Appendix C

MSEC Area 4 Subsidence Report

mine subsidence ENGINEERING CONSULTANTS

DONALDSONCOAL
Part of the Yancoal Australia Group

ABEL UNDERGROUND MINE:

EP / SMP Area 4 - Proposed Panels 27 to 35

Subsidence Predictions and Impact Assessments for the Natural and Built Features in Support of the EP / SMP Application

DOCUMENT REGISTER

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01	Draft Issue	JB	-	17th Apr 14
A	Final Issue	JB	PD	27th May 14

Report produced to:- Support the EP / SMP Application for the Extraction of Panels 27 to 35 in EP / SMP Area 4.

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)

Donaldson Coal Pty Limited (Donaldson Coal) operates the Abel Underground Mine (ML1618, the mine), which is located in the Newcastle Coalfield of New South Wales. The mine was approved under Part 3A of the *Environmental Planning and Assessment Act 1979* in June 2007 (Project Approval 05-0136). Donaldson Coal is currently extracting coal at the mine using bord and pillar total and partial extraction methods within the Upper Donaldson Seam in SMP Area 3.

Donaldson Coal is proposing to extract Panels 27 to 35 in Area 4 at the mine using bord and pillar total extraction methods within the Upper Donaldson Seam. The layout of the proposed panels is indicated in Drawing Nos. MSEC676-01 and MSEC676-02, in Appendix F.

Mine Subsidence Engineering Consultants (MSEC) has been commissioned by Donaldson Coal to provide subsidence predictions for the proposed extraction of Panels 27 to 35, to identify the natural and built features in the mining area, and to prepare impact assessments and any recommendations for these features. This report has been prepared to support the Extraction Plan (EP) / Subsidence Management Plan (SMP) Application to be submitted to the Department of Trade and Investment, Regional Infrastructure and Services and the Department of Planning and Infrastructure.

The predicted subsidence for the proposed panels has been determined using the Incremental Profile Method, which has been calibrated for local conditions using the monitoring data from the previously extracted bord and pillar total extraction panels in SMP Areas 1 to 3 at the mine. The maximum predicted subsidence is 1,450 mm, which represents 51 % of the maximum extraction height of 2.8 metres, and is the maximum achievable for bord and pillar total extraction in single-seam mining conditions.

The EP / SMP Area has been defined, as a minimum, as the surface area enclosed by a 26.5 degree angle of draw line from the limit of proposed mining and by the predicted 20 mm subsidence contour resulting from the proposed mining. Other features which could be subjected to far-field or valley related movements and could be sensitive to such movements have also been assessed in this report.

A number of natural and built features have been identified within the EP / SMP Area, including the upper reaches of Four Mile Creek, ephemeral tributaries, steep slopes, local roads and drainage culverts, rural building structures, farm dams, 11 kV and low voltage powerlines, copper telecommunications cables, farm dams, fences, principal residences and archaeological sites.

The assessments provided in this report should be read in conjunction with the assessments provided in the reports by other specialist consultants on the project. The main findings from this report are as follows:-

- The Schedule 2 streams are all located more than 1 kilometre outside the extents of the proposed panels and, therefore, are not expected to experience any measurable conventional or valley related movements. It is not anticipated that these streams would experience any adverse impacts.
- Four Mile Creek is a second order ephemeral stream which is located above the southern end of the proposed Panel 27 and above the approved Panel 26. There are also ephemeral tributaries located across the proposed mining area. The streams have shallow incisions into the surface soils, with some sandstone bedrock outcropping in isolated locations.

  No areas of increased ponding have been identified along the section of Four Mile Creek which is located directly above the proposed panel 27. Localised increased ponding areas could occur along the ephemeral tributaries which are located across the mining area, having depths up to approximately 0.5 metres and lengths up to approximately 100 metres.

  Fracturing of the underlying bedrock beneath the upper reaches of Four Mile Creek and the ephemeral tributaries is expected to occur directly above the proposed panels. The fractured zone above the northern ends of the proposed panels could extend from the seam up to the surface and, therefore, it is possible that there could be some loss of the surface water flows into the mine, where the depths of cover are the shallowest.

  It is recommended that the upper reaches of Four Mile Creek and the ephemeral tributaries are visually monitored as the proposed panels are extracted directly beneath them. It is also recommended, that remediation measures are developed to repair the surface cracks, especially where the depths of cover are the shallowest.
- Steep slopes have been identified along the ridgeline which is located above the southern part of the proposed mining area, and in isolated locations along the banks of the streams. The natural surface gradients in these locations typically vary up to around 1 in 2 (i.e. 27º, or 50 %), with some isolated areas having natural gradients up to 1 in 1.5 (i.e. 33º, or 67 %). Surface cracking could develop at the tops and sides of the slopes and compression ridges could possibly form at the bottoms of the slopes as a result of the proposed mining.

It may be necessary for some remediation to be carried out, at the completion of mining, 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.

- Black Hill Road crosses directly above the proposed Panels Panels 27, 28, 30, 31 and 33, with a total length of approximately 1.4 kilometres located directly above the proposed mining area. Meredith Road is located above the proposed Panels 28, 30 and 32 and is also partially located above the historic workings in the Borehole Seam. Browns Road is located above the northern ends of the proposed Panels 32 and 34.

  It is expected that the roads would experience cracking and heaving as the proposed panels are extracted directly beneath them. The cracking observed along the section of Black Hill Road above the currently active Panels 23 and 24 was typically between 25 mm and 50 mm. It is possible that larger cracking could occur in the northern part of the mining area, where the depths of cover are the shallowest. It is expected, however, that the roads could be maintained in safe and serviceable conditions throughout the mining period using normal road maintenance techniques.

  It is recommended that roads are visually monitored as the proposed panels are extracted beneath them, such that any impacts can be identified and remediated accordingly during active subsidence. It is also recommended that a ground monitoring line is established along Black Hill Road, which will assist in the early detection of any irregular or non-conventional ground movements.

- 11 kV and low voltage aerial powerlines supported on timber poles are located across the EP / SMP Area. It is possible, that the powerlines could experience some adverse impacts resulting from the proposed mining. It may be necessary that preventive measures are implemented, which could include the installation of cable rollers, guy wires or additional poles, or the adjustment of cable catenaries.

- Direct buried copper telecommunications cables cross the EP / SMP Area. It is also possible that these copper cables could experience some adverse impacts. Previous mining experience indicates that impacts to these types of cables are relatively infrequent and readily repairable.

- There are 46 rural building structures which have been identified within the EP / SMP Area, of which nine are located directly above the proposed areas of secondary extraction. The rural building structures include sheds, garages and other non-residential building structures.

  It is unlikely that the rural building structures would become unstable or unsafe as a result of the proposed mining, based on the experience of mining at similar depths of cover in the NSW Coalfields. It is possible, that some of the rural building structures could experience minor impacts, however, it would be expected that these could be remediated using normal building maintenance techniques.

- There are 38 farm dams which have been identified within the EP / SMP Area, of which 32 are located partially or fully above the proposed areas of secondary extraction. The farm dams are typically of earthen construction and have been established by localised cut and fill operations within the natural drainage lines.

  It is possible that the storage capacities of some of the farm dams which are located directly above the proposed panels could be reduced. If the storage capacities of any farm dams were adversely affected, they could be re-established by raising the earthen walls, if required.

  It is also likely, that the farm dams which are located directly above the proposed panels could be affected by cracking, heaving or stepping in the bases or dam walls. Any surface cracking or leakages in the farm dams could be identified by visual inspections and remediated by re-instating the bases and walls of the dams with cohesive materials.

  It is recommended that management strategies are developed, as per the Project Approval Statement of Commitments, for the larger farm dams which are located directly above the proposed panels, which could include lowering the stored water levels prior to mining directly beneath them.

  Detailed management strategies and monitoring should be developed for Dam Ref. D02d01, which could include: a geotechnical investigation; installation of a piezometers and/or extensometer; risk assessments for the loss of stored water from the dam wall or loss of water into the mine; the development of a detailed monitoring program; and the development of a Trigger Action Response Plan. The extent of secondary extraction beneath the dam should also be reviewed based on the outcomes of these assessments.

- There are four archaeological sites located within the EP / SMP Area, which comprise three Open Artefact Sites and one Scarred Tree. There is also a cultural place (i.e. area of cultural sensitivity) which is partially located above the southern end of the proposed Panel 32.

  It is unlikely, that the Open Artefact Sites or the Scarred Tree would be adversely impacted by surface cracking. The potential impacts on the cultural place include surface cracking and deformations and changes in surface water drainage.

- The survey control marks within around 3 kilometres of the mining area, could experience small far-field horizontal movements. It will be necessary on the completion of mining, when the ground has stabilised, to re-establish any state survey control marks that are required for future use.
- There are 15 principal residences (i.e. privately owned houses) located within the EP / SMP Area. The Project Approval 05-0136 MOD 3 requires Donaldson Coal to *"limit mining operations to first workings beneath, and ensure mining causes no subsidence requiring mitigation works"* for principal residences. Subsidence control zones have been established around each of the principal residences, based on 26.5 degree angle of draw lines.

  The principal residences are predicted to experience less than 20 mm of vertical subsidence. Whilst these structures could experience some low level subsidence, they would not be expected to experience any significant tilts, curvatures or strains. It is unlikely, therefore, that the principal residences would be adversely impacted, hence, it is not anticipated that the principal residences would require mitigation or remedial works.

  Property (i.e. Built Features) Management Plans will be developed for the properties within the EP / SMP Area, to manage any potential impacts on infrastructure associated with the principal residences.

The assessments provided in this report indicate that the levels of impact on the natural and built features within the EP / SMP Area can be managed by the preparation and implementation of the appropriate management strategies. It should be noted, however, that more detailed assessments of some features have been undertaken by other consultants, and the findings in this report should be read in conjunction with the findings in all other relevant reports.

CONTENTS

Tables

Table numbers are prefixed by the number of the chapter in which they are presented.

Figures

Figure numbers are prefixed by the number of the chapter or the letter of the appendix in which they are presented.

Drawings

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

Drawing No.	*Description*	*Revision*
MSEC676-01	General Layout	A
MSEC676-02	Layout of Panels 27 to 35	A
MSEC676-03	Surface Level Contours	A
MSEC676-04	Upper Donaldson Seam Floor Contours	A
MSEC676-05	Upper Donaldson Seam Thickness Contours	A
MSEC676-06	Upper Donaldson Depth of Cover Contours	A
MSEC676-07	Geological Structures Identified at Seam Level	A
MSEC676-08	Natural Features	A
MSEC676-09	Roads and Tracks	A
MSEC676-10	Electrical Infrastructure	A
MSEC676-11	Telecommunications Infrastructure	A
MSEC676-12	Building Structures and Farm Dams	A
MSEC676-13	Survey Marks, Archaeological and Heritage Sites	A
MSEC676-14	Predicted Total Subsidence Contours due to the Extraction of Panels 23 to 35	A

1.0 INTRODUCTION

1.1. Background

Donaldson Coal Pty Limited (Donaldson Coal) operates the Abel Underground Mine (ML1618, the mine), which is located in the Newcastle Coalfield of New South Wales. The mine was approved under Part 3A of the *Environmental Planning and Assessment Act 1979* in June 2007 (Project Approval 05-0136). Donaldson Coal is currently extracting coal at the mine using bord and pillar total and partial extraction methods within the Upper Donaldson Seam in SMP Area 3.

Donaldson Coal is proposing to extract Panels 27 to 35 in Area 4 at the mine using bord and pillar total extraction methods within the Upper Donaldson Seam. The layout of the proposed panels is indicated in Drawing Nos. MSEC676-01 and MSEC676-02, in Appendix F.

Mine Subsidence Engineering Consultants (MSEC) has been commissioned by Donaldson Coal to:-

- provide subsidence predictions for the proposed extraction of Panels 27 to 35 within the Upper Donaldson Seam,
- identify the natural and built features located above and in the vicinity of the proposed panels,
- provide subsidence predictions for each of these natural and built features,
- provide impact assessments, in conjunction with other specialist consultants, for each of these natural and built features, and
- provide recommendations for any preventive measures and monitoring.

This report has been prepared to support the Extraction Plan (EP) / Subsidence Management Plan (SMP) Application to be submitted to the Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS-DRE) and the Department of Planning and Infrastructure (DoPI).

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

Chapter 2 defines the EP / SMP Area and provides a summary of the natural and built features within this area.

Chapter 3 provides an overview of bord and pillar mining, mine subsidence parameters, and the methods that have been used to predict the mine subsidence for the proposed panels.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of the proposed Panels 27 to 35.

Chapters 5 and 6 provide the predictions and impact assessments for each of the natural and built features which have been identified within the mining Area. Recommendations for each of these features have also been provided, which have been based on the predictions and impact assessments.

1.2. Mining Geometry

The layouts of the proposed Panels 27 to 35 within the Upper Donaldson Seam are shown in Drawing No. MSEC676-02. A summary of the proposed dimensions of these panels is provided in Table 1.1.

Table 1.1 Geometry of the Proposed Panels 27 to 35

Panel	Overall Void Length Including First Workings (m)	Overall Void Width Including First Workings (m)	Solid Barrier Pillar Width (m)
Panel 27	1,110	190	27
Panel 28	1,110	170	26
Panel 29	450	180	-
Panel 30	1,110	170	35
Panel 31	540	170	25
Panel 32	1,050	170 / 230	35
Panel 33	600	170	25
Panel 34	630	170	35
Panel 35	630	170	25

It is noted, that secondary extraction will not be undertaken within the S*ubsidence Control Zones* (SCZs) around each of the principal residences (i.e. houses). The SCZs have been based on 26.5 degree angle of draw lines around the perimeters of the principal residences and are shown in Drawing No. MSEC676-12.

There are historical workings in the Borehole Seam which are partially located above the southern end of Panel 32. The record tracings indicate that the majority of the pillars in this area have been extracted.

1.3. Surface Topography

The surface level contours in the vicinity of the proposed panels are shown in Drawing No. MSEC676-03. The natural surface falls towards the north-east with the tributaries draining into Four Mile Creek above and downstream of the proposed panels.

The surface levels directly above the proposed panels vary from a low point of approximately 50 metres AHD along the tributary above the proposed Panel 29, to a high point of approximately 190 metres AHD above the southern end of the proposed Panel 34. The natural surface gradients above the proposed mining area are typically less than 1 in 3 (i.e. 18º, or 33 %), with natural grades varying up to around 1 in 2 (i.e. 27º, or 50 %) along the ridgeline in the southern part of the mining area.

1.4. Seam Information

The seam floor contours, seam thickness contours and depth of cover contours for the Upper Donaldson Seam are shown in Drawing Nos. MSEC676-04, MSEC676-05 and MSEC676-06, respectively.

The depths of cover directly above the proposed Panels 27 to 35 vary between a minimum of 50 metres above the northern end of the proposed Panel 29, and a maximum of 280 metres above the southern end of the proposed Panel 32.

The seam floor falls from the north-east to the south-west within the proposed mining area. The grade of the seam within the extents of the proposed panels is approximately 7 % (i.e. 1 in 14). The thickness of the Upper Donaldson Seam within the extents of the proposed panels varies between approximately 1.4 metres and 3.5 metres. The maximum extraction height is proposed to be 2.8 metres.

The variations in the surface and seam levels across the mining area are illustrated along Cross-sections 1 and 2 in Fig. 1.1 and Fig. 1.2, respectively. The locations of these sections are shown in Drawing Nos. MSEC676-03 to MSEC676-06.

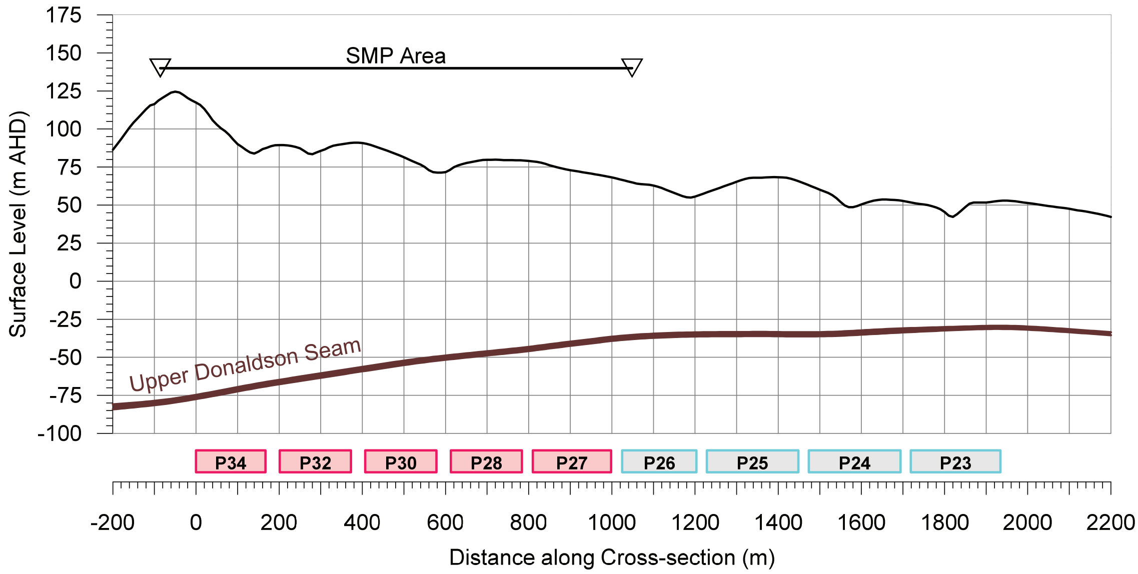

Fig. 1.1 Surface and Seam Levels along Cross-section 1

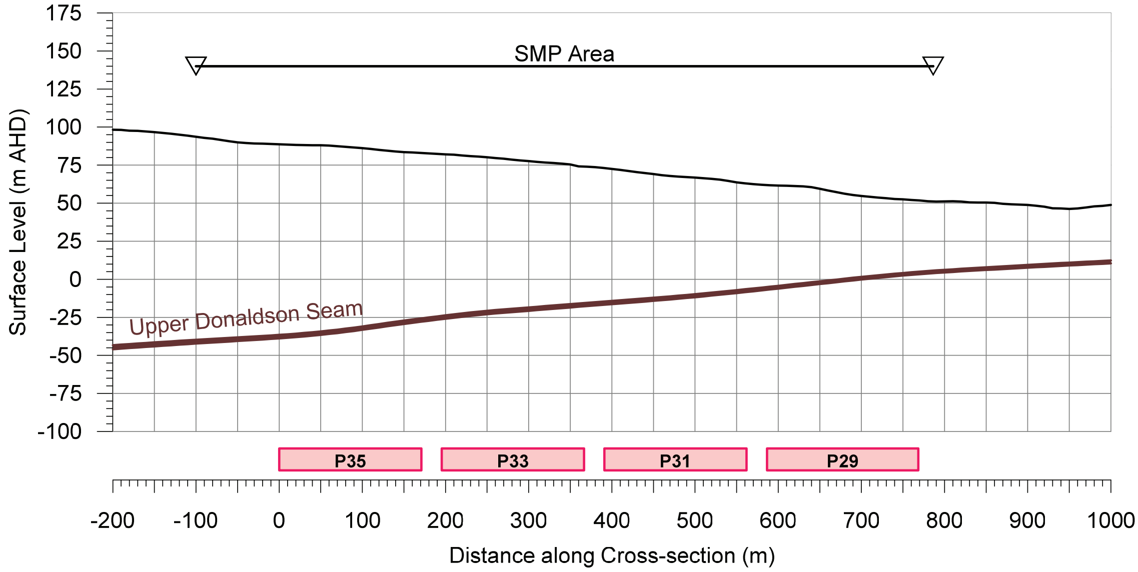

Fig. 1.2 Surface and Seam Levels along Cross-section 2

There are historical workings in the Borehole Seam which are partially located above the southern end of Panel 32. The record tracings indicate that the majority of the pillars in this area have been extracted. The surface and seam levels along Long-section 1, taken through the southern end of Panel 32, are illustrated Fig. 1.3.

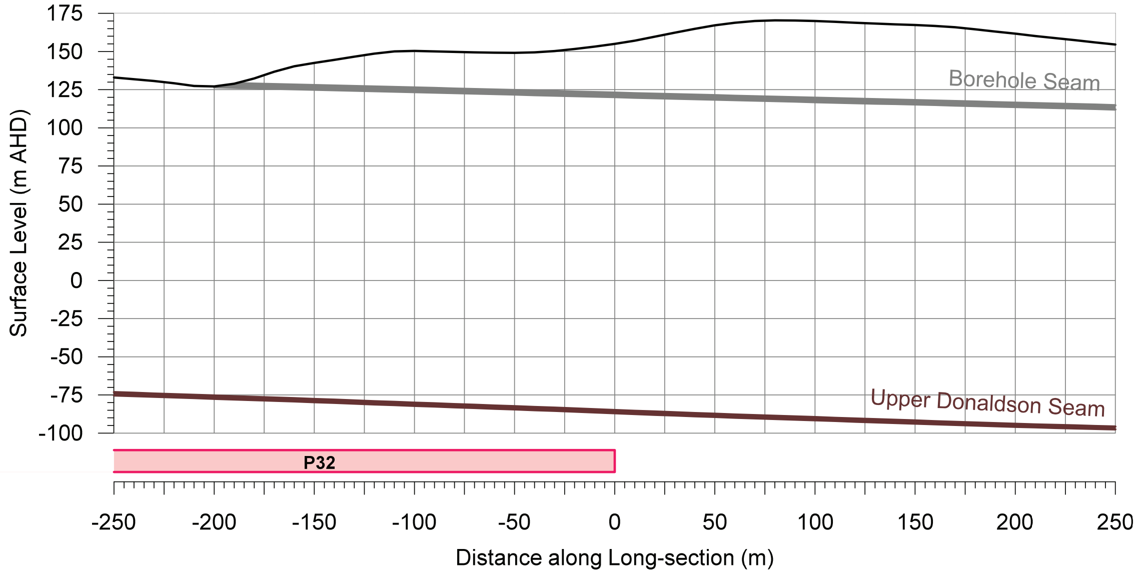

Fig. 1.3 Surface and Seam Levels along Long-section 1

It can be seen in the above figure, that the Borehole Seam outcrops above the proposed Panel 32.

1.5. Geological Details

The Abel Underground Mine lies in the Newcastle Coalfield, within the Northern Sydney Basin. A typical stratigraphic section of the Newcastle Coalfield (after Ives et al, 1999, Moelle and Dean-Jones, 1995, Lohe and Dean-Jones, 1995, Sloan and Allman, 1995) is shown in Table 1.2. The strata shown in this table were laid down between the Early Permian and the Middle Triassic Periods.

Table 1.2 Stratigraphy of the Newcastle Coalfield
(after Ives et al, 1999, Moelle & Dean-Jones, 1995, Lohe & Dean-Jones, 1995, Sloan & Allan, 1995)

Stratigraphy			Lithology
Group	**Formation**	**Coal Seams**	
Narrabeen Group	Clifton		Sandstone, siltstone, mudstone, claystone
Newcastle Coal Measures	Moon Island Beach	Vales Point Wallarah Great Northern	Sandstone, shale, conglomerate, claystone, coal
	Awaba Tuff		Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone, chert
	Boolaroo	Fassifern Upper Pilot Lower Pilot Hartley Hill	Conglomerate, sandstone, shale, claystone, coal
	Warners Bay Tuff		Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone, chert
	Adamstown	Australasian Montrose Wave Hill Fern Valley Victoria Tunnel	Conglomerate, sandstone, shale, claystone, coal
	Nobbys Tuff		Tuff, tuffaceous sandstone, tuffaceous siltstone, claystone chert
	Lambton	Nobbys Dudley Yard Borehole	Sandstone, shale, minor conglomerate, claystone, coal
	Waratah Sandstone		Sandstone
Tomago Coal Measures	Dempsey		Shale, siltstone, fine sandstone, coal, and minor tuffaceous claystone
	Four Mile Creek	**Upper Donaldson** Lower Donaldson	
	Wallis Creek		
Maitland Group	Mulbring Siltstone		Siltstone
	Muree Sandstone		Sandstone
	Braxton		Sandstone, and siltstone
Greta Coal Measures	Paxton	Pelton	Sandstone, conglomerate, and coal
	Kitchener	Greta	
	Kurri Kurri	Homeville	
	Neath Sandstone		Sandstone
Dalwood Group	Farley		Shale, siltstone, lithic sandstone, conglomerate, minor marl and coal, and interbedded basalts, volcanic breccia, and tuffs
	Rutherford		
	Allandale		
	Lochinvar		
Seaham Formation			

The panels are proposed to be extracted in the Upper Donaldson Seam, which is located within the Permian Tomago Coal Measures. The immediate overburden comprises frequently interbedded sandstone, shale, carbonaceous mudstone, tuffaceous claystone and coal. The overlying Waratah Sandstone separates the Tomago Coal and the Newcastle Coal Measures.

The available boreholes indicate that the strata layers are frequently bedded having thickness up to around 10 metres. There were no massive sandstone or conglomerate units identified from this information.

The geological features identified at seam level are shown in Drawing No. MSEC676-07. A north-south oriented dyke crosses the southern part of the proposed Panel 34 and is located immediately to the west of the proposed Panel 32. A second dyke also crosses the southern end of the proposed Panel 32 and immediately to the west of the historic workings in the overlying Borehole Seam.

A series of faults is also located to the east of the northern end of the proposed Panel 27, which have throws up to around 0.6 metres. The proposed panels are supercritical in this location and, therefore, are predicted to achieve the maximum subsidence for single-seam mining conditions. The presence of these faults, therefore, are unlikely to affect the subsidence predictions and, hence, impact assessments provided in this report.

The surface lithology within the mining area is shown in Fig. 1.4, which shows the proposed panels overlaid on a reproduced Geological Series Sheet 9232, which is published by the Department of Mineral Resources (DMR, 1993), now referred to as DTIRIS.

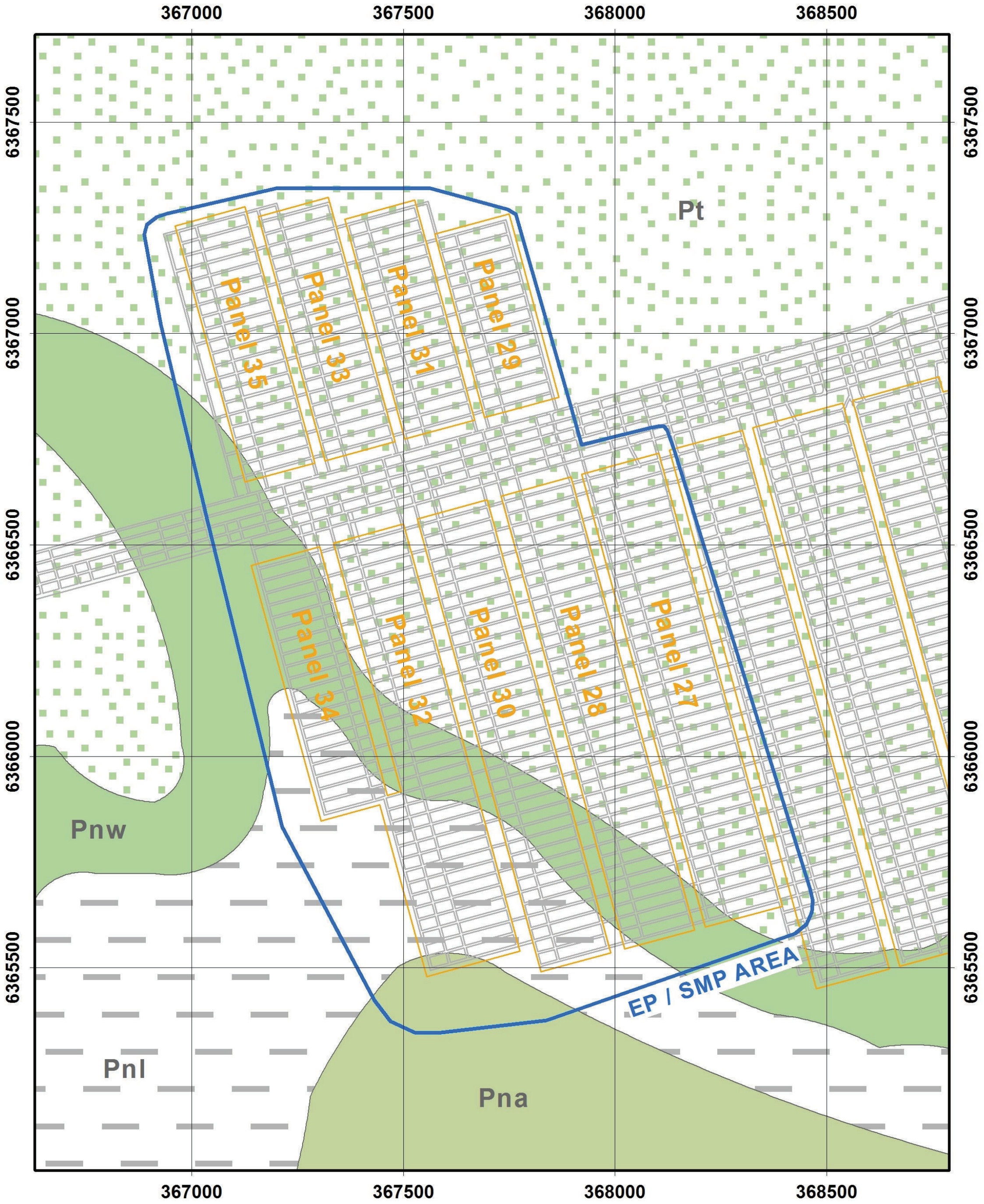

Fig. 1.4 Surface Lithology based on Geological Series Sheet 9232 (DMR, 1993)

It can be seen from this figure, that the surface lithology within the EP / SMP Area is generally derived from the Tomago Coal Measures (Pt), with areas in the south-western part of the mining area derived from the Waratah Sandstone (Pnw), the Lambton Subgroup (Pnl) and the Adamstown Subgroup (Pna) of the Newcastle Coal Measures.

2.1. Definition of the EP / SMP Area

The EP / SMP Area is defined as the surface area that is likely to be affected by the proposed extraction of Panels 27 to 35 within the Upper Donaldson Seam. The extent of the EP / SMP Area has been calculated by combining the areas bounded by the following limits:-

- The 26.5 degree angle of draw line from the extents of the proposed Panels 27 to 35, and
- The predicted limit of vertical subsidence, taken as the 20 mm subsidence contour resulting from the extraction of the proposed panels.

The 26.5 degree angle of draw line is described as the "*surface area defined by the cover depths, angle of draw of 26.5 degrees and the limit of the proposed extraction area in mining leases for all other NSW Coalfields*" (i.e. other than the Southern Coalfield), as stated in Section 6.2 of the Guideline for Applications for Subsidence Management Approvals (DMR, 2003).

The depths of cover contours for the Upper Donaldson Seam are shown in Drawing No. MSEC676-06. It can be seen from this drawing that the depths of cover vary between 50 metres and 280 metres within the extents of the proposed panels. The 26.5 degree angle of draw line, therefore, has been determined by drawing a line that is a horizontal distance varying between 25 metres and 140 metres around the limits of the proposed panels.

The predicted limit of vertical subsidence, taken as the predicted total 20 mm subsidence contour, has been determined using the Incremental Profile Method, which is described in Chapter 3. The predicted total subsidence contours, including the predicted 20 mm subsidence contour line, resulting from the extraction of the proposed Panels 27 to 35 are shown in Drawing No. MSEC676-14.

In all locations, the predicted 20 mm subsidence contour is located within the 26.5 degree angle of draw line. A line has therefore been drawn defining the EP / SMP Area, based upon the 26.5 degree angle of draw line, which is shown in Drawing Nos. MSEC676-01 and MSEC676-02.

There are areas that lie outside the EP / SMP Area that are expected to experience either far-field movements, or valley related movements. The surface features which could be sensitive to such movements have been identified and have been included in the assessments provided in this report.

2.2. Overview of the Natural and Built Features within the EP / SMP Area

A number of the major natural and built features within the EP / SMP Area can be seen in the 1:25,000 Topographic Map of the area, published by the Central Mapping Authority (CMA), numbered 9232. The proposed Panels 27 to 35 and the EP / SMP Area have been overlaid on an extract of this CMA map in Fig. 2.1.

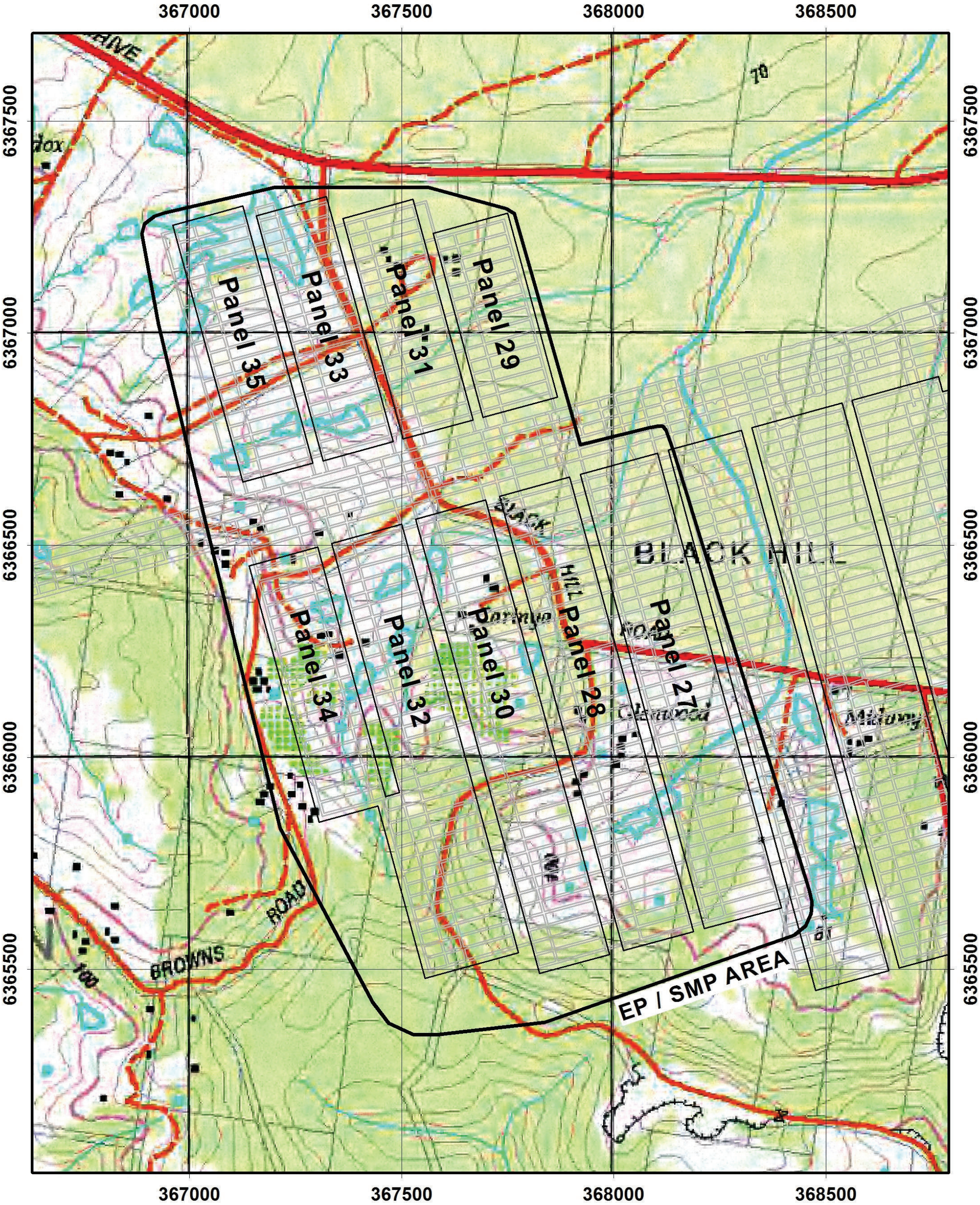

Fig. 2.1 Proposed Panels 27 to 35 Overlaid on CMA Map No. 9232

A summary of the natural and built features which have been identified within the EP / SMP Area is provided in Table 2.1. The locations of these features are shown in Drawing Nos. MSEC676-08 to MSEC676-13. The descriptions, predictions and impact assessments for each of the natural and built features identified are provided in Chapters 5 and 6.

Table 2.1 Natural and Built Features and within the EP / SMP Area

Item	Within EP / SMP Area	Section Number
NATURAL FEATURES		
Catchment Areas or Declared Special Areas	×	
Streams	✓	5.1
Aquifers or Known Groundwater Resources	✓	5.2
Springs or Groundwater Seeps	×	
Sea or Lake	×	
Shorelines	×	
Natural Dams	×	
Cliffs or Rock Outcrops	×	5.3
Steep Slopes	✓	5.4
Escarpments	×	
Land Prone to Flooding or Inundation	✓	5.5
Swamps or Wetlands	×	5.6
Water Related Ecosystems	✓	5.7
Threatened or Protected Species	×	5.8
Lands Defined as Critical Habitat	×	
National Parks or Wilderness Areas	×	
State Forests	×	
State Recreation or Conservation Areas	×	
Natural Vegetation	✓	5.9
Areas of Significant Geological Interest	×	
Any Other Natural Features Considered Significant	×	
PUBLIC UTILITIES		
Railways	×	
Roads (All Types)	✓	6.1 & 6.2
Bridges	×	
Tunnels	×	
Culverts	✓	6.1
Water, Gas or Sewerage Infrastructure	×	
Liquid Fuel Pipelines	×	
Electricity Transmission Lines or Associated Plants	✓	6.3
Telecommunication Lines or Associated Plants	✓	6.4
Water Tanks, Water or Sewage Treatment Works	×	
Dams, Reservoirs or Associated Works	×	
Air Strips	×	
Any Other Public Utilities	×	
PUBLIC AMENITIES		
Hospitals	×	
Places of Worship	×	
Schools	×	
Shopping Centres	×	
Community Centres	×	
Office Buildings	×	
Swimming Pools	×	
Bowling Greens	×	
Ovals or Cricket Grounds	×	
Race Courses	×	
Golf Courses	×	
Tennis Courts	×	
Any Other Public Amenities	×	

Item	Within EP / SMP Area	Section Number
FARM LAND AND FACILITIES		
Agricultural Utilisation or Agricultural Suitability of Farm Land	✓	6.5
Farm Buildings or Sheds	✓	6.6
Tanks	✓	6.7
Gas or Fuel Storages	✓	6.11
Poultry Sheds	×	
Glass Houses	×	
Hydroponic Systems	×	
Irrigation Systems	×	
Fences	✓	6.8
Farm Dams	✓	6.9
Wells or Bores	×	
Any Other Farm Features	×	
INDUSTRIAL, COMMERCIAL AND BUSINESS ESTABLISHMENTS		
Factories	×	
Workshops	×	
Business or Commercial Establishments or Improvements	✓	6.11
Gas or Fuel Storages or Associated Plants	×	
Waste Storages or Associated Plants	×	
Buildings, Equipment or Operations that are Sensitive to Surface Movements	×	
Surface Mining (Open Cut) Voids or Rehabilitated Areas	×	
Mine Related Infrastructure Including Exploration Bores and Gas Wells	×	
Any Other Industrial, Commercial or Business Features	×	
AREAS OF ARCHAEOLOGICAL SIGNIFICANCE	✓	6.12
AREAS OF HISTORICAL SIGNIFICANCE	×	
ITEMS OF ARCHITECTURAL SIGNIFICANCE	×	
PERMANENT SURVEY CONTROL MARKS	✓	6.13
RESIDENTIAL ESTABLISHMENTS		
Principal Residences (i.e. Houses)	✓	6.14
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	✓	6.15
Any Other Residential Features	×	
ANY OTHER ITEM OF SIGNIFICANCE	×	
ANY KNOWN FUTURE DEVELOPMENTS	×	

3.0 OVERVIEW OF BORD AND PILLAR MINING, MINE SUBSIDENCE PARAMETERS AND THE METHODS USED TO PREDICT THE MINE SUBSIDENCE FOR THE PROPOSED PANELS

3.1. Introduction

This chapter provides a brief overview of bord and pillar mining, mine subsidence parameters and the methods that have been used to predict the mine subsidence for the proposed panels. Further details on methods of 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 Bord and Pillar Mining

Donaldson Coal has extracted coal using bord and pillar total and partial extraction methods within the Upper Donaldson Seam in SMP Areas 1, 2 and 3. Panels 27 to 35 in EP / SMP Area 4 are proposed to be extracted using bord and pillar total extraction methods immediately to the west of the currently active panels in SMP Area 3.

The existing panels in Areas 1 and 2 have lengths between 0.3 kilometres and 2 kilometres, overall void widths between 110 metres and 160 metres and are separated by barrier pillars having widths of around 20 metres. The approved panels in SMP Area 3 have lengths between 0.9 kilometres and 1.3 kilometres, overall void widths of 220 metres and are separated by barrier pillars having widths of 25 metres.

The proposed Panels 27 to 35 have lengths between 0.45 kilometres and 1.1 kilometres, overall void widths between 170 metres and 230 metres and are separated by barrier pillars having widths between 25 metres and 35 metres.

Initially grids of roadways are developed off the main headings, using continuous miners, which are referred to as *first workings*. The roadways are nominally 5.5 metres wide and around 2.5 metres high. The panels each comprise three main roadways off the main headings, with a series of cross-roadways, leaving a grid of coal pillars. The coal pillars for the proposed Panels 27 to 35 have widths of 25 metres and lengths between 25 metres and 115 metres.

The development of the roadways typically extracts around 25 % of the available coal. The first workings are self-supporting and, therefore, do not result in any significant subsidence at the surface (i.e. less than 20 mm of subsidence).

The coal pillars are then extracted using the continuous miners and shuttle cars. The panels are mined towards the main headings (i.e. retreat mining). Small remnant pillars (referred to as stooks) are left to support the roof, during the mining operations, and are designed to yield in the long term.

The maximum achievable subsidence in the Newcastle Coalfield, for single-seam super-critical conditions, is generally 55 % to 60 % of the effective extracted thickness. The bord and pillar extraction methods typically mine around 85 % of the available coal (including the coal extracted as part of the *first workings*) and, therefore, the maximum achievable subsidence is typically 47 % to 51 %, for single-seam conditions.

Higher levels of subsidence could occur at the southern end of the proposed Panel 32, where it is partially located beneath the historic workings in the Borehole Seam. Further discussions on the predicted levels of subsidence for multi-seam conditions are provided in Section 3.7.

In some locations, such as beneath the *subsidence control zones*, the coal pillars will not be extracted (i.e. first workings only). These coal pillars are designed to be stable, in the long term and, therefore, the subsidence in these locations will be less than the maximum achievable.

3.3. Overview of Conventional Subsidence Parameters

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

- **Subsidence** usually refers to vertical displacement of a point, but subsidence of the ground actually includes both vertical and horizontal displacements. These horizontal displacements in some cases, where the subsidence is small beyond the panel goaf edges, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.

- **Tilt** is the change in the slope of the ground as a result of differential subsidence, and is calculated as the change in subsidence between two points divided by the distance between those points. Tilt is, therefore, the first derivative of the subsidence profile. Tilt is usually expressed in units of *millimetres per metre (mm/m)*. A tilt of 1 mm/m is equivalent to a change in grade of 0.1 %, 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 values 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 movements 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. Strain is typically expressed in units of *millimetres per metre (mm/m)*. **Tensile Strains** occur where the distances between two points increases and **Compressive Strains** occur when the distances between two points decreases. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

  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.

- **Horizontal shear deformation** across monitoring lines can be described by various parameters including horizontal tilt, horizontal curvature, mid-ordinate deviation, angular distortion and shear index. It is not possible, however, to determine the horizontal shear strain across a monitoring line using 2D or 3D monitoring techniques. 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), and vice versa.

A cross-section through a typical single extraction panel, for a horizontal seam in level terrain, showing typical profiles of conventional subsidence, tilt, curvature and strain is provided in Fig. 3.1.

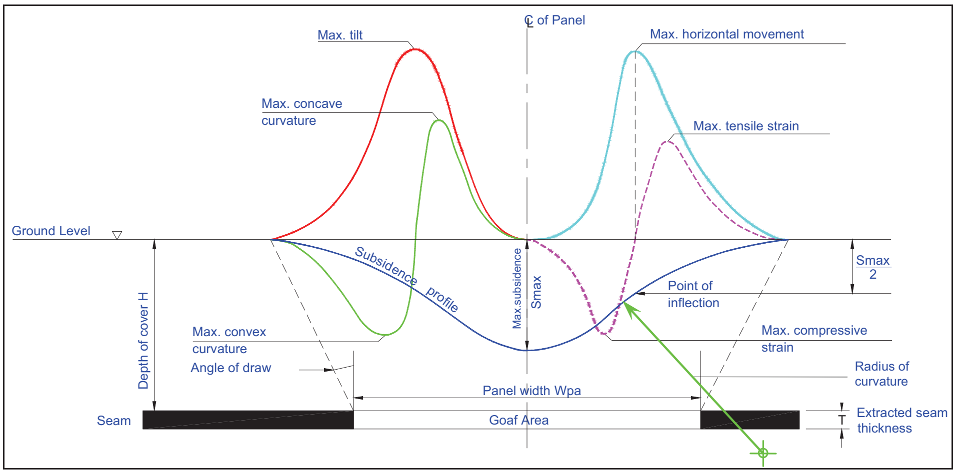

Fig. 3.1 Typical Profiles of Conventional Subsidence Parameters for a Single Extraction Panel

The **incremental** subsidence, tilts, curvatures and strains are the additional parameters which result from the extraction of each panel. The **total** subsidence, tilts, curvatures and strains are the accumulated parameters which result from the extraction of a series of panels. The **travelling** tilts, curvatures and strains are the transient movements as mining occurs directly beneath a given point.

3.4. Far-field Movements

The measured horizontal movements at survey marks which are located beyond the panel goaf edges and over solid unmined coal areas are often much greater than the observed vertical movements at those marks. An empirical database of observed horizontal movements has been developed which confirms this.

The strata mechanisms that are believed to have caused the horizontal movements to be higher than the vertical movements, at locations beyond the panel edges and over solid unmined coal, are associated with the redistribution of the in situ horizontal compressive stresses in the strata around the panels. Before mining these in situ stresses, which are generally compressive in all directions, are in a state of equilibrium or balance. When mining occurs, this 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 redistributed.

Far-field horizontal movements have been observed at considerable distances from extracted panels. Such movements are predictable and occur whenever significant excavations occur at the surface or underground. When large horizontal movements are measured outside the goaf area, they are likely to be the result of a combination of mechanisms, including far-field and valley related movements, in addition to the conventional mine subsidence 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 or built features, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

In some cases, higher levels of far-field horizontal movements have been 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 panels or near other previously extracted series of panels. In these cases, the levels of observed subsidence can be slightly higher than normally predicted, but these increased movements are generally accompanied by very low levels of tilt and strain.

Far-field horizontal movements and the method used to predict such movements are described further in Section 4.5 of this report.

3.5. Overview of Non-Conventional Subsidence Movements

Conventional subsidence profiles are typically smooth in shape and can be explained by the expected caving mechanisms associated with overlying strata spanning the extracted void. Normal conventional subsidence movements due to mining are easy to identify where panels 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 higher, such as the case in the southern part of the mining area, the observed subsidence profiles would be expected to be generally smooth. Where the depth of cover is less than 100 metres, such as the case in the northern part of the mining area, the observed subsidence profiles are expected to be more irregular. Very irregular subsidence movements are observed with much higher tilts, curvatures and strains at very shallow depths of cover where the collapsed zone above the extracted panel extends up to or near to the surface.

Irregular subsidence movements are occasionally observed in single-seam mining conditions at the higher depths of cover along an otherwise smooth subsidence profile. The cause of these irregular subsidence movements can be associated with:-

- sudden or abrupt changes in geological conditions,
- steep topography, and
- valley related movements.

Non-conventional movements due to shallow depths of cover, changes in geological conditions, steep topography and valley related movements are discussed in the following sections.

3.5.1. Non-Conventional Subsidence Movements due to Shallow Depth of Cover

Irregular ground movements are commonly observed in shallow mining situations, where the collapsed zone, which develops above the extracted panels, extends near to the surface. This type of irregularity is generally only seen where panel widths are super-critical and where the depths of cover are less than 100 metres, such as the case in the northern part of the mining area. These irregular movements appear as localised bumps and steps in the observed subsidence profiles, which are accompanied by elevated tilts, curvatures and ground strains.

The levels of irregular subsidence movement at varying depths of cover can be seen in the observed subsidence profiles over the previously extracted Whybrow Seam longwalls at South Bulga Colliery, which are shown in Fig. 3.2.

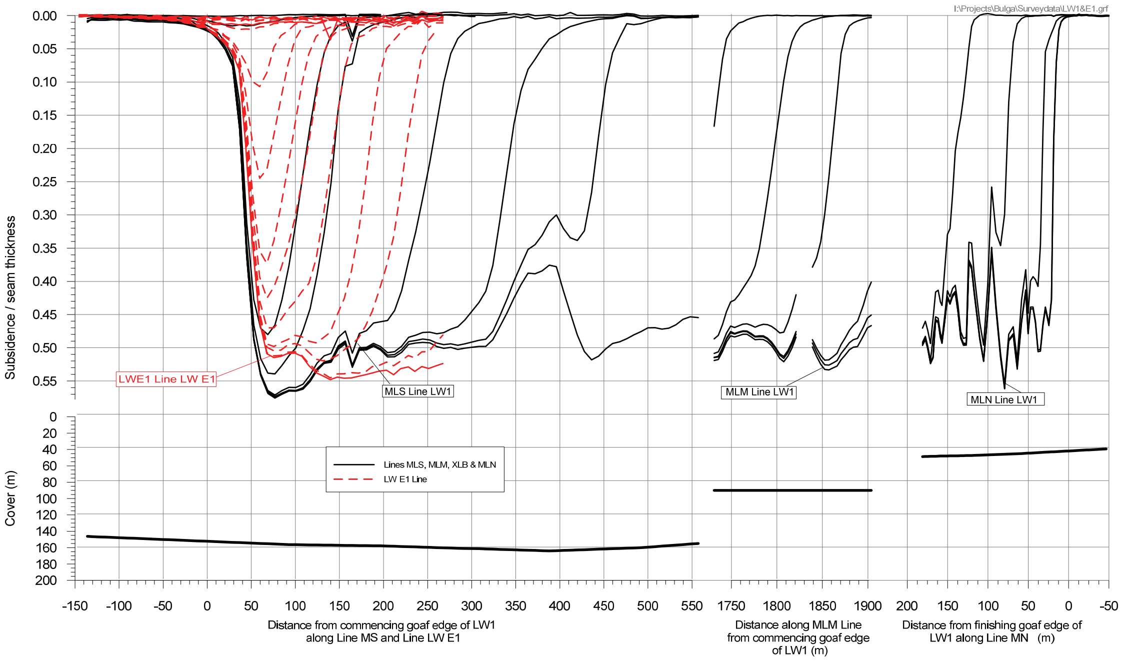

Fig. 3.2 Observed Subsidence Profiles at South Bulga Colliery

The observed subsidence profiles along the MLS and LWE1 monitoring lines above the southern ends of Whybrow Seam Longwalls 1 and E1, respectively, having average depths of cover of 160 metres, are shown in the left of this figure. The observed subsidence profile along the MLM monitoring line above the northern end of Longwall 1, having an average depth of cover of 90 metres, is shown near the middle of the figure. The observed subsidence profile along the MLN monitoring line above the northern end of Longwall 1, having an average depth of cover of 45 metres, is shown in the right of this figure.

The observed subsidence profiles are relatively smooth (i.e. normal or conventional) along the MLS and LWE1 monitoring lines, where the depths of cover are much greater than 100 metres. The observed subsidence profile is still relatively smooth along the MLM monitoring line, where the depth of cover is just less than 100 metres. The observed subsidence profile along the MLN line is very irregular (i.e. irregular or non-conventional), where the depth of cover is less than 50 metres.

3.5.2. Non-conventional Subsidence Movements due to 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, curvatures and ground strains. Buckling of near surface bedrock 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 by any of the above possible causes.

It is not possible to predict the locations and magnitudes of non-conventional anomalous movements. In some cases, approximate predictions for the non-conventional ground movements can be made where the underlying geological or topographic conditions are known in advance. It is expected that these methods will improve as further knowledge is gained through ongoing research and investigation.

In this report, non-conventional ground movements are being included statistically in the predictions and impact assessments, by basing these on the frequency of past occurrence of both the conventional and non-conventional ground movements and impacts. The analysis of strains provided in Section 4.3 includes those resulting from both conventional and non-conventional anomalous movements. The impact assessments for the natural and built features, which are provided in Chapters 5 and 6, include historical impacts resulting from previous mining which have occurred as the result of both conventional and non-conventional subsidence movements.

3.5.3. Non-conventional Subsidence Movements due to Steep Topography

Non-conventional movements can also result from down slope movements where panels are extracted beneath steep slopes. In these cases, elevated tensile strains develop near the tops and along the sides of the steep slopes and elevated compressive strains develop near the bases of the steep slopes. The potential impacts resulting from down slope movements include tension cracks at the tops and along the sides of the steep slopes and compression ridges at the bottoms of the steep slopes.

Further discussions on the potential for down slope movements for the steep slopes within the EP / SMP Area are provided in Section 5.4 in this report.

3.5.4. Valley Related Movements

The watercourses within the EP / SMP Area may be subjected to valley related movements, which are commonly observed along stream alignments in the Southern Coalfield, but less commonly observed in the Newcastle and Hunter Coalfields. The reason why valley related movements are less commonly observed in the northern coalfields could be that the conventional subsidence movements are typically much larger than those observed in the Southern Coalfield and, therefore, these movements tend to mask any smaller valley related movements which may occur.

Valley bulging movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.3. The potential for these natural movements are influenced by the geomorphology of the valley.

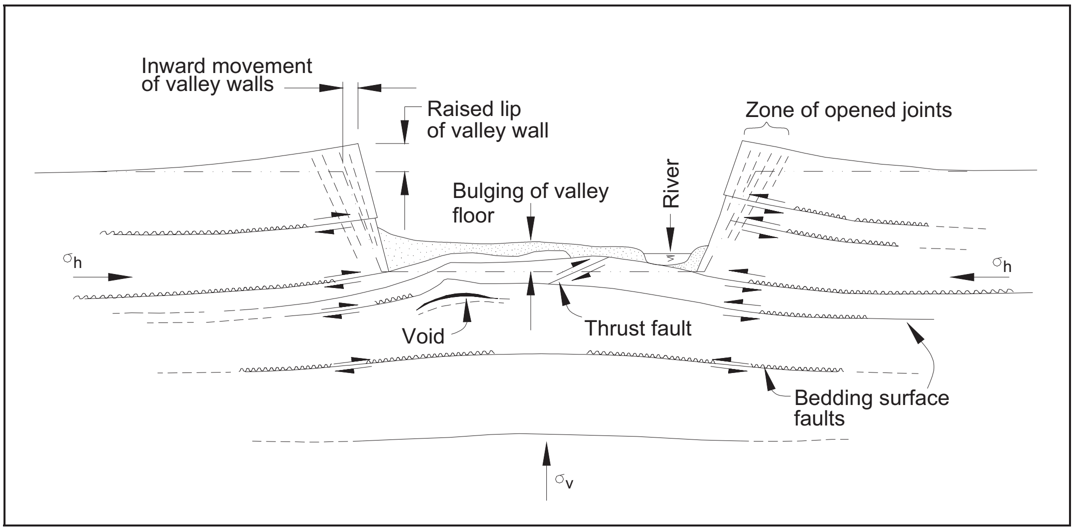

Fig. 3.3 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

Valley related movements can also be caused by or accelerated by mine subsidence as the result of a number of factors, including the redistribution of horizontal in situ stresses and down slope movements. Mining induced valley related movements are normally described by the following parameters:-

- **Upsidence** is the reduced subsidence within a valley which results from the dilation or buckling of near surface strata at or near the base of the valley. The term uplift is used for the cases where the ground level is raised above the pre-mining level, i.e. when the upsidence is greater than the subsidence. 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.
- **Compressive Strains** occur within the bases of valleys as a result of valley closure and upsidence movements. **Tensile Strains** also occur in the sides and near the tops of the valleys as a 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.

The predicted valley related movements resulting from the extraction of the proposed longwalls were made using the empirical method outlined in Australian Coal Association Research Program (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*.

3.6. The Incremental Profile Method

The Incremental Profile Method (IPM) was initially developed by Waddington Kay and Associates, now known as MSEC, as part of a study in 1994 to assess the potential impacts of subsidence on surface infrastructure. The method has been continually refined using the extensive monitoring data which has been gathered from the Southern, Newcastle, Hunter and Western Coalfields of New South Wales and from the Bowen Basin in Queensland.

The empirical database comprises monitoring data from numerous collieries including: Abel, Angus Place, Appin, Awaba, Baal Bone, Bellambi, Beltana, Blakefield South, Bulga, Bulli, Burwood, Carborough Downs, Chain Valley, Clarence, Coalcliff, Cook, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Eastern Main, Ellalong, Elouera, Fernbrook, Glennies Creek, Grasstree, Gretley, Invincible, John Darling, Kemira, Kestrel, Lambton, Liddell, Mandalong, Metropolitan, Moranbah North, Mt. Kembla, Munmorah, Nardell, Newpac, Newstan, Newvale, Newvale 2, NRE Wongawilli, Oaky Creek, Ravensworth, South Bulga, South Bulli, Springvale, Stockton Borehole, Tasman, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend, and Wyee.

A detailed review of the monitoring data showed that, whilst the final subsidence profiles measured over a series of panels are irregular, the observed incremental subsidence profiles due to the extraction of individual panels are consistent in both magnitude and shape and vary according to local geology, depth of cover, panel width, seam thickness, the extent of adjacent previous mining, the widths and stabilities of the pillars and a time-related subsidence component.

MSEC has developed standard subsidence prediction curves for the Southern, Newcastle and Hunter Coalfields of New South Wales using the empirical database. The predictions curves can then be further refined, for the local geology and local conditions, based on the available monitoring data from the area. Discussions on the calibration of the Incremental Profile Method for the proposed Panels 27 to 35 at the Abel Underground Mine are provided in Section 3.7.

The prediction of subsidence is a three stage process where, first, the magnitude of each increment is calculated, then, the shape of each incremental profile is determined and, finally, the total subsidence profile is derived by adding the incremental profiles from each panel in the series. In this way, subsidence predictions can be made anywhere above or outside the extracted panels, based on the local surface and seam information.

For panels in the Newcastle and Hunter Coalfields, the maximum predicted incremental subsidence is initially determined, using the IPM subsidence prediction curves for a single isolated panel, based on the void width (W) and the depth of cover (H). The incremental subsidence is then increased, using the IPM subsidence prediction curves for multiple panels, based on the panel series, panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (W_{pi}/H). In this way, the influence of the panel width (W), depth of cover (H), as well as panel width-to-depth ratio (W/H) and pillar width-to-depth ratio (W_{pi}/H) are each taken into account.

The shapes of the incremental subsidence profiles are then determined using the large empirical database of observed incremental subsidence profiles. The profile shapes are derived from the normalised subsidence profiles for monitoring lines where the mining geometry and overburden geology are similar to that for the proposed panels. The profile shapes can be further refined, based on local monitoring data, which is discussed further in Section 3.7.

Finally, the total subsidence profiles resulting from the series of panels are derived by adding the predicted incremental profiles from each of the panels. Comparisons of the predicted total subsidence profiles, obtained using the Incremental Profile Method, with observed profiles indicates that the method provides reasonable, if not, slightly conservative predictions where the mining geometry and overburden geology are within the range of the empirical database. The method can also be further tailored to local conditions where observed monitoring data is available close to the mining area.

3.7. Calibration of the Incremental Profile Method

The available boreholes indicate that the strata layers within the mining area are frequently bedded having thickness up to around 10 metres. There were no massive sandstone or conglomerate units identified from the available information and, therefore, the standard Incremental Profile Method for the Newcastle Coalfield was used for the subsidence predictions.

There are historic workings in the Borehole Seam located partially above the southern end of the proposed Panel 32 (i.e. multi-seam mining conditions). Elsewhere, above the majority of the proposed mining area, there are no historic workings above the proposed panels (i.e. single-seam mining conditions). The following sections provide discussions on the calibration of the Incremental Profile Method for single-seam and multi-seam mining conditions.

Single-seam mining conditions

The Incremental Profile Method was refined for local single-seam mining conditions using the available ground monitoring data from the existing bord and pillar mining operations at the mine. Donaldson Coal is using bord and pillar total extraction methods, where the majority of the coal pillars are extracted, leaving only small remnant pillars (i.e. stooks) to support the roof during mining.

The maximum achievable subsidence in the Newcastle Coalfield, for single-seam super-critical conditions, is generally 55 % to 60 % of the effective extracted thickness. The total extraction mining method can extract around 85 % of the available coal (including the coal extracted as part of the first workings) and, therefore, the maximum achievable subsidence for this type of mining is typically around 47 % to 51 %, for single-seam mining conditions.

The locations of the available ground monitoring lines for the previous mining at the Abel Underground Mine are shown in Drawing No. MSEC676-01. The monitoring lines located above Panels 1 to 6 in SMP Area 1 and above Panels 23 and 24 in SMP Area 3 in the Upper Donaldson Seam have been used to refine the Incremental Profile Method for local single-seam mining conditions.

The comparisons between the observed and the back-predicted subsidence, tilt and curvature for Centreline and Crossline monitoring lines above Panels 1 to 6 in SMP Area 1 are shown in Figs. C.01 to C.12, in Appendix C. Panel 1 has an overall void width of 110 metres at a depth of cover around 100 metres and, therefore, the width-to-depth ratio is around 1.1 (i.e. critical in width). Panels 2 to 6 have overall void widths of 160 metres at depths of cover between 50 metres and 100 meters and, therefore, the width-to-depth ratios vary between 1.6 and 3.2 (i.e. supercritical in width).

It can be seen from these figures, that the maximum observed subsidence along these monitoring lines were less than the maximum predicted. The maximum observed subsidence of approximately 1,300 mm represents around 46 % of the maximum extraction height of 2.8 metres. The maximum predicted subsidence, based on supercritical mining conditions, is 51 % of the extraction height.

The profiles of observed subsidence reasonably match those predicted. In some cases, the observed subsidence exceeds those predicted just inside the panel edges, however, in these cases the steepness of the observed profiles (i.e. tilt) were less than those predicted.

The magnitudes of the maximum observed tilts and curvatures along the monitoring lines were also reasonably similar to or less than those predicted. In some cases, there were small lateral shifts between the observed and predicted maxima, however, the offsets were generally less than 30 metres.

In most cases, the profiles of observed tilts and curvatures reasonably match those predicted. There were some localised irregularities in the observed profiles (i.e. non-conventional movements) which are expected at these very shallow depths of cover. It is then noted, that the Incremental Profile Method provides predictions of conventional movements and that non-conventional movements are assessed using the statistical analysis of strain, which is discussed in Section 4.3.

The comparisons between the observed and the back-predicted subsidence, tilt and curvature along Black Hill Road and along the centrelines of Panels 23 and 24 in SMP Area 3 are shown in Figs. C.13 to C.15, in Appendix C. Panels 23 and 24 have overall void widths of 220 metres at depths of cover between 110 metres and 160 metres along the monitoring lines and, therefore, the width-to-depth ratios are between 1.4 and 2.0 (i.e. supercritical in width).

It can be seen from these figures, that the maximum observed subsidence along these monitoring lines were less than the maximum predicted. The maximum observed subsidence of approximately 1,000 mm represents around 38 % of the seam thickness of 2.6 metres. The maximum predicted subsidence, based on supercritical mining conditions, is 51 % of the extraction height.

The magnitudes of the maximum observed subsidence are less than what would normally be expected for single-seam supercritical mining conditions. Whilst, the prediction model could be calibrated to reduce the magnitudes of the predicted subsidence, it was considered appropriate to maintain the current levels of conservatism, since the observed subsidence were much closer to those predicted in SMP Area 1.

The profiles of observed subsidence reasonably match those predicted inside of panel edges, i.e. on the steep parts of the subsidence profiles away from the maximum observed subsidence. In some cases, there are lateral shifts between the observed and predicted profiles, which could be the result of surface dip, seam dip, or variations in the overburden geology.

In most cases, the profiles of observed tilts and curvatures reasonably match those predicted. There were some localised irregularities in the observed profiles (i.e. non-conventional movements) which are expected at these very shallow depths of cover. It is then noted, that the Incremental Profile Method provides predictions of conventional movements and that non-conventional movements are assessed using the statistical analysis of strain, which is discussed in Section 4.3.

Based on these comparisons along the selected monitoring lines at the Abel Underground Mine, it would appear that the standard Incremental Profile Method provides reasonable predictions of conventional subsidence, tilt and curvature. It has not been considered necessary, therefore, to provide any site specific calibration of the standard IPM subsidence prediction curves for the proposed extraction of Panels 27 to 35 within the Upper Donaldson Seam for single-seam mining conditions.

Multi-seam mining conditions

The southern end of the proposed Panel 32 will be partially extracted beneath the historic workings in the Borehole Seam. The record tracings indicate that the majority of the pillars in this area have been extracted.

Monitoring data from multi-seam mining operations in the NSW Coalfields and overseas show that the maximum subsidence, as proportions of the extracted seam heights, are greater than those for equivalent single-seam mining cases. The monitoring data from the multi-seam cases also show that the shapes of the subsidence profiles are affected by the locations and stabilities of the overlying goafs and pillars in the previously extracted seam as the panels in the lower seam pass underneath.

The overall void width of the proposed Panel 32 is 230 metres. The depth of cover to the Upper Donaldson Seam at the southern end of this panel varies between 220 metres and 260 metres and, therefore, the width-to-depth ratio varies between 0.9 and 1.1. The Interburden thickness between the Upper Donaldson Seam and the Borehole Seam in this location is around 200 metres.

The available multi-seam monitoring data from the NSW Coalfields was reviewed in the subsidence report which supported the Abel Modification Application (MSEC, 2012a). The empirical multi-seam data is illustrated in Fig. 3.4, below, which shows the maximum observed subsidence, as a proportion of the extracted seam thickness, versus the panel width-to-depth ratio. The multi-seam cases for mining beneath bord and pillar workings are shown as the red diamonds and the cases for mining beneath longwalls are shown as the blue diamonds. Single-seam mining cases are also shown in this figure, for comparison, as the light grey diamonds.

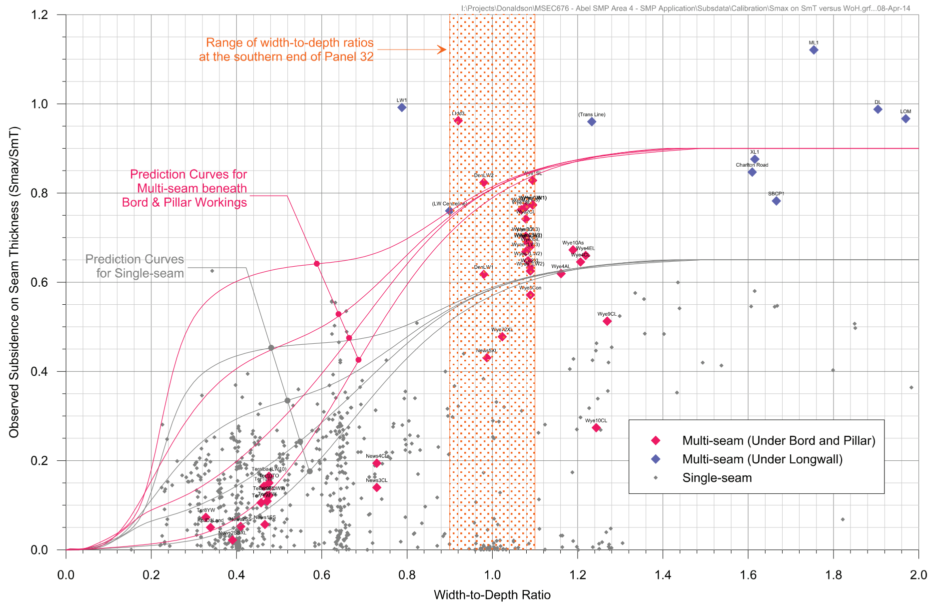

Fig. 3.4 Maximum Observed Subsidence versus Panel Width-to-Depth Ratio for Historical Multi-seam Mining Cases

It can be seen from the above figure, that the maximum observed subsidence, as a proportion of the extracted seam thickness, for multi-seam cases are greater than those for single-seam cases having similar width-to-depth ratios.

The typical prediction curves used for single-seam mining conditions are shown as the grey lines, in the above Fig. 3.4, for various mine geometries. These prediction curves have been scaled up, so as to achieve a maximum predicted incremental subsidence of 90 % of extracted seam thickness, which are shown as the red curves in this figure. It can be seen, that these prediction curves provide reasonable estimates of the maximum subsidence for the multi-seam cases for mining beneath bord and pillar workings (i.e. red diamonds).

The multi-seam prediction curves provide subsidence around 40 % greater than those obtained using the standard single-seam prediction curves. In reality, the additional subsidence, due to multi-seam mining conditions, will be dependent on a number of factors, including the interburden thickness, the extraction heights in both seams and the conditions of the remnant pillars in the overlying seam.

It is considered, that the multi-seam prediction curves, illustrated in Fig. 3.4 as the red curves, should provide conservative predictions for the multi-seam mining conditions above the southern end of Panel 32, since the interburden thickness of 200 metres is greater than those for the case studies and since the majority of the pillars in the historic workings have been extracted.

The predicted additional subsidence above the southern end of the proposed Panel 32, due to the effects of the historic workings in the overlying Borehole Seam, is 100 mm. The predicted subsidence contours and the impact assessments for the natural and built features in this location include the additional subsidence due to the multi-seam conditions.

3.8. Reliability of the Predicted Conventional Subsidence Parameters

The Incremental Profile Method is based upon a large database of observed subsidence movements in the NSW and Queensland Coalfields and has been found, in most cases, to give reasonable, if not, slightly conservative predictions of maximum subsidence, tilt and curvature. The predicted profiles obtained using this method also reflect the way in which each parameter varies over the mined area and indicate the movements that are likely to occur at any point on the surface.

The prediction of the conventional subsidence parameters at a specific point is more difficult. Variations between predicted and observed parameters at a point can occur where there is a lateral shift between the predicted and observed subsidence profiles, which can result from seam dip or variations in topography. In these situations, the lateral shift can result in the observed parameters being greater than those predicted in some locations, whilst the observed parameters being less than those predicted in other locations.

The prediction of strain at a point is even more difficult as there tends to be a large scatter in observed strain profiles. It has been found that measured strains can vary considerably from those predicted at a point, not only in magnitude, but also in sign, that is, the tensile strains have been observed where compressive strains were predicted, and vice versa. The following reasons contribute to why strain predictions cannot be provided with the same degree of confidence as subsidence and tilt predictions:-

- 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 the surface strata layers are thinly bedded or if localised cross bedding exists within the top strata layer, then shearing can occur at relatively low values of stress. These variations in the local geology can result in fluctuations in the local strains, which can range from tensile to compressive. In the tensile zones around mined voids, existing joints can be opened up at relatively low strain values 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 conventional 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 existing natural joints open up or new cracks develop in the tensile phase, it may be difficult for these joints to close up during the compressive phase, if the joints fill with soil or if shearing occurs during the movements. In these cases, the ground can appear to be in tension when, in reality, it is actually in compression.
- Sometimes, survey limitations or errors can also affect the measured strain values and these can result from movement in the benchmarks, inaccurate instrument readings, or disturbed survey pegs. In these circumstances it is not surprising that the predicted conventional strain at a point does not match the measured strain.
- In sandstone dominated environments, much of the earlier tensile ground movements can be concentrated at existing natural joints. These concentrations of strain at these pre-existing joints results in higher strain values being observed at the natural joints accompanied by lower values between the joints.
- Current conventional horizontal movement prediction methods are principally based on factors being applied to the predicted ground curvature movements and do not account for the release of in situ horizontal stress, the far-field movement mechanisms or valley related movements.
- It is also recognised that the ground movements above a panel can be affected by the gradient of the coal seam, the direction of mining and the presence of faults and dykes above the panel, which can result in a lateral shift in the subsidence profile.

It is also likely that some localised irregularities will occur in the subsidence profiles due to near surface geological features. The irregular movements are accompanied by elevated tilts, curvatures and strains, which often exceed the conventional predictions. In most cases, it is not possible to predict the locations or magnitudes of these irregular movements. For this reason, the strain predictions provided in this report are based on a statistic analysis of measured strains at the mine, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.3. Further discussions on irregular movements are provided in Section 4.6.

The Incremental Profile Method approach allows site specific predictions for each natural and built feature and, hence, provides a more realistic assessment of the subsidence impacts than by applying the maximum predicted parameters at every point, which would be overly conservative and would yield an excessively overstated assessment of the potential subsidence impacts.

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of the proposed Panels 27 to 35 in the Upper Donaldson Seam. The predicted subsidence parameters and the impact assessments for the natural and built features are provided in Chapters 5 and 6.

The predicted subsidence, tilt and curvature have been obtained using the standard Incremental Profile Method for the Newcastle Coalfield, as described in Sections 3.6 and 3.7. The predicted strains have been determined by analysing the strains measured during the previous extraction of the bord and pillar total extraction panels in SMP Areas 1, 2 and 3 at the mine.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report describe and 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 Chapters 5 and 6.

4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

The locations of the proposed Panels 27 to 35 in the Upper Donaldson Seam are shown in Drawing No. MSEC676-02. A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of each of the proposed panels, is provided in Table 4.1.

Table 4.1 Maximum Predicted Incremental Conventional Subsidence, Tilt and Curvature Resulting from the Extraction of Each of the Proposed Panels

Panel	Maximum Predicted Incremental Conventional Subsidence (mm)	Maximum Predicted Incremental Conventional Tilt (mm/m)	Maximum Predicted Incremental Conventional Hogging Curvature (km^{-1})	Maximum Predicted Incremental Conventional Sagging Curvature (km^{-1})
Due to Panel 27	1,400	70	> 3.0	> 3.0
Due to Panel 28	1,350	50	> 3.0	> 3.0
Due to Panel 29	1,050	40	> 3.0	> 3.0
Due to Panel 30	1,400	40	3.0	3.0
Due to Panel 31	1,200	40	> 3.0	> 3.0
Due to Panel 32	1,350*	35*	1.5*	1.5*
Due to Panel 33	1,300	60	> 3.0	> 3.0
Due to Panel 34	750	10	0.5	0.5
Due to Panel 35	1,350	60	> 3.0	> 3.0

Note: * denotes that locally increased subsidence could occur above the southern end of Panel 32 where it is located beneath the historic workings in the Borehole Seam. The predicted parameters in this location, however, are less than the maxima provided in the above table due to the higher depths of cover. The maximum predicted parameters above the southern end of Panel 32, for multi-seam conditions, are 800 mm subsidence, 15 mm/m tilt and 0.5 km^{-1} hogging and sagging curvature. The calibration of the prediction method for multi-seam conditions is discussed in Section 3.7.

The predicted total conventional subsidence contours, resulting from the extraction of the proposed Panels 27 to 35, are shown in Drawing No. MSEC676-14. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, after the extraction of each of series of proposed panels, is provided in Table 4.2.

Table 4.2 **Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of Each Series of the Proposed Panels**

Panel Series	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})
Panels 27, 28, 30, 32 and 34	1,450	70	> 3.0	> 3.0
Panels 29, 31, 33 and 35	1,450	70	> 3.0	> 3.0

The maximum predicted total subsidence after the completion of the proposed panels, is 1,450 mm, which represents around 51 % of the maximum extraction height of 2.8 metres. The maximum predicted total conventional tilt is 70 mm/m (i.e. 7 %), which represents a change in grade of 1 in 14. The maximum predicted total conventional hogging and sagging curvatures are both greater than 3.0 km^{-1}, which represents a minimum radius of curvature of less than 0.3 kilometres.

The predicted conventional subsidence parameters vary across the EP / SMP Area as the result of, amongst other factors, variations in the depths of cover and extraction heights. To illustrate this variation, the predicted profiles of conventional subsidence, tilt and curvature have been determined along Prediction Lines 1 and 2, the locations of which are shown in Drawing No. MSEC676-14.

The predicted profiles of conventional subsidence, tilt and curvature along Prediction Lines 1 and 2, resulting from the extraction of the proposed panels, are shown in Figs. E.01 and E.02, respectively, in Appendix E. The predicted total profiles along the alignment of these prediction lines, after the extraction of each of the proposed panels, are shown as solid blue lines. The predicted total profiles after the completion of the approved Panels 23 to 26 are shown as the solid cyan lines.

4.3. Predicted Strains

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is 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 pre-existing natural joints at bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

It has been found that applying a constant factor to the predicted maximum curvatures provides a reasonable prediction for the normal or conventional strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones.

In the Newcastle Coalfield, it has been found that a factor of 10 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains. The maximum predicted conventional strains resulting from the extraction of the proposed Panels 27 to 35, based on applying a factor of 10 to the maximum predicted conventional curvatures, are greater than 30 mm/m tensile and compressive. It is noted, that these maxima occur in the north-eastern corner of the mining area, where the minimum depth of cover is the shallowest and, elsewhere, the predicted conventional strains are less.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature. In this report, therefore, we have provided a statistical approach to account for the variability, instead of just providing a single predicted conventional strain.

The range of potential strains above the proposed Panels 27 to 35 has been determined using the monitoring data from the previously extracted bord and pillar total extraction panels in SMP Areas 1 to 3 at the mine. The data used in the analysis of observed strains 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.

The width-to-depth ratios of the proposed Panels 27 to 35 vary between 0.8 (at a maximum depth of cover of 280 metres) and 3.6 (at a minimum depth of cover of 50 metres). The ground strains will vary considerably across the mining area, with the greatest strains occurring in the locations of shallowest depths of cover and lower strains occurring in the locations of higher depths of cover.

Donaldson Coal has previously extracted bord and pillar total extraction panels in SMP Areas 1, 2 and 3 at the Abel Underground Mine. Comparisons of the overall void widths, depths of cover, width-to-depth ratios and extraction heights for the proposed Panels 27 to 35 with the previously extracted panels in SMP Areas 1, 2 and 3 are provided in Table 4.3.

Table 4.3 Comparison of the Mine Geometry for the Proposed Panels 27 to 35 with the Previously Extracted Panels in SMP Areas 1, 2 and 3 at the Mine

Parameter	Proposed Panels 27 to 35		Existing Panels in SMP Areas 1, 2 and 3	
	Range	Average	Range	Average
Width	170 ~ 230	175	120 ~ 220	160
Depth of Cover	50 ~ 280	125	50 ~ 140	80
Overall W/H Ratio	0.8 ~ 3.6	1.4	1.2 ~ 3.2	2.0
Extraction Height	1.4 ~ 2.8	2.5	2.2 ~ 2.8	2.6

It can be seen from the above table, that the range of width-to-depth ratios for the proposed Panels 27 to 35 is similar to, but, wider than the range of width-to-depth ratios for the existing panels in SMP Areas 1, 2 and 3. The average width-to-depth ratio for the proposed panels of 1.4, however, is less than that for the existing panels of 2.0. Also, the extraction heights for the proposed Panels 27 to 35 are similar to, but, slightly less than those for the existing panels in SMP Areas 1, 2 and 3.

The strain analysis using the monitoring data from the existing panels in SMP Areas 1, 2 and 3 should, therefore, provide a reasonable indication of the range of potential strains for the proposed Panels 27 to 35 where the width-to-depth ratio is around 2.0, i.e. around an average depth of cover of 90 metres. Higher strains are expected to occur above the proposed panels where the width-to-depth ratios are greater than 2.0 and, conversely, lesser strains are expected to occur where the width-to-depth ratios are less than 2.0.

The locations of the available ground monitoring lines for the previous mining at the Abel Underground Mine are shown in Drawing No. MSEC676-01. The strain analysis utilised the Centreline and Crossline monitoring lines above Panels 1 to 6 in SMP Areas 1 and 2 and the Black Hill Road monitoring line in SMP Area 3.

The frequency distribution of the maximum observed tensile and compressive strains measured in survey bays located directly above the previously extracted panels in SMP Areas 1, 2 and 3 is provided in Fig. 4.1. The probability distribution functions, based on the fitted Generalised Pareto Distributions (GPDs), are also shown in this figure.

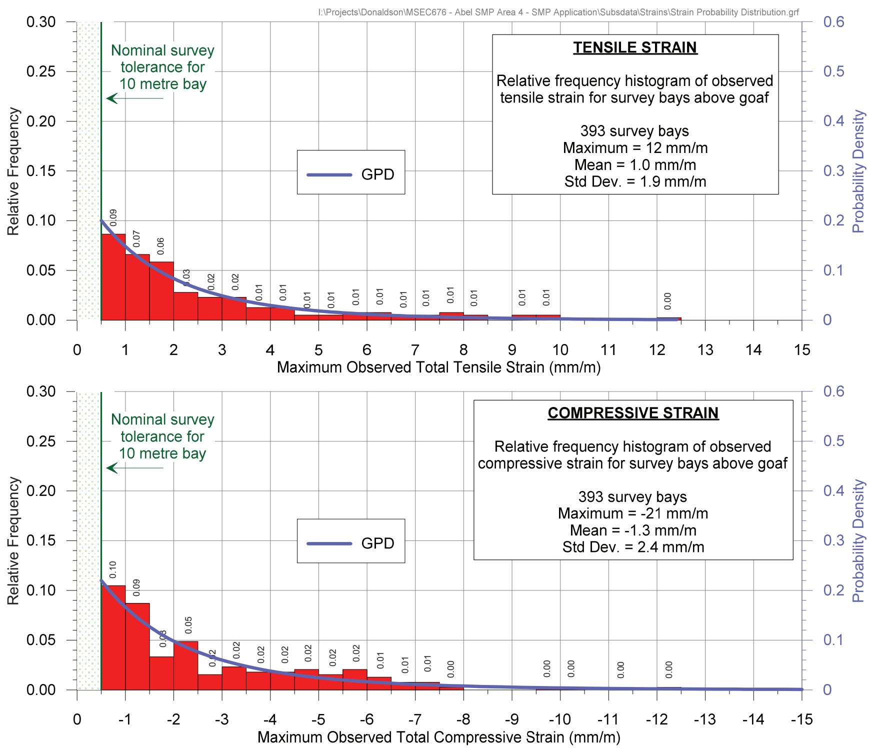

Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains for Previously Extracted Panels in SMP Areas 1, 2 and 3 at the Abel Underground Mine

Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a panel extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

The 95 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining were 5 mm/m tensile and 6 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays experienced at any time during mining were 9 mm/m tensile and 11 mm/m compressive.

4.4. Predicted Conventional Horizontal Movements

The predicted conventional horizontal movements over the proposed panels 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 maximum conventional strains from the maximum curvatures, and this has been found to give a reasonable correlation with measured data. 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 EP / SMP Area is 70 mm/m, which occurs at the northern ends of the mining area. The maximum predicted conventional horizontal movement is, therefore, approximately 700 mm, i.e. 70 mm/m multiplied by a factor of 10.

Horizontal movements do not directly impact on natural and built features, rather impacts occur as the result of differential horizontal movements. Strain is the rate of change of horizontal movement. The impacts of ground strain on the natural and built features are addressed in the impact assessments for each feature in Chapters 5 and 6.

4.5. Predicted Far-field Horizontal Movements

In addition to the conventional subsidence movements that have been predicted above and adjacent to the proposed panels, and the predicted valley related movements along the creeks, it is also likely that far-field horizontal movements will be experienced during the proposed mining.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data from the NSW Coalfields, but predominantly from the Southern Coalfield. The far-field horizontal movements resulting from mining were generally observed to be orientated towards the extracted panels. At very low levels of far-field horizontal movements, however, there was a high scatter in the orientation of the observed movements.

The observed incremental far-field horizontal movements, resulting from the extraction of a single panel, is provided in Fig. 4.2. The confidence levels, based on fitted GPDs, have also been shown in this figure to illustrate the spread of the data.

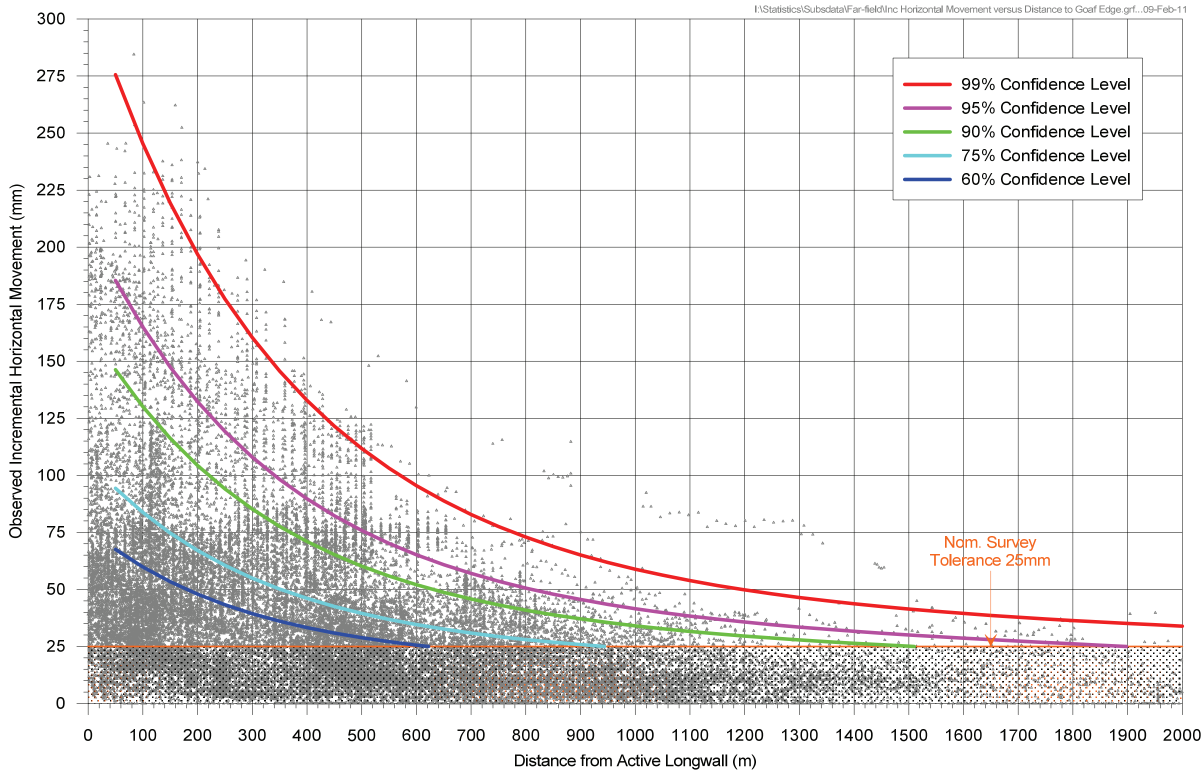

Fig. 4.2 Observed Incremental Far-Field Horizontal Movements

As successive panels within a series 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 within the strata have been redistributed around the collapsed zones above the first few extracted panels, 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 panels.

The predicted far-field horizontal movements resulting from the extraction of the proposed panels are very small and could only be detected by ground 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 in the order of survey tolerance. The impacts of far-field horizontal movements on the natural and built features in the vicinity of the proposed panels are not expected to be significant.

4.6. Non-Conventional Ground Movements

It is likely non-conventional ground movements will occur within the EP / SMP Area, due to near surface geological conditions and, to lesser extents, steep topography and valley related movements, which were discussed in Section 3.5. These non-conventional movements are often accompanied by elevated tilts, curvatures and strains which are likely to exceed the conventional predictions.

In most cases, it is not possible to predict the exact locations or magnitudes of the non-conventional anomalous movements due to near surface geological conditions. For this reason, the strain predictions provided in this report are based on a statistic analysis of measured strains at the mine, which is discussed in Section 4.3.

Specific predictions of upsidence, closure and compressive strain due to the valley related movements are provided for the streams in Section 5.1. The impact assessments for the streams are based on both the conventional and valley related movements. The potential for non-conventional movements associated with steep topography is discussed in the impact assessments for the steep slopes provided in Section 5.4.

4.7. General Discussion on Mining Induced Ground Deformations

Bord and pillar total extraction mining can result in surface cracking, heaving, buckling, humping and stepping at the surface. The extent and severity of these mining induced ground deformations are dependent on a number of factors, including the mine geometry, depth of cover, overburden geology, locations of natural jointing in the bedrock and the presence of near surface geological structures.

Fractures and joints in bedrock occur naturally during the formation of the strata and from subsequent erosion and weathering processes. Bord and pillar total extracted mining can result in additional fracturing in the bedrock, which tends to occur in the tensile zones, but fractures can also occur due to buckling of the surface beds in the compressive zones. The incidence of visible cracking at the surface is dependent on the pre-existing jointing patterns in the bedrock as well as the thickness and inherent plasticity of the soils that overlie the bedrock.

The incidence of surface cracking is dependent on the location relative to the extracted panel edges, the depth of cover, the extracted seam thickness and the thickness and inherent plasticity of the soils that overlie the bedrock. The widths and frequencies of the cracks are also dependent upon the pre-existing jointing patterns in the bedrock. Large joint spacing can lead to concentrations of strain and possibly the development of fissures at rockhead, which are not necessarily coincident with the joints.

The surface cracks will generally be parallel to the longitudinal edges of the panels. It is also likely that some cracking would occur across the panels as the subsidence trough develops. This cracking tends to be transient, since the tensile phase which causes the cracks to open up, is generally followed by a compressive phase that partially closes them. In some cases, however, the transient cracks do not fully close up or they form compression heaving.

As subsidence occurs, surface cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the extents of the extracted panel perimeters. Most of the cracks will occur within a distance of approximately 0.1 times the depth of cover from the perimeters. At shallow depths of cover, such as the case in the northern part of the proposed mining area, surface cracking and heaving can potentially occur in any location above the extracted panels. The larger and more permanent cracks, however, are usually located in the final tensile zones around the perimeters of the panels. Open fractures and heaving, however, can also occur due to the buckling of surface beds that are subject to compressive strains.

The size and extent of surface cracking in the northern part of the proposed mining area are expected to be similar to those observed above the previously extracted panels in SMP Areas 1 and 2. The range of surface crack widths measures above these panels is illustrated in Fig. 4.3.

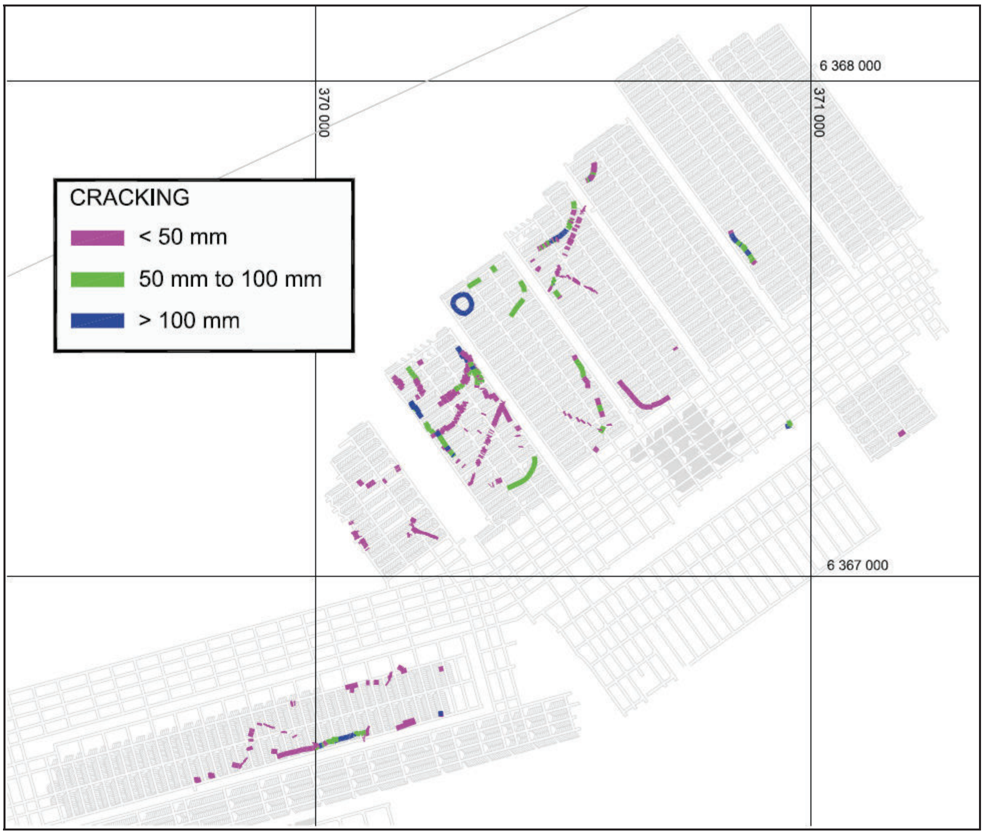

Fig. 4.3 Surface Cracking Observed above the Panels in SMP Areas 1 and 2

It can be seen from this figure, that the surface crack widths in SMP Areas 1 and 2 were typically between 25 mm and 100 mm, with localised surface crack widths greater than 100 mm. The largest surface crack width measured above these panels was around 375 mm. The depth of cover above the panels in SMP Areas 1 and 2 varies between 50 metres and 100 metres.

The size and extent of surface cracking in the southern part of the proposed mining are expected to be similar to or less than those observed above the currently active Panels 23 and 24 in SMP Area 3, due to the higher depths of cover. The observed crack widths are typically between 25 mm and 50 mm, with localised surface crack widths greater than 100 mm.

It is possible, that larger surface cracking could occur along the steep slopes due to down slope movements resulting from the extraction of the proposed panels. The potential for surface cracking from down slope movements is discussed in Section 5.4.

Photographs of typical surface cracking observed from previous mining in SMP Areas 1 and 3 at the Abel Underground Mine are provided in Fig. 4.4 and Fig. 4.5, respectively.

Fig. 4.4 Photographs of Typical Surface Cracking in SMP Area 1 at the Abel Underground Mine (50 metres to 100 metres Depth of Cover)

Fig. 4.5 Photographs of Typical Surface Cracking in SMP Area 3 at the Abel Underground Mine (110 metres to 140 metres Depth of Cover)

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

4.8. Estimated Height of the Fractured Zone

The estimated heights of fracturing in the overburden for the proposed panels have been determined using the method described in the ACARP Research Project C10023 (ACARP, 2003). This method was previously used to estimate the heights of fracturing in the Part 3A Environmental Assessment (SE, 2006).

As described in the Part 3A Environmental Assessment, "*Continuous sub-surface cracking refers to the extent of fracturing above a total extraction panel that would provide a direct flow-path or hydraulic connection to the workings, if a sub-surface aquifer or coal seam were intersected*" (SE, 2006). The height of continuous cracking is referred to as the "*A Horizon*".

Also, as described in the Part 3A Environmental Assessment, "*Discontinuous fracturing refers to the extent above a total extraction panel that could experience a general increase in horizontal and vertical permeability with the rock mass, due to bending or curvature deformation of the overburden. This type of fracturing does not provide a direct flow path or connection to the workings and is more likely to interact with surface cracks or joints*" (SE, 2006). The height of discontinuous cracking is referred to as the "*B Horizon*".

The estimated heights of continuous and discontinuous fracturing are based on the depth of cover and either the maximum 'smooth profile' (i.e. conventional) tensile strain or the '*overburden curvature index*'. The relationship between the estimated heights of the *A Horizon* and the *B Horizon*, based on the maximum conventional tensile strain, are illustrated in Fig. 4.6.

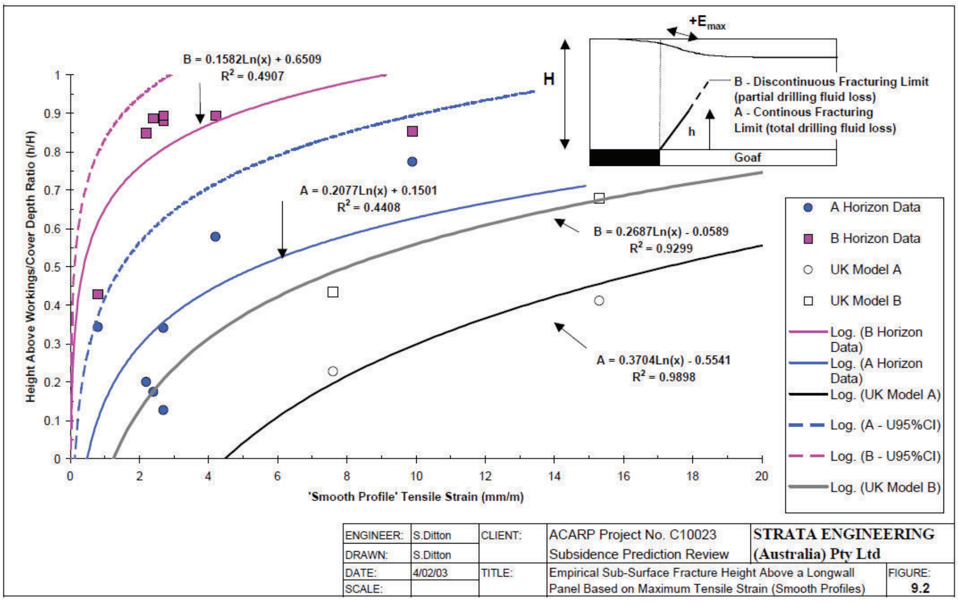

Fig. 4.6 Estimated Heights of the A and B Horizons (ACARP, 2003)

The estimated heights of continuous and discontinuous fracturing as proportions of the depths of cover, based on the maximum conventional tensile strain, are provided by the following equations (ACARP, 2003):-

Equation 1 $A = 0.2077 Ln(+E_{max}) + 0.150$ *Height of continuous fracturing divided by cover*

$B = 0.1582 Ln(+E_{max}) + 0.651$ *Height of discontinuous fracturing divided by cover*

where $+E_{max}$ = the maximum conventional tensile strain (mm/m)

The estimated heights of continuous and discontinuous fracturing as proportions of the depths of cover, based on the '*overburden curvature index*', are provided by the following equations (ACARP, 2003):-

Equation 2 $A = 0.2295 Ln(S_{max} / W^2) + 1.132$ *Height of continuous fracturing divided by cover*

$B = 0.1694 Ln(S_{max} / W^2) + 1.381$ *Height of discontinuous fracturing divided by cover*

where S_{max} = maximum subsidence (mm)

W = width of panel (m)

A summary of the estimated heights of continuous and discontinuous fracturing for the proposed panels, based on the ACARP 2003 method, is provided in Table 4.4. The heights of fracturing have been based on the greater of those determined using the maximum conventional tensile strain and the maximum subsidence.

Table 4.4 Estimated Heights of Continuous and Discontinuous Cracking Based on ACARP 2003

Location	Depth of Cover (m)	Maximum Predicted Conventional Tensile Strain (mm/m)	Maximum Predicted Subsidence (mm)	Estimated Height of the A Horizon (m)	Estimated Height of the B Horizon (m)
Panels 27 to 35	50	> 30	1,450	50 ~ 140	100 ~ 200
	280	5	1,000		

It can be seen from the above table, that continuous cracking is predicted to extend up to the surface where the depths of cover are shallowest above the northern and central parts of the proposed mining area. It is also possible, that discontinuous cracking could extend near to the surface above the southern part of the proposed mining area.

It is noted, that the height of continuous fracturing could be towards the lower end of the range predicted using the ACARP (2003) model, as extensometer measurements at the nearby West Wallsend Colliery indicate that the caved zone extended 71 metres above the West Borehole Seam (DoPI, 2012).

Further details on sub-surface strata movements are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained at *www.minesubsidence.com*.

The following sections provide the descriptions, predictions and impact assessments for the natural features identified within the EP / SMP Area. All significant natural features located outside the EP / SMP Area, which may be subjected to valley related or far-field horizontal movements and may be sensitive to these movements, have also been included as part of these assessments.

5.1. Streams

5.1.1. Description of the Streams

The locations of the streams within the EP / SMP Area are shown in Drawing No. MSEC676-08.

There are no named rivers or Schedule 2 (i.e. third order and above) streams located the EP / SMP Area. The nearest Schedule 2 streams are Long Gully and Buttai Creek, which are located more than 1 kilometre outside the extents of the proposed panels.

Four Mile Creek is a second order ephemeral stream which is located above the southern end of the proposed Panel 27 and above the approved Panel 26. There are also first and second order ephemeral tributaries located across the EP / SMP Area. The natural surface falls towards the north-east with the tributaries draining into Four Mile Creek above or downstream of the proposed panels.

The streams have shallow incisions into the natural surface soils, with some sandstone bedrock outcropping in isolated locations. Farm dams have been established along the alignments of the streams, which are shown in Drawing No. MSEC676-08. Photographs of typical streams within the EP / SMP Area are provided in Fig. 5.1.

Fig. 5.1 Photographs of Typical Tributaries within the EP / SMP Area

5.1.2. Predictions for the Streams

The Schedule 2 streams (i.e. third order or greater) are all located outside the EP / SMP Area, at distances greater than 1 kilometre outside the extents of the proposed panels. It is unlikely, therefore, that these streams would experience any measurable conventional or valley related movements.

The upper reaches of Four Mile Creek are located above the southern end of the proposed Panel 27. The maximum predicted additional subsidence parameters for this creek, due to the extraction of the proposed Panels 27 to 35, are 950 mm vertical subsidence, 20 mm/m tilt and 1.0 km^{-1} hogging curvature and 2.0 km^{-1} sagging curvature.

The ephemeral tributaries are located across the EP / SMP 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 EP / SMP Area is provided in Chapter 4.

The predicted profiles of subsidence, tilt and curvature along three typical tributaries, referred to as Tributaries A, B and C, are shown in Figs. E.03 to E.05, in Appendix E. The predicted movements along the upper reaches of Four Mile Creek are also shown in Fig. E.03. The predicted total profiles along the alignments of the tributaries, after the extraction of each of the proposed panels, are shown as solid blue lines. The predicted total profiles after the completion of the approved Panels 23 to 26 are shown as the solid cyan lines. The locations of these tributaries are shown in Drawing No. MSEC676-08.

The streams within the EP / SMP Area have shallow incisions into the surface soils and, therefore, the valley related upsidence and closure movements are expected to be insignificant when compared to the conventional subsidence movements.

5.1.3. Impact Assessments for the Streams

The Schedule 2 streams are all located well outside the mining area and, therefore, are not expected to experience any measurable conventional or valley related movements. It is not anticipated that these streams would experience any adverse impacts, resulting from the extraction of the proposed Panels 27 to 35, even if the predictions were exceeded by a factor of 2 times.

The impact assessments for the upper reaches of Four Mile Creek and the ephemeral tributaries located within the EP / SMP Area are provided in the following sections. The assessments provided in this report should be read in conjunction with the assessments provided in the report by the specialist surface water consultant (Evans and Peck, 2014).

Potential for Increased Levels of Ponding, Flooding and Scouring

Mining can potentially result in increased levels of ponding in locations where the mining induced tilts oppose and are greater than the natural stream gradients that exist before mining. Mining can also potentially result in an increased likelihood of scouring of the stream beds in the locations where the mining induced tilts considerably increase the natural stream gradients that exist before mining.

The maximum predicted tilt within the EP / SMP Area is 70 mm/m (i.e. 7 %, or 1 in 14), which occurs at the northern ends of the panels, where the depths of cover are the shallowest. The predicted tilts are greater than the natural surface gradients and, therefore, mining could result in localised ponding along the ephemeral tributaries upstream and inside of the panel edges.

The natural surface levels and grades and the predicted post mining surface levels and grades along Tributaries A, B and C are illustrated in Fig. 5.2, Fig. 5.3 and Fig. 5.4, respectively. The predicted profiles along the upper reaches of Four Mile Creek are also shown in Fig. 5.2. The natural surface levels and grades shown in these figures do not include the dam walls which have been constructed along the alignments of the tributaries.

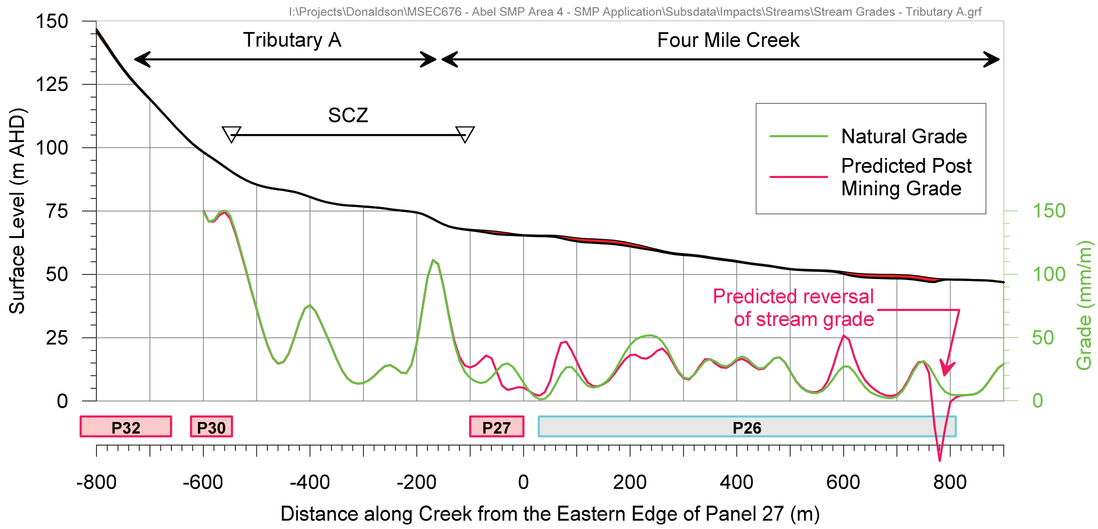

Fig. 5.2 Natural and Predicted Post-Mining Levels and Grades along Tributary A and the Upper Reaches of Four Mile Creek

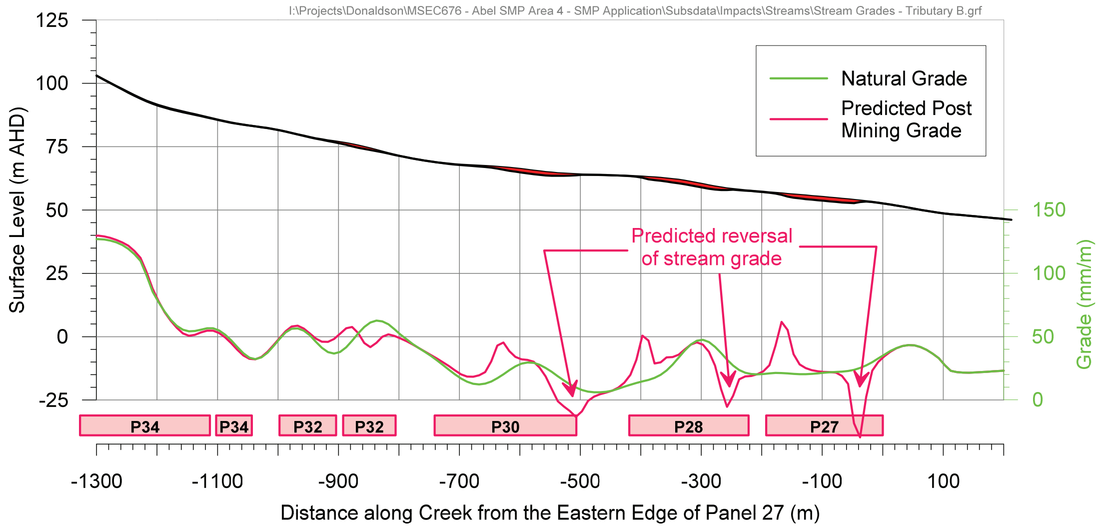

Fig. 5.3 Natural and Predicted Post-Mining Levels and Grades along Tributary B

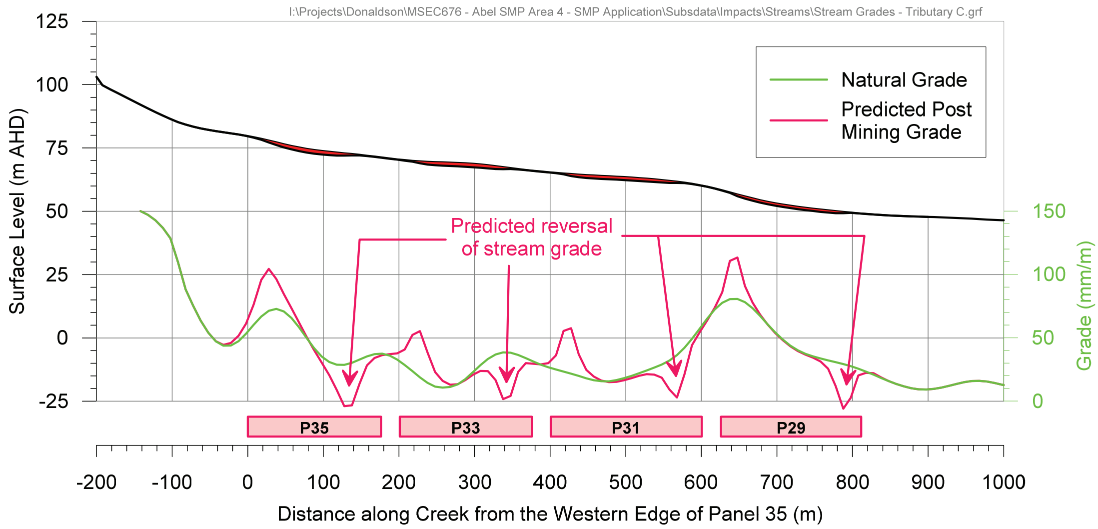

Fig. 5.4 Natural and Predicted Post-Mining Levels and Grades along Tributary C

It can be seen from the above figures, that there are predicted reversals of grade along Tributaries B and C immediately upstream of the eastern edges of the proposed panels. There is also a predicted reversal of grade along Four Mile Creek above the approved Panel 26 immediately upstream of the northern edge of this approved panel. There are no predicted reversals of grade along the upper reaches of Four Mile Creek or along Tributary A directly above the proposed Panels 27 to 32.

Localised increased ponding areas could occur along the ephemeral tributaries, as a result of the proposed mining, upstream of the eastern edges of the panels. In some locations, however, the localised ponding areas are coincident with existing farm dams which have been constructed along the alignments of the tributaries.

The mining induced ponding are predicted to have depths up to approximately 0.5 metres and lengths up to approximately 100 metres. The locations of these predicted ponding areas are illustrated by the magenta hatching in Fig. 5.8. It can be seen from that figure, that the mining induced ponding areas are localised and relatively small when compared with the existing farm dams along the alignments of the tributaries.

The levels and extents of ponding are similar to or less than those assessed in the Part 3A Environmental Assessment, which states that "*potential ponding depths of 0.1 to 0.5 m estimated for the majority of these [Schedule 1] creeks*" with "*ponding depths ranging between 0.4 and 1.0 m*" for two tributaries (SE, 2006).

If the mining induced ponding areas were to result in any adverse impacts, these could be remediated by locally regrading the tributaries, so as to re-establish the natural gradients. The tributaries have shallow incisions in the natural surface soils and, therefore, it is expected that the mining induced ponding areas could be reduced by locally excavating the tributary channels downstream of these areas.

It is possible that increased levels of bed scouring could also occur in the locations of the maximum increasing tilts, during times of high surface water flows, where the velocities of the flows exceed 1 metre per second. If significant levels of bed scouring were to occur along the tributaries, it may be necessary to provide erosion control measures, or to locally regrade the beds of the tributaries in these locations.

Further discussions and recommendations for the management of the potential changes in ponding and flooding along the streams are provided in the report by the specialist surface water consultant (Evans and Peck, 2014).

Potential for Cracking in the Creek Beds and Fracturing of Bedrock

Fracturing of the uppermost bedrock has been observed in the past, as a result of mining, where the tensile strains have been greater than 0.5 mm/m or where the compressive strains have been greater than 2 mm/m. It is likely, therefore, that fracturing would occur in the uppermost bedrock based on the predicted maximum strains.

The upper reaches of Four Mile Creek and the ephemeral tributaries within the EP / SMP Area have shallow incisions into the surface soils, with some sandstone bedrock outcropping in isolated locations. Cracking in the beds of the streams would only be visible at the surface where the depths of the surface soils are shallow, or where the bedrock is exposed.

The streams are ephemeral and so water typically flows during and for short periods of time after rain events. In times of heavy rainfall, the majority of the runoff would flow over the beds and would not be diverted into the fractured and dilated strata below. In times of low flow, however, some of the water could be diverted into the fractures and dilated strata below the stream beds.

As described in Section 4.8, it is likely that the fractured zone in the northern part of the proposed mining area could extend from the seam up to the surface. It is possible, therefore, that there could be some loss of the surface water flows into the mine, where the depths of cover are the shallowest. It may be necessary, at the completion of mining, to remediate the larger surface cracking along the alignments of the streams so as to reduce the potential for the loss of surface water flows.

The previous bord and pillar total and partial extraction panels in SMP Areas 1 and 2 at the mine were extracted beneath the first and second order ephemeral tributaries to Weakleys Flat and Viney Creeks. The total length of streams directly mined beneath in these areas is approximately 2 kilometres at depths of cover varying between 50 metres and 100 metres. Also, the total length of ephemeral tributaries directly mined beneath by the currently active panels in SMP Area 3 is approximately 1 kilometre at depths of cover varying between 100 metres and 150 metres. To date, there has been no reported loss of surface water flows into the workings at the Abel Underground Mine.

Also, the longwalls in the Whybrow Seam at South Bulga and the Beltana No. 1 Underground Mine were previously extracted beneath a number of ephemeral drainage lines, where the depths of cover varied between 40 metres and 200 metres. Although surface cracking was observed across the mining areas, there were no observable surface water flow diversions in the drainage lines, after the remediation of the larger surface cracks had been completed.

It is expected, therefore, that there would be no significant loss of surface water flows along the upper reaches of Four Mile Creek and the ephemeral tributaries after the remediation of any large surface cracking along their alignments. Further discussions on the potential impacts on the streams within the EP / SMP Area are provided in the report by the specialist surface water consultant (Evans and Peck, 2014).

5.1.4. Impact Assessments for the Streams Based on Increased Predictions

If the actual conventional subsidence movements exceeded those predicted by a factor of 2 times, the maximum tilt within the EP / SMP Area would be greater than 100 mm/m (i.e. > 10 %), which represents a change in grade greater than 1 in 10. In this case, increased levels of ponding are expected to occur along the tributaries immediately upstream of the panel edges, especially in the northern part of the mining area. This is illustrated in Fig. 5.5 to Fig. 5.7, which show the natural and predicted post mining surface levels and grade along Tributaries A to C and the upper reaches of Four Mile Creek, based on the subsidence exceeding the predictions by a factor of 2 times.

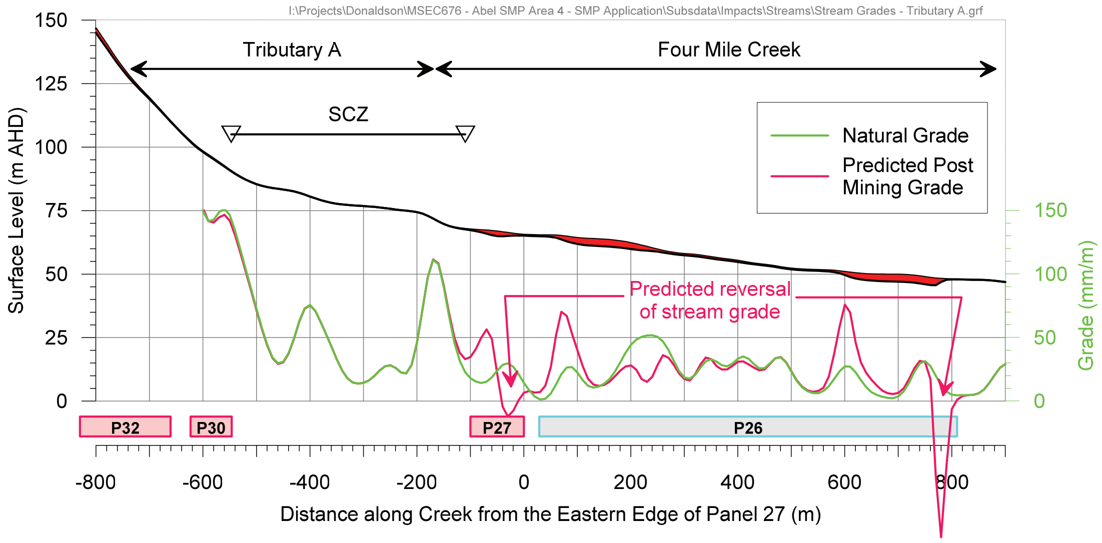

Fig. 5.5 Natural and Predicted Post-Mining Levels and Grades along Tributary A and the Upper Reaches of Four Mile Creek Based on Subsidence Exceeding Predictions by a Factor of 2 Times

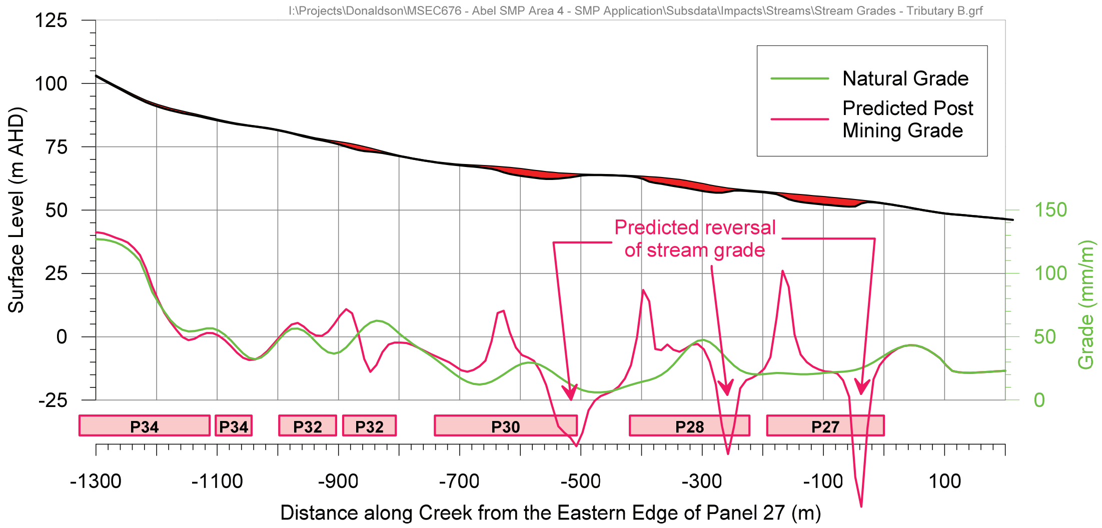

Fig. 5.6 Natural and Predicted Post-Mining Levels and Grades along Tributary B Based on Subsidence Exceeding Predictions by a Factor of 2 Times

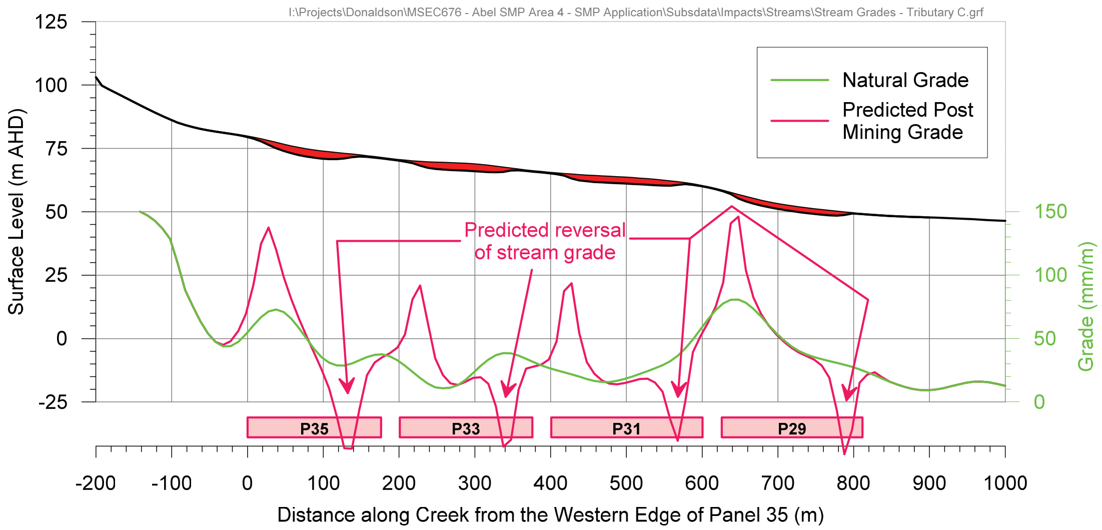

Fig. 5.7 Natural and Predicted Post-Mining Levels and Grades along Tributary C Based on Subsidence Exceeding Predictions by a Factor of 2 Times

It is estimated that locally increased ponding could occur upstream of the eastern edges of the proposed panels, having depths up to approximately 1.0 metre and lengths up to approximately 150 metres, if the actual subsidence exceeded the predictions by a factor of 2 times. Any adverse impacts resulting from the increased ponding could be remediated by locally regrading the stream channels so as to re-establish the natural gradients.

If the actual curvatures or strains exceeded those predicted by a factor of 2 times, it would be expected that the extent of fracturing in the uppermost bedrock would increase along the sections of the streams located directly above the proposed panels. In this case, the extent of remediation would also be expected to increase, however, the methods of remediation would not be expected to change significantly. The experience of mining beneath ephemeral tributaries at the Abel Underground Mine and at other collieries in the region indicates that the potential for the loss of surface water is low after the remediation of the larger surface cracking.

5.1.5. Recommendations for the Streams

It is recommended that the upper reaches of Four Mile Creek and the ephemeral tributaries are visually monitored as the proposed panels are extracted directly beneath them. It is also recommended that the larger surface cracking along the alignments of these streams are remediated, using similar methods to those that have been established in SMP Areas 1 to 3 at the mine.

5.2. Aquifers or Known Groundwater Resources

As described in Section 6.10, there are no registered groundwater bores within EP / SMP Area which are used for potable water or for stock. The alluvium associated with Blue Gum Creek and Long Gully provides groundwater resource in the area, however, the alluvial is located almost 2 kilometres south of the proposed panels and, therefore, is unlikely to be adversely impacted by the proposed mining.

5.3. Cliffs

For the purposes of this report, cliffs have been defined as continuous rockfaces, having heights greater than 10 metres and minimum slopes of 2 to 1 (i.e. greater than 63°) and lengths greater than 20 metres. Minor cliffs have been defined as continuous or segmented rockfaces, having heights greater than 5 metres and minimum slopes of 2 to 1.

There were no cliffs or minor cliffs identified within the EP / SMP Area, based on the Light Detection and Ranging (LiDAR) survey, the orthophotograph of the area, or from the site investigations.

5.4. Steep Slopes

5.4.1. Descriptions of the Steep Slopes

For the purposes of this report, steep slopes have been defined as areas of land having natural gradients greater than 1 in 3 (i.e. 33 %, or an angle to the horizontal of 18°). The locations of the steep slopes within the EP / SMP Area were determined using the surface level contours generated from a LiDAR survey of the area. The areas identified as having steep slopes within the EP / SMP Area are shown in Drawing No. MSEC676-08.

The ridgeline located above the southern part of the proposed mining area has natural gradients typically varying up to 1 in 2 (i.e. 27º, or 50 %), with some isolated areas having natural gradients up to 1 in 1.5 (i.e. 33º, or 67 %). Elsewhere, the natural gradients are typically less than 1 in 3, which is the threshold used to define steep slopes in this report.

The surface soils along steep slopes have been derived from the Waratah Sandstone (Pnw), the Lambton Subgroup (Pnl) and the Adamstown Subgroup (Pna) of the Newcastle Coal Measures, as indicated in Fig. 1.4. The steep slopes are stabilised by natural bushland, which can be seen from Fig. 5.10.

5.4.2. Predictions for the Steep Slopes

A summary of the maximum predicted conventional subsidence, tilt and curvatures for steep slopes located above the southern part of the proposed mining area is provided in Table 5.1. The values are the maxima within the EP / SMP Area resulting from the extraction of Panels 23 to 35.

Table 5.1 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Steeps Slopes Located above the Southern Part of the Proposed Mining Area

Panel	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})
After Panel 27	< 20	< 0.5	< 0.01	< 0.01
After Panel 28	600	15	0.5	1.0
After Panel 30	650	20	1.0	1.0
After Panel 32	1,250	25	1.0	1.0
After Panel 34	1,250	30	1.0	1.0

The maximum predicted conventional curvatures for the steep slopes are 1.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of 1 kilometre. The maximum predicted conventional strains, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 10 mm/m tensile and compressive.

The analysis of strains measured above the previously extracted bord and pillar total extraction panels at the Abel Underground Mine is provided in Section 4.3. 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.

The isolated steep slopes along the alignments of the streams are located across the EP / SMP 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 EP / SMP Area is provided in Chapter 4.

5.4.3. Impact Assessments for the Steep Slopes

The maximum predicted tilt for the steep slopes located in the southern part of the proposed mining area is 30 mm/m (i.e. 3.0 %, or 1 in 33). The maximum predicted tilt for the isolated steep slopes along the banks of the streams is 70 mm/m (i.e. 7 %, or 1 in 140). The predicted tilts are small when compared to the natural grades of the steep slopes, which are greater than 1 in 3 and, therefore, the tilts are unlikely to result in any adverse impact on the stability of the steep slopes.

The steep slopes are more likely to be affected by curvatures and strains. The potential impacts would generally result from the downslope movement of the surface soils, causing tension cracks to appear at the tops and sides of the slopes and compression ridges could possibly form at the bottoms of the slopes.

It is expected, that the sizes and extents of surface cracking for the steep slopes located in the southern part of the proposed mining area would be similar to those observed during the extraction of Longwalls 1 and 2 at Dendrobium Mine. These longwalls were extracted beneath steep slopes greater than 1 in 2, at similar depths of cover, similar void width-to-depth ratios, and also included some multi-seam mining.

Dendrobium Longwalls 1 and 2 had void widths of 245 metres and a solid chain pillar width of 50 metres and were extracted from the Wongawilli Seam at depths of cover ranging between 170 metres and 320 metres. These longwalls partially mined beneath previous bord and pillar workings in the overlying Bulli Seam, having an interburden thickness of approximately 20 metres to 30 metres.

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

If tension cracks were to develop, as a result of the extraction of the proposed Panels 27 to 35, 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 surface soils on the slopes in the longer term.

The requirement and methodology for any erosion and sediment control and remediation techniques would be determined in consideration of the: potential impacts when unmitigated, including potential risks to public safety and the potential for self-healing or long-term degradation; potential impacts of the control/remediation technique, including site accessibility; and consultation with relevant stakeholders.

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

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilts would be 60 mm/m (i.e. 6 %, or 1 in 17) for the steep slopes located above the southern part of the proposed mining area, and, greater than 100 mm/m (i.e. > 10 %, or 1 in 10) for the isolated steep slopes along the alignments of the tributaries. In this case, the tilts at the steep slopes would still be small in comparison with the existing natural grades, which exceed 1 in 3.

If the actual curvatures exceeded those predicted by a factor of 2 times, the maximum curvatures at the steep slopes would be 2.0 km^{-1} hogging and sagging for the steep slopes located above the southern part of the proposed mining area, and, greater than 3.0 km^{-1} for the isolated steep slopes along the alignments of the tributaries. Whilst the sizes and extents of the surface cracking would increase, it would still be unlikely that any large scale slope instabilities would occur. This is based on the extensive experience of mining beneath similar steep slopes in the NSW Coalfields.

5.4.5. Recommendations for the Steep Slopes

It is recommended that the steep slopes are visually monitored throughout the mining period and until any necessary rehabilitation measures are completed. In addition to this, it is recommended that any significant surface cracking which could result in increased erosion or restrict access to areas be remediated by infilling with soil or other suitable materials, or by locally regrading and compacting the surface.

5.5. Land Prone to Flooding or Inundation

The natural surface within the EP / SMP Area falls towards the north-east with the tributaries draining into Four Mile Creek above and downstream of the proposed panels. There are a number of existing farm dams which have been developed along the alignments of the tributaries.

The natural surface level contours (grey lines) and the predicted post-mining surface level contours (green lines) are illustrated in Fig. 5.8. The existing farm dams are indicated by the cyan hatching and the predicted mining induced ponding areas are indicated by the magenta hatching in this figure.

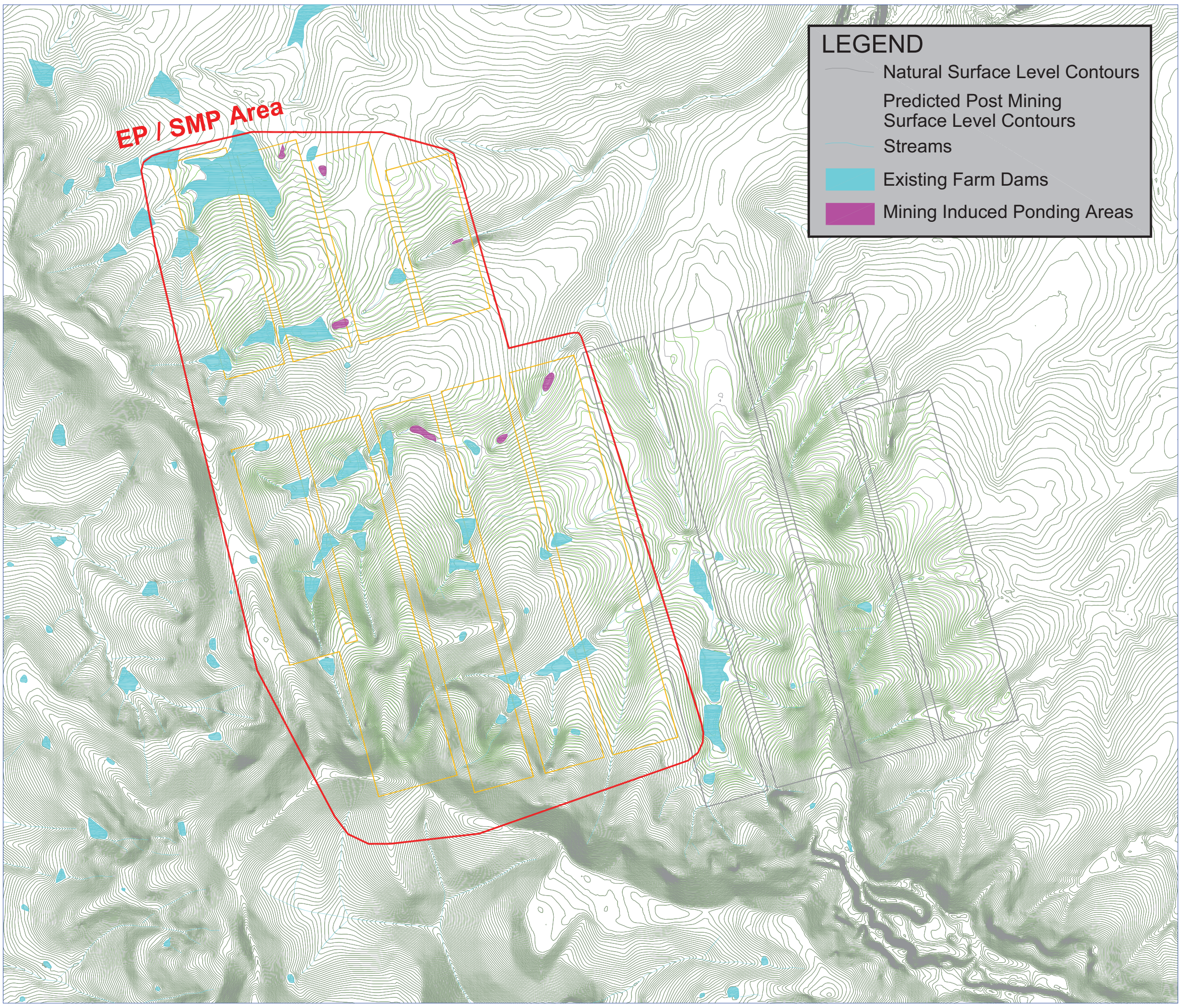

Fig. 5.8 Natural and Predicted Subsided Surface Levels and Ponding Areas

It can be seen from the above figure that, outside the locations of the existing farm dams (i.e. cyan hatching), the surface naturally drains along the alignments of the tributaries. It is not considered, therefore, that the land is naturally susceptible to flooding or inundation.

Localised increased ponding areas could occur along the tributaries, as a result of the proposed mining, which are indicated by the magenta hatching in the above figure. The mining induced ponding areas are predicted to have depths up to approximately 0.5 metres and lengths up to approximately 100 metres. The mining induced ponding areas are localised and relatively small when compared with the existing farm dams along the alignments of the tributaries.

The assessments of the potential for increased ponding along the upper reaches of Four Mile Creek are provided in Section 5.1.3. Further discussions are provided in the report by the specialist surface water consultant (Evans and Peck, 2014).

5.6. Swamps and Wetlands

There were no swamps or wetlands identified within the EP / SMP Area. There are swamps along the lower reaches of Blue Gum Creek and in the Pambalong Nature Reserve, south-east of the EP / SMP Area, which are located at distances greater than 2 kilometres outside the extents of the proposed panels.

At these distances, it is unlikely that the swamps would experience any measurable conventional or valley related movements resulting from the extraction of the proposed Panels 27 to 35. It is not anticipated, therefore, that the swamps would experience any adverse impacts, due to the proposed mining, even if the predictions were exceeded by a factor of 2 times.

5.7. Water Related Ecosystems

There are water related ecosystems within the EP / SMP Area associated with the streams. The assessments of the potential impacts on the streams are provided in Section 5.1. Further discussions are provided in the report by the specialist ecology consultant on the project.

5.8. Threatened and Protected Species

Rainforest communities have been identified along the upper reaches of Long Gully, which are located immediately to the south of the proposed Panel 32. The location of this community is shown in Drawing No. MSEC676-08 and a photograph is provided in Fig. 5.9.

Fig. 5.9 Photograph of the Rainforest Community along the Upper Reaches of Long Gully (after Fig. 6.6 of SE, 2006)

The proposed panels have been setback from the rainforest communities so that no more than 20 mm of subsidence is predicted within the mapped extents of these areas. Whilst it is possible that the rainforest communities could experience subsidence slightly greater than 20 mm, they would not be expected to experience any significant conventional tilts, curvatures or strains. It is not anticipated, therefore, that the rainforest communities would experience any adverse impacts, due to the proposed mining, even if the predictions were exceeded by a factor of 2 times.

Further discussions are provided in the report by the specialist ecology consultant on the project.

5.9. Natural Vegetation

The vegetation within the EP / SMP Area generally consists of undisturbed native bush located north of Black Hill Road and along the alignments of the streams south of the road. The land south of Black Hill Road has been cleared for residential and light agricultural purposes. The extent of natural vegetation can be seen from the aerial photograph provided in Fig. 5.10.

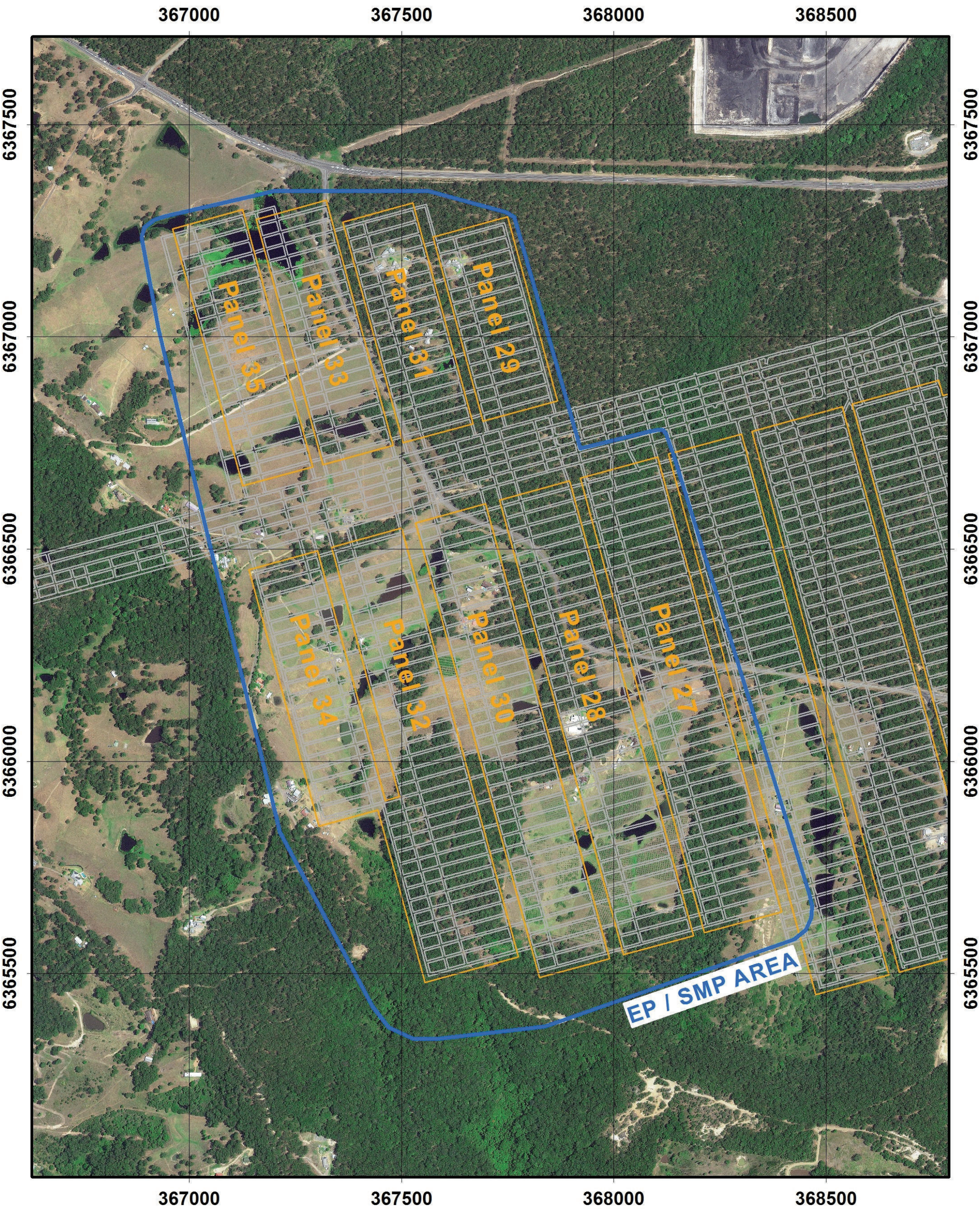

Fig. 5.10 Aerial Photograph showing the Extent of Natural Vegetation

There are rainforest communities identified to the south of the proposed Panel 32, which is discussed in Section 5.8. Further discussions on the native vegetation are provided in the report by the specialist ecology consultant on the project.

The following sections provide the descriptions, predictions and impact assessments for the built features identified within the EP / SMP Area. All significant built features located outside the EP / SMP Area, which may be subjected to valley related or far-field horizontal movements and may be sensitive to these movements, have also been included as part of these assessments.

6.1. Local Roads

6.1.1. Description of the Local Roads

The local roads within the EP / SMP Area are Black Hill, Meredith and Browns Roads. The locations of these roads are shown in Drawing No. MSEC676-09.

Black Hill Road is the main public road within the EP / SMP Area which provides a connection between the township of Black Hill, to the east of the proposed panels, through to John Renshaw Draw, to the north of the proposed panels. The road crosses directly above the proposed Panels 27, 28, 30, 31 and 33, with a total length of approximately 1.4 kilometres located directly above the proposed mining area. Black Hill Road has a bitumen seal and is maintained by the Cessnock Council.

Photographs of Black Hill Road and are provided in Fig. 6.1.

Fig. 6.1 Photographs of Black Hill Road

Meredith and Browns Roads provide access to the private properties located off Black Hill Road. Meredith Road is located above the proposed Panels 28, 30 and 32 and is also partially located above the historic workings in the Borehole Seam. Browns Road is located above the northern ends of the proposed Panels 32 and 34. These roads have bitumen seals, except for a section of Meredith Road which is unsealed near the southern boundary of the EP / SMP Area.

Drainage culverts have been constructed where the roads cross the streams. The locations of the drainage culverts along Black Hill Road are shown in Drawing No. MSEC676-09 and the details are provided in Table 6.1.

Table 6.1 Drainage Culverts along Black Hill Road

Culvert Ref.	Description	Location
BHR-C1	1 x ϕ1350 concrete culvert	Above the western edge of the proposed Panel 31
BHR-C2	1 x ϕ1500 concrete culvert	Above the proposed Panel 28
BHR-C3	1 x ϕ600 concrete culvert	Above the proposed Panel 27

The drainage culverts along Black Hill Road have concrete headwalls at each end and concrete scour aprons at the downstream ends. Photographs of these drainage culverts are provided in Fig. 6.2.

Fig. 6.2 Photographs of Drainage Culverts BHR-C1 (Left), BHR-C2 (Middle) and BHR-C3 (Right)

There are also additional concrete drainage culverts located along the other public and private roads within the EP / SMP Area, which typically have diameters of 600 mm or less.

6.1.2. Predictions for the Local Roads

The predicted profiles of conventional subsidence, tilt and curvature along Black Hill Road are shown in Fig. E.06, in Appendix E. The predicted total profiles along the alignment of the road, after the extraction of each of the proposed panels, are shown as solid blue lines. The predicted total profiles after the completion of the approved Panels 23 to 26 are shown as the solid cyan lines.

A summary of the maximum predicted conventional subsidence, tilt and curvatures for Black Hill Road is provided in Table 6.2. The values are the maxima within the EP / SMP Area resulting from the extraction of Panels 23 to 35.

Table 6.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for Black Hill Road

Panel	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})
After Panel 27	1,400	40	2.0	1.5
After Panel 28	1,450	40	2.0	1.5
After Panel 30	1,450	40	2.0	1.5
After Panel 31	1,450	40	2.0	1.5
After Panel 33	1,450	40	2.0	1.5

The maximum predicted conventional curvatures for Black Hill Road are 2.0 km^{-1} hogging and 1.5 km^{-1} sagging, which represent minimum radii of curvature of 0.5 kilometres and 0.7 kilometres, respectively. The maximum predicted conventional strains for the road, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 20 mm/m tensile and 15 mm/m compressive.

The maximum predicted conventional movements for Meredith Road are 1,200 mm subsidence, 30 mm/m tilt and 1.5 km^{-1} hogging and sagging curvatures. The predictions include the effects of the historic workings in the Borehole Seam located above the southern end of the proposed Panel 32. The maximum predicted conventional strains for the road, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 15 mm/m tensile and compressive.

The maximum predicted conventional movements for Browns Road are 200 mm subsidence, 5 mm/m tilt, 0.3 km^{-1} hogging curvature and 0.07 km^{-1} sagging curvature. The maximum predicted conventional strains for the road, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 3 mm/m tensile and 1 mm/m compressive. The predictions for this road are smaller than the other two roads as it is located immediately adjacent to SCZ at the northern ends of the proposed Panels 32 and 34.

The analysis of strains measured above the previously extracted bord and pillar total extraction panels at the Abel Underground Mine is provided in Section 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.

A summary of the maximum predicted conventional subsidence, tilt and curvatures for the culverts located along Black Hill Road is provided in Table 6.3. The predicted tilts and curvatures are the maxima in any direction.

Table 6.3 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Culverts Located along Black Hill Road

Culvert Ref.	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})
BHR-C1	500	50	> 3.0	1.0
BHR-C2	1,400	10	1.5	1.5
BHR-C3	1,450	5	1.0	1.0

The remaining drainage culverts are across the EP / SMP 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.

6.1.3. Impact Assessments for the Local Roads

The predicted vertical subsidence and tilts along could potentially affect the surface water drainage along the public roads. The existing and predicted post-mining levels and grades along Black Hill Road are illustrated in Fig. 6.3.

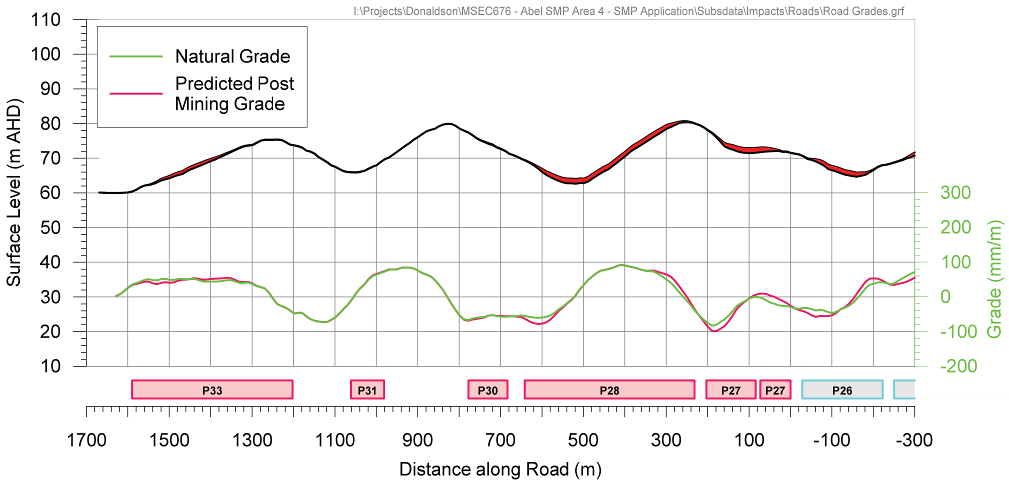

Fig. 6.3 Existing and Predicted Post-Mining Levels and Grades along Black Hill Road

It can be seen from the above figure, that the predicted post-mining grades are similar to the existing grades along Black Hill Road. The predicted changes in grade along Black Hill, Meredith and Browns Roads, resulting from the proposed mining, are small when compared with the natural grades.

The potential changes in the surface water drainage for the public roads, therefore, are not expected to be significant. Whilst it is possible that localised increased ponding could occur at the drainage line crossings, directly above the proposed panels, it would be expected that this could be remediated using normal road maintenance techniques.

It is expected, at the magnitudes of predicted curvatures and strains, that cracking and heaving would occur in the public roads as each of the proposed panels are extracted beneath them. The predicted curvatures and strains along Black Hill Road, resulting from the extraction of the proposed panels, are similar to those predicted where Panels 23 and 24 were extracted directly beneath this road. The cracking observed along Black Hill Road was typically between 25 mm and 50 mm which occurred inside each of the panel edges. Photographs of the impacts observed along Black Hill Road after the completion of temporary repairs are provided in Fig. 6.4.

Fig. 6.4 Impacts after the Completion of Temporary Repairs along Black Hill Road above Panels 23 and 24

The depth of cover along Black Hill Road reduces to around 60 metres at the northern end of the proposed Panel 33. The panel width-to-depth ratio in this location is around 2.8. Larger impacts could occur along Black Hill Road in the northern part of the mining area due to the shallower depths of cover.

The minimum depth of cover and the maximum panel width-to-depth ratio along Black Hill Road are similar to those for Longwalls 1 to 10 at the Beltana No. 1 Underground Mine, which were extracted directly beneath Charlton Road. The impacts observed along Charlton Road should, therefore, provide a reasonable guide to the potential impacts along Black Hill Road in the northern part of the mining area.

Beltana Longwalls 1 to 10 had void widths of 275 metres and a solid chain pillar width of 25 metres and were extracted from the Whybrow Seam at depths of cover ranging between 80 metres and 115 metres. The crack widths observed along Charlton Road, due to the extraction of Beltana Longwalls 1 to 10, typically varied between 50 mm and 100 mm, with a maximum observed crack width around 380 mm. The heave and step heights observed along the road were typically in the order of 25 mm. Examples of the impacts observed along Charlton Road at Beltana are provided in Fig. 6.5.

Fig. 6.5 Impacts Observed along Charlton Road at the Beltana No. 1 Underground Mine

It is expected, that Black Hill Road could be maintained in a safe and serviceable condition throughout the mining period using visual monitoring and the repair of the larger cracks during active subsidence using normal road maintenance techniques. It is expected, that the impacts would develop gradually as the panels are extracted directly beneath the road.

The maximum predicted tilt at the drainage culverts along Black Hill Road is 50 mm/m (i.e. 5 %, or 1 in 20), which is orientated in the downstream direction, i.e. the mining induced tilt increases the existing grade. The predicted tilts at the other two culverts along Black Hill Road also slightly increase the existing grades. It is possible, that the existing grades at the other culverts within the EP / SMP Area could be reduced, as a result of the proposed mining, depending on their orientation to the proposed panels. If the flow of water through any culverts were to be adversely affected, this could be remediated by relevelling the culvert.

The predicted curvatures and strains could be of sufficient magnitudes to result in cracking in the culvert or the headwalls. It is unlikely, however, that these movements would adversely impact on the stability or structural integrity of the culvert. The potential impacts on the drainage culvert could be managed by visual inspection and, if required, any affected sections of the culvert repaired or replaced.

Previous experience of mining beneath culverts in the NSW Coalfields, at similar depths of cover, indicates that the incidence of impacts is low. Impacts have generally been limited to cracking in the concrete headwalls which can be readily remediated. In some cases, however, cracking in the culvert pipes occurred which required the culverts to be replaced.

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

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilt along Black Hill Road would be 80 mm/m (i.e. 8.0 %, or 1 in 13). In this case, the tilts would still be small when compared with the natural grades along the road and, therefore, would still be unlikely to adversely impact on the serviceability of the road. This is illustrated in Fig. 6.6, which shows the existing and predicted post-mining levels and grades along Black Hill Road, based on the subsidence exceeding the predictions by a factor of 2 times.

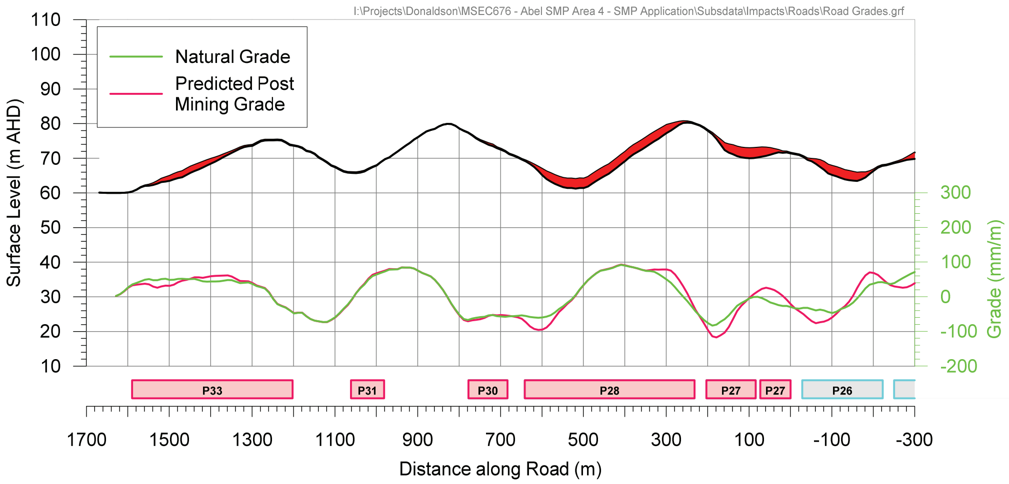

Fig. 6.6 Existing and Predicted Post-Mining Levels and Grades along Black Hill Road Based on Subsidence Exceeding Predictions by a Factor of 2 Times

It can be seen from the above figure, that the predicted post-mining grades are similar to the existing grades along Black Hill Road, even if the predictions were exceeded by a factor of 2 times.

If the actual curvatures or strains exceeded those predicted by a factor of 2 times, the incidence of cracking, stepping and heaving along Black Hill Road would increase directly above the proposed panels. It would still be expected that the road could be maintained in safe and serviceable conditions, throughout the mining period, using visual monitoring and remediation using normal road maintenance techniques.

6.1.5. Recommendations for the Local Roads

It is recommended that Black Hill Road is visually monitored as the proposed panels are extracted beneath it, such that any impacts can be identified and remediated accordingly during active subsidence. It is also recommended that a ground monitoring line is established along the road, which will assist in the early detection of any irregular or non-conventional ground movements.

Management strategies have been developed for the section of Black Hill Road which is located above the currently active panels in SMP Area 3. It is recommended that these management strategies are reviewed and, where required, revised to incorporate the sections of road within EP / SMP Area 4, such that they can be maintained in safe and serviceable conditions throughout the mining period.

6.2. The F3 Freeway, Hunter Expressway and Bridges

The Sydney-Newcastle (M1) Freeway is located well outside the EP / SMP Area. The freeway is located around 3 kilometres east of the proposed Panel 27, at its closest point to the proposed panels. The Hunter Expressway is completed to the south-west of the EP / SMP Area. The expressway is located more than 3 kilometres from the proposed Panel 32, at its closest point to the proposed panels.

At these distances, the Sydney-Newcastle (M1) Freeway and the Hunter Expressway are not predicted to experience any measurable conventional subsidence movements. It is unlikely, therefore, that the pavements, bridges, or other associated infrastructure would be adversely impacted as a result of the extraction of the proposed Panels 27 to 35, even if the predictions were exceeded by a factor of 2 times.

6.3. Electrical Infrastructure

6.3.1. Description of the Electrical Infrastructure

The locations of the electrical infrastructure are shown in Drawing No. MSEC676-10. The infrastructure within the EP / SMP Area comprises 11 kV and low voltage aerial powerlines, supported on timber poles, which service the residential properties. The powerlines are owned by *Ausgrid*.

6.3.2. Predictions for the Electrical Infrastructure

The predicted profiles of conventional subsidence, tilt along and tilt across the alignments of the 11 kV Powerline Branch 1 and Branch 2 are shown in Figs. E.07 and E.08, respectively, in Appendix E. The predicted total profiles after the extraction of each of the proposed panels are shown as solid blue lines. The predicted total profiles after the completion of the approved Panels 23 to 26 are shown as the solid cyan lines

A summary of the maximum predicted subsidence parameters for the powerlines is provided in Table 6.4. The parameters provided in this table are the maximum anywhere along the alignments of the powerline (i.e. not just at the powerpole locations).

Table 6.4 Maximum Predicted Total Conventional Subsidence and Tilts for the 11 kV Powerlines

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt Along Alignment (mm/m)	Maximum Predicted Total Conventional Tilt Across Alignment (mm/m)
Branch 1	1,300	70	45
Branch 2	1,400	30	30

The maximum predicted tilts for the 11 kV Powerline Branch 1 are 70 mm/m (i.e. 7 %, or 1 in 14) along its alignment and 45 mm/m (i.e. 4.5 %, or 1 in 22) across its alignment. The maximum predicted horizontal movements at ground level for this branch, based on applying a factor of 10 to the predicted tilts, are 700 mm along its alignment and 450 mm across its alignment.

The maximum predicted tilts for the 11 kV Powerline Branch 2 are 30 mm/m (i.e. 3 %, or 1 in 33) both along and across its alignment. The maximum predicted horizontal movements at ground level for this branch, based on applying a factor of 10 to the predicted tilts, are 300 mm both along and across its alignment.

The maximum predicted subsidence parameters at the locations of the powerpoles are provided in Table D.02 for the 11 kV Powerline Branch 1 and Table D.03 for the 11 kV Powerline Branch 2. The predicted horizontal movements at the tops of the poles are the additional of the predicted horizontal movements at the bases of the poles plus the predicted tilts multiplied by an adopted pole height of 15 metres.

A summary of the maximum predicted subsidence parameters at the locations of the powerpoles along the 11 kV Powerline Branches 1 and 2 is provided in Table 6.5. The values provided in this table are the maxima predicted within 20 metres of each of the pole locations.

Table 6.5 Maximum Predicted Total Conventional Subsidence, Tilts and Horizontal Movements at the Powerpoles along the 11 kV Powerlines

Location	Maximum Predicted Total Conventional Subsidence (mm)	Maximum Predicted Total Conventional Tilt Along Alignment (mm/m)	Maximum Predicted Total Conventional Tilt Across Alignment (mm/m)	Maximum Predicted Total Horizontal Movement Along Alignment at Top of Pole (mm)	Maximum Predicted Total Horizontal Movement Across Alignment at Top of Pole (mm)
Branch 1	1,250	30	30	750	775
Branch 2	1,350	30	20	700	500

The maximum predicted tilts at the locations of the powerpoles for the 11 kV Powerline Branch 1 are 30 mm/m (i.e. 3 %, or 1 in 33) both along and across its alignment. The maximum predicted horizontal movements at the tops of the poles for this powerline are 750 mm along and 775 mm across its alignment.

The maximum predicted tilts at the locations of the powerpoles for the 11 kV Powerline Branch 2 are 30 mm/m (i.e. 3 %, or 1 in 33) along and 20 mm/m (i.e. 2 %, or 1 in 50) across its alignment. The maximum predicted horizontal movements at the tops of the poles for this powerline are 700 mm along and 500 mm across its alignment.

6.3.3. Impact Assessments for the Powerlines

A rule of thumb used by some electrical engineers is that the tops of the poles may displace up to 2 pole diameters horizontally before remediation works are considered necessary. Based on pole heights of 15 metres and pole diameters of 250 mm, the maximum tolerable tilt at the pole locations is in the order of 20 mm/m.

It is possible, therefore, that the powerlines could experience some adverse impacts resulting from the proposed mining. It may be necessary that preventive measures are implemented, which could include the installation of cable rollers, guy wires or additional poles, or the adjustment of cable catenaries.

The previous bord and pillar total extraction in SMP Areas 1, 2 and 3 at the mine have been extracted beneath around 74 powerpoles. These powerlines were maintained in safe and serviceable conditions after the implementation of the necessary preventive measures.

Also, there is extensive experience of mining beneath powerlines in the NSW Coalfields, where the mine subsidence movements were similar to those predicted for the proposed mining, indicates that incidences of impacts is very low and of a minor nature.

6.3.4. Impact Assessments and Recommendations for the Powerlines Based on Increased Predictions

If the actual tilts at the powerlines exceeded those predicted by a factor of 2 times, the likelihoods of impacts would also increase. It would be expected, however, that the types of preventive measures would not change, although these would be more extensive.

6.3.5. Recommendations for the Powerlines

It is recommended that the predicted movements are provided to *Ausgrid* so that the necessary preventive measures can be developed, which may include the installation of cable rollers, guy wires or additional poles, or the adjustment of cable catenaries. The powerlines should also be visually monitored during active subsidence, so that they can be maintained in safe and serviceable conditions at all times.

Built Features Management Plans have been developed for the powerlines for the previous bord and pillar total extraction in SMP Areas 1, 2 and 3. It is recommended that these management strategies are reviewed and, where required, revised to incorporate the powerlines within EP / SMP Area 4. With the implementation of these management strategies, it would be expected that the powerlines can be maintained in serviceable conditions throughout the mining period.

6.4. Telecommunications Infrastructure

6.4.1. Description of the Telecommunications Infrastructure

The locations of the telecommunications infrastructure within the EP / SMP Area are shown in Drawing No. MSEC676-11.

There are direct buried copper telecommunications cables located above the proposed panels which are owned by *Telstra*. A main copper cable follows the alignment of Black Hill Road and consumer cables then service the residential properties.

There is also a telecommunications tower in the southern part of the EP / SMP Area associated with a commercial establishment, which is discussed in Section 6.11.

6.4.2. Predictions for the Telecommunications Infrastructure

The predicted profiles of conventional subsidence, tilt and curvature along the alignment of the main copper telecommunications cable along Black Hill Road are similar to those predicted along the road, which are shown in Fig. E.06, in Appendix E. The predicted total profiles along the alignment of the cable, after the extraction of each of the proposed panels, are shown as solid blue lines. The predicted total profiles after the completion of the approved Panels 23 to 26 are shown as the solid cyan lines.

A summary of the maximum predicted conventional subsidence parameters for the main copper telecommunications cable along Black Hill Road is provided in Table 6.6. The values are the maxima within the EP / SMP Area resulting from the extraction of Panels 23 to 35.

Table 6.6 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Main Copper Telecommunications Cable along Black Hill Road

Location	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})
After Panel 27	1,400	40	2.0	1.5
After Panel 28	1,450	40	2.0	1.5
After Panel 30	1,450	40	2.0	1.5
After Panel 31	1,450	40	2.0	1.5
After Panel 33	1,450	40	2.0	1.5

The maximum predicted conventional curvatures for the main copper telecommunications cable are 2.0 km^{-1} hogging and 1.5 km^{-1} sagging, which represent minimum radii of curvature of 0.5 kilometres and 0.7 kilometres, respectively. The maximum predicted conventional strains for this cable, based on applying a factor of 10 to the maximum predicted conventional curvatures, are 20 mm/m tensile and 15 mm/m compressive.

The analysis of strains measured above the previously extracted bord and pillar total extraction panels at the Abel Underground Mine is provided in Section 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.

6.4.3. Impact Assessments for the Telecommunications Infrastructure

Copper telecommunications cables can typically tolerate tensile strains of up to 20 mm/m without adverse impacts. It is possible, therefore, that the copper telecommunications cables in the northern part of the proposed mining area could be impacted as a result of the proposed mining.

The previous bord and pillar total extraction in SMP Areas 1, 2 and 3 at the mine have been extracted directly beneath around 3 kilometres of buried copper telecommunications cables. There were no reported impacts on these cables as a result of mining. The maximum observed strains along the monitoring lines above these panels were around 20 mm/m tensile and compressive.

Also, there is extensive experience of mining beneath copper telecommunications cables in the NSW Coalfields, where the mine subsidence movements were similar to those predicted for the proposed mining, indicates that incidences of impacts is extremely low and of a minor nature.

For example, copper telecommunications cables were previously mined beneath by the Whybrow Seam longwalls at South Bulga Colliery and the Beltana No. 1 Underground Mine and there were no reported impacts. The maximum observed strains, where the Beltana Longwalls 1 to 10 mined directly beneath the copper cables, were 26 mm/m tensile and 24 mm/m compressive.

Based on this experience, it is unlikely that the proposed mining would result in any significant impacts on the copper telecommunications cables within the EP / SMP Area. Any impacts on these cables would be expected to be relatively infrequent and readily repairable.

6.4.4. Recommendations for the Telecommunications Infrastructure

Built Features Management Plans have been developed for the copper telecommunications cables for the previous bord and pillar total extraction in SMP Areas 1, 2 and 3. It is recommended that these management strategies are reviewed and, where required, revised to incorporate the telecommunications infrastructure within EP / SMP Area 4. With the implementation of these management strategies, it would be expected that the telecommunications infrastructure can be maintained in serviceable conditions throughout the mining period.

6.5. Agriculture Utilisation and Agriculture Improvements

The land above the proposed panels has been partially cleared and is used for residential and light agricultural purposes, including orchards and some grazing. The agricultural utilisation could be affected by surface cracking, which is discussed in Section 4.7. The predictions, impact assessments and discussions for the rural building structures, tanks, fences and farm dams are provided in Sections 6.6, 6.7, 6.8 and 6.9, respectively.

6.6. Rural Building Structures

6.6.1. Description of the Rural Building Structures

The locations of the rural building structures within the EP / SMP Area are shown in Drawing No. MSEC676-12. These structures include sheds, garages and other non-residential building structures. There are 46 rural building structures which have been identified within the EP / SMP Area, of which nine are located directly above the proposed areas of secondary extraction. The remaining rural building structures are located within the SCZs around the principal residences or outside the extents of the proposed panels.

6.6.2. Predictions for the Rural Building Structures

The predicted conventional subsidence, tilt and curvatures for each of the building structures within the EP / SMP Area are provided in Table D.01, in Appendix D. A summary of the maximum predicted subsidence parameters for the rural building structures is provided in Table 6.7. The predicted movements are the maxima within a distance of 20 metres of each structure, at any time during or after the extraction of the proposed panels.

Table 6.7 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Rural Building Structures within the EP / SMP Area

Location (Number above the Proposed Secondary Extraction)	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})
Above Panel 27 (2 Total)	600	20	0.7	0.5
Above Panel 29 (2 Total)	850	45	> 3.0	> 3.0
Above Panel 30 (1 Total)	1,300	40	1.5	2.0
Above Panel 31 (4 Total)	1,050	50	> 3.0	> 3.0
Above Panel 32 (Nil)	25	2.0	0.2	0.02
Above Panel 34 (Nil)	25	1.0	0.1	0.03

The maximum predicted conventional curvatures for the rural building structures are greater than 3.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of less than 0.3 kilometres. The maximum predicted conventional strains for these structures, based on applying a factor of 10 to the maximum predicted conventional curvatures, are greater than 30 mm/m tensile and compressive.

The analysis of strains measured above the previously extracted bord and pillar total extraction panels at the Abel Underground Mine is provided in Section 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.

6.6.3. Impact Assessments for the Rural Building Structures

The predicted final tilts exceed 10 mm/m at Structure Refs. A01r01 and A01r02 with 20 mm/m (i.e. 2 %, or 1 in 50), at C05r04 with 40 mm/m (i.e. 4 %, or 1 in 25), at C18r01 and C18r02 with 45 mm/m (i.e. 4.5 %, or 1 in 22), and at C17r02 with 50 mm/m (i.e. 5 %, or 1 in 20). It is possible that these structures could experience serviceability impacts, including door swings and issues with roof and pavement drainage, all of which can be remediated using normal building maintenance techniques. The rural building structures are generally of light-weight construction and, therefore, it is unlikely that these structures would become unstable as the result of mining induced tilt.

The predicted final tilts at the remaining rural building structures are less than 10 mm/m (i.e. 1 %, or 1 in 100). It is unlikely that these structures would experience any serviceability impacts or have issues with stability as the result of mining induced tilt.

The predicted curvatures exceed 1 km^{-1} at Structure Refs. C05r04 with 1.5 km^{-1} hogging and 2.0 km^{-1} sagging, and at C17r01, C17r02, C17r03, C17r04, C18r01 and C18r02 with greater than 3.0 km^{-1} hogging and sagging. It is likely that some of these structures would experience impacts, including cracking or differential movement of the wall claddings and flexing or distortion of the structural frames. It is unlikely that any of these structures would become unstable due to the more flexible types of constructions. It has been found, from past mining experience, that the incidence of impacts on rural building structures is low and that any impacts can generally be remediated using normal building maintenance techniques.

The predicted curvatures at the remaining rural building structures are less than 1 km^{-1} hogging and sagging. It is unlikely that these structures would experience any substantial impacts, but could still experience some differential movement of the wall claddings and flexing or distortion of the structural frames. It would still be expected that any impacts could be remediated using normal building maintenance techniques.

6.6.4. Impact Assessments for the Rural Building Structures Based on Increased Predictions

If the actual tilts exceeded those predicted by a factor of 2 times, the maximum tilt at the rural building structures would be 100 mm/m (i.e. 10 %, or 1 in 10). In this case, the likelihood of serviceability impacts, such as door swings and issues with gutter and pavement drainage would increase primarily for Structure Refs. A01r01, A01r02, C05r04, C18r01, C18r02 and C17r02. It would still be unlikely that stabilities of these rural building structures would be affected by tilts of these magnitudes.

If the actual curvatures or strains exceeded those predicted by a factor of 2 times, the likelihood of impacts would increase primarily for Structure Refs. C05r04, C17r01, C17r02, C17r03, C17r04, C18r01 and C18r02. It would still be expected that these structures would 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.

6.6.5. Recommendations for the Rural Building Structures

It is recommended, that the rural building structures which are located above the proposed panels are inspected, as per the Abel Project Approval Statement of Commitments, to confirm the existing conditions and to determine whether any preventive measures are required, prior to mining beneath these structures. With the implementation of these management measures, it would be expected that the rural building structures could be maintained in safe and serviceable conditions during and after the proposed mining.

6.7. Tanks

The properties within the EP / SMP Area have water storage tanks which collect rainwater from the roofs of the principal residences (i.e. houses) and the sheds (i.e. rural building structures).

The tanks adjacent to the principal residences are located within the subsidence control zones, which limits mining to first workings beneath the principal residence. It is unlikely, therefore, that these water tanks would experience any adverse impacts as a result of the proposed mining.

The tanks adjacent to the rural structures could experience subsidence movements similar to these structures, which were summarised in Section 6.6.2. The tanks are typically resting on the natural ground and, therefore, are unlikely to experience adverse impacts from the curvatures and ground strains resulting from the proposed panels.

It is possible, that any buried water pipelines associated with the tanks within the EP / SMP 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 readily repaired.

Property (Built Features) Management Plans will be developed for the properties within the EP / SMP Area, to manage any potential impacts on these tanks or associated infrastructure.

6.8. Fences

The fences are located across the EP / SMP Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence parameters within the EP / SMP Area is provided in Chapter 4.

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 EP / SMP Area would be impacted as the result of the extraction of the proposed panels. Any impacts on the wire fences could be remediated by re-tensioning the fencing wire, straightening the fence posts, and if necessary, replacing some sections of fencing.

6.9. Farm Dams

6.9.1. Description of the Farm Dams

The locations of the farm dams within the EP / SMP Area are shown in Drawing No. MSEC676-13.

There are 38 farm dams which have been identified within the EP / SMP Area, of which 32 are located partially or fully above the proposed areas of secondary extraction. The remaining farm dams are located within the SCZs around the principal residences or outside the extents of the proposed panels.

The farm dams are typically of earthen construction and have been established by localised cut and fill operations along the tributaries. The heights of the dam walls are typically less than 5 metres, but are greater than 10 metres at Farm Dam Refs. C10d01 and D02d01.

The largest farm dam is Ref. D02d01, which is located above the northern ends of the proposed Panels 33 and 35, and has a surface area of 31,400 m^2 and a maximum plan dimension of 295 metres. Photographs of this dam are provided in Fig. 6.7.

The remaining farm dams within the EP / SMP Area have surface areas ranging between 60 m^2 and 5,500 m^2 and maximum plan dimensions ranging between 15 metres and 160 metres. Photographs of the typical farm dams within the EP / SMP Area are provided in Fig. 6.8.

Fig. 6.7 Photographs of Farm Dam Ref. D02d01

Fig. 6.8 Photograph of Typical Farm Dams

6.9.2. Predictions for the Farm Dams

The predicted conventional subsidence, tilt and curvatures for each of the farm dams within the EP / SMP Area are provided in Table D.04, in Appendix D. A summary of the maximum predicted subsidence parameters for these dams is provided in Table 6.8. The parameters provide in this table are the maximum values within 20 metres of the perimeters of the dams, at any time during or after the extraction of the proposed panels.

Table 6.8 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Farm Dams within the EP / SMP Area

Location (Number above the Proposed Secondary Extraction)	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})
Above Panel 27 (1 Total)	1,400	40	2.5	2.0
Above Panel 28 (3 Total)	600	15	0.6	0.9
Above Panel 30 (7 Total)	1,400	45	> 3.0	> 3.0
Above Panel 31 (2 Total)	1,100	50	> 3.0	> 3.0
Above Panel 32 (6 Total)	1,400	35	2.5	2.5
Above Panel 33* (2 Total)	1,350	70	> 3.0	> 3.0
Above Panel 34 (7 Total)	450	50	2.0	2.0
Above Panel 35* (5 Total)	1,350	70	> 3.0	> 3.0

Note: * denotes that Dam Ref. D02d01 is located above both the proposed Panels 33 and 35 and has been included in the results for both these panels.

The maximum predicted conventional curvatures for the farm dams are greater than 3.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of less than 0.3 kilometres. The maximum predicted conventional strains for these dams, based on applying a factor of 10 to the maximum predicted conventional curvatures, are greater than 30 mm/m tensile and compressive.

The analysis of strains measured above the previously extracted bord and pillar total extraction panels at the Abel Underground Mine is provided in Section 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.

6.9.3. Impact Assessments for the Farm Dams

The predicted final tilts for the farm dams located directly above the proposed panels vary up to 70 mm/m (i.e. 7 %, or 1 in 14). 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.

The predicted changes in freeboard for the farm dams have been 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 final changes in freeboard for the farm dams within the EP / SMP Area are provided in Table D.04, in Appendix D. A summary of the maximum predicted changes in freeboard for the farm dams within the EP / SMP Area is provided in Table 6.9.

Table 6.9 Maximum Predicted Changes in Freeboard for the Farm Dams within the EP / SMP Area

Predicted Final Change in Freeboard (mm)	Number of Farm Dams	Dam Refs.
< 50	17	C01d03, C04d01, C04d03, C04d04, C04d05, C04d06, C04d07, C07d04, C08d01, C11d01, C13d01, C14d01, C15d01, C17d01, D01d01, D01d03 and D01d05
50 ~ 250	12	C01d02, C04d02, C04d08, C04d09, C09d01, C09d04, C09d06, C10d01, C10d02, C10d03, D01d02 and D04d01
250 ~ 500	1	A02d05
500 ~ 750	3	A02d04, C07d01 and C09d03
750 ~ 1,000	2	C16d01 and D03d01
1,000 ~ 1,250	4	C01d01, C05d01, C09d02 and C09d05
1,250 ~ 1,500	4	C07d02, C07d03, D02d01 and D04d02

It can be seen from the above table, that there are eight farm dams predicted to have changes in freeboard greater than 1.0 metre and a further five dams with predicted changes in freeboard between 0.5 metres and 1.0 metre. It is possible that the storage capacities of some of these farm dams could reduce as a result of the proposed mining. If the storage capacities of any farm dams were adversely affected, they could be re-established by raising the earthen walls, if required.

The farm dams within the EP / SMP Area are predicted to experience curvatures up to and greater than 3.0 km^{-1} hogging and sagging and strains up to and greater than 30 mm/m tensile and compressive. A summary of the maximum predicted conventional curvatures and conventional strains for the farm dams is provided in Table 6.10.

Table 6.10 Maximum Predicted Conventional Curvatures and Conventional Strains for the Farm Dams within the EP / SMP Area

Maximum Predicted Conventional Curvature and Strain	Number of Farm Dams	Dam Refs.
< 1.0 km^{-1} curvature < 10 mm/m strain	23	A02d05, C01d02, C01d03, C04d01, C04d02, C04d03, C04d04, C04d05, C04d06, C04d07, C04d08, C04d09, C07d04, C08d01, C10d01, C10d02, C11d01, C13d01, C14d01, C15d01, D01d01, D01d03 and D01d05
1.0 ~ 2.0 km^{-1} curvature 10 ~ 20 mm/m strain	12	A02d04, C01d01, C07d01, C07d02, C09d01, C09d02, C09d03, C09d04, C09d05, C09d06, D04d01 and D04d02
2.0 ~ > 3.0 km^{-1} curvature 20 ~ > 30 mm/m strain	8	C05d01, C07d03, C10d03, C16d01, C17d01, D01d02, D02d01 and D03d01

It is expected, at the higher magnitudes of the predicted curvatures and strains, that the farm dams could be affected by cracking, heaving or stepping in the bases or the dam walls. It is also likely that fracturing and buckling uppermost bedrock would occur beneath these farm dams.

There is also a possibility that high concentrations of strain could occur at faults, fissures and other geological features, or points of weaknesses in the strata, and such occurrences could be coupled with localised stepping in the surface. If this type of phenomenon coincided with a farm dam wall, then, there is a possibility that cracking in the dam wall or base could occur resulting in loss of the stored water.

The farm dams which are at higher risk from surface cracking are those located in the final tensile zones (i.e. inside the perimeters of the proposed secondary extraction) and where the depths of cover are less than 100 metres, which are Dam Refs. C07d03, C16d01, D02d01 and D03d01. Other dams which are located within the final tensile zone, at higher depths of cover, could also be affected by surface cracking but to a lesser extent.

Surface cracking or leakages in the farm dams could be identified by visual inspections and remediated by re-instating the bases and walls of the dams with cohesive materials. Any loss of stored water from the farm dams would flow into the drainage line in which the dam was formed. The mine would provide an alternative water source until such time that the Mine Subsidence Board completes the necessary repairs.

As described in Section 4.8, continuous cracking (i.e. the *A Horizon*) could extend from the seam up to the surface where the depths of cover are shallowest above the northern and central parts of the proposed mining area. Extensometer measurements at the nearby West Wallsend Colliery indicate that the caved zone extended 71 metres above the West Borehole Seam (DoPI, 2012). It is possible, therefore, that stored water could be lost into the workings from Dam Refs. C16d01 and D02d01.

The dam at greatest risk of the loss of stored water is Dam Ref. D02d01, as it is by far the largest dam within the EP / SMP Area and it is located directly above the secondary extraction at the shallowest depth of cover. The consequences of loss of stored water are also the highest, due to the large volume of water which could flow into the downstream tributary beneath John Renshaw Drive or flow into the mine.

It is recommended that detailed management strategies and monitoring are developed for Dam Ref. D02d01, which could include the following:

- Geotechnical investigation and assessment of the existing condition of the dam wall;
- Installation of piezometers and/or extensometers at the northern end of the proposed Panel 29 to measure the height of fracturing above the seam;
- Assess of the capacity of the drainage culverts beneath John Renshaw Drive;
- Undertake a risk assessment for this dam for loss of water from the dam wall;
- Undertake a Clause 88 assessment for the loss of water into the mine;
- Review the extent of secondary extraction beneath the dam based on the geotechnical investigation, the results of the piezometers and/or extensometer and the outcomes of the risk assessments;
- Develop a detailed monitoring program for the dam, including visual, surface water level and ground monitoring; and
- Develop a Trigger Action Response Plan (TARP) based on the detailed monitoring.

Further impact assessments and recommendations for the farm dams are provided by the specialist surface water consultant (Evans and Peck, 2014).

6.9.4. Recommendations for the Farm Dams

Dam Monitoring management strategies will be developed for the larger farm dams which are located directly above the proposed panels, which could include lowering the stored water levels prior to mining directly beneath them. It is also recommended that the farm dams are visually monitored, during active subsidence, such that any impacts can be identified and remediated accordingly.

As part of Donaldson Coal's commitments for the Abel Underground Mine, Donaldson Coal will develop a Dam Monitoring and Management Strategy (DMMS) for dams prior to any mining which will potentially impact on the dams.

6.10. Groundwater Bores

There are no registered groundwater bores within the EP / SMP Area, based on the information obtained from the Department of Natural Resources using the *Natural Resource Atlas* website (NRAtlas, 2014).

6.11. Business Establishments

The following sections provide discussions for the business and commercial establishments which are located within the EP / SMP Area. Property Subsidence Management Plans (PSMPs) will be developed for each of the establishments to manage the potential impacts resulting from the proposed mining.

6.11.1. Commercial Orchard on Property C04

A commercial orchard has been established on Property C04 (Lot 611 DP1035588), which is located above the proposed Panels 27, 28 and 30. The locations of the orchards are shown in Drawing No. MSEC676-12 and photographs are provided in Fig. 6.9. Farm dams C04d01 to C04d09 are also associated with the commercial orchard.

Fig. 6.9 Photograph of the Commercial Orchard

The impact assessments for the rural building structures, tanks, fences and farm dams on the property are included in Sections 6.6, 6.7, 6.8 and 6.9, respectively. If there are any adverse impacts on the farm dams, the mine would provide an alternative water source until such time that the Mine Subsidence Board repairs the affected dams.

Extensive experience from mining in the NSW Coalfields shows that the incidence of impacts on trees is extremely rare. Impacts on trees have only been previously observed where the depths of cover were extremely shallow, in the order of 50 metres or less, or on very steeply sloping terrain, in the order of 1 in 1 or greater. It is unlikely that the trees in the commercial orchard would be impacted by the proposed mining, as the depths of cover are greater than 125 metres and the natural surface slopes are less than 1 in 2.

6.11.2. Wine Cellar on Property C02

A wine cellar has been established in Rural Building Structure Ref. C02r01, which is located above the proposed Panel 28. The structure is an industrial shed which is designed for fork lift and commercial storage loads. The ground slab is supported on piers down to bedrock. The location of the shed is shown in Drawing No. MSEC676-12 and a photograph is provided in Fig. 6.10.

Fig. 6.10 Photograph of the Rural Building Structure C02r01

The structure is located within the SCZ for the adjacent principal residence. The maximum predicted movements for this structure are less than 20 mm vertical subsidence, less than 0.5 mm/m tilt and less than 0.01 km^{-1} curvature. It is unlikely, therefore, that this structure would experience any adverse impacts, even if the predictions were exceeded by a factor of 2 times.

6.11.3. Transport Business on Property C12

A transport business has been established on Property C12, which is located to the west of the proposed Panel 34. The business includes the sheds C12r01 and C12r02, diesel storage tanks and a telecommunications tower. The location of this property is shown in Drawing No. MSEC676-12 and a photograph is provided in Fig. 6.11.

Fig. 6.11 Photograph of the Transport Business

The structures are located within the SCZ for the adjacent principal residence. The maximum predicted movements are less than 20 mm vertical subsidence, less than 0.5 mm/m tilt and less than 0.01 km^{-1} curvature. It is unlikely, therefore, that these structures would experience any adverse impacts, even if the predictions were exceeded by a factor of 2 times.

The tower has microwave dishes which can be very sensitive to tilt. It is recommended that a telecommunications engineer inspects the tower and that strategies are developed to adjust these dishes, if required, during active subsidence.

6.12. Archaeological Sites

6.12.1. Description of the Archaeological Sites

There are four archaeological sites which have been identified within the EP / SMP Area, which are shown in Drawing No. MSEC676-13. A summary of these sites is provided in Table 6.11.

Table 6.11 Archaeological Sites within the EP / SMP Area

Site Ref.	Site Name	Type	Location
38-4-0106	Black Hill Open Site	Open Artefact Site	Directly above Panel 32
38-4-0669	FMC7 Donaldson Mine	Open Artefact Site	Directly above West Mains
38-4-0670	FMC8 Donaldson Mine	Scarred Tree	Directly above Panel 29
CA7	CA7	Open Artefact Site	Directly above West Mains

There is also a cultural place (i.e. area of cultural sensitivity) identified within the EP / SMP Area, which is shown in Drawing No. MSEC676-13. The *Black Hill Pathway* is partially located within the EP / SMP Area and above the southern end of the proposed Panel 32.

Further descriptions of the archaeological sites and cultural places are provided in the report prepared by South East Archaeology (SEA, 2014).

6.12.2. Predictions for the Archaeological Sites

A summary of the maximum predicted subsidence, tilt and curvatures for the archaeological sites and cultural place is provided in Table 6.12. The parameters provide are the maximum values within a 20 metre radius of the sites. The tilt and curvatures are the maxima at any time during or after the completion of mining.

Table 6.12 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Archaeological Sites and Cultural Place within the EP / SMP Area

Site Name	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})
38-4-0106	525	12	0.2	0.1
38-4-0669	< 20	< 0.5	< 0.01	< 0.01
38-4-0670	950	0.5	> 3.0	> 3.0
CA7	< 20	< 0.5	< 0.01	< 0.01
Black Hill Pathway	700	11	0.2	0.3

The maximum predicted conventional curvatures for Site 38-4-0670 are greater than 3.0 km^{-1} hogging and sagging, which represents a minimum radius of curvature of less than 0.3 kilometres. The maximum predicted conventional curvatures for Site 38-4-0106 and the Black Hill Pathway are 0.2 km^{-1} hogging and 0.3 km^{-1} sagging, which represent minimum radii of curvature of 5 kilometres and 3 kilometres, respectively. The maximum predicted conventional curvatures for Sites 38-4-0669 and CA7 are less than 0.01 km^{-1} hogging and sagging, which represents a minimum radius of curvature greater than 100 kilometres.

The maximum predicted conventional strains, based on applying a factor of 10 to the maximum predicted conventional curvatures, are greater than 30 mm/m tensile and compressive for Site 38-4-0670, 2 mm/m tensile and 3 mm/m compressive for Site 38-4-0106 and the Black Hill Pathway, and less than 0.3 mm/m tensile and compressive for Sites 38-4-0669 and CA7.

The analysis of strains measured above the previously extracted bord and pillar total extraction panels at the Abel Underground Mine is provided in Section 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.

6.12.3. Impact Assessments for the Archaeological Sites

Sites 38-4-0106, 38-4-0669 and CA7 are Open Artefact Sites. Site 38-4-0106 is located directly above the proposed Panel 32 and, therefore, could potentially be affected by cracking of the surface soils as a result of mine subsidence movements. The other two sites are located outside the extents of secondary extraction and, therefore, are unlikely to be affected by surface cracking.

Discussions on the potential for surface deformations resulting from the proposed mining are provided in Section 4.7. It is unlikely, that the scattered artefacts or isolated finds themselves would be impacted by surface cracking.

Site 38-4-0670 is a Scarred Tree which is located directly above the proposed Panel 29. Extensive experience from mining in the NSW Coalfields shows that the incidence of impacts on trees is extremely rare. Impacts on trees have only been previously observed where the depths of cover were extremely shallow, in the order of 50 metres or less, or on very steeply sloping terrain, in the order of 1 in 1 or greater. It is unlikely that the Scarred Trees would be impacted by the proposed mining, as the depth of cover is around 60 metres and the natural surface slopes are less than 1 in 3.

Further discussions on the potential impacts on the archaeological sites are provided in the report by the specialist archaeological consultant (SEA, 2014).

6.12.4. Impact Assessments for the Cultural Places

The cultural places identified within the EP / SMP Area are the Black Hill Pathway. The potential impacts on the cultural places include surface cracking and deformations (refer to Sections 4.7 and 5.4) and changes in surface water drainage (refer to Sections 5.1, 5.6, 5.8 and 5.9). Further discussions on the potential impacts on the cultural places are provided in the report specialist archaeological consultant (SEA, 2014).

6.12.5. Recommendations for the Archaeological Sites and Cultural Places

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

6.13. State Survey Control Marks

The locations of the state survey control marks in the vicinity of the proposed panels are shown in Drawing No. MSEC676-13. The survey control mark located directly above the proposed panels could experience the full range of predicted subsidence movements, which were described in Chapter 4. The survey control marks located in the immediate area could be affected by far-field horizontal movements, up to 3 kilometres outside the extents of the proposed mining 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 proposed panels, when the ground has stabilised, to re-establish any survey control marks that are required for future use. Consultation between Donaldson Coal and the Department of Lands will be required to ensure that these survey control marks are reinstated at the appropriate time, as required.

6.14. Principal Residences

6.14.1. Description of the Principal Residences

There are 15 principal residences (i.e. privately owned houses) which have been identified within the EP / SMP Area. The locations of the principal residences are shown in Drawing No. MSEC676-12 and details are provided in Table 6.13. The properties are not located within a declared Mine Subsidence District.

Table 6.13 Details of the Principal Residences within the EP / SMP Area

Structure Reference	Number of Storeys	Wall Construction			Footings		Roof Construction	
		Brick	Timber Framed	Slab on Ground	Suspended	Combination	Tiles	Metal
C01h01	1	✓			✓		✓	
C02h01	1		✓		✓			✓
C03h01	1	✓			✓		✓	
C04h01	1		✓		✓		✓	
C05h01	1	✓		✓			✓	
C06h01	1	✓			✓			✓
C07h01	1	✓			✓			✓
C08h01	1	✓		✓				✓
C09h01	1		✓		✓			✓
C10h01	1		✓		✓			✓
C11h01	1		✓		✓		✓	
C12h01	1	✓				✓	✓	
C13h01	1		✓		✓			✓
C14h01	1		✓		✓			✓
C15h01	1	✓				✓	✓	

There are also four houses which are owned by mine, being Structure Refs. A01h01, C16h01, C17h01 and C18h01, which are located directly above the approved Panel 26 and the proposed Panels 29 and 31.

6.14.2. Predictions for the Principal Residences

The Project Approval 05-0136 MOD 3 requires Donaldson Coal to *"limit mining operations to first workings beneath, and ensure mining causes no subsidence requiring mitigation works"* for principal residences (i.e. privately owned houses). Subsidence control zones have been established around each of the principal residences, based on 26.5 degree angle of draw lines, which are shown in Drawing No. MSEC676-12.

The predicted conventional subsidence, tilt and curvatures for each of the principal residences within the EP / SMP Area are provided in Table D.01, in Appendix D. A summary of the maximum predicted subsidence parameters for these structures is provided in Table 6.14. The predicted movements are the maxima within a distance of 20 metres of each structure, at any time during or after the extraction of the proposed panels.

Table 6.14 Maximum Predicted Total Conventional Subsidence, Tilt and Curvatures for the Principal Residences within the EP / SMP Area

Locations	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})
Principal Residences	< 20	< 0.5	< 0.01	< 0.01

The maximum predicted conventional hogging and sagging curvatures for the principal residences are both less than 0.01 km^{-1}, which represents a minimum radius of curvature greater than 100 kilometres. The maximum predicted conventional strains for these structures, based on applying a factor of 10 to the maximum predicted conventional curvatures, are less than 0.3 mm/m tensile and compressive (i.e. less than the order of survey tolerance).

The three houses owned by the mine could be directly mined beneath (i.e. secondary extraction) by the proposed Panels 29 and 31. The maximum predicted movements for these structures are 1,050 mm subsidence, 50 mm/m tilt and greater than 3.0 km^{-1} hogging and sagging curvatures.

6.14.3. Impact Assessments for the Principal Residences

The principal residences are predicted to experience less than 20 mm of vertical subsidence. Whilst these structures could experience some low level subsidence, they would not be expected to experience any significant tilts, curvatures or strains. It is unlikely, therefore, that the principal residences would be adversely impacted, even if the predictions were exceeded by a factor of 2 times. That is, it is not anticipated that impacts would occur to the principal residences which would require mitigation or remedial works.

The three houses owned by the colliery could experience substantial impacts if secondary extraction were to occur directly beneath these structures. It is recommended that these houses are vacated (i.e. not occupied) during active subsidence and are remediated prior to the structures being re-tenanted.

6.14.4. Recommendations for the Principal Residences

It is recommended that the principal residences are periodically visually monitored when secondary extraction is occurring in the vicinity of the structures. It is also recommended, that Built Features Management Plans are developed for the properties within the EP / SMP Area, to manage any potential impacts on infrastructure associated with the principal residences.

6.15. Infrastructure Associated with the Principal Residences

The properties within the EP / SMP Area also have other non-residential buildings and infrastructure. The descriptions, predictions and impact assessments for the rural building structures, tanks, fences and farm dams are provided in Sections 6.6, 6.7, 6.8 and 6.9, respectively.

There are three privately owned swimming pools which are located within the EP / SMP Area, being Structure Refs. C05p01, C06p01 and C14p01. These pools are all located within the SCZ associated with the adjacent principal residences. The maximum predicted movements for these pools are less than 20 mm vertical subsidence, less than 0.5 mm/m tilt and less than 0.01 km^{-1} curvature. It is unlikely, therefore, that these pools would experience any adverse impacts, even if the predictions were exceeded by a factor of 2 times.

There is also one pool which is owned by the mine, being Structure Ref. C17p01, which is located above the area of secondary extraction for the proposed Panel 29. It is very likely that this pool would be adversely impacted as a result of the proposed mining.

Other infrastructure on the private properties include water storage tanks, septic tanks and driveways. The potential impacts on this infrastructure can managed with the implementation of Built Features Management Plans.

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	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 movements 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	The 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 built 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 built 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	Upsidence results from the dilation or buckling of near surface strata at or near the base of the valley. The term uplift is used for the cases where the ground level is raised above the pre-mining level, i.e. when the upsidence is greater than the subsidence. 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

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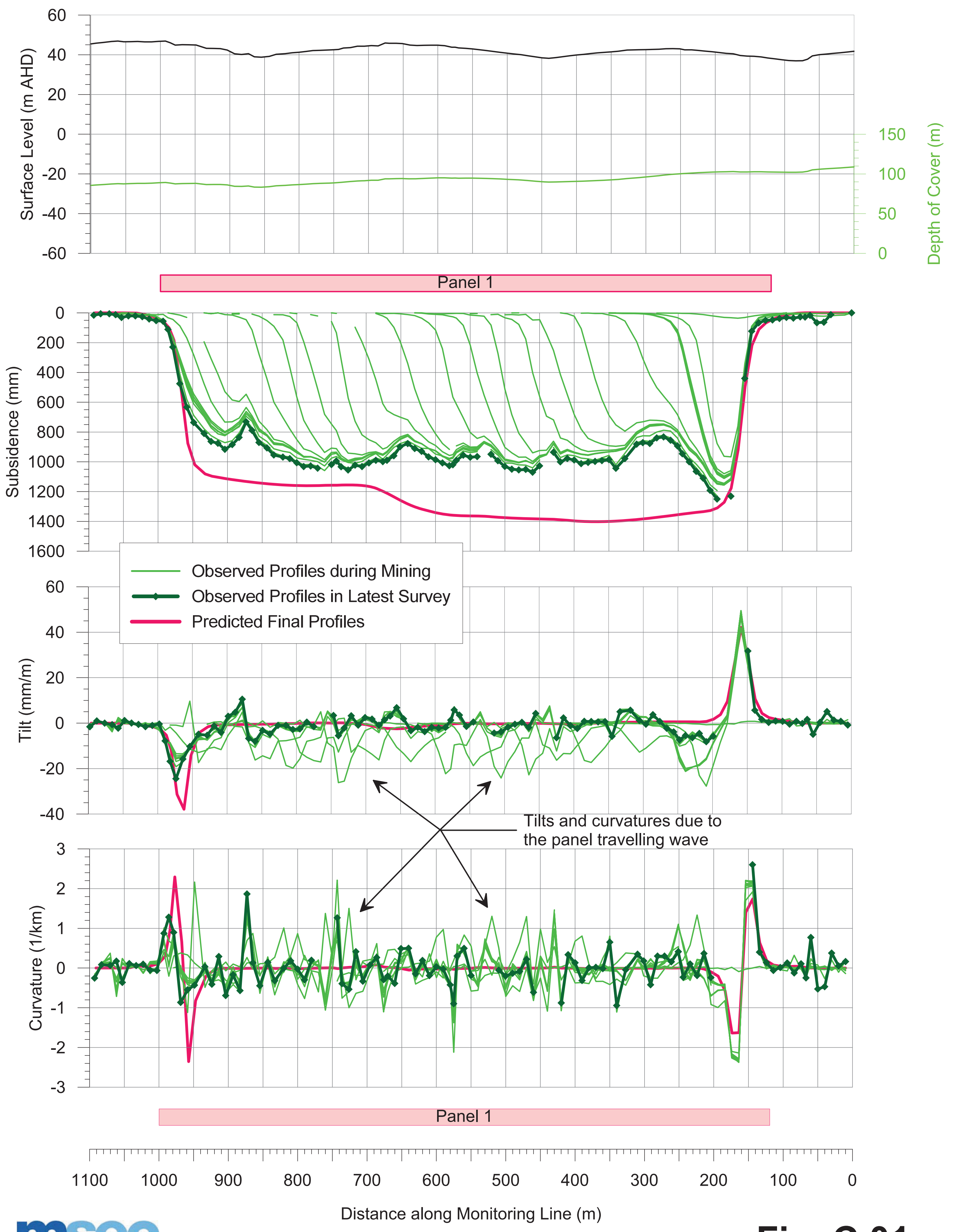
APPENDIX C. COMPARISONS BETWEEN OBSERVED AND PREDICTED MINE SUBSIDENCE MOVEMENTS AT THE ABEL UNDERGROUND MINE

I:\Projects\Donaldson\MSEC676 - Abel SMP Area 4 - SMP Application\Subsdata\SurveyData\Fig. C.01 - Panel 1 Centreline.grf

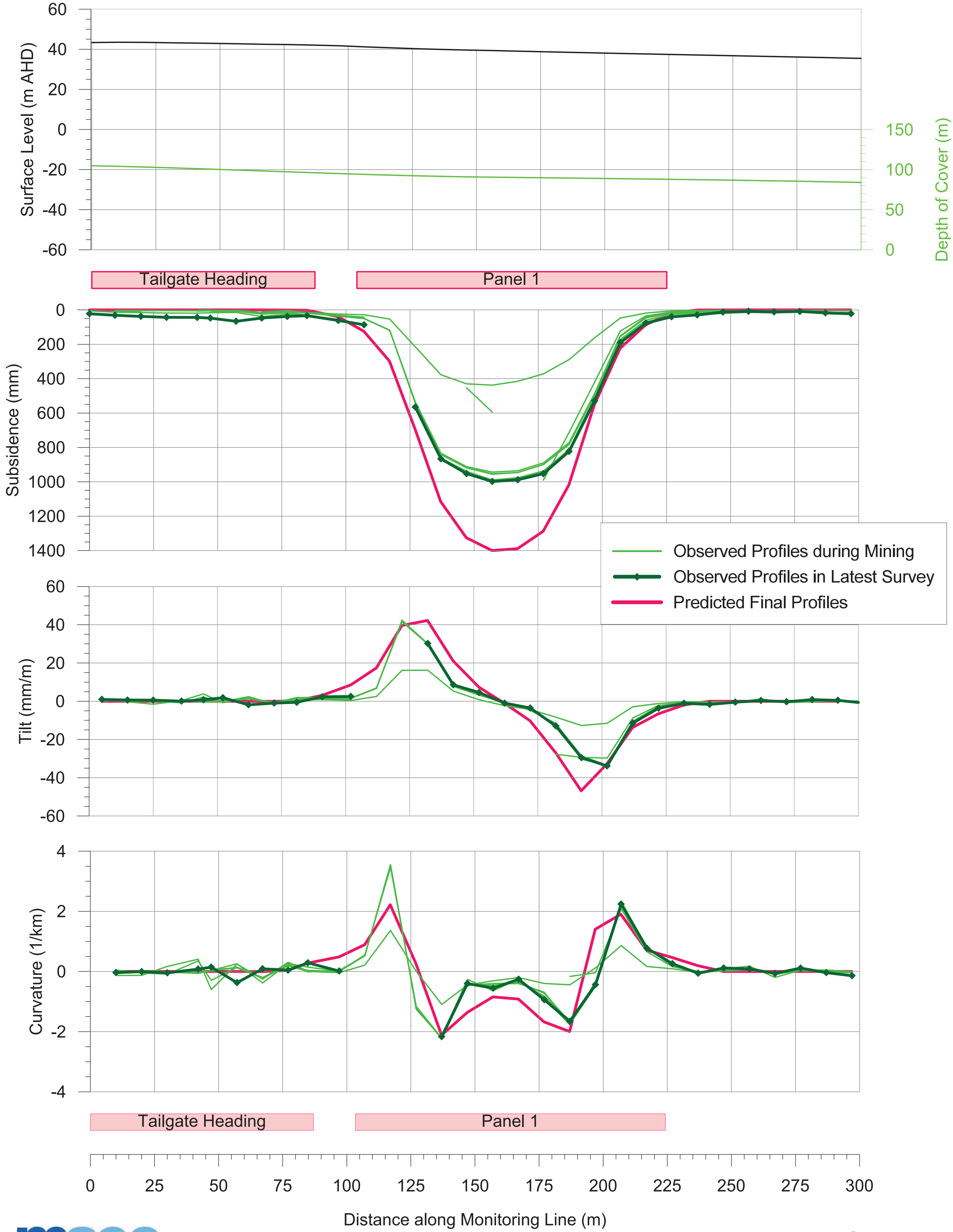
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 1 Centreline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.01

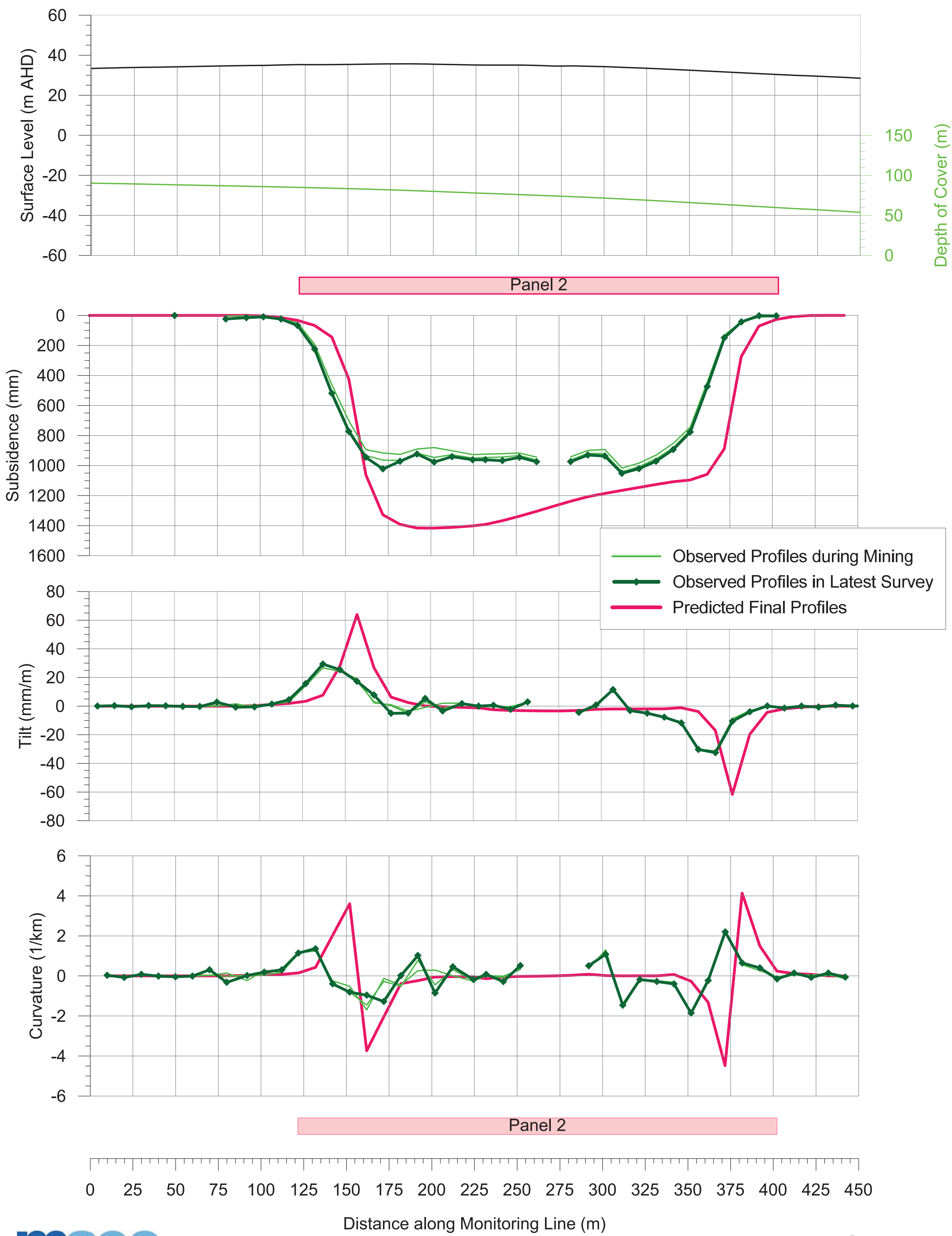
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 1 Crossline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.02

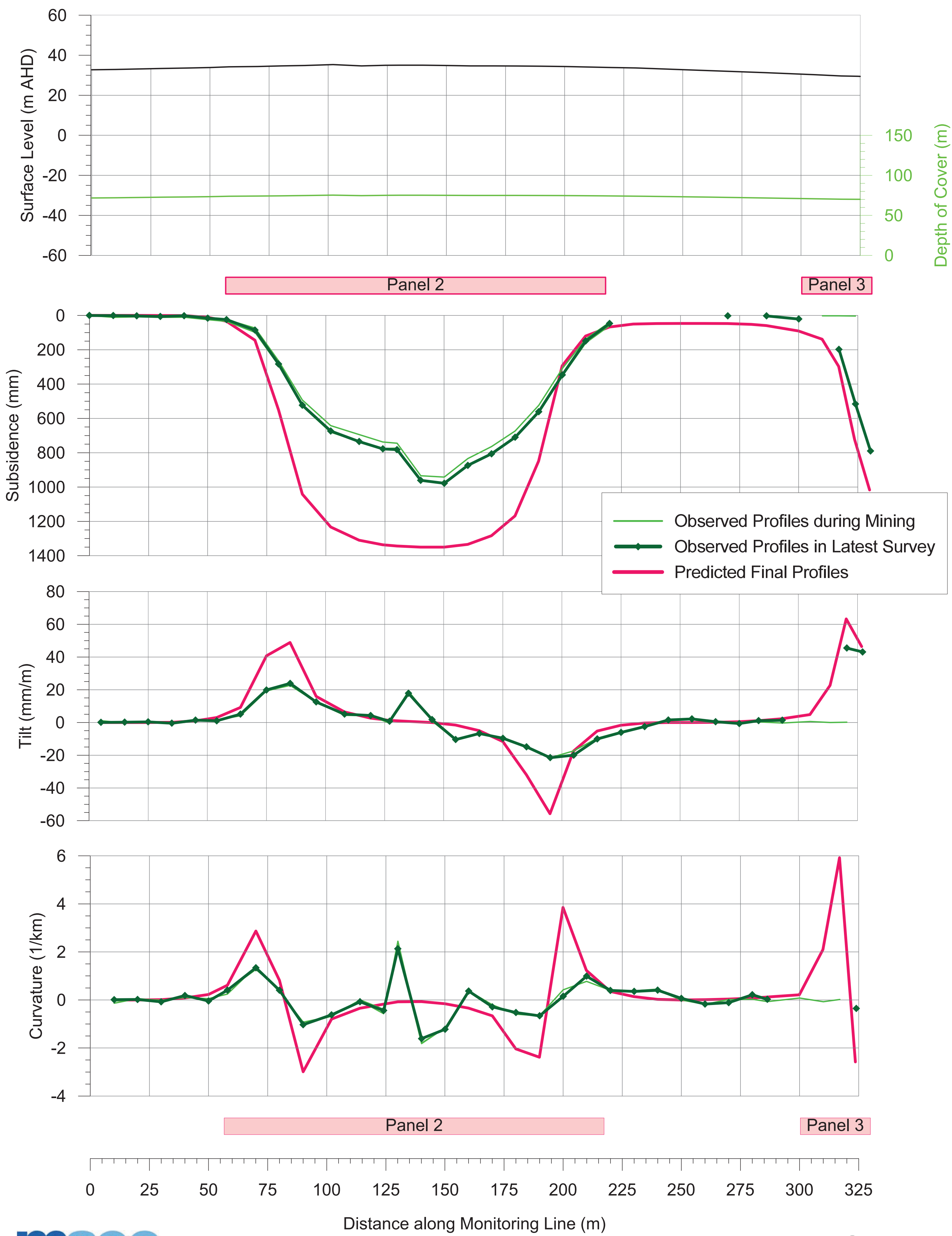
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 2 Centreline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.03

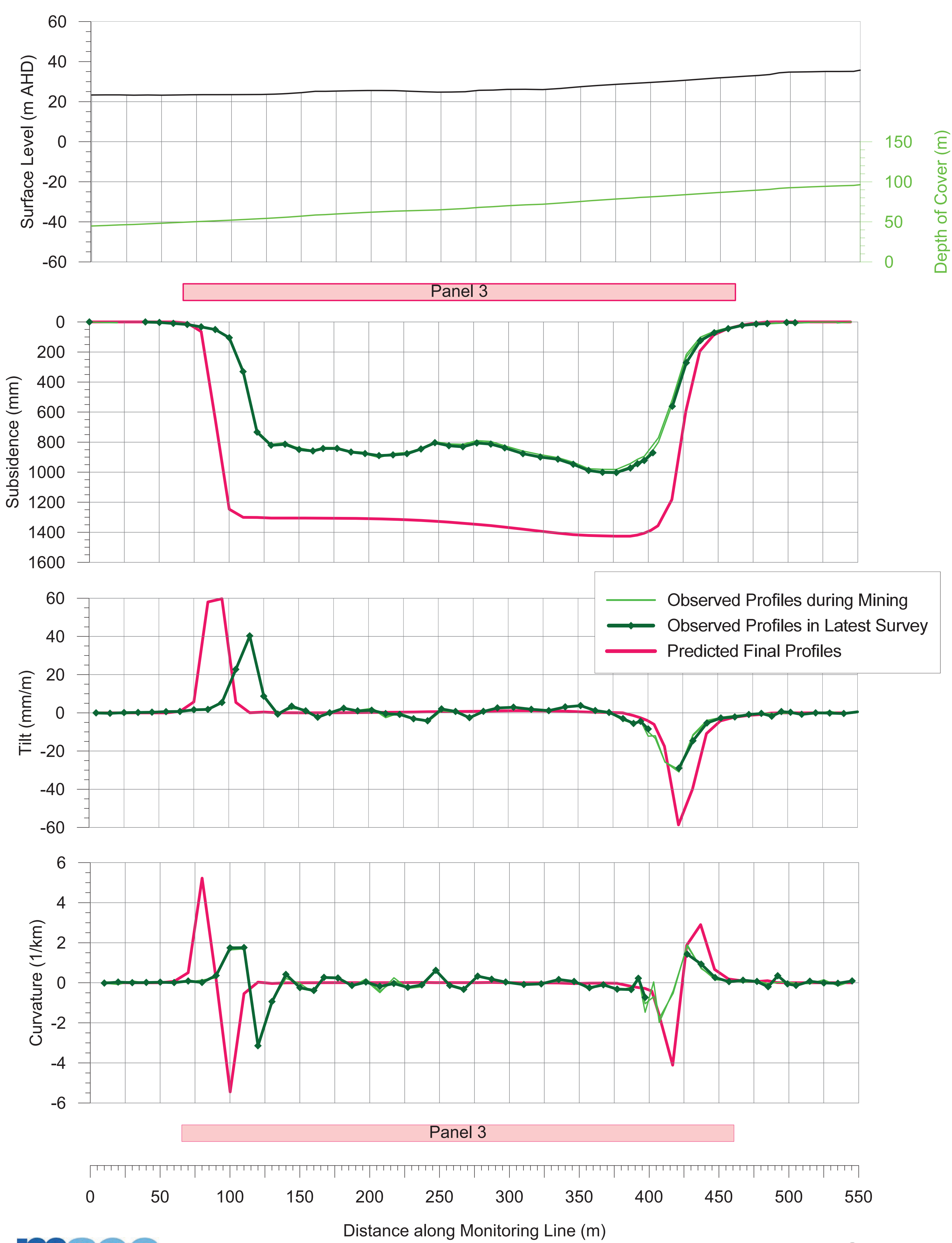
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 2 Crossline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.04

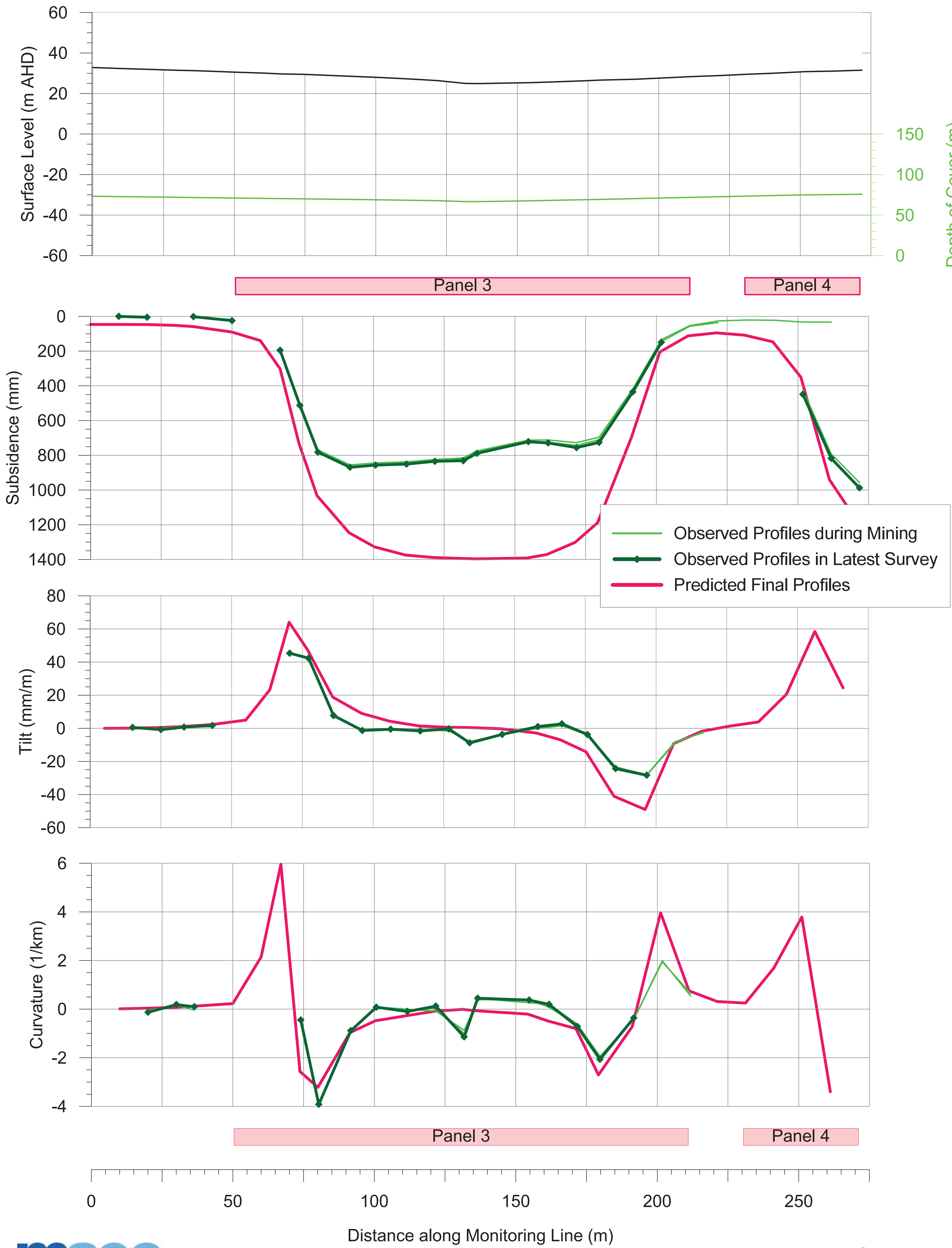
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 3 Centreline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.05

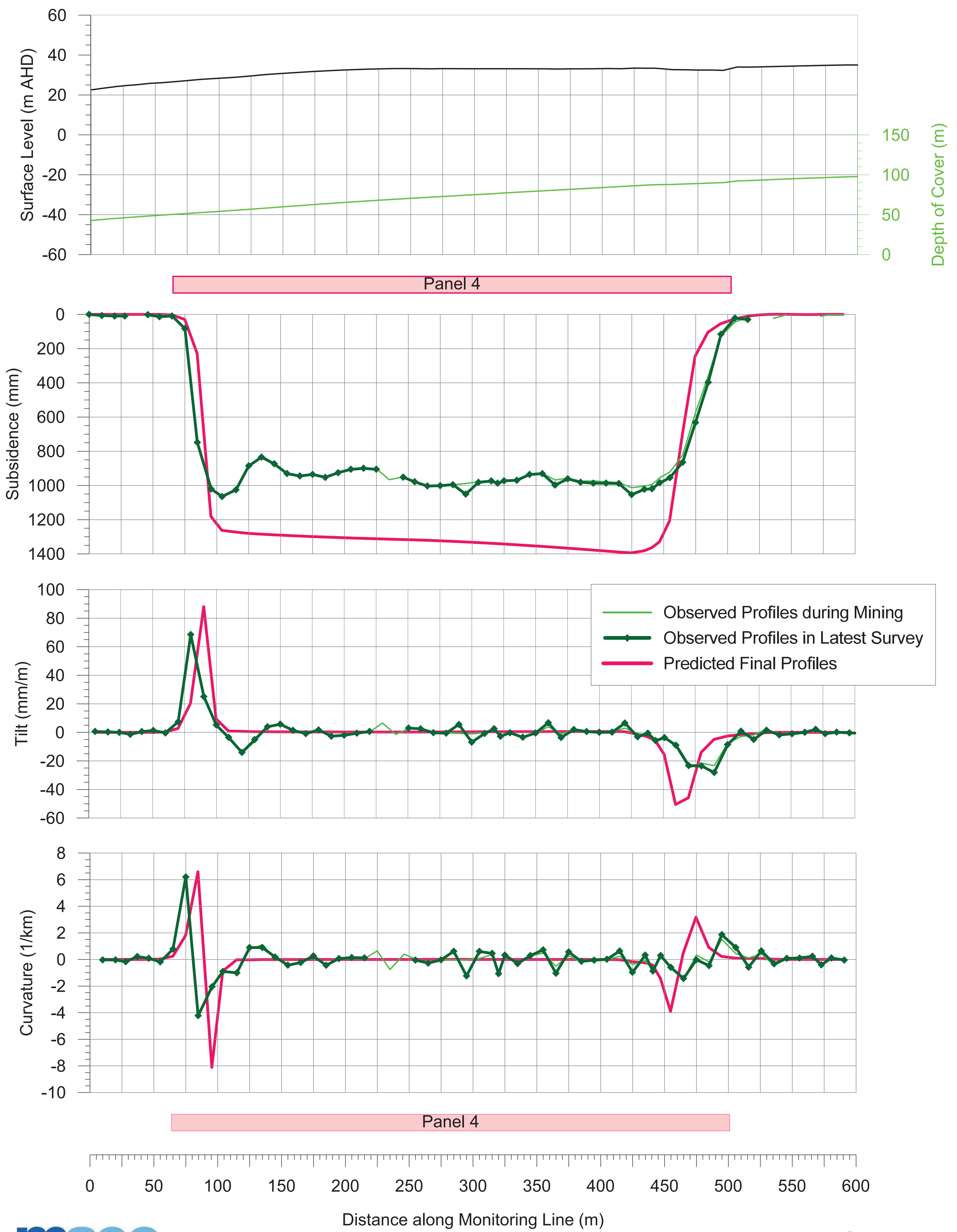
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 3 Crossline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.06

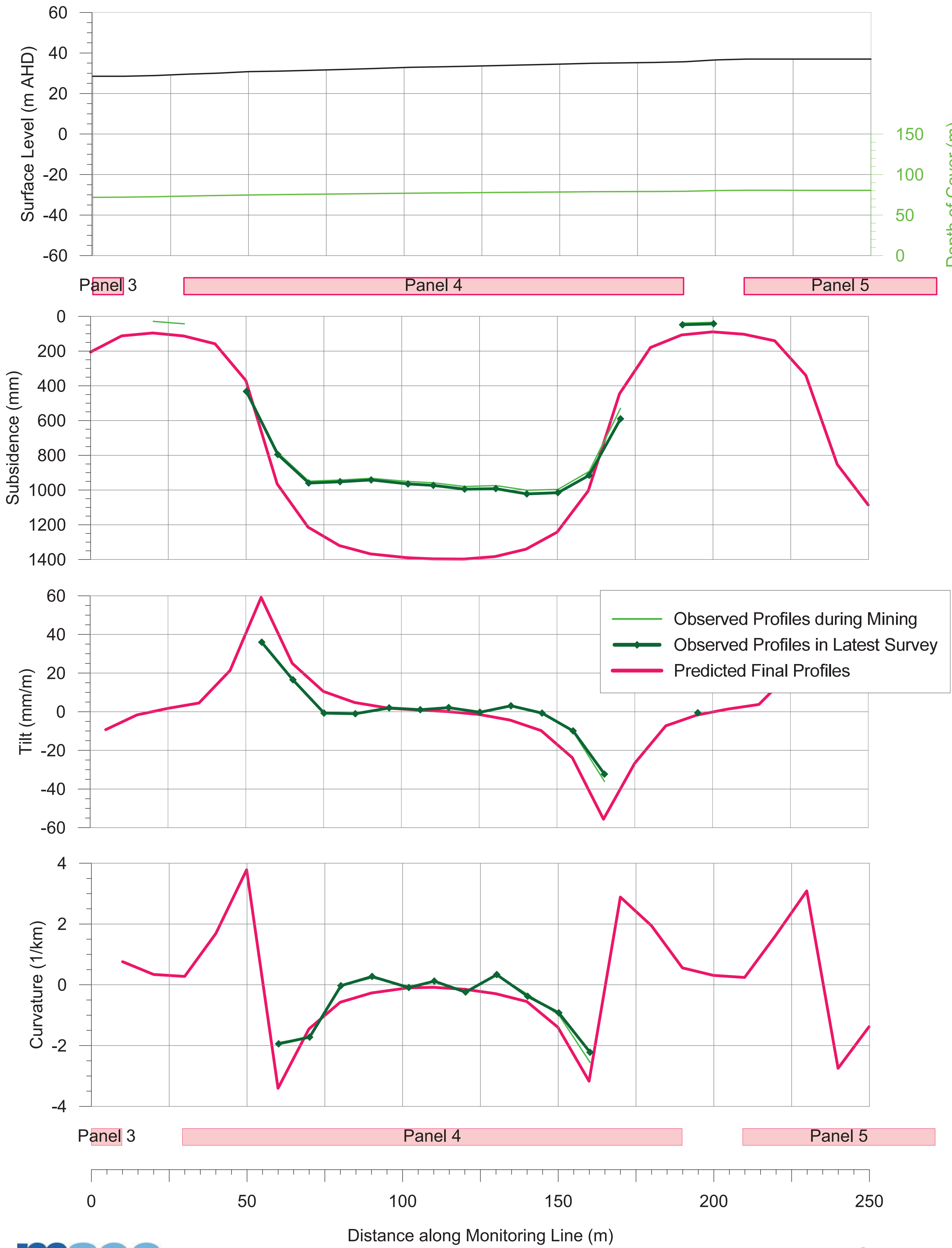
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 4 Centreline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.07

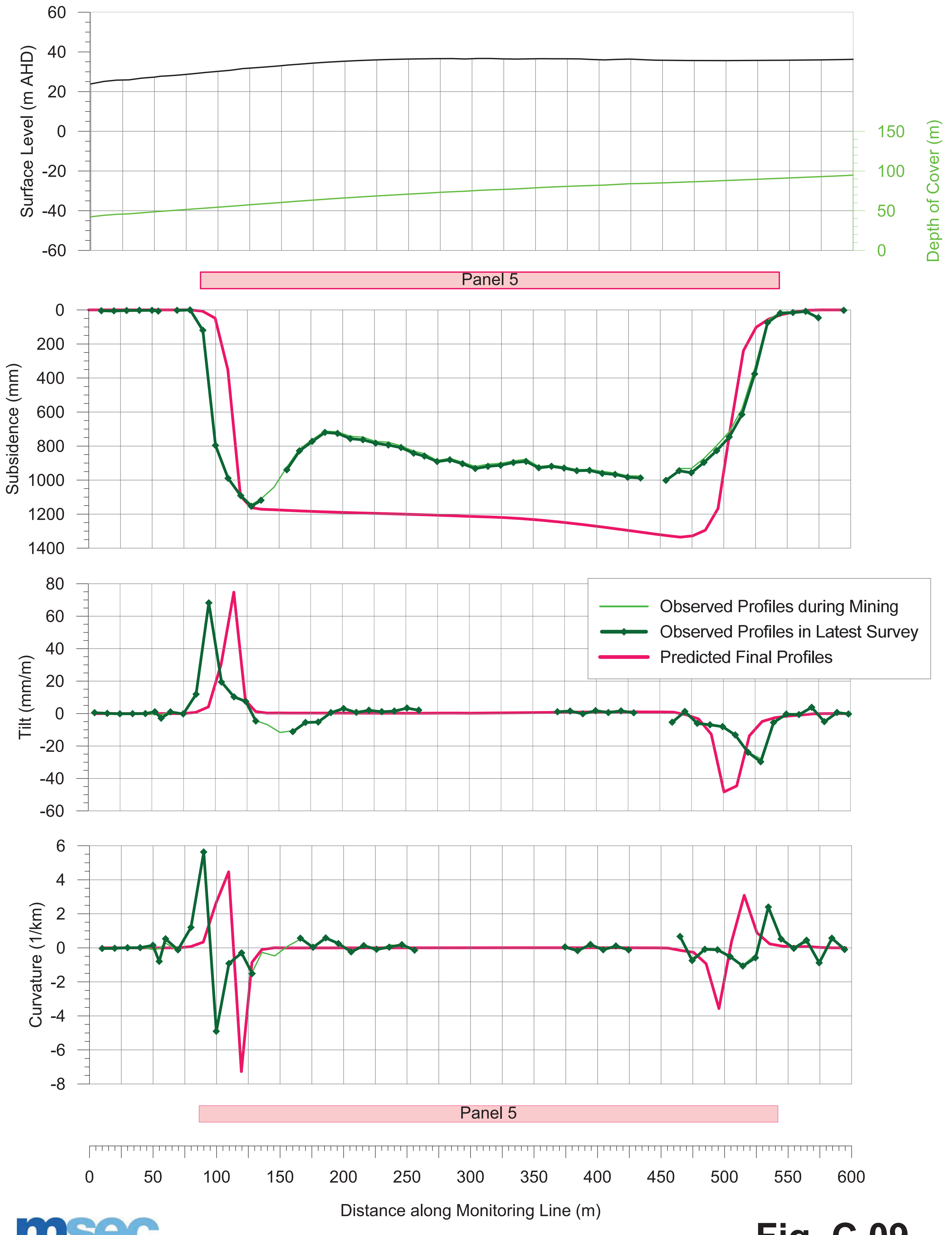
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 4 Crossline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.08

Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 5 Centreline in SMP Area 1 at the Abel Underground Mine

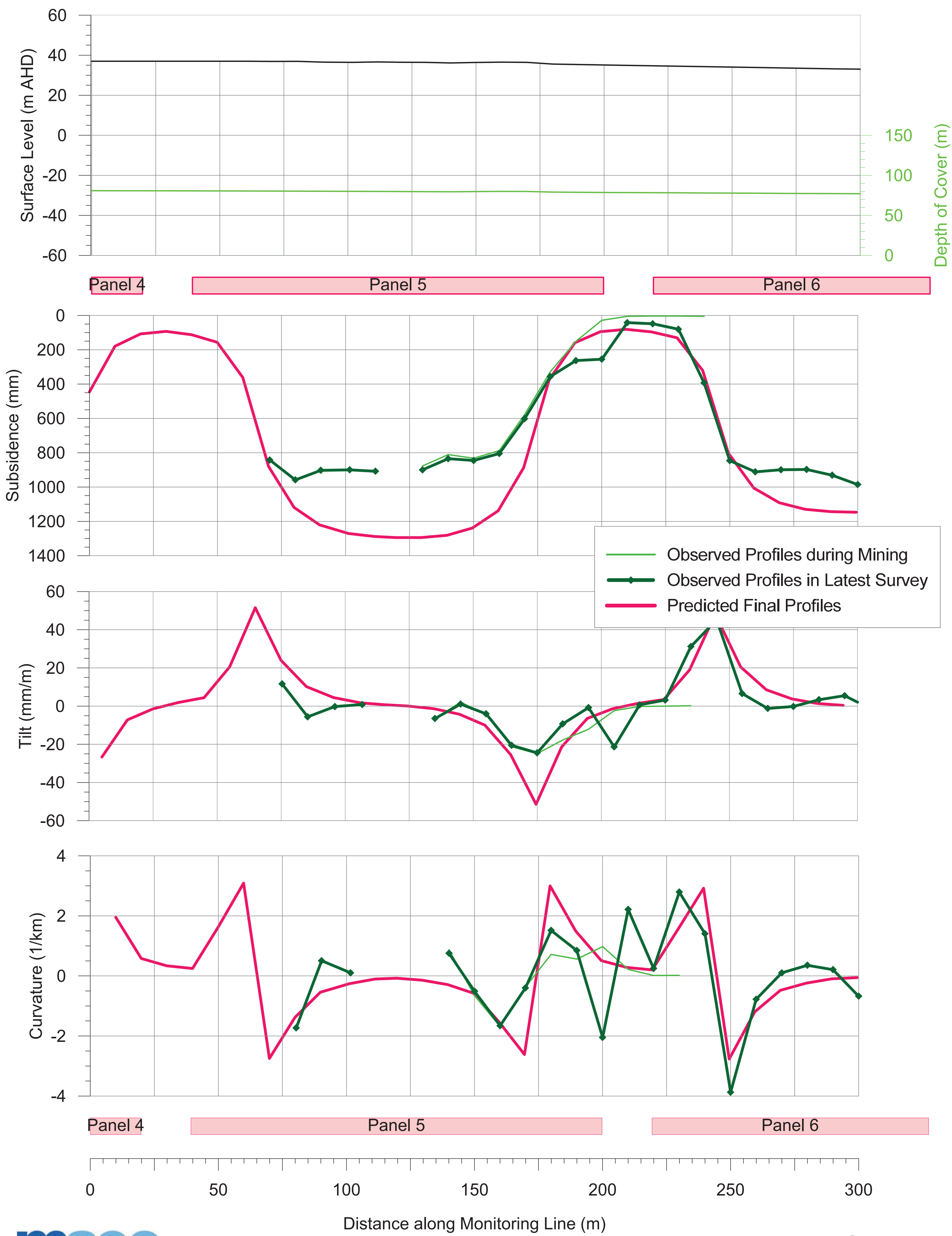


msec

Fig. C.09

I:\Projects\Donaldson\MSEC676 - Abel SMP Area 4 - SMP Application\Subsdata\SurveyData\Fig. C.10 - Panel 5 Crossline.grf

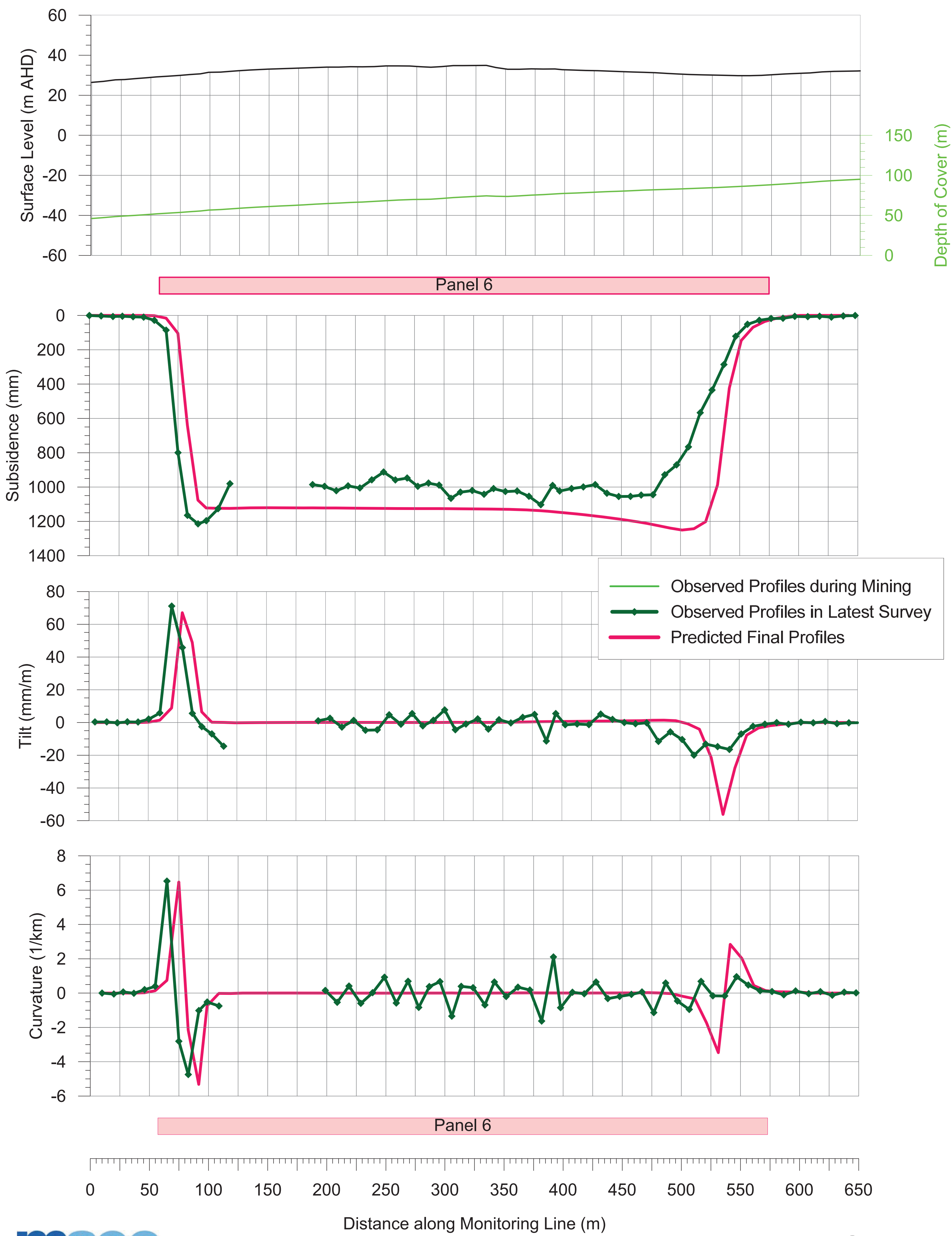
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 5 Crossline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.10

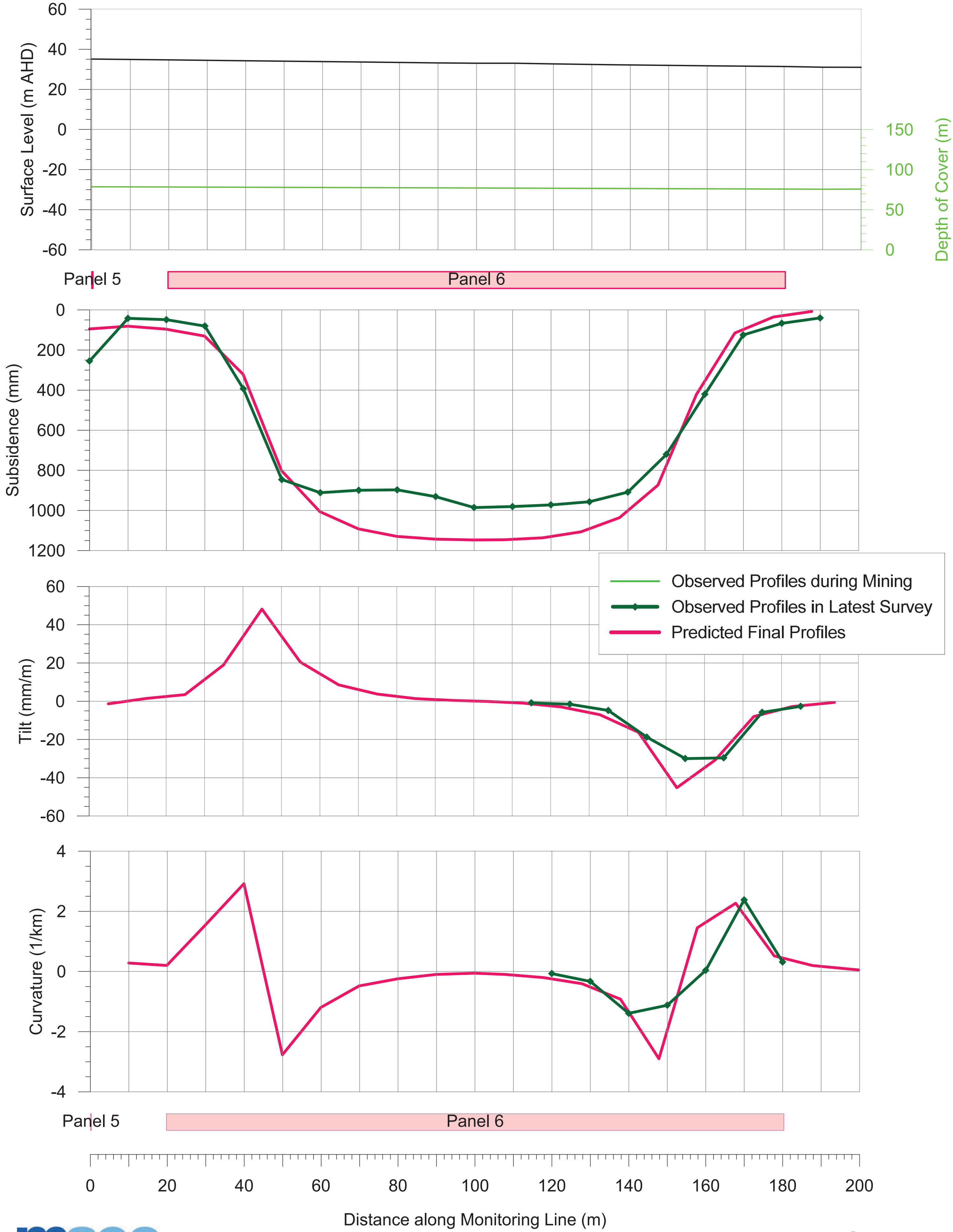
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 6 Centreline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.11

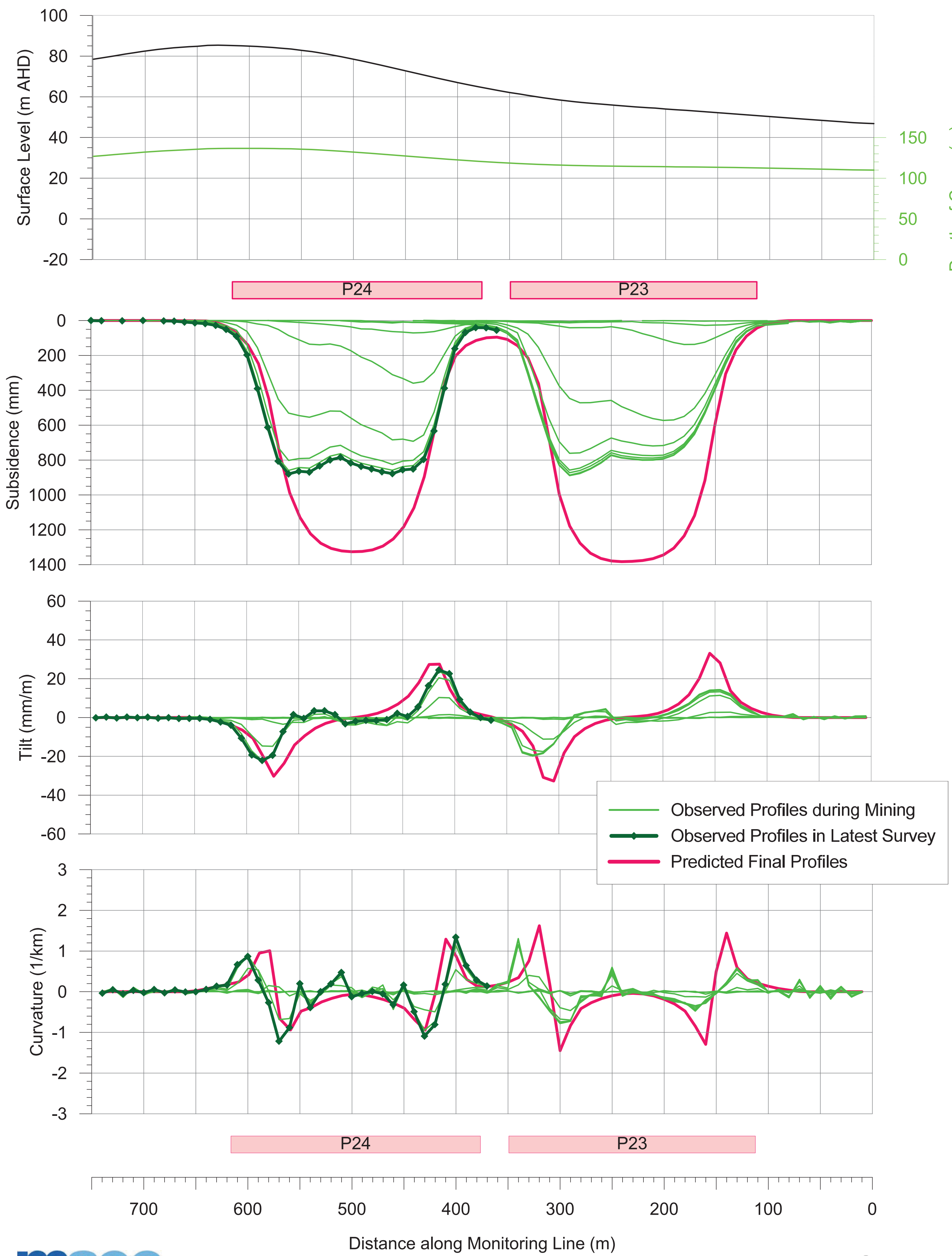
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along the Panel 6 Crossline in SMP Area 1 at the Abel Underground Mine



msec

Fig. C.12

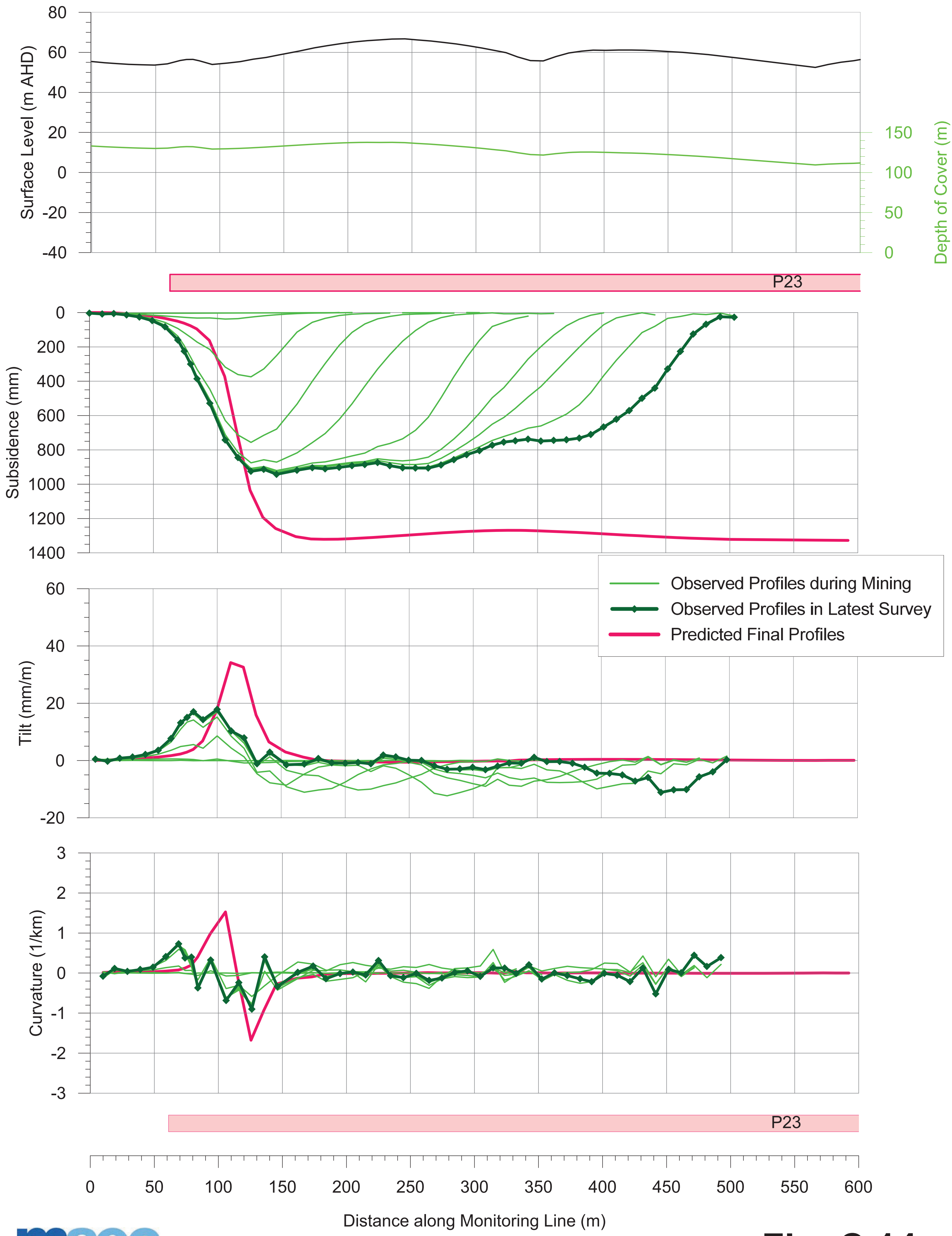
Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along Black Hill Road in SMP Area 3 at the Abel Underground Mine



msec

Fig. C.13

Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along Panel 23 Centreline in SMP Area 3 at the Abel Underground Mine

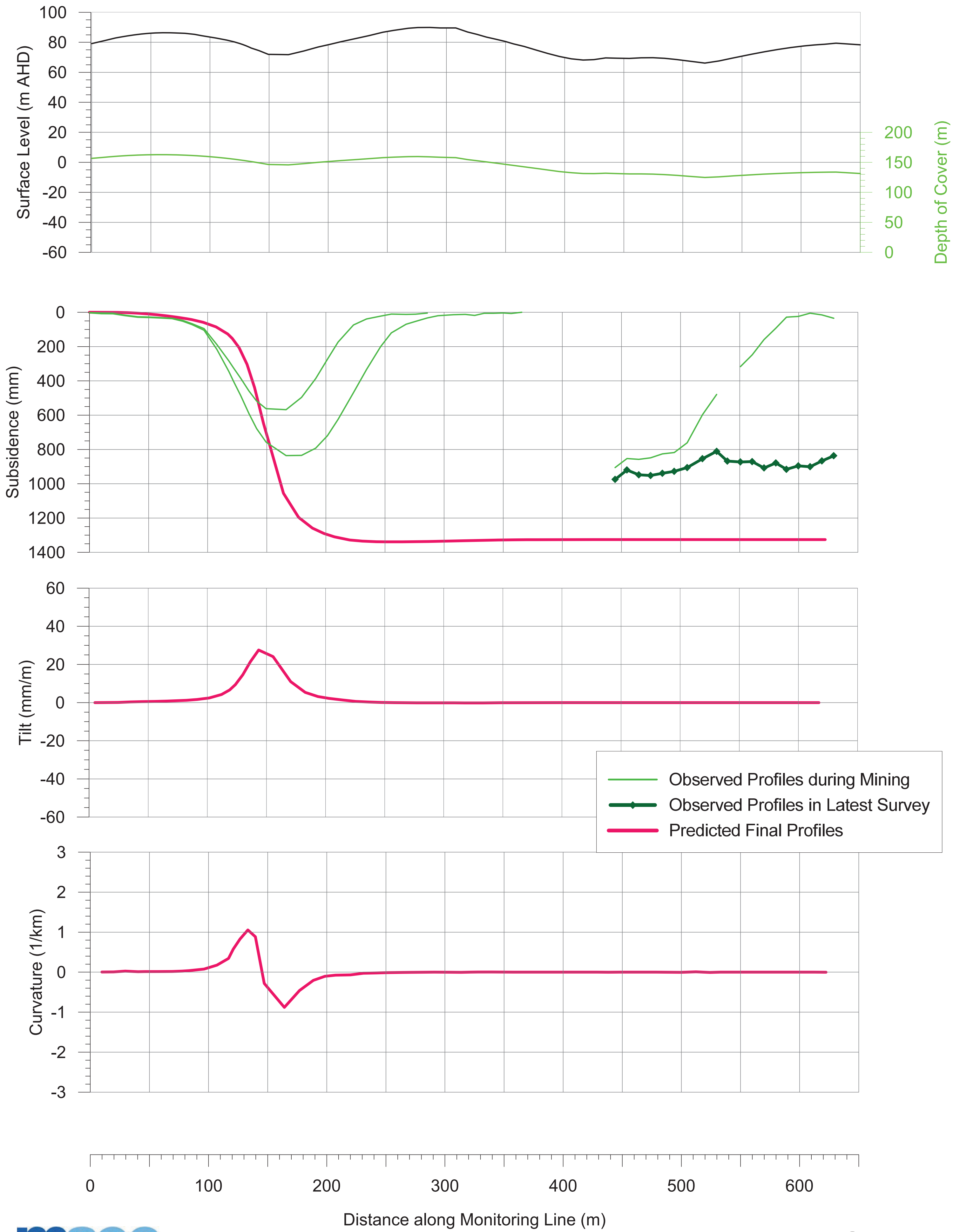


msec

Fig. C.14

I:\Projects\Donaldson\MSEC676 - Abel SMP Area 4 - SMP Application\Subsdata\SurveyData\Fig. C.15 - Panel 24 Centreline.grf

Measured and Predicted Profiles of Total Subsidence, Tilt and Curvature along Panel 24 Centreline in SMP Area 3 at the Abel Underground Mine



msec

Fig. C.15

APPENDIX D. TABLES

Table D.01 - Predicted Conventional Subsidence, Tilt and Curvature for the Building Structures within the EP / SMP Area

Ref.	MGA Easting	MGA Northing	Type	Incremental Subsidence due to Panel 27 (mm)	Incremental Subsidence due to Panel 28 (mm)	Incremental Subsidence due to Panel 29 (mm)	Incremental Subsidence due to Panel 30 (mm)	Incremental Subsidence due to Panel 31 (mm)	Incremental Subsidence due to Panel 32 (mm)	Incremental Subsidence due to Panel 33 (mm)	Incremental Subsidence due to Panel 34 (mm)	Incremental Subsidence due to Panel 35 (mm)	Total Subsidence after Panel 35 (mm)	Total Final Tilt after Panel 35 (mm/m)	Total Hogging Curvature after Panel 35 (1/km)	Total Sagging Curvature after Panel 35 (1/km)
A01h01	368400	6365900	House (Colliery Owned)	50	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1300	30	1.5	1
A01r01	368350	6365800	Rural Structure	450	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	500	20	0.7	0.4
A01r02	368325	6365800	Rural Structure	600	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	600	20	0.7	0.6
C01h01	368050	6366050	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C01r01	368025	6366025	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C01r02	368025	6366025	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C01r03	368000	6366000	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C01r04	368000	6366000	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C01r05	368100	6365975	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.03	< 0.01
C02h01	367900	6366100	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C02r01	367900	6366075	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C02r02	367925	6366100	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.1	< 0.01
C03h01	367925	6365950	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C03r01	367900	6365950	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C03r02	367900	6365925	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C03r03	367875	6365900	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C04h01	367850	6365950	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C04r01	367825	6365950	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.1	< 0.01
C04r02	367850	6365950	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.1	< 0.01
C04r03	367925	6365800	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C05h01	367700	6366425	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C05r01	367725	6366400	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1	0.02	0.04
C05r02	367725	6366400	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1	0.02	0.03
C05r03	367650	6366400	Rural Structure	< 20	< 20	< 20	50	< 20	< 20	< 20	< 20	< 20	50	3	0.1	0.03
C05r04	367600	6366475	Rural Structure	< 20	< 20	< 20	1250	< 20	50	< 20	< 20	< 20	1300	40	1.5	2
C06h01	367650	6366325	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C06r01	367675	6366325	Rural Structure	< 20	< 20	< 20	25	< 20	< 20	< 20	< 20	< 20	25	2	0.2	< 0.01
C06r02	367675	6366300	Rural Structure	< 20	< 20	< 20	50	< 20	< 20	< 20	< 20	< 20	50	2	0.2	0.02
C07h01	367375	6366575	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C07r01	367350	6366550	Rural Structure	< 20	< 20	< 20	< 20	< 20	25	< 20	< 20	< 20	25	1	0.2	0.02
C07r02	367325	6366600	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C07r03	367325	6366600	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C08h01	367300	6366525	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C08r01	367300	6366500	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.02	< 0.01
C09h01	367400	6366275	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C09r01	367425	6366275	Rural Structure	< 20	< 20	< 20	< 20	< 20	25	< 20	< 20	< 20	25	2	0.1	0.01
C10h01	367300	6366275	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C10r01	367325	6366275	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C10r02	367350	6366250	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	25	< 20	25	1	0.1	0.03
C11h01	367175	6366200	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C11r01	367150	6366175	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.01	< 0.01
C11r02	367175	6366175	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.03	< 0.01
C11r03	367175	6366150	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.02	0.02
C12h01	367225	6365950	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C12r01	367250	6365925	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.01	< 0.01
C12r02	367225	6365925	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.03	< 0.01
C13h01	367275	6365875	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C13r01	367275	6365850	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C13r02	367325	6365825	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C13r03	367325	6365825	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C13r04	367350	6365825	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C13r05	367350	6365800	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C14h01	367075	6366475	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C14r01	367075	6366475	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C14r02	367050	6366475	Rural Structure	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C15h01	367150	6366550	Principal Residence	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01
C16h01	367550	6367000	House (Colliery Owned)	< 20	< 20	< 20	< 20	1050	< 20	50	< 20	< 20	1050	50	> 3.0	> 3.0
C17h01	367500	6367150	House (Colliery Owned)	< 20	< 20	< 20	< 20	1000	< 20	50	< 20	< 20	1000	15	> 3.0	> 3.0
C17r01	367475	6367175	Rural Structure	< 20	< 20	< 20	< 20	1000	< 20	50	< 20	< 20	1050	3	> 3.0	> 3.0
C17r02	367450	6367150	Rural Structure	< 20	< 20	< 20	< 20	1000	< 20	50	< 20	< 20	1050	50	> 3.0	> 3.0
C17r03	367450	6367200	Rural Structure	< 20	< 20	< 20	< 20	1000	< 20	50	< 20	< 20	1050	6	> 3.0	> 3.0
C17r04	367475	6367200	Rural Structure	< 20	< 20	< 20	< 20	1000	< 20	50	< 20	< 20	1050	4	> 3.0	> 3.0
C18h01	367625	6367175	House (Colliery Owned)	< 20	< 20	800	< 20	50	< 20	< 20	< 20	< 20	850	45	> 3.0	> 3.0
C18r01	367600	6367175	Rural Structure	< 20	< 20	750	< 20	50	< 20	< 20	< 20	< 20	800	45	> 3.0	> 3.0
C18r02	367625	6367150	Rural Structure	< 20	< 20	800	< 20	50	< 20	< 20	< 20	< 20	850	45	> 3.0	> 3.0
			Maxima:	**600**	**< 20**	**800**	**1250**	**1050**	**50**	**50**	**25**	**< 20**	**1300**	**50**	**> 3.0**	**> 3.0**

Table D.02 - Predicted Subsidence Parameters for the Powerpoles along the 11 kV Powerline Branch 1

Pole ID	MGA Easting	MGA Northing	Total Subsidence after Panel 26 (mm)	Total Subsidence after Panel 27 (mm)	Total Subsidence after Panel 28 (mm)	Total Subsidence after Panel 30 (mm)	Total Subsidence after Panel 32 (mm)	Total Subsidence after Panel 34 (mm)	Total Subsidence after Panel 29 (mm)	Total Subsidence after Panel 31 (mm)	Total Subsidence after Panel 33 (mm)	Total Subsidence after Panel 35 (mm)
PB1-1	367040	6365580	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-2	367180	6365650	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-3	367210	6365850	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-4	367220	6365965	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-5	367235	6366050	< 20	< 20	< 20	< 20	< 20	60	60	60	60	60
PB1-6	367255	6366135	< 20	< 20	< 20	< 20	< 20	100	100	100	100	100
PB1-7	367305	6366205	< 20	< 20	< 20	< 20	< 20	90	90	90	90	90
PB1-8	367350	6366265	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-9	367395	6366330	< 20	< 20	< 20	< 20	30	30	30	30	30	30
PB1-10	367440	6366390	< 20	< 20	< 20	< 20	875	875	875	875	875	875
PB1-11	367490	6366455	< 20	< 20	< 20	< 20	1200	1200	1200	1200	1200	1200
PB1-12	367535	6366520	< 20	< 20	< 20	60	60	60	60	60	60	60
PB1-13	367585	6366585	< 20	< 20	< 20	50	60	60	60	60	60	60
PB1-14	367595	6366600	< 20	< 20	< 20	30	30	30	30	30	30	30
PB1-15	367565	6366630	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-16	367520	6366730	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-17	367470	6366840	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	90	90
PB1-18	367425	6366930	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	100	100
PB1-19	367380	6367025	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	275	300
PB1-20	367330	6367135	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1050	1100
PB1-21	367285	6367235	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1250	1250
PB1-22	367210	6367385	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
		Maxima:	**< 20**	**< 20**	**< 20**	**60**	**1200**	**1200**	**1200**	**1200**	**1250**	**1250**

Table D.02 - Predicted Subsidence Parameters for the Powerpoles along the 11 kV Powerline Branch 1

Pole ID	Total Tilt Along Alignment after Panel 26 (mm/m)	Total Tilt Along Alignment after Panel 27 (mm/m)	Total Tilt Along Alignment after Panel 28 (mm/m)	Total Tilt Along Alignment after Panel 30 (mm/m)	Total Tilt Along Alignment after Panel 32 (mm/m)	Total Tilt Along Alignment after Panel 34 (mm/m)	Total Tilt Along Alignment after Panel 29 (mm/m)	Total Tilt Along Alignment after Panel 31 (mm/m)	Total Tilt Along Alignment after Panel 33 (mm/m)	Total Tilt Along Alignment after Panel 35 (mm/m)
PB1-1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-2	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-3	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-4	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	6	6	6	6	6
PB1-6	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	14	14	14	14	14
PB1-7	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1	1	1	1	1
PB1-8	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-9	< 0.5	< 0.5	< 0.5	< 0.5	1	1	1	1	1	1
PB1-10	< 0.5	< 0.5	< 0.5	< 0.5	30	30	30	30	30	30
PB1-11	< 0.5	< 0.5	< 0.5	< 0.5	30	30	30	30	30	30
PB1-12	< 0.5	< 0.5	< 0.5	1	2	2	2	2	2	2
PB1-13	< 0.5	< 0.5	< 0.5	1	1	1	1	1	1	1
PB1-14	< 0.5	< 0.5	< 0.5	1	1	1	1	1	1	1
PB1-15	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-16	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1	1	1
PB1-17	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-18	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1
PB1-19	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	5	5
PB1-20	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	5	5
PB1-21	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	5	5
PB1-22	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	< 0.5	**< 0.5**	**< 0.5**	**1**	**30**	**30**	**30**	**30**	**30**	**30**

Pole ID	Total Tilt Across Alignment after Panel 26 (mm/m)	Total Tilt Across Alignment after Panel 27 (mm/m)	Total Tilt Across Alignment after Panel 28 (mm/m)	Total Tilt Across Alignment after Panel 30 (mm/m)	Total Tilt Across Alignment after Panel 32 (mm/m)	Total Tilt Across Alignment after Panel 34 (mm/m)	Total Tilt Across Alignment after Panel 29 (mm/m)	Total Tilt Across Alignment after Panel 31 (mm/m)	Total Tilt Across Alignment after Panel 33 (mm/m)	Total Tilt Across Alignment after Panel 35 (mm/m)
PB1-1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-2	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-3	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-4	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	5	5	5	5	5
PB1-6	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	4	4	4	4	4
PB1-7	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-8	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-9	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-10	< 0.5	< 0.5	< 0.5	< 0.5	7	8	8	8	8	8
PB1-11	< 0.5	< 0.5	< 0.5	< 0.5	17	17	17	17	17	17
PB1-12	< 0.5	< 0.5	< 0.5	6	6	6	6	6	6	6
PB1-13	< 0.5	< 0.5	< 0.5	3	3	3	3	3	3	3
PB1-14	< 0.5	< 0.5	< 0.5	2	2	2	2	2	2	2
PB1-15	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB1-16	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1	1	1
PB1-17	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	2	1	1
PB1-18	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	3	3
PB1-19	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	30	30
PB1-20	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	30	30
PB1-21	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	6	6
PB1-22	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
	< 0.5	**< 0.5**	**< 0.5**	**6**	**17**	**17**	**17**	**17**	**30**	**30**

Table D.02 - Predicted Subsidence Parameters for the Powerpoles along the 11 kV Powerline Branch 1

Pole ID	Total Horizontal Movement Along Alignment at Top of Pole after Panel 26 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 27 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 28 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 30 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 32 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 34 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 29 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 31 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 33 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 35 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 26 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 27 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 28 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 30 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 32 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 34 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 29 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 31 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 33 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 35 (mm)
PB1-1	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-2	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-3	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-4	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-5	< 20	< 20	< 20	< 20	< 20	150	150	150	150	150	< 20	< 20	< 20	< 20	< 20	125	125	125	125	125
PB1-6	< 20	< 20	< 20	< 20	< 20	350	350	350	350	350	< 20	< 20	< 20	< 20	< 20	100	100	100	100	100
PB1-7	< 20	< 20	< 20	< 20	< 20	20	20	20	20	20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-8	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-9	< 20	< 20	< 20	< 20	40	40	40	40	40	40	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-10	< 20	< 20	< 20	< 20	725	750	750	750	750	750	< 20	< 20	< 20	< 20	175	200	200	200	200	200
PB1-11	< 20	< 20	< 20	< 20	750	750	750	750	750	750	< 20	< 20	< 20	< 20	425	425	425	425	425	425
PB1-12	< 20	< 20	< 20	20	60	60	60	60	60	60	< 20	< 20	< 20	150	150	150	150	150	150	150
PB1-13	< 20	< 20	< 20	30	30	30	30	30	30	30	< 20	< 20	< 20	60	70	70	70	70	70	70
PB1-14	< 20	< 20	< 20	30	30	30	30	30	30	30	< 20	< 20	< 20	40	40	40	40	40	40	40
PB1-15	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB1-16	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	20	20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	20	20	20
PB1-17	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	50	30	30
PB1-18	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	70	80
PB1-19	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	125	125	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	750	775
PB1-20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	125	125	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	725	725
PB1-21	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	125	125	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	150	150
PB1-22	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
	< 20	**< 20**	**< 20**	**30**	**750**	**750**	**750**	**750**	**750**	**750**	**< 20**	**< 20**	**< 20**	**150**	**425**	**425**	**425**	**425**	**750**	**775**

Table D.03 - Predicted Subsidence Parameters for the Powerpoles along the 11 kV Powerline Branch 2

Pole ID	MGA Easting	MGA Northing	Total Subsidence after Panel 26 (mm)	Total Subsidence after Panel 27 (mm)	Total Subsidence after Panel 28 (mm)	Total Subsidence after Panel 30 (mm)	Total Subsidence after Panel 32 (mm)	Total Subsidence after Panel 34 (mm)	Total Subsidence after Panel 29 (mm)	Total Subsidence after Panel 31 (mm)	Total Subsidence after Panel 33 (mm)	Total Subsidence after Panel 35 (mm)
PB2-1	367920	6366105	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB2-2	367965	6366110	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB2-3	368050	6366080	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB2-4	368065	6366075	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB2-5	368140	6366050	< 20	650	650	650	650	650	650	650	650	650
PB2-6	368320	6365995	150	275	275	275	275	275	275	275	275	275
PB2-7	368385	6365980	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
PB2-8	368460	6365985	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
PB2-9	368590	6366000	1300	1300	1300	1300	1300	1300	1300	1300	1300	1300
PB2-10	368605	6366020	1350	1350	1350	1350	1350	1350	1350	1350	1350	1350
PB2-11	368770	6365930	275	275	275	275	275	275	275	275	275	275
PB2-12	368875	6365915	1350	1350	1350	1350	1350	1350	1350	1350	1350	1350
PB2-13	369035	6365865	600	600	600	600	600	600	600	600	600	600
PB2-14	369210	6365825	1350	1350	1350	1350	1350	1350	1350	1350	1350	1350
		Maxima:	**1350**	**1350**	**1350**	**1350**	**1350**	**1350**	**1350**	**1350**	**1350**	**1350**

Table D.03 - Predicted Subsidence Parameters for the Powerpoles along the 11 kV Powerline Branch 2

Pole ID	Total Tilt Along Alignment after Panel 26 (mm/m)	Total Tilt Along Alignment after Panel 27 (mm/m)	Total Tilt Along Alignment after Panel 28 (mm/m)	Total Tilt Along Alignment after Panel 30 (mm/m)	Total Tilt Along Alignment after Panel 32 (mm/m)	Total Tilt Along Alignment after Panel 34 (mm/m)	Total Tilt Along Alignment after Panel 29 (mm/m)	Total Tilt Along Alignment after Panel 31 (mm/m)	Total Tilt Along Alignment after Panel 33 (mm/m)	Total Tilt Along Alignment after Panel 35 (mm/m)	Total Tilt Across Alignment after Panel 26 (mm/m)	Total Tilt Across Alignment after Panel 27 (mm/m)	Total Tilt Across Alignment after Panel 28 (mm/m)	Total Tilt Across Alignment after Panel 30 (mm/m)	Total Tilt Across Alignment after Panel 32 (mm/m)	Total Tilt Across Alignment after Panel 34 (mm/m)	Total Tilt Across Alignment after Panel 29 (mm/m)	Total Tilt Across Alignment after Panel 31 (mm/m)	Total Tilt Across Alignment after Panel 33 (mm/m)	Total Tilt Across Alignment after Panel 35 (mm/m)
PB2-1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB2-2	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB2-3	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB2-4	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
PB2-5	< 0.5	25	25	25	25	25	25	25	25	25	< 0.5	20	20	20	20	20	20	20	20	20
PB2-6	8	6	6	6	6	6	6	6	6	6	4	4	4	4	4	4	4	4	4	4
PB2-7	30	25	25	25	25	25	25	25	25	25	16	15	15	15	15	15	15	15	15	15
PB2-8	30	30	30	30	30	30	30	30	30	30	4	4	4	4	4	4	4	4	4	4
PB2-9	30	30	30	30	30	30	30	30	30	30	7	7	7	7	7	7	7	7	7	7
PB2-10	25	25	25	25	25	25	25	25	25	25	7	7	7	7	7	7	7	7	7	7
PB2-11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
PB2-12	30	30	30	30	30	30	30	30	30	30	13	13	13	13	13	13	13	13	13	13
PB2-13	25	25	25	25	25	25	25	25	25	25	15	15	15	15	15	15	15	15	15	15
PB2-14	8	8	8	8	8	8	8	8	8	8	4	4	4	4	4	4	4	4	4	4
	30	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**30**	**16**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**

Table D.03 - Predicted Subsidence Parameters for the Powerpoles along the 11 kV Powerline Branch 2

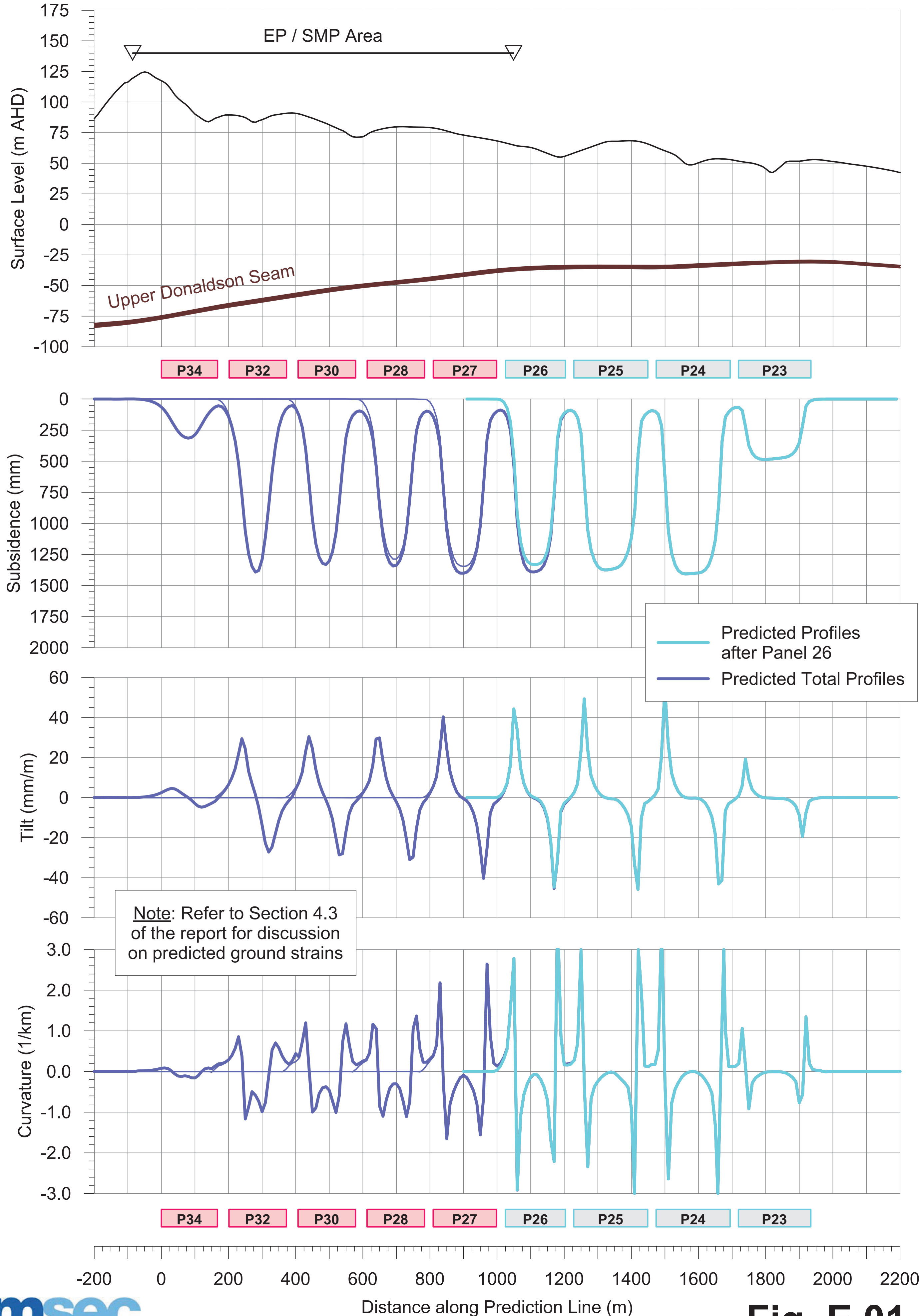
Pole ID	Total Horizontal Movement Along Alignment at Top of Pole after Panel 26 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 27 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 28 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 30 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 32 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 34 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 29 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 31 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 33 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 35 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 26 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 27 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 28 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 30 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 32 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 34 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 29 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 31 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 33 (mm)	Total Horizontal Movement Along Alignment at Top of Pole after Panel 35 (mm)
PB2-1	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB2-2	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB2-3	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB2-4	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20
PB2-5	< 20	600	600	600	600	600	600	600	600	600	< 20	500	500	500	500	500	500	500	500	500
PB2-6	200	150	150	150	150	150	150	150	150	150	100	90	90	90	90	90	90	90	90	90
PB2-7	725	675	675	675	675	675	675	675	675	675	400	375	375	375	375	375	375	375	375	375
PB2-8	800	800	800	800	800	800	800	800	800	800	90	90	90	90	90	90	90	90	90	90
PB2-9	800	800	800	800	800	800	800	800	800	800	175	175	175	175	175	175	175	175	175	175
PB2-10	625	625	625	625	625	625	625	625	625	625	175	175	175	175	175	175	175	175	175	175
PB2-11	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275	275
PB2-12	725	725	725	725	725	725	725	725	725	725	325	325	325	325	325	325	325	325	325	325
PB2-13	600	600	600	600	600	600	600	600	600	600	375	375	375	375	375	375	375	375	375	375
PB2-14	200	200	200	200	200	200	200	200	200	200	100	100	100	100	100	100	100	100	100	100
	800	**800**	**800**	**800**	**800**	**800**	**800**	**800**	**800**	**800**	**400**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**

Table D.04 - Predicted Conventional Subsidence, Tilt and Curvature for the Farm Dams within the EP / SMP Area

Ref.	MGA Easting	MGA Northing	Maximum Planar Dimension (m)	Surface Area (m2)	Incremental Subsidence due to Panel 27 (mm)	Incremental Subsidence due to Panel 28 (mm)	Incremental Subsidence due to Panel 29 (mm)	Incremental Subsidence due to Panel 30 (mm)	Incremental Subsidence due to Panel 31 (mm)	Incremental Subsidence due to Panel 32 (mm)	Incremental Subsidence due to Panel 33 (mm)	Incremental Subsidence due to Panel 34 (mm)	Incremental Subsidence due to Panel 35 (mm)	Total Subsidence after Panel 35 (mm)	Total Tilt after Panel 35 (mm/m)	Total Hogging Curvature after Panel 35 (1/km)	Total Sagging Curvature after Panel 35 (1/km)	Predicted Final Change in Freeboard (mm)
A02d04	368500	6365675	140	4750	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1250	25	0.8	1	550
A02d05	368475	6365525	40	770	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	850	20	0.6	0.8	400
C01d01	368075	6366200	60	1480	1400	150	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1400	40	2.5	2	1050
C01d02	368025	6366150	40	710	50	150	< 20	< 20	< 20	< 20	< 20	< 20	< 20	150	5	0.3	0.5	100
C01d03	367975	6366000	15	160	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01	< 50
C04d01	367800	6365925	30	320	< 20	< 20	< 20	50	< 20	< 20	< 20	< 20	< 20	50	1	0.1	< 0.01	< 50
C04d02	367900	6365700	30	550	< 20	< 20	< 20	300	< 20	< 20	< 20	< 20	< 20	300	7	0.2	0.2	100
C04d03	367925	6365750	50	1320	< 20	< 20	< 20	75	< 20	< 20	< 20	< 20	< 20	75	2	0.1	0.01	< 50
C04d04	367925	6365800	60	1190	< 20	< 20	< 20	25	< 20	< 20	< 20	< 20	< 20	25	< 0.5	0.01	< 0.01	< 50
C04d05	367975	6365825	15	90	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01	< 50
C04d06	368050	6365825	105	3100	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.1	< 0.01	< 50
C04d07	368125	6365900	85	2760	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1	0.1	< 0.01	< 50
C04d08	368100	6365650	25	310	< 20	550	< 20	< 20	< 20	< 20	< 20	< 20	< 20	600	15	0.5	0.9	250
C04d09	368050	6365650	20	150	< 20	550	< 20	< 20	< 20	< 20	< 20	< 20	< 20	550	15	0.6	0.9	200
C05d01	367575	6366450	125	2430	< 20	< 20	< 20	1350	< 20	150	< 20	< 20	< 20	1400	45	> 3.0	> 3.0	1100
C07d01	367100	6366700	95	3490	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1150	1200	40	2.5	2	600
C07d02	367225	6366775	105	3170	< 20	< 20	< 20	< 20	< 20	< 20	25	< 20	1350	1450	40	2.5	2.5	1350
C07d03	367350	6366775	160	5550	< 20	< 20	< 20	< 20	< 20	< 20	1300	< 20	100	1350	60	> 3.0	> 3.0	1300
C07d04	367475	6366700	15	160	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1	0.3	< 0.01	< 50
C08d01	367225	6366475	45	900	< 20	< 20	< 20	< 20	< 20	< 20	< 20	75	< 20	100	3	0.2	0.05	< 50
C09d01	367400	6366175	105	2510	< 20	< 20	< 20	< 20	< 20	550	< 20	250	< 20	600	30	2.5	1	200
C09d02	367500	6366200	50	1250	< 20	< 20	< 20	< 20	< 20	2000	< 20	< 20	< 20	1400	30	1.5	1.5	1000
C09d03	367500	6366250	105	3090	< 20	< 20	< 20	< 20	< 20	1300	< 20	< 20	< 20	900	25	1.5	2	750
C09d04	367425	6366350	45	860	< 20	< 20	< 20	< 20	< 20	600	< 20	< 20	< 20	400	25	2	0.1	100
C09d05	367475	6366400	100	3480	< 20	< 20	< 20	< 20	< 20	2150	< 20	< 20	< 20	1300	35	2	2.5	1150
C09d06	367550	6366450	45	580	< 20	< 20	< 20	300	< 20	350	< 20	< 20	< 20	350	20	2	0.4	50
C10d01	367325	6366350	75	2640	< 20	< 20	< 20	< 20	< 20	50	< 20	400	< 20	450	15	0.4	0.5	150
C10d02	367325	6366200	15	160	< 20	< 20	< 20	< 20	< 20	< 20	< 20	200	< 20	200	4	0.04	0.2	50
C10d03	367375	6366075	70	2010	< 20	< 20	< 20	< 20	< 20	< 20	< 20	650	< 20	400	50	> 3.0	2	250
C11d01	367200	6366150	25	370	< 20	< 20	< 20	< 20	< 20	< 20	< 20	50	< 20	50	3	0.05	0.2	< 50
C13d01	367425	6365850	50	1350	< 20	< 20	< 20	< 20	< 20	50	< 20	50	< 20	50	2	0.1	0.1	< 50
C14d01	367150	6366450	15	60	< 20	< 20	< 20	< 20	< 20	< 20	< 20	25	< 20	25	1	0.03	0.02	< 50
C15d01	367125	6366600	25	420	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	0.2	< 0.01	< 50
C16d01	367600	6366925	50	1330	< 20	< 20	< 20	< 20	1050	< 20	50	< 20	< 20	1100	50	> 3.0	> 3.0	900
C17d01	367375	6367275	50	860	< 20	< 20	< 20	< 20	200	< 20	50	< 20	< 20	200	35	> 3.0	0.8	< 50
D01d01	366950	6367450	105	4320	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01	< 50
D01d02	366950	6367275	115	3800	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	600	600	60	> 3.0	> 3.0	100
D01d03	366850	6367225	90	2920	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01	< 50
D01d05	366900	6367100	85	3060	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 0.5	< 0.01	< 0.01	< 50
D02d01	367125	6367200	295	31430	< 20	< 20	< 20	< 20	< 20	< 20	1250	< 20	1250	1300	70	> 3.0	> 3.0	1300
D03d01	367000	6367025	90	3510	< 20	< 20	< 20	< 20	< 20	< 20	< 20	< 20	1100	1200	50	> 3.0	3	800
D04d01	367800	6366225	75	2290	< 20	300	< 20	700	< 20	< 20	< 20	< 20	< 20	500	25	1.5	0.9	100
D04d02	367800	6366125	85	1940	< 20	< 20	< 20	1400	< 20	< 20	< 20	< 20	< 20	1400	30	1	1	1250
				Maxima:	**1400**	**550**	**< 20**	**1400**	**1050**	**2150**	**1300**	**650**	**1350**	**1450**	**70**	**> 3.0**	**> 3.0**	**> 3.0**

APPENDIX E. FIGURES

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 Resulting from the Extraction of Panels 23 to 34



msec

Fig. E.01

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 Resulting from the Extraction of Panels 29 to 35

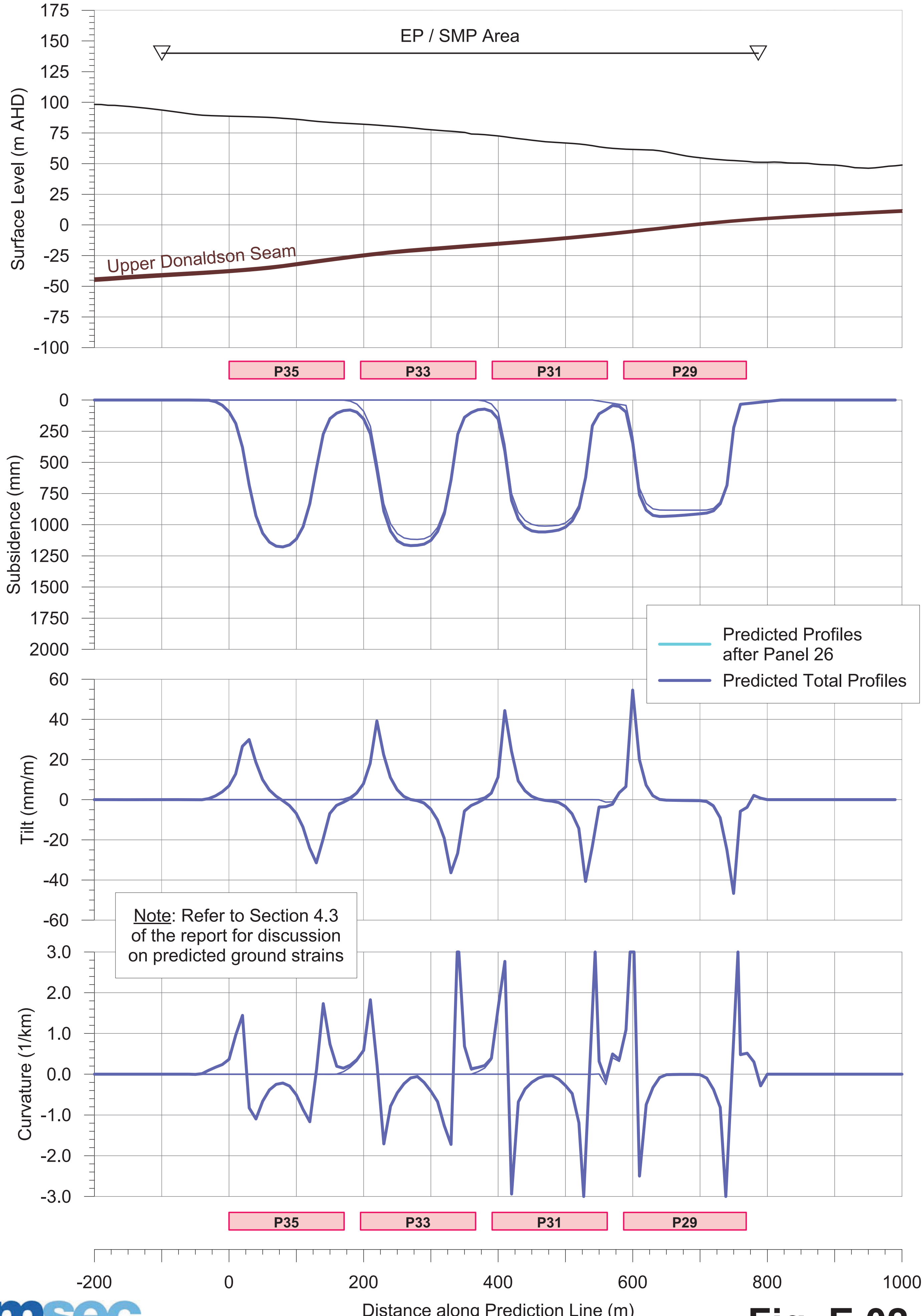


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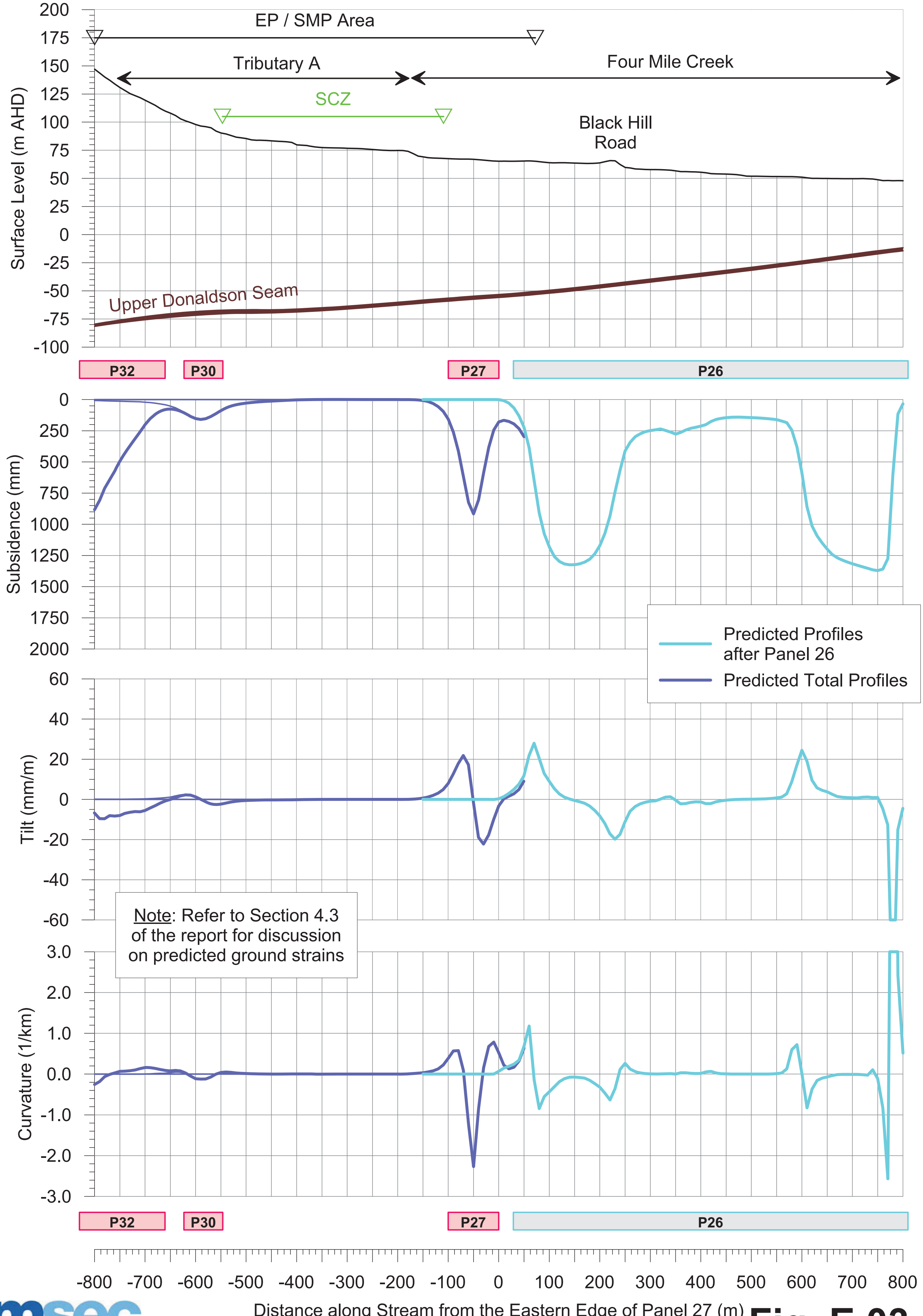
Fig. E.02

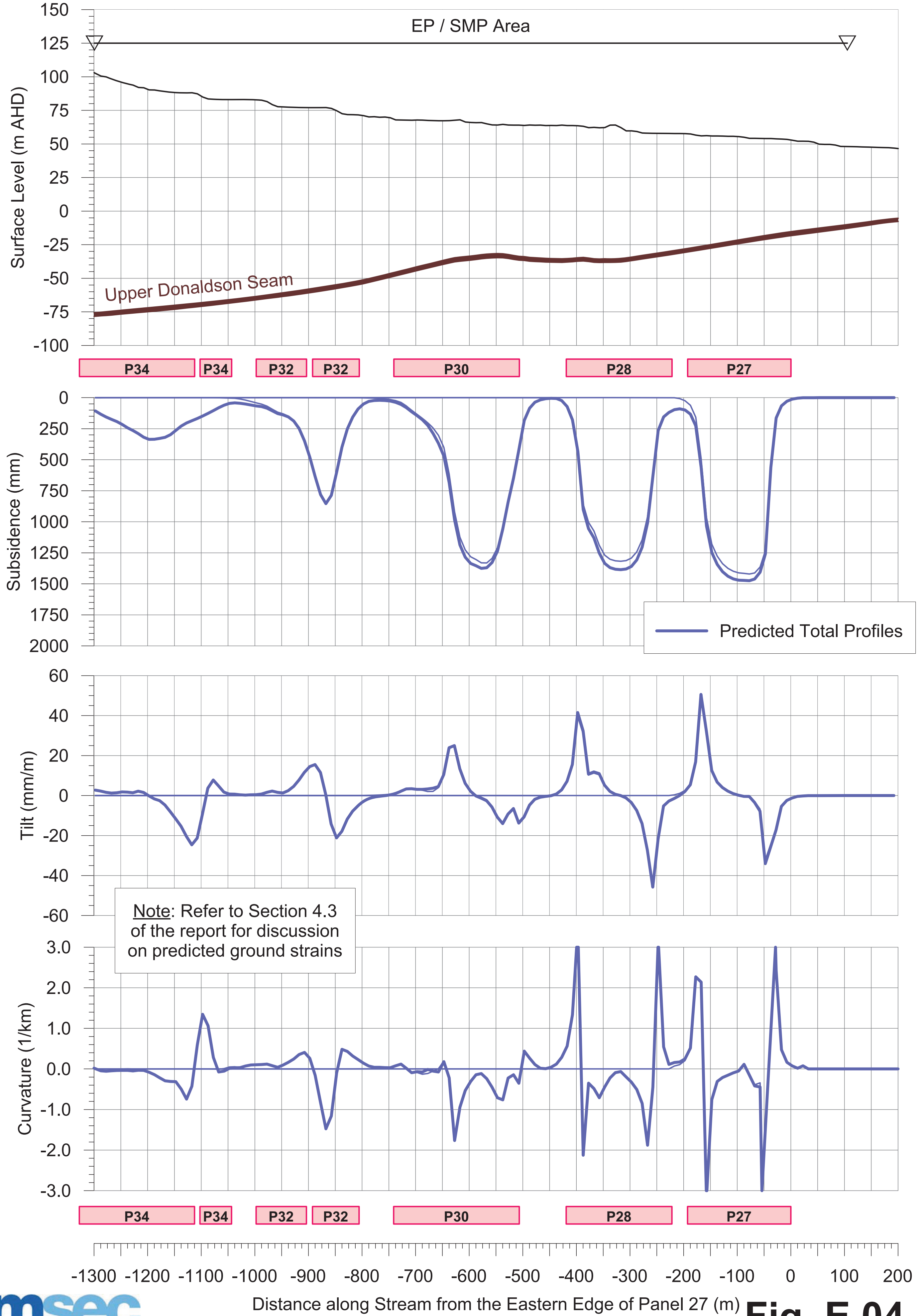
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Tributary A Resulting from the Extraction of Panels 23 to 35



msec

Fig. E.03

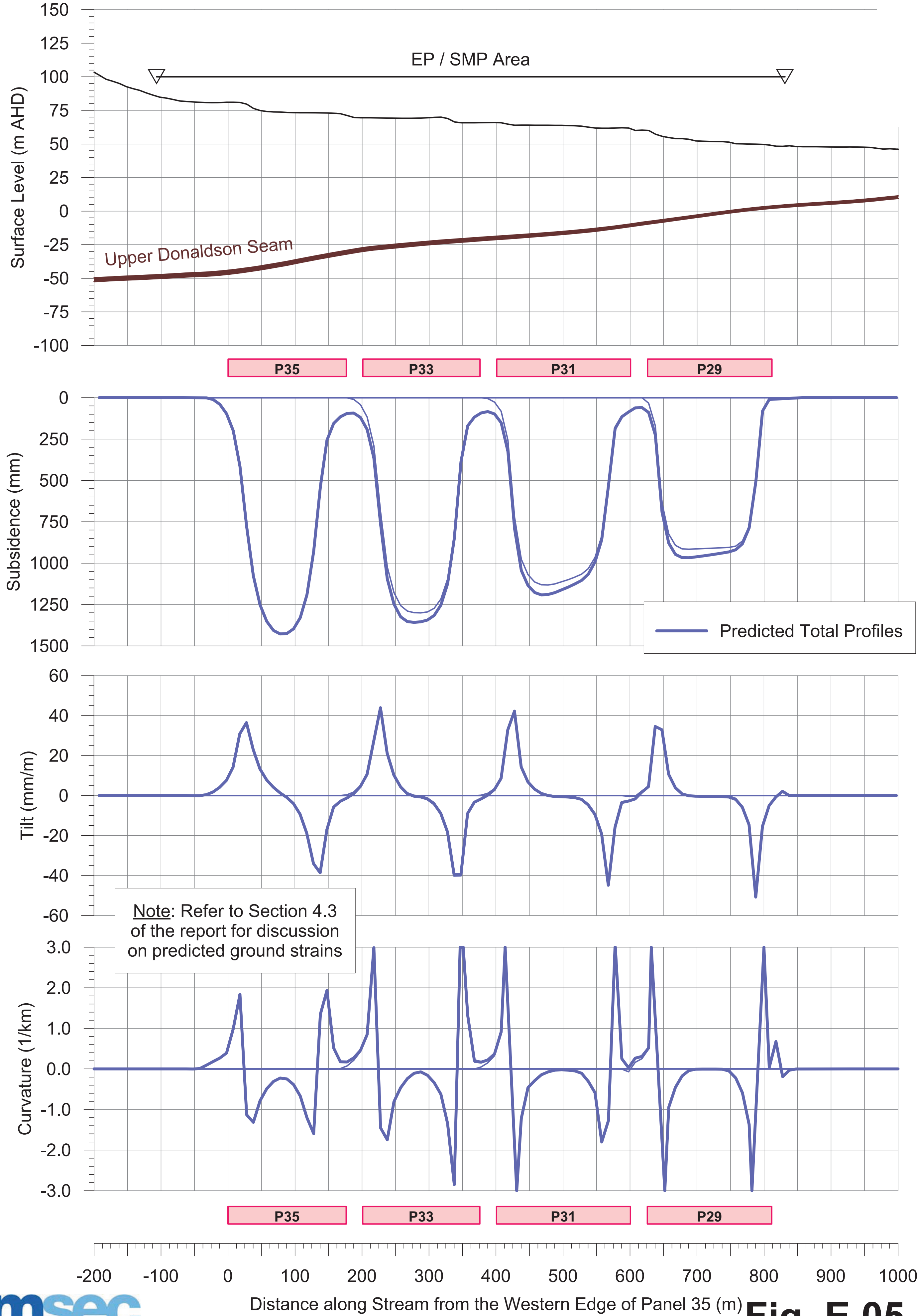
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Tributary B Resulting from the Extraction of Panels 23 to 35



msec

Fig. E.04

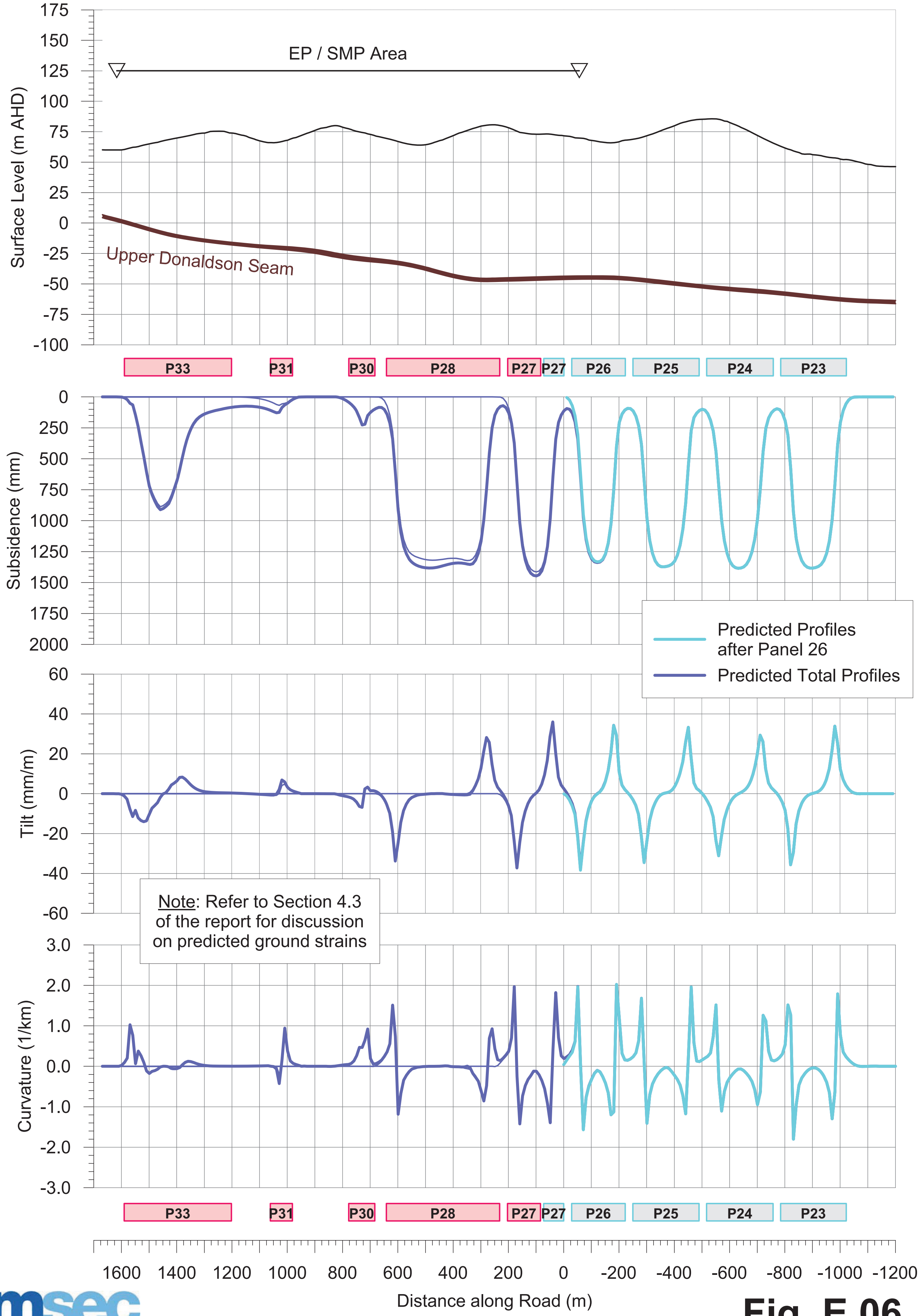
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Tributary C Resulting from the Extraction of Panels 23 to 35



msec

Fig. E.05

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Black Hill Road Resulting from the Extraction of Panels 23 to 35



msec

Fig. E.06

Predicted Profiles of Conventional Subsidence, Tilt along and Tilt across the 11 kV Powerline (1) Resulting from the Extraction of Panels 23 to 35

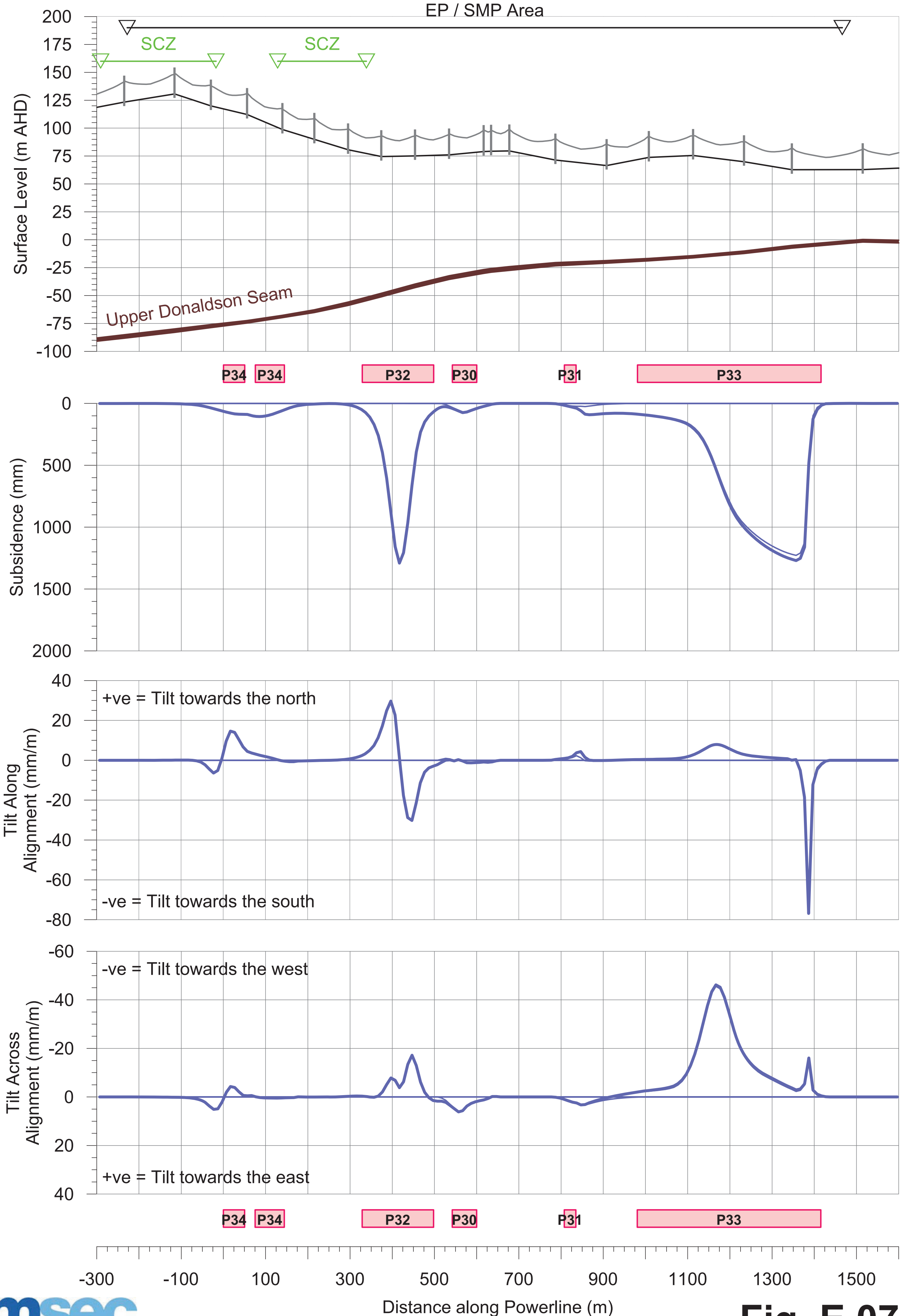


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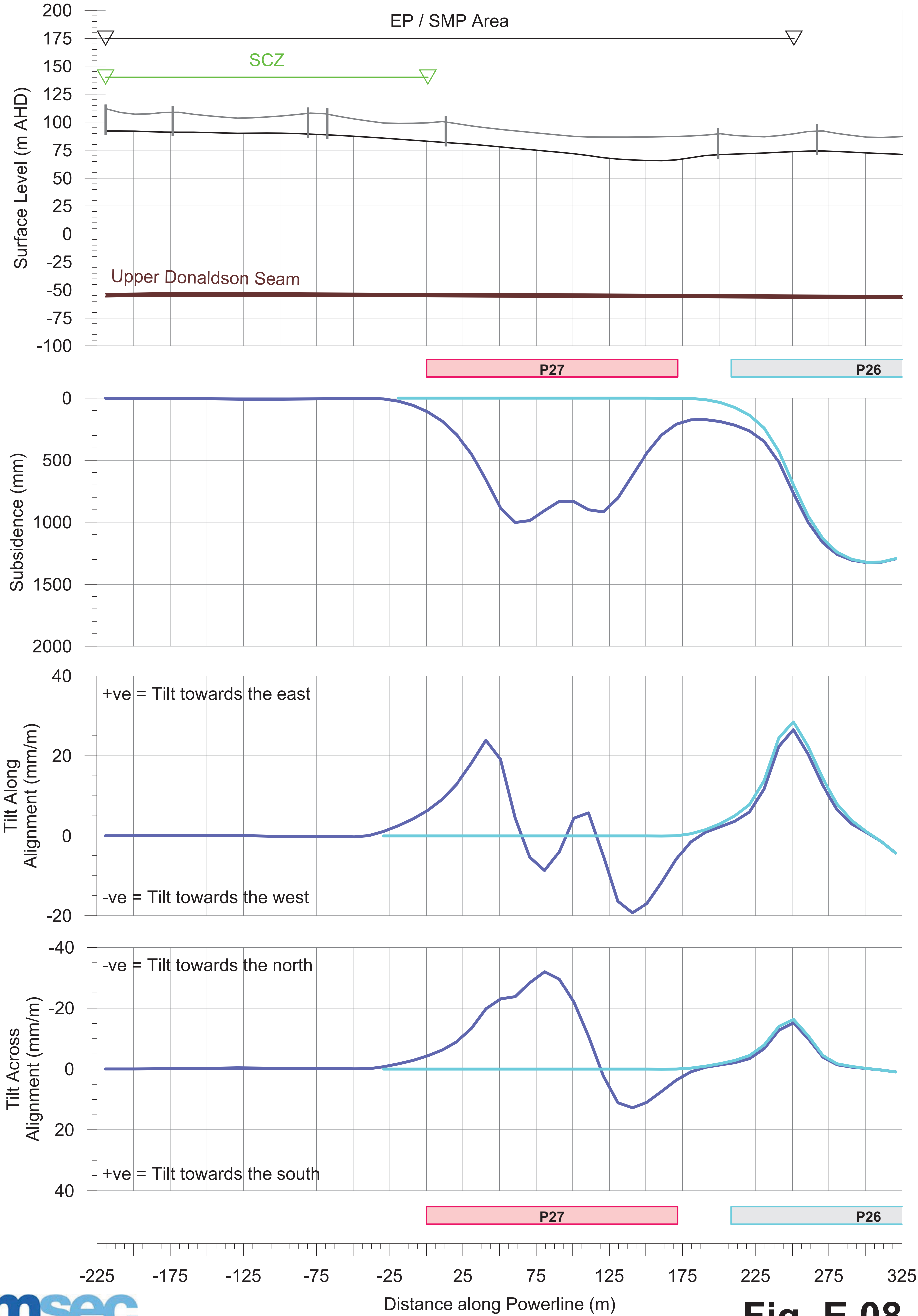
Fig. E.07

Predicted Profiles of Conventional Subsidence, Tilt along and Tilt across the 11 kV Powerline (2) Resulting from the Extraction of Panels 23 to 35



msec

Fig. E.08

APPENDIX F. DRAWINGS

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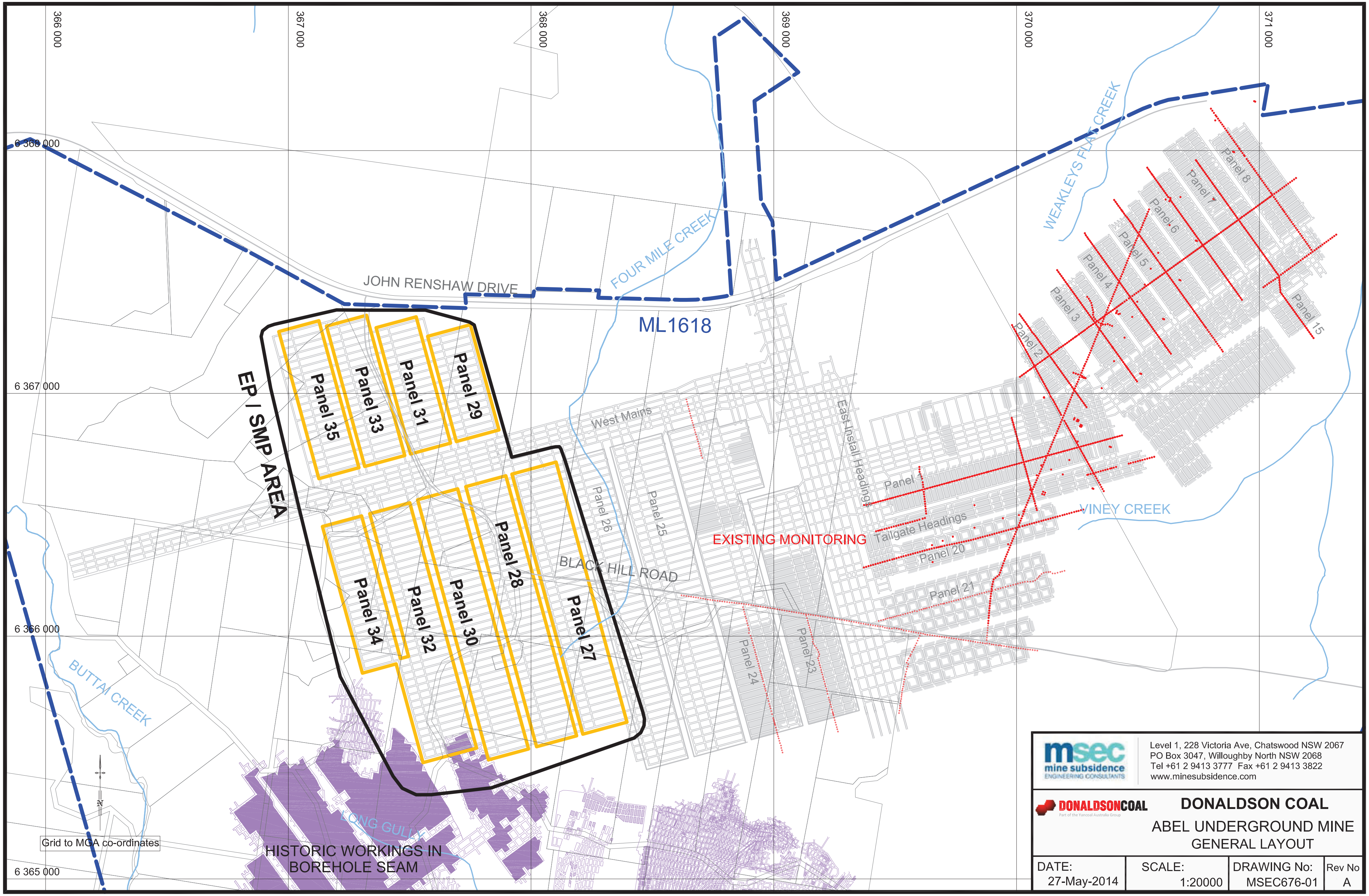

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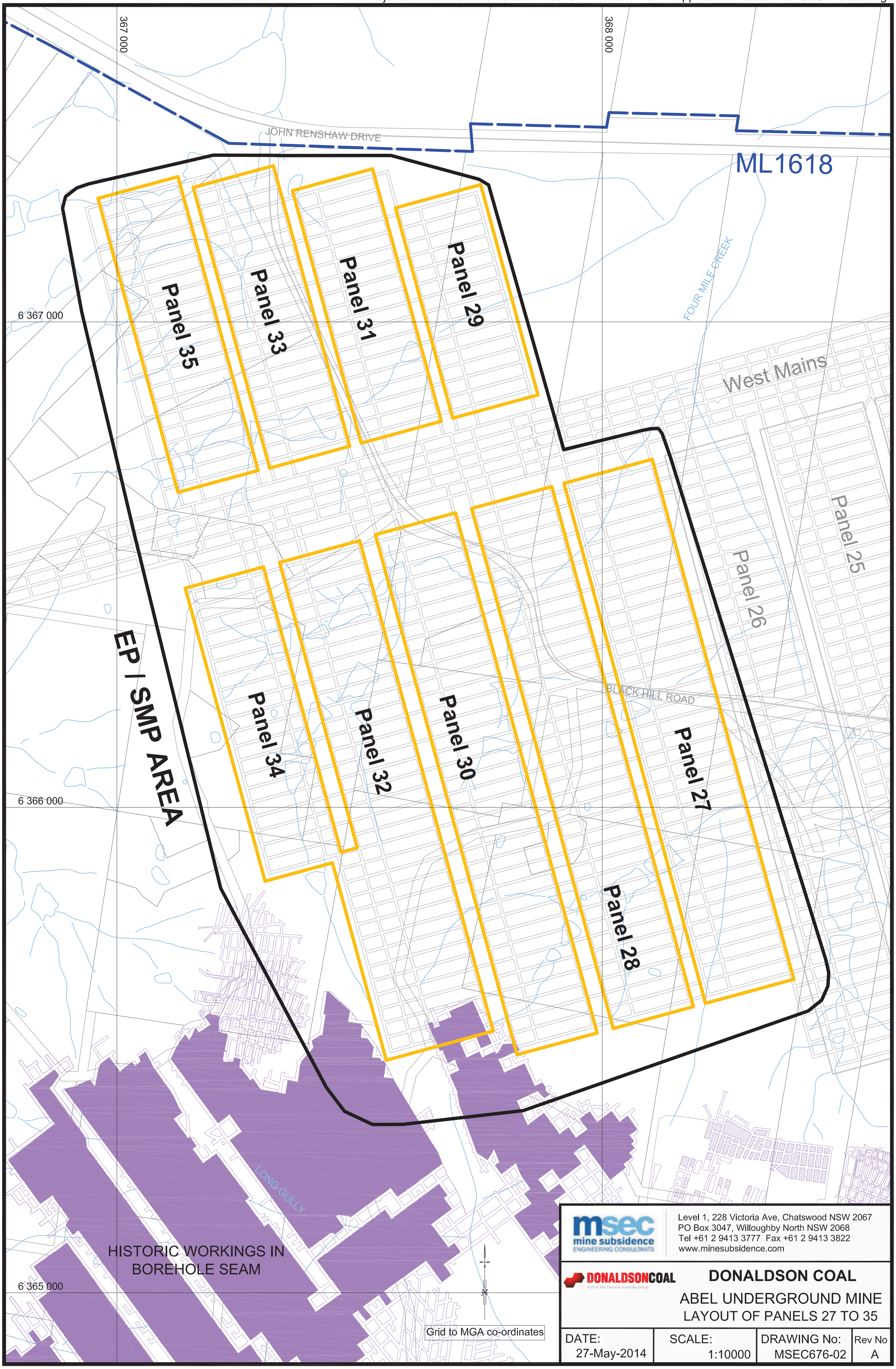

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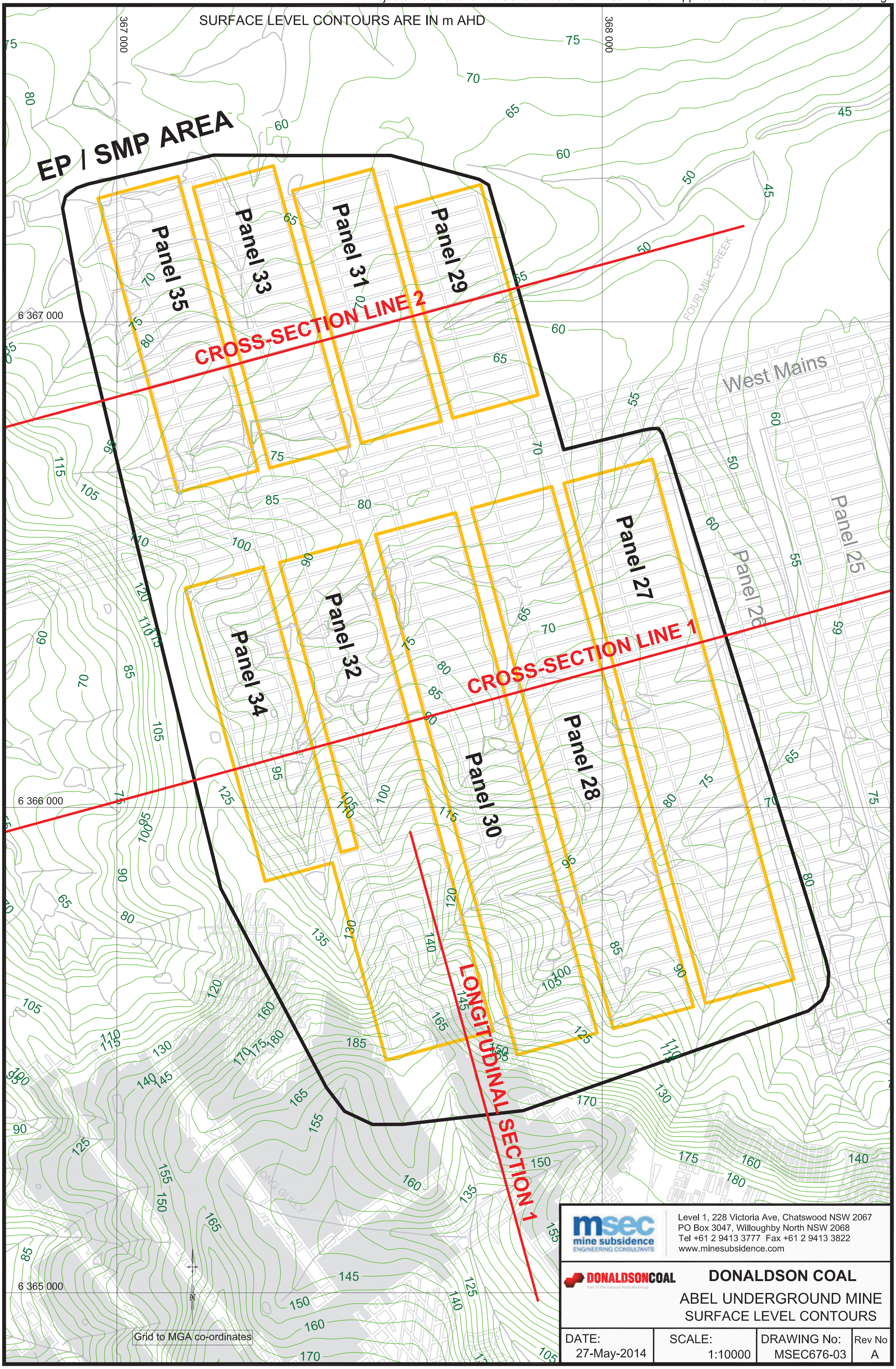

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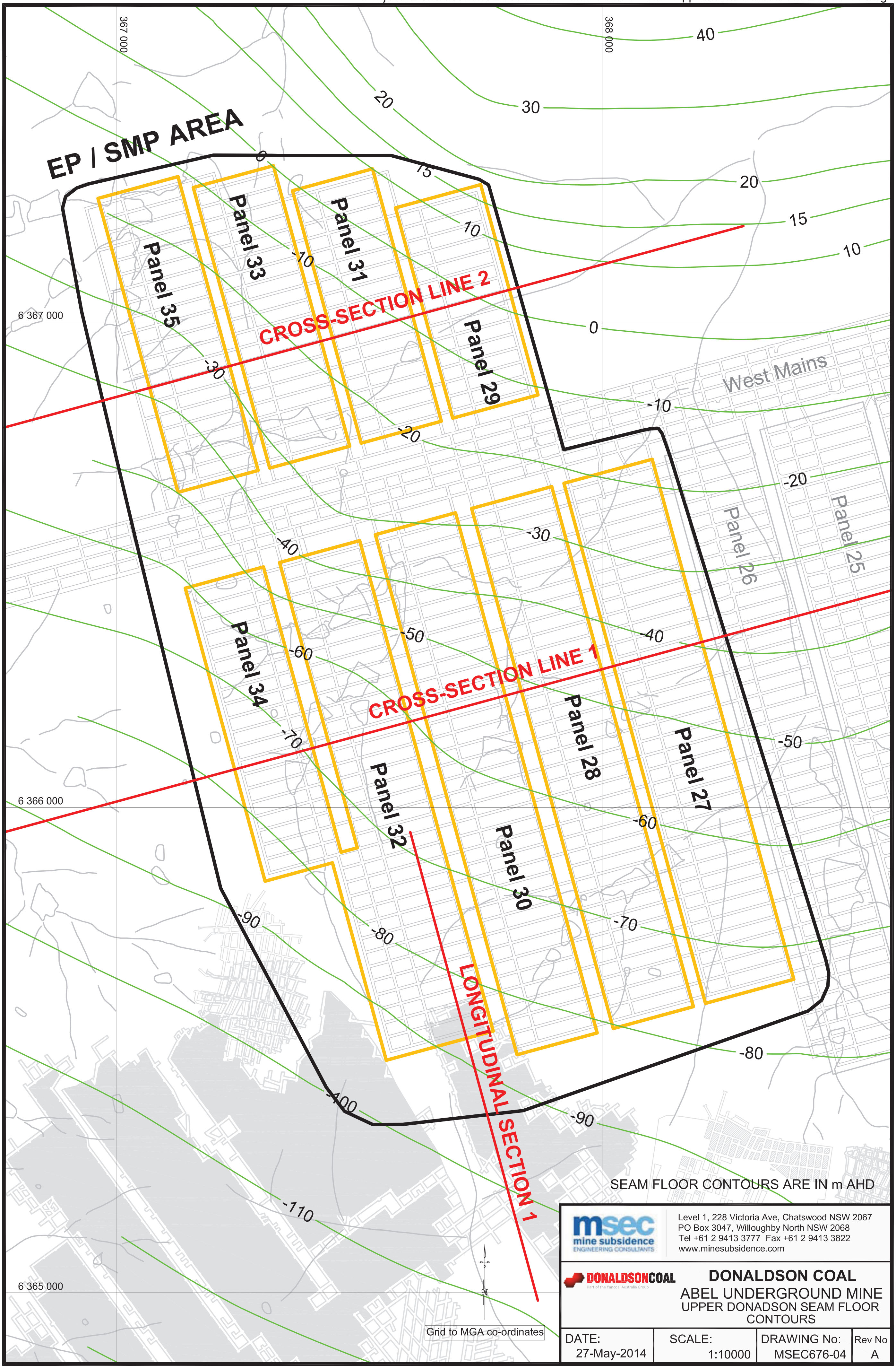

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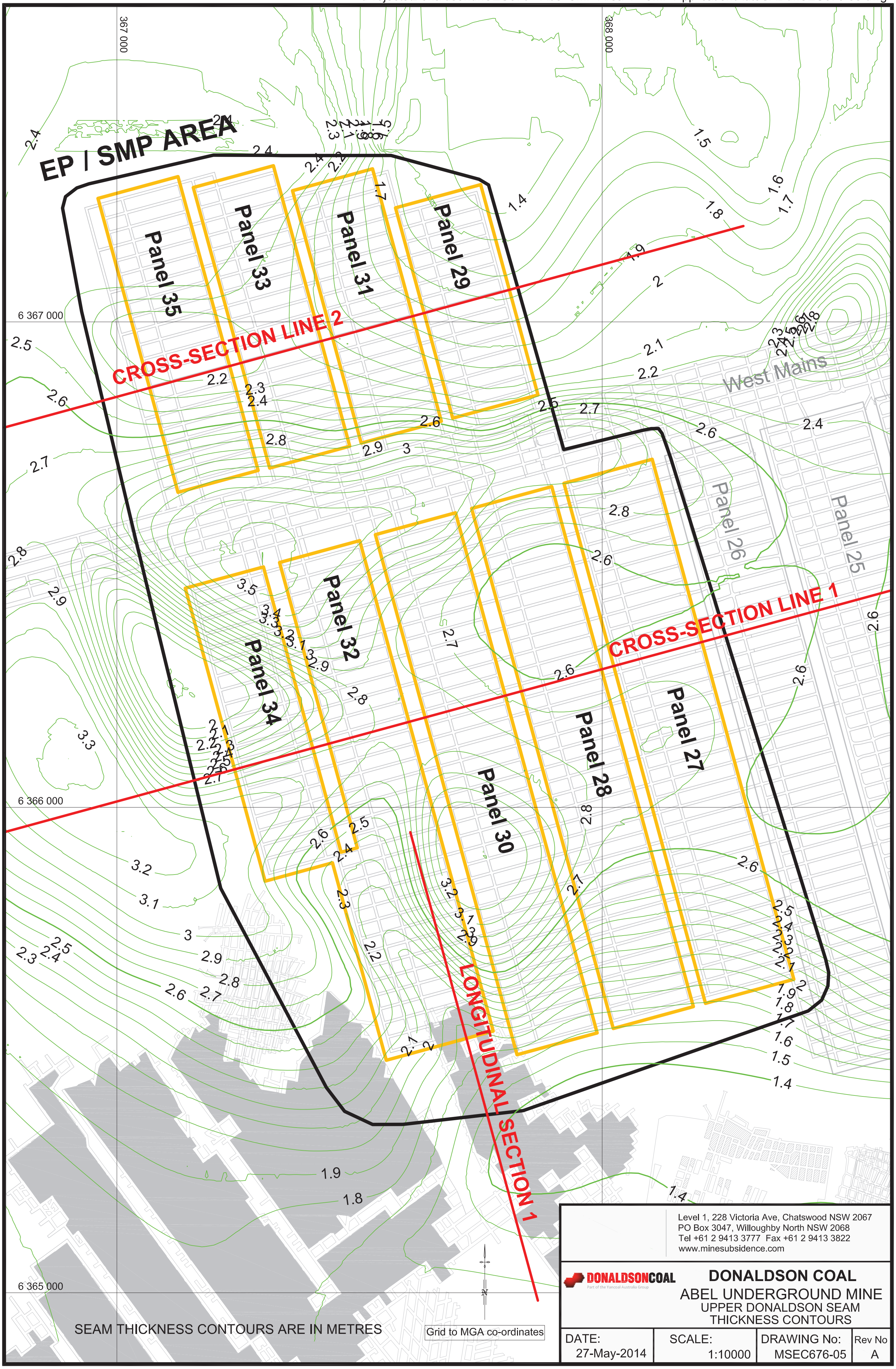

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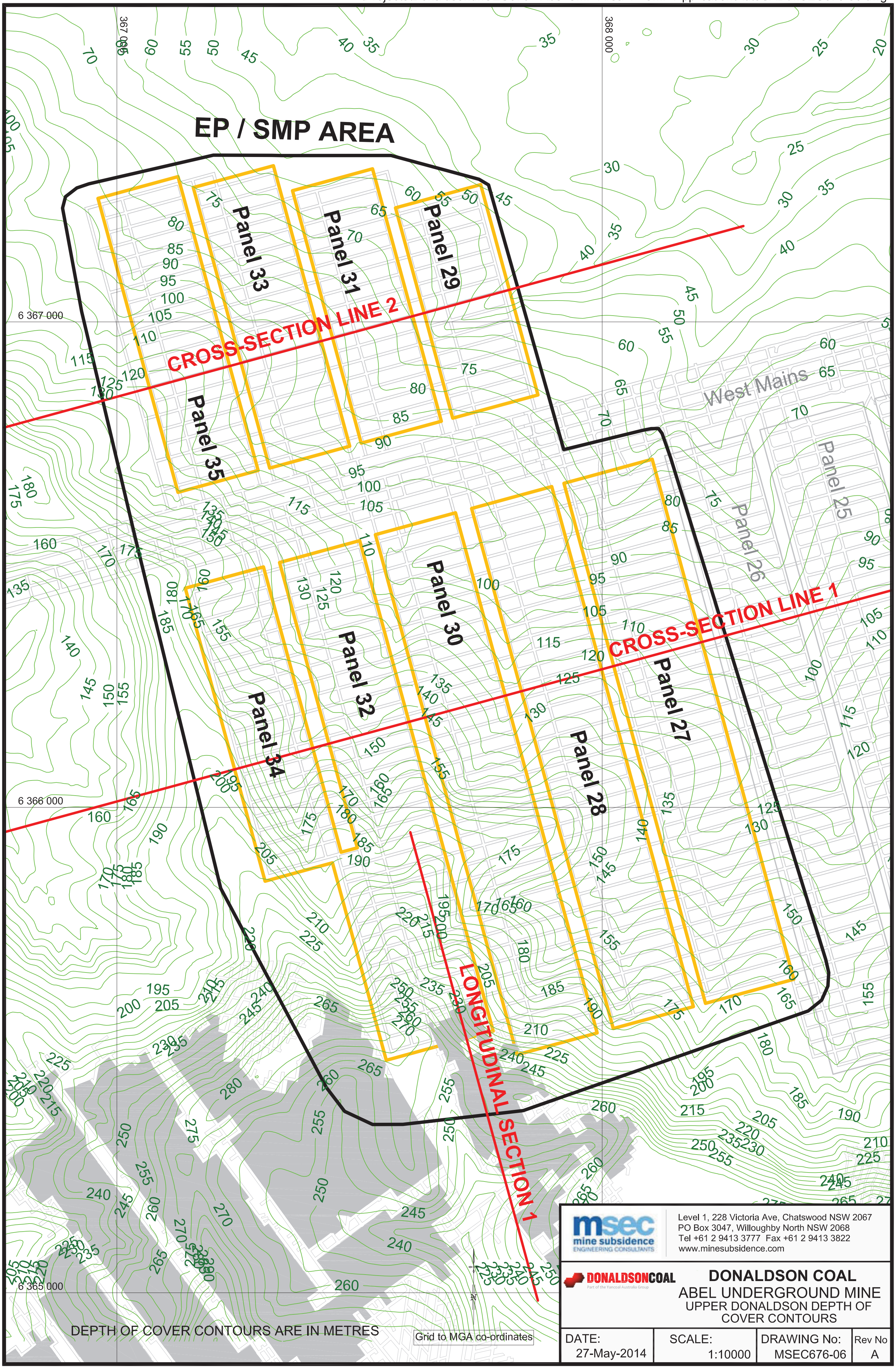

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UPPER DONALDSON DEPTH OF COVER CONTOURS

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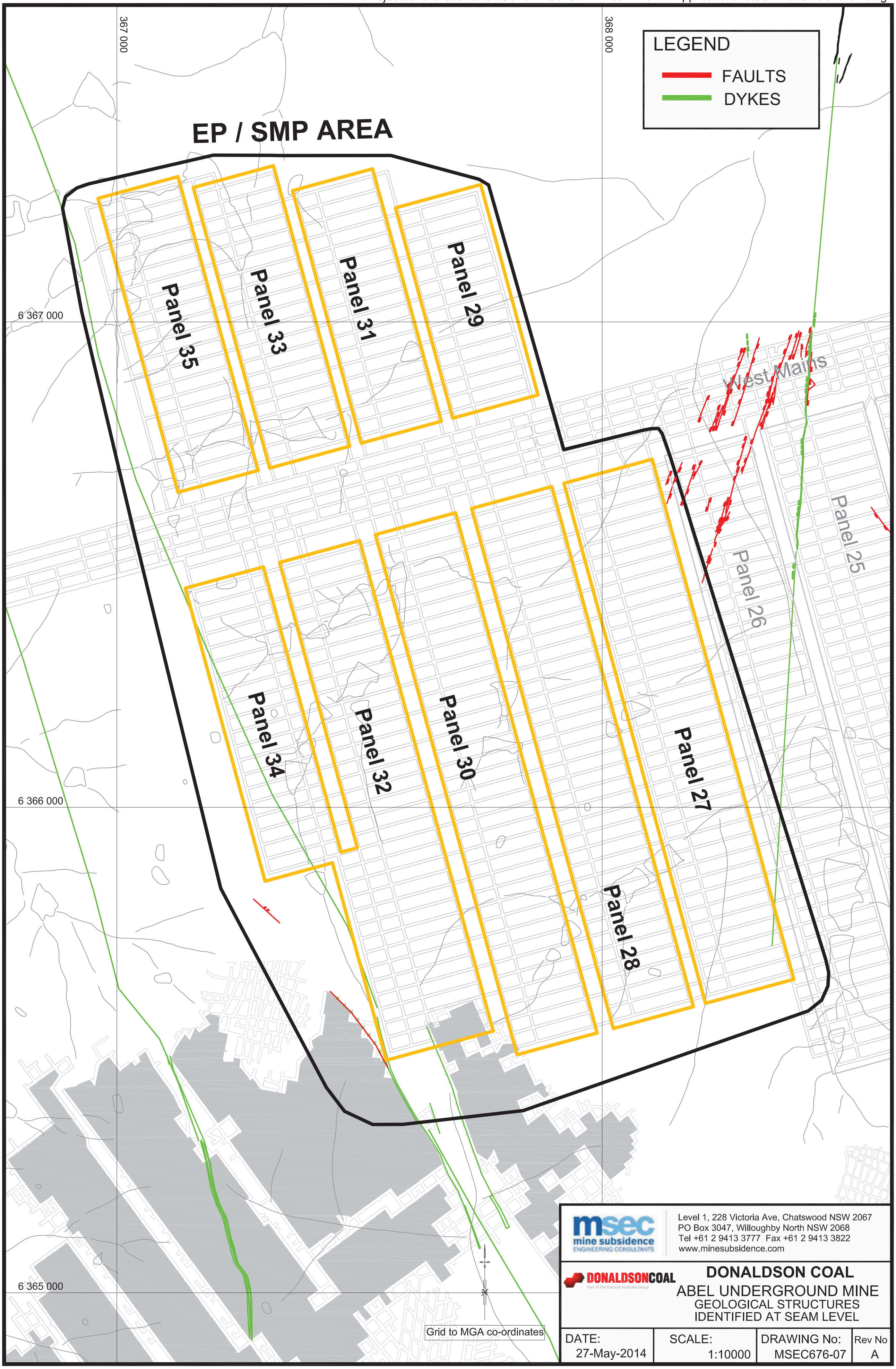

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IDENTIFIED AT SEAM LEVEL

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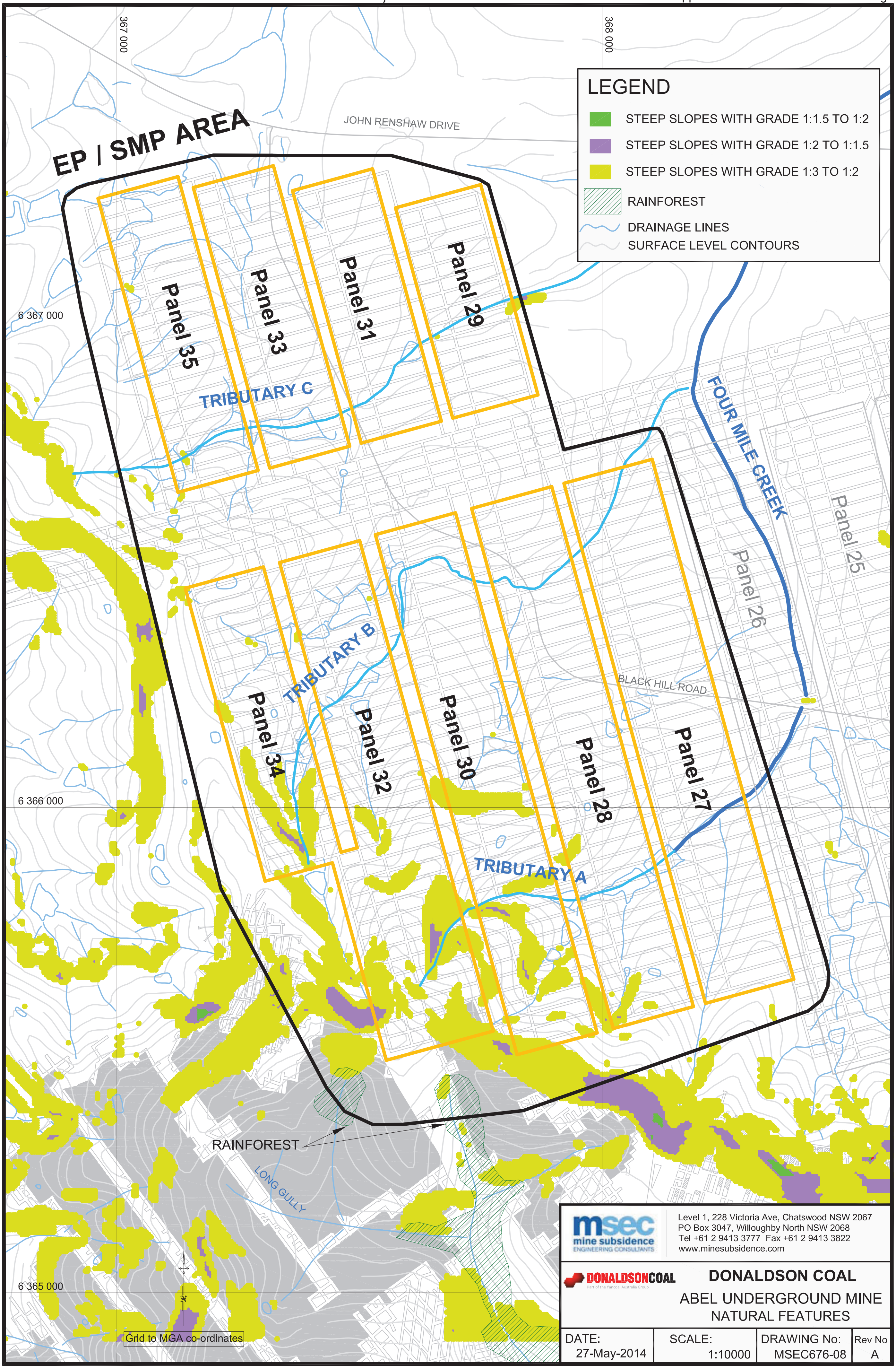

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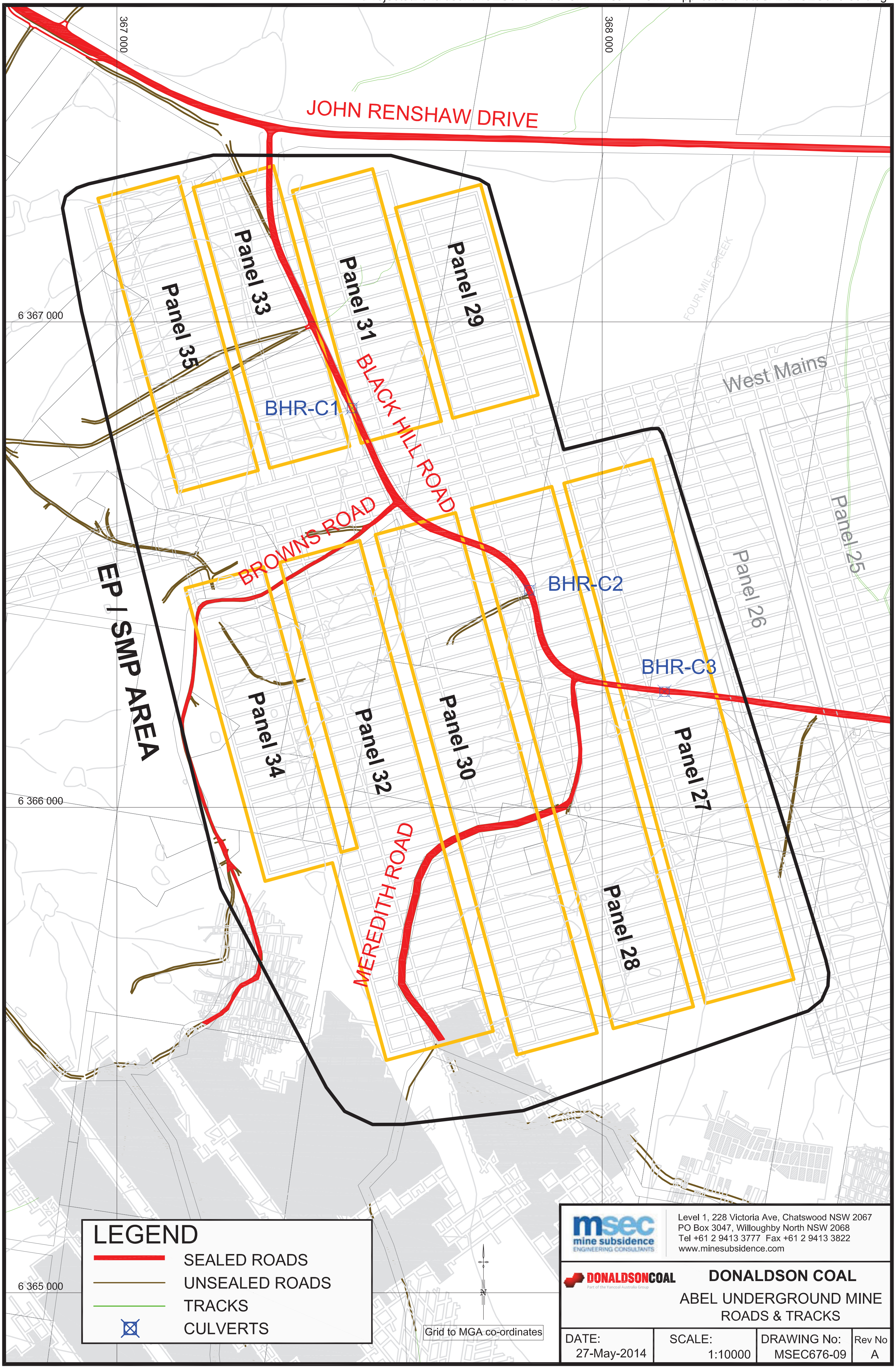

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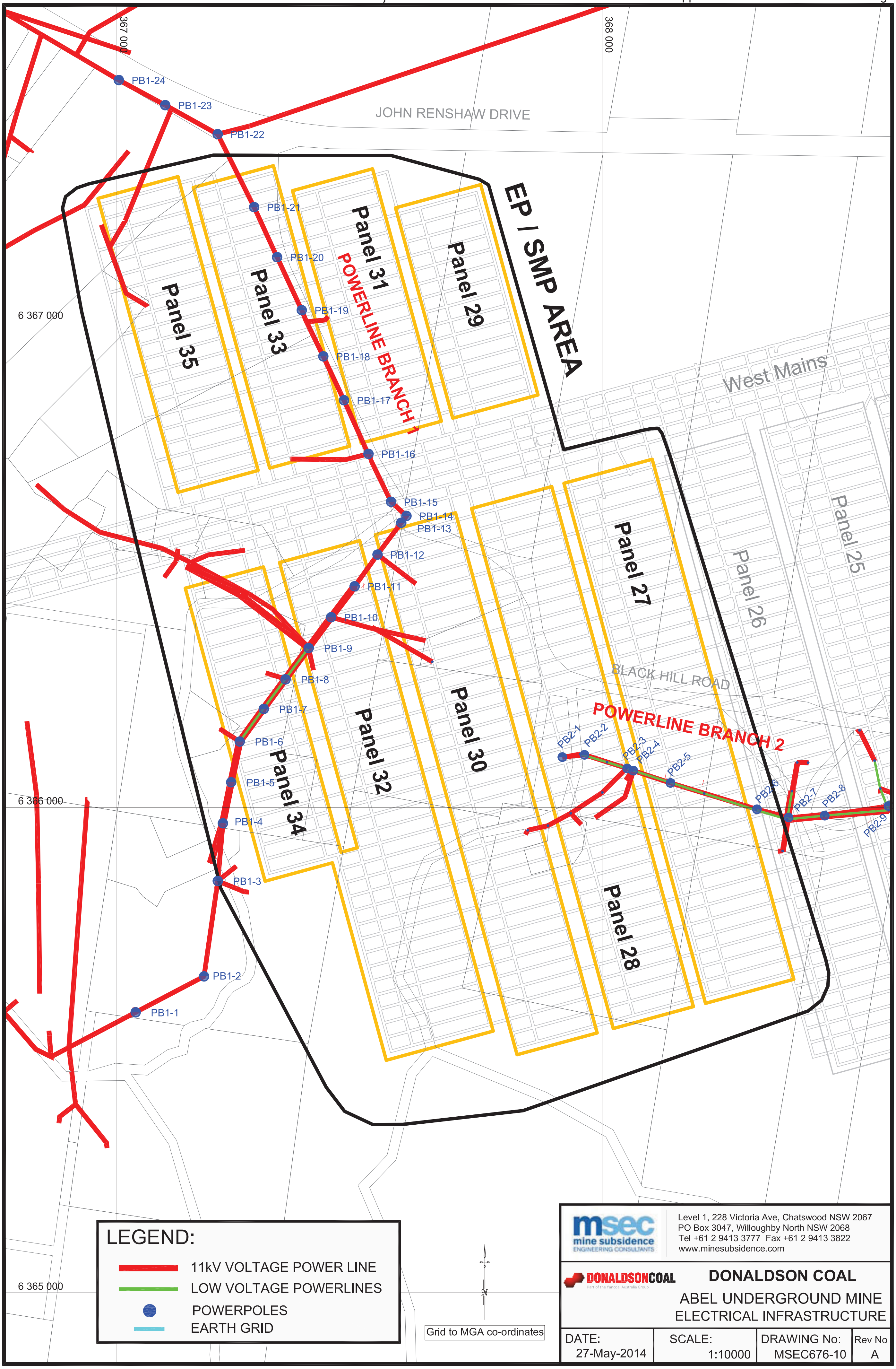

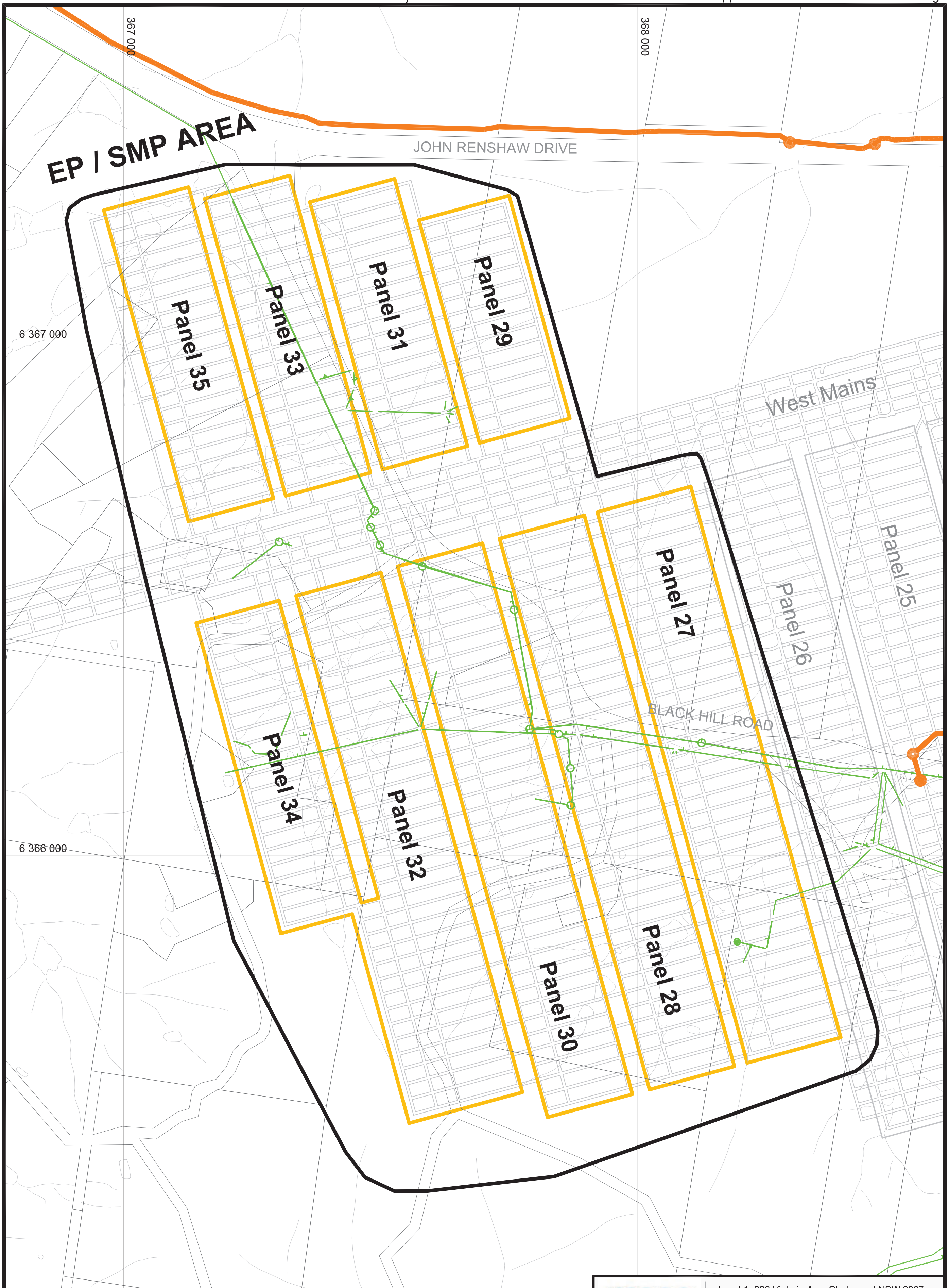

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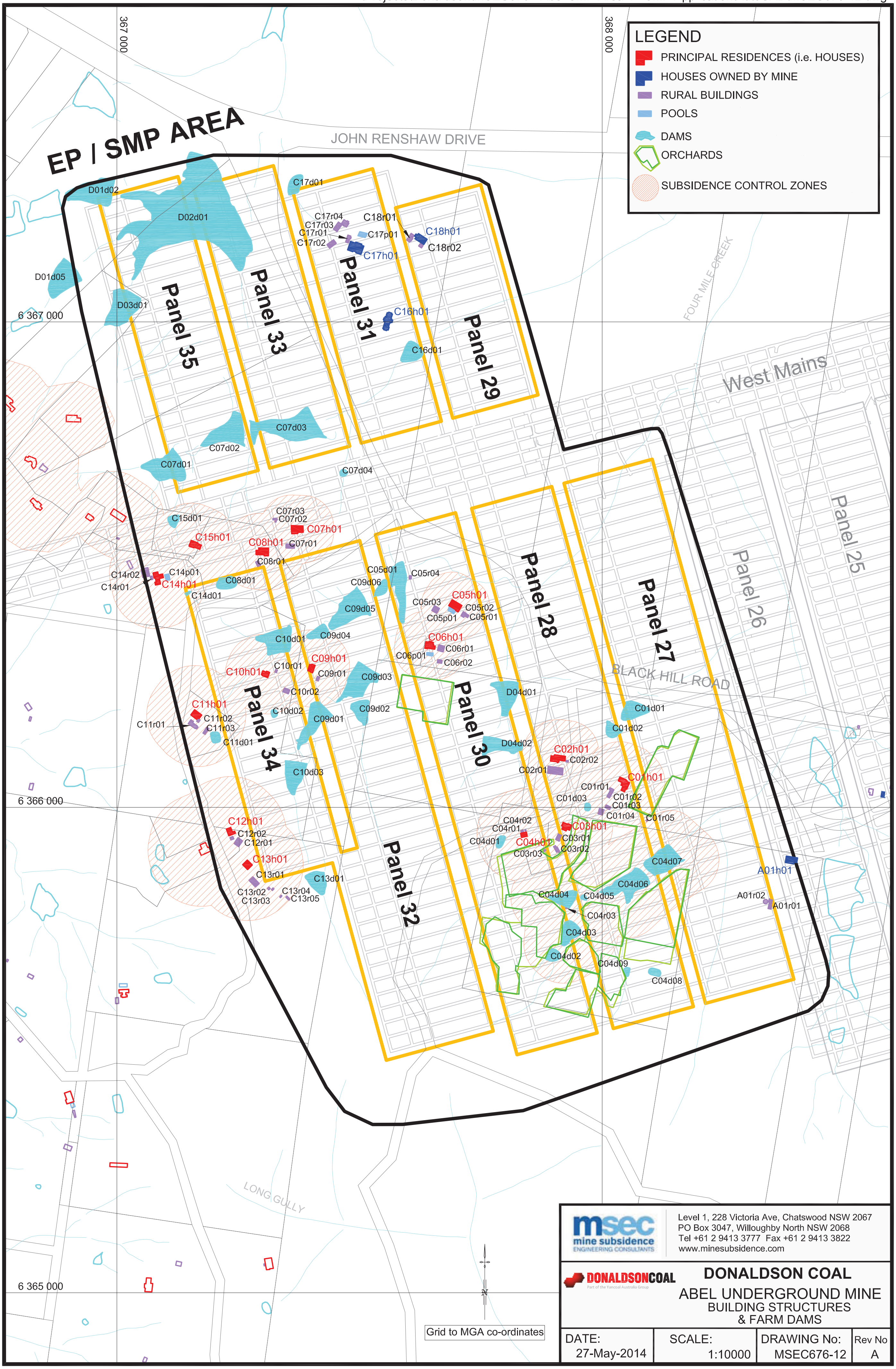

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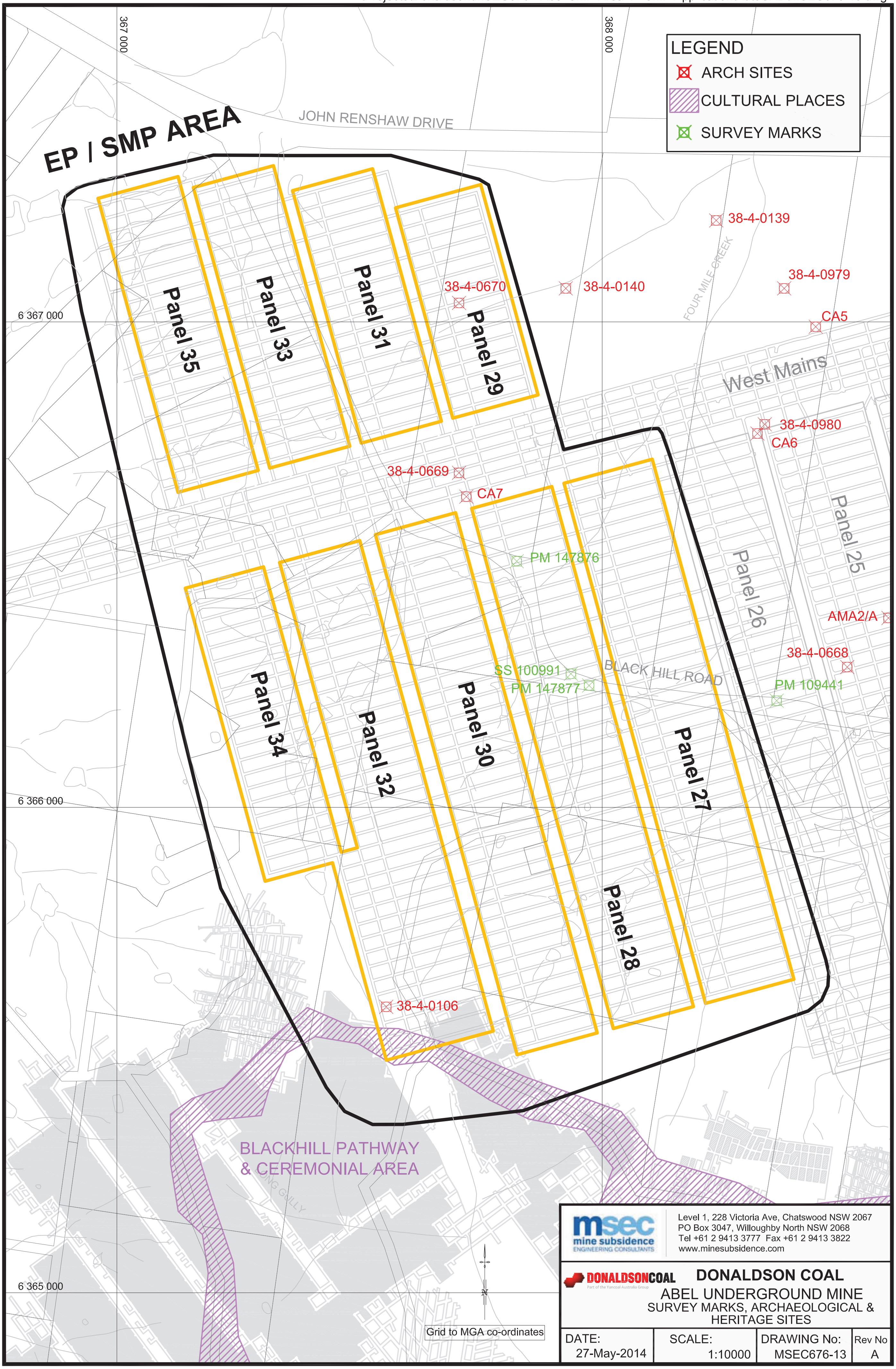

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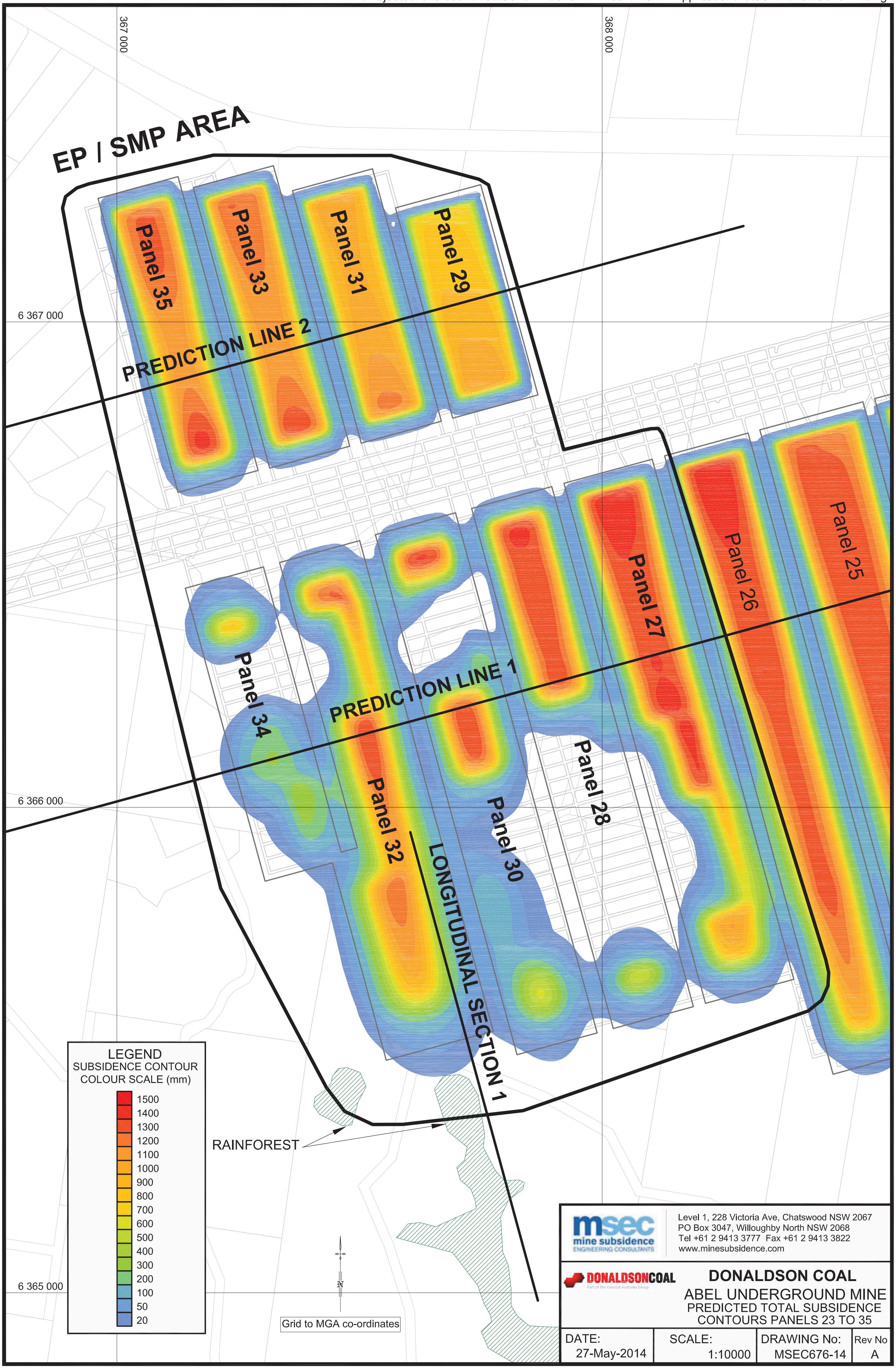

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PREDICTED TOTAL SUBSIDENCE
CONTOURS PANELS 23 TO 35

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