of conventional strain and potential for non-conventional movements.

This was unfortunately a necessary shortcoming of the previous method at the time as there was very little statistical information available to quantify the potential for impacts due to non-conventional movement. However, a great deal of statistical information is now available following the mining of Tahmoor Longwalls 22 to 24A and the method and message to the community can be improved.

While additional statistical information is now available, there remains limited knowledge at this point in time to accurately predict the locations of non-conventional movement. Substantial gains are still to be made in this area.

In the meantime, therefore, a probabilistic method of impact assessment has been developed. The method combines the potential for impacts from both conventional and non-conventional subsidence movement.

C.4.2. Factors that could be used to develop a probabilistic method of prediction

Trend analyses have highlighted a number of factors that could be used to develop a probabilistic method. The trends examined were:-

- *Ground tilt*

  This was found to be an ineffective parameter at Tahmoor Colliery as ground tilts have been relatively benign and a low number of claims have been made in relation to tilt.

- *Ground strain*

  There appears to be a clear link between ground strain and impacts, particularly compressive strain. The difficulty with adopting ground strain as a predictive factor lies in the ability to accurately predict ground strain at a point.

  Another challenge with using strain to develop a probabilistic method is that there is limited information that links maximum observed strains with observed impacts at a structure. Horizontal strain is a two-dimensional parameter and it has been measured along survey lines that are oriented in one direction only.

  The above issues are less problematic for curvature and the statistical analysis on the relationship between strain and curvature shows that the observed frequency of high strains increased with increasing observed curvature.

- *Ground curvature*

  Curvature appears to be the most effective subsidence parameter to develop a probabilistic method. The trend analysis showed that the frequency of impacts increased with increasing observed curvature.

It should be noted that we are referring to conventional curvature and not curvatures that have developed as a result of non-conventional subsidence behaviour. This is because conventional curvature can be readily predicted with reasonable correlation with observations. It is also a relatively straight-forward exercise to estimate the observed smoothed or "conventional" curvature provided some ground monitoring is undertaken across and along extracted longwalls.

Non-conventional curvature cannot be predicted prior to mining and is accounted for by using a probabilistic method of impact assessment.

It has also been shown that the observed frequency of high strains increased with increasing observed curvature.

- *Position of structure relative to longwall*

  A clear trend was understandably found that structures located directly above goaf were substantially more likely to experience impact. The calculated probabilities may be applicable for mining conditions that are similar to those experienced at Tahmoor Colliery but will be less applicable for other mining conditions. An effective probabilistic method should create a link between the magnitude of differential subsidence movements and impact.

- *Construction type*

  Two trends have been observed. Not surprisingly, structures constructed with lightweight flexible external linings are able to accommodate a far greater range of subsidence movements than brittle inflexible linings such as masonry. The analyses merely quantified what was already well known.
  The second observation was that houses constructed with strip footings were noticeably more likely to experience impacts than houses constructed with a ground slab, particularly in relation to higher levels of impact. This is because houses with strip footings are more susceptible to slippage along the damp proof course.

- *Structure size*

  Trend analysis showed that larger structures attract a higher likelihood of impact. This is understandable as the chance of impacts increases with increasing footprint area. However, it is noted that the probability of severe impacts was not substantially greater for larger structures even though this would be expected if considering probabilities theoretically rather than empirically.
  It may be worthwhile including structure size as a factor in the development of a probabilistic method, though it is considered that it is a third order effect behind subsidence movements and construction type.

- *Structure age*

  The trend analysis for structure age did not reveal any noticeable trends.

- *Extensions, variable foundations and building joints*

  There is a clear trend of a higher frequency of impacts for structures that include extensions, variable foundations and building joints. The increased frequency appears to be related mainly to lower impact categories.

- *Urban or rural setting*

  While trends were observed, it is considered that they can be explained by other factors. However, consideration can be made to provide a more conservative estimate of probabilities in rural areas if structure size has not been taken into account.

C.4.3. Revised Method of Impact Assessment

A revised method of impact assessment has been developed. The method is probabilistic and currently includes conventional ground curvature and construction type as input factors.

Because of the relatively low number of buildings that suffered damage, the trends in the data were difficult to determine within small ranges of curvature. A decision was therefore taken to analyse the data in a limited number of curvature ranges, so that where possible a reasonable sample size would be available in each range. The ranges of curvature chosen were 5 to 15 kilometres, 15 to 50 kilometres and greater than 50 kilometres.

Because the incidence of damage for different construction types showed strong trends and because the sample size was reasonable for each type of structure, the data were analysed to determine the effect of radius of curvature on the incidence of damage for each of the three structure types and for each of the three curvature ranges.

The following probabilities are proposed in Table C.5.

Table C.5 Probabilities of Impact based on Curvature and Construction Type based on the Revised Method of Impact Classification

R (km)	Repair Category			
	No Repair or R0	R1 or R2	R3 or R4	R5
Brick or brick-veneer houses with Slab on Ground				
> 50	90 ~ 95 %	3 ~ 10 %	1 %	< 0.1 %
15 to 50	80 ~ 85 %	12 ~ 17 %	2 ~ 5 %	< 0.5 %
5 to 15	70 ~ 75 %	17 ~ 22 %	5 ~ 8 %	< 0.5 %
Brick or brick-veneer houses with Strip Footing				
> 50	90 ~ 95 %	3 ~ 10 %	1 %	< 0.1 %
15 to 50	80 ~ 85 %	7 ~ 12 %	2 ~ 7 %	< 0.5 %
5 to 15	70 ~ 75 %	15 ~ 20 %	7 ~ 12 %	< 0.5 %
Timber-framed houses with flexible external linings of any foundation type				
> 50	90 ~ 95 %	3 ~ 10 %	1 %	< 0.1 %
15 to 50	85 ~ 90 %	7 ~ 13 %	1 ~ 3 %	< 0.5 %
5 to 15	80 ~ 85 %	10 ~ 15 %	3 ~ 5 %	< 0.5 %

The results have been expressed as a range of values rather than a single number, recognising that the data had considerable scatter within each curvature range. While structure size and building extensions have not been included in the predictive tables, it is recommended to adopt percentages at the higher end of the range for larger structures or those with building extensions.

The percentages stated in each table are the percentages of building structures of that type that would be likely to be damaged to the level indicated within each curvature range. The levels of damage in the tables are indicated with reference to the repair categories described in the damage classification given in Table C.4.

To place these values in context, Table C.6 shows the actual percentages recorded at Tahmoor Colliery for all buildings within the sample.

Table C.6 Observed Frequency of Impacts observed for all buildings at Tahmoor Colliery

R (km)	Repair Category			
	No Claim or R0	R1 or R2	R3 or R4	R5
> 50	94%	4%	1%	0%
15 to 50	86%	9%	4%	0.7%
5 to 15	76%	17%	7%	0%

It can be seen that the proposed probabilities for the higher impact categories have been increased compared to those observed to date. These have been deliberately increased, because it has been noticed that some of the claims for damage have been submitted well after the event and it is possible that the numbers damaged in this category could be increased as further claims are received and investigated. These numbers are particularly sensitive to change because the sample size is very small. In light of the above, it is recommended that the probabilities be revisited in the future as mining progresses.

The ranges provided in Table C.5 have been converted into a set of probability curves to remove artificial discontinuities that are formed by dividing curvatures into three categories. These are shown in Fig. C.4. The probability curves are applicable for all houses and civil structures.

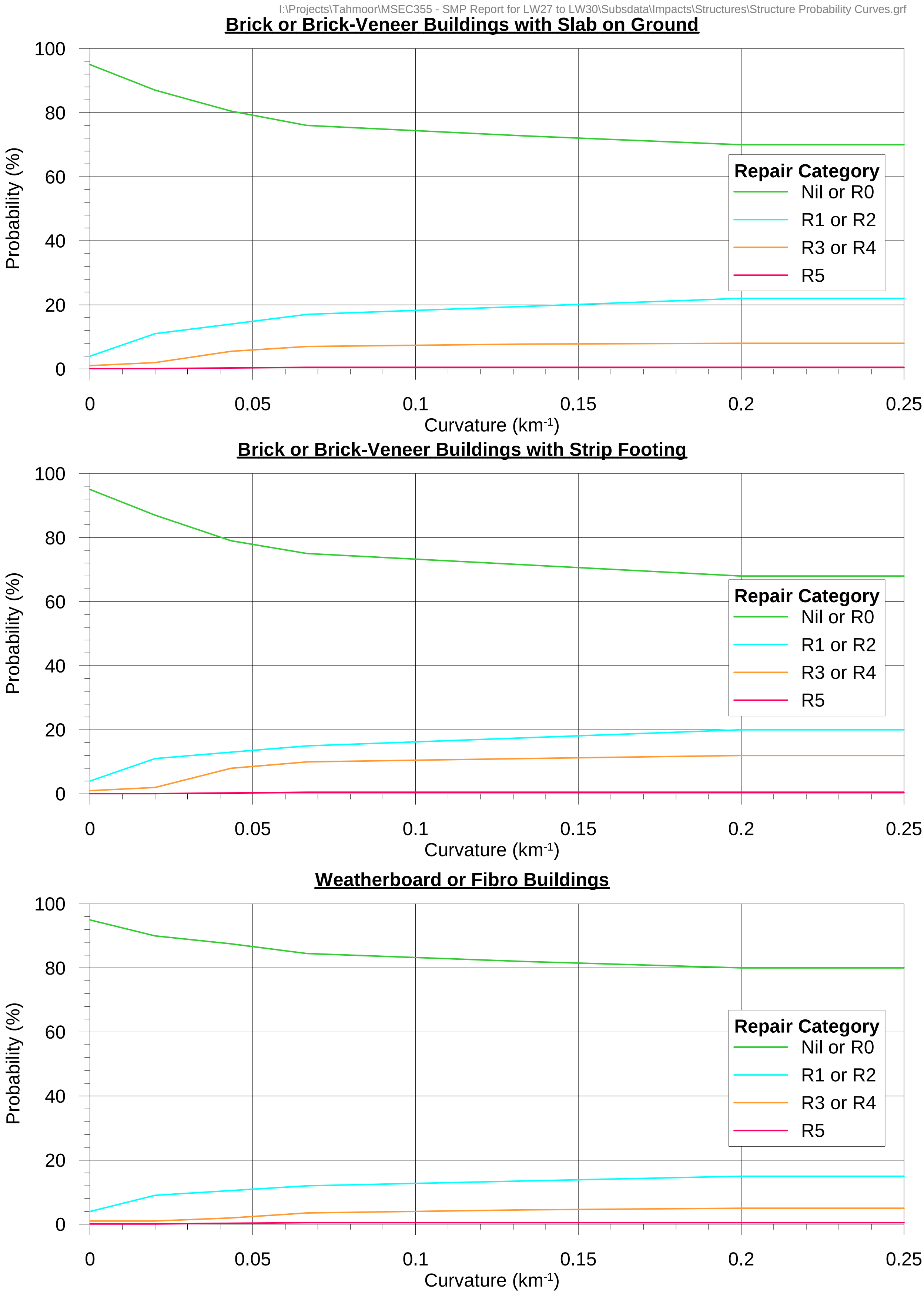


Fig. C.4 Probability Curves for Impacts to Buildings

APPENDIX D. TABLES

Table D.01 - Houses within the Study Area
Maximum Predicted Conventional Subsidence Parameters and Impact Assessments

House No.	Mine Subsidence District	Natural Ground Slope (mm/m)	Wall Type	Footing Type	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Predicted Probabulity of Nil or Category R0 Impact (%)	Predicted Probabulity of Category R1 or R2 Impact (%)	Predicted Probabulity of Category R3 or R4 Impact (%)	Predicted Probabulity of Category R5 Impact (%)
1	Wyong	50	Timber Frame	Suspended	13	1	1500	1.2	0.08	0.04	84	12	4	< 0.5
2	Wyong	< 50	Brick-Veneer	Suspended	37	1	200	1.5	0.01	< 0.01	89	9	2	< 0.1
3	Wyong	< 50	Timber Frame	Suspended	18	1	2250	3.1	0.05	0.04	86	11	3	< 0.4
4	Wyong	250	Brick-Veneer	Not Available	29	2	1200	9.3	0.08	0.06	75	18	7	< 0.5
5	Wyong	150	Not Available	Not Available	26	NA	2250	2.4	0.06	0.18	71	21	8	< 0.5
6	Wyong	100	Brick-Veneer	On Ground	34	2	2100	3.2	0.09	0.04	75	18	7	< 0.5
7	Wyong	< 50	Not Available	Not Available	17	NA	100	1.0	< 0.01	< 0.01	92	7	1	< 0.1
8	Wyong	200	Timber Frame	Suspended	13	1	700	7.7	0.08	< 0.01	84	12	4	< 0.5
9	Wyong	< 50	Brick-Veneer	Suspended	20	1	25	0.3	< 0.01	< 0.01	94	5	1	< 0.1
10	Wyong	50	Timber Frame	Suspended	13	1	25	0.3	< 0.01	< 0.01	94	5	1	< 0.1
11	Wyong	100	Not Available	Not Available	12	1	100	0.7	< 0.01	< 0.01	93	6	1	< 0.1
12	Wyong	150	Brick-Veneer	Not Available	37	1	100	0.7	< 0.01	< 0.01	93	6	1	< 0.1
13	Wyong	50	Timber Frame	Suspended	25	1	2050	2.9	0.09	0.04	84	12	4	< 0.5
14	Wyong	< 50	Brick-Veneer	Suspended	17	1	200	1.8	0.02	< 0.01	87	11	2	< 0.1
15	Wyong	100	Timber Frame	Suspended	19	1	1500	1.8	0.04	0.15	81	14	5	< 0.5
16	Wyong	< 50	Timber Frame	Suspended	18	1	1450	5.8	0.04	0.12	83	13	4	< 0.5
17	Wyong	< 50	Timber Frame	Suspended	19	1	500	3.9	0.03	0.02	89	9	1	< 0.2
18	Wyong	100	Brick-Veneer	Suspended	20	2	1900	2.8	0.07	0.11	73	17	11	< 0.5
19	Wyong	100	Brick-Veneer	Suspended	23	1	1450	4.2	0.09	0.05	74	16	10	< 0.5
20	Wyong	100	Brick-Veneer	Suspended	38	1	1350	2.5	0.10	0.03	73	16	11	< 0.5
21	Wyong	150	Brick-Veneer	On Ground	48	1	1650	3.7	0.09	0.04	75	18	7	< 0.5
22	Wyong	100	Brick-Veneer	Not Available	44	1	2350	4.7	0.17	0.26	67	24	9	< 0.5
23	Wyong	150	Brick-Veneer	Suspended	24	1	1450	2.1	0.04	0.09	74	16	10	< 0.5
24	Wyong	100	Timber Frame	Suspended	24	1	1200	1.9	0.04	0.03	87	11	2	< 0.3
25	Wyong	< 50	Timber Frame	Suspended	29	1	1050	2.3	0.15	0.04	82	14	5	< 0.5
26	Wyong	150	Brick-Veneer	Suspended	32	1	50	0.7	< 0.01	< 0.01	91	7	1	< 0.1
27	Wyong	100	Brick-Veneer	On Ground	16	1	25	0.6	< 0.01	< 0.01	92	7	1	< 0.1
28	Wyong	100	Timber Frame	Suspended	17	1	1300	3.9	0.14	0.19	80	15	5	< 0.5
29	Wyong	50	Brick-Veneer	Not Available	23	1	1250	10.4	0.19	0.23	68	23	9	< 0.5
30	Wyong	100	Brick-Veneer	Not Available	25	1	1900	5.6	0.08	0.06	75	17	7	< 0.5
31	Wyong	< 50	Not Available	Not Available	10	NA	300	3.7	0.07	0.01	76	17	7	< 0.5
32	Wyong	50	Timber Frame	Suspended	17	1	950	10.2	0.18	0.09	81	14	5	< 0.5
33	Wyong	100	Brick-Veneer	On Ground	31	1	1250	3.9	0.14	0.18	71	21	8	< 0.5
34	Wyong	50	Brick-Veneer	Suspended	11	1	1300	6.6	0.22	0.16	67	21	13	< 0.5
35	Wyong	50	Brick-Veneer	On Ground	24	1	1150	1.4	0.13	0.04	73	19	8	< 0.5
36	Wyong	100	Brick-Veneer	On Ground	37	1	1100	3.1	0.05	0.04	80	14	6	< 0.3
37	Wyong	50	Brick-Veneer	On Ground	26	1	25	0.3	< 0.01	< 0.01	94	5	1	< 0.1
38	Wyong	100	Brick-Veneer	Suspended	47	1	1200	1.9	0.05	0.03	78	13	8	< 0.3
39	Wyong	100	Brick-Veneer	On Ground	21	1	1350	5.7	0.05	0.22	69	23	8	< 0.5
40	Wyong	100	Brick-Veneer	On Ground	26	1	75	1.0	< 0.01	< 0.01	91	7	1	< 0.1
41	Wyong	< 50	Timber Frame	Suspended	15	1	75	0.4	< 0.01	< 0.01	94	5	1	< 0.1
42	Wyong	100	Brick-Veneer	On Ground	24	1	1250	1.8	0.06	0.03	77	16	7	< 0.4
43	Wyong	< 50	Brick-Veneer	Suspended	19	1	1250	4.6	0.13	0.18	69	19	12	< 0.5
44	Wyong	100	Brick-Veneer	Suspended	23	1	1300	2.1	0.04	0.03	81	13	7	< 0.3

Table D.01 - Houses within the Study Area
Maximum Predicted Conventional Subsidence Parameters and Impact Assessments

House No.	Mine Subsidence District	Natural Ground Slope (mm/m)	Wall Type	Footing Type	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Predicted Probabulity of Nil or Category R0 Impact (%)	Predicted Probabulity of Category R1 or R2 Impact (%)	Predicted Probabulity of Category R3 or R4 Impact (%)	Predicted Probabulity of Category R5 Impact (%)
45	Wyong	< 50	Brick-Veneer	Suspended	22	1	1200	1.5	0.05	0.03	78	13	8	< 0.3
46	Wyong	50	Timber Frame	Suspended	20	1	1100	1.8	0.08	0.03	84	12	4	< 0.5
47	Wyong	50	Timber Frame	Suspended	19	1	< 20	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
48	Wyong	< 50	Brick-Veneer	On Ground	20	1	25	0.2	< 0.01	< 0.01	93	5	1	< 0.1
49	Wyong	50	Brick-Veneer	On Ground	23	2	50	0.5	< 0.01	< 0.01	92	6	1	< 0.1
50	Wyong	150	Brick-Veneer	On Ground	29	1	< 20	< 0.2	< 0.01	< 0.01	93	6	1	< 0.1
51	Wyong	100	Brick-Veneer	Suspended	49	1	75	0.9	0.01	< 0.01	90	8	2	< 0.1
52	Wyong	50	Timber Frame	Suspended	20	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
53	Wyong	100	Timber Frame	Suspended	17	1	25	0.3	< 0.01	< 0.01	94	5	1	< 0.1
54	Wyong	100	Brick-Veneer	Not Available	28	1	1400	1.9	0.03	0.09	75	18	7	< 0.5
55	Wyong	50	Brick-Veneer	On Ground	17	2	75	0.7	< 0.01	< 0.01	92	6	1	< 0.1
56	Wyong	300	Brick-Veneer	On Ground	27	2	< 20	< 0.2	< 0.01	< 0.01	93	6	1	< 0.1
57	Wyong	< 50	Brick-Veneer	On Ground	21	1	1200	1.6	0.05	0.03	79	15	6	< 0.3
58	Wyong	50	Brick-Veneer	On Ground	15	1	1050	2.2	0.08	0.03	76	17	7	< 0.5
59	Wyong	100	Timber Frame	Suspended	24	1	25	< 0.2	< 0.01	< 0.01	93	6	1	< 0.1
60	Wyong	150	Brick-Veneer	Not Available	30	1	50	0.4	< 0.01	< 0.01	92	7	1	< 0.1
61	Wyong	100	Timber Frame	Suspended	19	1	50	0.4	< 0.01	< 0.01	94	5	1	< 0.1
62	Wyong	100	Timber Frame	Suspended	24	1	200	1.4	0.01	< 0.01	92	7	1	< 0.1
63	Wyong	50	Timber Frame	Suspended	19	1	25	0.2	< 0.01	< 0.01	94	5	1	< 0.1
64	Wyong	100	Brick-Veneer	On Ground	21	1	1300	2.6	0.09	0.15	72	20	8	< 0.5
65	Wyong	100	Timber Frame	Suspended	15	1	< 20	< 0.2	< 0.01	< 0.01	93	6	1	< 0.1
66	Wyong	200	Brick-Veneer	On Ground	30	1	1450	5.6	0.06	0.06	78	16	6	< 0.4
67	Wyong	100	Brick-Veneer	On Ground	23	1	1650	3.7	0.16	0.04	72	21	8	< 0.5
68	Wyong	100	Timber Frame	Suspended	13	1	< 20	< 0.2	< 0.01	< 0.01	93	6	1	< 0.1
69	Wyong	150	Brick-Veneer	Suspended	32	2	1700	1.9	0.04	0.05	79	13	8	< 0.3
70	Wyong	< 50	Timber Frame	Suspended	16	1	1250	2.0	0.04	0.03	88	10	2	< 0.3
71	Wyong	< 50	Timber Frame	Suspended	35	1	1150	1.3	0.12	0.03	82	13	4	< 0.5
72	Wyong	50	Timber Frame	Suspended	16	1	1300	2.1	0.04	0.03	88	10	2	< 0.3
73	Wyong	50	Brick-Veneer	On Ground	32	1	1200	2.0	0.12	0.04	73	19	8	< 0.5
74	Wyong	50	Brick-Veneer	On Ground	29	1	450	2.7	0.02	0.01	89	10	2	< 0.1
75	Wyong	100	Timber Frame	Suspended	16	1	25	< 0.2	0.01	< 0.01	92	7	1	< 0.1
76	Wyong	50	Timber Frame	Suspended	16	1	50	0.4	< 0.01	< 0.01	94	5	1	< 0.1
77	Wyong	50	Timber Frame	Suspended	15	1	200	1.8	0.02	< 0.01	90	9	1	< 0.1
78	Wyong	200	Brick-Veneer	On Ground	23	1	25	0.2	< 0.01	< 0.01	94	5	1	< 0.1
79	Wyong	200	Brick-Veneer	Suspended	27	2	25	0.3	< 0.01	< 0.01	94	5	1	< 0.1
80	Wyong	100	Timber Frame	Suspended	15	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
81	Wyong	50	Brick-Veneer	On Ground	24	1	100	1.2	0.02	< 0.01	88	10	2	< 0.1
82	Wyong	100	Timber Frame	On Ground	18	1	1350	7.5	0.25	0.27	75	18	7	< 0.5
83	Wyong	150	Timber Frame	Suspended	20	1	1200	2.8	0.09	0.04	84	12	4	< 0.5
84	Wyong	100	Brick-Veneer	Suspended	26	1	1350	7.0	0.24	0.27	63	23	14	< 0.5
85	Wyong	100	Brick-Veneer	Suspended	25	1	1200	3.4	0.05	0.04	77	14	9	< 0.4
86	Wyong	< 50	Brick-Veneer	Not Available	26	1	1150	4.3	0.06	0.10	74	18	7	< 0.5
87	Wyong	100	Brick-Veneer	Suspended	26	1	350	4.4	0.07	0.03	75	15	10	< 0.5
88	Wyong	< 50	Timber Frame	On Ground	30	1	450	5.3	0.06	0.02	85	12	3	< 0.5

Table D.01 - Houses within the Study Area
Maximum Predicted Conventional Subsidence Parameters and Impact Assessments

House No.	Mine Subsidence District	Natural Ground Slope (mm/m)	Wall Type	Footing Type	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Predicted Probabulity of Nil or Category R0 Impact (%)	Predicted Probabulity of Category R1 or R2 Impact (%)	Predicted Probabulity of Category R3 or R4 Impact (%)	Predicted Probabulity of Category R5 Impact (%)
89	Wyong	< 50	Timber Frame	On Ground	22	1	1100	1.8	0.04	0.08	84	12	4	< 0.5
90	Wyong	50	Timber Frame	Suspended	26	1	1200	3.0	0.18	0.04	81	15	5	< 0.5
91	Wyong	50	Timber Frame	Suspended	19	1	1350	3.8	0.06	0.27	74	19	7	< 0.5
92	Wyong	100	Brick-Veneer	Suspended	23	1	1300	3.3	0.06	0.05	76	15	10	< 0.5
93	Wyong	< 50	Not Available	Suspended	14	2	1100	3.2	0.25	0.04	68	23	9	< 0.5
94	Wyong	< 50	Brick-Veneer	On Ground	27	1	750	2.6	0.11	0.10	74	19	8	< 0.5
95	Wyong	< 50	Brick-Veneer	On Ground	21	1	750	2.3	0.03	0.05	80	14	6	< 0.3
96	Wyong	50	Brick-Veneer	Suspended	29	1	1350	3.4	0.06	0.24	65	22	13	< 0.5
97	Wyong	50	Brick-Veneer	On Ground	28	1	1350	5.9	0.05	0.24	68	23	9	< 0.5
98	Wyong	100	Brick-Veneer	Suspended	16	1	< 20	0.3	< 0.01	< 0.01	93	6	1	< 0.1
99	Hue Hue	100	Brick-Veneer	On Ground	26	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
100	Hue Hue	50	Brick-Veneer	Suspended	34	1	50	0.3	< 0.01	< 0.01	94	5	1	< 0.1
101	Hue Hue	50	Brick-Veneer	On Ground	34	1	75	0.6	< 0.01	< 0.01	91	7	1	< 0.1
102	Hue Hue	< 50	Brick-Veneer	On Ground	24	1	750	2.1	0.03	0.08	75	18	7	< 0.5
103	Hue Hue	50	Brick-Veneer	On Ground	25	1	700	2.2	0.03	0.04	82	13	5	< 0.3
104	Hue Hue	100	Brick-Veneer	On Ground	22	1	700	2.2	0.03	0.04	81	14	5	< 0.3
105	Hue Hue	< 50	Brick-Veneer	On Ground	24	1	700	2.3	0.03	0.04	81	14	5	< 0.3
106	Hue Hue	100	Brick-Veneer	On Ground	28	1	750	2.0	0.10	0.14	72	20	8	< 0.5
107	Hue Hue	50	Brick-Veneer	On Ground	41	1	750	0.9	0.09	0.14	73	20	8	< 0.5
108	Hue Hue	100	Brick-Veneer	Suspended	32	1	850	2.5	0.09	0.02	74	16	10	< 0.5
109	Hue Hue	50	Brick-Veneer	On Ground	31	1	1000	2.6	0.04	0.03	82	13	5	< 0.3
110	Hue Hue	100	Brick-Veneer	On Ground	29	1	1000	2.4	0.04	0.05	79	15	6	< 0.4
111	Hue Hue	100	Brick-Veneer	On Ground	25	1	1000	3.0	0.10	0.18	71	21	8	< 0.5
112	Hue Hue	100	Brick-Veneer	On Ground	39	1	1000	2.5	0.11	0.15	72	20	8	< 0.5
113	Hue Hue	100	Brick-Veneer	On Ground	23	1	950	1.4	0.09	0.02	75	18	7	< 0.5
114	Hue Hue	100	Brick-Veneer	On Ground	36	1	1000	2.5	0.11	0.15	72	20	8	< 0.5
115	Hue Hue	100	Brick-Veneer	Suspended	17	1	1000	1.9	0.04	0.14	71	18	11	< 0.5
116	Hue Hue	100	Brick-Veneer	Suspended	29	1	900	2.6	0.06	0.03	76	15	10	< 0.5
117	Hue Hue	100	Brick-Veneer	On Ground	33	1	800	2.5	0.08	0.07	75	18	7	< 0.5
118	Hue Hue	100	Brick-Veneer	On Ground	26	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
119	Hue Hue	100	Brick-Veneer	On Ground	36	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
120	Hue Hue	100	Brick-Veneer	Suspended	29	1	700	2.2	0.02	0.10	73	16	10	< 0.5
121	Hue Hue	100	Brick-Veneer	On Ground	26	1	700	1.7	0.07	0.11	74	19	8	< 0.5
122	Hue Hue	50	Brick-Veneer	On Ground	24	1	900	2.6	0.07	0.02	76	17	7	< 0.5
123	Hue Hue	< 50	Brick-Veneer	Suspended	35	1	1000	2.2	0.04	0.12	72	17	11	< 0.5
124	Hue Hue	< 50	Brick-Veneer	On Ground	32	1	1000	2.3	0.10	0.15	72	20	8	< 0.5
125	Hue Hue	50	Brick-Veneer	On Ground	34	1	950	1.5	0.11	0.02	74	18	7	< 0.5
126	Hue Hue	50	Brick-Veneer	Suspended	28	1	1050	1.6	0.03	0.05	78	14	9	< 0.4
127	Hue Hue	50	Brick-Veneer	On Ground	21	1	1050	1.6	0.03	0.08	76	17	7	< 0.5
128	Hue Hue	100	Brick-Veneer	On Ground	28	1	1050	1.1	0.08	0.02	75	18	7	< 0.5
129	Hue Hue	50	Brick-Veneer	On Ground	30	1	1000	1.4	0.09	0.02	75	18	7	< 0.5
130	Hue Hue	50	Brick-Veneer	Suspended	24	1	1050	1.6	0.09	0.13	72	17	11	< 0.5
131	Hue Hue	100	Brick-Veneer	On Ground	23	1	1050	1.6	0.09	0.08	75	18	7	< 0.5
132	Hue Hue	100	Brick-Veneer	On Ground	30	1	1050	1.5	0.07	0.12	74	19	8	< 0.5

Table D.01 - Houses within the Study Area
Maximum Predicted Conventional Subsidence Parameters and Impact Assessments

House No.	Mine Subsidence District	Natural Ground Slope (mm/m)	Wall Type	Footing Type	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Predicted Probabulity of Nil or Category R0 Impact (%)	Predicted Probabulity of Category R1 or R2 Impact (%)	Predicted Probabulity of Category R3 or R4 Impact (%)	Predicted Probabulity of Category R5 Impact (%)
133	Hue Hue	100	Brick-Veneer	On Ground	30	2	1050	1.4	0.03	0.12	74	19	8	< 0.5
134	Hue Hue	150	Brick-Veneer	Suspended	25	2	1050	1.8	0.03	0.12	72	17	11	< 0.5
135	Hue Hue	150	Brick-Veneer	Suspended	19	2	1050	1.6	0.03	0.10	73	16	10	< 0.5
136	Hue Hue	100	Brick-Veneer	Suspended	41	1	1050	1.6	0.05	0.04	78	13	8	< 0.3
137	Hue Hue	50	Brick-Veneer	On Ground	18	1	700	1.1	0.04	0.13	73	19	8	< 0.5
138	Hue Hue	< 50	Brick-Veneer	On Ground	41	1	700	2.3	0.03	0.04	82	13	5	< 0.3
139	Hue Hue	< 50	Brick-Veneer	On Ground	24	1	600	3.9	0.02	0.07	76	17	7	< 0.5
140	Hue Hue	< 50	Brick-Veneer	On Ground	27	1	350	3.7	0.05	0.03	80	15	6	< 0.3
141	Hue Hue	< 50	Brick-Veneer	On Ground	28	1	450	4.0	0.05	0.05	79	15	6	< 0.4
142	Hue Hue	< 50	Brick-Veneer	Suspended	27	1	300	3.0	0.05	0.04	78	13	8	< 0.3
143	Hue Hue	< 50	Brick-Veneer	On Ground	28	1	150	1.7	0.02	< 0.01	87	11	2	< 0.1
144	Hue Hue	< 50	Brick-Veneer	On Ground	24	1	75	0.5	< 0.01	< 0.01	92	6	1	< 0.1
145	Hue Hue	< 50	Brick-Veneer	On Ground	52	2	50	0.4	< 0.01	< 0.01	93	6	1	< 0.1
146	Hue Hue	< 50	Brick-Veneer	On Ground	23	1	50	0.2	< 0.01	< 0.01	94	5	1	< 0.1
147	Hue Hue	< 50	Brick-Veneer	On Ground	25	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
148	Hue Hue	< 50	Brick-Veneer	On Ground	25	1	200	2.1	0.02	0.01	87	11	2	< 0.1
149	Hue Hue	< 50	Brick-Veneer	Suspended	27	1	150	1.5	0.02	< 0.01	88	10	2	< 0.1
150	Wyong	200	Timber Frame	Not Available	17	2	200	1.5	0.01	< 0.01	92	7	1	< 0.1
151	Wyong	150	Not Available	Not Available	21	1	50	0.5	< 0.01	< 0.01	93	5	1	< 0.1
152	Wyong	50	Timber Frame	Suspended	17	1	1550	2.8	0.07	0.03	84	12	4	< 0.5
153	Wyong	< 50	Timber Frame	Suspended	33	1	1200	9.7	0.09	0.13	82	14	5	< 0.5
154	Wyong	100	Not Available	Not Available	18	2	350	3.5	0.03	0.03	83	13	4	< 0.2
155	Wyong	100	Timber Frame	Suspended	12	2	< 20	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
156	Wyong	100	Brick-Veneer	Not Available	18	2	2200	3.0	0.06	0.23	68	23	9	< 0.5
157	Wyong	150	Brick-Veneer	On Ground	32	1	25	0.3	< 0.01	< 0.01	94	5	1	< 0.1
158	Wyong	100	Not Available	Not Available	30	NA	100	0.6	< 0.01	< 0.01	93	6	1	< 0.1
159	Wyong	100	Brick-Veneer	On Ground	22	2	25	0.3	< 0.01	< 0.01	94	5	1	< 0.1
160	Wyong	250	Brick-Veneer	Suspended	34	2	50	0.3	< 0.01	< 0.01	93	5	1	< 0.1
161	Wyong	150	Not Available	Not Available	38	NA	150	1.1	0.01	< 0.01	91	8	2	< 0.1
162	Hue Hue	< 50	Brick-Veneer	On Ground	39	1	100	0.9	0.01	< 0.01	89	9	2	< 0.1
163	Hue Hue	100	Brick-Veneer	On Ground	27	1	1050	1.4	0.03	0.06	77	16	7	< 0.5
164	Hue Hue	50	Brick-Veneer	Suspended	29	1	1000	1.4	0.09	0.02	74	16	10	< 0.5
165	Hue Hue	50	Brick-Veneer	Suspended	26	1	950	1.6	0.09	0.08	74	16	10	< 0.5
166	Hue Hue	100	Brick-Veneer	On Ground	35	1	950	1.4	0.03	0.10	74	18	7	< 0.5
167	Hue Hue	50	Brick-Veneer	On Ground	20	1	700	1.0	0.05	0.09	75	18	7	< 0.5
168	Hue Hue	50	Brick-Veneer	On Ground	28	1	600	3.9	0.02	0.06	77	16	7	< 0.5
169	Hue Hue	50	Brick-Veneer	On Ground	30	1	100	1.2	0.02	< 0.01	89	10	2	< 0.1
170	Hue Hue	50	Brick-Veneer	On Ground	25	1	50	0.3	< 0.01	< 0.01	93	5	1	< 0.1
171	Hue Hue	100	Brick-Veneer	On Ground	25	1	50	0.3	< 0.01	< 0.01	94	5	1	< 0.1
172	Hue Hue	100	Brick-Veneer	On Ground	23	1	75	0.6	0.01	< 0.01	90	8	2	< 0.1
173	Hue Hue	100	Brick-Veneer	Suspended	26	1	150	1.8	0.02	< 0.01	87	11	2	< 0.1
174	Hue Hue	100	Brick-Veneer	Not Available	27	NA	150	1.6	0.02	< 0.01	87	11	2	< 0.1
175	Hue Hue	150	Brick-Veneer	On Ground	45	1	75	0.6	< 0.01	< 0.01	92	7	1	< 0.1
176	Hue Hue	50	Brick-Veneer	On Ground	38	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1

Table D.01 - Houses within the Study Area
Maximum Predicted Conventional Subsidence Parameters and Impact Assessments

House No.	Mine Subsidence District	Natural Ground Slope (mm/m)	Wall Type	Footing Type	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Predicted Probabulity of Nil or Category R0 Impact (%)	Predicted Probabulity of Category R1 or R2 Impact (%)	Predicted Probabulity of Category R3 or R4 Impact (%)	Predicted Probabulity of Category R5 Impact (%)
177	Hue Hue	50	Brick-Veneer	On Ground	23	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
178	Hue Hue	100	Brick-Veneer	On Ground	24	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
179	Hue Hue	150	Brick-Veneer	On Ground	28	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
180	Hue Hue	100	Brick-Veneer	On Ground	27	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
181	Hue Hue	100	Brick-Veneer	On Ground	23	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
182	Hue Hue	150	Brick-Veneer	On Ground	28	2	75	0.7	< 0.01	< 0.01	92	7	1	< 0.1
183	Wyong	100	Brick-Veneer	On Ground	32	1	200	1.4	0.02	< 0.01	89	9	2	< 0.1
184	Wyong	< 50	Brick-Veneer	On Ground	19	1	25	< 0.2	< 0.01	< 0.01	93	6	1	< 0.1
185	Wyong	50	Brick-Veneer	On Ground	34	1	75	1.1	0.02	< 0.01	89	10	2	< 0.1
186	Hue Hue	150	Brick-Veneer	Not Available	29	1	1250	3.8	0.04	0.19	71	21	8	< 0.5
187	Hue Hue	100	Brick-Veneer	On Ground	29	1	1250	2.1	0.05	0.05	79	15	6	< 0.4
188	Hue Hue	150	Brick-Veneer	Not Available	25	1	1150	1.8	0.10	0.03	74	18	7	< 0.5
189	Hue Hue	100	Brick-Veneer	On Ground	37	1	50	0.7	< 0.01	< 0.01	91	7	1	< 0.1
190	Wyong	50	Not Available	Not Available	17	NA	1350	6.6	0.06	0.27	67	24	9	< 0.5
191	Wyong	50	Timber Frame	Suspended	17	1	25	0.3	< 0.01	< 0.01	93	6	1	< 0.1
192	Wyong	100	Timber Frame	Suspended	19	2	150	1.8	0.02	0.02	90	9	1	< 0.1
193	Wyong	100	Brick-Veneer	Suspended	25	1	1250	10.7	0.13	0.29	60	25	15	< 0.5
194	Wyong	50	Timber Frame	Suspended	22	1	1100	6.0	0.26	0.04	76	18	6	< 0.5
195	Hue Hue	100	Brick-Veneer	Suspended	17	2	1100	3.7	0.22	0.03	67	21	12	< 0.5
196	Wyong	< 50	Brick-Veneer	On Ground	31	1	1300	5.7	0.23	0.23	69	23	9	< 0.5
197	Wyong	< 50	Brick-Veneer	Suspended	34	1	50	0.3	< 0.01	< 0.01	94	5	1	< 0.1
198	Wyong	< 50	Timber Frame	Suspended	19	1	1000	8.4	0.09	0.07	83	13	4	< 0.5
199	Wyong	< 50	Timber Frame	Suspended	22	1	1400	2.2	0.13	0.02	82	13	4	< 0.5
200	Wyong	150	Brick-Veneer	On Ground	33	1	1550	3.9	0.15	0.07	72	20	8	< 0.5
201	Hue Hue	100	Brick-Veneer	On Ground	40	1	1000	1.5	0.11	0.03	74	19	8	< 0.5
202	Hue Hue	150	Timber Frame	Suspended	21	2	1300	1.9	0.04	0.04	87	11	2	< 0.3
203	Wyong	100	Timber Frame	Suspended	18	2	1400	9.6	0.04	0.06	86	11	3	< 0.4
204	Wyong	50	Timber Frame	Suspended	20	1	2000	4.9	0.06	0.10	83	13	4	< 0.5
205	Wyong	100	Timber Frame	Not Available	14	2	2100	2.8	0.17	0.04	81	14	5	< 0.5
206	Wyong	< 50	Timber Frame	Suspended	15	1	75	0.4	< 0.01	< 0.01	93	6	1	< 0.1
207	Wyong	150	Brick-Veneer	Suspended	23	1	< 20	0.2	< 0.01	< 0.01	91	7	1	< 0.1
208	Wyong	300	Timber Frame	Suspended	17	NA	250	1.9	0.02	< 0.01	91	8	1	< 0.1
209	Hue Hue	150	Brick-Veneer	Suspended	26	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
210	Hue Hue	100	Brick-Veneer	On Ground	28	1	500	3.8	0.04	0.06	78	16	6	< 0.4
211	Hue Hue	100	Brick-Veneer	On Ground	21	1	700	1.8	0.02	0.09	75	18	7	< 0.5
212	Wyong	< 50	Timber Frame	Suspended	18	1	1500	2.5	0.15	0.03	82	14	5	< 0.5
213	Hue Hue	< 50	Brick-Veneer	On Ground	31	1	25	< 0.2	< 0.01	< 0.01	94	5	1	< 0.1
214	Wyong	< 50	Brick-Veneer	Suspended	30	1	1500	2.4	0.13	0.20	68	20	12	< 0.5
215	Wyong	< 50	Timber Frame	Suspended	20	1	700	7.7	0.10	0.02	83	13	4	< 0.5
216	Wyong	50	Brick-Veneer	Suspended	30	1	100	1.3	0.02	0.02	88	11	2	< 0.1
217	Wyong	300	Timber Frame	On Ground	26	2	300	3.3	0.03	< 0.01	89	10	2	< 0.2
218	Hue Hue	< 50	Brick-Veneer	On Ground	25	1	300	3.1	0.04	0.03	80	14	6	< 0.3
219	Hue Hue	100	Brick-Veneer	On Ground	32	1	550	3.9	0.02	0.06	77	16	7	< 0.5
220	Hue Hue	100	Timber Frame	On Ground	14	1	600	2.9	0.02	0.05	86	11	3	< 0.4

Table D.01 - Houses within the Study Area
Maximum Predicted Conventional Subsidence Parameters and Impact Assessments

House No.	Mine Subsidence District	Natural Ground Slope (mm/m)	Wall Type	Footing Type	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Predicted Probabulity of Nil or Category R0 Impact (%)	Predicted Probabulity of Category R1 or R2 Impact (%)	Predicted Probabulity of Category R3 or R4 Impact (%)	Predicted Probabulity of Category R5 Impact (%)
221	Hue Hue	50	Brick-Veneer	On Ground	39	1	750	1.6	0.07	0.07	76	17	7	< 0.5
222	Hue Hue	100	Brick-Veneer	On Ground	28	1	850	2.4	0.06	0.02	78	16	6	< 0.4
223	Wyong	150	Brick-Veneer	Suspended	33	1	1300	6.6	0.25	0.24	64	22	13	< 0.5
224	Wyong	< 50	Brick-Veneer	Suspended	31	1	1350	1.8	0.05	0.07	75	15	10	< 0.5
225	Wyong	50	Timber Frame	Suspended	41	1	1350	2.0	0.04	0.08	84	12	4	< 0.5
226	Wyong	< 50	Timber Frame	Suspended	18	1	1250	3.2	0.15	0.03	82	14	5	< 0.5
227	Wyong	100	Timber Frame	Suspended	29	2	1200	1.5	0.10	0.02	83	13	4	< 0.5
228	Wyong	100	Brick-Veneer	On Ground	10	1	< 20	< 0.2	< 0.01	< 0.01	91	7	1	< 0.1
229	Wyong	100	Timber Frame	Suspended	20	1	100	0.7	< 0.01	< 0.01	93	6	1	< 0.1
230	Wyong	100	Brick-Veneer	Suspended	19	1	25	0.3	< 0.01	< 0.01	92	7	1	< 0.1
231	Wyong	100	Brick-Veneer	Suspended	14	1	200	2.5	0.03	< 0.01	84	12	4	< 0.2
232	Wyong	150	Timber Frame	Suspended	18	2	2050	12.8	0.07	0.27	75	19	7	< 0.5
233	Wyong	< 50	Not Available	Not Available	24	NA	2250	11.1	0.07	0.30	65	25	10	< 0.5
234	Wyong	< 50	Timber Frame	On Ground	12	1	950	3.3	0.05	0.02	87	11	2	< 0.3
235	Wyong	< 50	Timber Frame	Suspended	15	1	1250	4.5	0.11	0.17	81	14	5	< 0.5
236	Wyong	50	Brick-Veneer	On Ground	25	1	< 20	0.3	< 0.01	< 0.01	93	6	1	< 0.1
237	Wyong	100	Brick-Veneer	On Ground	30	1	< 20	< 0.2	< 0.01	< 0.01	92	7	1	< 0.1
238	Wyong	150	Timber Frame	Suspended	15	1	1100	8.3	0.04	0.06	86	11	3	< 0.4
239	Wyong	50	Timber Frame	Suspended	14	1	25	0.2	< 0.01	< 0.01	94	5	1	< 0.1
240	Wyong	100	Timber Frame	Suspended	30	1	1250	2.0	0.05	0.04	87	11	2	< 0.3
241	Wyong	100	Not Available	Not Available	16	NA	75	0.7	< 0.01	< 0.01	93	6	1	< 0.1
242	Wyong	100	Timber Frame	Not Available	22	1	1350	2.9	0.07	0.05	85	12	3	< 0.5
						Maximums:	2350	13	0.26	0.30				

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
1	9	1	600	6.9	0.08	< 0.01
2	5	1	750	8.2	0.08	< 0.01
3	1	1	800	8.3	0.08	< 0.01
4	4	1	25	0.3	< 0.01	< 0.01
5	4	1	1700	3.3	0.05	0.03
6	8	1	600	7.2	0.08	0.04
7	7	1	650	7.7	0.08	0.05
8	4	1	550	7.0	0.07	0.04
9	4	1	450	5.8	0.06	0.03
10	4	1	500	6.4	0.06	0.03
11	7	1	1150	3.7	0.05	0.03
12	4	1	300	2.9	0.04	0.02
13	8	1	250	2.3	0.02	0.01
14	4	1	150	1.3	< 0.01	< 0.01
15	3	1	150	1.1	< 0.01	< 0.01
16	4	1	50	0.5	< 0.01	< 0.01
17	4	1	50	0.5	< 0.01	< 0.01
18	8	1	100	0.8	< 0.01	< 0.01
19	8	1	100	0.7	< 0.01	< 0.01
20	4	1	75	0.7	< 0.01	< 0.01
21	13	1	100	0.8	< 0.01	< 0.01
22	7	1	100	0.9	< 0.01	< 0.01
23	16	1	100	0.8	< 0.01	< 0.01
24	11	1	75	0.6	< 0.01	< 0.01
25	11	1	100	0.8	< 0.01	< 0.01
26	10	1	1400	9.1	0.03	0.14
27	6	1	1450	9.6	0.11	0.07
28	24	1	1350	9.7	0.11	0.10
29	11	1	150	1.3	0.02	< 0.01
30	14	1	100	0.6	< 0.01	< 0.01
31	12	1	100	0.7	< 0.01	< 0.01
32	11	1	75	0.5	< 0.01	< 0.01
33	2	1	75	0.5	< 0.01	< 0.01
34	13	1	100	0.8	< 0.01	< 0.01
35	8	1	100	0.9	< 0.01	< 0.01
36	8	1	150	1.3	0.01	< 0.01
37	13	1	300	2.8	0.03	< 0.01
38	3	1	200	1.9	0.02	< 0.01
39	4	1	150	1.7	0.02	0.01
40	8	1	400	4.0	0.04	0.03
41	15	1	< 20	< 0.2	< 0.01	< 0.01
42	21	1	< 20	< 0.2	< 0.01	< 0.01
43	6	1	< 20	< 0.2	< 0.01	< 0.01
44	10	1	25	0.3	< 0.01	< 0.01
45	21	1	25	0.3	< 0.01	< 0.01
46	5	1	< 20	< 0.2	< 0.01	< 0.01
47	4	1	< 20	< 0.2	< 0.01	< 0.01
48	5	1	< 20	< 0.2	< 0.01	< 0.01
49	13	1	200	1.5	0.01	< 0.01
50	8	1	200	1.6	0.01	0.01
51	11	1	300	2.7	0.04	0.01
52	5	1	1600	2.0	0.06	0.03
53	5	1	1550	1.8	0.08	0.03
54	17	1	1700	1.7	0.03	0.10
55	9	1	1700	1.6	0.03	0.08
56	5	1	150	1.6	0.02	0.01
57	8	1	150	1.6	0.02	< 0.01

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
58	11	1	200	1.9	0.03	< 0.01
59	6	1	200	1.9	0.03	< 0.01
60	22	1	200	1.7	0.02	< 0.01
61	2	1	150	1.5	0.02	< 0.01
62	6	1	150	1.5	0.02	< 0.01
63	2	1	50	0.5	< 0.01	< 0.01
64	12	1	50	0.5	< 0.01	< 0.01
65	13	1	< 20	< 0.2	< 0.01	< 0.01
66	3	1	25	0.3	< 0.01	< 0.01
67	15	1	< 20	< 0.2	< 0.01	< 0.01
68	18	1	2050	5.1	0.15	0.20
69	14	1	2150	3.1	0.06	0.08
70	10	1	1800	3.9	0.09	0.04
71	7	1	1750	4.0	0.10	0.04
72	11	1	1750	4.1	0.13	0.04
73	4	1	1700	4.1	0.16	0.04
74	26	1	1300	2.1	0.08	0.02
75	8	1	1250	2.2	0.10	0.02
76	27	1	1200	1.5	0.10	0.02
77	12	1	1250	2.6	0.10	0.11
78	7	1	1650	2.9	0.05	0.04
79	31	1	1700	2.9	0.05	0.08
80	11	1	1750	2.7	0.05	0.17
81	19	1	1650	2.9	0.05	0.04
82	16	1	1700	2.9	0.05	0.09
83	10	1	1700	0.6	0.06	0.03
84	46	1	1350	2.1	0.04	0.03
85	10	1	1300	2.1	0.04	0.03
86	24	1	1300	2.1	0.05	0.03
87	8	1	1350	2.2	0.04	0.04
88	6	1	1300	2.1	0.04	0.04
89	9	1	1400	1.6	0.03	0.14
90	4	1	1400	1.5	0.03	0.12
91	2	1	1400	1.5	0.03	0.12
92	15	1	1250	1.7	0.05	0.02
93	24	1	1250	1.7	0.03	0.14
94	8	1	1250	1.9	0.03	0.05
95	5	1	1250	1.7	0.03	0.09
96	17	1	1200	1.9	0.03	0.03
97	3	1	1400	2.5	0.04	0.17
98	5	1	1200	1.9	0.05	0.03
99	10	1	1250	2.0	0.04	0.03
100	10	1	1200	2.0	0.04	0.03
101	10	1	1150	1.9	0.04	0.03
102	5	1	1100	1.6	0.10	0.03
103	8	1	1050	1.5	0.13	0.03
104	6	1	1100	1.6	0.10	0.03
105	8	1	1100	1.7	0.09	0.03
106	8	1	1050	3.0	0.14	0.02
107	5	1	1100	1.6	0.10	0.03
108	9	1	1050	1.5	0.13	0.02
109	8	1	1050	1.3	0.13	0.02
110	5	1	1200	4.8	0.14	0.15
111	5	1	1200	4.7	0.14	0.13
112	8	1	1250	4.8	0.13	0.18
113	9	1	1150	4.7	0.14	0.09
114	23	1	1150	4.7	0.14	0.08

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
115	6	1	1250	4.7	0.13	0.18
116	10	1	1250	4.7	0.14	0.18
117	27	1	1250	1.6	0.04	0.15
118	17	1	1250	3.4	0.04	0.18
119	9	1	1250	4.6	0.06	0.18
120	10	1	1250	4.0	0.04	0.18
121	7	1	1250	2.7	0.04	0.18
122	8	1	1250	2.0	0.04	0.17
123	7	1	1250	4.5	0.11	0.17
124	8	1	1200	4.5	0.13	0.15
125	14	1	1150	1.5	0.09	0.03
126	12	1	1150	2.3	0.13	0.03
127	8	1	1100	1.9	0.12	0.03
128	6	1	1200	1.7	0.03	0.03
129	6	1	1100	1.5	0.09	0.03
130	5	1	1050	1.9	0.09	0.03
131	12	1	1100	2.5	0.03	0.03
132	9	1	1100	2.5	0.03	0.03
133	22	1	1000	2.8	0.07	0.03
134	7	1	1100	4.9	0.03	0.10
135	18	1	400	2.6	0.02	< 0.01
136	9	1	150	0.8	< 0.01	< 0.01
137	7	1	750	4.8	0.02	0.06
138	7	1	350	3.0	0.03	0.02
139	2	1	450	2.6	0.02	0.01
140	25	1	1300	1.8	0.04	0.04
141	23	1	1250	1.8	0.04	0.03
142	8	1	1250	3.8	0.08	0.18
143	20	1	1250	3.7	0.10	0.18
144	3	1	1200	2.1	0.04	0.03
145	16	1	1300	2.0	0.04	0.04
146	9	1	1300	4.0	0.15	0.09
147	22	1	1500	2.2	0.04	0.20
148	18	1	1450	2.2	0.15	0.03
149	53	1	2200	4.4	0.09	0.07
150	3	1	1950	5.5	0.08	0.06
151	3	1	1900	5.6	0.08	0.06
152	3	1	1200	10.4	0.06	0.23
153	14	1	1300	9.1	0.05	0.23
154	18	1	600	7.5	0.16	0.02
155	13	1	1100	2.7	0.05	0.04
156	18	1	1350	4.6	0.05	0.22
157	10	1	1350	4.0	0.05	0.22
158	4	1	1350	2.1	0.05	0.04
159	12	1	1150	2.4	0.14	0.03
160	9	1	1200	3.7	0.14	0.03
161	9	1	1200	3.9	0.14	0.05
162	5	1	1150	1.9	0.05	0.03
163	8	1	1150	1.9	0.04	0.03
164	5	1	1300	6.0	0.17	0.22
165	12	1	1150	1.9	0.06	0.03
166	30	1	1250	1.9	0.04	0.04
167	8	1	1300	3.6	0.04	0.19
168	5	1	1300	2.7	0.04	0.19
169	19	1	1300	3.9	0.04	0.19
170	9	1	1300	3.3	0.04	0.19
171	17	1	1300	3.4	0.04	0.19

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
172	5	1	1300	3.7	0.04	0.19
173	4	1	1300	3.6	0.04	0.19
174	5	1	1300	3.7	0.04	0.19
175	5	1	1300	3.1	0.04	0.19
176	19	1	1300	3.9	0.10	0.19
177	13	1	1300	3.9	0.13	0.19
178	2	1	1150	3.3	0.14	0.03
179	5	1	1300	3.8	0.04	0.19
180	15	1	25	0.3	< 0.01	< 0.01
181	5	1	25	0.3	< 0.01	< 0.01
182	9	1	100	1.7	0.02	< 0.01
183	6	1	25	0.5	< 0.01	< 0.01
184	8	1	50	0.8	< 0.01	< 0.01
185	4	1	50	0.7	< 0.01	< 0.01
186	14	1	100	1.6	0.02	< 0.01
187	14	1	1150	1.6	0.19	0.03
188	6	1	1150	1.3	0.12	0.04
189	15	1	1400	6.6	0.22	0.25
190	21	1	1100	3.6	0.22	0.03
191	10	1	1100	1.8	0.12	0.04
192	5	1	1100	1.8	0.09	0.04
193	18	1	1150	5.2	0.22	0.03
194	11	1	1100	7.5	0.22	0.03
195	10	1	900	4.6	0.05	0.05
196	2	1	950	3.6	0.06	0.05
197	11	1	850	5.3	0.05	0.06
198	12	1	350	4.4	0.07	0.01
199	4	1	400	5.0	0.07	0.01
200	10	1	400	5.1	0.07	0.01
201	11	1	100	1.4	0.01	0.01
202	16	1	250	4.8	0.07	0.03
203	12	1	200	4.2	0.06	< 0.01
204	6	1	< 20	< 0.2	< 0.01	< 0.01
205	5	1	< 20	0.2	< 0.01	< 0.01
206	24	1	1150	3.4	0.24	0.04
207	7	1	1200	3.4	0.07	0.04
208	9	1	1250	3.4	0.06	0.05
209	16	1	1350	6.0	0.23	0.24
210	4	1	1300	6.0	0.24	0.21
211	17	1	1150	6.6	0.25	0.03
212	4	1	1100	3.4	0.14	0.19
213	12	1	1100	1.8	0.04	0.17
214	7	1	1100	1.8	0.04	0.11
215	7	1	1100	3.1	0.24	0.04
216	10	1	950	1.4	0.06	0.02
217	7	1	950	2.6	0.11	0.11
218	3	1	1000	1.8	0.04	0.16
219	9	1	1000	2.0	0.04	0.16
220	10	1	1000	3.1	0.12	0.17
221	14	1	1000	2.1	0.04	0.06
222	17	1	900	2.5	0.05	0.03
223	4	1	750	2.1	0.09	0.03
224	9	1	750	2.4	0.09	0.02
225	12	1	700	2.3	0.03	0.03
226	12	1	700	2.2	0.03	0.04
227	6	1	700	2.2	0.03	0.04
228	13	1	750	2.5	0.10	0.02

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
229	23	1	750	1.4	0.03	0.17
230	11	1	750	2.0	0.03	0.10
231	16	1	750	2.1	0.03	0.12
232	10	1	750	1.3	0.03	0.17
233	9	1	100	1.0	0.02	< 0.01
234	8	1	100	0.9	0.01	< 0.01
235	19	1	25	< 0.2	< 0.01	< 0.01
236	7	1	50	0.2	< 0.01	< 0.01
237	9	1	50	0.3	< 0.01	< 0.01
238	7	1	50	0.4	< 0.01	< 0.01
239	9	1	25	< 0.2	< 0.01	< 0.01
240	15	1	300	4.1	0.05	0.02
241	4	1	450	5.2	0.06	0.02
242	16	1	350	4.6	0.06	0.01
243	4	1	50	0.7	< 0.01	< 0.01
244	5	1	100	1.3	0.02	< 0.01
245	12	1	1150	3.0	0.11	0.04
246	6	1	1150	3.4	0.05	0.11
247	18	1	1150	5.3	0.16	0.27
248	16	1	75	0.9	0.01	< 0.01
249	13	1	450	6.9	0.10	0.02
250	12	1	1100	10.8	0.22	0.29
251	15	1	250	3.1	0.04	0.02
252	9	1	400	4.5	0.07	0.05
253	13	1	1150	3.9	0.05	0.04
254	5	1	1050	4.4	0.05	0.04
255	6	1	1300	6.8	0.19	0.27
256	10	1	1350	6.9	0.10	0.26
257	13	1	1150	2.9	0.12	0.04
258	4	1	1350	2.5	0.06	0.05
259	11	1	1250	7.4	0.25	0.14
260	8	1	1350	6.1	0.06	0.26
261	12	1	1000	1.5	0.08	0.02
262	10	1	1050	1.3	0.03	0.10
263	5	1	550	4.0	0.02	0.07
264	12	1	700	2.2	0.04	0.13
265	8	1	900	2.6	0.04	0.03
266	4	1	150	1.4	0.02	< 0.01
267	3	1	150	1.4	0.02	< 0.01
268	5	1	100	1.2	0.02	< 0.01
269	18	1	25	< 0.2	< 0.01	< 0.01
270	9	1	25	0.2	< 0.01	< 0.01
271	15	1	50	0.3	< 0.01	< 0.01
272	10	1	50	0.2	< 0.01	< 0.01
273	13	1	50	0.3	< 0.01	< 0.01
274	18	1	450	4.0	0.05	0.06
275	13	1	200	2.1	0.02	< 0.01
276	11	1	100	1.0	0.01	< 0.01
277	6	1	25	< 0.2	< 0.01	< 0.01
278	11	1	50	0.4	< 0.01	< 0.01
279	24	1	< 20	0.2	< 0.01	< 0.01
280	3	1	100	1.4	0.01	< 0.01
281	7	1	75	1.1	0.01	< 0.01
282	7	1	75	1.1	0.02	< 0.01
283	4	1	100	1.2	0.02	< 0.01
284	3	1	150	1.8	0.02	< 0.01
285	8	1	50	0.6	< 0.01	< 0.01

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
286	20	1	100	1.4	0.01	< 0.01
287	6	1	75	0.8	< 0.01	< 0.01
288	9	1	25	0.3	< 0.01	< 0.01
289	12	1	< 20	0.2	< 0.01	< 0.01
290	5	1	< 20	< 0.2	< 0.01	< 0.01
291	5	1	150	1.7	0.02	< 0.01
292	15	1	75	0.8	< 0.01	< 0.01
293	39	1	200	2.7	0.03	< 0.01
294	33	1	100	1.5	0.02	< 0.01
295	6	1	100	1.2	0.02	< 0.01
296	18	1	50	0.6	< 0.01	< 0.01
297	16	1	50	0.5	< 0.01	< 0.01
298	4	1	50	0.5	< 0.01	< 0.01
299	9	1	50	0.4	< 0.01	< 0.01
300	8	1	25	0.3	< 0.01	< 0.01
301	6	1	25	0.3	< 0.01	< 0.01
302	4	1	50	0.6	< 0.01	< 0.01
303	4	1	50	0.5	< 0.01	< 0.01
304	4	1	50	0.6	< 0.01	< 0.01
305	6	1	50	0.6	< 0.01	< 0.01
306	4	1	25	0.4	< 0.01	< 0.01
307	12	1	< 20	0.2	< 0.01	< 0.01
308	12	1	25	0.3	< 0.01	< 0.01
309	5	1	25	0.4	< 0.01	< 0.01
310	7	1	25	< 0.2	< 0.01	< 0.01
311	6	1	50	0.5	< 0.01	< 0.01
312	27	1	100	1.1	0.01	< 0.01
313	2	1	25	0.4	< 0.01	< 0.01
314	13	1	25	0.4	< 0.01	< 0.01
315	16	1	< 20	< 0.2	< 0.01	< 0.01
316	18	1	< 20	< 0.2	< 0.01	< 0.01
317	8	1	25	0.3	< 0.01	< 0.01
318	8	1	< 20	< 0.2	< 0.01	< 0.01
319	11	1	< 20	< 0.2	< 0.01	< 0.01
320	10	1	< 20	< 0.2	< 0.01	< 0.01
321	3	1	25	0.2	< 0.01	< 0.01
322	5	1	25	< 0.2	< 0.01	< 0.01
323	9	1	25	0.2	< 0.01	< 0.01
324	20	1	25	< 0.2	< 0.01	< 0.01
325	5	1	< 20	0.2	< 0.01	< 0.01
326	16	1	< 20	< 0.2	< 0.01	< 0.01
327	9	1	< 20	< 0.2	< 0.01	< 0.01
328	26	1	25	< 0.2	< 0.01	< 0.01
329	10	1	25	< 0.2	0.01	< 0.01
330	7	1	< 20	< 0.2	< 0.01	< 0.01
331	3	1	< 20	< 0.2	< 0.01	< 0.01
332	12	1	25	< 0.2	0.01	< 0.01
333	15	1	< 20	< 0.2	< 0.01	< 0.01
334	11	1	< 20	< 0.2	< 0.01	< 0.01
335	20	1	25	0.4	< 0.01	< 0.01
336	11	1	25	0.3	< 0.01	< 0.01
337	7	1	25	0.2	< 0.01	< 0.01
338	10	1	< 20	< 0.2	< 0.01	< 0.01
339	2	1	< 20	< 0.2	< 0.01	< 0.01
340	5	1	< 20	< 0.2	< 0.01	< 0.01
341	4	1	< 20	< 0.2	< 0.01	< 0.01
342	2	1	25	0.3	< 0.01	< 0.01

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
343	16	1	< 20	< 0.2	< 0.01	< 0.01
344	13	1	25	0.3	< 0.01	< 0.01
345	4	1	75	0.9	< 0.01	< 0.01
346	8	1	75	0.8	< 0.01	< 0.01
347	8	1	600	6.2	0.09	0.02
348	7	1	550	6.5	0.10	0.02
349	8	1	1950	2.9	0.05	0.17
350	20	1	1800	8.9	0.17	0.19
351	7	1	2350	4.7	0.05	0.26
352	2	1	2300	4.7	0.11	0.26
353	6	1	2250	4.7	0.17	0.16
354	11	1	2350	3.3	0.06	0.15
355	6	1	25	< 0.2	< 0.01	< 0.01
356	7	1	50	0.3	< 0.01	< 0.01
357	13	1	50	0.3	< 0.01	< 0.01
358	2	1	50	0.4	< 0.01	< 0.01
359	5	1	25	0.3	< 0.01	< 0.01
360	13	1	50	0.3	< 0.01	< 0.01
361	10	1	50	0.3	< 0.01	< 0.01
362	6	1	25	0.3	< 0.01	< 0.01
363	2	1	25	0.3	< 0.01	< 0.01
364	1	1	50	0.5	< 0.01	< 0.01
365	4	1	100	0.8	< 0.01	< 0.01
366	17	1	75	0.6	< 0.01	< 0.01
367	14	1	25	0.3	< 0.01	< 0.01
368	4	1	75	0.5	< 0.01	< 0.01
369	8	1	250	2.1	0.02	0.01
370	8	1	200	1.8	0.01	< 0.01
371	9	1	200	1.8	0.02	< 0.01
372	9	1	200	1.4	0.01	0.01
373	23	1	1700	6.6	0.06	0.07
374	9	1	1550	1.5	0.04	0.13
375	10	1	1500	1.1	0.08	0.05
376	2	1	1500	1.3	0.04	0.10
377	4	1	1500	1.4	0.05	0.09
378	9	1	1500	1.6	0.03	0.11
379	8	1	1900	3.2	0.08	0.09
380	5	1	1900	3.3	0.05	0.09
381	18	1	250	2.3	0.02	< 0.01
382	14	1	300	2.6	0.02	0.01
383	22	1	350	3.0	0.03	0.01
384	13	1	50	0.2	< 0.01	< 0.01
385	11	1	2300	3.2	0.05	0.07
386	8	1	2100	2.9	0.05	0.04
387	13	1	2050	2.8	0.08	0.04
388	10	1	2200	3.1	0.05	0.04
389	6	1	2200	3.1	0.05	0.04
390	4	1	2200	3.1	0.05	0.04
391	6	1	1850	2.9	0.05	0.11
392	12	1	1900	2.9	0.07	0.11
393	12	1	1950	2.5	0.09	0.04
394	5	1	2050	2.9	0.08	0.04
395	6	1	2100	3.0	0.07	0.04
396	9	1	2250	3.3	0.05	0.04
397	4	1	2150	3.1	0.05	0.04
398	9	1	2050	1.4	0.15	0.04
399	4	1	2300	4.3	0.05	0.26

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
400	12	1	2250	3.4	0.06	0.24
401	3	1	2250	4.3	0.06	0.25
402	13	1	2150	3.3	0.06	0.04
403	9	1	200	1.5	0.02	< 0.01
404	8	1	200	1.8	0.02	< 0.01
405	18	1	300	2.4	0.02	< 0.01
406	8	1	850	7.9	0.09	0.04
407	12	1	550	4.2	0.03	0.03
408	3	1	250	2.0	0.02	< 0.01
409	16	1	1100	8.4	0.09	0.11
410	11	1	1500	4.1	0.04	0.05
411	8	1	1550	3.3	0.11	0.10
412	15	1	1400	2.2	0.13	0.02
413	14	1	800	4.4	0.02	0.07
414	3	1	200	1.5	0.02	< 0.01
415	25	1	100	0.8	< 0.01	< 0.01
416	10	1	1350	4.2	0.08	0.03
417	9	1	1600	3.2	0.04	0.19
418	13	1	1600	4.1	0.08	0.21
419	11	1	1500	4.3	0.15	0.02
420	11	1	1600	3.6	0.06	0.20
421	10	1	1450	2.1	0.04	0.08
422	12	1	1500	1.8	0.03	0.15
423	9	1	1400	2.2	0.04	0.04
424	13	1	1450	1.4	0.03	0.14
425	12	1	50	0.3	< 0.01	< 0.01
426	18	1	50	0.3	< 0.01	< 0.01
427	9	1	75	0.4	< 0.01	< 0.01
428	2	1	75	0.5	< 0.01	< 0.01
429	20	1	150	1.3	0.01	< 0.01
430	19	1	150	1.0	0.01	< 0.01
431	14	1	100	0.7	< 0.01	< 0.01
432	9	1	300	2.7	0.02	0.01
433	8	1	75	0.4	< 0.01	< 0.01
434	3	1	25	0.3	< 0.01	< 0.01
435	7	1	2250	4.7	0.17	0.13
436	3	1	950	2.9	0.12	0.10
437	12	1	25	0.2	< 0.01	< 0.01
438	9	1	350	3.0	0.03	0.01
439	14	1	2150	3.2	0.05	0.04
440	9	1	1500	4.0	0.04	0.06
441	15	1	< 20	< 0.2	0.01	< 0.01
442	4	1	< 20	< 0.2	< 0.01	< 0.01
443	9	1	< 20	< 0.2	0.01	< 0.01
444	5	1	150	2.1	0.02	< 0.01
445	14	1	25	0.3	< 0.01	< 0.01
446	7	1	25	0.3	< 0.01	< 0.01
447	4	1	1500	2.1	0.04	0.20
448	6	1	1500	2.1	0.04	0.20
449	3	1	1050	3.2	0.14	0.02
450	10	1	1050	2.8	0.14	0.02
451	4	1	1150	1.8	0.06	0.03
452	7	1	1150	1.8	0.06	0.03
453	9	1	1050	3.3	0.19	0.03
454	14	1	1150	5.8	0.19	0.02
455	6	1	25	0.4	< 0.01	< 0.01
456	9	1	1200	3.4	0.08	0.04

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
457	3	1	1350	5.2	0.06	0.27
458	4	1	1250	5.9	0.24	0.16
459	12	1	1100	5.3	0.22	0.03
460	7	1	850	2.9	0.08	0.03
461	8	1	750	2.6	0.11	0.02
462	9	1	650	3.1	0.03	0.07
463	16	1	650	2.5	0.03	0.04
464	17	1	1000	1.4	0.07	0.02
465	9	1	750	1.7	0.06	0.05
466	6	1	1200	4.5	0.13	0.17
467	13	1	1150	1.4	0.07	0.03
468	3	1	1150	1.5	0.05	0.03
469	13	1	450	4.3	0.05	0.01
470	5	1	< 20	0.2	< 0.01	< 0.01
471	5	1	25	0.4	< 0.01	< 0.01
472	5	1	25	0.3	< 0.01	< 0.01
473	15	1	1100	2.2	0.11	0.03
474	11	1	1750	12.8	0.13	0.19
475	2	1	2150	2.3	0.06	0.05
476	3	1	2250	3.0	0.06	0.24
477	11	1	150	1.7	0.02	< 0.01
478	16	1	< 20	< 0.2	< 0.01	< 0.01
479	18	1	75	0.5	< 0.01	< 0.01
480	8	1	50	0.3	< 0.01	< 0.01
481	15	1	1050	1.6	0.09	0.13
482	11	1	1100	1.8	0.04	0.08
483	10	1	1100	1.8	0.04	0.04
484	7	1	25	0.4	< 0.01	< 0.01
485	8	1	25	0.3	< 0.01	< 0.01
486	8	1	< 20	< 0.2	< 0.01	< 0.01
487	6	1	100	0.7	< 0.01	< 0.01
488	8	1	200	1.4	0.01	< 0.01
489	8	1	150	1.3	0.01	< 0.01
490	48	1	2100	4.8	0.05	0.23
491	10	1	2100	2.6	0.05	0.22
492	7	1	50	0.4	< 0.01	< 0.01
493	9	1	300	3.3	0.05	0.01
494	8	1	300	3.4	0.05	< 0.01
495	6	1	250	2.2	0.03	< 0.01
496	8	1	250	2.7	0.04	< 0.01
497	18	1	< 20	< 0.2	< 0.01	< 0.01
498	12	1	25	0.3	< 0.01	< 0.01
499	11	1	150	1.6	0.02	< 0.01
500	6	1	150	1.6	0.02	0.01
501	8	1	1500	4.1	0.06	0.04
502	4	1	1050	8.4	0.03	0.06
503	4	1	1200	3.1	0.09	0.03
504	7	1	150	1.7	0.02	< 0.01
505	7	1	1300	9.7	0.04	0.05
506	7	1	2050	6.5	0.03	0.06
507	9	1	2300	3.1	0.05	0.06
508	3	1	2300	3.3	0.06	0.11
509	5	1	< 20	< 0.2	< 0.01	< 0.01
510	3	1	< 20	< 0.2	< 0.01	< 0.01
511	5	1	< 20	< 0.2	< 0.01	< 0.01
512	11	1	1350	2.1	0.04	0.04
513	3	1	1400	4.1	0.04	0.20

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
514	8	1	1000	3.3	0.05	0.04
515	7	1	1200	3.9	0.14	0.08
516	18	1	1300	3.9	0.06	0.19
517	9	1	1150	2.0	0.04	0.03
518	6	1	1100	1.8	0.06	0.03
519	6	1	1250	1.7	0.04	0.03
520	7	1	1250	1.3	0.04	0.16
521	7	1	1250	1.5	0.04	0.10
522	15	1	1250	1.6	0.04	0.06
523	8	1	1200	3.8	0.13	0.06
524	8	1	1250	2.3	0.04	0.03
525	5	1	250	2.1	0.04	< 0.01
526	5	1	50	< 0.2	< 0.01	< 0.01
527	6	1	50	0.2	< 0.01	< 0.01
528	5	1	25	< 0.2	< 0.01	< 0.01
529	17	1	1850	7.5	0.06	0.24
530	19	1	1600	4.2	0.05	0.21
531	7	1	50	0.7	< 0.01	< 0.01
532	7	1	75	0.7	< 0.01	< 0.01
533	7	1	100	0.8	< 0.01	< 0.01
534	7	1	100	0.7	< 0.01	< 0.01
535	7	1	100	1.0	0.01	< 0.01
536	7	1	150	1.4	0.01	< 0.01
537	6	1	200	1.9	0.02	< 0.01
538	6	1	250	2.3	0.02	0.01
539	5	1	200	1.7	0.01	< 0.01
540	2	1	200	1.9	0.02	< 0.01
541	8	1	250	2.0	0.02	< 0.01
542	4	1	900	8.2	0.09	0.04
543	4	1	1300	2.6	0.04	0.03
544	11	1	1150	1.2	0.15	0.03
545	11	1	1350	1.8	0.05	0.05
546	5	1	1300	6.1	0.17	0.22
547	11	1	1300	6.1	0.19	0.21
548	11	1	1250	3.8	0.13	0.18
549	12	1	700	4.3	0.02	0.04
550	6	1	50	0.5	< 0.01	< 0.01
551	3	1	100	1.4	0.01	0.01
552	6	1	1200	10.5	0.24	0.28
553	15	1	50	0.7	< 0.01	< 0.01
554	5	1	250	2.3	0.02	< 0.01
555	6	1	350	3.0	0.02	0.01
556	9	1	250	2.0	0.02	< 0.01
557	3	1	450	3.5	0.02	0.02
558	11	1	150	0.9	0.01	< 0.01
559	3	1	100	0.6	< 0.01	< 0.01
560	14	1	200	1.6	0.02	< 0.01
561	5	1	25	0.3	< 0.01	< 0.01
562	5	1	1100	1.2	0.04	0.03
563	6	1	1350	6.3	0.06	0.27
564	3	1	100	1.6	0.02	0.02
565	5	1	1200	3.5	0.10	0.04
566	6	1	900	0.9	0.09	0.02
567	7	1	1000	1.0	0.09	0.02
568	5	1	1050	1.5	0.03	0.11
569	7	1	1350	2.5	0.06	0.12
570	15	1	950	1.4	0.11	0.02

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
571	6	1	1000	2.0	0.04	0.06
572	7	1	900	2.6	0.04	0.03
573	13	1	750	2.3	0.08	0.02
574	9	1	900	2.6	0.04	0.03
575	7	1	700	1.6	0.03	0.11
576	16	1	500	3.7	0.04	0.05
577	5	1	25	0.3	< 0.01	< 0.01
578	3	1	< 20	0.3	< 0.01	< 0.01
579	16	1	500	3.9	0.05	0.06
580	8	1	550	4.0	0.02	0.07
581	5	1	500	4.0	0.05	0.07
582	3	1	700	1.5	0.08	0.10
583	9	1	800	2.7	0.09	0.02
584	14	1	950	2.9	0.04	0.03
585	5	1	450	5.1	0.06	0.02
586	10	1	300	4.2	0.05	0.02
587	13	1	750	2.1	0.03	0.11
588	16	1	750	2.3	0.03	0.05
589	4	1	650	2.7	0.03	0.05
590	8	1	700	2.2	0.03	0.04
591	11	1	700	2.2	0.03	0.04
592	6	1	600	3.1	0.02	0.06
593	5	1	200	2.2	0.02	0.02
594	6	1	400	3.8	0.05	0.04
595	6	1	150	1.7	0.02	< 0.01
596	17	1	100	1.0	0.01	< 0.01
597	9	1	75	0.6	0.01	< 0.01
598	3	1	25	< 0.2	< 0.01	< 0.01
599	10	1	25	< 0.2	< 0.01	< 0.01
600	3	1	25	< 0.2	< 0.01	< 0.01
601	11	1	25	< 0.2	< 0.01	< 0.01
602	3	1	25	< 0.2	< 0.01	< 0.01
603	6	1	25	0.2	< 0.01	< 0.01
604	5	1	50	0.3	< 0.01	< 0.01
605	2	1	75	0.8	0.01	< 0.01
606	2	1	100	0.9	0.01	< 0.01
607	2	1	100	1.1	0.02	< 0.01
608	7	1	50	0.4	< 0.01	< 0.01
609	4	1	25	< 0.2	< 0.01	< 0.01
610	17	1	50	0.3	< 0.01	< 0.01
611	9	1	50	0.2	< 0.01	< 0.01
612	7	1	1400	1.4	0.03	0.14
613	5	1	1350	1.7	0.03	0.08
614	6	1	400	5.4	0.07	0.05
615	3	1	350	4.6	0.06	0.04
616	9	1	< 20	< 0.2	< 0.01	< 0.01
617	10	1	< 20	< 0.2	0.01	< 0.01
618	8	1	< 20	< 0.2	< 0.01	< 0.01
619	11	1	< 20	< 0.2	< 0.01	< 0.01
620	3	1	50	0.7	< 0.01	< 0.01
621	7	1	1300	4.0	0.05	0.22
622	8	1	250	1.9	0.02	< 0.01
623	3	1	250	1.9	0.02	< 0.01
624	8	1	850	8.9	0.09	0.02
625	5	1	1000	2.6	0.07	0.16
626	10	1	200	1.7	0.01	< 0.01
627	18	1	150	1.3	< 0.01	< 0.01

Table D.02 - Rural Building Structures within the Study Area
Maximum Predicted Conventional Subsidence Parameters

Structure No.	Longest Side (m)	No. of Storeys	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)
628	10	1	150	1.3	< 0.01	< 0.01
629	10	1	750	1.9	0.03	0.11
630	3	1	900	2.6	0.04	0.03
631	7	1	1300	7.6	0.25	0.25
632	11	1	250	3.3	0.07	0.03
633	14	1	1250	3.4	0.06	0.05
634	2	1	1300	6.3	0.05	0.06
635	3	1	1350	5.7	0.05	0.06
636	5	1	75	0.7	< 0.01	< 0.01
637	6	1	200	1.9	0.02	< 0.01
638	8	1	50	0.4	< 0.01	< 0.01
639	13	1	1000	1.4	0.09	0.02
640	12	1	1000	1.6	0.03	0.03
641	6	1	100	1.3	0.02	< 0.01
642	7	1	950	1.8	0.08	0.11
643	8	1	750	1.0	0.09	0.13
644	12	1	25	< 0.2	< 0.01	< 0.01
645	15	1	75	0.8	< 0.01	< 0.01
646	15	1	75	0.8	< 0.01	< 0.01
647	11	1	1100	5.7	0.24	0.03
648	11	1	800	2.8	0.11	0.02
649	3	1	1050	1.1	0.08	0.02
650	4	1	1350	7.6	0.06	0.27
651	10	1	950	2.6	0.11	0.09
652	9	1	75	0.6	< 0.01	< 0.01
653	5	1	1400	9.5	0.11	0.05
654	3	1	1700	3.9	0.13	0.04
655	3	1	75	0.6	< 0.01	< 0.01
656	13	1	1300	2.6	0.10	0.12
657	4	1	1500	2.2	0.04	0.14
658	3	1	1450	2.5	0.04	0.04
659	3	1	1400	2.5	0.04	0.03
660	3	1	1500	2.2	0.04	0.15
661	11	1	2050	1.7	0.16	0.04
662	3	1	2300	3.1	0.05	0.07
663	3	1	1250	3.8	0.13	0.12
664	4	1	1250	3.2	0.04	0.18
665	3	1	1250	4.4	0.04	0.18
666	3	1	1250	4.6	0.04	0.18
667	3	1	1200	1.9	0.05	0.03
668	6	1	1050	2.8	0.05	0.04
669	3	1	1100	2.8	0.05	0.04
670	5	1	1100	2.6	0.05	0.03
671	6	1	1100	1.7	0.13	0.03
672	13	1	250	2.4	0.02	0.01
673	6	1	25	< 0.2	< 0.01	< 0.01
674	25	1	1300	2.1	0.05	0.18
675	7	1	1250	2.1	0.04	0.06
676	6	1	50	0.2	< 0.01	< 0.01
677	3	1	25	< 0.2	< 0.01	< 0.01
678	7	1	25	< 0.2	< 0.01	< 0.01
679	12	1	25	< 0.2	< 0.01	< 0.01
680	6	1	1000	3.2	0.11	0.18
		Maximums:	**2350**	**13**	**0.25**	**0.29**

Table D.03 - Farm Dams within Study Area
Maximum Predicted Conventional Subsidence Parameters

Dam No.	Length (m)	Surface Area (m2)	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Tilt At Any Time (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Maximum Predicted Change in Freeboard after All Longwalls (mm)
1	33	561	1200	1.6	4.0	0.05	0.04	< 50
2	48	1041	1250	1.8	4.4	0.05	0.16	< 50
3	29	520	1200	1.5	4.2	0.05	0.05	< 50
4	38	1000	1400	2.0	4.5	0.06	0.13	< 50
5	22	295	1400	6.2	9.9	0.05	0.25	75
6	8	47	1400	1.1	4.5	0.06	0.13	< 50
7	39	885	400	4.5	4.5	0.05	0.01	100
8	44	781	550	6.1	6.2	0.15	0.02	200
9	18	190	450	7.7	7.9	0.15	0.04	100
10	17	204	800	8.0	9.6	0.24	0.03	100
11	26	335	1100	5.0	5.0	0.06	0.22	100
12	29	427	1350	1.8	4.1	0.05	0.05	< 50
13	39	891	1350	1.8	4.0	0.05	0.05	< 50
14	22	264	1200	1.5	3.8	0.08	0.03	< 50
15	21	316	1300	2.1	4.1	0.05	0.04	< 50
16	21	237	1250	1.9	4.0	0.06	0.04	< 50
17	74	624	1500	7.4	11.3	0.25	0.28	300
18	11	85	1250	2.3	4.1	0.05	0.04	< 50
19	35	327	1450	2.3	4.6	0.06	0.07	< 50
20	24	660	1400	2.5	4.6	0.06	0.05	50
21	19	184	1250	2.6	4.4	0.06	0.04	< 50
22	24	306	1400	1.8	4.9	0.06	0.22	< 50
23	38	721	1400	2.4	5.0	0.07	0.24	< 50
24	48	984	1350	2.7	4.7	0.07	0.05	75
25	21	224	1050	2.5	7.0	0.25	0.03	< 50
26	31	598	1250	9.7	11.5	0.06	0.30	200
27	26	346	1200	3.5	4.2	0.06	0.04	75
28	24	312	1050	3.1	6.4	0.23	0.04	< 50
29	41	886	1350	2.5	4.5	0.06	0.05	75
30	26	415	1200	2.5	4.1	0.05	0.04	50
31	25	423	950	2.5	7.6	0.20	0.03	< 50
32	25	400	850	5.5	5.9	0.04	0.11	100
33	88	2241	25	0.5	0.5	< 0.01	< 0.01	< 50
34	58	1917	1050	4.3	9.0	0.20	0.24	100
35	25	332	1050	4.1	8.7	0.18	0.13	75
36	81	2094	1250	2.2	3.8	0.05	0.14	100
37	54	763	1050	5.0	9.4	0.25	0.03	75
38	38	818	900	2.9	3.3	0.04	0.14	100
39	34	696	500	5.1	5.2	0.06	0.03	200
40	26	431	50	0.6	0.6	< 0.01	< 0.01	< 50
41	20	247	500	7.4	7.4	0.11	0.03	100
42	11	85	< 20	0.3	0.3	< 0.01	< 0.01	< 50
43	44	961	50	1.0	1.0	0.01	< 0.01	< 50
44	58	1036	25	0.4	0.4	< 0.01	< 0.01	< 50
45	44	1131	< 20	< 0.2	< 0.2	< 0.01	< 0.01	< 50
46	45	692	25	0.5	0.5	< 0.01	< 0.01	< 50
47	13	49	25	0.4	0.4	< 0.01	< 0.01	< 50
48	34	590	50	0.5	0.5	< 0.01	< 0.01	< 50
49	46	918	25	0.6	0.6	< 0.01	< 0.01	< 50
50	28	375	100	1.1	1.1	0.01	< 0.01	< 50
51	33	661	< 20	< 0.2	< 0.2	0.01	< 0.01	< 50
52	22	284	100	1.4	1.4	0.02	< 0.01	< 50
53	17	124	75	1.0	1.0	0.01	< 0.01	< 50
54	31	507	900	4.2	4.2	0.04	0.05	100
55	20	201	1100	2.2	3.7	0.05	0.03	< 50
56	23	355	1150	1.7	4.0	0.10	0.03	< 50
57	30	506	1250	3.8	8.7	0.05	0.19	75
58	42	684	1200	6.1	10.0	0.19	0.08	700
59	55	724	1350	1.7	4.0	0.05	0.05	< 50
60	20	230	1250	1.8	3.9	0.05	0.04	< 50
61	31	591	1200	2.5	4.7	0.11	0.04	75
62	84	2811	1400	5.6	10.3	0.19	0.23	300
63	76	2362	1400	2.5	3.7	0.04	0.03	100
64	46	485	1500	2.1	4.1	0.04	0.18	< 50
65	83	1347	1500	2.6	9.5	0.15	0.18	75
66	35	460	1400	2.6	3.8	0.05	0.03	100
67	62	2179	1450	2.9	9.7	0.15	0.15	75
68	134	5885	1750	4.2	8.8	0.05	0.23	300
69	35	489	1450	9.2	12.7	0.25	0.06	200
70	48	947	1100	11.8	11.8	0.05	0.21	300
71	20	116	1850	9.0	9.0	0.09	0.37	100

Table D.03 - Farm Dams within Study Area
Maximum Predicted Conventional Subsidence Parameters

Dam No.	Length (m)	Surface Area (m2)	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Tilt At Any Time (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Maximum Predicted Change in Freeboard after All Longwalls (mm)
72	32	176	1700	5.5	6.5	0.08	0.06	100
73	7	27	1300	4.3	4.7	0.17	0.04	< 50
74	7	22	1250	14.2	14.9	0.17	0.04	75
75	23	362	2150	2.1	6.1	0.07	0.24	< 50
76	26	208	2250	3.6	6.8	0.08	0.17	< 50
77	59	1706	1900	5.5	6.1	0.11	0.06	300
78	30	208	1700	4.7	10.3	0.15	0.15	100
79	28	212	1750	5.2	5.3	0.11	0.05	100
80	39	622	1800	1.2	10.0	0.17	0.04	< 50
81	15	108	1750	2.5	7.1	0.04	0.21	< 50
82	28	516	1750	2.1	6.7	0.04	0.18	< 50
83	49	1053	1750	1.9	8.6	0.08	0.16	50
84	10	34	1550	2.4	3.7	0.04	0.03	< 50
85	7	33	1650	2.6	3.9	0.04	0.03	< 50
86	6	20	1500	1.5	8.4	0.03	0.12	< 50
87	16	163	1200	1.9	8.3	0.14	0.02	< 50
88	55	1582	1600	2.1	7.4	0.03	0.14	50
89	27	356	1250	1.3	5.1	0.11	0.02	< 50
90	72	1033	1250	3.8	8.9	0.14	0.15	100
91	28	418	1300	3.8	9.0	0.08	0.19	100
92	50	594	1200	2.0	3.5	0.04	0.03	100
93	26	329	1250	2.1	3.9	0.05	0.04	< 50
94	21	273	1250	2.1	3.9	0.05	0.04	< 50
95	43	799	1300	2.2	3.7	0.05	0.06	75
96	23	308	1200	2.2	3.7	0.05	0.04	< 50
97	17	199	1150	5.5	9.3	0.17	0.07	75
98	29	362	1300	2.6	4.4	0.06	0.04	75
99	19	196	950	1.6	2.9	0.05	0.03	< 50
100	17	199	1100	1.5	4.4	0.04	0.18	< 50
101	21	336	900	3.2	8.2	0.15	0.02	< 50
102	51	1216	1050	1.8	3.1	0.04	0.03	50
103	34	710	950	1.6	3.8	0.11	0.03	< 50
104	21	286	1000	2.0	3.2	0.04	0.03	< 50
105	67	1831	1000	2.6	3.2	0.04	0.03	100
106	44	766	950	3.6	8.1	0.14	0.13	75
107	35	748	750	1.5	6.1	0.12	0.15	< 50
108	80	1576	650	3.3	3.3	0.03	0.07	200
109	33	473	550	4.1	4.1	0.02	0.07	100
110	22	228	350	3.3	3.3	0.05	0.04	50
111	35	419	150	1.5	1.5	0.02	< 0.01	< 50
112	31	308	700	2.2	2.2	0.03	0.04	< 50
113	28	429	800	2.8	3.6	0.09	0.03	50
114	30	409	750	1.5	6.2	0.10	0.16	< 50
115	19	210	600	2.8	2.8	0.03	0.03	50
116	26	401	250	3.7	3.7	0.04	0.02	75
117	22	287	100	1.2	1.2	0.02	< 0.01	< 50
118	27	460	50	0.6	0.6	< 0.01	< 0.01	< 50
119	33	625	< 20	< 0.2	< 0.2	< 0.01	< 0.01	< 50
120	39	809	25	< 0.2	< 0.2	< 0.01	< 0.01	< 50
121	39	523	50	0.2	0.2	< 0.01	< 0.01	< 50
122	29	462	25	< 0.2	< 0.2	< 0.01	< 0.01	< 50
123	20	174	50	0.3	0.3	< 0.01	< 0.01	< 50
124	17	160	25	< 0.2	< 0.2	< 0.01	< 0.01	< 50
125	36	699	25	< 0.2	< 0.2	< 0.01	< 0.01	< 50
126	41	433	200	1.9	1.9	0.02	< 0.01	75
127	54	1157	350	3.4	3.4	0.04	0.03	100
128	76	2082	200	1.8	1.8	0.02	0.01	100
129	23	349	100	0.7	0.7	< 0.01	< 0.01	< 50
130	22	113	150	1.4	1.4	0.01	< 0.01	< 50
131	40	614	50	0.2	0.3	< 0.01	< 0.01	< 50
132	10	47	2100	2.9	5.1	0.06	0.04	< 50
133	47	1169	1700	2.9	8.0	0.04	0.16	< 50
134	36	837	1700	1.3	5.8	0.03	0.11	< 50
135	66	854	1700	1.5	7.3	0.08	0.10	< 50
136	16	139	1800	2.2	4.4	0.06	0.03	< 50
137	20	235	1900	2.8	4.7	0.05	0.04	50
138	49	567	400	4.4	4.4	0.07	< 0.01	50
139	8	26	350	4.1	4.1	0.07	< 0.01	< 50
140	11	50	350	3.6	3.6	0.06	0.02	< 50
141	34	613	150	1.4	1.4	0.01	0.01	< 50
142	71	1797	1450	4.2	6.1	0.03	0.10	200

Table D.03 - Farm Dams within Study Area
Maximum Predicted Conventional Subsidence Parameters

Dam No.	Length (m)	Surface Area (m2)	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Tilt At Any Time (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Maximum Predicted Change in Freeboard after All Longwalls (mm)
143	9	46	1450	2.4	3.1	0.03	0.05	< 50
144	15	123	75	0.7	0.7	< 0.01	< 0.01	< 50
145	16	166	2300	2.3	4.4	0.03	0.03	< 50
146	20	297	< 20	< 0.2	< 0.2	< 0.01	< 0.01	< 50
147	32	615	50	0.5	0.5	< 0.01	< 0.01	< 50
148	9	60	25	0.3	0.3	< 0.01	< 0.01	< 50
149	33	654	50	0.7	0.7	< 0.01	< 0.01	< 50
150	25	308	< 20	0.2	0.2	< 0.01	< 0.01	< 50
151	75	661	< 20	< 0.2	< 0.2	< 0.01	< 0.01	< 50
152	28	369	75	1.1	1.1	0.01	< 0.01	< 50
153	9	60	850	5.1	5.6	0.14	0.05	< 50
154	27	352	1350	1.6	3.8	0.09	0.02	< 50
155	9	43	1200	1.4	3.3	0.06	0.03	< 50
156	17	173	1250	1.9	3.3	0.04	0.03	< 50
157	17	134	1350	2.1	3.4	0.04	0.03	< 50
158	21	251	1400	1.6	3.3	0.03	0.10	< 50
159	33	627	1350	1.3	3.5	0.03	0.11	< 50
160	6	23	1250	1.7	3.2	0.04	0.03	< 50
161	9	57	1250	2.7	8.0	0.05	0.08	< 50
162	22	258	1300	1.3	3.3	0.04	0.05	< 50
163	54	449	1250	2.4	6.5	0.03	0.15	< 50
164	17	221	75	0.6	0.6	< 0.01	< 0.01	< 50
165	16	110	50	0.8	0.8	0.01	< 0.01	< 50
166	42	726	50	0.5	0.5	< 0.01	< 0.01	< 50
167	114	2295	75	0.9	0.9	0.01	< 0.01	< 50
168	26	424	25	0.3	0.3	< 0.01	< 0.01	< 50
169	32	407	25	0.3	0.3	< 0.01	< 0.01	< 50
170	20	268	< 20	< 0.2	< 0.2	< 0.01	< 0.01	< 50
171	25	367	< 20	< 0.2	< 0.2	< 0.01	< 0.01	< 50
172	21	246	25	0.3	0.3	< 0.01	< 0.01	< 50
173	26	449	< 20	0.2	0.2	< 0.01	< 0.01	< 50
174	28	415	75	0.9	0.9	0.01	< 0.01	< 50
175	22	279	250	2.9	2.9	0.04	0.02	50
176	31	569	2050	5.9	6.4	0.06	0.23	100
177	36	409	1100	9.3	9.3	0.14	0.02	200
178	70	1917	2250	8.6	12.9	0.06	0.26	200
179	13	135	2350	4.6	12.9	0.04	0.12	50
180	9	48	100	0.8	0.8	< 0.01	< 0.01	< 50
181	23	352	450	4.5	4.5	0.07	< 0.01	75
182	33	593	1050	9.0	9.0	0.03	0.04	300
183	32	735	1400	8.4	8.4	0.03	0.05	200
184	13	102	1500	1.5	4.2	0.03	0.11	< 50
185	5	19	1600	2.5	3.0	0.03	0.03	< 50
186	41	574	2100	2.4	4.8	0.07	0.03	75
187	13	117	1700	2.6	3.4	0.03	0.08	< 50
188	14	155	2250	3.1	5.1	0.05	0.05	< 50
189	16	154	2100	3.1	5.0	0.05	0.04	< 50
190	14	107	1900	2.0	6.5	0.08	0.03	< 50
191	103	3454	1900	2.9	6.9	0.08	0.10	200
192	18	219	2300	3.9	10.5	0.05	0.26	< 50
193	21	109	2050	1.4	5.6	0.08	0.04	< 50
194	17	150	2050	3.6	12.2	0.17	0.03	< 50
195	23	390	2200	4.9	13.6	0.14	0.07	100
196	20	226	2250	3.1	5.6	0.06	0.11	50
197	39	674	2100	6.6	13.8	0.18	0.07	200
198	63	2438	2150	2.6	6.1	0.07	0.05	100
199	48	1303	25	0.2	0.3	< 0.01	< 0.01	< 50
200	46	335	200	1.3	1.3	0.02	< 0.01	< 50
201	24	210	300	2.3	2.3	0.03	< 0.01	< 50
202	32	525	1200	2.0	4.8	0.03	0.16	< 50
203	14	87	1250	1.7	4.1	0.04	0.16	< 50
204	24	310	1150	1.5	3.0	0.04	0.03	< 50
205	13	66	1150	1.4	3.3	0.04	0.03	< 50
206	22	295	1250	5.7	9.5	0.04	0.20	100
207	29	298	1300	1.9	3.9	0.05	0.04	50
208	32	519	1300	2.3	4.9	0.04	0.19	< 50
209	85	2778	1250	1.6	3.7	0.04	0.05	75
210	25	120	1250	4.7	8.0	0.04	0.19	< 50
211	6	21	1100	0.9	3.5	0.07	0.03	< 50
212	5	19	1150	2.7	8.6	0.13	0.02	< 50
213	3	9	1250	1.8	3.7	0.04	0.03	< 50

Table D.03 - Farm Dams within Study Area
Maximum Predicted Conventional Subsidence Parameters

Dam No.	Length (m)	Surface Area (m2)	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Tilt At Any Time (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Maximum Predicted Change in Freeboard after All Longwalls (mm)
214	9	60	1200	3.6	9.3	0.15	0.02	< 50
215	8	46	1150	1.3	3.5	0.04	0.03	< 50
216	13	95	1300	3.4	7.3	0.04	0.18	< 50
217	27	127	1250	1.7	3.6	0.04	0.03	50
218	9	41	1150	1.2	3.4	0.05	0.03	< 50
219	15	123	1200	1.7	3.4	0.04	0.03	< 50
220	134	2163	650	7.0	7.0	0.07	0.02	200
221	14	105	200	1.5	1.5	0.02	< 0.01	< 50
222	24	339	< 20	< 0.2	< 0.2	< 0.01	< 0.01	< 50
223	55	1776	< 20	< 0.2	< 0.2	< 0.01	< 0.01	< 50
224	35	744	25	0.2	0.2	< 0.01	< 0.01	< 50
225	7	30	50	0.6	0.6	< 0.01	< 0.01	< 50
226	24	295	150	1.5	1.5	0.01	0.01	< 50
227	41	636	100	1.2	1.2	0.01	< 0.01	< 50
228	31	527	350	3.8	3.8	0.06	0.01	75
229	17	177	850	10.1	10.1	0.03	0.14	100
230	72	2602	650	6.8	6.8	0.13	0.02	300
231	61	1849	1650	5.4	5.5	0.06	0.20	100
232	10	73	1600	2.8	3.4	0.03	0.03	< 50
233	36	512	1950	3.1	5.2	0.09	0.04	100
234	21	291	1800	1.5	7.8	0.04	0.12	< 50
235	42	916	1900	2.7	7.4	0.10	0.04	100
236	103	3974	2150	3.3	5.4	0.09	0.04	300
237	38	1058	1500	4.5	10.9	0.14	0.04	100
238	59	1936	1400	3.0	9.5	0.15	0.02	< 50
239	23	341	1500	2.7	3.1	0.05	0.02	< 50
240	19	52	1650	2.5	3.2	0.03	0.06	< 50
241	72	775	1900	2.9	7.1	0.08	0.11	200
242	22	217	1500	2.6	9.2	0.09	0.02	< 50
243	36	759	1550	3.3	4.1	0.04	0.07	75
244	19	143	200	1.9	1.9	0.02	< 0.01	< 50
245	24	145	500	4.4	4.4	0.05	0.02	75
246	15	158	1350	4.1	4.1	0.04	0.03	50
247	26	335	500	4.0	4.0	0.03	0.02	100
248	37	468	1450	4.0	4.0	0.04	0.04	100
249	21	280	1500	3.8	4.6	0.05	0.07	75
250	12	75	1350	2.4	3.4	0.04	0.03	< 50
251	18	189	1250	4.5	4.5	0.04	0.09	75
252	126	5919	650	5.5	5.5	0.09	0.04	300
253	52	1172	250	3.5	3.5	0.07	0.01	100
254	29	307	900	5.0	5.0	0.05	0.05	75
255	7	33	400	6.1	6.1	0.07	< 0.01	< 50
256	136	13976	1350	2.8	4.3	0.06	0.20	200
257	33	422	1300	4.3	9.1	0.08	0.17	75
258	24	260	1250	3.3	7.8	0.03	0.17	50
259	45	1158	1300	1.4	3.7	0.04	0.16	< 50
260	14	115	1150	1.8	3.2	0.04	0.03	< 50
261	15	158	1050	1.5	3.0	0.05	0.03	< 50
262	30	374	1250	1.9	3.3	0.04	0.04	< 50
263	12	94	1100	1.7	3.3	0.04	0.03	< 50
264	16	171	1400	8.1	10.6	0.06	0.31	100
265	20	272	300	5.8	5.8	0.10	0.02	75
266	69	839	1300	2.7	5.0	0.07	0.05	100
267	80	3345	1250	1.7	3.5	0.05	0.03	100
268	48	1081	1000	1.8	6.1	0.05	0.12	100
269	13	111	900	3.2	4.4	0.06	0.03	< 50
270	25	214	1000	1.8	6.0	0.08	0.02	< 50
271	42	584	800	5.2	5.5	0.10	0.10	200
272	37	562	100	1.3	1.4	0.02	< 0.01	< 50
273	28	444	300	3.6	3.6	0.04	< 0.01	75
274	36	261	850	3.2	3.2	0.05	0.05	50
275	22	191	800	2.8	2.8	0.04	0.05	< 50
276	13	89	1350	0.9	3.8	0.04	0.05	< 50
277	69	694	1350	1.7	3.8	0.04	0.05	< 50
278	46	820	1300	3.3	4.3	0.04	0.05	100
279	14	87	300	2.4	2.4	0.02	< 0.01	< 50
280	15	124	350	2.4	2.4	0.01	< 0.01	< 50
281	12	85	650	4.2	4.2	0.02	0.02	50
282	31	458	250	1.9	1.9	0.02	< 0.01	< 50
283	24	164	75	0.3	0.3	< 0.01	< 0.01	< 50
284	21	149	50	0.3	0.3	< 0.01	< 0.01	< 50

Table D.03 - Farm Dams within Study Area
Maximum Predicted Conventional Subsidence Parameters

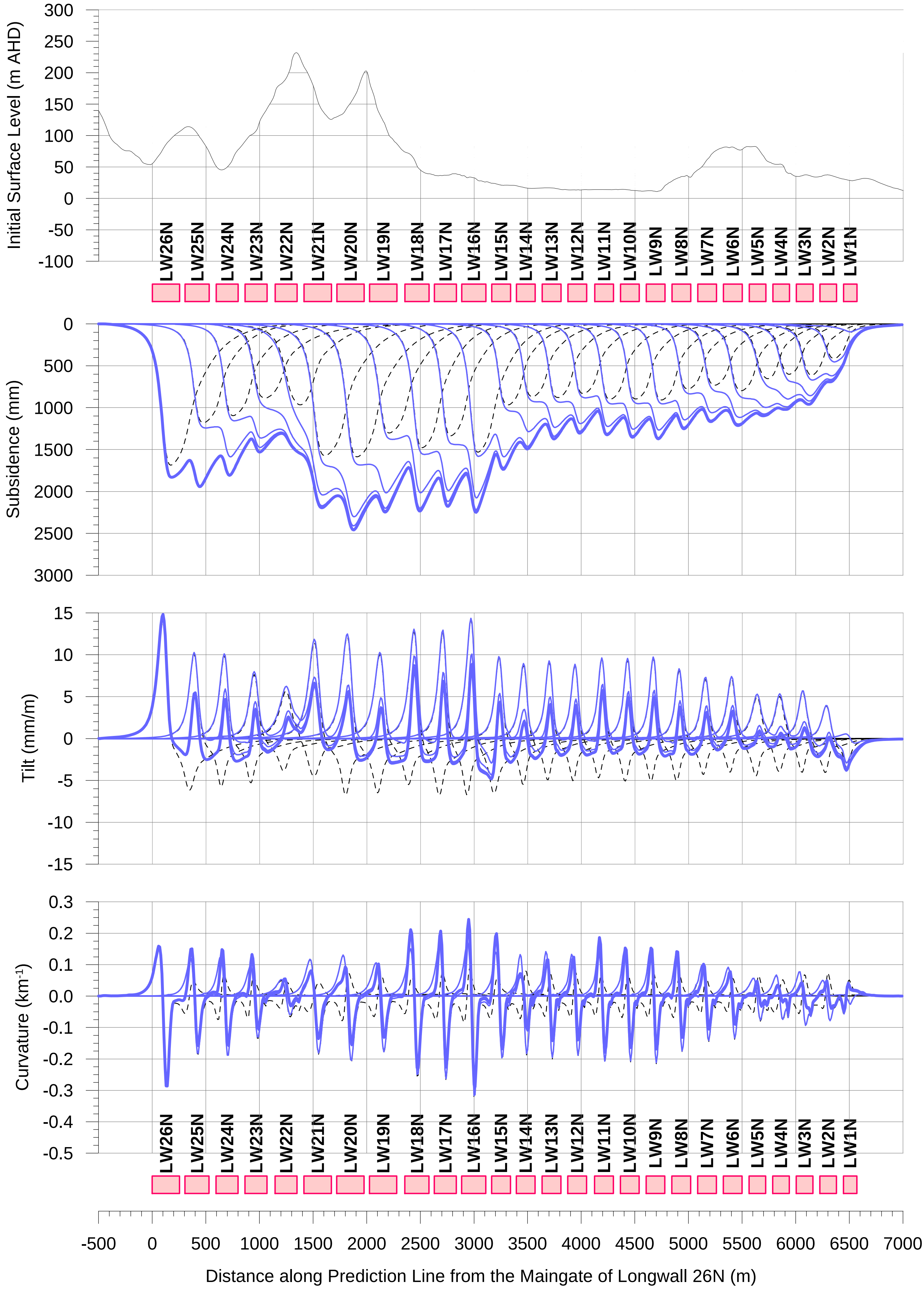
Dam No.	Length (m)	Surface Area (m2)	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Tilt At Any Time (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Maximum Predicted Change in Freeboard after All Longwalls (mm)
285	28	362	75	0.5	0.5	< 0.01	< 0.01	< 50
286	24	310	< 20	0.2	0.2	< 0.01	< 0.01	< 50
287	42	449	75	0.6	0.6	< 0.01	< 0.01	< 50
288	11	86	25	0.3	0.3	< 0.01	< 0.01	< 50
289	27	207	50	0.4	0.4	< 0.01	< 0.01	< 50
290	213	17528	50	0.2	0.2	< 0.01	< 0.01	< 50
291	183	4118	50	0.3	0.3	< 0.01	< 0.01	< 50
292	44	839	350	3.0	3.0	0.03	0.02	100
293	53	1327	200	1.8	1.8	0.02	< 0.01	75
294	30	506	200	1.5	1.5	0.02	< 0.01	< 50
295	119	1448	1250	2.8	3.9	0.04	0.04	100
296	66	1498	1250	2.2	3.0	0.06	0.03	75
297	28	242	1250	2.1	3.1	0.06	0.02	< 50
298	31	241	700	2.7	2.7	0.03	0.06	50
299	37	77	75	0.8	0.9	< 0.01	< 0.01	< 50
300	16	133	1350	2.2	4.4	0.06	0.10	< 50
301	21	213	1100	5.9	10.1	0.16	0.12	75
302	60	1522	25	0.5	0.5	< 0.01	< 0.01	< 50
303	31	583	200	2.9	2.9	0.03	< 0.01	75
304	22	202	1250	1.3	3.5	0.04	0.17	200
305	25	436	1000	1.5	3.1	0.04	0.11	< 50
306	27	432	950	2.4	3.0	0.04	0.03	50
307	20	262	500	4.0	4.0	0.02	0.07	75
308	52	661	1000	2.6	7.2	0.06	0.16	75
309	31	450	550	3.2	3.2	0.02	0.07	50
310	22	345	700	0.2	3.0	0.05	0.06	< 50
311	44	700	200	1.7	1.7	0.02	0.01	< 50
312	24	356	50	0.4	0.4	< 0.01	< 0.01	< 50
313	12	34	1100	0.8	3.4	0.07	0.03	< 50
314	14	129	25	0.2	0.3	< 0.01	< 0.01	< 50
315	15	158	25	0.3	0.3	< 0.01	< 0.01	< 50
316	30	520	25	0.4	0.4	< 0.01	< 0.01	< 50
317	24	170	25	0.3	0.3	< 0.01	< 0.01	< 50
318	22	327	50	0.8	0.8	0.01	< 0.01	< 50
319	59	1534	75	1.5	1.5	0.02	< 0.01	50
320	256	24517	450	3.4	3.4	0.02	0.02	400
321	21	290	75	0.5	0.5	< 0.01	< 0.01	< 50
322	15	110	75	0.4	0.4	< 0.01	< 0.01	< 50
323	25	346	25	0.3	0.3	< 0.01	< 0.01	< 50
324	35	628	25	0.3	0.3	< 0.01	< 0.01	< 50
325	32	329	75	0.5	0.5	< 0.01	< 0.01	< 50
326	19	236	50	0.3	0.3	< 0.01	< 0.01	< 50
327	53	695	2050	2.7	6.0	0.07	0.08	100
328	10	52	25	0.2	0.2	< 0.01	< 0.01	< 50
329	12	65	1150	9.3	9.3	0.01	0.06	100
330	282	12214	2100	5.2	12.2	0.15	0.23	300
331	18	186	950	2.5	7.0	0.07	0.10	< 50
332	25	318	950	1.2	2.5	0.03	0.02	< 50
333	23	353	950	0.9	3.7	0.08	0.02	< 50
334	15	152	1050	0.9	5.8	0.02	0.08	< 50
335	46	688	250	2.2	2.2	0.02	< 0.01	75
336	14	104	25	0.3	0.3	< 0.01	< 0.01	< 50
337	52	1111	50	0.4	0.4	< 0.01	< 0.01	< 50
338	33	345	900	0.9	6.3	0.12	0.02	< 50
339	21	192	1250	1.4	3.4	0.04	0.12	< 50
340	9	59	1350	1.2	4.0	0.05	0.07	< 50
341	13	101	1350	3.4	6.0	0.05	0.22	< 50
342	22	284	1350	2.7	5.2	0.05	0.21	< 50
343	15	135	< 20	0.3	0.3	< 0.01	< 0.01	< 50
344	7	40	1100	2.2	8.1	0.24	0.03	< 50
345	15	130	950	1.3	2.7	0.06	0.02	< 50
346	24	408	1000	1.6	2.7	0.03	0.03	< 50
347	29	370	1050	1.1	4.7	0.03	0.12	< 50
348	13	84	900	1.1	3.0	0.08	0.02	< 50
349	25	197	750	1.6	3.9	0.05	0.02	< 50
350	15	107	< 20	< 0.2	< 0.2	< 0.01	< 0.01	< 50
351	94	3577	1300	4.0	9.1	0.13	0.18	200
352	16	124	1700	4.9	10.0	0.04	0.20	< 50
353	9	55	100	0.7	0.7	0.01	< 0.01	< 50
354	13	119	250	2.3	2.3	0.02	0.02	< 50
355	24	306	500	4.0	4.0	0.03	0.06	100

Table D.03 - Farm Dams within Study Area
Maximum Predicted Conventional Subsidence Parameters

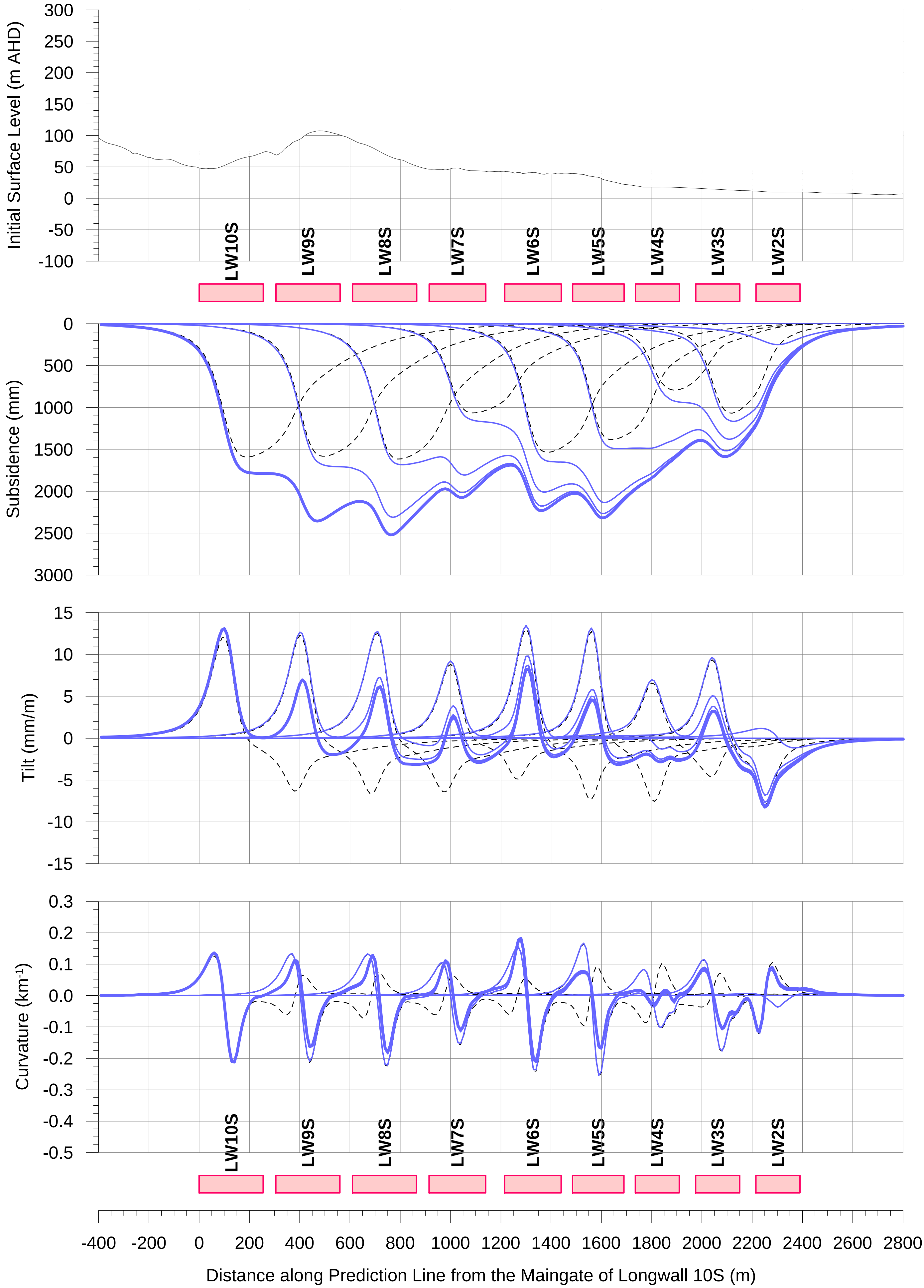
Dam No.	Length (m)	Surface Area (m2)	Maximum Predicted Subsidence after All Longwalls (mm)	Maximum Predicted Tilt after All Longwalls (mm/m)	Maximum Predicted Tilt At Any Time (mm/m)	Maximum Predicted Hogging Curvature At Any Time (1/km)	Maximum Predicted Sagging Curvature At Any Time (1/km)	Maximum Predicted Change in Freeboard after All Longwalls (mm)
356	29	402	1100	6.5	10.3	0.25	0.03	100
357	20	240	1100	2.8	4.2	0.05	0.11	< 50
358	16	135	1100	1.0	6.0	0.10	0.02	< 50
359	41	616	1600	3.5	4.5	0.05	0.04	75
360	13	119	1250	2.6	4.3	0.06	0.04	< 50
361	30	469	2200	3.7	6.3	0.07	0.17	100
362	39	625	1850	5.0	7.1	0.09	0.07	100
363	9	34	1400	2.4	3.6	0.04	0.04	< 50
364	11	83	1200	1.6	3.1	0.04	0.02	< 50
365	15	57	2200	2.1	5.6	0.06	0.06	< 50
366	51	357	1250	1.9	3.5	0.04	0.04	100
367	13	75	1050	3.4	8.7	0.19	0.02	< 50
368	27	344	1150	1.7	7.7	0.15	0.03	< 50
369	36	701	50	0.5	0.5	< 0.01	< 0.01	< 50
370	16	169	25	0.3	0.3	< 0.01	< 0.01	< 50
371	23	230	200	2.2	2.2	0.02	0.01	< 50
372	24	347	50	0.3	0.3	< 0.01	< 0.01	< 50
373	21	153	25	0.2	0.2	< 0.01	< 0.01	< 50
374	13	97	25	< 0.2	< 0.2	< 0.01	< 0.01	< 50
375	10	61	100	0.8	0.8	< 0.01	< 0.01	< 50
		Maximums:	**2350**	**14**	**15**	**0.25**	**0.37**	**700**

APPENDIX E. FIGURES

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 Resulting from the Extraction of the Proposed Longwalls



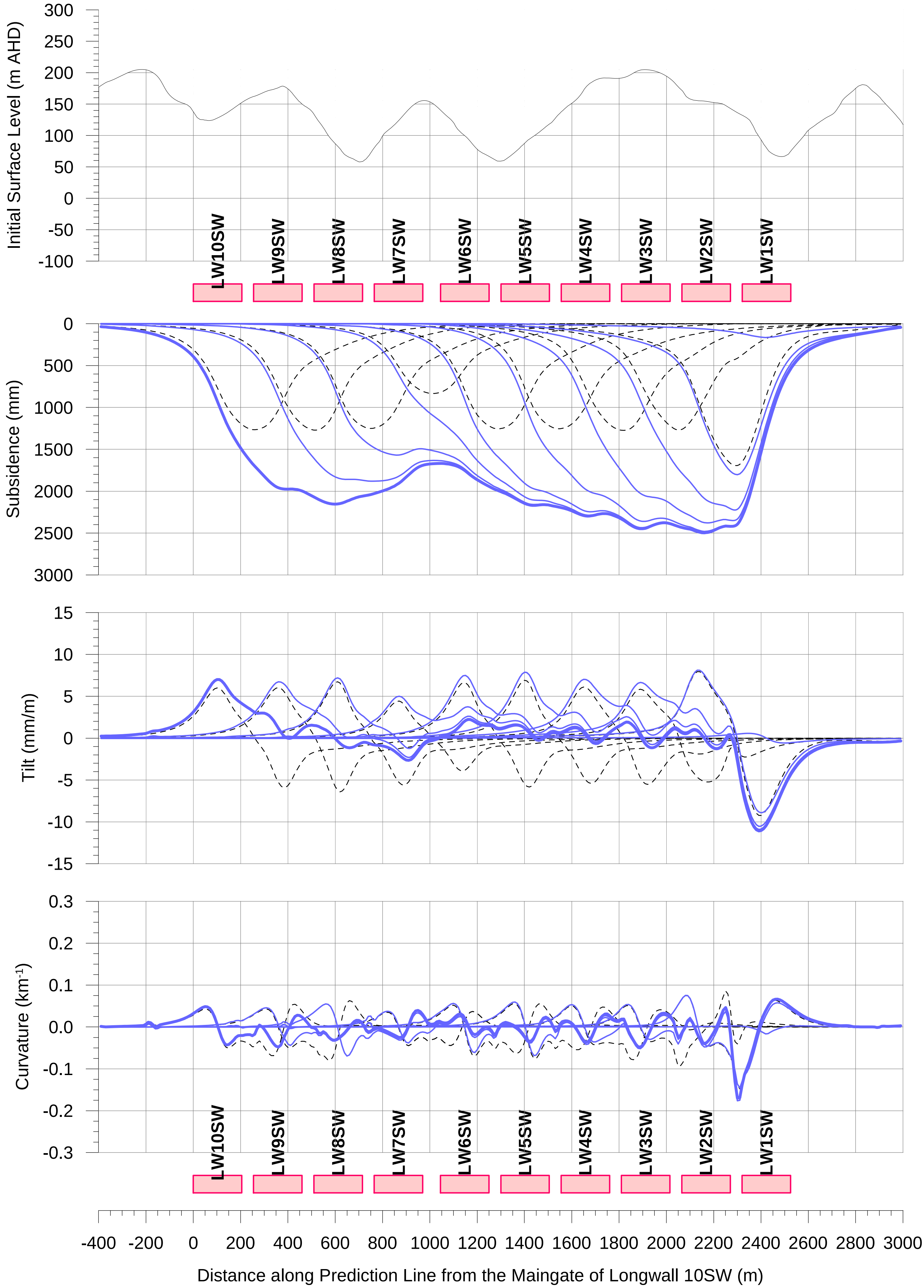
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 Resulting from the Extraction of the Proposed Longwalls



Mine Subsidence Engineering Consultants

Fig. E.02

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 3 Resulting from the Extraction of the Proposed Longwalls



Mine Subsidence Engineering Consultants

Fig. E.03

I:\Projects\Wyong\MSEC428 - Subsidence Report for Part 3A\Subsdata\Impacts\Prediction Lines\Fig. E.04 - Prediction Line 4.grf.....04-Feb-10

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 4 Resulting from the Extraction of the Proposed Longwalls

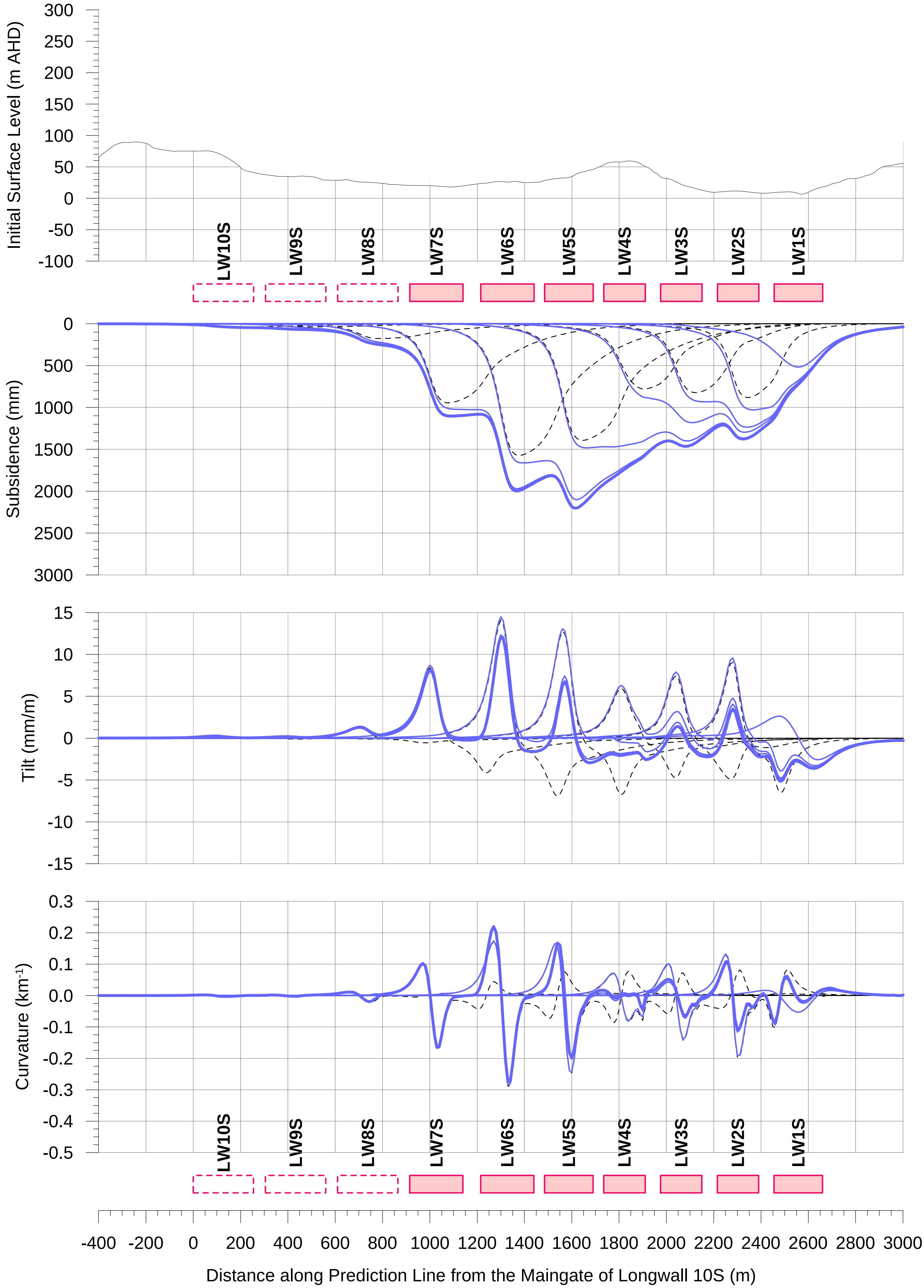
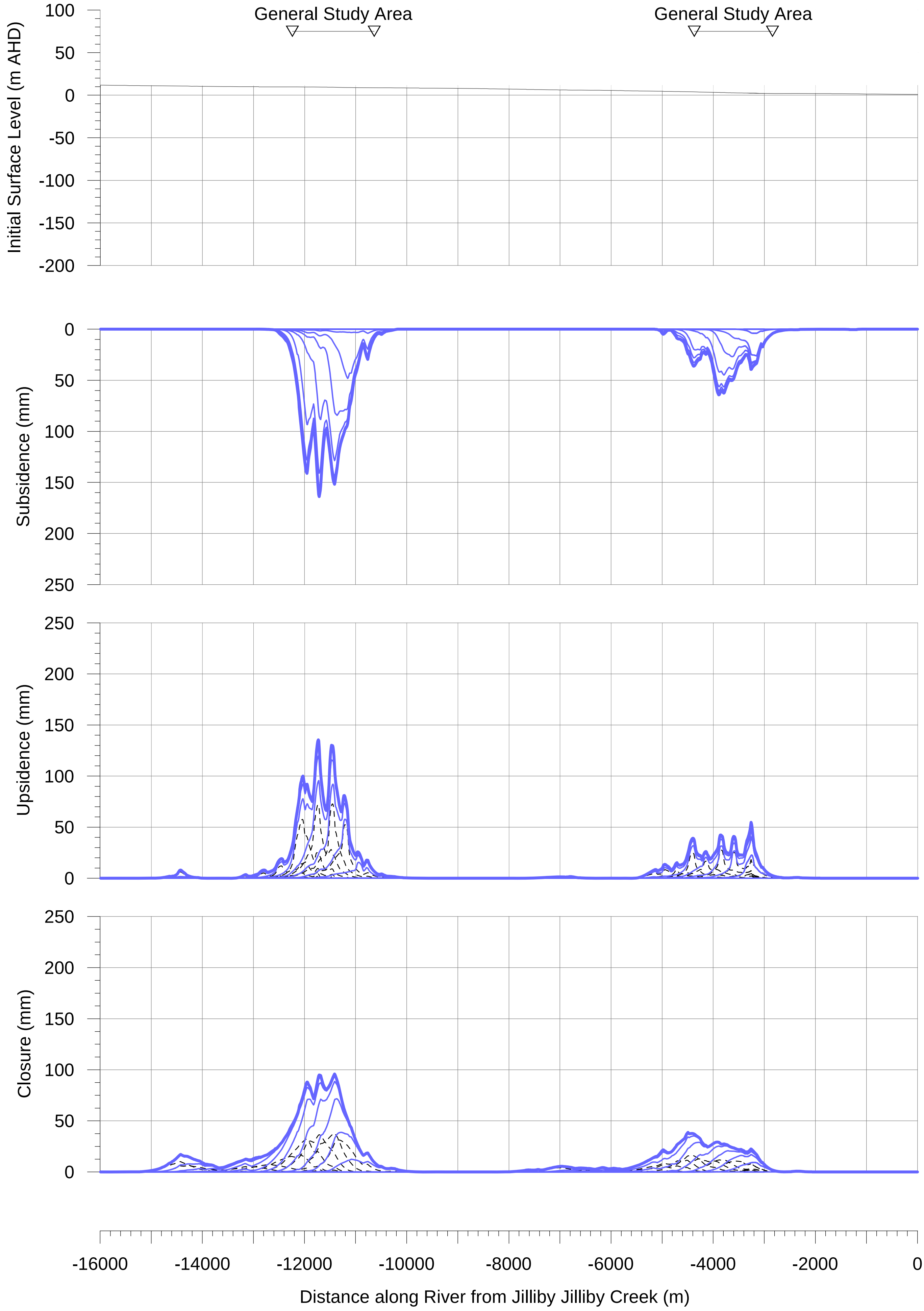


Fig. E.04

Mine Subsidence Engineering Consultants

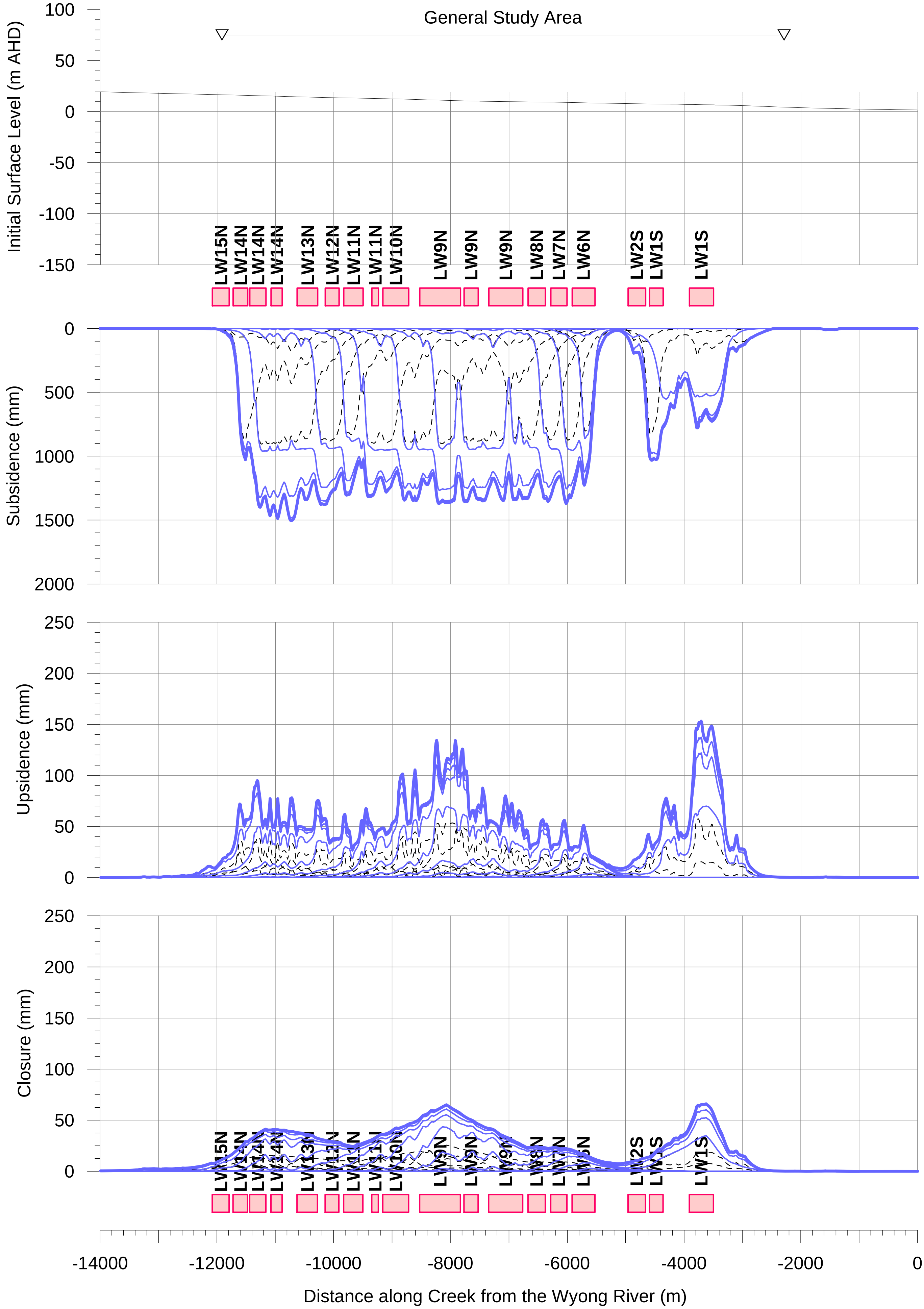
Predicted Profiles of Subsidence, Upsidence and Closure along the Wyong River Resulting from the Extraction of the Proposed Longwalls



Mine Subsidence Engineering Consultants

Fig. E.05

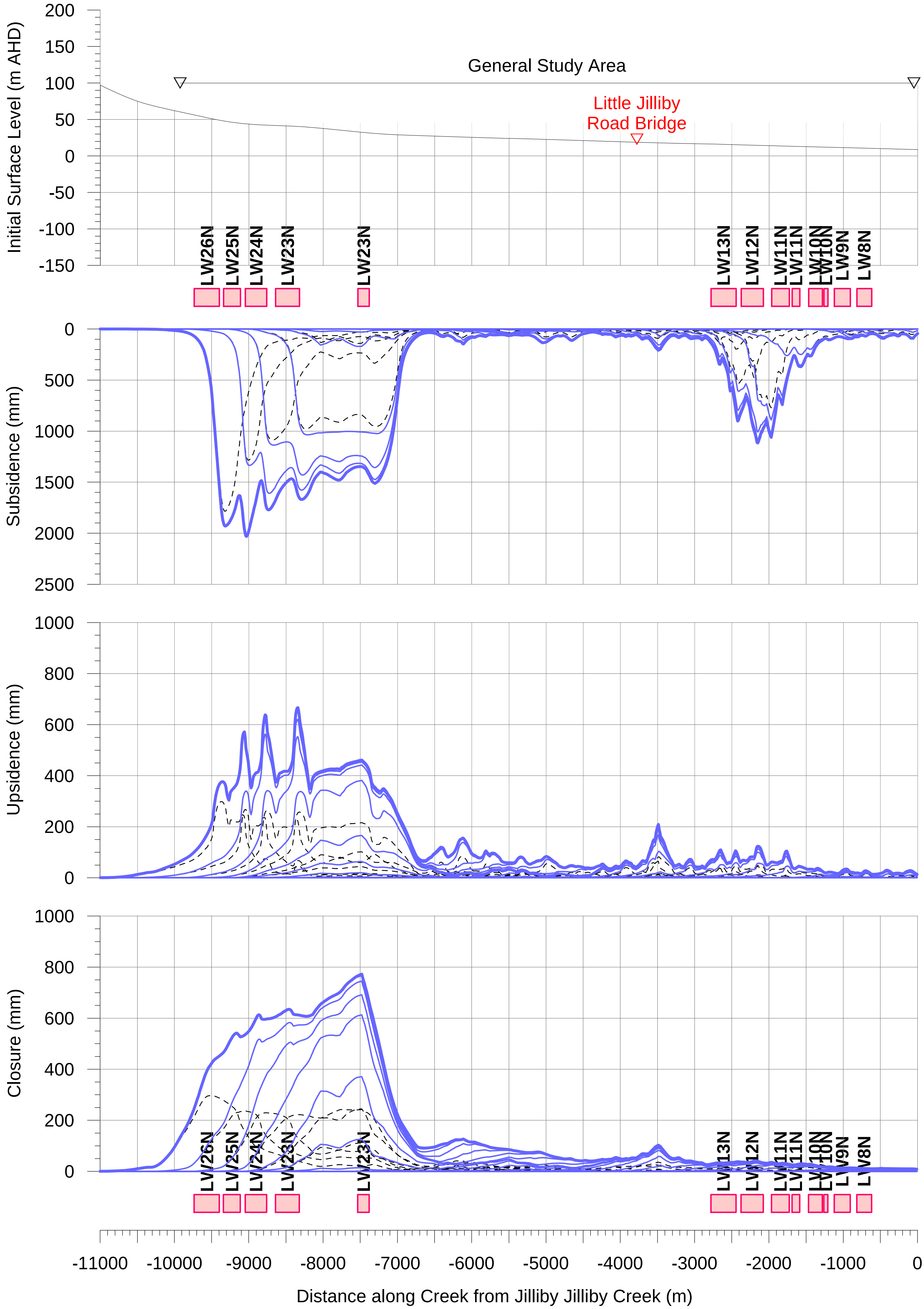
Predicted Profiles of Subsidence, Upsidence and Closure along Jilliby Jilliby Creek Resulting from the Extraction of the Proposed Longwalls



Mine Subsidence Engineering Consultants

Fig. E.06

Predicted Profiles of Subsidence, Upsidence and Closure along Little Jilliby Jilliby Creek Resulting from the Extraction of the Proposed Longwalls



Mine Subsidence Engineering Consultants

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Jilliby Road Resulting from the Extraction of the Proposed Longwalls

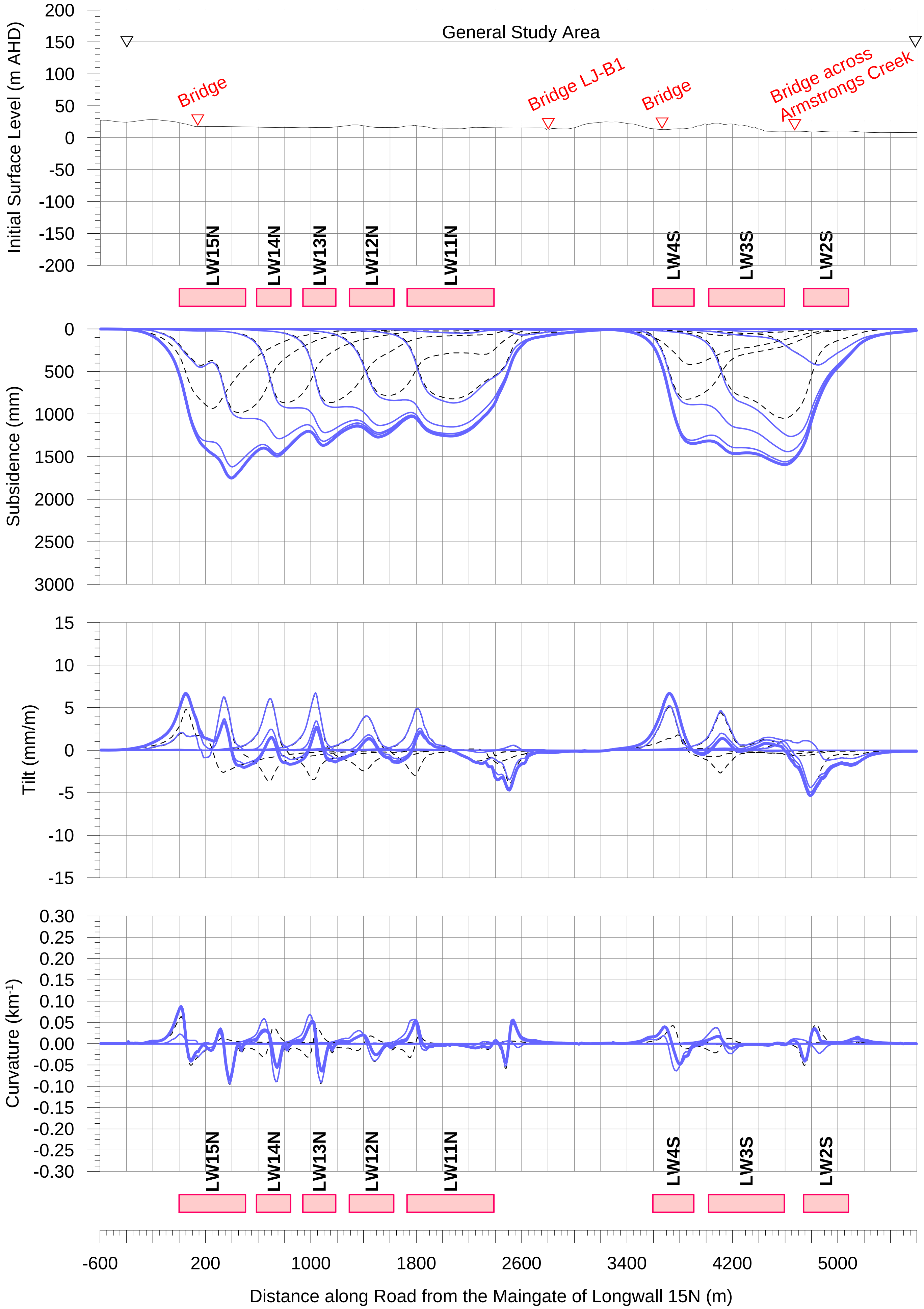
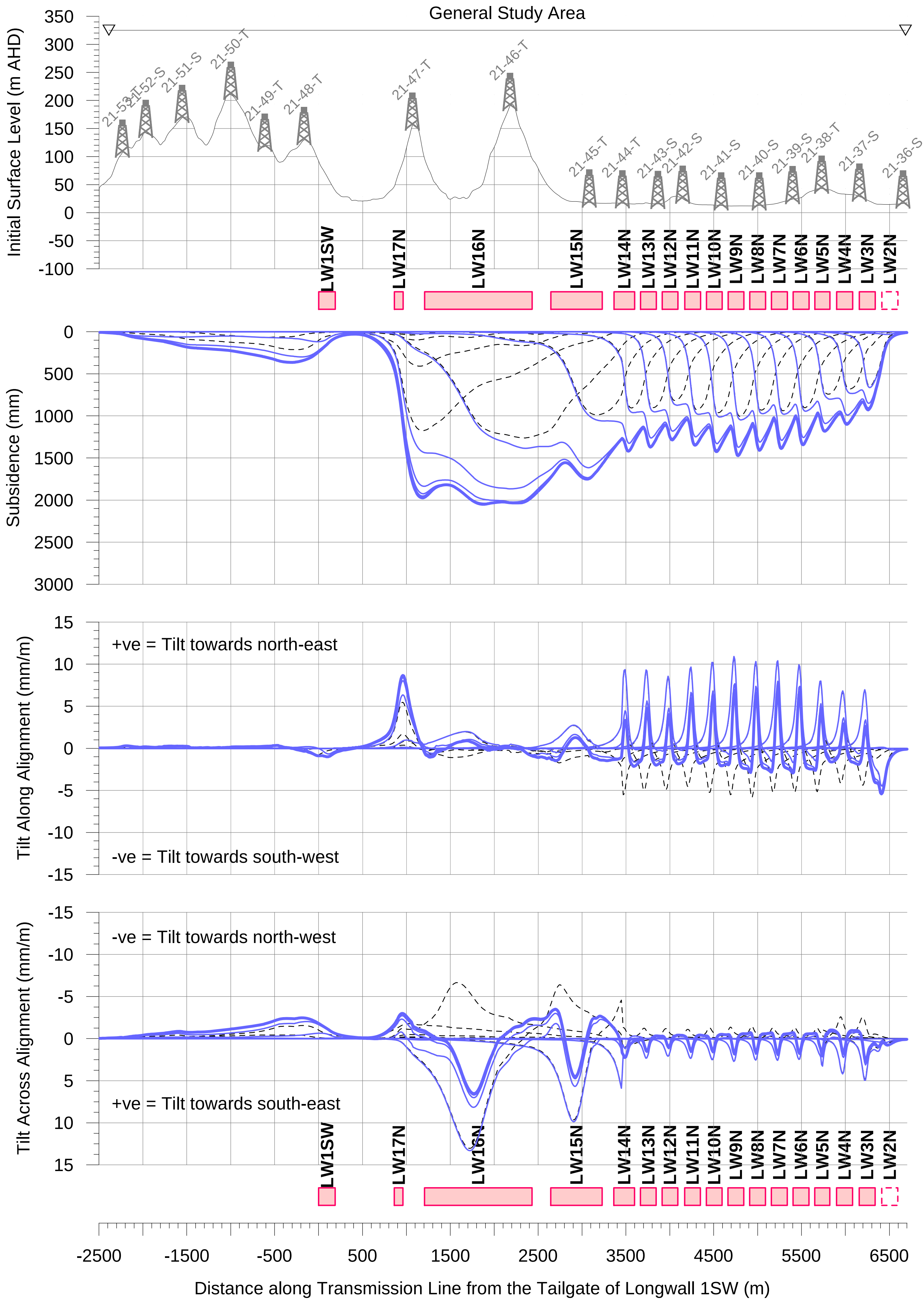


Fig. E.08

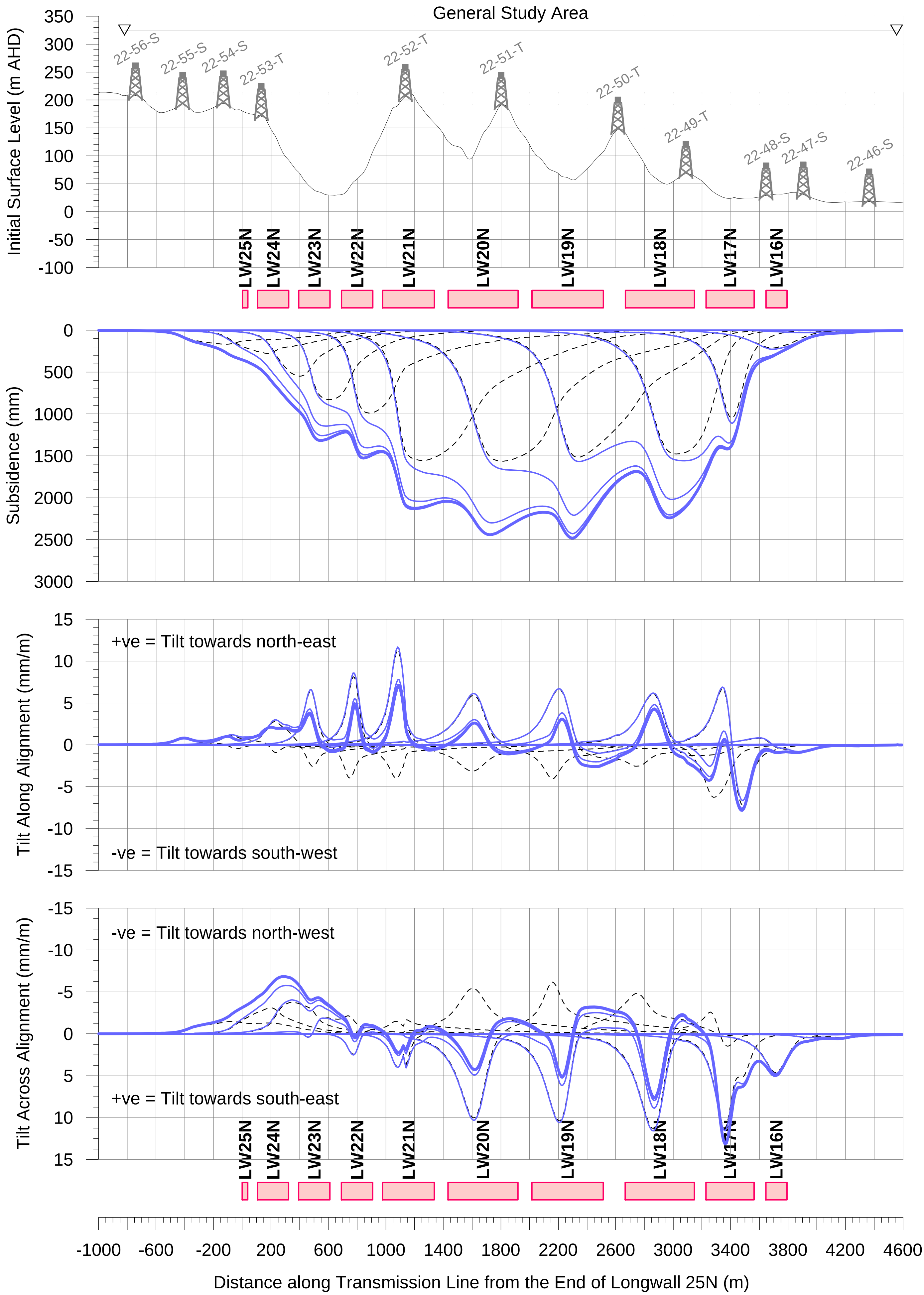
Predicted Profiles of Conventional Subsidence, Tilt Along and Tilt Across the Alignment of the Transmission Line 21 Resulting from the Extraction of the Proposed Longwalls



Mine Subsidence Engineering Consultants

Fig. E.09

Predicted Profiles of Conventional Subsidence, Tilt Along and Tilt Across the Alignment of the Transmission Line 22 Resulting from the Extraction of the Proposed Longwalls



Mine Subsidence Engineering Consultants

Fig. E.10

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along the Optical Fibre Cable Resulting from the Extraction of the Proposed Longwalls

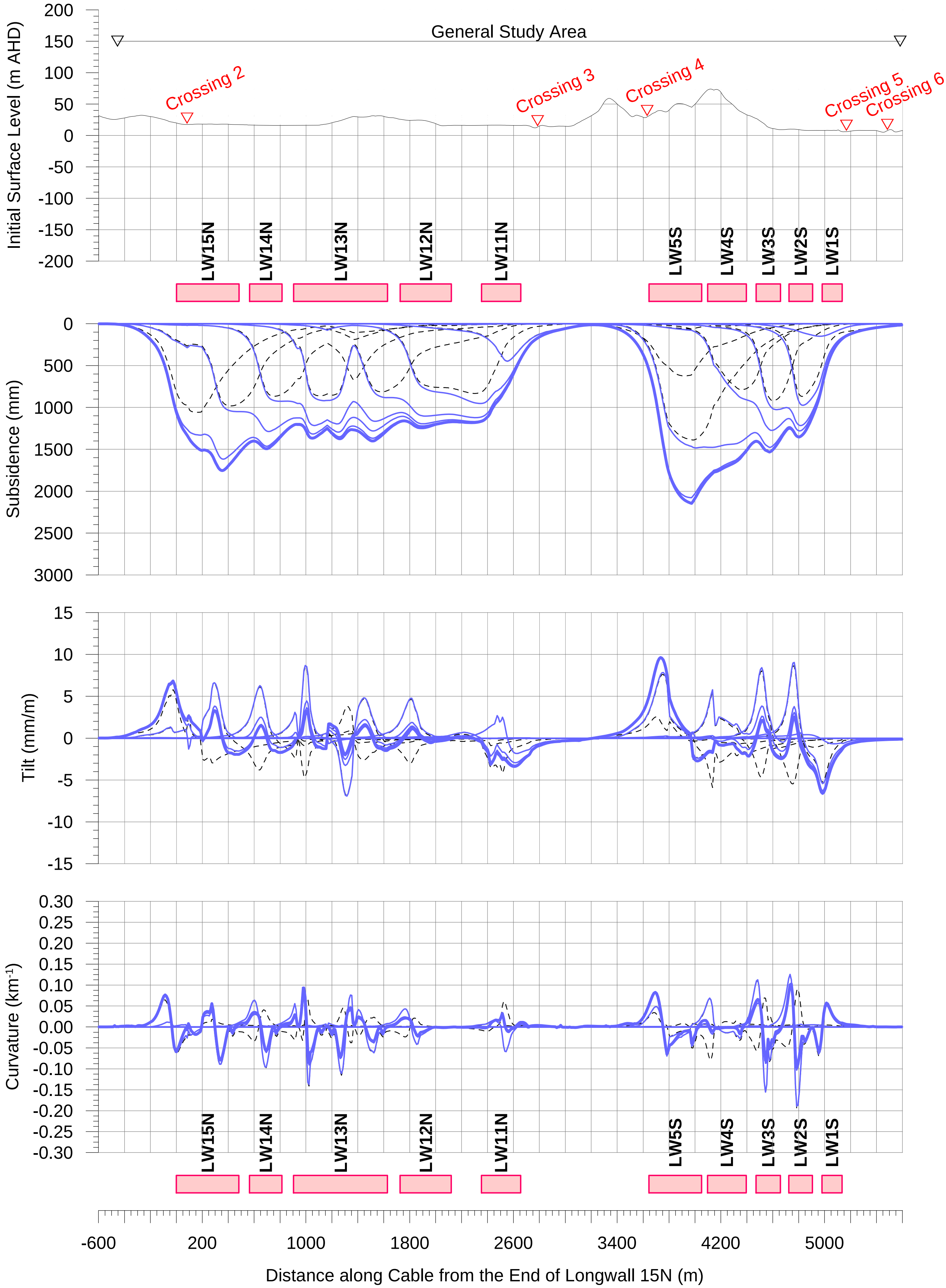
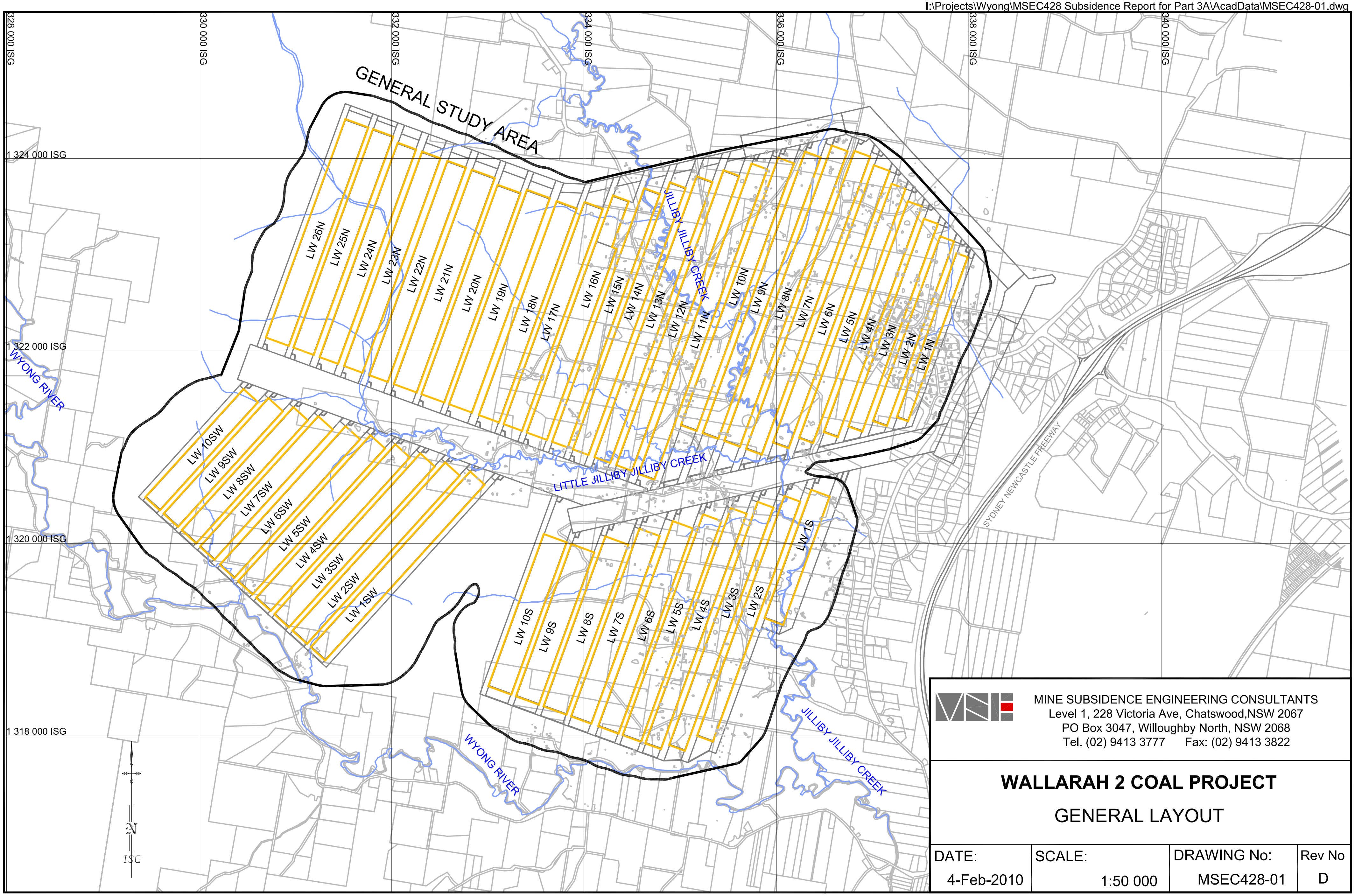


Fig. E.11

APPENDIX F. DRAWINGS

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-01.dwg



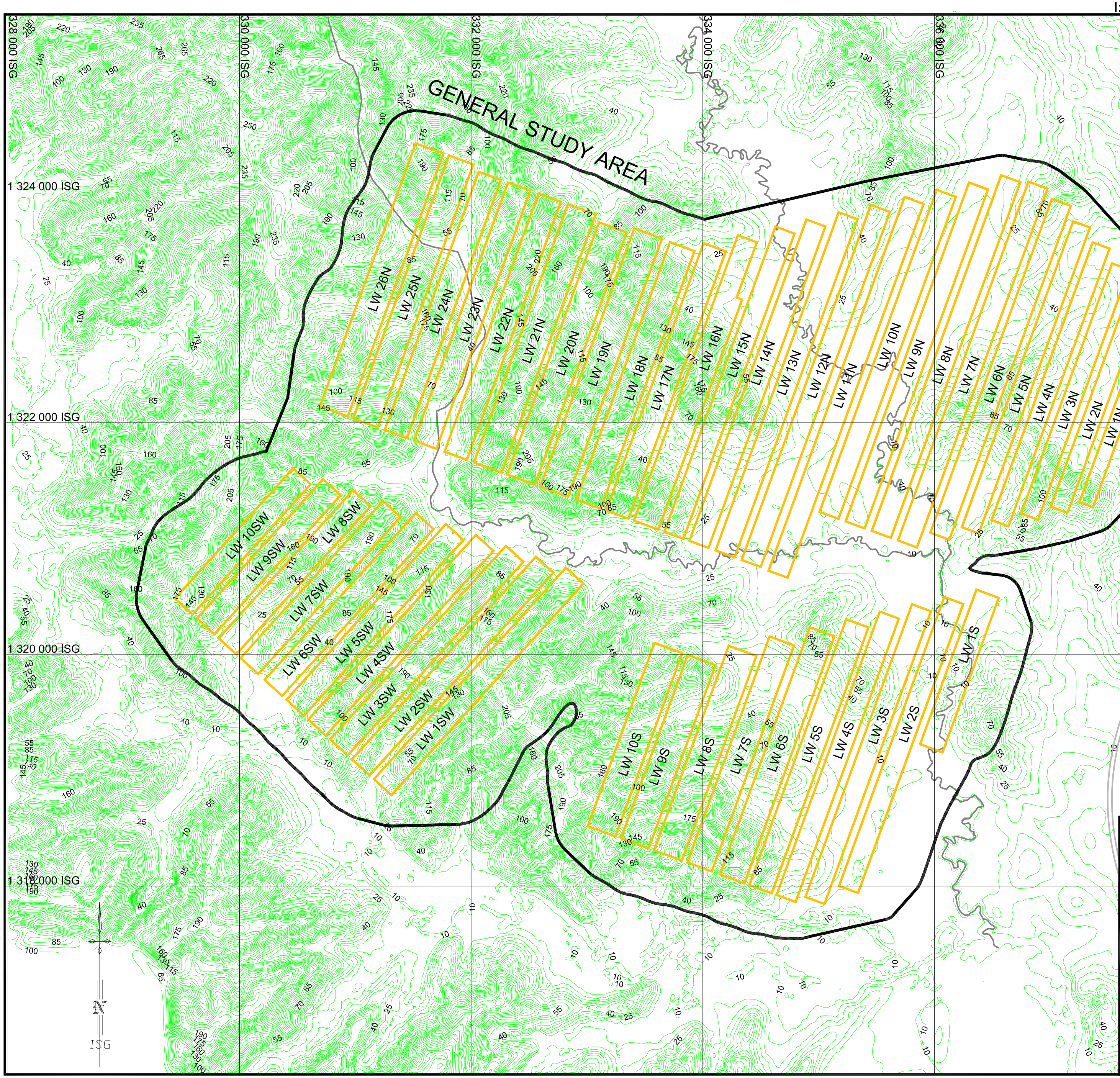
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

GENERAL LAYOUT

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-01	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-02.dwg



SURFACE LEVEL CONTOURS ARE IN m AHD

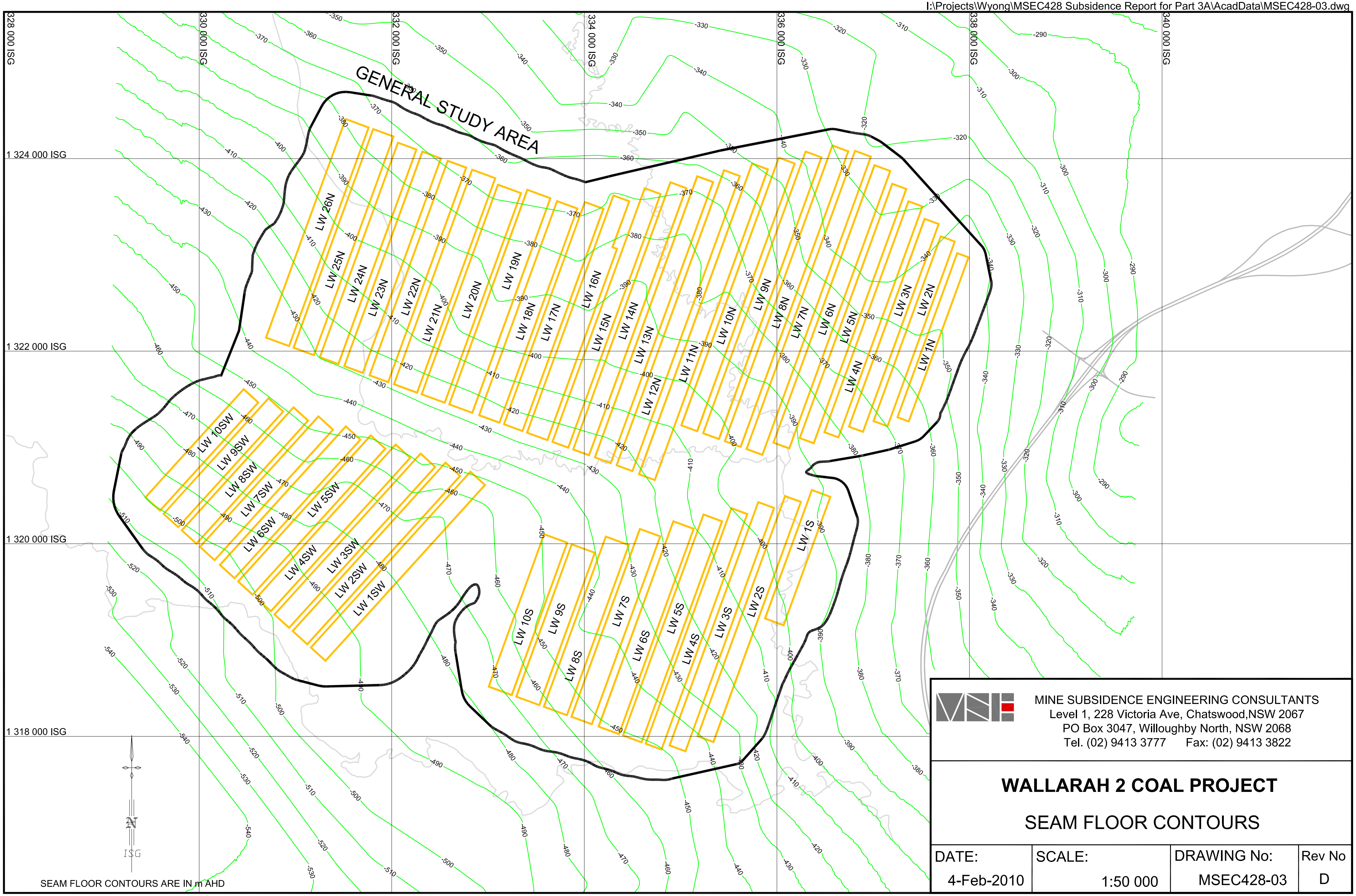
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

SURFACE LEVEL CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-02	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-03.dwg



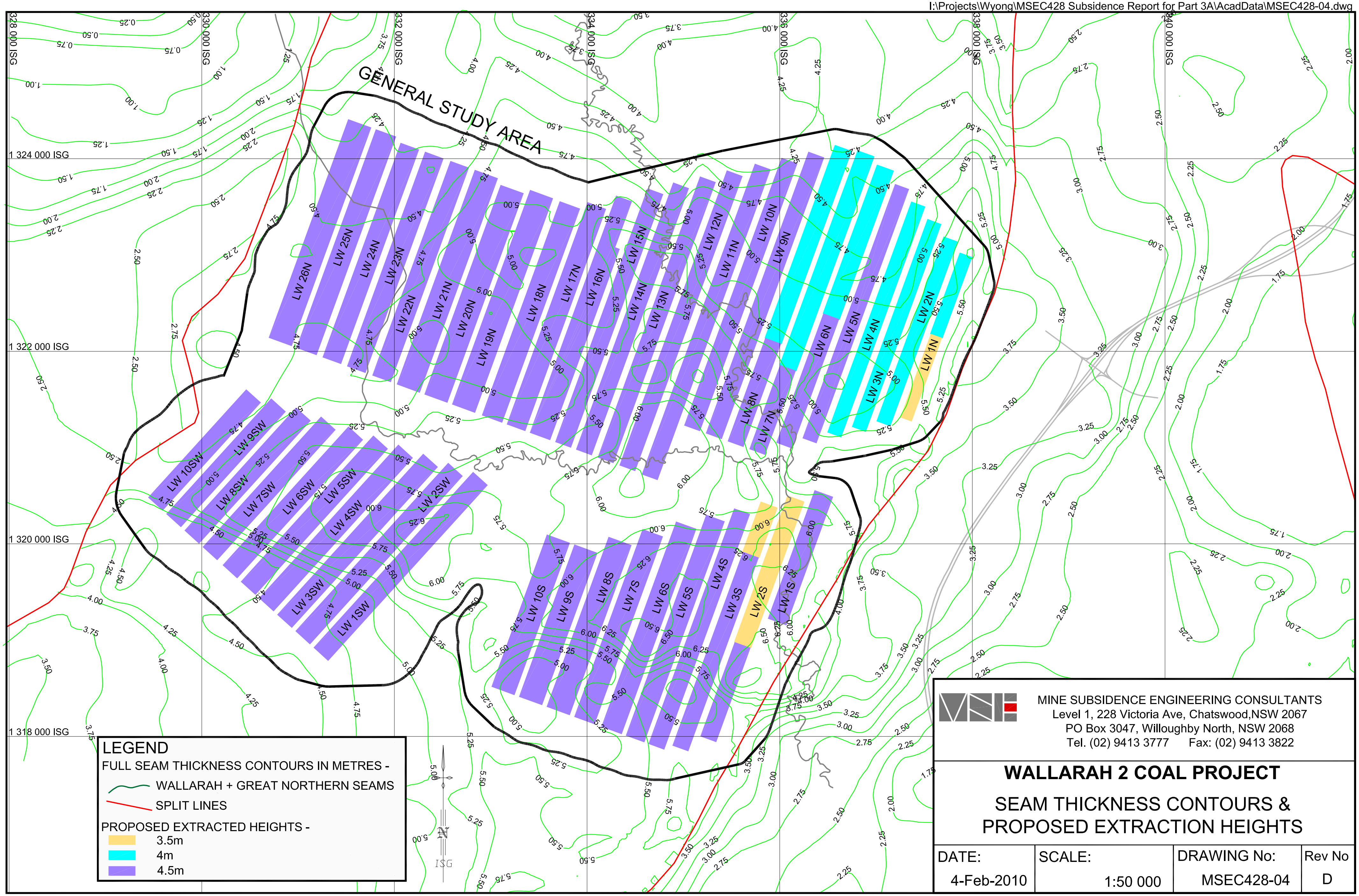
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

SEAM FLOOR CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-03	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-04.dwg



LEGEND

FULL SEAM THICKNESS CONTOURS IN METRES -

- WALLARAH + GREAT NORTHERN SEAMS
- SPLIT LINES

PROPOSED EXTRACTED HEIGHTS -

- 3.5m
- 4m
- 4.5m

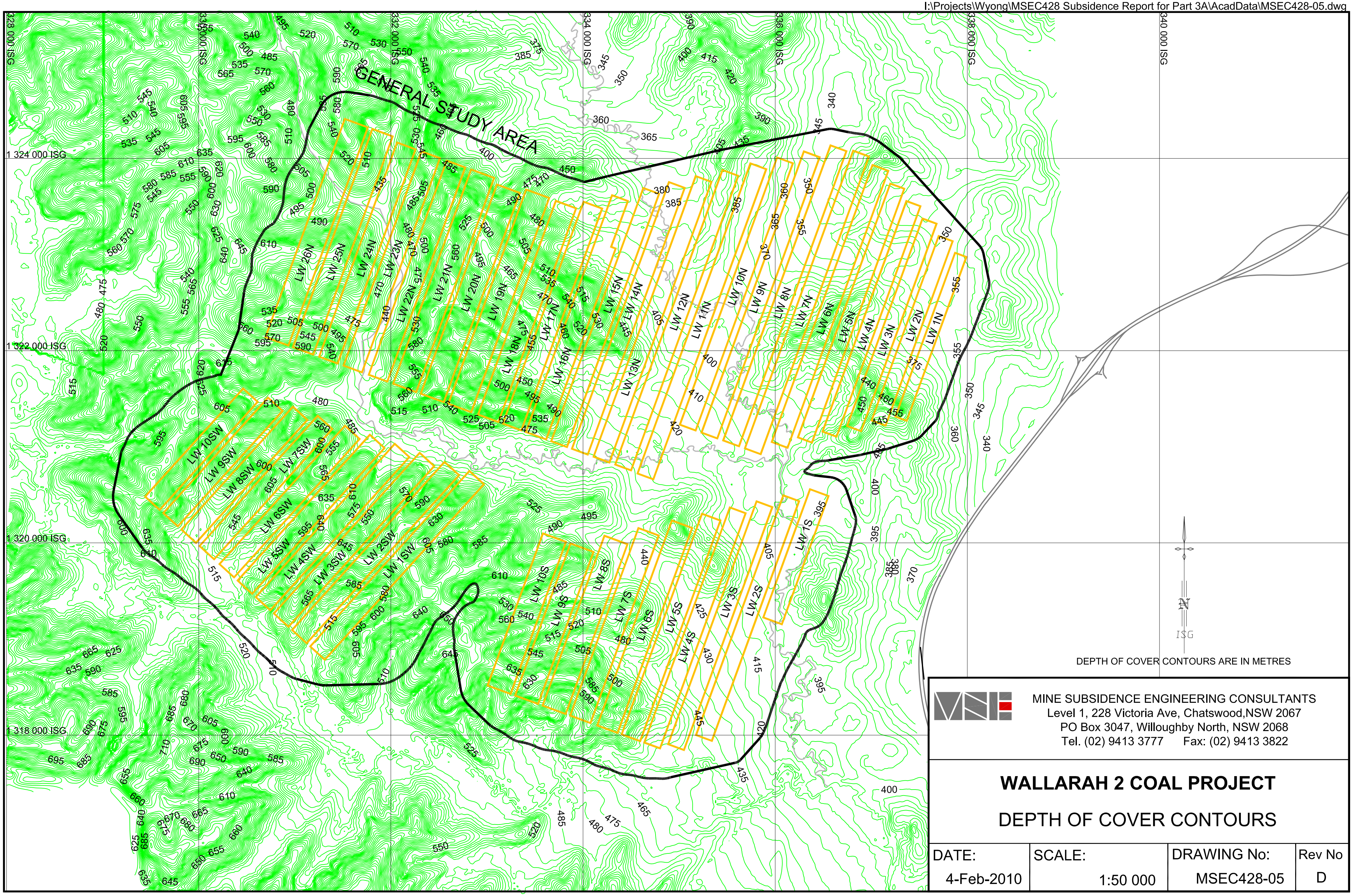
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

SEAM THICKNESS CONTOURS & PROPOSED EXTRACTION HEIGHTS

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-04	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-05.dwg



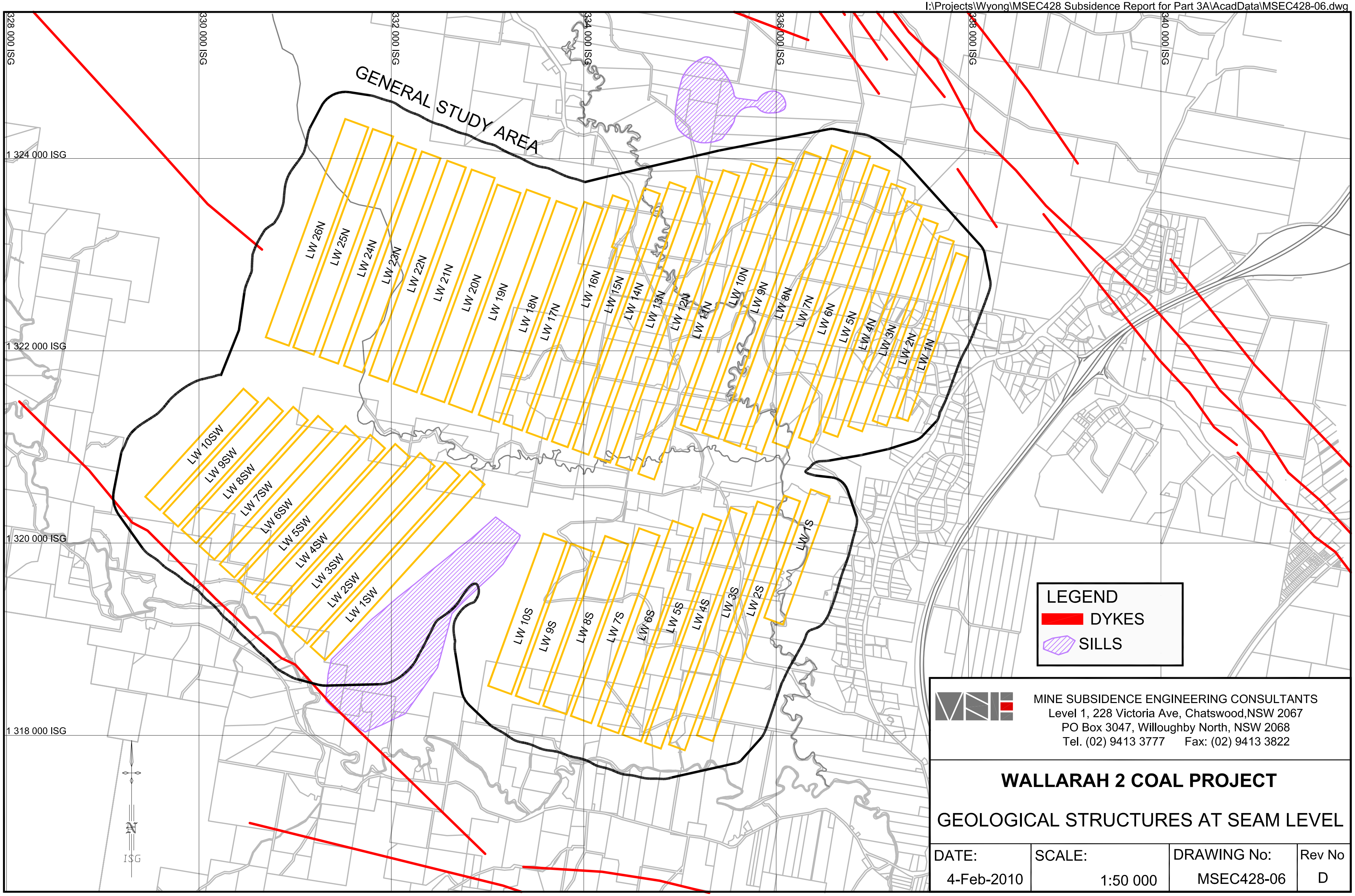
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

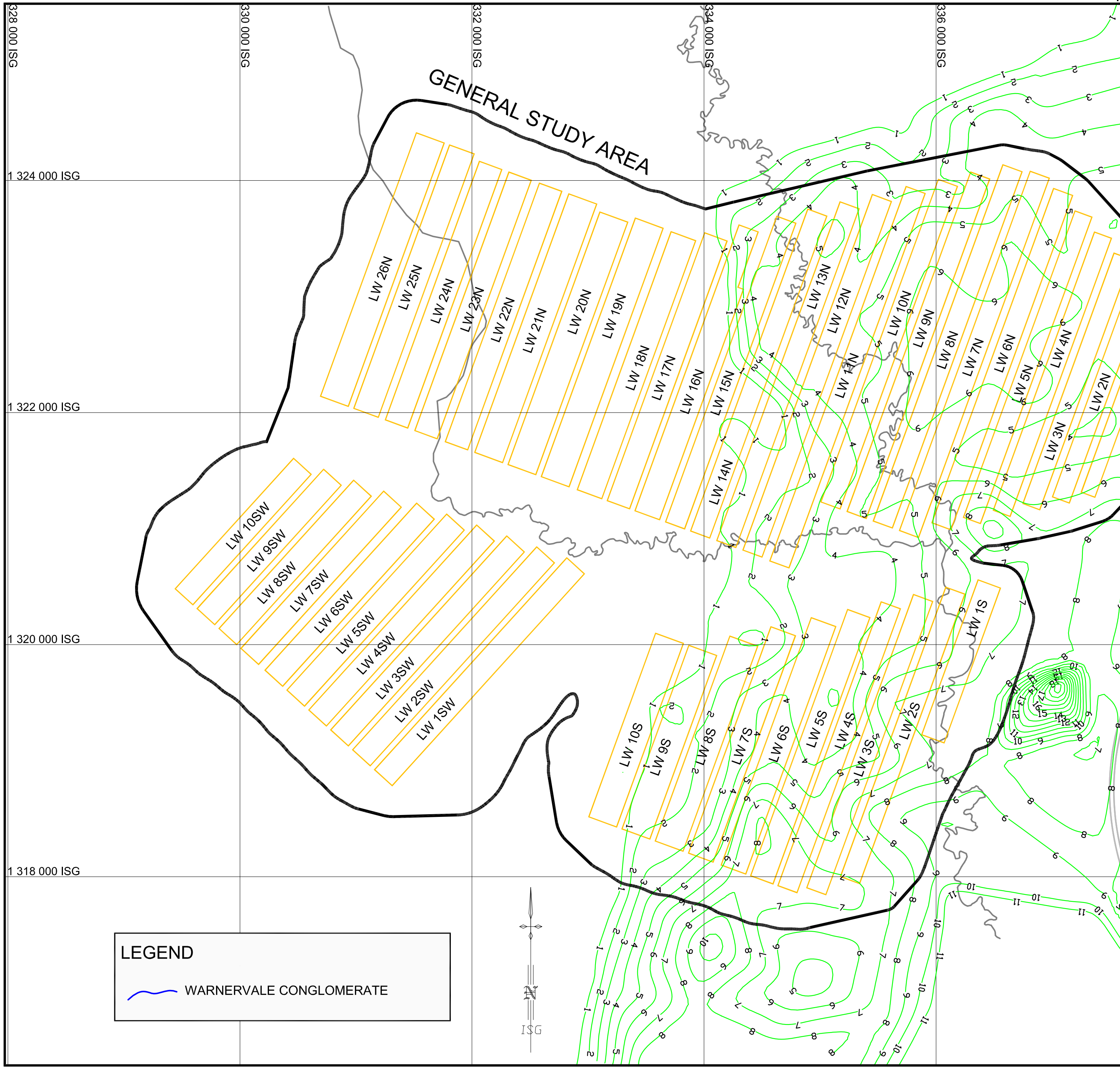
DEPTH OF COVER CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-05	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-06.dwg



I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-07.dwg



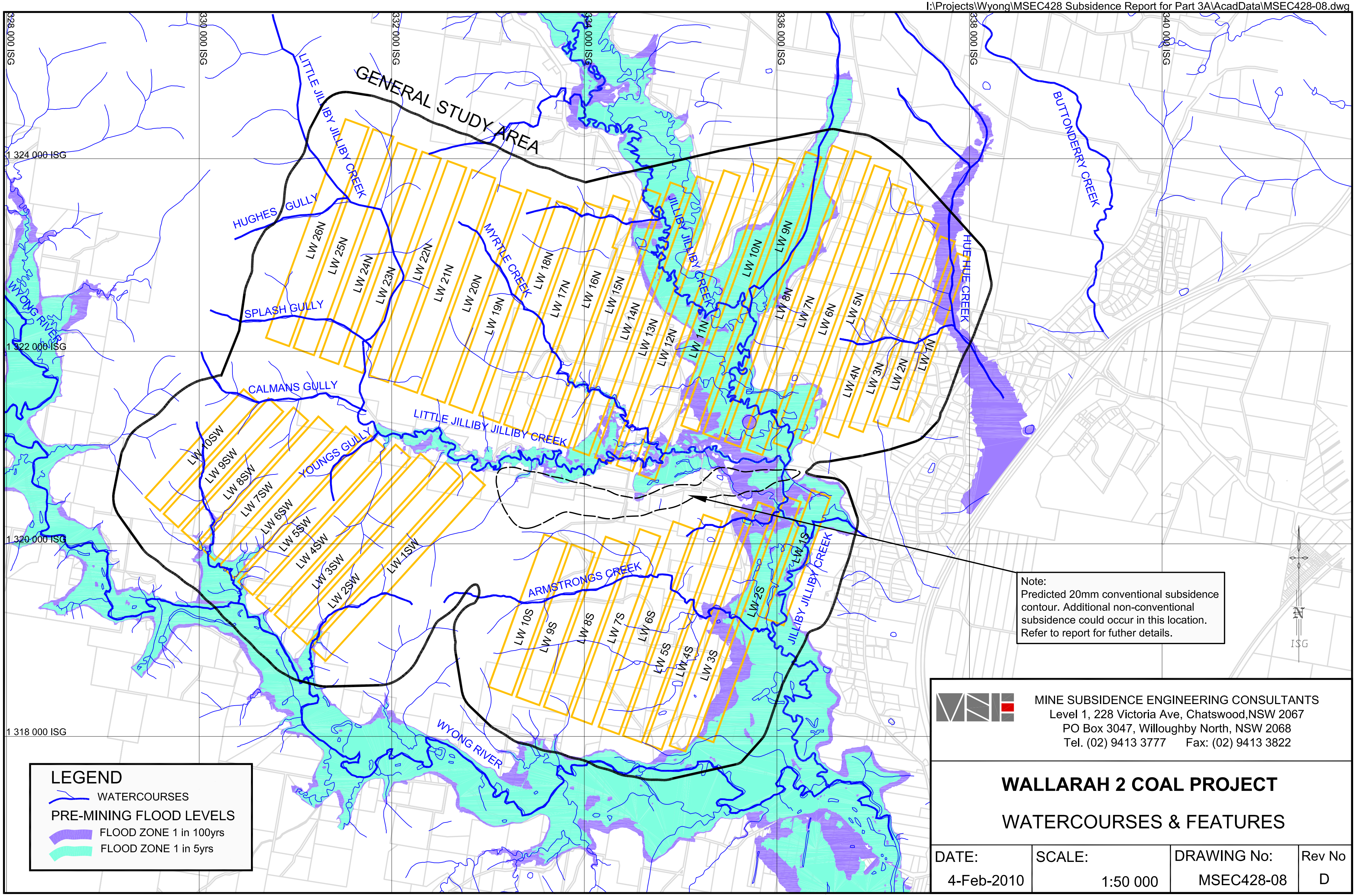
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood, NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

EXTENT & THICKNESS OF THE WARNERVALE CONGLOMERATE

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-07	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-08.dwg



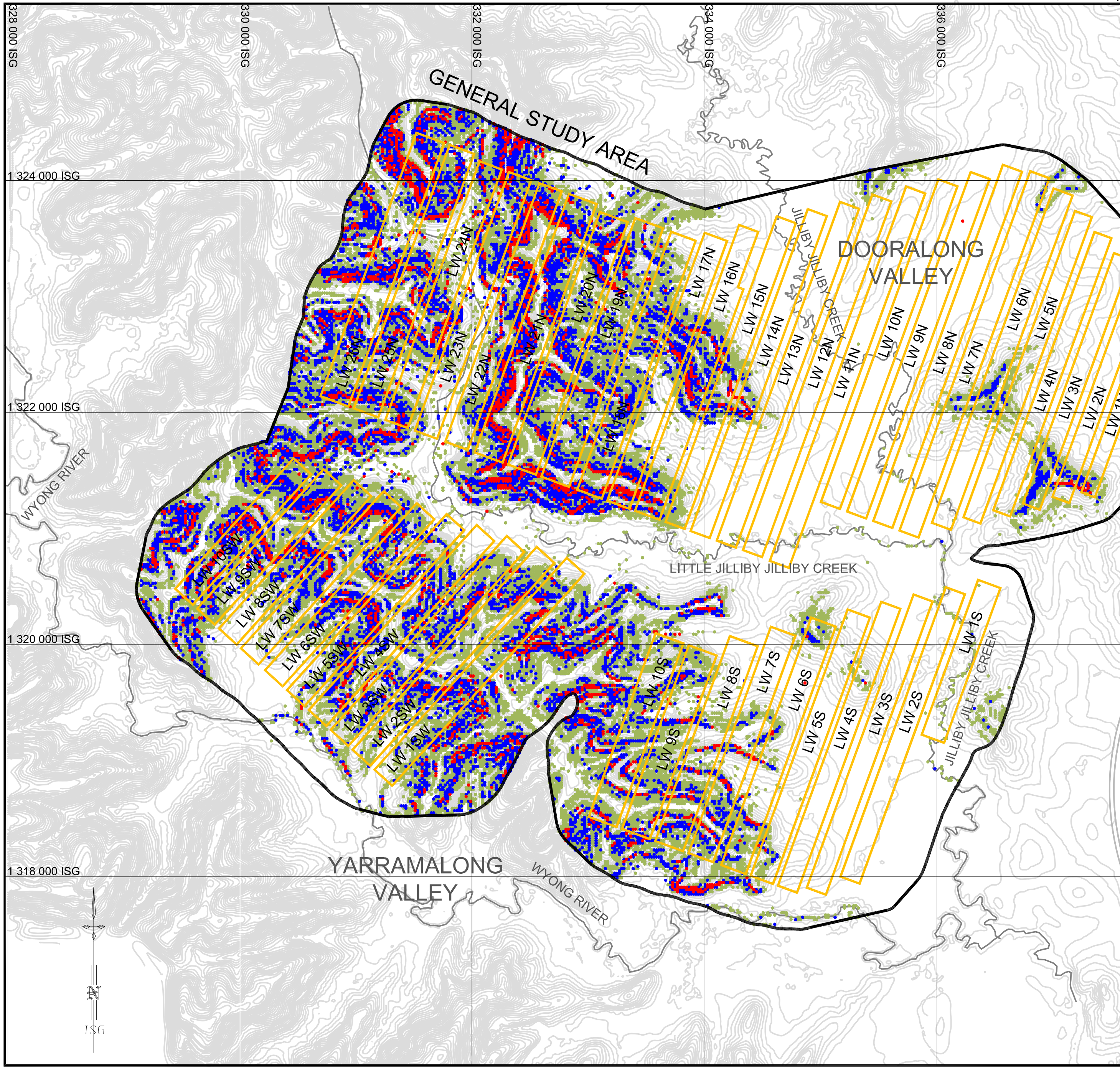
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

WATERCOURSES & FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-08	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-09.dwg



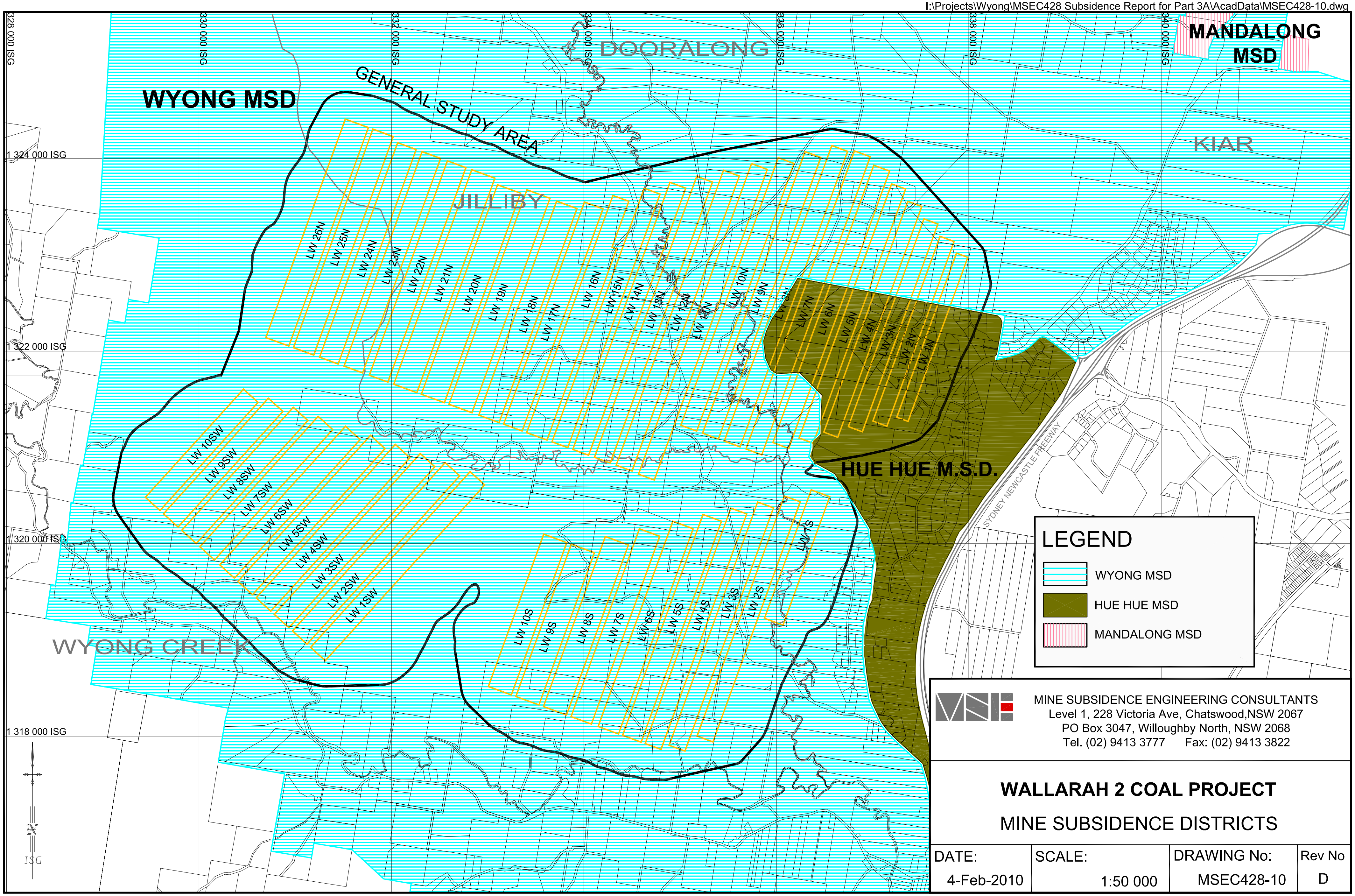
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

STEEP SLOPES

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-09	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-10.dwg



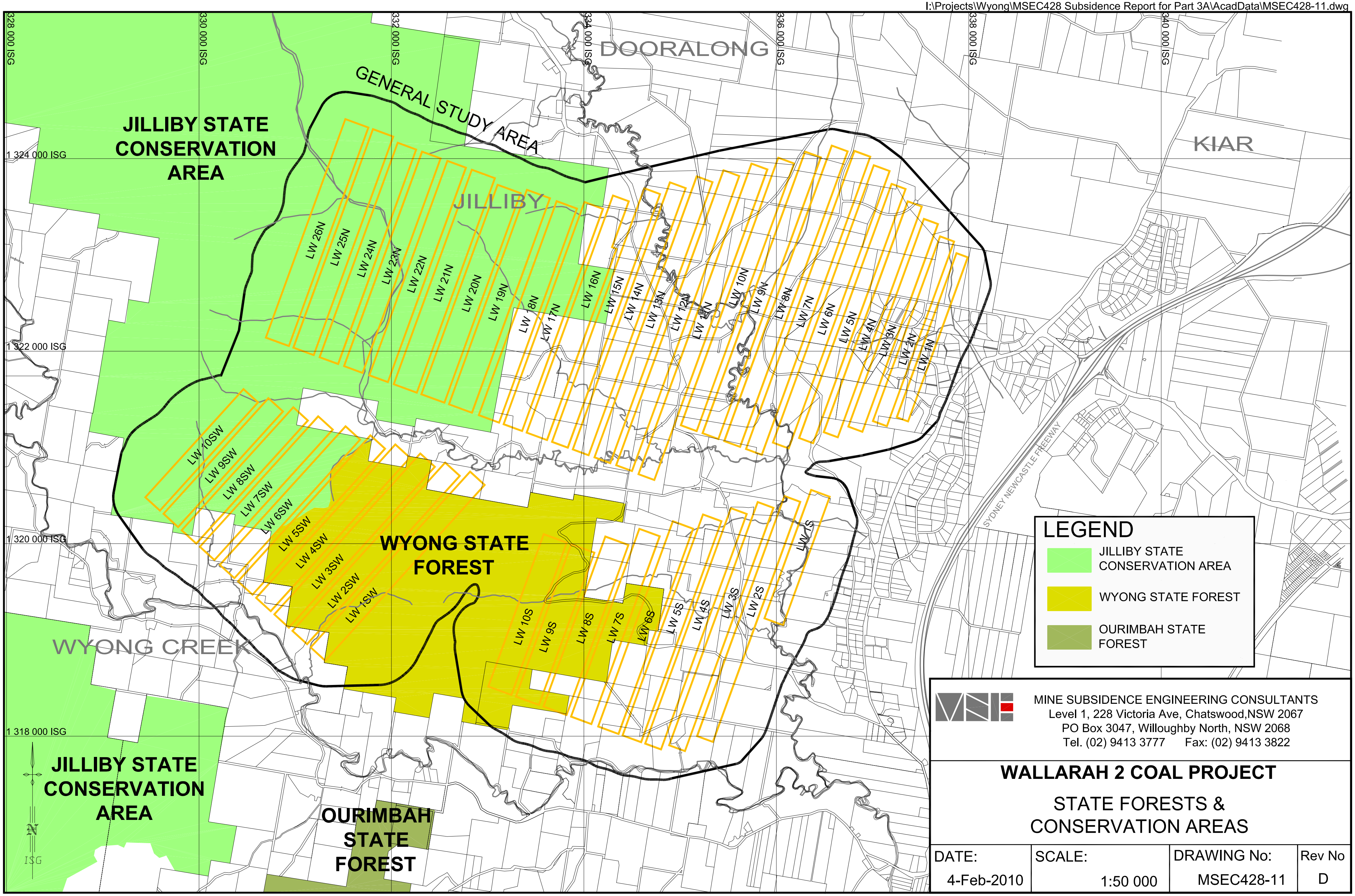
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

MINE SUBSIDENCE DISTRICTS

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-10	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-11.dwg



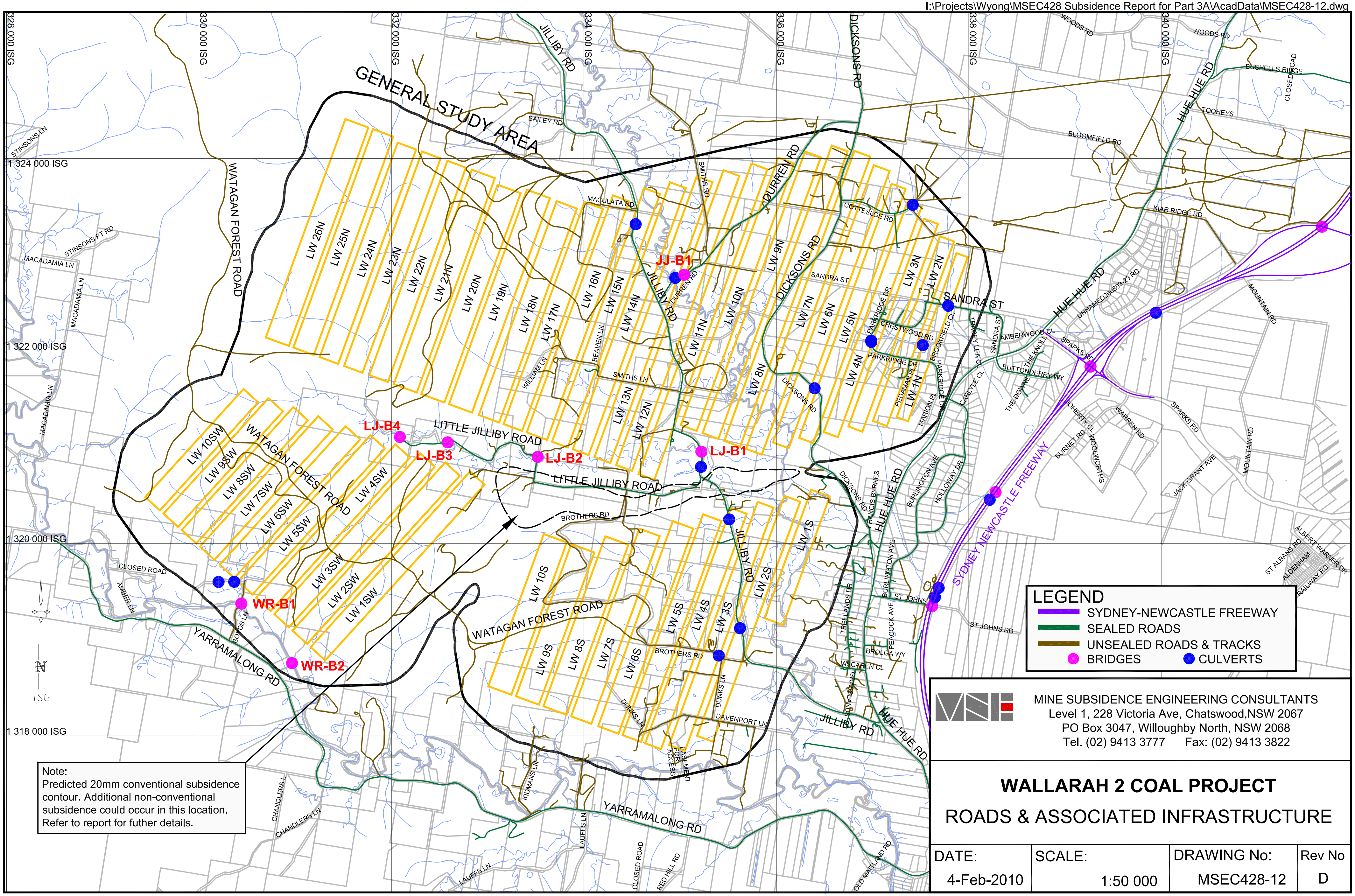
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

STATE FORESTS & CONSERVATION AREAS

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-11	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-12.dwg



Note:
Predicted 20mm conventional subsidence contour. Additional non-conventional subsidence could occur in this location. Refer to report for futher details.

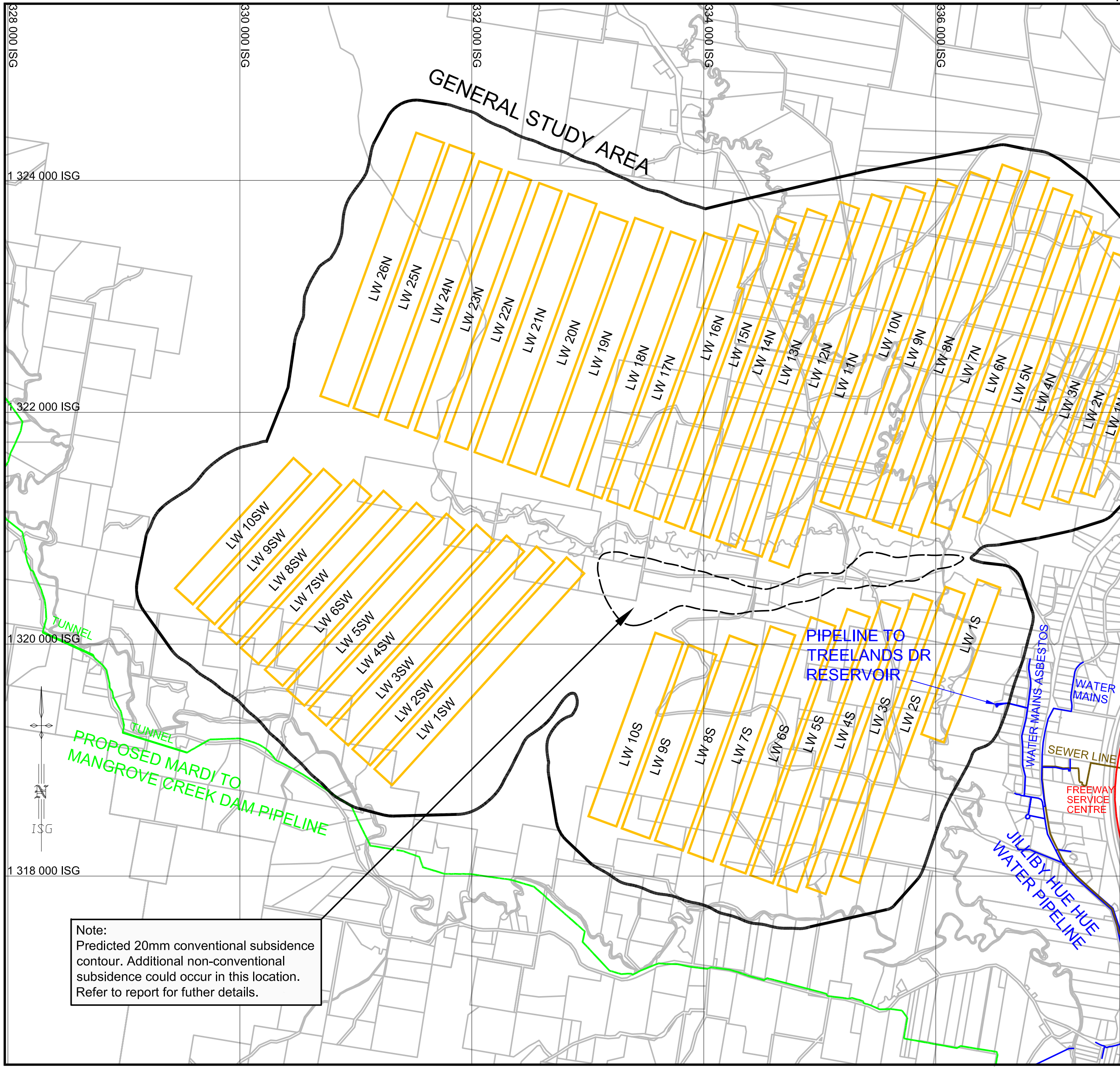
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

ROADS & ASSOCIATED INFRASTRUCTURE

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-12	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-13.dwg

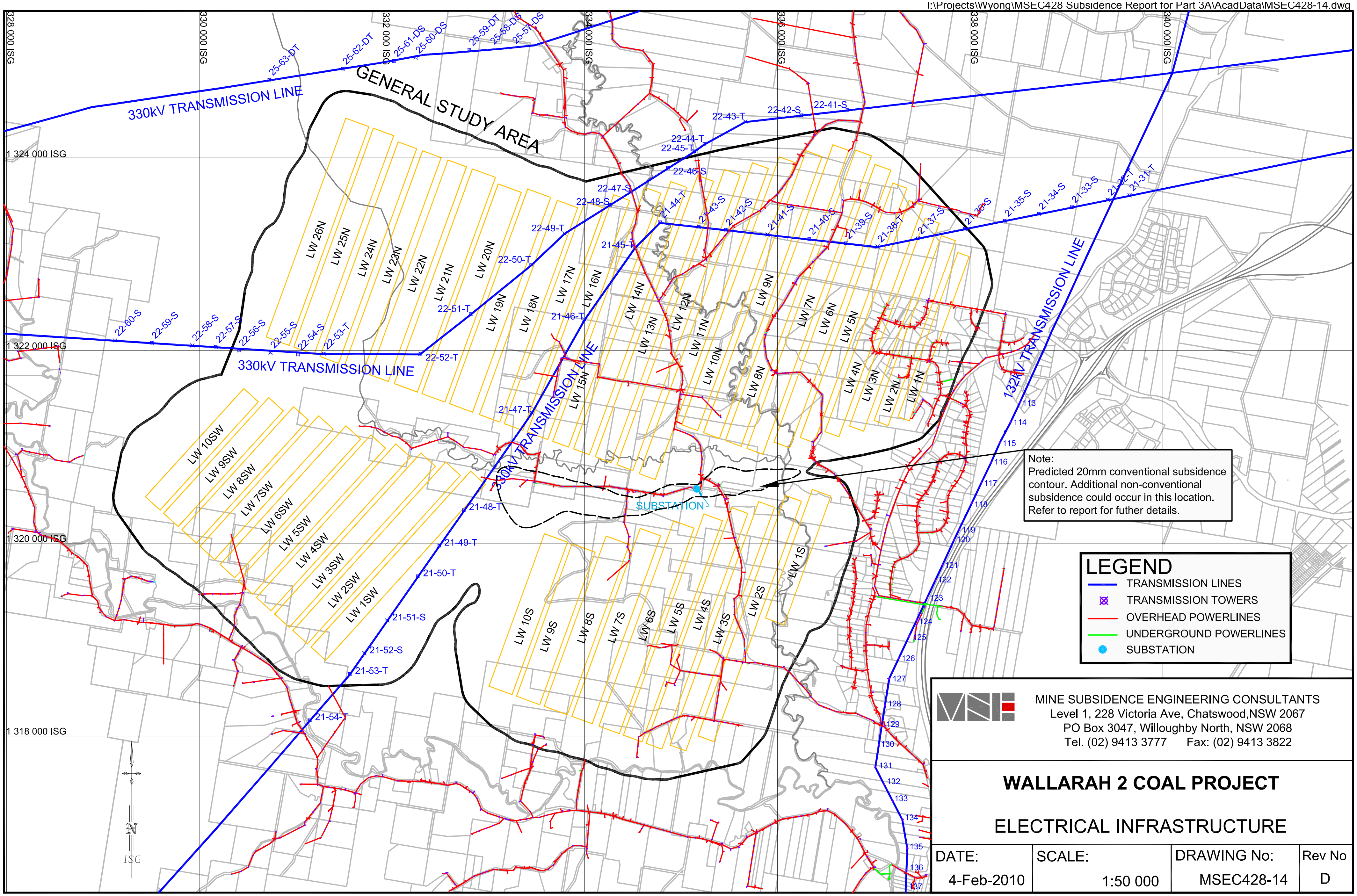


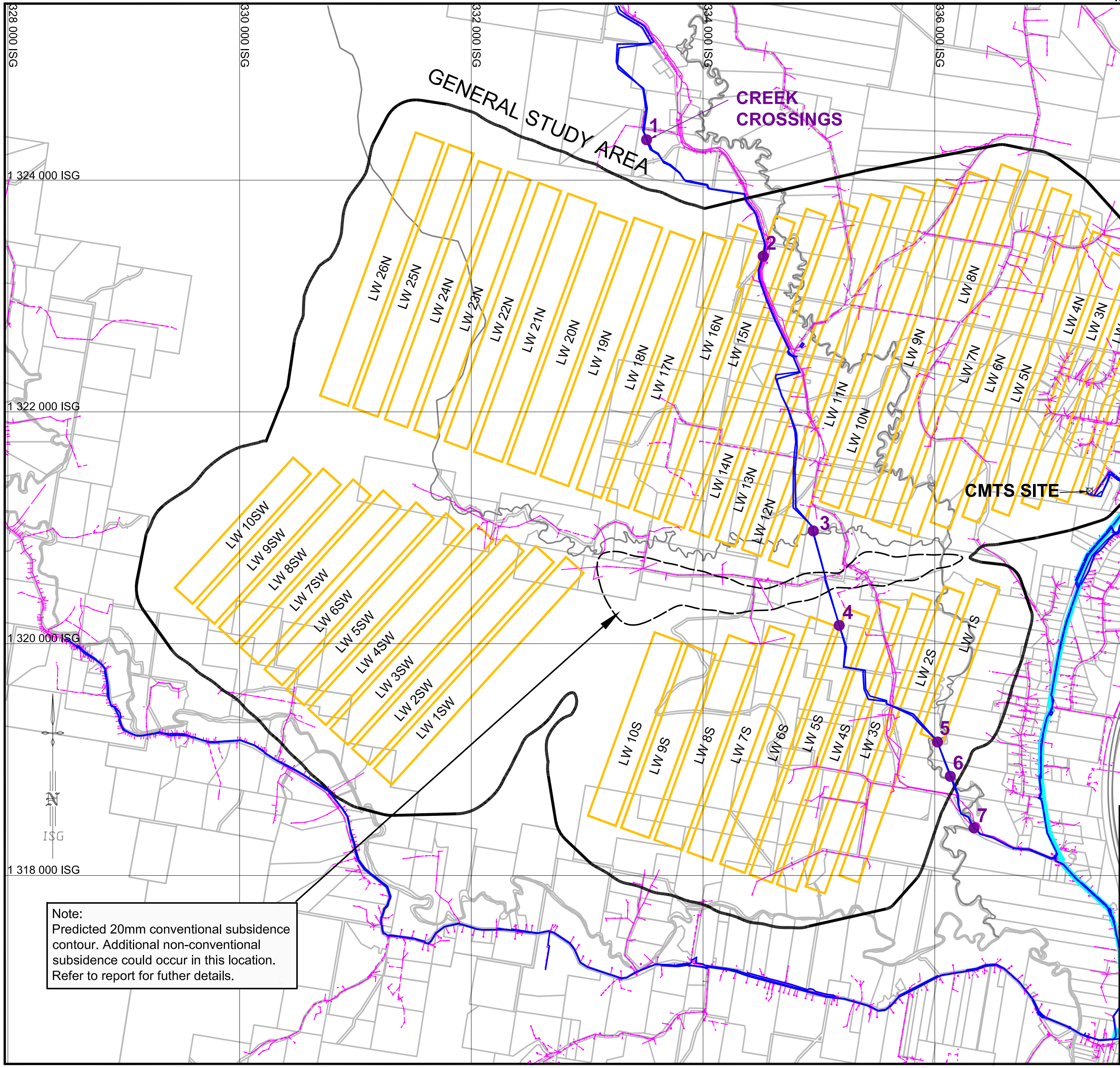
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

WATER & GAS INFRASTRUCTURE

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-13	D


I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-14.dwg
GENERAL STUDY AREA
330kV TRANSMISSION LINE
330kV TRANSMISSION LINE
330kV TRANSMISSION LINE
132kV TRANSMISSION LINE
SUBSTATION
Note:
Predicted 20mm conventional subsidence contour. Additional non-conventional subsidence could occur in this location.
Refer to report for futher details.
LEGEND
TRANSMISSION LINES
TRANSMISSION TOWERS
OVERHEAD POWERLINES
UNDERGROUND POWERLINES
SUBSTATION
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822
WALLARAH 2 COAL PROJECT
ELECTRICAL INFRASTRUCTURE
DATE: 4-Feb-2010
SCALE: 1:50 000
DRAWING No: MSEC428-14
Rev No D



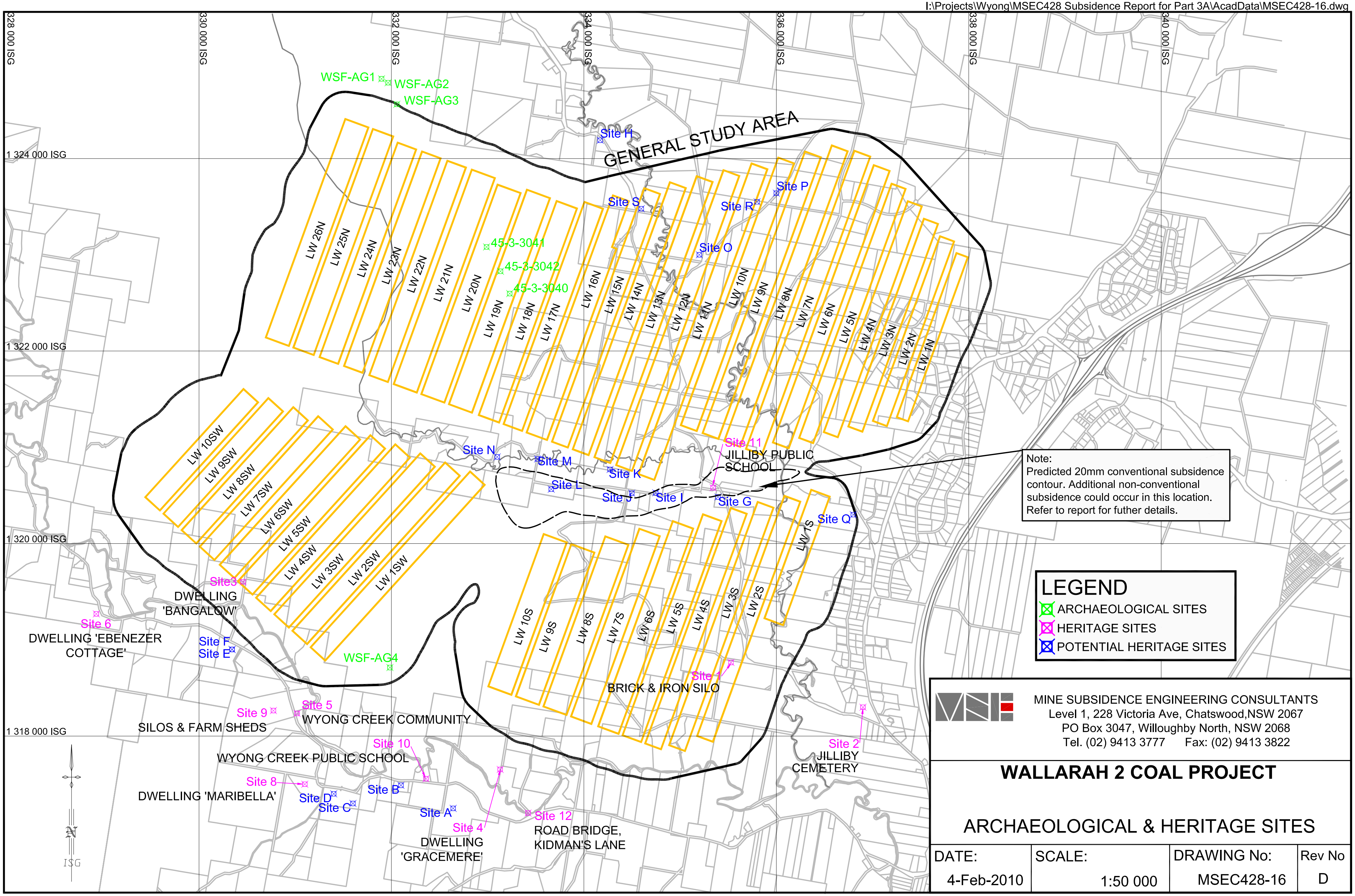
Note:
Predicted 20mm conventional subsidence contour. Additional non-conventional subsidence could occur in this location. Refer to report for futher details.

MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT
TELECOMMUNICATIONS INFRASTRUCTURE

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-15	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-16.dwg



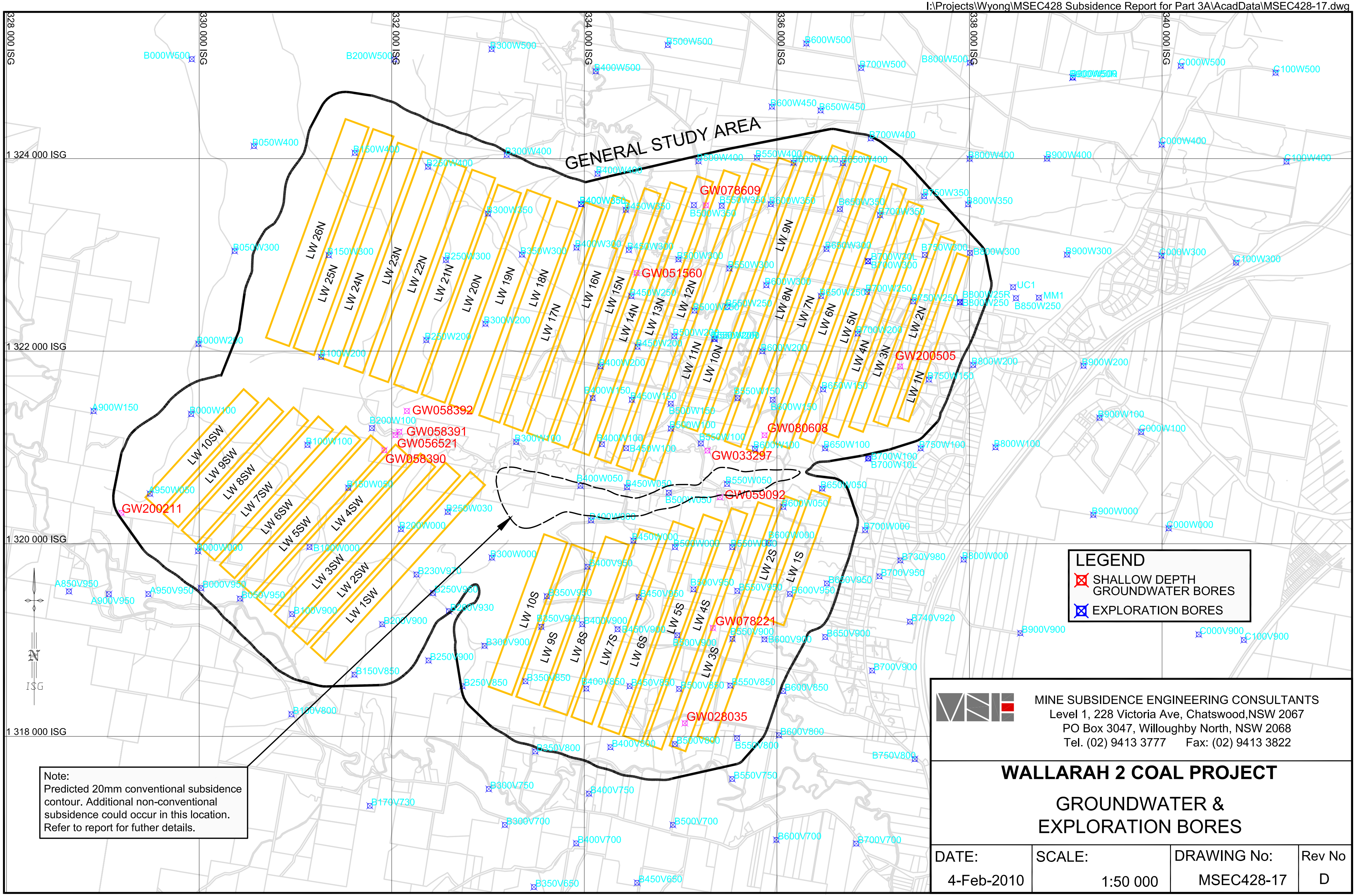
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

ARCHAEOLOGICAL & HERITAGE SITES

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-16	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-17.dwg



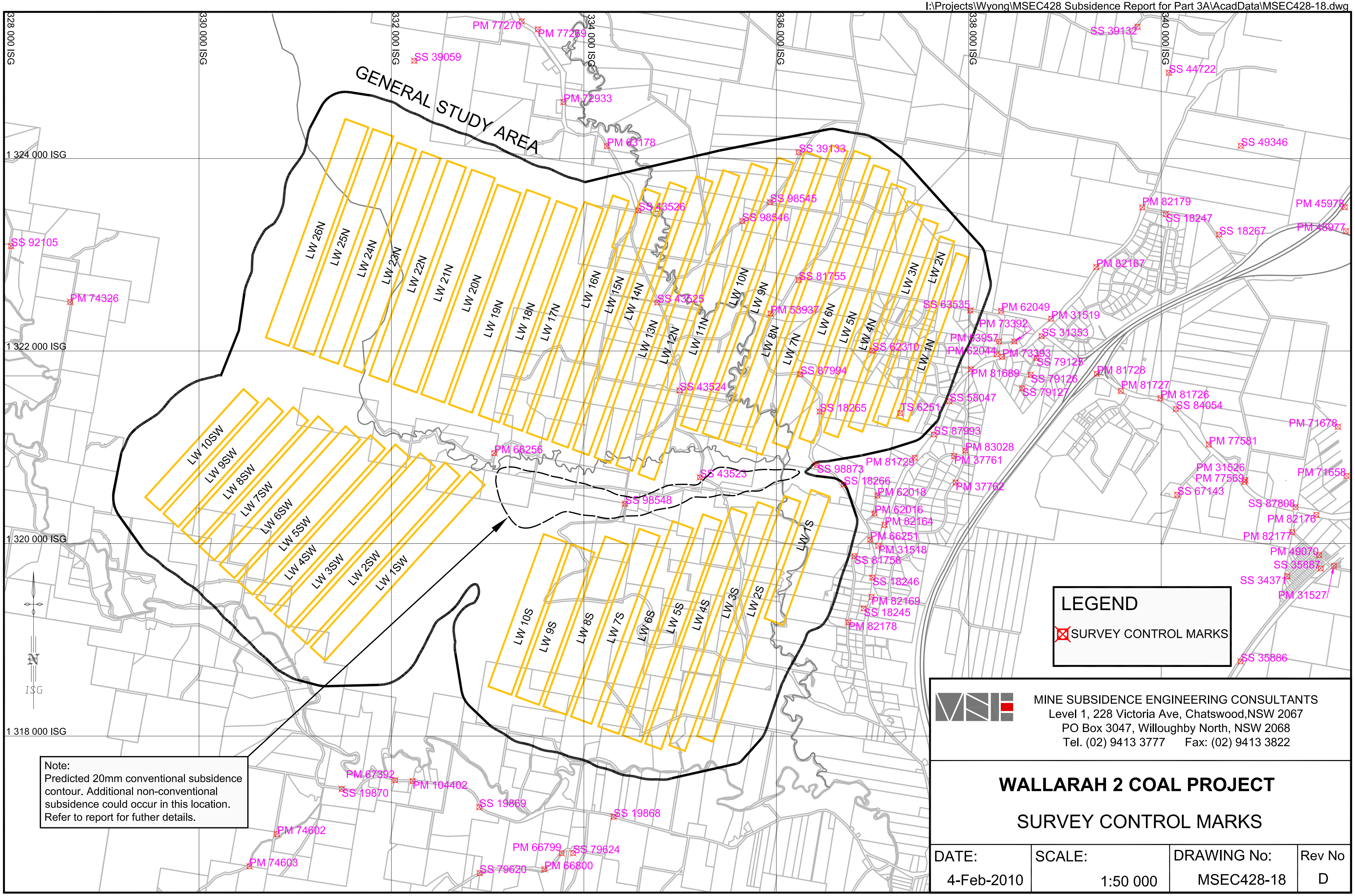
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

GROUNDWATER & EXPLORATION BORES

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-17	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-18.dwg



Note:
Predicted 20mm conventional subsidence contour. Additional non-conventional subsidence could occur in this location. Refer to report for futher details.

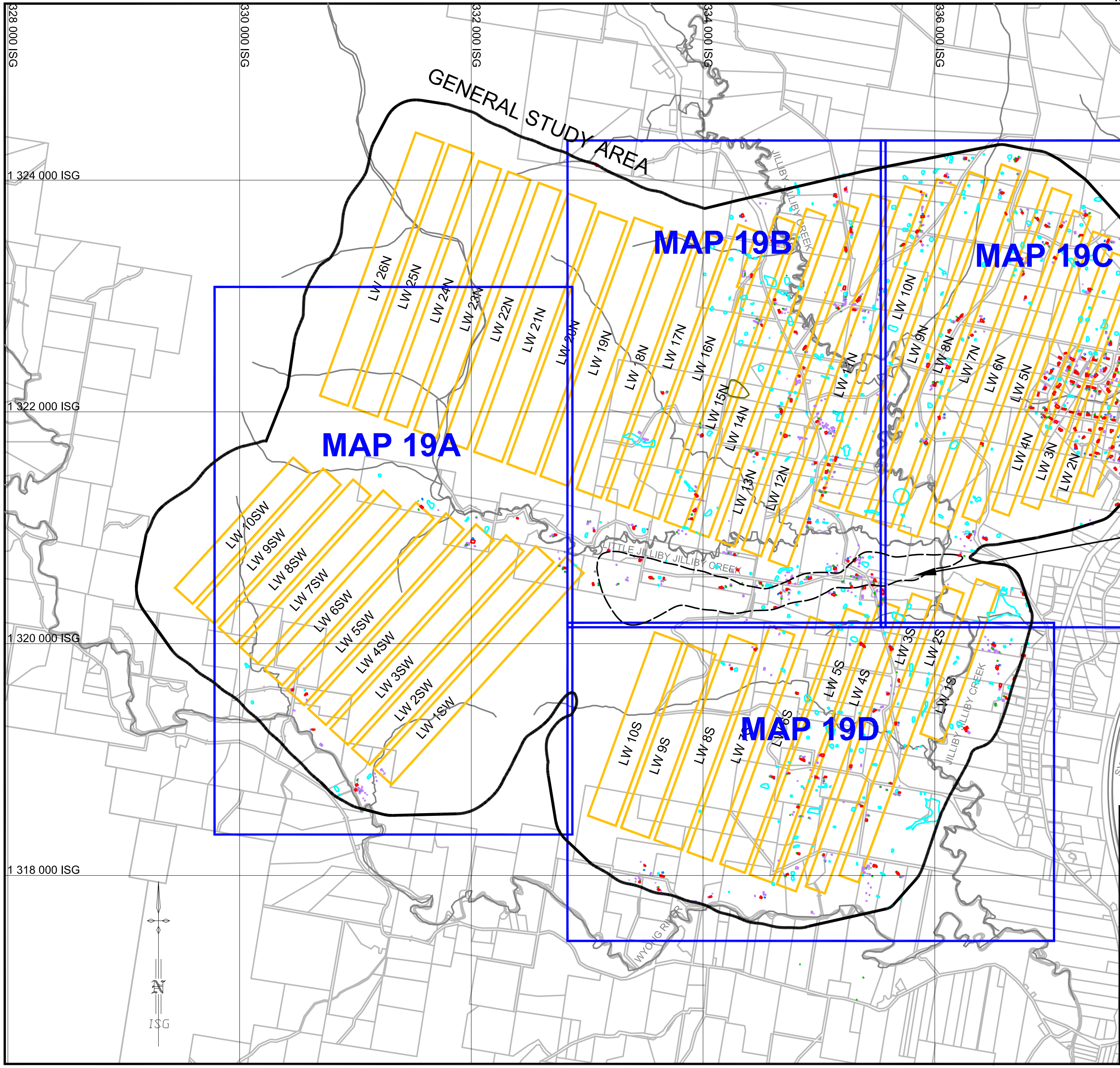
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

SURVEY CONTROL MARKS

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-18	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-19.dwg

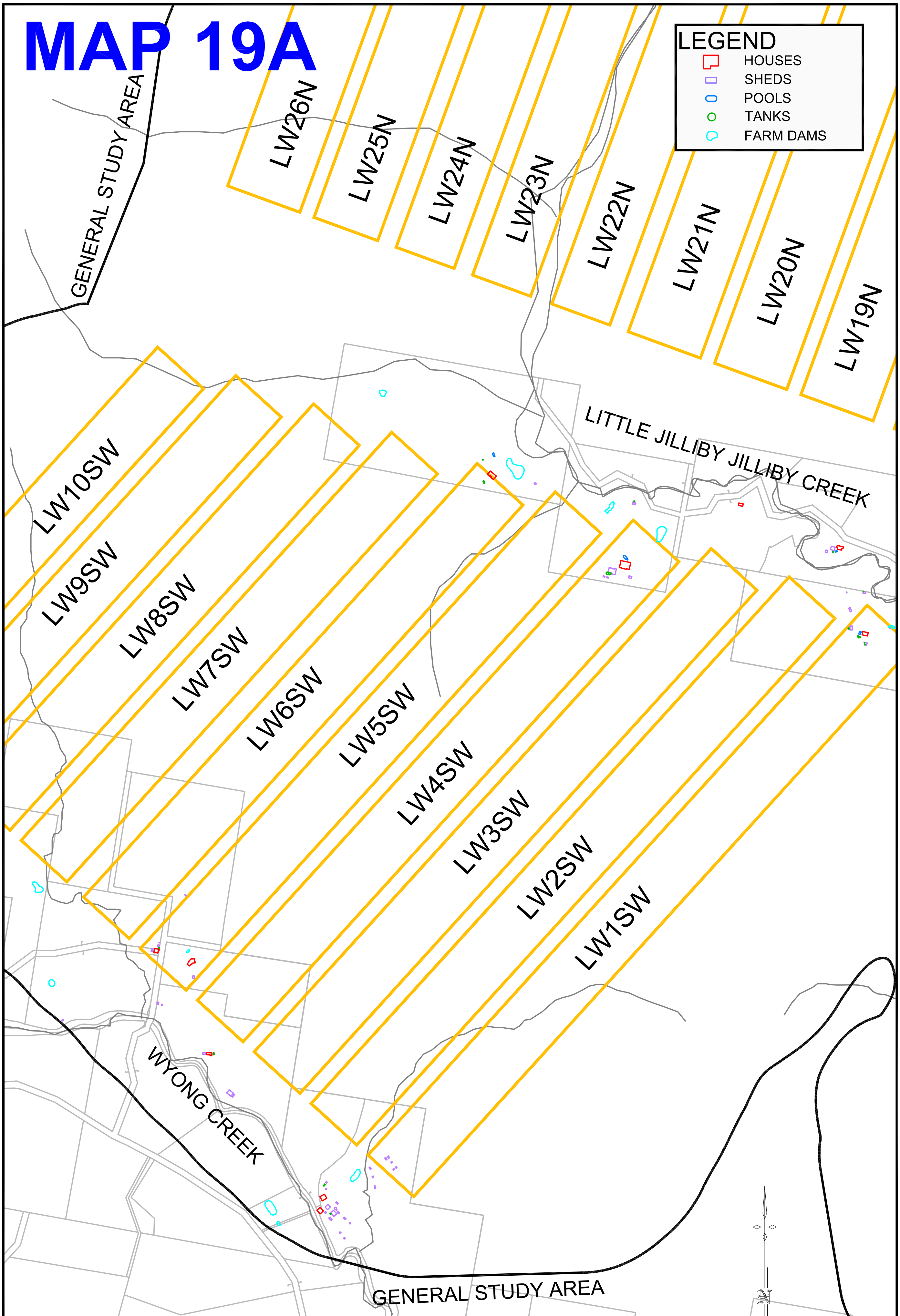


MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

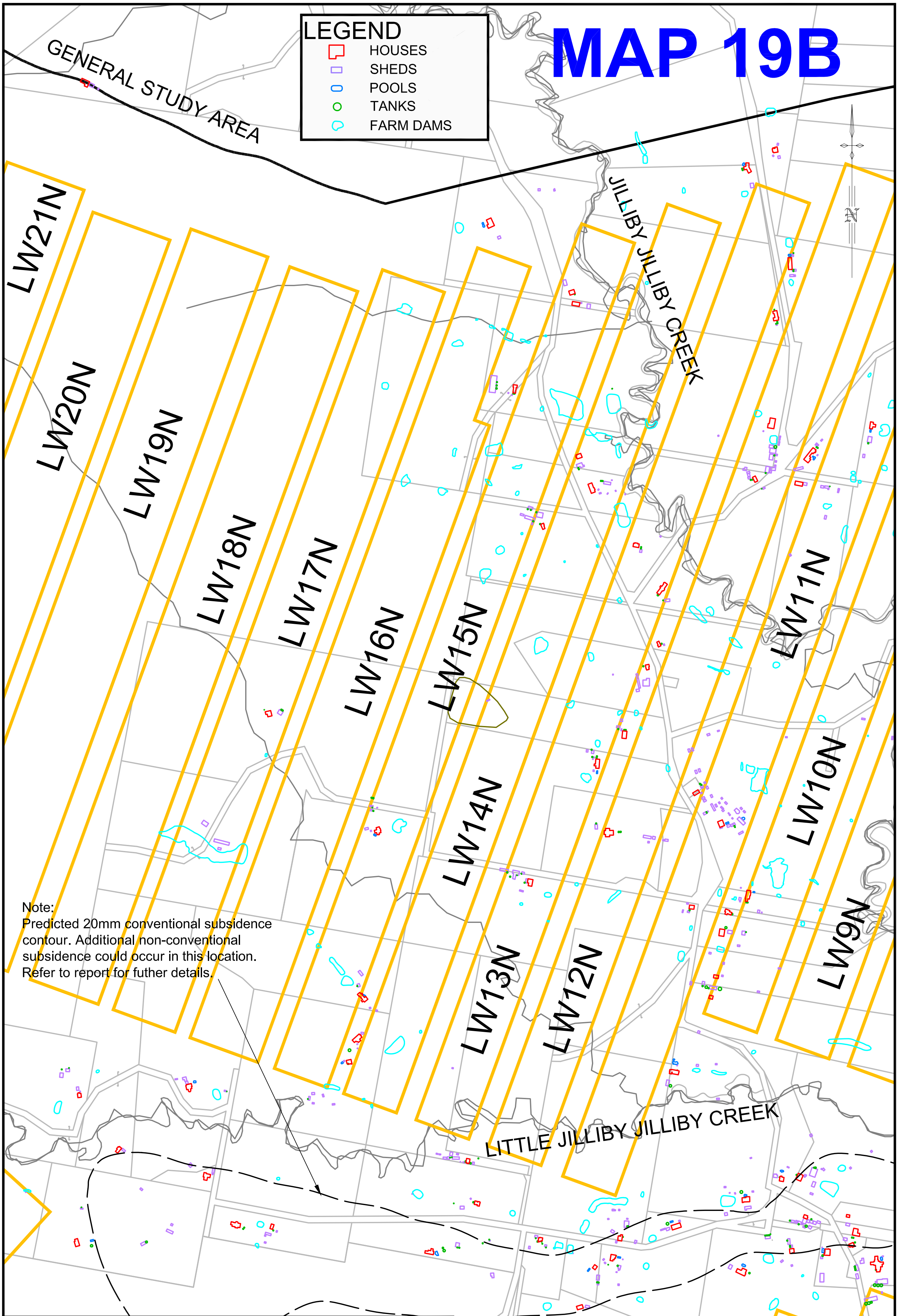
WALLARAH 2 COAL PROJECT
BUILDING STRUCTURES & FARM DAMS
KEYPLAN

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-19	D

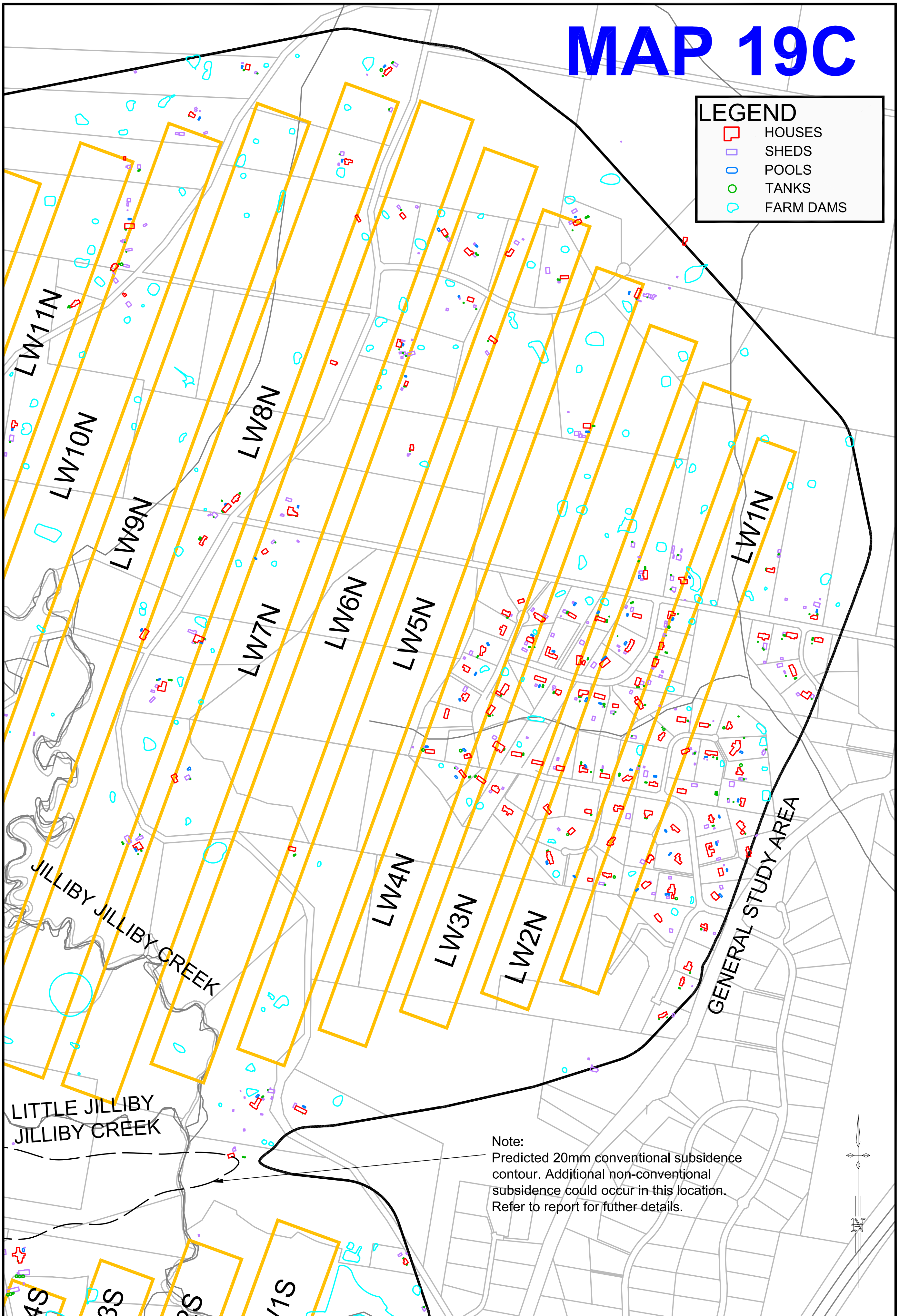
MAP 19A



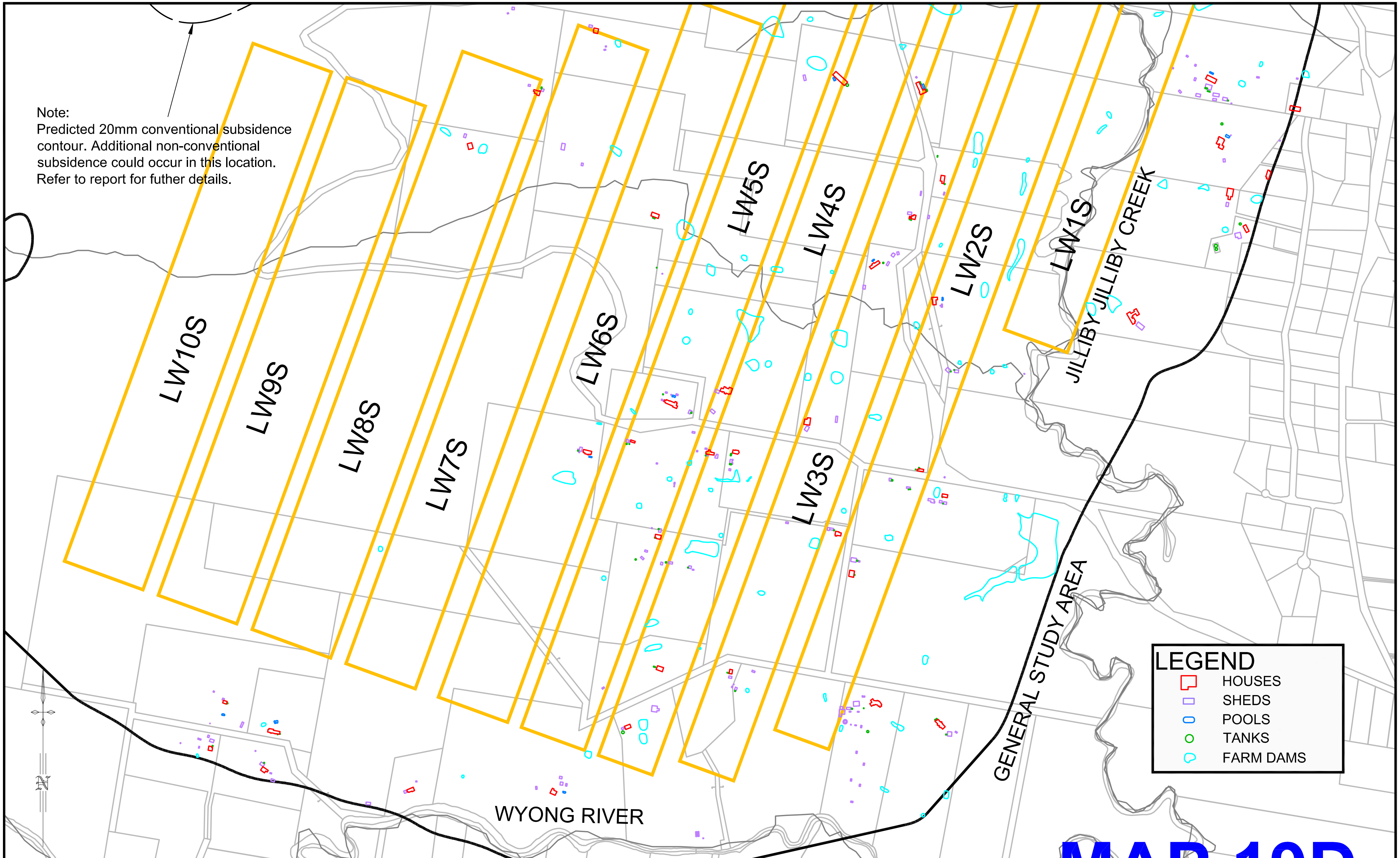
DATE:	SCALE:	DRAWING No:	Rev No:
4-Feb-2010	1:15000	MSEC428-19A	D



DATE:	SCALE:	DRAWING No:	Rev No:
4-Feb-2010	1:15000	MSEC428-19B	D

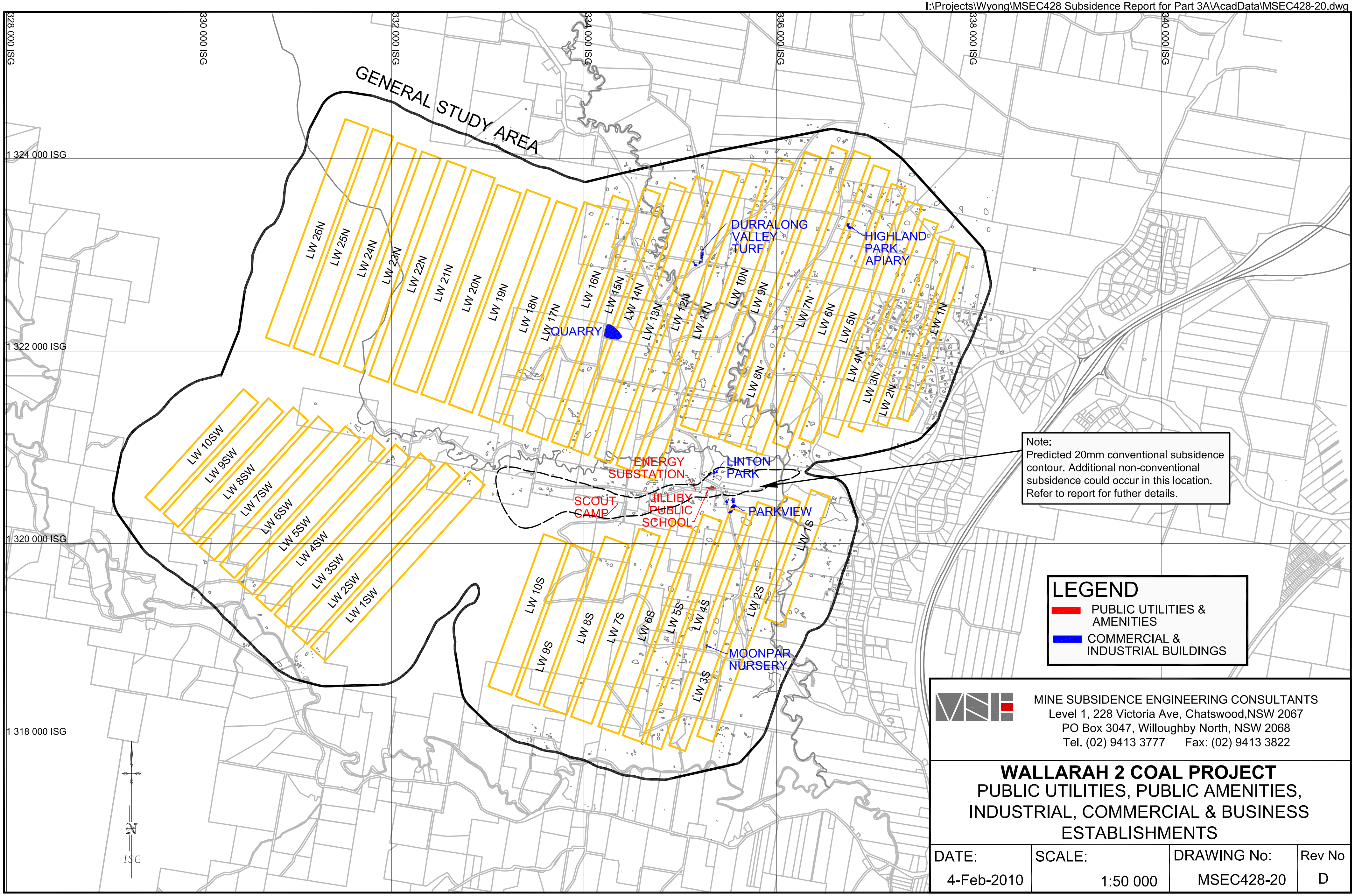


DATE:	SCALE:	DRAWING No:	Rev No:
4-Feb-2010	1:15000	MSEC428-19C	D



DATE:	SCALE:	DRAWING No:	Rev No:
4-Feb-2010	1:15000	MSEC428-19D	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-20.dwg



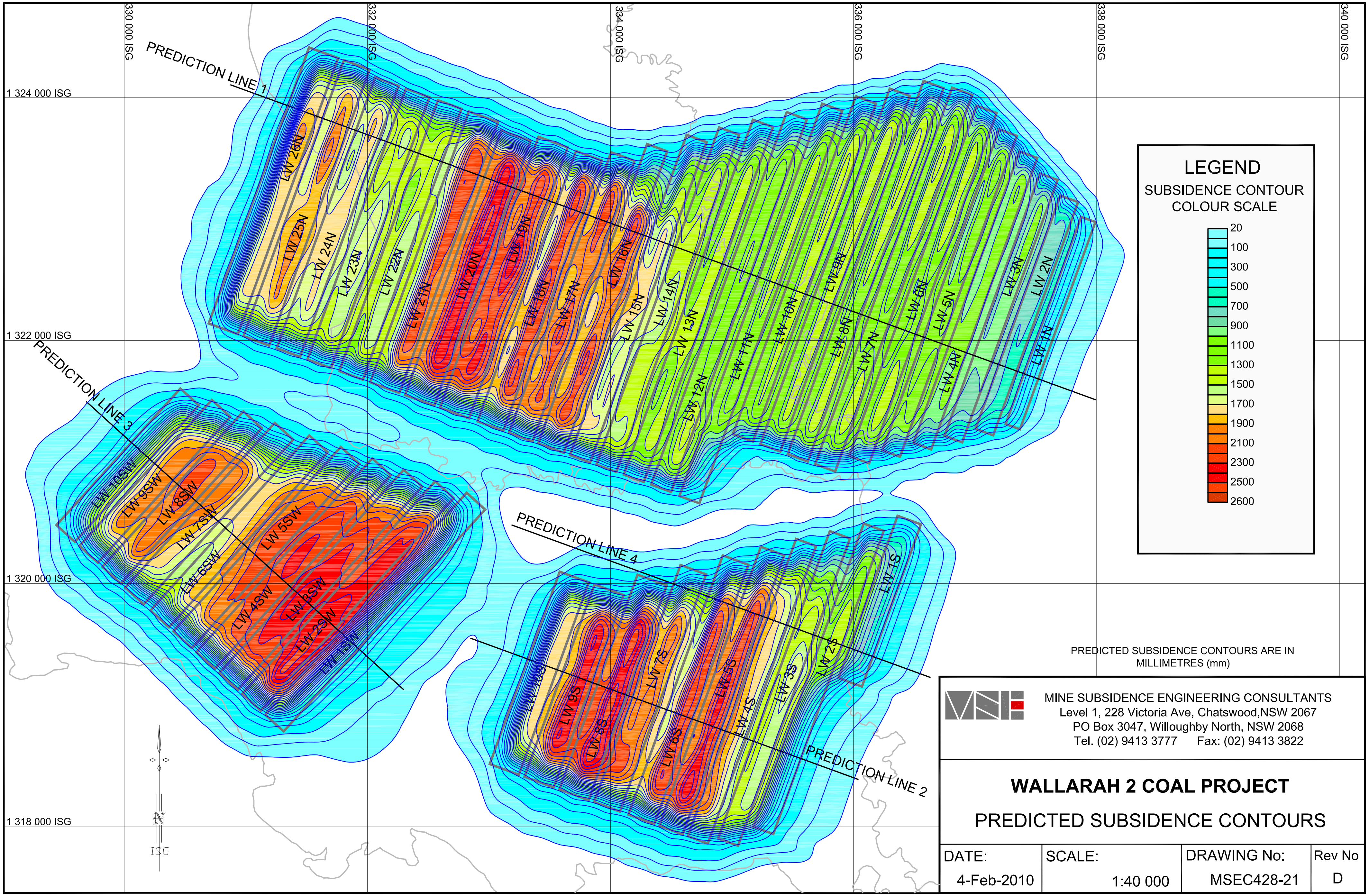
MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

PUBLIC UTILITIES, PUBLIC AMENITIES, INDUSTRIAL, COMMERCIAL & BUSINESS ESTABLISHMENTS

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:50 000	MSEC428-20	D

I:\Projects\Wyong\MSEC428 Subsidence Report for Part 3A\AcadData\MSEC428-21.dwg



MINE SUBSIDENCE ENGINEERING CONSULTANTS
Level 1, 228 Victoria Ave, Chatswood,NSW 2067
PO Box 3047, Willoughby North, NSW 2068
Tel. (02) 9413 3777 Fax: (02) 9413 3822

WALLARAH 2 COAL PROJECT

PREDICTED SUBSIDENCE CONTOURS

DATE:	SCALE:	DRAWING No:	Rev No
4-Feb-2010	1:40 000	MSEC428-21	D