APPENDIX 14e

Carmichael Coal Mine and Rail Project Supplementary EIS Extracts, Appendix B

Adani Mining Pty Ltd

adani

Carmichael Coal Mine and Rail Project SEIS

Report for Updated Mine Project Description

18 October 2013

GHD

This Carmichael Coal Mine and Rail Project SEIS: Updated Mine Project Description (the Report) has been prepared by GHD Pty Ltd (GHD) on behalf of and for Adani Mining Pty Ltd (Adani) in accordance with an agreement between GHD and Adani.

The Report may only be used and relied on by Adani for the purpose of informing environmental assessments and planning approvals for the proposed Carmichael Coal Mine and Rail Project (Purpose) and may not be used by, or relied on by any person other than Adani.

The services undertaken by GHD in connection with preparing the Report were limited to those specifically detailed in Section 1.3 of the Report.

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- *reliance on the Report by a third party, or use of this Report other than for the Purpose.*

Table of contents

Table index

Figure index

1. Introduction

1.1 Project overview

Adani Mining Pty Ltd (Adani, the Proponent), commenced an Environmental Impact Statement (EIS) process for the Carmichael Coal Mine and Rail Project (the Project) in 2010. On 26 November 2010, the Queensland (Qld) Office of the Coordinator General declared the Project a 'significant project' and the Project was referred to the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (referral No. 2010/5736). The Project was assessed to be a controlled action on the 6 January 2011 under section 75 and section 87 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The controlling provisions for the Project include:

- World Heritage properties (sections 12 & 15A)
- National Heritage places (sections 15B & 15C)
- Wetlands (Ramsar) (sections 16 & 17B)
- Listed threatened species and communities (sections 18 & 18A)
- Listed migratory species (sections 20 & 20A)
- The Great Barrier Reef Marine Park (GBRMP) (sections 24B & 24C)
- Protection of water resources (sections 24D & 24E)

The Qld Government's EIS process has been accredited for the assessment under Part 8 of the EPBC Act in accordance with the bilateral agreement between the Commonwealth of Australia and the State of Queensland.

The Proponent prepared an EIS in accordance with the Terms of Reference (ToR) issued by the Qld Coordinator-General in May 2011 (Qld Government, 2011). The EIS process is managed under section 26(1) (a) of the *State Development and Public Works Act 1971* (SDPWO Act), which is administered by the Qld Government's Department of State Development, Infrastructure and Planning (DSDIP).

The EIS, submitted in December 2012, assessed the environmental, social and economic impacts associated with developing a 60 million tonne (product) per annum (Mtpa) thermal coal mine in the northern Galilee Basin, approximately 160 kilometres (km) north-west of Clermont, Central Queensland, Australia. Coal from the Project will be transported by rail to the existing Goonyella and Newlands rail systems, operated by Aurizon Operations Limited (Aurizon). The coal will be exported via the Port of Hay Point and the Point of Abbot Point over the 60 year (90 years in the EIS) mine life.

Project components are as follows:

- The Project (Mine): a greenfield coal mine over EPC 1690 and the eastern portion of EPC 1080, which includes both open cut and underground mining, on mine infrastructure and associated mine processing facilities (the Mine) and the Mine (offsite) infrastructure including a workers accommodation village and associated facilities, a permanent airport site, an industrial area and water supply infrastructure

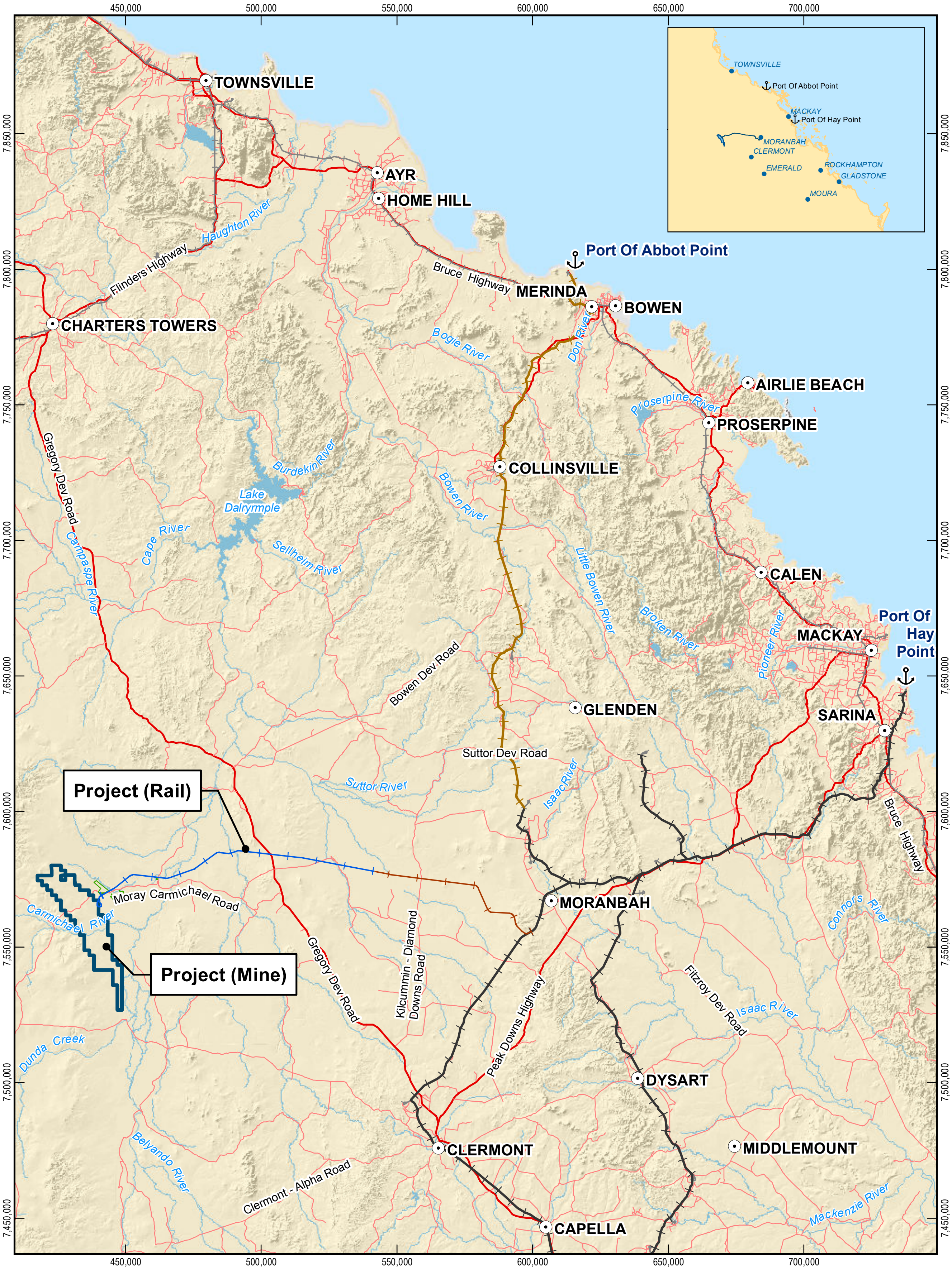
- The Project (Rail): a greenfield rail line connecting to mine to the existing Goonyella and Newlands rail systems to provide for the export of coal via the Port of Hay Point (Dudgeon Point expansion) and the Port of Abbot Point, respectively including:
  - Rail (west): a 120 km dual gauge portion running west from the Mine site east to Diamond Creek
  - Rail (east): a 69 km narrow gauge portion running east from Diamond Creek connecting to the Goonyella rail system south of Moranbah
  - Quarries: five local quarries to extract quarry materials for construction and operational purposes

Figure 1 illustrates the location of the Project.

1.2 Purpose of this report

This report outlines the updated project description for the Project (Mine). The following sections provide details regarding:

- rationale for the mine design and operational features
- the expected capital investment in the Project (Mine)
- the proposed onsite mine infrastructure
- the proposed coal handling process and associate coal handling plant layout and services
- activities associated with the mine pre-construction and construction phases
- activities associated with the mine commissioning and operation
- the proposed offsite infrastructure
- hazardous materials associated with the Project (Mine)
- proposed mine rehabilitation and decommissioning



LEGEND

- Major Port
- Other Rail Network
- Goonyella System
- Newlands System
- Local Road
- Watercourse
- Project (Rail)
  - Rail (West)
  - Rail (East)
- Mine (Offsite)
- Project (Mine)

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Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number	41-26422
Revision	B
Date	14-10-2013

Project Location

Figure 1

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Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: © Commonwealth of Australia (Geoscience Australia): Town, Railways, Watercourses (2007); DNRM: LGA, (2011), Hillshade (2009); DMR: State Roads (2008); DME: EPC1690 (2010), EPC1080 (2011); Adani: Mine Offsite, Alignment SP1 Opt11 Rev2, SP2 Opt 9 Rev 3 (2013). Created by: MS

1.3 Mine site details

The Project (Mine) is located in the northern part of the Galilee Basin, Central Queensland. The Mine will be developed over EPC1690 (incorporating Mining Lease Application (MLA) 70441, previously MDLA372) and the eastern and northern portion of EPC1080 (MLA70505 and MLA 70506). The Project is located approximately 160 km north-west of the town of Clermont. The nearest regional centre is Emerald, approximately 350 km south (refer to Figure 1). The Project (Mine) is predominantly within the Local Government Area (LGA) of Isaac Regional Council (IRC), with the exception of 167 ha within the north-western corner of the EPC1690, which is located within the LGA of Charters Towers Regional Council (CTRC). The IRC is located within the Isaac, Mackay and Whitsunday Region while the CTRC is located within the Northern Region of Queensland.

The Mine onsite infrastructure includes all infrastructure located within the boundary of EPC1690 and part of EPC1080. Adani currently holds EPC1690 and has lodged a MLA over EPC 1690) and EPC1080 . EPC1690 runs northwest to southeast, covering approximately 45 km in length and approximately 7 km in width. Adani has obtained consent from Waratah Coal Pty Ltd to lodge a mining lease application over the eastern and northern portion of EPC1080. The eastern and northern portion of EPC1080 is approximately 50 km in length and between 3 and 6 km wide. The offsite infrastructure is located outside EPC1690 and EPC1080, and is not within the proposed mining lease.

1.4 Ongoing evaluation and exploration activities

An ongoing programme of geological and geotechnical investigations is being, and will continue to be, carried out to further define the coal resources and refine the mine plan as the Project (Mine) progresses. This will include coverage across the Mine Area as well as more intense drilling of the sub-crop during early production, covering both the open cut mine areas and underground mine. This drilling program will increase knowledge of the deposit for resource estimation, washability testing as well as hydrogeological and geotechnical evaluation. These investigations will also provide further detail on ground conditions and enable detailed design of all infrastructure and structures associated with the Project (Mine).

Exploration activities will progress in stages aligned to the development of the Project (Mine); these will include:

- resource drilling to improve the level of certainty of the deposit characteristics and elevate the resource category
- geotechnical drilling to acquire knowledge of the appropriate underground working sections and the geotechnical environment affecting open cut slope stability
- Further line of oxidation line drilling to accurately define seam sub-crops for box cut designs
- 3D seismic surveys over the underground mining area to clearly define the structural geology
- hydrology studies to develop models of the subsurface hydrology regime for geotechnical studies, and evaluation of mine drainage and aquifer impacts of both open cut and underground mining

- coal quality drilling to improve knowledge of the coal raw quality and the coal washability characteristics to allow detailed CHPP design in later stages of planning

1.5 Relationship to other projects

The Project has a relationship to third party projects and approvals that will be completed separately to this environmental approval including:

- power transmission system, indicatively between Strathmore (near Collinsville) and the Project (Mine) site
- upgrade to the Moray Carmichael Access Road by Isaac Regional Council
- upgrades to the existing Aurizon rail system
- development of the North Galilee Basin Standard Gauge Rail System
- development of the Terminal 0 Expansion at Abbot Point Coal Terminal
- development of the Dudgeon Point Coal Terminal at Hay Point.

2. Rationale for mine design and operational features

2.1 Overview

The objectives of the Project (Mine) are to:

- produce 100 percent thermal coal product
- achieve a maximum production of 60 Mtpa of product coal sourced from open cut and underground mining
- produce coal with an energy and ash requirement saleable on the international seaborne thermal coal trading market

Adani in conjunction with GHD Pty Ltd, Runge Pty Ltd, Xenith Pty Ltd, Calibre Global Pty Ltd, Hyder Pty Ltd and other expert consultants has completed a detailed mine and supporting infrastructure plan for the development of the Project. The outcomes of these works include:

- development of macro level life of mine designs and associated mine plans
- outlining infrastructure, equipment and plant requirements for life of mine
- development of concept level cost estimates and production schedules
- identification of the mining, infrastructure and environmental constraints
- identification of any major risks or opportunities associated with the Project

Mine planning and design is in the pre-feasibility stage, with the mine plan developed on the basis of:

- an assessment of the general physical characteristics of the deposit based on a geological model built from existing exploration data
- an assessment of the detailed physical characteristics of the first 15 years of mine development deposit based on a geological model built from detailed 2012 exploration data
- the determination of the target coal resource and mine limits based on resource quality and economic considerations
- selection of low risk, high reliability mining methods, and particularly, which parts of the resource to target through open cut and underground methods
- mine waste characteristics and management requirements
- identification of the supporting infrastructure needs including both on-site and offsite infrastructure
- identifying optimal locations for infrastructure including minimisation of sterilisation of resource, location of workers accommodation away from noise and dust sources and overall efficiency of operation

This work has led to the pre-feasibility mine plan presented in this supplementary environmental impact statement (SEIS), which is based on the outcomes of the detailed planning works completed by the Proponent in conjunction with support consultants. While the overall mine concept and mining and infrastructure components are unlikely to change, further geological exploration and geotechnical investigations may result in a number of operational refinements throughout the life of the mine.

2.2 Coal seam physical characteristics

The technical feasibility of the Project (Mine) is dependent on the environmental, geological, geotechnical, hydrological and hydrogeological characteristics of the Project Area. Mine resource characteristics include the geology and location of varying qualities, quantities and depths of coal deposits, the surface water and groundwater features of the site, the location of the coal sub-crop and the geotechnical characteristics of the coal seam strata and overburden. The location and structure of the resource dictates the Project (Mine) layout, however, as the resource is further defined through continued exploration, the Project (Mine) layout may also be reviewed and amended accordingly.

The geological data used to support the mine plan is based on the Galilee Project – in situ JORC Coal Resources Estimate (Xenith Consulting, April 2013). This model has been developed in Mincom's Minescape software, and is underpinned by a total of 416 holes that were used to construct the geological model; 196 chip holes, 165 cored holes and 55 line of oxidation holes. A total of 157 holes were used as JORC points of observation and the topographic surface uses data from a detailed LiDAR survey commissioned by Adani in August 2011 that contains two data points per square metre. Adani has an ongoing exploration programme from which the geological model will be progressively updated.

The coal deposit underlies almost 100 percent of EPC1690. The results of the geological model show the coal seams gradually dip to the west at between 2 degrees and 6 degrees and the seams sub-crop along the eastern boundary of the Project (Mine). Four faults have been interpreted with vertical throws between 20 m and 40 m, trending in a general east - west direction. This orientation is concurrent with the trends seen elsewhere in the Galilee Basin. Mine planning has taken into account the impact and position of these faults through avoiding mine layout across the fault zones.

The overburden thickness to the shallowest coal seams ranges from 50 m of weathered Tertiary and upper Permian material in the east of the tenement, to over 400 m of weathered Triassic age Dunda beds and Rewan formation in the west. The seams are contained within the Permian coal measures, which are overlain across the total area by a poorly consolidated to unconsolidated cover of Tertiary materials, averaging 74 m in thickness but ranging to over 150 m in some areas. Figure 2 shows a generalised mine stratigraphic column.

Figure 2 Carmichael mine stratigraphic column

Age		Lithology	Stratigraphy	Thickness
Tertiary		Clay / Mudstones		40 – 100 m
Triassic		Mudstone / Siltstone	Rewan Formation	
Late Permian		Sandstone	Bandanna Formation	
		COAL – AB Seam		12 – 18 m Resource Seam
		Sandstone / Siltstone		10 m
		COAL – B Splits		1 – 2 m
		Siltstone / Mudstone		60 – 70 m
		COAL – C Seam (carbonaceous)		3 – 4 m
		Siltstone / Sandstone	Colinlea Sandstone	2 – 20 m
		COAL – D1 Seam		4 – 6 m Resource Seam
		Sandstone		5 – 30 m
		COAL D2/D3 Seam		8 – 10 m Resource Seam
		Siltstone / Mudstone		10 – 20 m
		COAL – E Seam		1 – 3 m Resource Seam
		Sandstone / Siltstone		5 – 10 m
		COAL – F Seam		1 – 5 m Resource Seam
Early Permian		Sandstone		

The coal seams occur in five main seam groups AB, C, D, E and F and have a maximum cumulative coal thickness of 50 m including the C seams and 40 m excluding the C seams. The C seams are excluded from the JORC resource estimate as they are not consistent in seam structure or thickness and often have high raw ash percentages of greater than 70 percent, air dried basis (adb). The cumulative coal thickness averages approximately 28 m (excluding C seams). The C seam and B splits have been excluded from the resource calculation because of high ash and inconsistent thicknesses.

The total JORC coal resource estimate within the Project (Mine) is 10.15 billion tonnes (Bt), of which 1.16 Bt is classified as measured resource, 3.24 Bt is classified as indicated resource and 5.74 Bt is classified as inferred resource. This is shown in Table 1.

Table 1 Summary of JORC coal resource estimate

Resource Category	Coal Tonnage (Billion Tonnes / Bt)
Measured	1.16
Indicated	3.24
Inferred	5.74
Total	**10.15**
Source: Xenith, April 2013	

The distribution between the main seam groups and comparison with the tonnage targeted for mining are shown in Table 2. The table also outlines the quality and thickness of the resource.

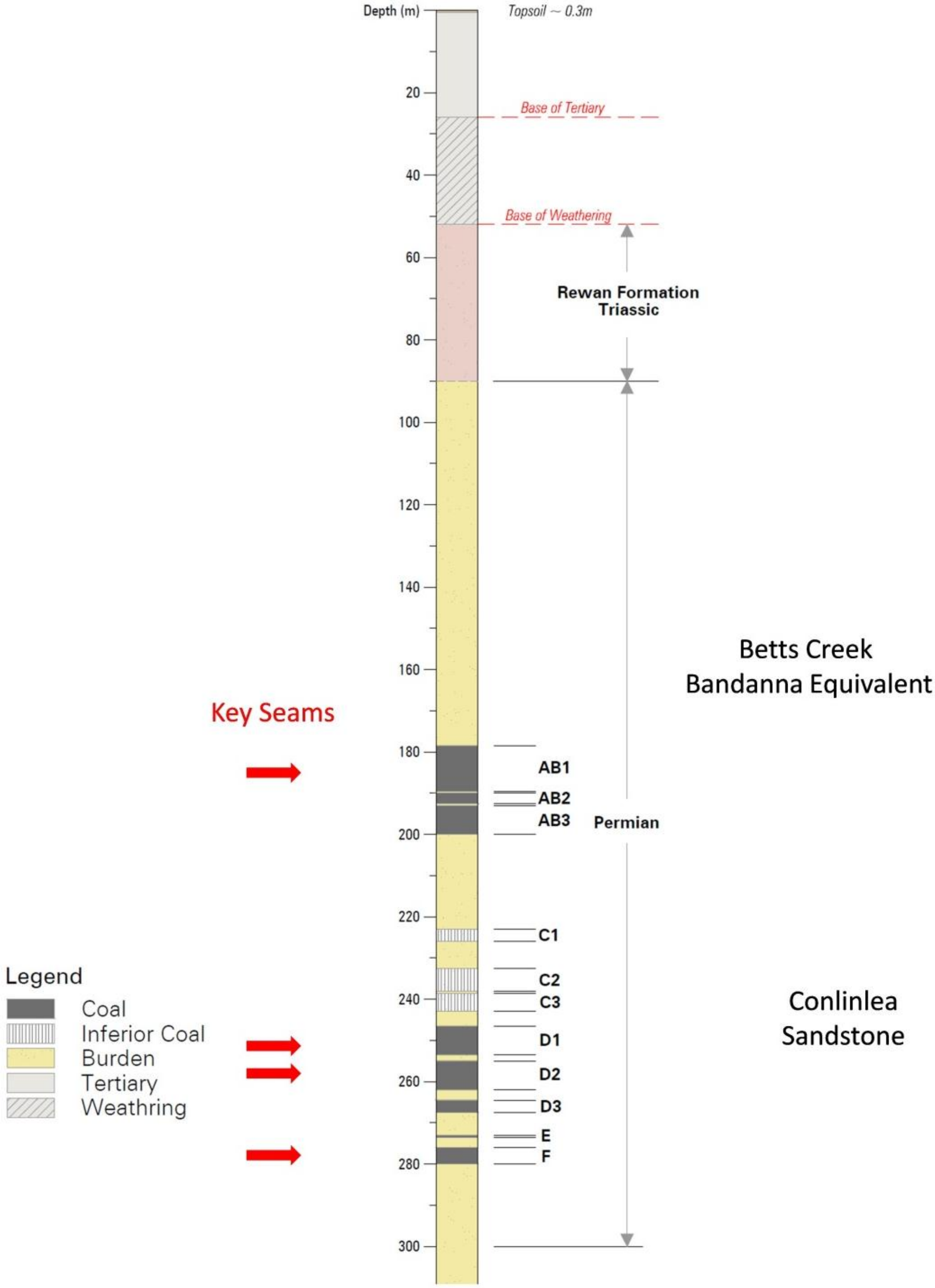
Table 2 Coal resource by seam, thickness and quality

Seam	Coal Tonnage (Bt)	Average Raw Ash (% air dried)	Average Thickness (m)
AB1	1.93	24.3	6.8
AB2	0.57	37.2	2.0
AB3	1.96	35.8	5.6
D1	1.71	23.1	5.7
D2	1.71	24.3	3.6
D3	1.10	20.5	4.0
E	0.21	19.3	1.2
F	0.96	18.9	1.1
Grand Total	**10.15**		**30.1**

The geotechnical evaluation for the Project (Mine) is based on the analysis of samples obtained from eight boreholes during successive annual field exploration drilling campaigns. The analysis was conducted to assess the overburden characteristics of the target coal seams. The geotechnical analysis undertaken has utilised all available data to provide information on appropriate in-pit slope angles, together with in-pit and out-of-pit spoil designs. The geotechnical analysis methods used for the pit design and mine planning for the Project (Mine) are considered commensurate with the industry standard and are supported with empirical assessments from international case studies with comparable ground conditions.

Given the extensive strike length of the coal seams in the Project (Mine), and the variation in geotechnical characteristics across the strike length, the overburden to the target mining seams has been interpreted in terms of geo-mechanical units, and on the basis of definition of geotechnical domains (Figure 3). Slope design parameters are provided for mine planning purposes for each of the identified domains.

Figure 3 Carmichael mine indicative strike length



2.3 Deposit economics

The optimum open cut pit shell and underground mine limits were defined through a cost ranking analysis. Cost ranking is a process that analyses the comparative mining costs of each potential mining block in the deposit to identify economic trends and the potential magnitude of the reserves tonnage that lie within a pre-determined cost cut off. The method defines the likely economic limits of the open cut mine layout and assists in the development of the most cost-effective scheduling sequence.

Cost ranking undertaken as part of the mine planning works was a key determinant in the size and shape of the current mine layout and provided a basic analysis of the possible sequencing of mining in advance of the preparation of the detailed mine plan. The extraction of the target quantity of product to meet demand was considered.

2.4 Mining methods rationale

A combination of both open cut and underground mining methods are proposed to extract the coal. The key factors considered in determining the mining method and the associated open cut mine plan are outlined as follows:

- targeted scale of production
- cost ranking to define the economic limits of the open cut mine
- strike of the coal seams
- geometry of the deposit
- stability of the overburden materials in the deployment of draglines and other mobile equipment
- application of draglines as a more flexible system, particularly to deal with changing geotechnical conditions and large operating cost advantages
- ability to use draglines with truck-shovel pre-strip for the removal of primary overburden for a robust and well proven application
- ability to provide flexible scheduling and access
- ability to develop long, consistent strips for the efficient use of large scale open cut equipment as quickly as possible
- haulage distances for waste once steady-state operations are reached

The key factors considered in determining the underground mining method and the associated underground mine plan include:

- a cost ranking exercise to determine an economic transition boundary between open cut and underground mining areas
- the need for a production output of approximately 20 Mtpa ROM to augment open cut operation to meet target production
- the safety, production rates and recovery rates of the single pass longwall mining method
- the depth ranges of 60 – 500 m of the resource, and productivity levels required to ensure economic extraction

- presence of lower ash AB1 seam and D1 seam which can be blended with higher ash product from open cut pits to achieve an export quality coal with minimised washing
- an assumed initial longwall productivity of approximately 5 Mtpa ROM from each longwall face installed including development
- benchmarking production levels based on comparative productive Australian longwall operations

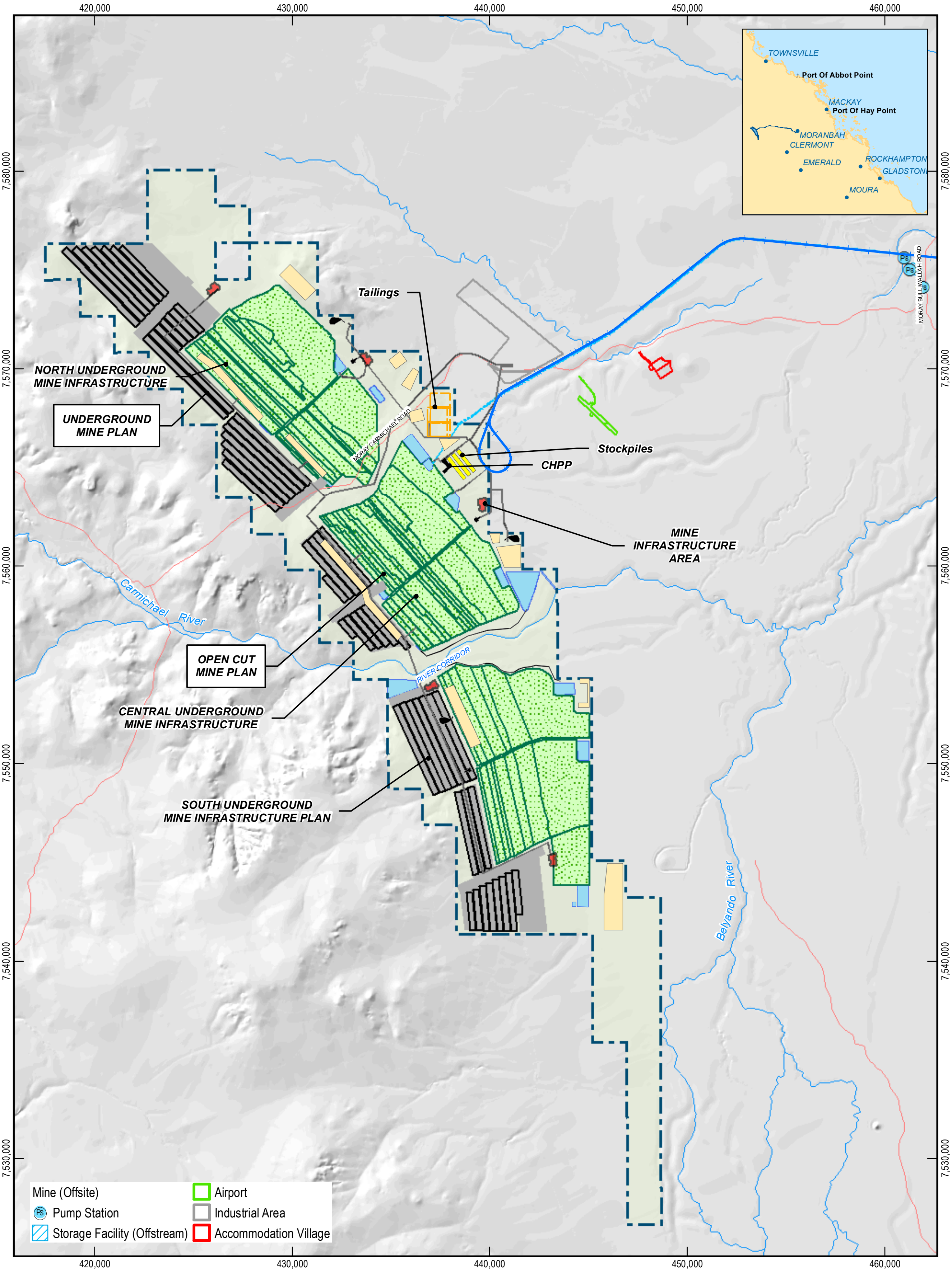
The management of the Carmichael River, which intersects the Project (Mine) in an east-west direction was also considered in the Project (Mine) design. The Carmichael River is an ephemeral tributary of the Belyando River that flows west to east across the lease and bisects the deposit. A minimum corridor of 500 m will be retained either side of the centre line of the Carmichael River to minimise any potential impacts to river and associated riparian zone during mining operations. Mine production is scheduled to commence on the southern side of the Carmichael River around 2021; a bridge or appropriate crossing infrastructure will be developed to allow access to the south of the river.

2.5 Placement of on-site infrastructure and out-of-pit dumps

The geological characteristics of the Project (Mine) define the location of open cut and underground mining operations. This in turn determines the optimal location of mine infrastructure and associated interdependencies including site access, services and other infrastructure required to access offsite infrastructure and third party service providers. If infrastructure is developed over economic coal deposits, those deposits will be difficult or unfeasible to extract. The layout of the infrastructure has subsequently been designed and located to minimise the likelihood of resource sterilisation. In particular, the main infrastructure area is located outside the sub-crop line of the identified economic seams.

The out-of pit dumps are located to minimise handling of material and also to avoid the sterilisation of coal resources. The out-of-pit dumps were initially located over the underground mining areas within EPC1690, however subsequent to the development of the 2011 mine plan, Adani was able to secure the eastern portion of EPC1080, adjacent to the eastern boundary of EPC1690 which allows for more efficient placement of spoil adjacent to the low wall of each open cut. EPC1080 will now be used for the out-of-pit dumps.

Further detail on the key operational activities associated with the mine infrastructure area is in Section 1. Figure 4 illustrates the general mine layout, and location of the mine and offsite infrastructure.



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Out of Pit Waste Dumps
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure
- Stockpiles
- Tailings Cell
- Top Soil Storage

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Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

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Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision B
Date 23-10-2013

Onsite and Offsite Mine Infrastructure

Figure 4

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Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS

2.6 Equipment and plant selection

The proposed scale of production requires large-scale mining equipment, which will vary in fleet numbers depending on the stage of mine operations. Equipment selection will depend on required production rates, reliability of equipment and suitability to the operating conditions, particularly high summer temperatures.

For the open cut component, truck-and-shovel equipment will be used for the pre-strip of overburden and for coal excavation. Other methods such as bucket wheels, continuous haulage systems and draglines may be used for removal of overburden after further investigation.

The underground mining method will be longwall mining. Longwall mining requires sets of equipment consisting of hydraulic shields to provide roof support during extraction, shearers to cut the coal from the seam and conveyors to transfer the coal to the surface. Underground mining equipment has not yet been selected.

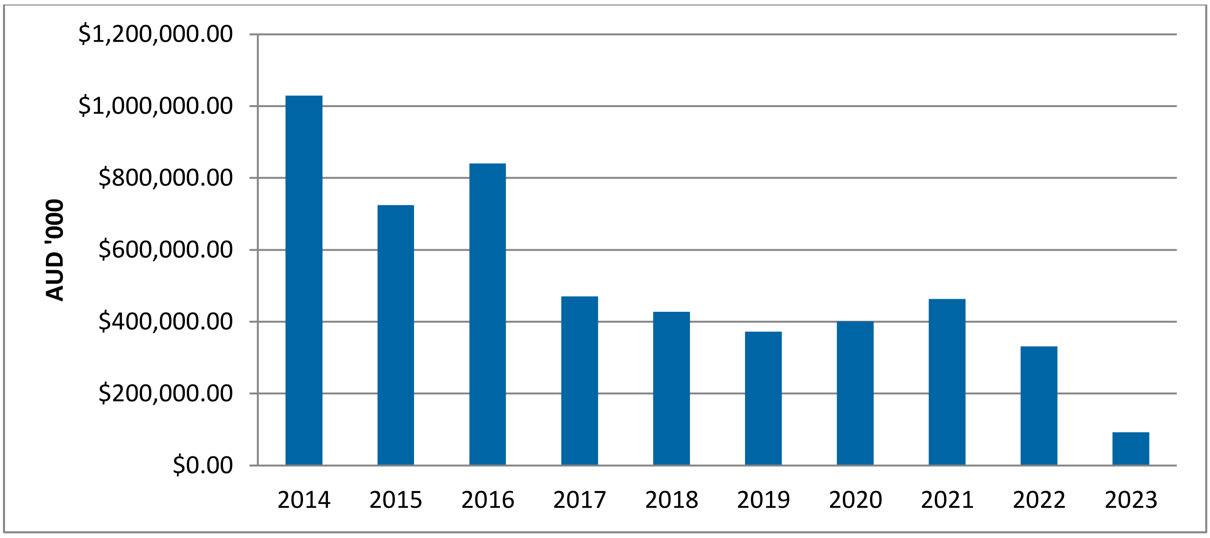
A combination of haul trucks and conveyors will be used to move coal from the extraction location to ROM stockpiles, with the balance yet to be determined. Conveyors generally provide for more efficient transport of coal, but are less flexible and cannot be readily re-routed and hence, an optimal combination of trucks and conveyors is being sought. Further detail on the selection and capacity of the equipment and plant is outlined in Section 8.4.

3. Mine schedule

3.1 Capital investment

Capital investment for the life of the Project (Mine) is expected to total $16.5 billion. It is estimated that $5.1 billion will be spent in the years preceding 2022, with the remaining $11.4 billion being spent over the remaining years of operation. Figure 5 shows capital investment for the life of the Project (Mine).

Figure 5 High level estimate of capital investment – construction phase to full production of the Project (Mine)



3.2 Mine plan

The Mine plan is based on achieving the production objective of 60 Mtpa (product) as quickly as possible and then maintaining a relatively steady rate of production over the life of the mine. Figure 6 outlines the coal production schedule of open cut ROM, underground ROM and total product tonnes for the operational life of 60 years.

Figure 6 Mine (product coal) production

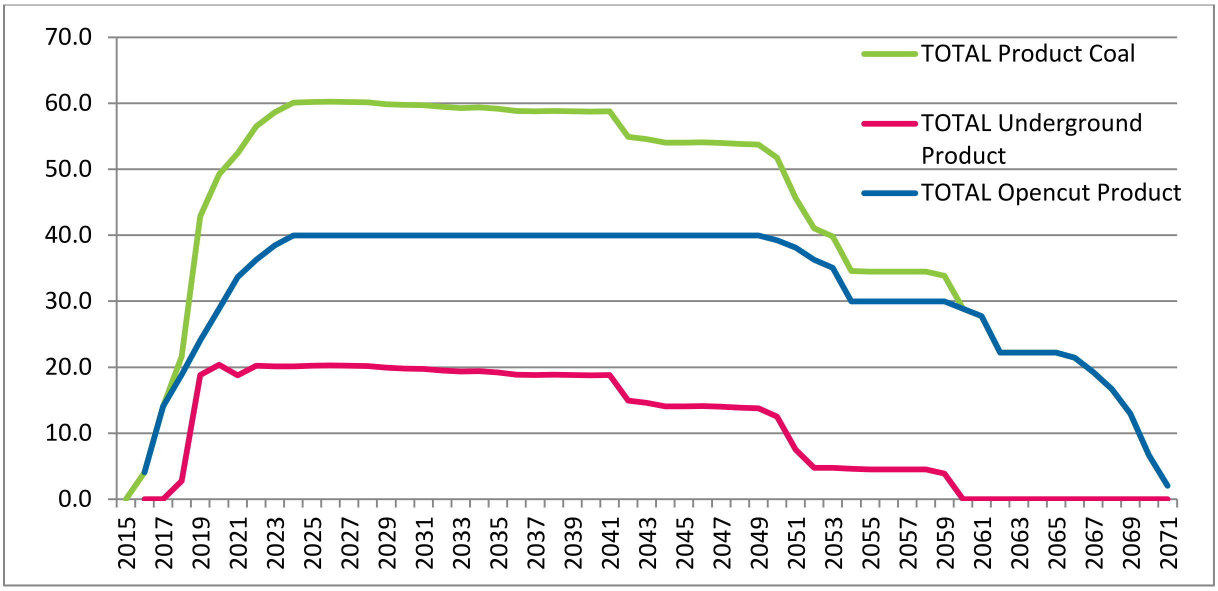


Table 3 outline the quantities of coal and waste that will be moved over the life of the Project (Mine), from the open cut and underground mining respectively. In order to maintain the target throughout the life of the Project (Mine), the annual production levels from the open cut will remain around 40 Mtpa (product).

Table 3 Combined ROM coal and product coal

Period (years)	ROM Coal Mt			Product Coal Mt
	Open Cut	Underground	TOTAL	TOTAL
2015	0	0	0	0
2016	5.5	0	5.5	4.1
2017	19.0	0	19	14.1
2018	25.5	2.8	28.3	21.6
2019	32.5	18.8	51.3	42.9
2020 - 2024	239.5	99.7	339.2	276.9
2025 - 2029	270	100.8	370.8	300.6
2030 - 2034	270	97.7	367.7	297.5
2035 - 2039	270	94.6	364.6	294.4
2040 - 2044	270	81.2	351.2	281.0
2045 - 2049	270	69.9	339.9	269.7
2050 - 2054	241.4	34.2	275.6	212.8
2055 - 2059	162	21.9	183.9	137.9
2060 - 2064	166.5		166.5	123.2
2065 - 2069	134.1		134.1	92.6
2070 - 2074	29.2		29.24	21.6

3.3 Mine staging

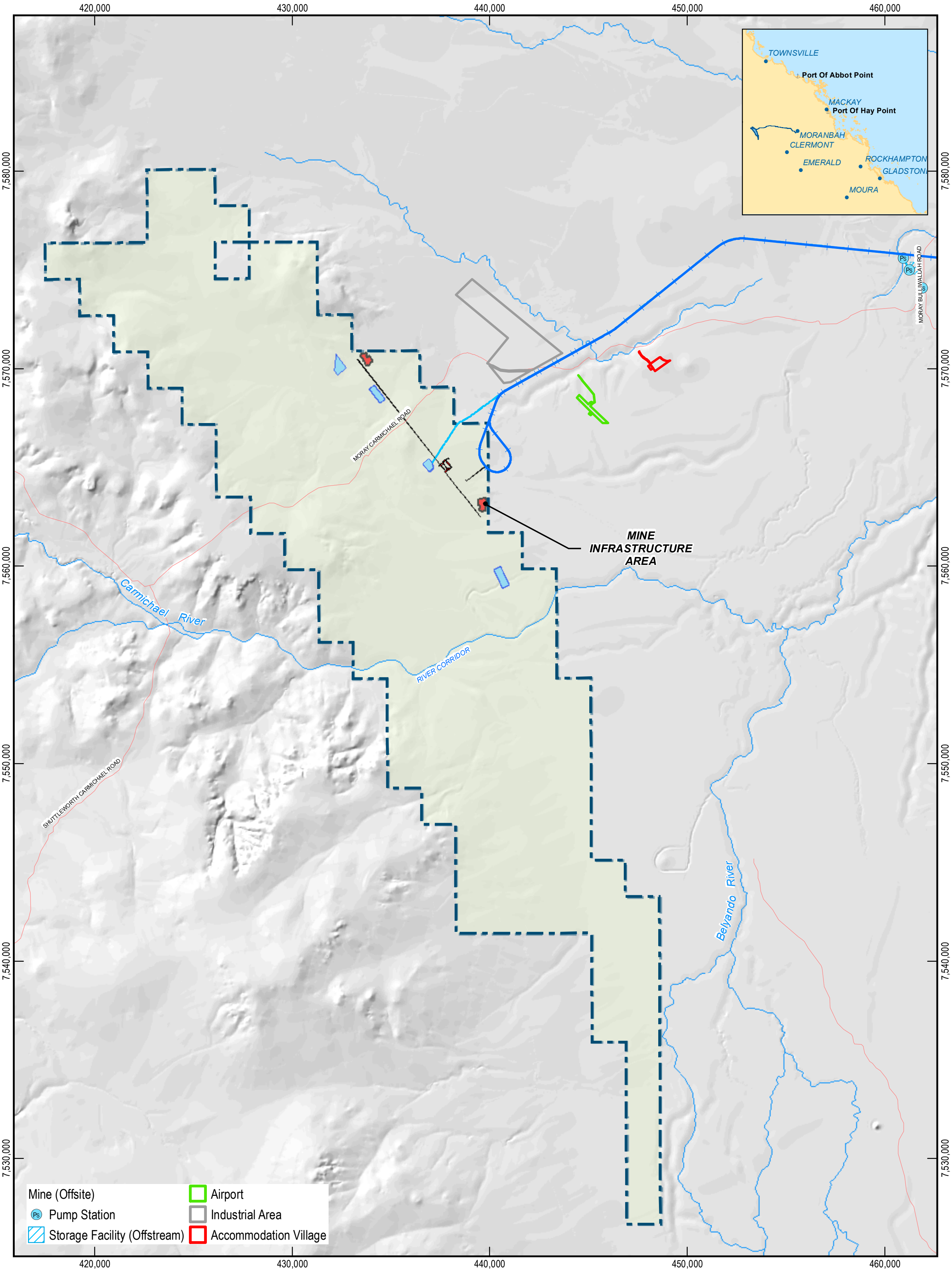
The Project (Mine) life cycle consists of preconstruction, construction, operation and closure and decommissioning. Rehabilitation will occur progressively throughout the mine life. The mine sequencing allows for operational activities to commence prior to the completion of construction of the mine; this facilitates a positive cash flow during early stages of the mine life. Table 4 provides an overview of the Project (mine) stage plan; Figure 7 to Figure 20 show selected stages of the construction and operation stages.

Table 4 Mine stage plan overview

Year(s)	Activities
2014	Commence construction of workers accommodation village stage 1 & 2
	Commence construction of permanent airport
	Commence construction of power, construction water supply and other external services
	Construction of flood harvesting infrastructure
	Commence construction of open cut facilities including Pits B/C and D/E MIA's, Site Fencing, Water Storage Dams and Temporary Roads.
	Refer Figure 7
2015	Commence B ,D & E Pit box-cut
	Complete Pit B Diversion Drains
	Construct Carmichael River Northern Flood Protection Levies
	Commence construction of workers accommodation village stage 3 & 4
	Complete construction of Permanent Airport
	Construct Additional Stages of Flood Harvesting Facilities
	Refer Figure 8
2016	Commence C Pit box cut
	Produce first coal from open cut B, D & E Pits
	Complete open cut facilities for Pit B/C and D/E MIA, ROM and Overland Conveyors
	Complete B,D&E Pits HV Roads and HV Power Distribution
	Complete Coal Handling and Processing Plant Modules 1&2 and Tailings Cell
	Complete Product Handling and Train Load-out Facility
	Commence construction of workers accommodation village stage 5
	Refer Figure 9
2017	First Coal Production from open cut C Pit
	Construct Underground Mine 1 MIA facilities
	Complete C Pit water diversion drain and HV Roads
	Refer Figure 10
2018	Commence development and longwall operations of underground mine UG 1
	Complete Coal Handling and Processing Plant Modules 3 & 4
	Refer Figure 11
2019	Complete development operations in UG1 and commence Longwall operations

Year(s)	Activities
	Construct coal processing plant (CPP) Bypass systems
	Refer Figure 12
2020 – 2024	2021– Construct Carmichael River southern flood protection levee
	2021 – Construct Carmichael River Crossing
	2021 – Commence development of underground mine UG 5
	2021 – Dragline 1 commences in D Pit
	2021 – Commence G Pit
	2021 – Commence minor rehabilitation of out of pit spoil emplacement
	2022 – Commence development of underground mines UG 4 and 5
	2022 – Commence open cut facilities for Pit F/G and UG 4, MIA, ROM and Overland Conveyors
	2023 – Complete open cut facilities for Pit F / G, Water Management
	Refer Figure 13
2025 – 2029	2026 - Commence F Pit
	2026 – Commence longwall operation of underground mine UG 5
	2026 – Complete UG 5 MIA
	2027 – Commence longwall operation of underground mine UG 4
	2027 – Complete UG 4 overland conveyors and facilities
	2028 – Commence development of underground mine UG 3
	2028 – Complete expansion of Pit D/E MIA for UG 3
	2029 – Rehabilitation works on Pits B, C, D, E out of pit spoil emplacement
	Refer Figure 14
2030 – 2034	2030 – Complete UG 5 Infrastructure
	2030 – Complete UG 1 Longwall Operations
	Refer Figure 15
2035 – 2039	2035 – Commence development of underground mine UG 2
	2035 – Commence UG 2 MIA
	2036 – Commence longwall operation of underground mine UG 3
	2036 – Complete UG3 Infrastructure
	Refer Figure 16
2040 – 2044	2040 – Commence longwall operation of underground Mine 2
	2040 – Complete UG2 Infrastructure
	2040 – Complete UG 4 Longwall Operations
	Refer Figure 17
2045 – 2049	No additional Pits Commenced
	2045 – Complete UG 5 Longwall Operations
	Refer Figure 18
2050 – 2060	2051 – Complete UG 3 Longwall Operations
	2051 – Complete mining in C Pit commence final rehabilitation.
	2053 – Complete mining in E Pit commence final rehabilitation.
	2059 – Complete UG 2 Longwall Operations
	Refer Figure 19

Year(s)	Activities
2061 – 2072	2061 – Complete mining in D Pit commence final rehabilitation
	2068 – Complete mining in G Pit commence final rehabilitation
	2069 – Complete mining in F Pit commence final rehabilitation
	2070 – Decommission Southern ROMs
	2071 – Complete mining in B Pit commence final rehabilitation.
	2071 – Decommission Southern ROMs
	2071 + – Rehabilitate mine site
	Refer Figure 20



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure

Based on or contains data provided by the State of QLD (DERM) [2010]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

GHD adani

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision B
Date 23-10-2013

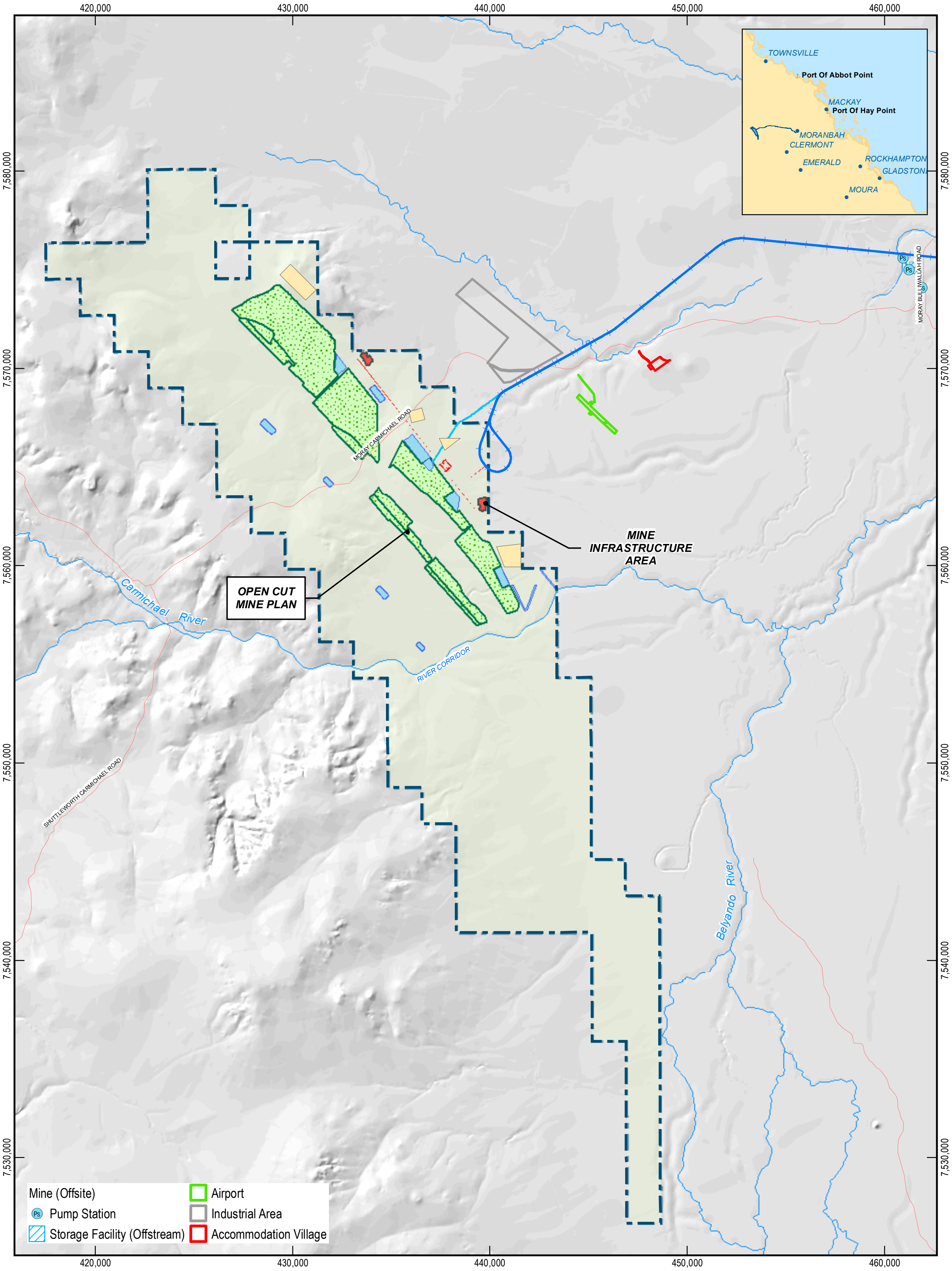
Mine Stage - Year 2014

Figure 7

G:\41\26422\GIS\Maps\MXD\01000_Project_Description\41_26422_01014_rev_b.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

- Local Road
- River / Watercourse
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Water Management Dams
- Mine Infrastructure Area
- Top Soil Storage

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number	41-26422
Revision	B
Date	23-10-2013

Mine Stage - Year 2015

Figure 8

G:\41\26422\GIS\Maps\MXD\01000_Project_Description\41_26422_01013_rev_b.mxd

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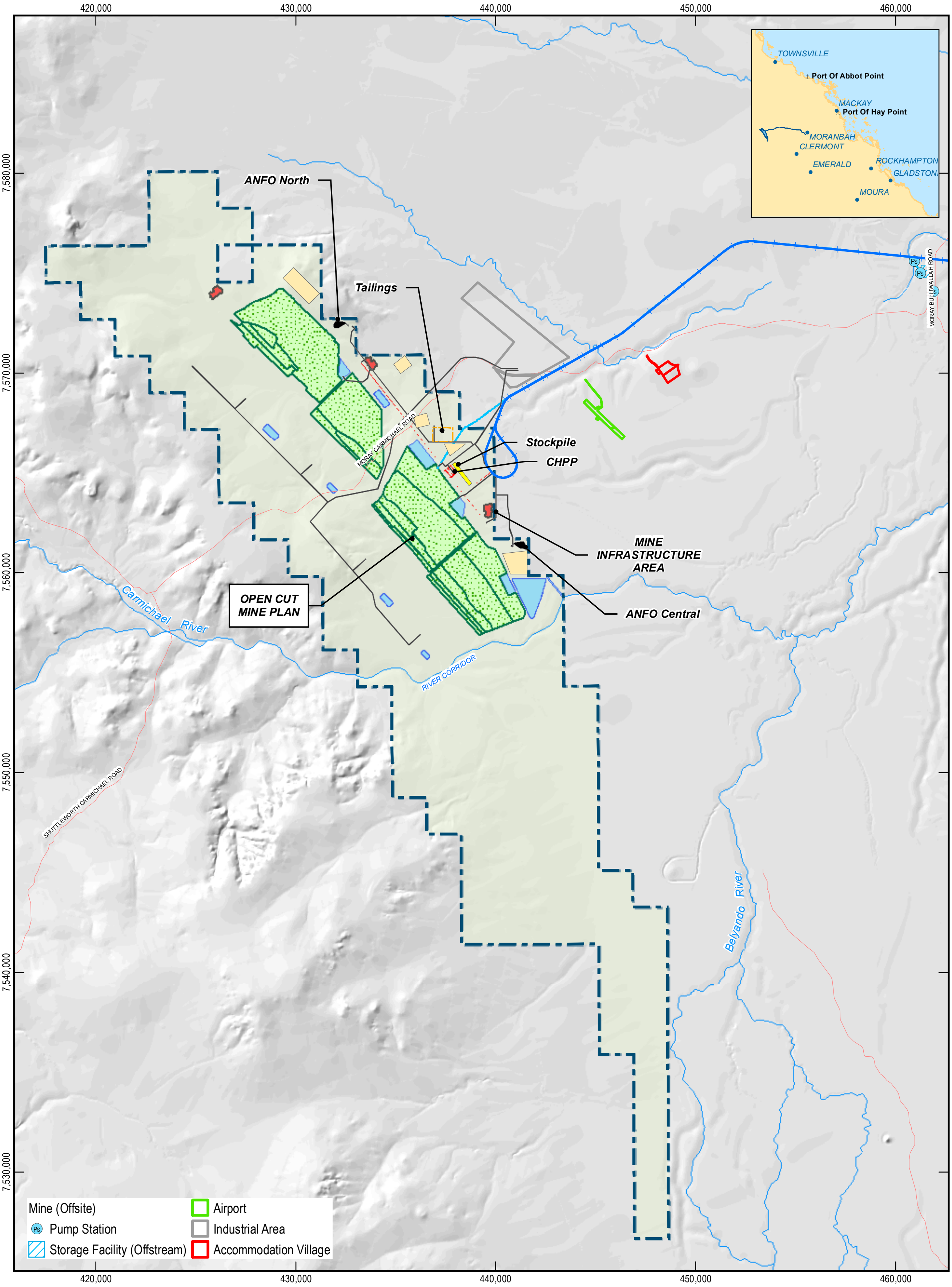
Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure
- Stockpiles
- Tailings Cell
- Top Soil Storage

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1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

GHD adani

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number	41-26422
Revision	B
Date	23-10-2013

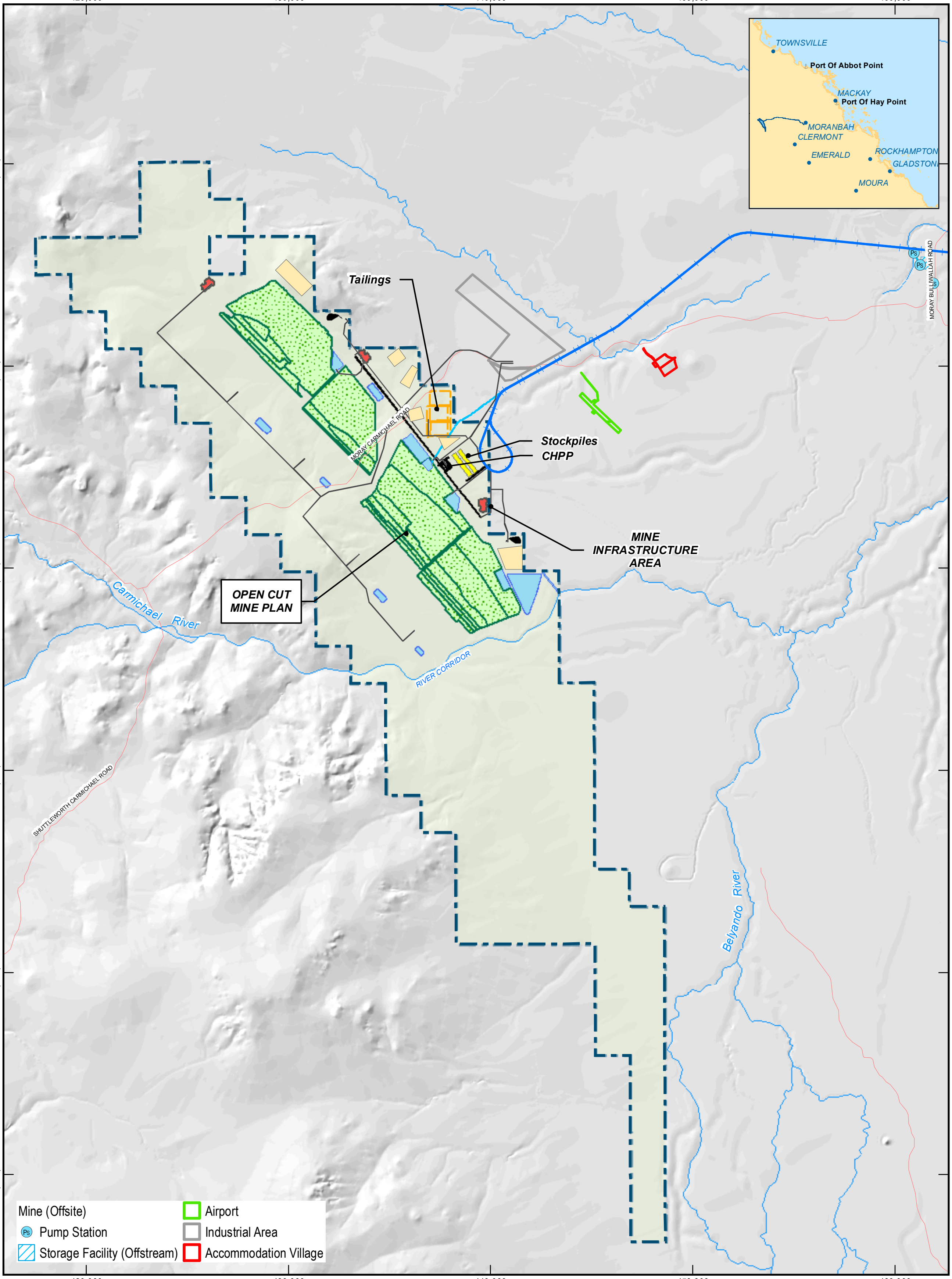
Mine Stage - Year 2016

Figure 9

G:\41\26422\GIS\Maps\MXD\01000_Project_Description\41_26422_01012_rev_b.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure
- Stockpiles
- Tailings Cell
- Top Soil Storage

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

GHD adani

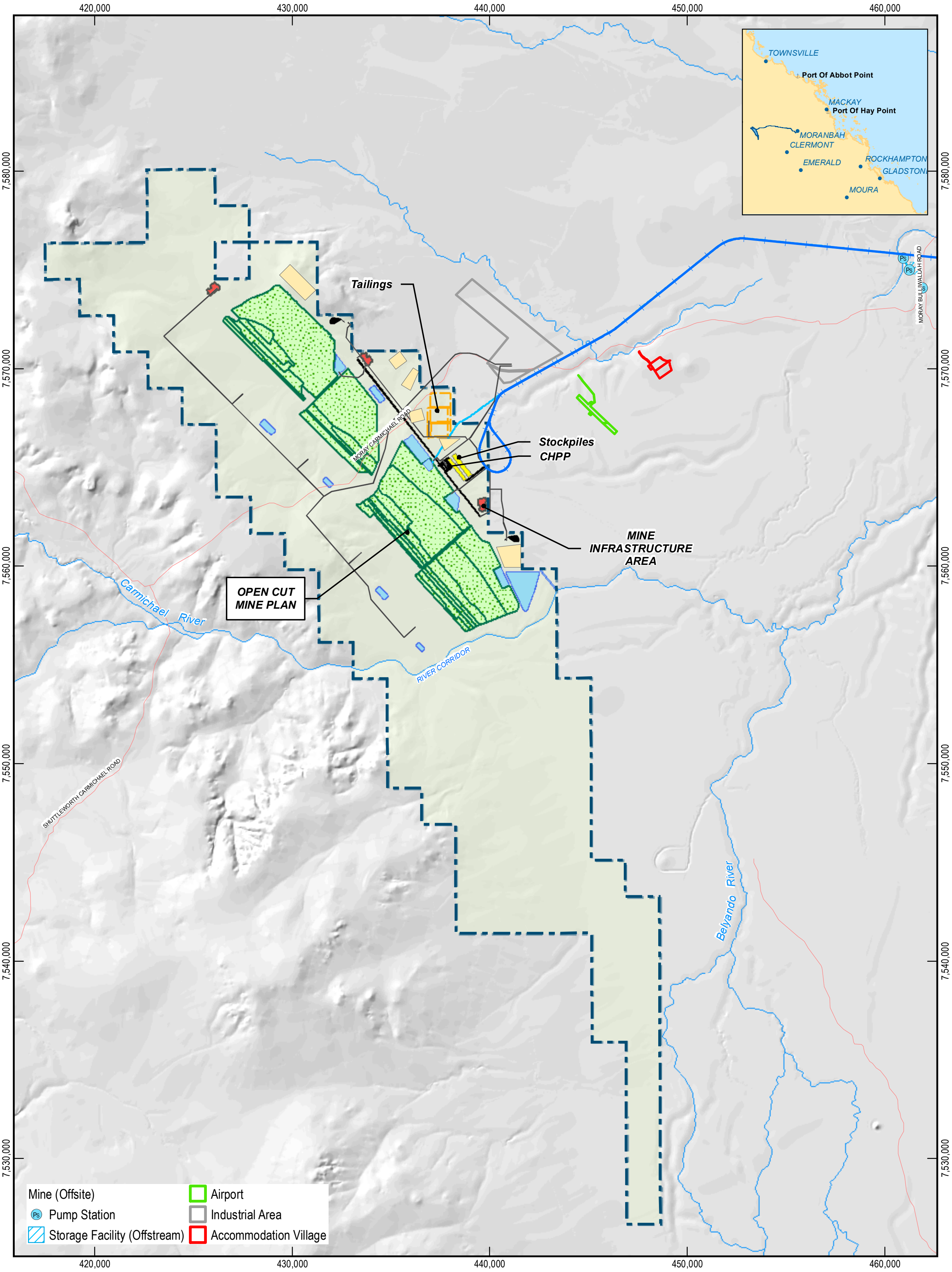
Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision B
Date 23-10-2013

Mine Stage - Year 2017

Figure 10

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure
- Stockpiles
- Tailings Cell
- Top Soil Storage

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1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number	41-26422
Revision	B
Date	23-10-2013

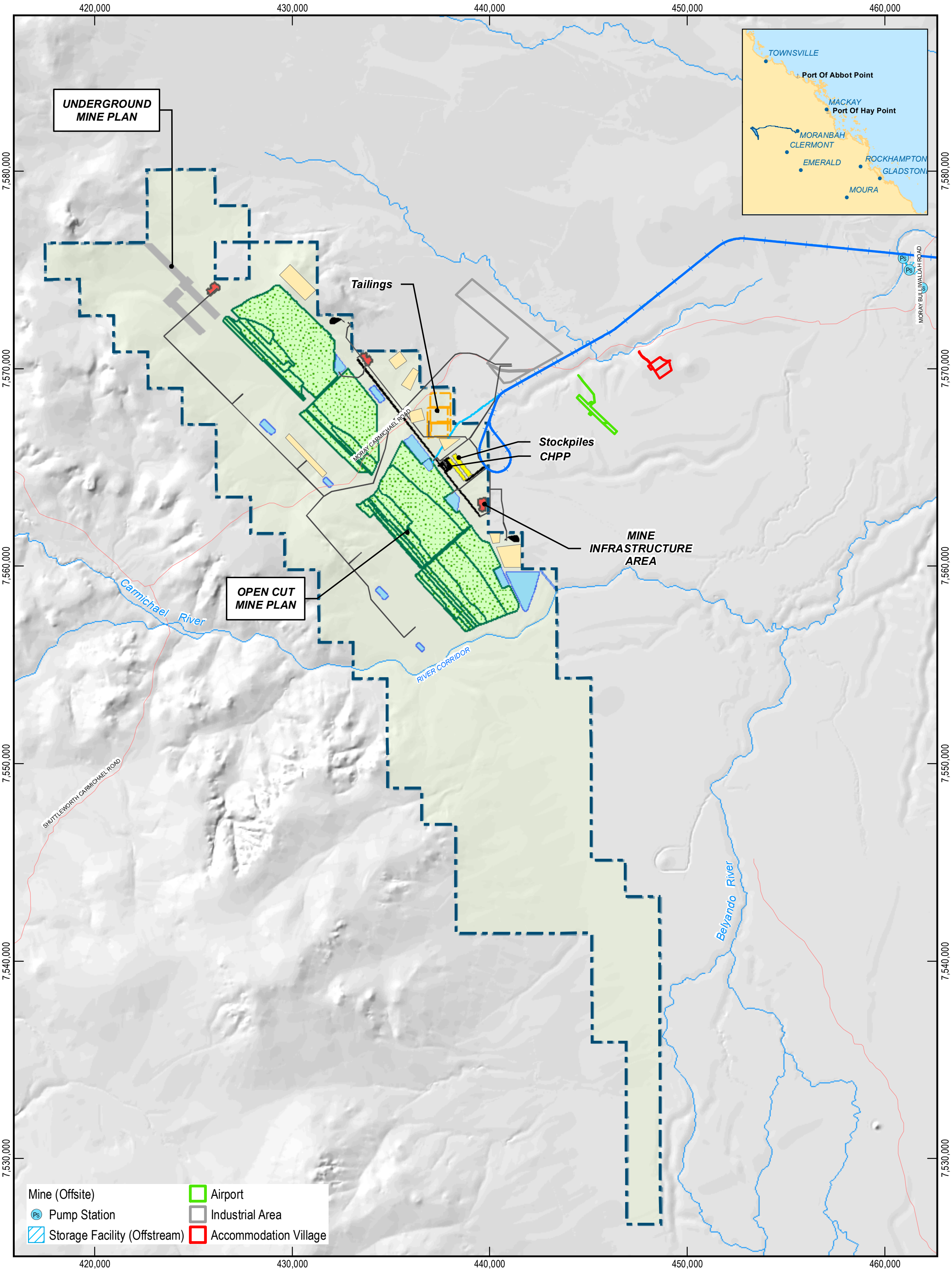
Mine Stage - Year 2018

Figure 11

G:\41\26422\GIS\Maps\MXD\01000_Project_Description\41_26422_01010_rev_b.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

Local Road	Rail (West)	Open Cut Blocks	Mine Infrastructure
River / Watercourse	Mine (Onsite)	Water Management Dams	Stockpiles
Overland Conveyors		Mine Infrastructure Area	Tailings Cell
			Top Soil Storage

Based on or contains data provided by the State of QLD (DERM) [2010]. In consideration of the State permitting use of this data you acknowledge and agree that the State gives no warranty in relation to the data (including accuracy, reliability, completeness, currency or suitability) and accepts no liability (including without limitation, liability in negligence) for any loss, damage or costs (including consequential damage) relating to any use of the data. Data must not be used for marketing or be used in breach of the privacy laws.

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision B
Date 23-10-2013

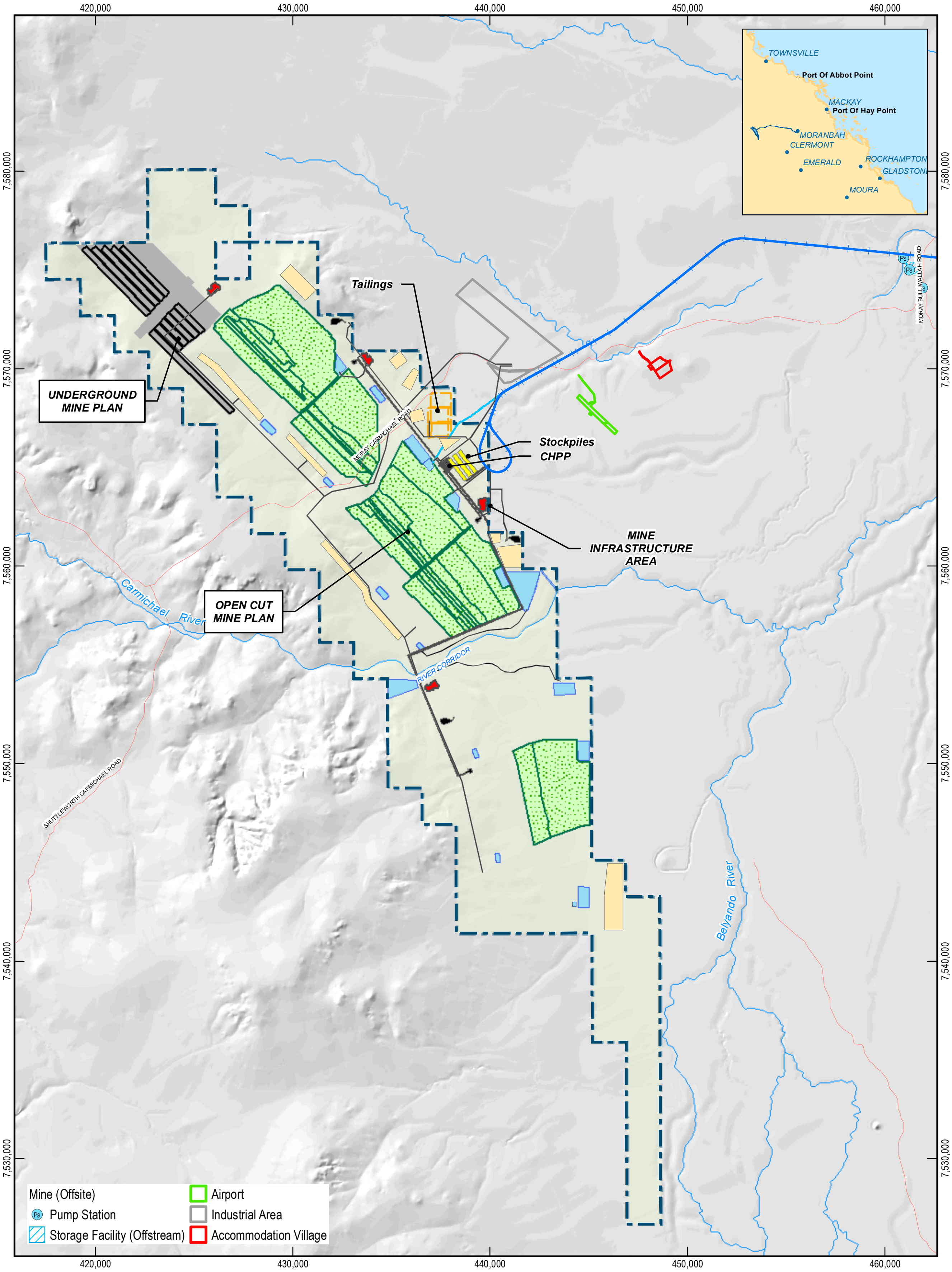
Mine Stage - Year 2019

Figure 12

G:\41\26422\GIS\Maps\MXD\01000_Project_Description\41_26422_01009_rev_b.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure
- Stockpiles
- Tailings Cell
- Top Soil Storage

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

GHD adani

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

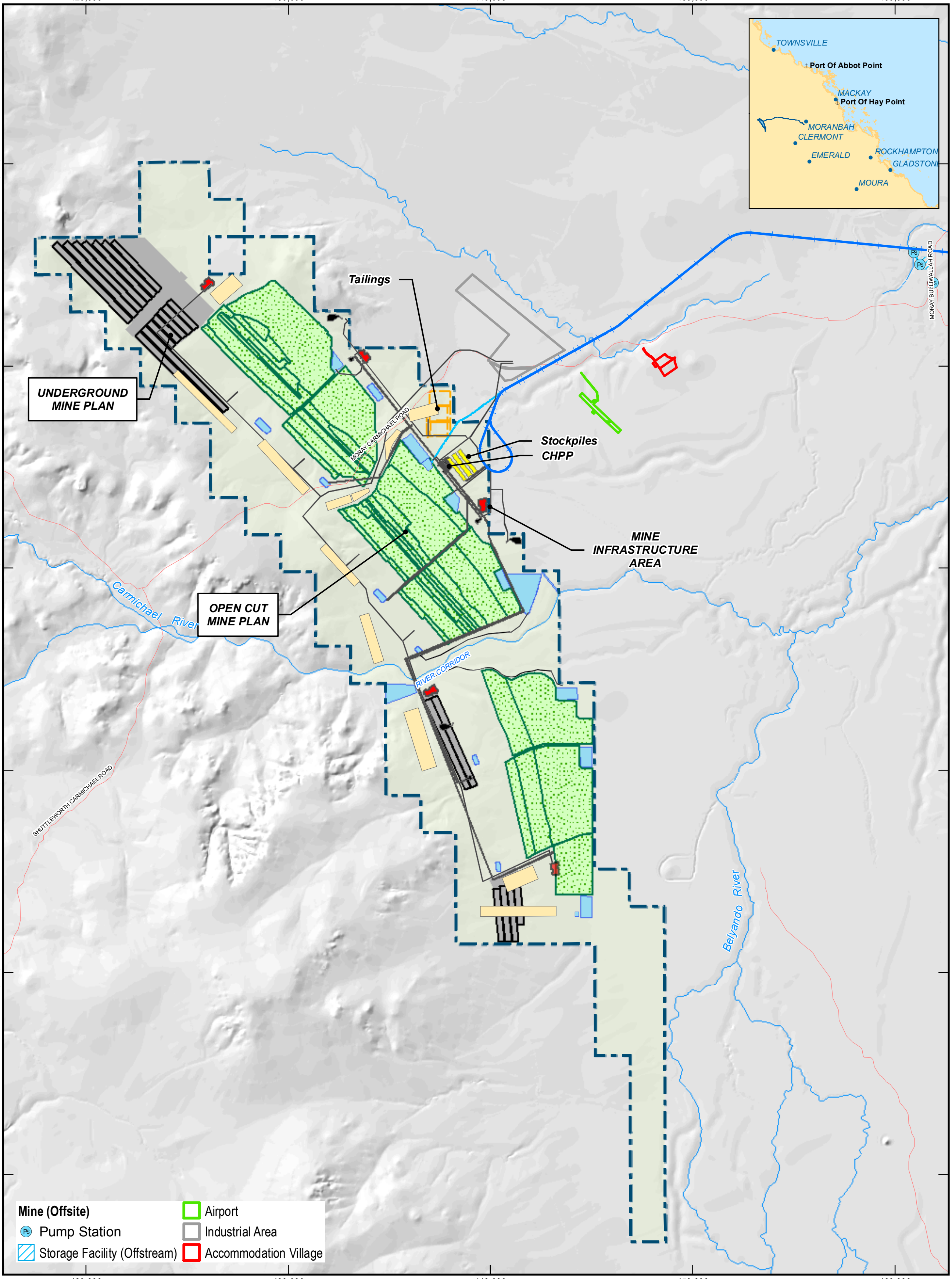
Mine Layout Progress Plot
Year 2020 - 2024

Job Number	41-26422
Revision	B
Date	23-10-2013

Figure 13

G:\41\26422\GIS\Maps\MXD\01000_Project_Description\41_26422_01008_rev_b.mxd Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure
- Stockpiles
- Tailings Cell
- Top Soil Storage

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1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd

Carmichael Coal Mine and Rail Project SEIS

Job Number	41-26422
Revision	C
Date	17-10-2013

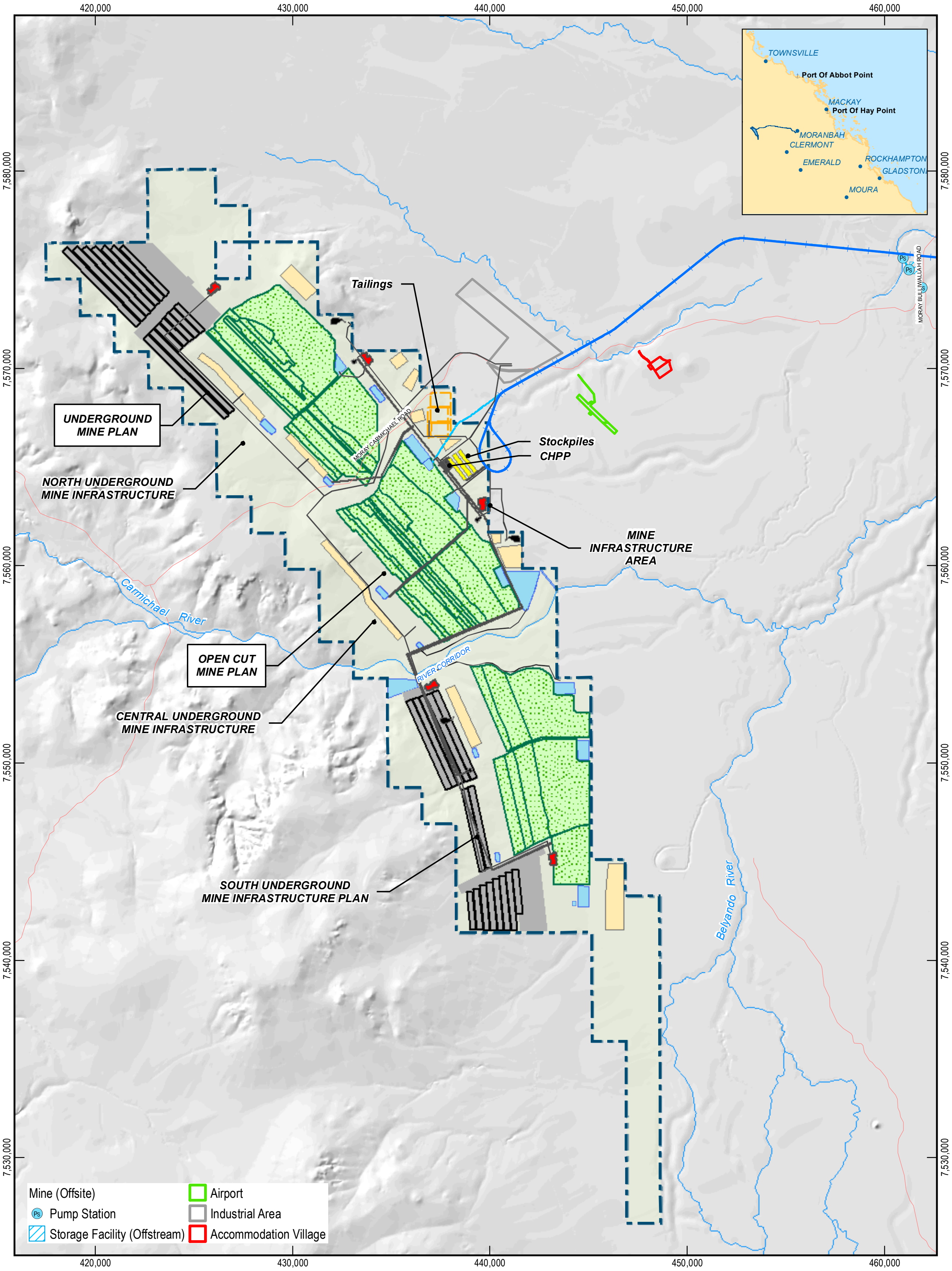
Mine Layout Progress Plot
Year 2025 - 2029

Figure 14

G:\41\26422\GIS\Maps\MXD\01000_Project_Description\41_26422_01007_rev_c.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure
- Stockpiles
- Tailings Cell
- Top Soil Storage

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

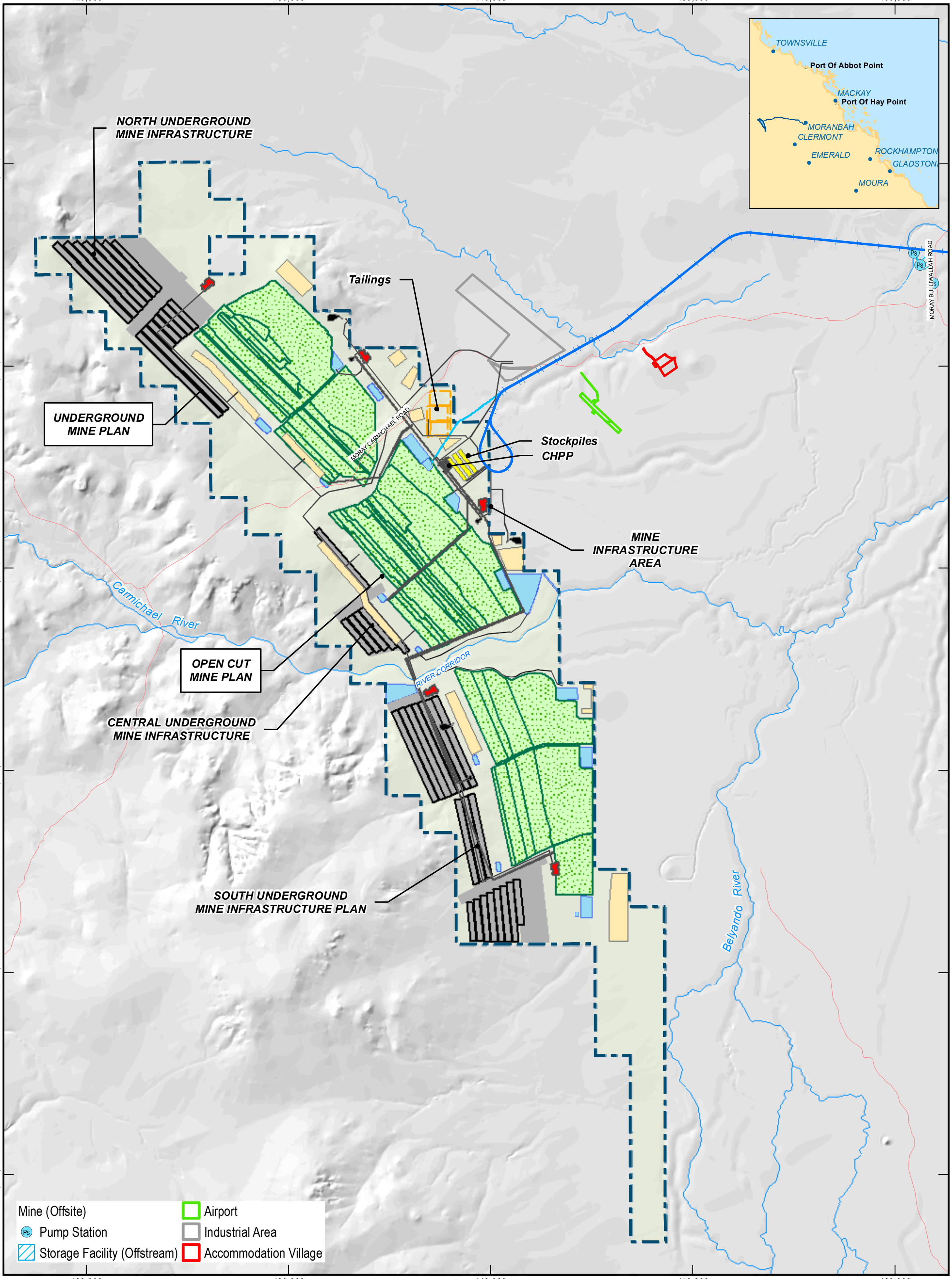
Job Number	41-26422
Revision	B
Date	23-10-2013

Mine Stage - Year 2030 - 2034

Figure 15

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure
- Stockpiles
- Tailings Cell
- Top Soil Storage

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

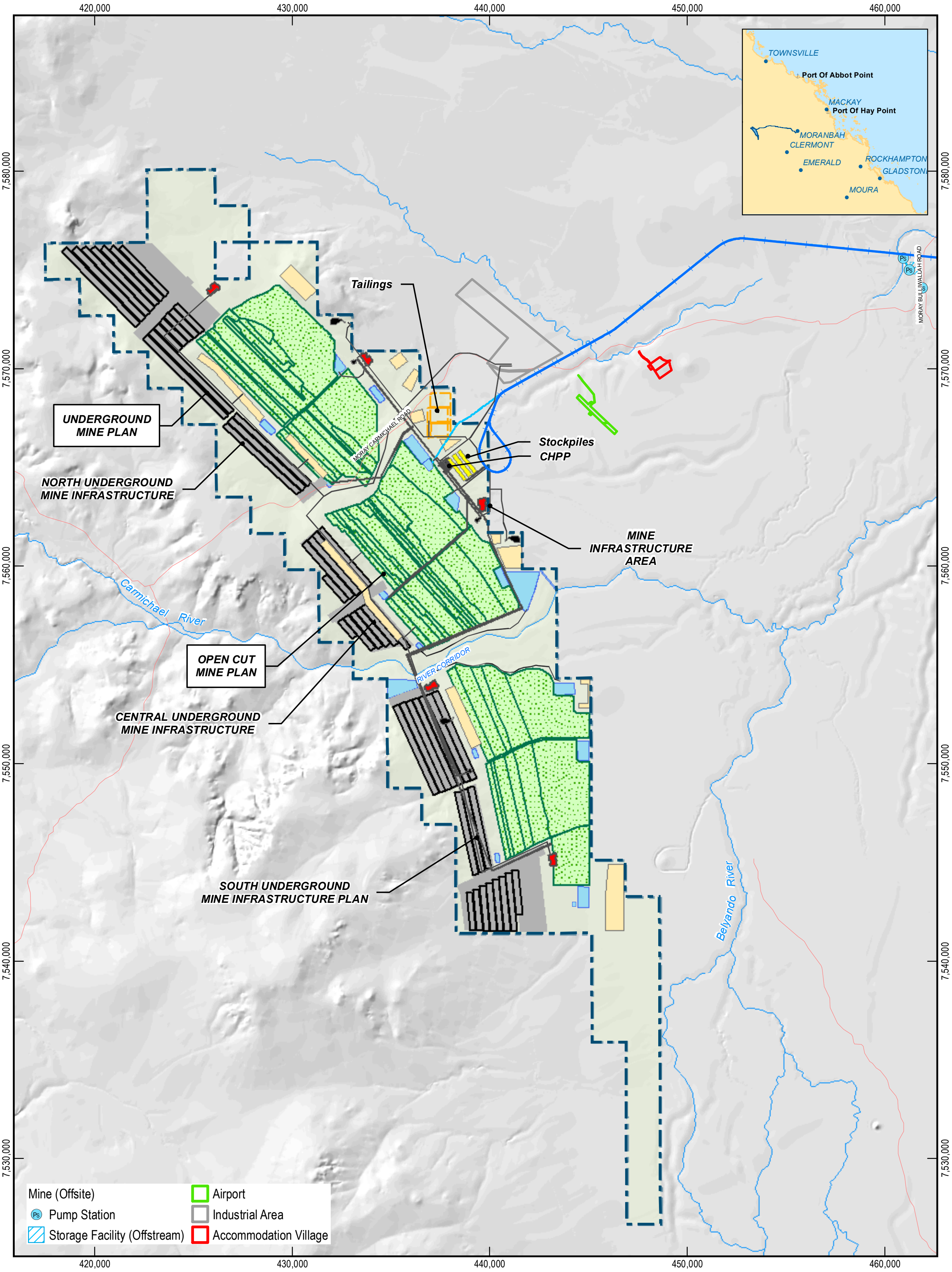
Job Number	41-26422
Revision	B
Date	23-10-2013

Mine Stage - Year 2035 - 2039

Figure 16

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

Local Road	Rail (West)	Open Cut Blocks	Mine Infrastructure
River / Watercourse	Mine (Onsite)	Water Management Dams	Stockpiles
Overland Conveyors		Mine Infrastructure Area	Tailings Cell
			Top Soil Storage

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

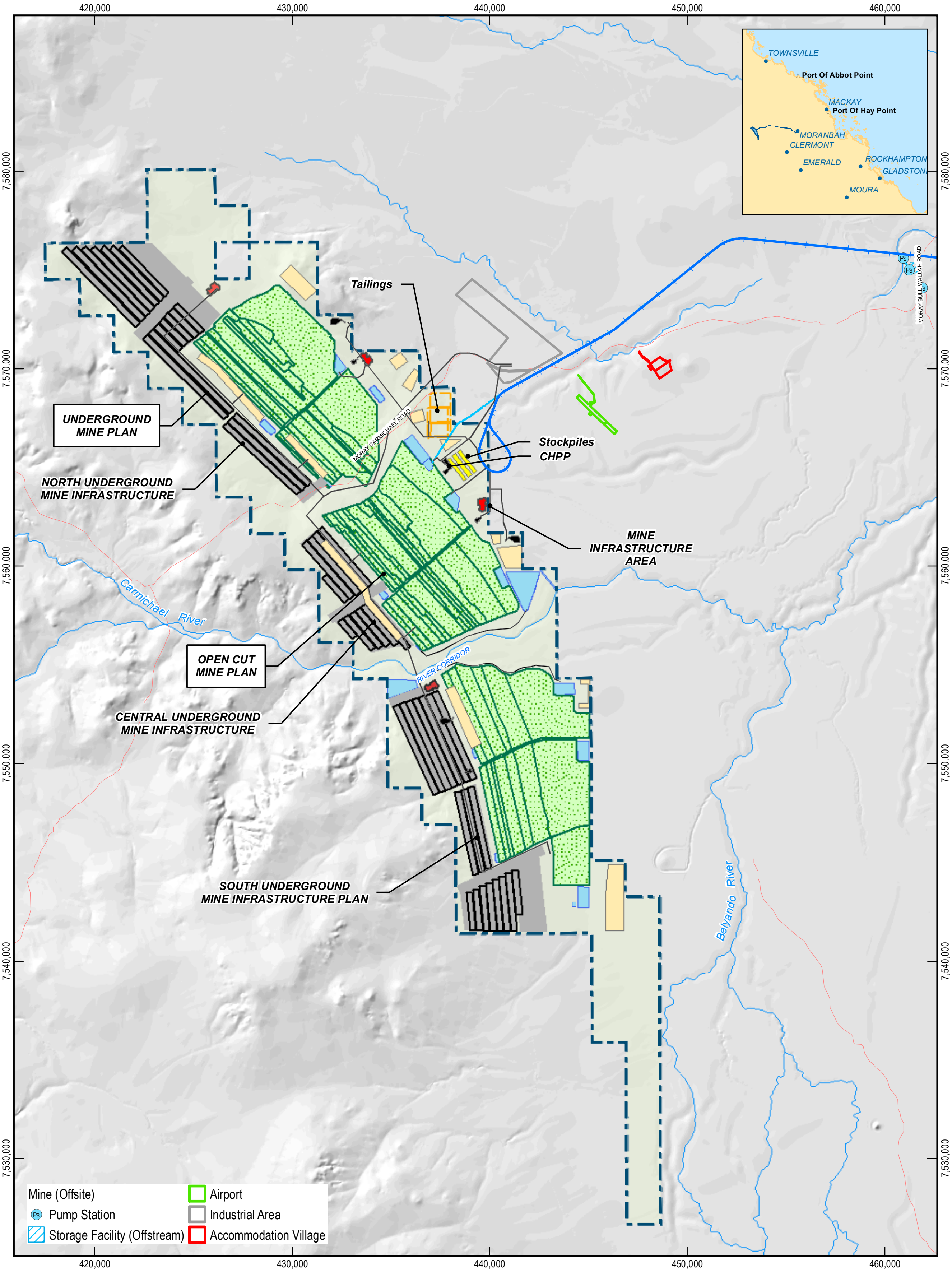
Job Number	41-26422
Revision	B
Date	23-10-2013

Mine Stage - Year 2040 - 2044

Figure 17

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure
- Stockpiles
- Tailings Cell
- Top Soil Storage

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number	41-26422
Revision	B
Date	23-10-2013

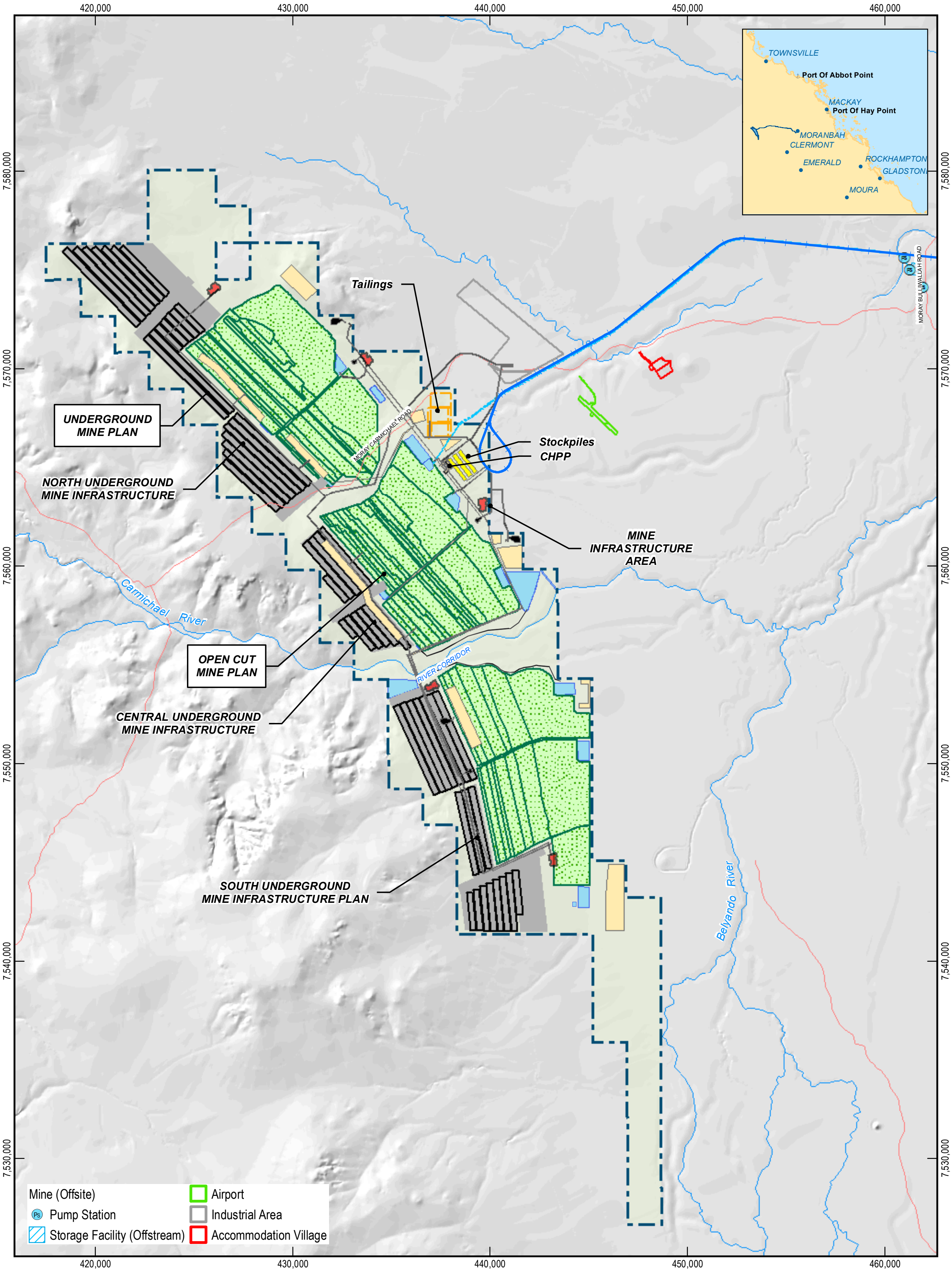
Mine Stage - Year 2045 - 2049

Figure 18

G:\41\26422\GIS\Maps\MXD\01000_Project_Description\41_26422_01003_rev_b.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

Local Road	Rail (West)	Open Cut Blocks	Mine Infrastructure
River / Watercourse	Mine (Onsite)	Water Management Dams	Stockpiles
Overland Conveyors		Mine Infrastructure Area	Tailings Cell
			Top Soil Storage

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1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision B
Date 23-10-2013

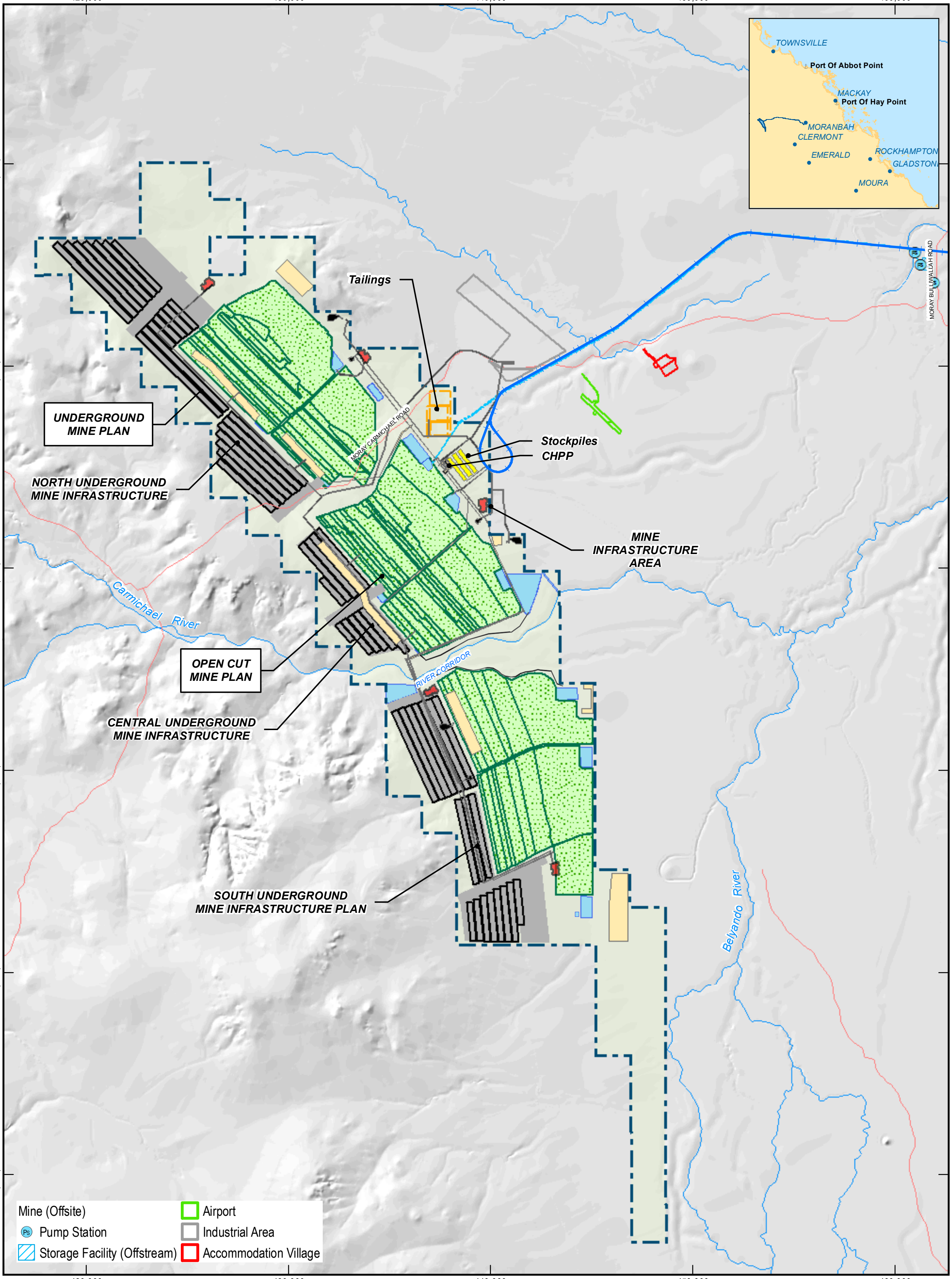
Mine Stage - Year 2050 - 2060

Figure 19

G:\41\26422\GIS\Maps\MXD\01000_Project_Description\41_26422_01002_rev_b.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS



LEGEND

- Local Road
- River / Watercourse
- Overland Conveyors
- Rail (West)
- Mine (Onsite)
- Open Cut Blocks
- Water Management Dams
- Mine Infrastructure Area
- Mine Infrastructure
- Stockpiles
- Tailings Cell
- Top Soil Storage

1:275,000 (at A4)

0 2 4 6 8 10

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number 41-26422
Revision B
Date 23-10-2013

Mine Stage - Year 2061 - 2072

Figure 20

G:\41\26422\GIS\Maps\MXD\01000_Project_Description\41_26422_01001_rev_b.mxd

Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data Source: GA: Road, River / Watercourse (2007); DME:EPC1690 (2010), EPC1080 (2011); Adani: Alignment, Offsite(2013), Mine Layout / Infrastructure (2013); Created by: MS

4. Mine onsite infrastructure

4.1 Mine infrastructure overview

The onsite mine infrastructure is divided into the following key areas:

- mine service areas
- power supply
- fuel supply and storage
- water supply and management
- mine water management
- roads
- transport facilities
- waste disposal facilities
- communications
- medical facilities
- enabling infrastructure

4.2 Location study

A location study was completed with the aim of coordinating all the site infrastructure requirements to define one site layout that locates all required infrastructure within the known constraints.

The site location study considered the following:

- Carmichael River and existing water courses
- dust and noise
- environmentally sensitive biodiversity
- mine pits and pit ramps
- out-of-pit spoil emplacement
- site drainage infrastructure and flood mitigation structures
- mine infrastructure areas (MIAs)
- internal roads (heavy vehicle and light vehicle)
- public roads
- existing site infrastructure
- coal handling infrastructure
- CPP
- CPP rejects handling

- mine lease
- high voltage infrastructure
- staging of the mine
- mine subsidence areas
- ammonium nitrate/fuel oil (ANFO)
- train loop

The outcome of the location study was to define the layout of all mine infrastructure on the mine site.

4.3 Temporary mine site layout

A temporary mine site layout will include all facilities required to support the first two years of mining activities. This facility will support initial mining operations while permanent facilities are constructed. The facilities included in the temporary mine site layout are as follows:

- Moray Carmichael Boundary Road realignment within the mine lease boundaries
- construction and operational water
- laydown areas/hardstands
- temporary explosive magazines
- temporary operations power
- enabling works fleet construction area
- enabling works MIA North (Pit B and Pit C)
- enabling works MIA Central (Pit D and Pit E)
- fencing and security
- construction roads and access roads
- development haul roads
- local disturbed area sediment and erosion control
- waste transfer station

4.4 Permanent mine site layout

The permanent mine site layout will include all facilities required to support mining operations. The facilities included in the permanent mine site layout area as follows:

- permanent MIA north (Pit B and Pit C)
- permanent MIA central (Pit D and Pit E)
- permanent MIA south (Pit F and Pit G)
- underground Mine MIA’s
- central administration area
- north ANFO (Pit B and Pit C)

- central ANFO (Pit D and Pit E)
- south ANFO (Pit F and Pit G)
- coal handling and processing plant (CHPP)
- tailings and reject disposal
- earthworks and road works
- power
- communications fibre network only
- CHPP controls
- water management inclusive of raw water, mine affected water, sediment affected water and process water
- flood management

4.5 Mine infrastructure area layout

There will be one MIA per major open cut (OC) pit cluster, and one MIA per underground (UG) mine. The mine administration office will be located in close proximity to the main site access road and adjacent to the CHPP area. All other functions associated with the mine operations and maintenance will be located at the MIA areas located near the pit ramps. Each of the MIA areas will service two adjacent pits.

The key drivers for the layout for the MIA is the location of the facilities close to the equipment they are servicing to minimise trip times and therefore operational costs, segregation of traffic classes for safety and flexibility to provide for future requirements.

To achieve this, the MIA layout is divided into the following facilities:

- enabling works fleet construction area
- enabling works MIA North (Pit B and Pit C)
- enabling works MIA Central (Pit D and Pit E)
- permanent MIA North (Pit B and Pit C)
- permanent MIA Central (Pit D and Pit E)
- permanent MIA South (Pit F and Pit G)
- permanent MIA UG Mine 1
- permanent MIA UG Mine 5
- central administration area
- north ANFO (Pit B and Pit C)
- central ANFO (Pit D and Pit E)
- south ANFO (Pit F and Pit G)

Traffic movement areas will be clearly segregated into Heavy Vehicle (HV), Light Vehicle (LV) and pedestrian areas; where required, crossing points will be clearly identified and signed to ensure safe pedestrian / vehicle interactions across the Project site. Additionally, traffic movement across the site will be designed to clearly identify and segregate operational areas; access to these areas will be controlled such that only vehicles involved in operational activities will be granted access. This will aim to minimise vehicle / pedestrian interactions.

4.6 Mine industrial area

4.6.1 Permanent MIA open cut - typical

The permanent MIA's will support the overburden and coal fleets for duration of the mine life. These areas will be located centrally to clusters of pits. The permanent MIA's will be constructed by expanding the enabling works MIA's to include a permanent heavy vehicle workshop and warehouse, a 3.5 ML diesel storage tank, additional lubricant storage and permanent power.

4.6.2 Permanent MIA's underground - typical

The permanent MIA's for underground mining will support the underground development of Mines 1-5 and will be progressively developed as the underground mines are constructed.

4.6.3 Central administration area

The central administration will provide the main entry to the mine site and the central administration facilities for the mine. It will be located next to the central MIA on the eastern side of the pits D and E. All visitor access to the mine site will be via the central administration area.

4.6.4 Typical ANFO facility

The ANFO will service the explosive requirements for O/C Pits. It will be constructed a minimum 1.5 km from any other facilities. The facility will cover an area of approximately 180,000m². This will provide a sufficient area for delivery, storage and mixing of ANFO.

4.6.5 Earthworks

MIA pads

The MIA pads are an earth platform required for the mine operation facilities and mine fleet facilities. The platform is elevated to provide 1 in 100 year AEP flood immunity to facilities with a cross fall for localised drainage. Longitudinal 'v- shaped' drains are required around the outside of the pad to direct localised drainage to mine affected water (MAW) storage. Fill batters have been used, based on geotechnical assumptions of the available general fill embankment materials.

All unsuitable replacement earthworks and subgrade materials are of a general fill quality and will be hauled locally to the areas under construction. All sub-base materials are of a select fill quality. All base and wearing materials required will be hauled from external sources. All general and select materials to be obtained on site from mining pre-strip operations or selective borrowing from drainage excavations. All quarried materials will be sourced from the closest available quarry.

Central administration area pad

The central administration pad is an earth platform required for the mine operation facilities and mine fleet facilities. The platform is elevated to provide 1 in 100 year AEP flood immunity to facilities with a cross fall for localised drainage. Longitudinal ‘v-shaped’ drains are required around the outside of the pad to direct localised drainage to mine affected water (MAW) storage. Fill batters have been used, based on geotechnical assumptions of the available general fill embankment materials.

All unsuitable replacement earthworks and subgrade materials are of a general fill quality and will be hauled locally to the areas under construction. All sub-base materials are of a select fill quality. All base and wearing materials required will be hauled from external sources. All general and select materials to be obtained on site from mining pre-strip operations or selective borrowing from drainage excavations. All quarried materials will be sourced from the closest available quarry.

Gatehouse pads

The gatehouse pads are earth platform required for the gatehouse facilities and medium vehicle road and car park facilities at the ingress from Moray-Carmichael Boundary Road for the MIAs and coal processing plant. The platform is elevated to provide 1 in 100 year AEP flood immunity to facilities with a cross fall for localised drainage. Longitudinal ‘v-shaped’ drains are required around the outside of the pad to direct localised drainage to sediment storage.

All unsuitable replacement earthworks and subgrade materials are of a general fill quality and will hauled locally to the areas under construction. All sub-base materials are of a select fill quality. All base and wearing materials required will be hauled from external sources. All general and select materials to be obtained on site from mining pre-strip operations or selective borrowing from drainage excavations. All quarried materials will be sourced from the closest available quarry.

ANFO facilities pad and medium vehicle access roads

The ANFO facilities pads are an earth platform required for the mine operation facilities and mine fleet facilities. The platform is elevated to provide 1 in 100 year AEP flood immunity to facilities with a cross fall for localised drainage. Longitudinal ‘v-shaped’ drains are required around the outside of the pad to direct localised drainage to mine affected water (MAW) storage. Fill batters have been used, based on geotechnical assumptions of the available general fill embankment materials.

All unsuitable replacement earthworks and subgrade materials are of a general fill quality and will be hauled locally to the areas under construction. All sub-base materials are of a select fill quality. All base and wearing materials required will be hauled from external sources. All general and select materials to be obtained on site from mining pre-strip operations or selective borrowing from drainage excavations. All quarried materials will be sourced from the closest available quarry.

4.7 Servicing facilities

In order to minimise the distance travelled by the haul trucks and other mine vehicles, refuelling areas will be constructed at strategic locations within the pits. These will typically include 1.5 ML of fuel storage per cluster and refuelling bowsers for heavy vehicles and service trucks. Basic maintenance facilities may also be allowed for at these locations.

4.8 Power supply

4.8.1 Introduction

Power will be delivered to the site via a 275 kV transmission line and a 275/66 kV substation the Galilee North Substation (supplied by others). The 275/66 kV substation will be located adjacent to the offsite industrial area about 5 km from the CHPP complex and adjacent to the Moray Carmichael Boundary Road. Power will be reticulated around site via overhead open mesh 66kV transmission line and delivered to local 66/22 kV substations. Reticulation to some areas will be at 22 kV. Some redundancy and security is achieved via the mesh reticulation and 66/22 kV transformers are standardised to allow a spare to be held for the event of transformer failure.

4.8.2 Summary of electrical works

The major elements of the onsite electrical works are as follows:

- Two 66 kV transmission lines from the Carmichael Coal Mine main Galilee north substation 275 kV/ 66 kV; one to the east 66 kV/ 22 kV substation and the other to the west 66 kV substation
- East 66 kV/ 22 kV substation and west 66kV distribution substation
- 22 kV cable/OHL meshes (to be closed in future) for supplying CHP, stacker and reclaimer, dam water pumps, TLO, north, central and south MIAs, CPP, central ROM, south ROM, north ROM, MIA substations and U/G MIA facilities, plus a spare feeder from the east 66 kV/ 22 kV substation
- Three 66 kV feeder bays in the west substation; one supplying pit D, E, F & G loads plus U/G mine 3,4 & 5, another supplying pit B and pit C loads, plus U/G mine 1, 2 & 3, and the other installed as spare
- Three 66 kV/ 22 kV, 25 MVA transformers (two in duty and one in standby) in the east substation where the standby transformer will be installed in the future
- The first ring from the 22 kV bus of the east SUB to supply CHP loads around the product yard conveyor and sediment D Dam water pumps
- One 22k V/3.3k V/415 V transformer to supply the CHP loads around the product yard conveyor
- One 22 k/415 V transformer to supply the sediment D loads
- The second ring of the east substation to supply the loads of the overland conveyors, crushing and the raw water dam substation
- The third ring of the east substation to supply the stacker and reclaimer substation and CPP substation
- The fourth ring of the east substation to supply the TLO, north gatehouse, north ANFO, central MIA and central MIA as well as central ROM substations
- The fifth 22 kV ring of the east substation to supply the tailings water dam, sediment C, north gatehouse, sediment B, north ANFO, north MIA, and north ROM substations
- Two-winding or three-winding transformers in RMU configurations for CHP, stacker and reclaimer, TLO, CPP and ROM substations with their primaries at 22 kV and the

secondaries at 415 V. The tertiary winding (if any) are rated at either 690 V or 3.3 kV depending on the size of the large motors in the MCC and the required cable run to obtain the most cost effective solution

- Two-winding pole mounted 22 kV/415 V transformers for water dam, sediment, ANFO and gatehouse substations and part of MIA
- Two sets of two-winding 22 kV/415 V transformers located in RMU kiosks for the north and south MIA main substations
- 3.3 kV, 690 V or 415 V MCCs (depending on which one can lead to the cost effective solution without exceeding the acceptable voltage drop limits specified in the design criteria for the MCC busbar and motor terminals during the steady state and worst-case scenario motor starting conditions of system)
- 22 kV, 3.3 kV and LV cables
- 3.3 kV, 690 V and 415 V electric motors
- PLC, control system and SCADA
- Instrumentation
- Communications fibre backbone

4.9 Fuel supply

The Project will be a significant consumer of diesel fuel with an estimated annual consumption of around 201 ML.

Fuel deliveries for the Project will generally be made by BAB-triple or quad road train tankers and it is proposed that a maximum of 10 days of diesel will be stored on the mine site at the peak of fuel consumption. The fuel strategy for the Project (Mine) includes refuelling facilities at:

- MIA's
- in-pit Refuelling Area
- offsite refuelling depot adjacent to the rail in the offsite industrial area
- south ROM refuelling area.

Fuel will be delivered by BAB triple or quad road train tankers from off-site storage to each of the fuel storage tanks at the MIAs. Fuel will then be transferred from these storage tanks to the in-pit refuelling areas by mine fuel service vehicle.

4.10 Roads

The Mine site will require a number of on-site roads, pads and dams for expected mine operations. The mine road network will be developed based on the requirement to provide access to critical locations on site for various vehicles and machinery. The pavement of each road will therefore be designed to accommodate the expected quantities and types of vehicles using them with a staged development to account for initial construction traffic and then upgrade them for mining traffic at the completion of construction.

It is expected that there will be limited available general fill materials from the mine overburden, the tailings dam and diversion drain construction and limited low-grade select pavement materials from Diversion Drain A construction. Any high quality pavement materials are expected to be sourced from the nearest quarry to site. Any rock within the overburden is expected to be extremely weathered and unsuitable for pavement materials.

Foundation treatment will be required under site roads to treat unsuitable in-situ materials. This process will require boxing out of the unsuitable materials to depths subject to geotechnical investigation. After box-out, general earthworks materials sourced from site will be used to backfill the box-out.

Select materials for roads are required to be sourced from the nearest available quarry/borrow source.

4.10.1 Access roads

The access road comprises a seven metre wide earth formation with lateral crossfall drainage and will be used to gain access to the mine site for mine vehicles and delivery traffic. The final road design will be based on the mine layout and surface grading will be designed to balance earthwork quantities and meet operational vehicle requirements.

The access road will be designed to achieve 1 in 20 year ARI flood immunity and 1 in 50 year ARI flood immunity where the road will form part of the Project emergency evacuation route. Where required, ‘v-shaped’ drainage will be incorporated along the access road to accommodate 1 in 10 year ARI flood events.

All unsuitable replacement earthworks and subgrade materials are considered to be of a general fill quality and will be hauled on lease. All general and select materials will be obtained on site from pre-stripping operations or selective borrowing from drainage excavations where relevant. All quarried materials will be sourced from the closest available quarry.

4.10.2 Haul roads

The heavy vehicle road comprises a 35 m wide, dual-lane earth formation (lane width is three and a half times the width of an ultra-class mine vehicle as per industry standards) with a single lateral cross-fall. The road will be required for access for heavy mine vehicles.

The final road design will be based on the mine layout and surface grading will be designed to balance earthwork quantities and meet operational vehicle requirements. Safety windrows and side slopes, will be designed as per industry standards (i.e. 1.8 m high, or ½ a heavy vehicle wheel height) where required to protect infrastructure or vehicles. Downstream windrows will be designed d to incorporate a turnout drain at regular intervals to allow for localised drainage and to prevent ponding on the formation surface.

The heavy vehicle formation will be designed to provide 1 in 50 year AEP flood immunity with floodways provided across major drainage paths, as this part of the formation forms part of the mine emergency evacuation route. Longitudinal ‘v-shaped’ drains will be incorporated on the outside of the safety windrows where required to direct localised drainage to MAW storage.

All unsuitable replacement earthworks and subgrade materials are considered to be of a general fill quality and will be hauled on lease. All general and select materials will be obtained from on-site pre-stripping operations or selective borrowing from drainage excavations. All quarried materials will be sourced from the closest available quarry.

4.10.3 Light vehicle roads

The light vehicle road formation comprises a five metre wide earth formation with a lateral cross-fall and will be used for low frequency use service access roads for mine light vehicles. The final road design will be based on the mine layout and surface grading will be designed to balance earthwork quantities and meet operational vehicle requirements.

The formation is designed to provide 1 in 2 year AEP flood immunity with a longitudinal ‘v-shaped’ drainage incorporated where required.

All unsuitable replacement earthworks and subgrade materials are considered to be of a general fill quality and will be hauled on lease. All general and select materials will be obtained from on-site pre-stripping operations or selective borrowing from drainage excavations. All quarried materials will be sourced from the closest available quarry.

4.11 Transport facilities

Traffic management protocols have been developed for the Project to minimise safety risks and provide effective traffic movement to each of the key infrastructure areas within the Project Area. These are outlined as follows:

- Road and security infrastructure has been developed to isolate heavy vehicle mining fleet movements from all other vehicles.
- A bus fleet will be used to transport mining staff between the Project site and relevant accommodation camps in order to minimise interactions between personnel and mine traffic.
- Security infrastructure has been designed to restrict access from the public road to any of the mine areas.
- Speed limits and road infrastructure have been designed to minimise the risk of traffic incidents occurring over the Mine Area.

4.12 Waste disposal facilities

Mine-site waste, including general, green and regulated waste, will be recycled, where possible, and disposed of according to its type. Waste management for general, steel and hazardous waste will be provided at all MIAs and be accessible by waste removal vehicles.

4.13 Sewerage waste

4.13.1 Sewage treatment system

Sewage will be processed at sewage treatment plants (STPs) at the MIAs. Sewage will be collected by an in-pit sewage pump and removed via rising mains to the STPs. Buildings external to the MIAs, such as the security gatehouses, will have a raw sewage tank emptied on a weekly basis by a sewage truck and transported to the STPs for processing.

4.13.2 Sewage treatment plant

STPs with a capacity of 40 kL/day will be provided at MIAs. An appropriate sewerage system will transfer the sewage to the STP which comprises a series of holding tanks for raw sewage, containerised treatment plants and a series of holding tanks for effluent. The effluent from the

STP will be disposed of by spray irrigation through a grid of irrigation, set out and fenced for this purpose.

In the event of failure, the sewage will be trucked to the STP at the mine workers accommodation village for treatment until the system is returned to service.

4.13.3 Sewage storage

Four days' worth of raw sewage and treated effluent storage will be stored at the following locations:

- north MIA – 160 kL raw sewage, 160 kL treated effluent
- north ANFO – 10 kL raw sewage
- north security gatehouse – 10 kL raw sewage
- central MIA – 160 kL raw sewage, 160 kL treated effluent
- central ANFO – 10 kL raw sewage
- central security gatehouse – 10 kL raw sewage
- CHPP security gatehouse – 10 kL raw sewage
- south MIA – 160 kL raw sewage, 160 kL treated effluent
- south ANFO – 10 kL raw sewage
- south Security Gatehouse – 10 kL raw sewage
- U/G Mine 1 MIA – 160 kL raw sewage, 160 kL treated effluent
- U/G Mine 1 Security Gatehouse – 10 kL raw sewage
- U/G Mine 5 MIA – 160 kL raw sewage, 160 kL treated effluent.

4.14 Communications

The scope of work for the Project's communications covers the provision of the fibre optic backbone on the mine lease. The fibre optic backbone is provided by running OPGW wires on the 66 kV overhead power lines on site which links the Galilee North Substation to all major areas of site including the North, South and Central MIA. The fibre optic backbone is further provided by following the conveyor routes linking all motor control centres and control rooms.

This provides a single fibre optic network covering all assets on the mine lease.

4.15 Onsite medical facilities

An emergency response facility will be located at each of the MIAs and will include:

- first aid room complying with Qld coal mining regulations
- emergency building including:
  - parking for one fire truck
  - parking for one paramedic response vehicle
  - store

A helipad for emergency airlift of injured personnel is not required as emergency air transport will be provided from the nearby airport. The helicopter can land in the mine lease at numerous emergency locations such as the pit, HV roads or hardstand area as required.

4.16 Enabling infrastructure

4.16.1 Fencing

Fencing will be provided at the following areas:

- permanent mine lease boundary
- permanent public road boundary

All fencing will be designed to the appropriate industry standards and in accordance with TMR standards.

4.16.2 Existing road improvements and upgrades

Moray Carmichael boundary road upgrade

The Moray-Carmichael Boundary Road comprises a crowned 10 m wide high use earth formation with lateral crossfall required for mine access, delivery traffic and general traffic. The final road design will be based on the mine layout and surface grading will be designed to balance earthwork quantities and meet operational vehicle requirements.

The formation is designed to provide 1 in 10 year AEP flood immunity for major cross drainage with 1 in 50 year AEP flood immunity where these roads form part of the mine emergency evacuation route. Where required, adequate drainage will be incorporated to achieve 1 in 2 year immunity for localised drainage.

All unsuitable replacement earthworks and subgrade materials are considered to be of a general fill quality and will be hauled on lease. All general and select materials will be obtained from on-site pre-stripping operations or selective borrowing from drainage excavations. All quarried materials will be sourced from the closest available quarry.

4.16.3 Enabling works MIA facilities

The Stage 1 MIA facilities will include the following facilities:

- mine fleet assembly area
- enabling works MIA north (pit B and pit C)
- enabling works MIA central (pit D and pit E)

The mine fleet assembly area will be constructed at the existing Labona Airstrip. The hardstand platform for heavy vehicle assembly will cover an area of approximately 95,000 m^2. This will provide a sufficient area for delivery and storage of heavy vehicle parts as well as providing ample space to complete the assembly of eight heavy vehicles at a time.

The platform will be constructed with an all-weather surface, including nominated heavy lift and jacking areas. These heavy load areas will require tightly compacted granular road base material, or alternatively will comprise localised concrete slabs where the required granular fill material not be available.

4.16.4 Power supply

Temporary power will be provided to the enabling works MIA by four Gensets at each MIA. Details of gensets are listed in the following:

- MIA power pack no. one including:
  - two off 850 kVA diesel generators
  - two off 450 kVA generators
  - complete switchboard and protective devices for the set
  - complete control and synchronising system
- MIA power pack no. two including:
  - one off 100 kVA generator
  - complete switchboard and protective devices for the set
  - complete control and synchronising system
- MIA power pack no. three including:
  - three off 250 kVA generators
  - complete switchboard and protective devices for the set
  - complete control and synchronising system
- MIA security hut power pack no. four including:
  - one off 100 kVA generator
  - complete switchboard and protective devices for the set

Each Genset supplies 415 V power to a Distribution board connected to the Genset by either LV cables or LV busducts depending upon the size of total demand. Co-generation of each Genset will be synchronised by the load sharing and control system of the Genset. The synchronism check will be provided by the Genset protection system.

Once permanent 415 V power is available, it will be supplied to the MIA and the Gensets will be used as a backup power station to kick in when the permanent power is interrupted. Also, the design of Genset synchronising, load sharing and control systems and the configuration of distribution boards allow to synchronise the Gensets with a reference voltage from the main grid. This will enable the injection of power to the main grid by MIA Gensets when additional reserve power is available.

5. Coal handling and processing

5.1 Overview

The Project's coal handling and preparation plant (CHPP) has been designed to receive size and process a maximum throughput of 74.5 Mtpa run of mine (ROM) coal, producing 60 Mtpa of product coal. CHPP is an overarching term for coal handling plant (CHP) and coal preparation plant (CPP)

The facility will operate 24 hours per day, seven days a week for a minimum of 7,200 hr/a for the life of the mine. The CPP will consist of four 1,600 tph modules providing a total capacity of 6,400 tph. The facility will be capable of receiving coal from haul trucks and underground ROM and washing 75 percent of the ROM coal. The raw coal surge stockpile has been included to provide minimum buffering between the differences in mining annual hours and processing operating hours.

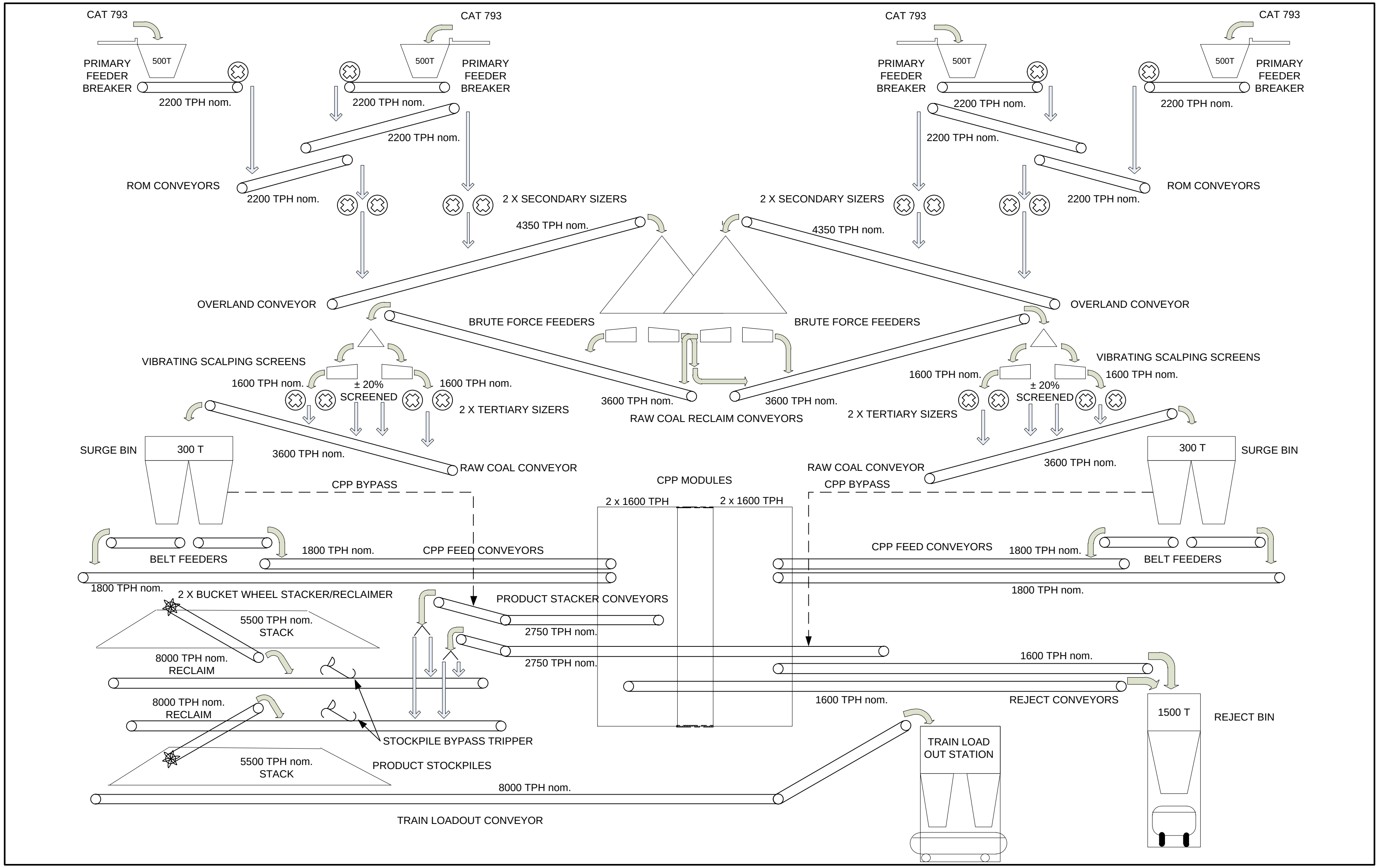
5.2 Summary scope of facilities

The mining operations will operate in up to six open cut pits and two underground mines simultaneously. Coal mined from open cut pits will be dumped into the ROM dump stations. Each ROM dump station will receive raw coal from two pits by rear dump trucks. Each ROM dump station consists of double tip bins equipped with a primary feeder breaker to reduce the raw coal to smaller sizes. The crushed raw coal from the primary sizing station will be transported via ROM conveyors into the secondary sizing station for further size reduction and will be stockpiled via an overland conveyor to a raw coal surge pile. Coal that cannot be received by the CHPP (during downtime or overloading) will be dumped to a ROM stockpile located on ground level from the ROM pad.

The -50 mm raw coal will be fed into the CPP at a throughput of 1,600 tph per module. The raw coal from the two surge piles will be transported via reclaim conveyor into the tertiary sizing station for further size reduction of +50 mm raw coal materials in order to meet the CPP feed size requirement; this process will be undertaken using a screen with 50 mm cut size. The −50 mm CPP feed materials from the tertiary sizing station will then be transported via a raw coal conveyor into the CPP feed bins. The CPP feed bins will each be feeding two CPP modules. The CPP will be constructed in separate building structures; each building consists of two module CPP.

The coarse and fine products from the CPP buildings will be collected by a common product stacker conveyor and will be stockpiled using bucket wheel stacker / reclaimers. The Product Coal stockpile will be designed to provide all the blending capabilities of chevron stacking and bucket wheel reclaiming. The washed coal will be reclaimed from the product stockpile and will be loaded into a train from the train loadout (TLO) station. The product by pass system of the CPP will be utilised for direct feed of underground products.

Figure 21 Coal handling plant flowchart (underground bypass and feed not shown)



5.3 Raw coal system

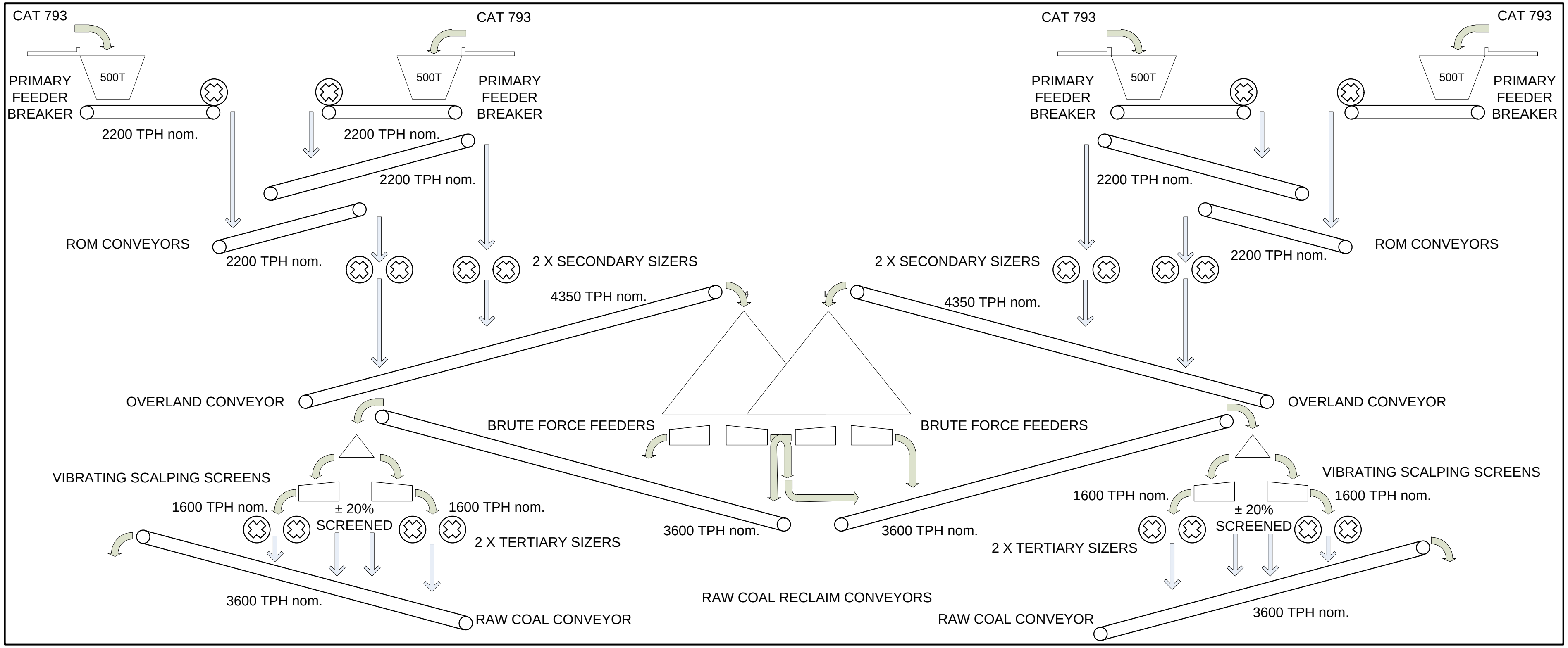
The raw coal system contains infrastructure to service open cut mine pits. The raw coal CHP infrastructure typically comprises of:

- truck dump hoppers
- primary sizing
- secondary crusher feed conveyors
- secondary sizing stations complete with:
  - magnet
  - secondary sizer one
  - secondary sizer two
- overland conveyor
- raw coal surge pile
- raw coal reclaim tunnel and feeders
- tertiary crusher feed conveyor
- tertiary sizing station 1 complete with:
  - bifurcated Splitter chute
  - screens
  - tertiary sizers
- surge bin feed conveyor
- coal analyser
- sampling system
- CPP surge bin dedicated to CPP modules

Similar systems for underground operations will be exclusive of the ROM bins but including a pit head conical stockpile and reclaimer.

Figure 22 shows the typical raw coal handling flowchart.

Figure 22 Raw coal handling flowchart



5.4 Coal preparation plant

Prior to receiving the raw coal in the CPP, the coal is reduced to a top size of 50 mm by three stages of sizing before being delivered to the CPP feed bins to ensure continuous feed to the four modules of the CPP.

Each of the modules will have a capacity of 1,600 tph and will be constructed in pairs that will consist of the following:

- coarse (-50 mm + 1.4 ww mm) beneficiation circuits utilising dense medium cyclones (DMC's)
- fine (-1.4 ww mm + 0.25 mm) fine beneficiation circuits utilising spirals
- one tailings thickener and clarified water circuit per pair of modules
- one set of plant services per pair of modules
- tailings disposal to tailings cells

Each pair of CPP modules will be housed in a common steel framed structure with the two CPP buildings offset along their long axis to allow a reject conveyor and a product conveyor to service each of the two CPP modules. The following description is for one CPP module, with services described in pairs of modules.

The material is discharged from each CPP feed bin by means of a belt feeder onto the plant feed conveyor feeding each module of the CPP. Within each module the feed material is equally divided to the two feed preparation screens by means of a feed hopper and two vibrating feeders. Figure 23 shows a simplified block diagram outlining the overall process.

5.5 Product coal system

The Product coal system comprises:

- product conveyors
- product coal transfer stations
- product yard conveyors
- product stockpiles
- bucket wheel stacker/reclaimers complete with stockpile bypass functionality
- product coal transfer stations (transfer between yard conveyors and TLO conveyor)
- train load out conveyor
- train loading system complete with
  - surge bin
  - batch weighing system
  - rail bunker for cleanout
  - control room
- coal analyser (on TLO conveyor)

Figure 24 shows the product coal handling flowchart

Figure 23 CPP block flow diagram

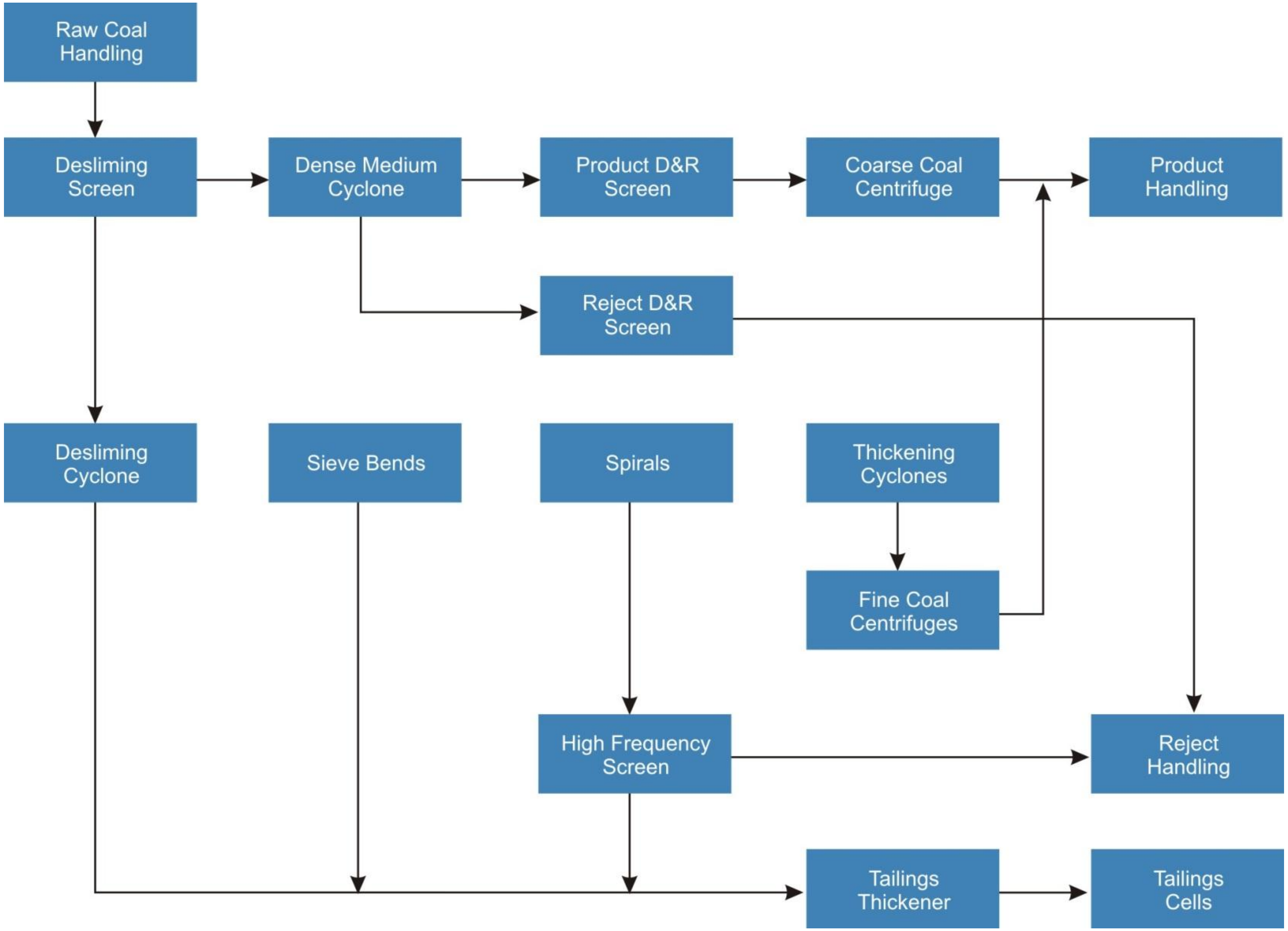
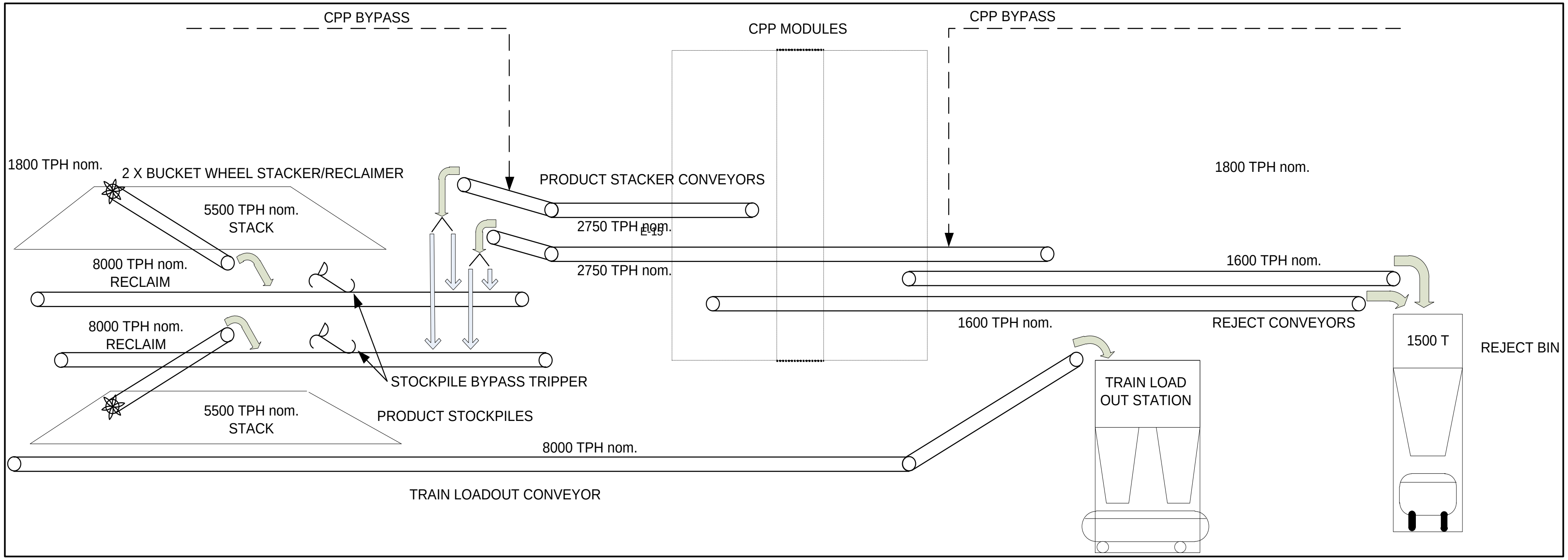


Figure 24 Product coal handling flowchart



5.6 CHPP site layout

5.6.1 Location study

A location study was completed with the aim of coordinating all the site infrastructure requirements to define one site layout that locates the entire required infrastructure within the known constraints.

5.6.2 Spontaneous combustion

Spontaneous combustion may occur for all types of Australian coal with the exception of certain anthracites. This oxidation starts at a slow rate, but doubles for every 10 degrees Celsius increase in temperature. The rate of oxidation increases slowly to the critical point of 70 to 75 degrees Celsius, which may occur within three to four days after stacking of the product. Between 140 to 230 degrees Celsius CO_2 forms until the heating process becomes self-sustaining up to 350 degrees Celsius where the coal starts to burn.

Of all the factors that may influence the spontaneous combustion of coal on large stockpiles the most important is the control of air flow. Although the flow of air may reduce the temperature of heating coal, it provides the oxygen that is essential for spontaneous combustion to occur.

It is most likely that spontaneous combustion will occur within the first one to two meters in depth over the entire surface of the stockpile, but most likely at the outer edges. In these areas the flow of air will be sufficient to provide oxygen for combustion to occur, but the flow will not be adequate to dissipate the heat generated.

To counter spontaneous combustion two approaches may be followed:

- promoting full ventilation to assist with dissipation of heat
- limiting air flow to prevent oxidation

For large stockpiles such as those proposed during the Project, the most feasible option is to limit air flow to prevent oxidation and subsequent combustion.

This can be achieved by aligning the stockpiles with the direction of the prevailing winds which in this case are predominantly south-easterly. Subsequently, it is proposed to align the product stockpiles from south-east to north-west to limit oxidation that may lead to spontaneous combustion.

5.6.3 CHPP – Civil design

The CHPP pad (earth platform) or conveyor corridors are required for the coal handling, process and wash facilities. Typically these will comprise elevated platforms to achieve 1 in 100 year AEP flood immunity to facilities with a cross fall of two percent for localised drainage. Longitudinal ‘v-shaped’ drains are required around the outside of the pads or conveyor alignments to direct localised drainage to MAW or SAW storage. Areas with a high potential for contamination from coal such as the central CHPP, ROM and stockpile areas will incorporate dedicated sediment traps and sumps as well as MAW dams.

Sediment control structures will be used to manage the run-off from infrastructure determined to have a low spill risk (i.e. overland conveyors etc.). Geological conditions at the Project site require the replacement of a 0.2 –1.0 m box of unsuitable foundation material prior to the construction of the pad embankments. All earthworks materials used for the pad construction will be obtained on-site from pre-stripping operations and are dependent on the location of suitable fill materials. Where suitable material is not available on-site, it will be imported from the closest project based or commercial quarry.

5.6.4 Tailings disposal

The proposed method of tailings disposal must be developed considering the following constraints:

- The limited physical space within the mining lease to accommodate the volume of tailings produced during the life of mine
- It must minimise impact to the environment, surface water, and groundwater
- It must maximise water recovery from the tailings for beneficial reuse in future coal washing operations on site

Strategy overview

Adani propose that the tailings be managed by:

- Approximately 35 percent of the tailings would be dewatered by passing them through a belt / filter press; and
- Approximately 65 percent of the tailings will be pumped as slurry and sub-aerially deposited into out of pit earth embankment tailings dams.

The tailings deposited into these dams would be placed in thin layers of a nominal maximum of approximately 150 mm to assist with the bleeding and consolidation of the tailings.

The bleed water will be decanted off into adjacent storage ponds for reuse in the plant. Once the tailings have sufficiently dried out and consolidated, the consolidated tailings would be excavated from the tailings dams and transported to pre-constructed containment cells located within the out of pit storage emplacements at Pits D and E. Dried tailings ‘cake’ generated from the belt / filter press would also be placed into the pre-constructed containment cells located within out of pit storage emplacements at Pits D and E.

The containment cells located within out of pit storage emplacements at Pits D and E would be constructed with a suitably designed and engineered clay liner at the base and sides. When at capacity, the cells would be clay capped. This should effectively fully contain the tailings and minimise the risk of any contaminants entering the surrounding environment.

Design parameters, assumptions and limitations

Table 5 provides a summary of the design parameters used to calculate:

- The size of the tailings drying ponds;
- The number of tailings drying ponds; and
- The size and number of permanent tailings containment cells in the out of pit storage emplacements.

The design parameters listed in Table 5 have been derived from best available information at the time of writing and will be refined during the preliminary and final design stages. Further details in relation to tailing management are provided in SEIS Volume 4 Appendix O2 Waste Management Strategy.

Table 5 Design parameters for tailings disposal

Parameter	Value
Discharge solids content (wt/wt)	30%
After bleed solids content (wt/wt)	50%
Settled solids content (wt/wt)	70%
Specific gravity, Gs	2.0 t/m^3
Settled dry density, rb	1.0 t/m^3
Settled bulk density, rd	1.37 t/m^3
Initial bleed water per dry tonne	1.33 m^3/t
Bleed water after settling	0.57 m^3/t
Annual loading rate	34,000 t/ha/annum
Beach slope for tailings deposition	1V:200H for 600m then 1V:1000H to decant structure

Tailings slurry management

The 65 percent of tailings not passing through the belt / filter press would be mixed with water to achieve a slurry of 30 percent solids by weight, and pumped to the tailings dams. The tailings dams would be constructed as above ground 'turkey's nest' earth embankment structures using selected and compacted earth fill excavated from within the basin of the dams. The size and number the dams required would be dependent upon the rate at which water will bleed from the slurry deposited into the dams, thereby allowing the tailings to consolidate sufficiently for them to be excavated and transported to the containment cells located within out of pit storage emplacements Pits D and E.

For concept purposes, a two to three year rotation of the dams has been made such that sufficient operational contingency is built into the system for them to be filled, for the tailings to dry, and for tailings removal. The estimated drying and tailings removal period would be refined during final design.

To further maximise the tailings slurry, it is proposed that each of the three tailings dams be divided into a number of individual cells. The tailings would be deposited into each cell on a rotational basis via a feed pipeline placed along the basin edge of the embankment crest. Flow controlled spigot tee off's, placed at approximately 25 m intervals along the pipeline would allow the tailings to be deposited in the thin, uniform layers required within the cells.

The deposited tailings would form a natural beach sloping towards the end of each cell where a suitably constructed decant structure would collect the bleed water, together with any rainfall sourced run-off during the wet season. The decant water would then be pumped back to the CHPP for reuse, or be stored in decant water dams constructed proximal to the tailings dams.

The floor of each individual cell would be gently graded towards the decant structure. Further, a series of slotted 'ag-pipes' would be laid in shallow sand filled trenches across the topographically lowest 200 m area of cell floor, to assist with maximising vertical drainage of bleed water.

Filter cake tailings management

The tailings filter cake removed from the belt / filter press, together with the dried tailings from the individual cells within the conventional tailings dams, would be permanently stored in the engineered containment cells constructed within the out of pit storage emplacements at Pits D and E.

To minimise the risk of any leachate migrating from the engineered containment cells, tailings would be emplaced within clay lined cells. The rectilinear cells would be constructed within selected over and interburden material in the out of pit storage emplacements.

5.7 CHP services

5.7.1 Raw water requirements

The CHP will require the use of raw water for the following components:

- conveyor belt cleaners on the head end of each conveyor
- ROM bin dust suppression nozzles
- conveyor tail and head end dust suppression nozzles
- raw coal surge pile dust suppression water cannons
- product coal stockpile dust suppression water cannons
- washdown hoses at head and tail end of each conveyor only
- fire hydrants
- fire hose reels

The significant differences in pumping requirements to operate these components resulted in the design of two separate raw water systems:

- CHP process water networks (utilises the low flow, high pressure and continuous use type devices)
- CHP fire water network (utilises the high pressure, low flow and intermittent use type devices)

5.7.2 Raw water supply

A dedicated fire water supply will provide a flooded suction arrangement to both the process water pump and fire water pump. This raw water reserve will be supplied with water from the clean water dam. It is anticipated this water will be of a high enough quality to service both process water and fire water networks.

5.7.3 Dust suppression

Dust suppression is provided as part of the process water system. The process water network is a shared piping network servicing both the belt cleaners and dust suppression nozzles. Dust suppression is proposed at the following locations:

- ROM bins
- tail end of the conveyor feeding the secondary sizing stations
- tail end of the overland conveyors
- tail end of the RC reclaim conveyors

- head end of overland conveyors
- tail end of CPP feed conveyors
- tail end of CPP surge bin feed conveyors

High pressure full cone nozzles are proposed to be used in dust suppression; these do not require compressed air to operate.

5.7.4 Fire water and wash down area

A dedicated firewater circuit has been included as part of the CHP. The CHP fire water network comprises of:

- sufficiently sized panel tank/s
- electric pump and standby diesel tank (with associated appurtenances)
- hydrant – North ROM
- hydrant – Central ROM
- hydrant – South ROM
- hose reels on all elevated gantries
- hydrant – tertiary sizing stations (covers CPP area as well)
- hydrant – Train loadout
- raw coal surge pile water cannons for dust suppression
- product coal stockpile water cannons for dust suppression

5.7.5 Compressed air

Compressed air has not been included to service dust suppression nozzles. The reclaim feeders included do not required compressed air to operate. Solenoid valves or manual valves will be utilised to control the water networks. As such the CHP has no compressed air requirements.

5.7.6 Potable water

The potable water network at the MIA's and CPP will service the CHP areas.

Safety showers or dedicated amenity blocks are not required as part of the CHP, as such a dedicated potable water circuit for the CHP has been excluded.

5.8 Mine waste

Approximately 13.1 billion bank cubic metres (bcm) of over and interburden will be generated from the open cut section of the Carmichael mine during the mine life. Initially this material will be stored in out of pit waste rock structures on the eastern side of the mine area. Subsequently, the balance of the material will be placed into mine voids as these become available.

Test results for 92 samples indicate that the clays, weathered rocks (including mudstone, claystone, carbonaceous mudstone and siltstone) may have dispersive behaviour. Slightly weathered siltstone may show very slight potential for dispersivity. The weathered sandstone did not show any indication of dispersive behaviour. Soil samples showed completely non-dispersive results due to the presence of calcite.

The fresh rocks were generally non-dispersive, although some claystones and siltstones may have a very low potential for dispersion. There was variability in dispersion results within each group.

Weathered rock, siltstone and sandstone showed potential for deterioration and breakdown after exposure to water. The siltstone showed moderate rate deterioration, and sandstone slow deterioration. This may indicate that although the fresh rock units are not dispersive, they are not durable, and with time may degrade to sand, silt or clay. The degraded material may be more prone to physical erosion than the original fresh rock.

Chromium reducible sulfur (CRS) tests indicated that not all acid generating capacity determined from total sulfur may be available to generate acid. Similarly, acid buffering characteristic curve (ABCC) testing indicated that not all acid neutralising capacity determined from ANC testing may be available to neutralise acid. Thus, there is expected to be some uncertainty on the accuracy of the NPR and AMIRA classifications of the samples.

Based on the available results the majority of the overburden and interburden materials (not immediately adjacent to the coal seams) and roof and floor wastes are not likely to be a source of acid immediately after mining. Nor would most of these materials be expected to be an immediate source of salinity; however, some portion could be a source of salinity. The clay materials of the overburden and interburden could have a markedly higher potential to release salts and metals to contact water even though the pH may remain alkaline. Typically however, the concentrations of metals in water contacting the waste would be expected to be low while waters remain circumneutral.

The majority of the overburden and interburden waste from all lithological groups is likely to be non-acid forming in the longer term. Some carbonaceous mudstone, carbonaceous sandstone, carbonaceous siltstone, clay, claystone, mudstone, sandstone, sandy clay, siltstone and tuff may be acid forming in the long term and there may be a requirement to manage these materials to prevent or limit the longer-term development of AMD.

Some portion of the roof, floor and coal could be expected to be acid forming in the long term. Washed coal wastes were not available for testing.

Kinetic testing of 10 samples to estimate rates of acid production and neutralisation and rates of metals release commenced in May 2013.

Details of the tailing management strategy are included in SEIS Volume 4 Appendix O2. Ultimately, 100 percent of the tailings and coarse rejects generated in the CHPP would report to the engineered co-disposal cells located within out of pit storage emplacements at Pits D and E. It is proposed that the tailings be managed by:

- approximately 26 percent of the tailings being dewatered by passing them through a belt / filter press
- approximately 74 percent of the tailings being pumped as slurry and sub-aerially deposited into out of pit earth embankment tailings dams to dry. The tailings deposited into these dams would be placed in thin layers of a nominal maximum of approximately 150 mm to assist with the bleeding and consolidation of the tailings

The bleed water will be decanted off into adjacent storage ponds for reuse in the plant. Once the tailings have sufficiently dried out and consolidated, the consolidated tailings would be excavated from the tailings dams and transported to pre-constructed containment cells located within the out of pit storage emplacements at Pits D and E. Dried tailings 'cake' generated from the belt / filter press would also be placed into the pre-constructed containment cells located within out of pit storage emplacements at Pits D and E.

The containment cells located within out of pit storage emplacements at Pits D and E would be constructed with a suitably designed and engineered clay liner at the base and sides. When at capacity, the cells would be clay capped. This should effectively fully contain the tailings and minimise the risk of any contaminants entering the surrounding environment

6. Mine pre-construction

This section describes the activities that will be undertaken on the mine site prior to commencement of production. During the pre-construction phase the Proponent will undertake a major realignment and upgrade works of the Moray Carmichael Road within the mine lease area, in accordance with the standard agreed between the Proponent and IRC and contained within the road maintenance and upgrade agreements. The workers accommodation village and permanent airport will be developed during this phase, to provide accommodation for the construction workforce and associated air transport.

The site clearing includes removal of vegetation and general debris, any structures and diversion of any existing infrastructure or services. Due to the rural nature of the region, the number of existing structures and services requiring relocation or removal will be minimal. While the terrain in these areas is relatively level, some earthworks will be required to:

- level, grade and compact the building footprint for any on mine or off site structures or platforms
- level and grade the access road to the Mine and the offsite infrastructure
- level and grade the airstrip at the permanent airport to engineering requirements
- provide stormwater management

All additional approvals required for the construction of the Project (Mine) will include Environmental Management Plans, and Safety Management Plans as approved by the relevant Federal, State and local authorities. Relevant environmental licences will also be applied for or attained for the purpose of the Project (Mine). The execution of the mining lease over EPC1690 and EPC1080 is also required before commencement of construction.

7. Mine construction

7.1 Overview

Construction will commence as soon as approval requirements are in place and, for activities within the MLA, once the Mining Lease has been granted.

Construction scheduling will focus on allowing production to commence as soon as possible and, as discussed in Section 7.2, there is an overlap between construction and operation phases. The majority of the construction works will take place over a 36-48 month period, however, the construction phases will continue until the mine reaches full production.

As the mine progresses south, additional construction works will be required to construct the bridge and infrastructure crossing of the Carmichael River and mine support facilities south of the river.

Construction activities will generally occur seven days per week and 24 hours per day and will be carried out by one or more contractors.

7.2 Main construction phase

The following off-site components are required to be constructed during the main construction period:

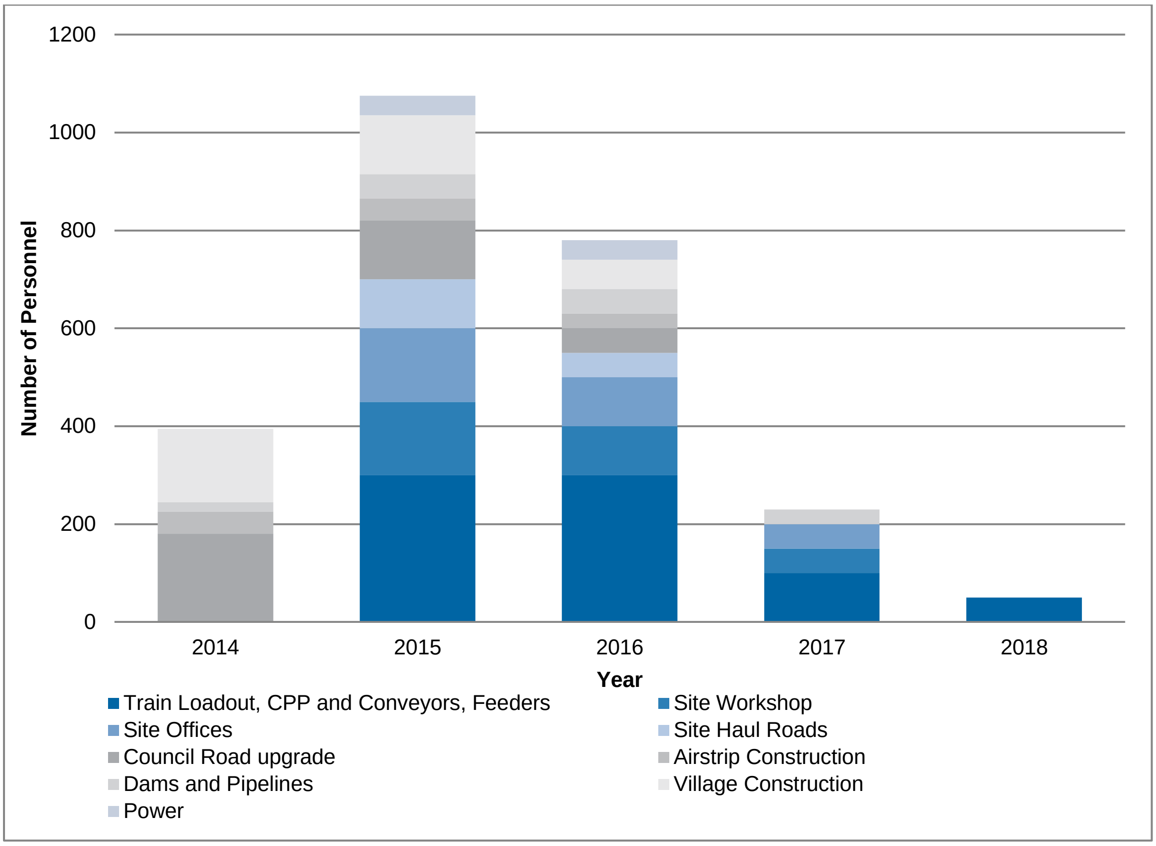
- Construction of access roads from Moray-Carmichael Road to the workers accommodation village, airstrip and industrial area. These will ultimately be bitumen sealed and provide year round access.
- Construction of the workers accommodation village. The village will be constructed in a number of stages.
- Installation of sewage treatment systems and water treatment systems at the workers accommodation village and also the industrial area and airport.
- Construction of the airstrip and terminal facilities.
- Construction of the industrial area including fuel storage and refuelling areas, maintenance facilities, vehicle wash areas and office and administration facilities.
- Construction of off-site water supply components. This will include:
  - construction of an off-stream storage near the Belyando River; including a “turkey nest” style dam
  - installation of pipelines connecting the water supply sources to the off-site infrastructure area and demand points within the proposed mine

Long term water supply infrastructure requirements in the form of a regional pipeline have not yet been determined but it is expected that, if required, offsite components of pipeline will be constructed by the relevant authorised supply authority.

7.3 Construction workforce

Construction of the Project is scheduled to commence in 2014. An initial workforce of 395 persons is anticipated for the pre-construction phase. Figure 25 shows the workforce numbers for the construction period with details of the number of personnel required for each different component of construction (onsite and offsite infrastructure).

Figure 25 Mine construction workforce by year



7.4 Moray Carmichael Road

As the Moray Carmichael Road passes through the proposed mine footprint, it will need to be realigned. It is proposed to temporarily realign the road while mining takes place in the central part of the proposed mine, and then, once rehabilitation in this area is complete, establish a permanent road alignment as close as possible to the existing alignment.

The temporary and final roads will meet the relevant rural road design standards that are in place at the time from Isaac Regional Council and Department of Transport and Main Roads.

7.5 Ongoing construction works

As mining progresses, a range of additional construction works will be required including:

- Underground mining ROM stockpile and infrastructure areas for each of the underground mines. These will have worker amenities, sewage treatment systems, raw and mine water storages, stormwater containment systems, minor vehicle maintenance facilities and fuel and other consumable storage.
- Extension of conveyor and haul road networks to the north and then to the south as mining progresses
- Construction of a bridge and infrastructure crossing of the Carmichael River

- Construction of levee banks along the north and south of the Carmichael River/Cabbage Tree Creek. Levees will be built a minimum of 500 m away from the river channel and will need to be in place before open cut mining extends into the Carmichael River floodplain. Design and construction will comply with *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* (DERM 2012)
- Diversions of streams away from open cut areas. Stream diversions will comply with guidelines in place at the time, with current relevant guidelines DERM 2011 *Watercourse Diversions – Central Queensland Mining Industry version 5.0*
- Construction of additional mine water storage dams.

7.6 Construction methods

7.6.1 Vegetation clearing

Vegetation clearing will be staged to minimise areas of disturbance prior to construction. Timber will be harvested, with scrub and stumps being grubbed utilising a bulldozer. Pre-clearing surveys will be conducted in areas where conservation significant flora and fauna may be present, including along vegetated creeks and drainage lines.

Depending on the type of vegetation and level of weed infestation, cleared timber will be mulched utilising a tub grinder, or similar, for use as soil conditioner or alternately cleared vegetation will be piled into windrows and left to decompose naturally.

7.6.2 Erosion and sediment controls

During wet periods, erosion and sediment controls will be installed immediately after vegetation clearing and prior to any other surface disturbance.

7.6.3 Bulk earthworks

While areas within the construction footprint are relatively flat, civil earthworks will be required for the installation of structural foundations, lay down areas and hardstand. Topsoil will be stripped ahead of earthworks and stockpiled for reuse in rehabilitation of areas no longer required for construction, or in rehabilitation trials.

The requirement for piling will be determined during the detailed design phase and where required, piling rigs will brought to site. It is not anticipated to generate excess spoil during this phase. If excess spoil is generated, this will be stockpiled for disposal with mine waste at a later date.

7.6.4 Buried infrastructure

Water supply pipelines will be buried and the requirement for other linear infrastructure to be buried will be determined during detailed design. Final alignments will seek to minimise clearing of remnant native vegetation.

For buried infrastructure, the construction method will consist of:

- Clearing vegetation along the proposed alignment, with clearing widths held to the minimal width required for safe construction. Larger trees will be felled and root systems grubbed, but where possible, root structures of smaller plants and grasses will be left intact in topsoil.

- installation of erosion and sediment controls
- removal of topsoil which will be set aside in windrows parallel to the proposed alignment for reuse in rehabilitation of the alignment
- excavation of a trench, with spoil material placed in windrows along the alignment
- installation of the pipeline or other buried infrastructure component, with quality control to ensure that there are no leaks or other faults
- Backfilling of the trench with spoil material. Excess spoil will be removed for use as fill in other construction areas or stockpiled for later disposal in mine waste stockpiles.
- Replacement of topsoil and stabilisation. Rehabilitation trials will be required to determine whether to utilise native or introduced grass species to attain the best ground cover.

Construction scheduling will focus on minimising the time between initial vegetation clearing and reinstatement to minimise risk of erosion and soil loss. Erosion and sediment control measures will remain in place until the disturbed surfaces are stabilised.

Water supply pipelines will be required to cross several ephemeral streams and drainage lines. Stream crossings will be performed in dry conditions wherever possible, with forward planning to minimise the length of time that there are disturbed areas within the bed and banks of streams and thus, the likelihood of flow conditions occurring during construction. The construction method will be similar to that outlined above for underground infrastructure, however in addition the following measures will be undertaken:

- Clearing of vegetation and particularly tall trees in the riparian zone and bed and banks of watercourses will be minimised as far as possible without compromising safety
- The bed level of the stream or drainage line will be restored so that there is no disruption to flows
- The bed and banks of the stream will be stabilised such that native vegetation can be re-established and scouring does not occur.

Codes and guidelines that will be incorporated into design, construction and rehabilitation of watercourse crossings are listed in Section 7.6.5. Laydown areas will be required for pipes and bedding material and will be located in areas already cleared of native vegetation.

7.6.5 General requirements for works in watercourses

Works in watercourses will need to be undertaken both on and off the proposed mining lease, including for access road crossings, water supply infrastructure and underground infrastructure. The regulatory requirements in relation to works in watercourses are different depending whether the works are on or off the proposed mining lease and hence, self-assessable codes and guidelines are not necessarily applicable in all instances. However, codes and guidelines still provide guidance in terms of standards and practices for design, construction and rehabilitation of works in watercourses and will be referenced as such for all works in watercourses.

Applicable codes in place at the time of proposed works will be utilised to inform design and development.

7.6.6 Mine raw water storage

While detailed design has not been commenced for the mine raw water storage, it is anticipated that in-situ materials will be used for construction of the embankments for this storage.

7.6.7 Belyando River pump station and storage dam

The Belyando River storage dam is an off-stream storage and will be located on the footprint of an old quarry. It is anticipated that the dam will be constructed by a combination of excavation into the ground and construction of embankment walls from in-situ material.

A channel will be installed into the bank of the Belyando River leading to a pump station. The construction area for the pump station will be approximately 2,500 m². This includes the pump station and channel area, and all laydown, spoil and stockpile areas.

The pump station structure will be cast in situ during non-flood periods. The excavation of the channel and pump station invert river level will be done in phases, with connection to the river made late in the construction period as the river level is higher in this area due to the retarding effect of the downstream causeway. The concrete structure will support a steel or concrete platform above to house the electrical infrastructure. Concrete will be likely obtained from a batching plant on site. Reinforcement, other steelwork, electrical and mechanical equipment will be delivered to site.

7.6.8 Boreholes

The Carmichael Coal Mine and Rail EIS proposed the development of an offsite bore field for water extraction. That bore field is no longer a component of the proposed project. Should external bore water be required, separate approvals and assessments would be required for this post the EIS and SEIS process. In that event, any bore would be constructed in accordance with the *Minimum Construction Requirements for Water Bores in Australia* (National Uniform Drillers Licensing Committee 2011) – the standard for constructing, maintaining, rehabilitating and decommissioning water bores in Australia.

7.6.9 Access roads and tracks

Both temporary and permanent access roads will be required for the off-site infrastructure and within the mining lease. Access road alignments have not yet been determined but will take into consideration utilisation of existing tracks where possible to minimise vegetation clearing. Permanent, long-term and/or high volume access roads will be constructed from bitumen or gravel and will have drainage provided to prevent concentration of flows across or along road alignments. Minor or temporary access tracks will generally be single lane dirt tracks with minimal earthworks.

Access roads and tracks will be required to cross ephemeral watercourses. Wherever possible, crossing locations will be selected to minimise the need to clear riparian or in-stream vegetation. For permanent, long-term and/or high volume access roads, culverts will be used with flood immunity design criteria as specified. Codes and guidelines listed in Section 7.6.5 will be followed as closely as possible, particularly in relation to minimising damage to the bed and banks of watercourses and maintaining flows and fish passage. If construction occurs in the wet periods, a sediment check dam or similar device will be installed downstream of the construction area to capture sediment released during construction.

For minor access roads, crossings will either be at bed level, or with a low flow pipe installed under a slightly elevated crossing. Again, locations will be selected to minimise clearing of riparian vegetation or in-stream vegetation and codes and guidelines listed in Section 7.6.5 will be followed as far as practicable. Crossing locations will be stabilised such that erosion and scouring does not occur.

7.6.10 Carmichael River Bridge

A bridge will be required across the Carmichael River in 2033 to access the southern part of the proposed mine. The bridge will be designed to minimise afflux impacts and to meet flood immunity criteria. The bridge will span the main channel of the Carmichael River, with no pylons or supports within the low flow channel.

During construction, it will be necessary to install a low level crossing across the Carmichael River to allow construction vehicles, equipment and materials to be transported to the south side of the River. This will consist of a compacted dirt roadway, with low flow pipes laid underneath. On completion of construction, this will be removed and the bed and banks rehabilitated.

7.6.11 Flood levees

Flood levees will be constructed to protect the open cut pits and underground mine portals from flooding from the Carmichael River and possibly Eight Mile Creek. While geotechnical investigations are yet to be undertaken, it is expected that levees will be able to be constructed from locally available materials. Flood levees will meet hydraulic design criteria.

7.7 Construction traffic and transport

The Project area encompasses several transport corridors of national, state, regional, district and local significance. These types of roads are either under the management and control of either the State road authority, Department of Transport and Main Roads (DTMR), or in the local road authority, the IRC. Table 6 provides the classification of each road within the study area and identifies the road authority that manages each road. The traffic volumes generated by the construction of the Mine will vary and will depend on the construction timetable. The main traffic generated through the construction phase will be from plant, equipment and material deliveries.

Table 6 Roads within vicinity of Project (Mine)

Road Name	Road Authority	Classification
Flinders Highway (Charters Towers to Townsville)	DTMR	State Strategic Road
Gregory Developmental Road (Charters Towers to Clermont)	DTMR	State Strategic Road
Gregory Developmental Road (Clermont to Emerald)	DTMR	State Strategic Road
Bowen Developmental Road (Bowen-Collinsville)	DTMR	District
Bowen Developmental Road (Collinsville – Belyando Crossing)	DTMR	District
Suttor Developmental Road (Nebo-Mount Coolon)	DTMR	Regional Road
Peak Downs Highway (Clermont – Nebo)	DTMR	State Strategic Road
Peak Downs Highway (Nebo – Mackay)	DTMR	State Strategic Road
Moray Carmichael Boundary Road	Isaac Regional council	Local Road

Road Name	Road Authority	Classification
Moray Bulliwallah Road	Isaac Regional council	Local Road
Elgin Moray Road	Isaac Regional council	Local Road

7.8 Construction water requirements

Water will be required for construction over the period of 2014 – 2022. This water will be used for purposes such as construction of roads, dam embankments and levees, as well as batching of concrete. The amount of water needed on a yearly basis is shown in Table 7. Construction water has been excluded from the water balance as a large part of the construction water requirements is required for dust suppression, which has been accounted for in the water balance.

Table 7 Construction water demands

Year	ML/year	ML/day
2014	1,000	2.74
2015	1,500	4.11
2016	2,000	5.48
2017	2,000	5.48
2018	1,000	2.74
2019	1,000	2.74
2020	500	1.37
2021	500	1.37
2022	500	1.37
Source: Adani		

7.9 Rehabilitation of temporary construction sites

For mine infrastructure temporary construction and laydown areas have been located in areas that will be required for mine operations to minimise the overall disturbance footprint. Hence, rehabilitation of these areas will not be required. Areas that are not to be used immediately will be stabilised by placement of gravel or seeding with grass if necessary to minimise erosion risk.

For the off-site infrastructure, temporary construction and laydown areas have been located in areas already cleared of native vegetation. If any areas are not required once construction is completed these will be ripped, topsoil replaced, and grass sown to provide ground cover. Erosion and sediment controls will be left in place until 70 percent ground cover is achieved.

7.10 Construction equipment

The types of heavy vehicles and equipment required for the construction include:

- three, five and seven axle trucks, flatbed semitrailers, extendable trailers, B-double tankers, road trains to transport plant and material to the site
- low loaders for construction equipment
- tipper trucks, to transport bedding sand on-site and excavated burden off-site
- excavation machinery

- dozers, backhoes, scrapers, graders, rollers and water carts
- buses for workers

8. Mine commissioning and operation

8.1 Commissioning

8.1.1 CHPP and coal handling systems

Commissioning of the CHPP and coal handling systems involves operating the systems under close supervision and monitoring quality of outputs until a satisfactory level of performance is achieved. Only normal coal fines and rejects waste will be produced during commissioning and there is no potential for hazardous wastes to be generated.

8.1.2 Plant and equipment

There are no specific commissioning requirements for plant and equipment.

8.1.3 Dams, pipes and pump stations

While there are no specific commissioning requirements for dams without mechanical gates, there are a number of surveillance requirements during design and construction, both under the *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* (DERM 2012) (dams within the mining lease) and *Queensland Dam Safety Management Guidelines* (NRM, 2002). Prior to allowing any dams to fill, a review will be undertaken to check that all design and construction requirements have been met.

Pipes and pump stations must be tested for hydraulic performance as part of commissioning. This is to check that all components are fully sealed and that the required capacity has been achieved. Pipelines also need to be cleaned of any debris that may be within the pipeline after construction. This is done by pressure testing pipes and pumps with water. Pipes are filled with water and pressurised and then monitored for drops in pressure that may indicate leaks. Pumps are also tested by monitoring pressure and checking for leaks.

Water from hydro-testing will either be discharged to land (irrigation) or surface waterways or transferred to water storage dams for reuse. It is not currently anticipated that any additives will be required, but water is likely to have collected debris from within the pipes and pumps and will need to be screened to remove this debris if it is to be discharged to surface waterways. Any discharge to surface waterways or land irrigation will be done in a manner that does not cause scouring or erosion.

8.2 Operations

The Project (Mine) includes the:

- open cut mine
- underground mine
- mine infrastructure area and CHPP
- out-of-pit dumps
- associated raw water and waste water management infrastructure

The open cut mine has a capacity of 40 Mtpa (product) and will be located along the eastern portion of Mine. The open cut mine will be predominantly truck/shovel/excavator operation. Six open cut pits will be mined over the life of the proposed mine, designated pits B to G. Pits B to E are located north of the Carmichael River and Pits F and G are south of the river.

During the early stage of development of each pit, overburden will be transported to out-of-pit dumps on EPC 1080 and on east side of sub-crop in EPC 1690, which will be profiled and rehabilitated as operations progress. Thereafter, backfilling of the pit will be maximised during operations and eventually a proportion of the waste used to re-profile the high-wall of the final voids.

Five underground longwall coal mines will be developed, designated as the Mine 1 to Mine 5 underground mines. The Mine 1 to Mine 3 underground mines are located to the north of the Carmichael River, with Mine 4 and 5 underground mines to the south of the river. The underground mines will produce 20 Mtpa (product) of lower ash coal over 42 years of the overall mine life. The lower ash coal will be blended with higher ash coal from the open cut mines, to minimise the overall need for coal processing and washing to meet the target ash content.

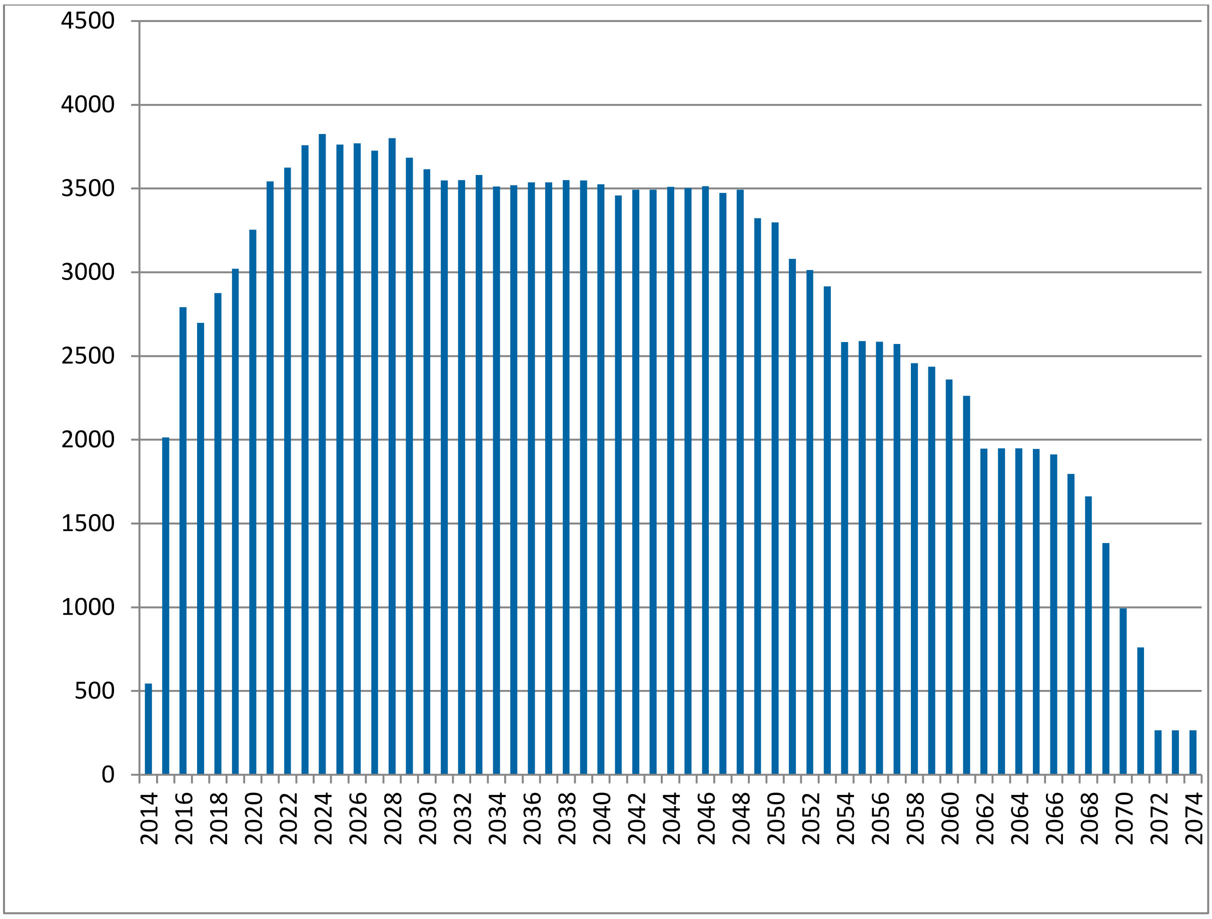
A north-south surface corridor will separate the underground mines from the open cut pits. This is used to locate the underground drift access and surface coal haulage access and provide a barrier pillar for safe concurrent working of the underground and open cut operations. Coal from both the underground and open cut mines will be conveyed by truck and overland conveyor to the centralised CHPP within the mine infrastructure area, where the high-ash portion will be processed and then blended with lower ash coal, which will bypass the CHPP.

8.3 Operational workforce

First coal production from the Project (Mine) is expected in 2016. However, preliminary operational activities will commence in 2015. The operations workforce will ramp up from 789 in 2015 to a peak of approximately 3,800 by 2024. It is expected that the workforce will remain above 3,400 from 2022 til 2048 (see Figure 26).

The workforce will drop to over 2,400 when underground mining ceases production by 2059, and will gradually reduce from year 2062 as the production slows and the Project (Mine) ceases production.

Figure 26 Total workforce for life of mine



8.4 Open cut mine operations

8.4.1 Mining method

The following outlines the nature and description of all key operations associated with the open cut mine. The open cut mining method includes:

- overburden removal
- overburden disposal
- drilling and blasting
- coal mining
- co-disposal of rejects and tailings

Figure 27 and Figure 28 provide schematics of open cut mine operations.

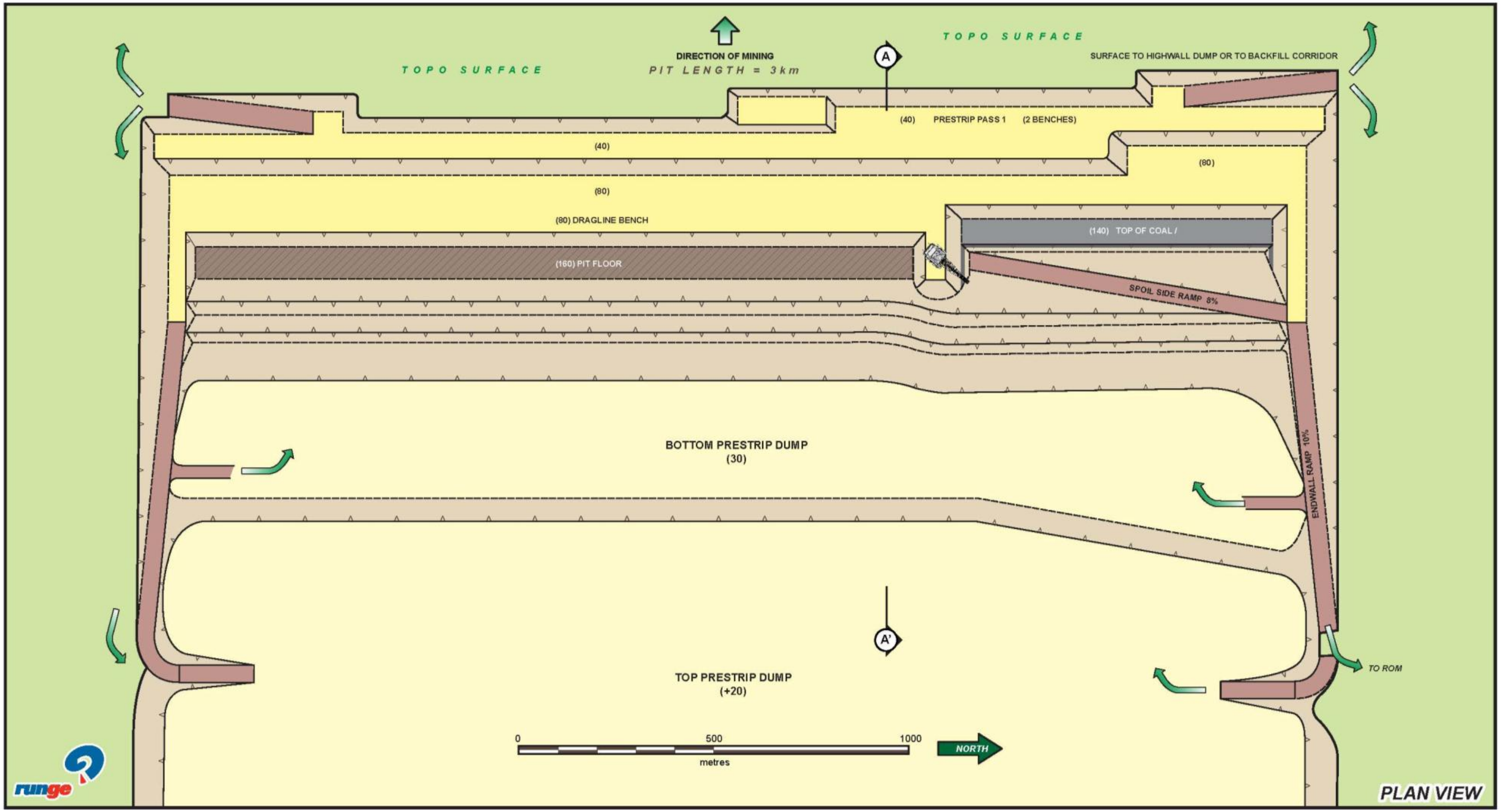
Vegetation clearing will be undertaken using bulldozers or similar equipment. In areas of high ecological value, pre-clearing surveys will be undertaken to identify conservation significant flora and fauna and determine appropriate methods to avoid or minimise harm. The clearing method and whether vegetation is stockpiled, mulched or otherwise treated will depend on the type of vegetation in a particular area, and the level of weed infestation.

Topsoil will be stripped prior to mining or dumping in each area by a combination of scrapers, dozers and excavators. Topsoil stripping depth will be determined prior to stripping as will the need for single or two phase stripping. The topsoil will be stockpiled until it is required for rehabilitation, or hauled directly for respreading on the completed and re-profiled mining areas. Depending on requirements to be specified in the rehabilitation management plan, some amelioration of topsoil may be required prior to or at the time of stripping and replacement. A topsoil register will be retained to track the origin, interim storage and final destination of topsoil.

An initial box cut will be constructed on the eastern side of each open cut to provide access for removal of overburden. The Tertiary layer overburden, consisting of an average 80 m thick layer will be removed using excavators loading material into rear dump trucks, as will the uppermost layers of the Permian formation. This will expose the AB seam, which will be mined.

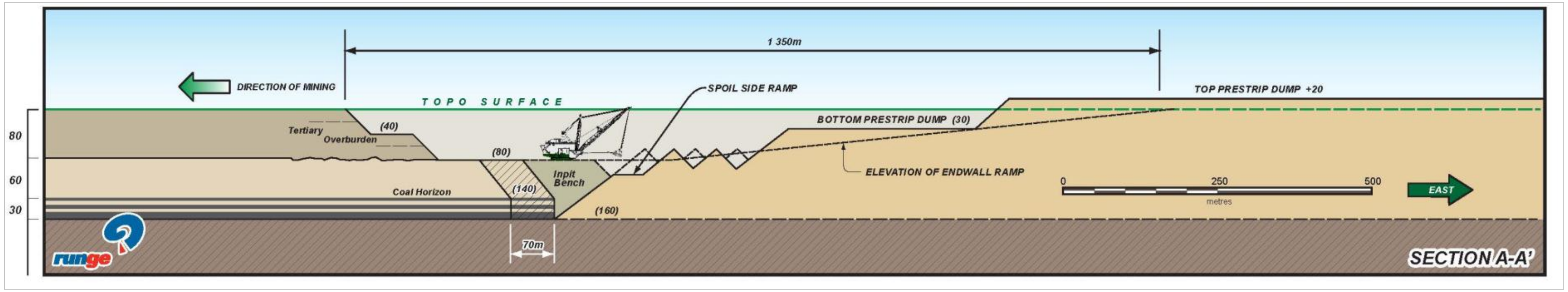
Mining will occur in an east to west direction, leaving a low wall of mined out material to the east with coal being removed from a high wall which will progress westwards. Because of the geometry of the Project (Mine) and limited access on the low wall side of the mine, backfilling of each pit cannot commence until the box-cut and several overburden strips have been completed. The waste associated with this phase of mining will be hauled to out-of-pit dumps located east of the pits, within EPC1080. After that time, all pre-strip material will be hauled to backfill dumps, using a series of endwall and in pit ramps.

Figure 27 Open cut mine concept – plan view



Source: Runge Limited 2011

Figure 28 Open cut mine concept – section A-A



Source: Runge Limited 2011

Much of the Tertiary and weathered Permian overburden is likely to be able to be dug with excavators and shovels but some light blasting will be used to speed up excavation. Thin inter-burden and coal will be ripped with bulldozers as and pushed into windrows for loading onto trucks by front-end loaders. All blasting will be undertaken using ANFO and emulsion explosives. The maximum tonnage of explosives required per year is approximately 165,000 t. All ANFO and emulsion explosives will be stored in a dedicated secure bulk explosives facilities with an associated high explosives magazine, located approximately 10 km from the mine infrastructure areas.

Trucks and equipment will access the open cut by ramps which will progress with depth and westward movement of mining, with a maximum length of approximately 5 km.

During the life of the Project (Mine), there will be approximately 1 billion m^3 of out-of-pit waste. The maximum height above the natural surface of the out-of-pit dumps is estimated to be up to 140 m. The outer face of the dumps will be profiled to a final rehabilitation gradient of 10 percent / (6.3 degrees). The inner face will be dumped to angle of repose, and later re-profiled between 10 and 20 percent (12 to 14 degrees) to assist in rehabilitation of the final landform and mining voids.

Figure 7 to Figure 20 provides an outline of the mine progress over the life of mine.

8.4.2 Equipment associated with open cut mining method

The open cut mine will initially consist of a conventional dragline and truck-shovel pre-strip operation, with coal haulage by rear-dump haul truck to one of three ROM dump stations. In steady-state operations, draglines may expose the coal in a single seam 2-pass operation on the D seam in selected pits or conventional truck shovel/excavator method will be employed. Once the upper D1 seam is exposed and mined, the underlying D2 and D3 seams will be exposed by the interburden in pit fleet and mined separately. Where the E and F seams are included in the block, these will also be exposed by the interburden fleet or dozed in pit.

In the pre-strip horizon, the overburden will be excavated ahead of the dragline by backhoe excavators (up to 800 t) and / or electric rope shovels, and hauled to out-of-pit dumps beyond the high-wall with RDT (up to ultra-class or 400 t). Much of the Tertiary and weathered Permian overburden is likely to be free-dig material, but it is planned that light blasting may be used to maintain productivity of digging.

The upper AB seams will be exposed by pre-strip as it descends to the fresh Permian horizon. Once the box-cuts have been completed and sufficient room has been created to commence backfill dumping, the waste trucks will haul the waste into backfill via a series of end-wall ramps, in-pit bridges or via the highwall ramp and an out-of-pit haul road located in the adjacent pit area. Due to the depth of the box-cuts, backfill dumping of the pits cannot commence until pre-stripping is around five strips in advance of the box-cut. Over the life of the project, up to a total of two draglines may be required. These will be staged from 2020 on an individual basis as required, with both being deployed prior to 2027. The draglines will be constructed on a dragline construction area located adjacent to the scheduled point of first deployment. The first dragline pad will be located within the footprint of D pit, and will be utilised until the end of the pit.

Large excavators and rear dump trucks will be used in the pre-strip to allow flexibility of mine sequencing and gain access to the deep box-cut. There may be opportunities in the future to optimise equipment sizes or incorporate continuous handling systems such as conveyors for waste haulage, and thereby minimise equipment numbers, labour and diesel consumption. In general, the complexity and depth of the operation restrict the application of large continuous systems over most areas of the mine.

The CAT 8750 dragline or equivalent with other manufacturers has been selected because it is the largest capacity dragline in common use in the Australian coal industry. The objective has been to minimise the size of the excavation required and to limit the volume of truck-shovel pre-strip and minimise the number of draglines consistent with the planned rate of coal exposure.

Mid-size rear dump trucks have been selected for mining the coal and inter-burden so that they can negotiate the deep ramps and match the scale of the coal and inter-burden benches. The fleet size has been limited by providing overland conveyor haulage for the long flat hauls back to the CHPP.

In some areas, the mix of equipment sizes is not optimised because of competing needs. This is particularly the case with the coal fleet, where medium sized rear dump trucks have been selected, loaded by either mid-size backhoe excavators or large front-end-loaders, depending on face height. These have been selected in order to match the excavator size on the smaller coal benches (79 percent of the coal is less than 3 m bench height) and to negotiate the spoil-side ramps. Bottom dump trucks have not been selected because of poor grade-ability and the possible poor pit conditions.

8.4.3 Major equipment – open cut

Table 8 outlines an overview of the major equipment list, the unit type, make/model, capacity and application as selected during the conceptual design phase. The make and model is given to illustrate size of the machine. Final equipment types and capacities will be determined as mine planning and design progresses; however the equipment types listed in Table 8 are unlikely to change significantly.

Table 8 Indicative major equipment list

Unit Type	Typical Make / Model	Capacity	Application
Main Waste			
Overburden drill	Pit Viper 250	270 mm diam.	Main waste drilling
Electric Shovel	P&H 4100 XPC	42 m^3	Main waste removal
Hydraulic Excavator	Liebherr R9800	800 t/42 m^3	Main waste loading
Hydraulic Excavator	CAT 6060	550t/34 m^3	Main waste loading
Hydraulic Excavator	Hitachi EX5600	550t/34 m^3	Main waste loading
Rear-dump truck	Caterpillar 797F	370 t	Main waste haulage
Rear-dump truck	Caterpillar 793F	230 t	Main water haulage
Secondary waste and coal			
Overburden drill	Sandvik D45KS	150-210 mm diam	Secondary waste drilling
Hydraulic Excavator	Liebherr 9400BH	300 t/ 17 m^3	Secondary waste loading
Front end loader	Caterpillar 994D	19 m^3	Backup and thin waste loading

Unit Type	Typical Make / Model	Capacity	Application
Rear-dump truck	Caterpillar 789C	140 t	Secondary waste haulage
Coal Mining			
Coal drill	Sandvik D45KS	150 diam.	Coal drilling (if required)
Front end loader	Caterpillar 994D	31 m^3	Coal handling – thin seams
Hydraulic Excavator	Liebherr 9400BH	300 t/20 m^3	Coal loading – thick seams
Rear-dump truck	Caterpillar 789C	140 t	Coal haulage
Reject Haulage			
Rear-dump truck	Caterpillar 789C	140 t	Reject haulage, coal and inter-burden back up
Major ancillaries			
Tracked Dozer	Caterpillar D11T	634 kW	Waste face clean-up, dragline dozer, spoil dump maintenance, misc. construction, thin waste ripping
Tracked Dozer	Caterpillar D10T	433 kW	Coal face clean-up, road maintenance, misc. construction, thin coal and waste ripping
Rubber tyred dozer	Caterpillar 854G	597 kW	Coal and waste face clean-up, road maintenance, misc. construction
Grader	Caterpillar 24M	373 kW	Coal and waste face clean-up, road maintenance, misc. construction
Water truck	Caterpillar 789C	170 kl	Road maintenance, misc. construction
Service truck	Caterpillar 789C	170 kl	Inpit servicing including fuel and lubes
Note: Model name is illustrative only to indicate size and type			

8.5 Underground mine operations

Underground mining will augment production from the open cut operations. Three multi-seam underground mines will be developed progressively in the deeper areas of the deposit to the west of the open cut highwall. The underground mines will target the lower ash AB1 and D1 seams. Although the D2 and D3 seams present attractive underground working sections, their close proximity to the D1 seam may present technical problems. There may be opportunities to mine these seams as well as the thinner underlying E and F seams at a later time.

The objective of these mines is to increase resource recovery beyond the economic open cut mining limit and produce a low ash coal to improve the blend from the open cut without washing, or reduce the amount of washing required.

The underground mine consists of:

- Mine 1 underground mine: installed with up to four longwall units
- Mine 2 underground mine: installed with up to four longwall units
- Mine 3 underground mine: installed with up to four longwall units
- Mine 4 underground mine: installed with two longwall units
- Mine 5 underground mine: installed with two longwall units

The longwall mining method will be used because of its ability to deliver a safe, high production rate and high resource recovery. Longwalls will be approximately three m to 4.5 m high.

Figure 29 and Figure 30 provide a schematic of underground longwall mine operations. Longwall mining involves the use of a longwall shearer, which is a coal cutting machine with a rotating drums. The shearer moves back and forth across a wide part of the coal seam called the longwall face. The cut coal falls and is loaded onto the chain conveyor by the shearer. The chain conveyor then transports the coal to the conveyor belt for removal from the work area. Longwall systems have in-built hydraulic roof supports, which advance as mining progresses. The supports make possible high levels of production and ensure the safety of the operators. As the longwall mining equipment moves forward, overlying rock that is no longer supported by coal/hydraulic roof supports is allowed to fall behind the operation in a controlled manner. This is known as goaf.

The underground mines will be developed as separate operations, operating independently of the open cut pits. The proposed conceptual layout is based around longwall panels extending out on both sides of a centrally located set of main headings.

Access to three underground mines will be located beyond the final highwall for the open cut, and each will have separate drift entry to both seams, and separate surface facilities (see Section 1. All coal from the underground mines will be transported from the pithead to the central coal handling plant (CHPP) by overland conveyor. Seam access for each mine will be via two inclined drifts, one providing drive in-drive out diesel vehicle access for personnel and materials and the other housing the conveyor coal clearance system.

Figure 29 Underground longwall mine operations – plan view

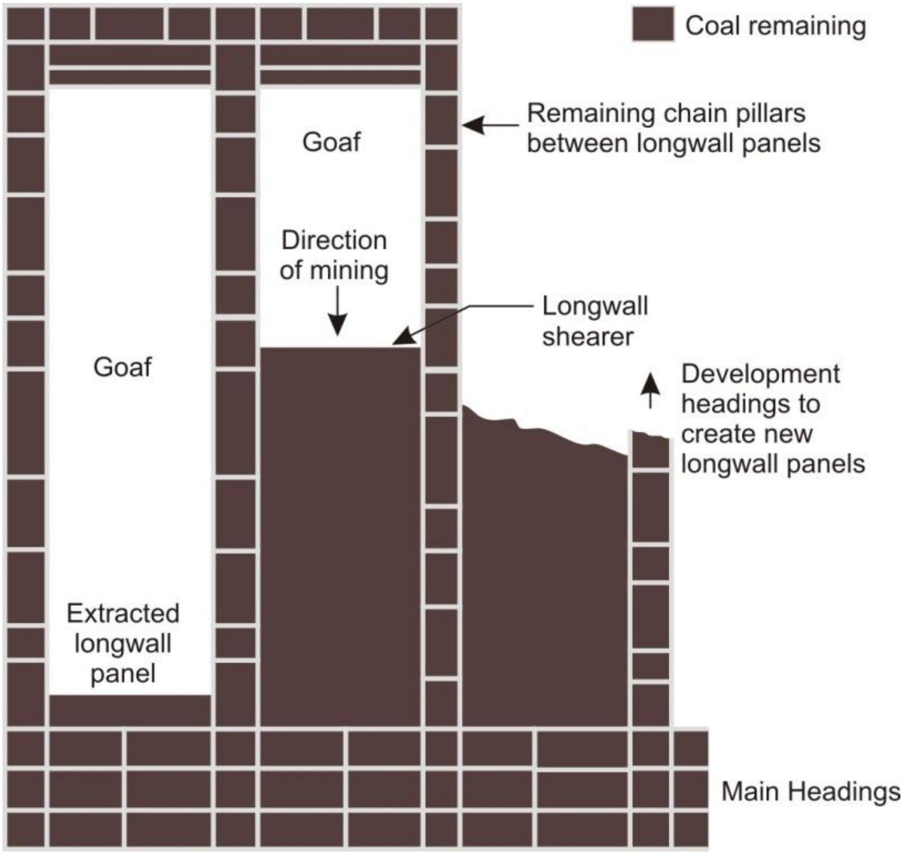
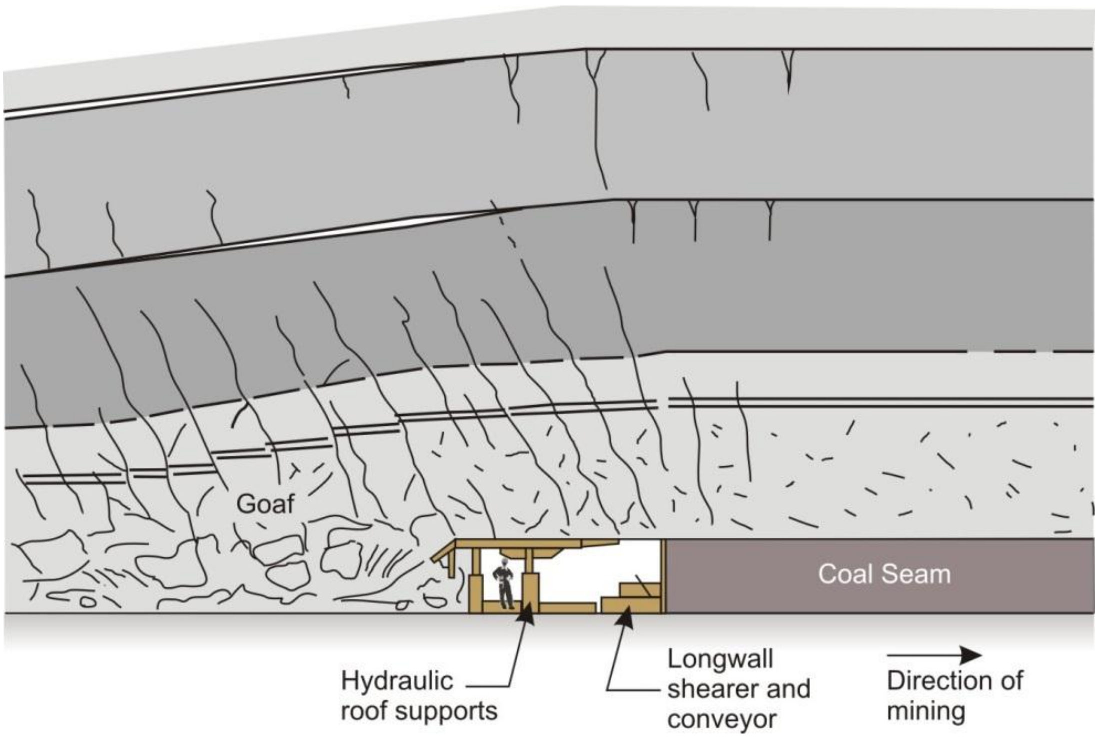


Figure 30 Underground longwall mine operations – section view



Initial development of the mine involves the construction of a tunnel, known as a drift from the surface to intersect the target seams. Once the target depth has been reached, the main entrance to the mine, known as pit bottom, will be established and transportation and ventilation systems installed. Conveyors will be installed in the drift to bring coal to the surface, and roadways and other infrastructure requirements will also be established.

The main heading will then be driven in a north-east to south-west direction, following the seam and thus becoming deeper as it progresses.

The longwall panels are then developed progressively by driving parallel headings perpendicular to the main heading. These headings allow mining equipment to be introduced and the ventilation and conveyor systems to be installed. Mining of the longwall panels then progresses from the furthest extremity, back towards the main heading.

As two seams are targeted by underground mining, the upper AB1 seam will be targeted first and then a second layer of headings and longwall panels will be developed about two to three years after the upper layer has been mined to target the D1 seam. This will allow for subsidence from mining of the AB1 seam to have occurred and settled adequately.

The north underground mine will be developed first, with development of the southern mines (Mine 5 and 4) to follow immediately.

The underground mines will each have a separate pit-head ROM stockpile, where the coal will be reclaimed, sized and conveyed on an overland conveyor to an independent product coal handling stockpile adjacent to the central CHPP facility.

The initial underground mine design parameters include:

- longwall face length of 300 m
- planned longwall panel block length of 5,000 m
- development face width of 5.2 – 5.8 m
- two headings per gateroad panel
- gateroad pillar dimensions (centre to centre) of 100 x 35 m
- 9 Headings mains panel
- mains pillar dimension (centre to centre) of 70 x 50 m

Figure 7 to Figure 20 provide an outline of the mine progress over the life of Project (Mine).

8.6 Water supply and management

8.6.1 Introduction

Water supply and management for the Project involves the supply and distribution of raw water, mine affected water (MAW), sediment affected water (SAW), clean water, process water and treated water throughout the site for both construction and operation requirements. A water balance for the Project (Mine) is included in SEIS Volume 4 Appendix K2 Water Balance.

Water inputs to the Project (Mine) are further defined as:

- Raw water is water that is received from an external water supply, is considered clean and has not been used in a task. Raw water is used for fire water and other high quality water requirements such as concrete batching and potable water. Raw water will predominantly be sourced from pit dewatering (groundwater) and flood water harvesting (surface water).

- MAW (also called worked water) is that which has been through a task and is potentially contaminated by exposure to mining activities and areas
- SAW contains a higher sediment load but has not been contaminated by direct mine activities
- Clean water is runoff from undisturbed catchments and will be diverted around the Project. As such clean water will not be part of the water balance for the Project
- Process water is that which is used on site to complete a task
- Treated water is water that has been treated on site to achieve a particular water quality objective. Raw water, MAW, SAW and process water can be treated as required to allow further use or release as a controlled discharge from a designated outlet.

Mine affected water

MAW is generated in active mining areas. Sources of MAW are:

- Dewatering of six open cut pits (four north of the Carmichael River and two south of the Carmichael River)
- Dewatering of five underground mines (three north of the Carmichael River and two south of the Carmichael River)
- Dewatering of three boxcut areas – underground mines 1, 4 and 5 (from north to south)
- Dewatering of two high wall access areas – Pit D and Pit C
- CHPP tailings decant dam
- Runoff from industrial working areas including the MIA, the ROM coal area, CHPP and the TLO facility
- Runoff from overburden sumps associated with open cut Pits D and E.

Sediment affected water

SAW is generated from disturbed areas; areas where runoff will not be contaminated with coal or other mining associated contaminants, but are likely to be disturbed due to vehicle movements or for example pre-stripping. Runoff from these areas typically has higher sediment loads than runoff from undisturbed areas. Runoff from overburden areas is also considered SAW (with the exception noted above).

8.6.2 Water management principles

The following general water management principles are proposed for the Project:

- Raw water will be delivered and temporarily stored in a raw water dam
- MAW is to be retained on site and stored in the MAW storages (dams) that will be designed and managed in accordance with the Manual for Assessing Hazard Categories and Hydraulic Performance of Dams (DERM, 2012)

- MAW will, when necessary, be discharged into receiving waterways from the centrally located MAW collection storages (central MAW dams) one for north and the other for south of the Carmichael River. Discharges will be in accordance with relevant licence conditions under the Environmental Authority. The aim is not to discharge into the Carmichael River except during extreme climatic circumstances in which the AEP of the storm event exceeds the design parameters adopted
- Runoff from disturbed catchments (SAW) has to be treated to achieve minimum reductions in key pollutant levels before being reused or released into the natural environment
- Clean water runoff from undisturbed catchments is diverted around any mine workings or disturbed areas and released downstream into the same waterway where possible
- Mine workings are protected from local stormwater runoff and regional flooding
- Any controlled discharges are in accordance with Environmental Authorities licence conditions
- Acid Mine Drainage (AMD) water needs to be treated through neutralisation processes in the sediment basins or the MAW storages. The nature of treatment will depend upon the water quality

8.6.3 Water demand requirements

To support the mine, a constant and secure water supply is needed throughout the life of the Project. The required water supply and demand was developed during the project feasibility. A further review of this assessment based on other coal mine operations, industry standard practices, and new information regarding coal washing and dust suppression, has been completed and a summary is included in this section. Detailed analysis of water demand is provided in SEIS Volume 4 Appendix K2 Water Balance Report.

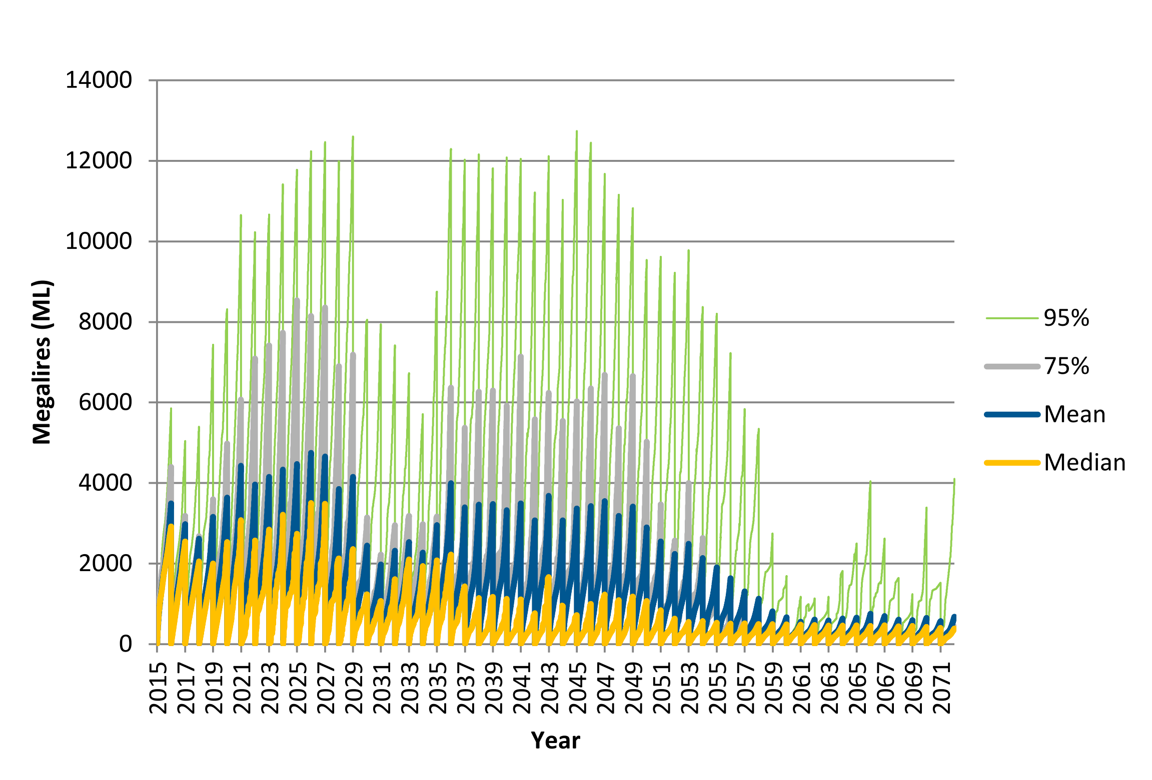
Water is required for:

- Water for potable use will be required for use at the on-site (mine) facilities and at offsite (mine workers accommodation village and airfield) facilities. A combined demand of 300 L/person/day (for both on-site and offsite facilities) has been used to calculate the potable demand with reference to the expected number of staff to be present on site.
- Dust suppression will be required on areas that would otherwise produce excessive volumes of dust as a result of the mining activities. These areas predominantly include the haul roads and the active mining areas.
- Process water is required for the CHPP and the longwall mining equipment.

Figure 31 shows the total estimates of external water demand for the mine site from 2015 to 2071. The mean water demand for the mine site and all associated operations is in the order of 12 GL/yr. This will occur during the majority of the mine's life with lower demands during the start-up and close down phases.

Water demand is presented for the 95th percentile as this is an industry standard for the required reliability of water supply for a mine.

Figure 31 Estimated water demand



8.6.4 On-site water balance

The water balance for the Project has been developed using GoldSim software. One of the objectives for the water balance is to determine the requirements of controlled discharge from the Project to the environment. Within the mine plan, the central MAW storages on both sides of the Carmichael River have been identified as the two potential discharge locations. Hence input and output information is frequently provided separately for the parts of the mine on both sides of the Carmichael River. Within GoldSim there are two approaches available for modelling a site water balance:

1. A deterministic approach where modelling of crucial mine stage snapshots and running the entire historical climate data for this single mine stage
2. A probabilistic approach where a number of climate sequences are run through the water balance of the mine to produce a statistical distribution of results from which a measure of risk can be extracted.

The probabilistic option has been applied for the following reasons:

- It provides a robust indication of water requirements over the life of the mine
- It represents a more robust estimation of storage volumes and the associated carry over storage between different mine phases.

Inflows to the water balance included:

- External water supplies
- Rainfall

- Runoff
- Groundwater inflows

Outflows included:

- Evaporation
- Dust suppression
- Process water requirements
- Seepage
- Potable water
- Tailing facilities

8.6.5 Water storage dams

Design criteria for dams

The methodology for the preliminary sizing of the diverse water management storages for the Project differs per type of storage:

- Central MAW dams
- Central process water dams
- MAW transfer dams
- Overburden MAW dams
- Sediment dams
- Raw water dams.

Central MAW dams

Required volumes for both of the MAW dams have been extracted from GoldSim. Conceptual designs have been generated for these volumes to accommodate the calculated volumes, with the dams having 0.5 m freeboard and an eight m crest width to the embankments. Batters for the dams have been based on 1 in 3 slopes to all sides. The dams have also been fitted within the allocated dam areas provided in the mine plans. For the Central MAW storages a non-rectangular area is available. Storage curves were developed to provide the relationship between volume of water in the dam and the associated area. This allows for a more accurate prediction of evaporation losses in the dams.

Table 9 provides the maximum volume and baseline dimensions of the Central MAW dams. Within GoldSim a sensitivity analysis has been carried out to verify the proposed maximum volumes against potential discharges. At this stage no detail cognisance has been given to ground water levels or balancing cut to fill.

Table 9 Central MAW dams

Dam	Required volume (m^3)	Footprint area (m^2)	Storage depth (m)	Water surface area (m^2)
Central MAW - North	8,000,000	695,810	15.9	574,709
Central MAW - South	7,000,000	680,917	13.9	571,861

* Dams have a triangular shape			

Central process water dams

Required volumes for both of the central process water dams have been extracted from GoldSim. Conceptual designs have been generated for these volumes to accommodate the calculated volumes, with the dams having 0.5 m freeboard and an 8 m crest width to the embankments. Batters for the dams have been based on 1 in 3 slopes to all sides. The dams have also been fitted within the allocated dam areas provided in the mine plans. Storage curves were developed to provide the relationship between volume of water in the dam and the associated area. Table 10 provides the maximum volume and baseline dimensions of the central process water dams.

Table 10 Central process water dams

	Required volume (m^3)	Footprint length (m)	Footprint width (m)	Footprint area (m2)	Storage depth (m)	Water surface area (m^2)
PWD –North	3,000,000	593	413	244,909	27.5	172,525
PWD –South	2,000,000	861	311	267,771	11.0	217,056

MAW transfer dams

The MAW transfer dams have been sized in accordance with expected pump rates of the two input sources (open cut pits and underground mine dewatering). The size of the dams equals a 7 day pumping volume, disregarding evaporation and seepage losses. Table 11 provides the maximum volume and baseline dimensions of the central process water dams.

Table 11 MAW transfer dams

	Required volume (m^3)	Footprint length (m)	Footprint width (m)	Footprint area (m2)	Storage depth (m)	Water surface area (m^2)
MAW-B	200,000	191	191	36,481	13.4	25,728
MAW-C	350,000	240	220	52,800	17.0	36,764
MAW-D	600,000	335	235	78,725	18.4	55,292
MAW-E	900,000	415	255	105,825	20.6	74,029
MAW-F	650,000	356	236	84,016	18.4	59,100
MAW-G	450,000	285	225	64,125	17.3	44,810

Overburden MAW dams

The overburden MAW dams have been sized equal to the DSA. As these dams will need to collect runoff they will be constructed as in-ground basins.

Table 12 provides the maximum volume and baseline dimensions of the central process water dams.

Table 12 Overburden MAW basins

	Required volume (m3)	Footprint length (m)	Footprint width (m)	Footprint area (m2)	Storage depth (m)	Water surface area (m2)

MAW Pit - D	13,660,000	1035	600	621,000	20	621,000
MAW Pit - E	11,250,000	1500	400	600,000	20	600,000

Sediment dams

Sediment dams can be found in both the overburden areas and the disturbed areas for each pit. For both situations the sediment dams are sized outside of GoldSim with help of Excel. The size of the catchment areas for the overburden dams and the disturbed area dams change over time with the disturbed areas decreasing over time and the overburden areas increasing over time. The width of disturbed soil adjacent to each pit at the mine site regresses over the life of the mine at a rate of approximately 50 linear metres per year. As such, the area of disturbed soil adjacent to each pit is systematically reduced over the life of the mine.

The following assumptions were used to calculate a total required storage volume for the sediment basins, in 1 year increments for the disturbed areas and 5 year increments for the overburden areas. This approach is expected to reflect actual mine operations as the sediment dams for the disturbed areas need frequent relocating due to pit progress, while the overburden sediment dams are fixed in location.

- Design rainfall event: 1 in 20 year ARI, 24 event
- Design rainfall depth: 6.77 mm/hr (over 24 hours)
- Runoff coefficient: 0.2 (20 percent of all rainfall reflecting relatively large catchment areas)
- Maximum basin width (disturbed area sediment basins): 80 m.

The width of disturbed soil adjacent to each pit at the mine site regresses over the life of the mine at a rate of approximately 50 linear metres per year. As such, the area of disturbed soil adjacent to each pit is systematically reduced over the life of the mine.

The following assumptions were used to calculate a total required storage volume for the sediment basins, in one year increments for the disturbed areas and five year increments for the overburden areas. This approach is expected to reflect actual mine operations as the sediment dams for the disturbed areas need frequent relocating due to pit progress, while the overburden sediment dams are fixed in location.

- Design rainfall event: 1 in 20 year ARI, 24 events
- Design rainfall depth: 6.77 mm/hr (over 24 hours)
- Runoff coefficient: 0.2 (20 per cent of all rainfall reflecting relatively large catchment areas)
- Maximum basin width (disturbed area sediment basins): 80 m.

The calculated volumes (sizes) of the storages are incorporated within GoldSim. Actual runoff from those areas has been calculated within GoldSim with the AWBM model. Refer to Section 4.3.3. Runoff for the runoff coefficients applied within the AWBM model. Table 13 shows the maximum basin sizes for the disturbed areas.

Table 13 Disturbed area maximum basin sizes

	Area (ha)	Storage Volume (ML)
Pit B	6.3	1,258

Pit C	3.0	602
Pit D	5.0	1,002
Pit E	4.4	883
Pit F	3.4	671
Pit G	3.4	670

Table 14 shows the maximum basin sizes for the overburden sediment basins.

Table 14 Overburden sediment basins

	Required storage volume (m^3)	Footprint length (m)	Footprint width (m)	Footprint area (m^2)	Storage depth (m)	Water surface area (m^2)
SAW Pit-B	744,505	626	200	125,121	10	125,121
SAW Pit-C	411,735	359	200	71,878	10	71,878
SAW Pit-F	565,468	346	400	138,241	5	138,241
SAW Pit-G	867,022	512	400	204,791	5	204,791

Raw water dams

Both raw water dams (north and south) have been sized based on the mine planning requirements at 1 GL each. Table 15 shows the dimensions for the raw water dams.

Table 15 Raw water dams

	Required volume (m3)	Footprint length (m)	Footprint width (m)	Footprint area (m2)	Storage depth (m)	Water surface area (m2)
RWD - North	1,000,000	341	321	109,461	24.0	74,976
RWD- South	1,000,000	404	379	152,959	10.4	122,274

Design storage allowance

The DSA is associated with the hazard category of a particular dam. The *Manual for Assessing Hazard Categories and Hydraulic Performance of Dams* (DERM, 2012) informs how to establish the hazard category. A preliminary hazard assessment in accordance with the Manual has been performed for the following dams:

- The central MAW dams where all MAW from the site will be collected
- The dams that capture the runoff in the overburden dams of pits D and E as it is understood that tailings and rejects are likely to be placed within these overburden areas.

The preliminary hazard assessment for the central MAW dams assumes that each dam will maintain a hazard category of high and thus need to be designed to withhold a 1 in 100 year AEP event. Section 2.2.2 of the Manual states that two approaches are available for the assessment of DSA. These comprise the ‘Method of Deciles’ and the ‘Method of Operational Simulation for Performance Based Containment’ as detailed in Appendix A of the Manual. The ‘Method of Operational Simulation …’ is a water balance approach based on a series of historical rainfall data (in excess of 100 years) which is assumed to be representative of the extremes in climate that could occur at the site. This approach accommodates the occurrence of a range of individual storm event magnitudes and storm sequences together with operational variations in storage prior to and during storm events. It therefore allows a more detailed representation of the operational performance of the system compared to the alternative approach based on the 'Method of Deciles'. This methodology has been applied for the central MAW dams, i.e. DSA is included in the presented dam dimensions.

The 'Method of Deciles' provides a more conservative estimate of the DSA given its reliance on the total volume of a wet season rainfall without losses and a disregard of system operation during the course of the wet season rainfall. This methodology has been applied for the overburden MAW dams as these are not sized within GoldSim.

Both overburden MAW dams have been assumed to have a significant hazard category. This assumption is solely based on the understanding tailings and rejects materials will be placed in the overburden areas for these two pits. While this material is placed it will be exposed to rainfall events meaning that runoff potentially contains contaminants associated with the mining activities. The dam itself will be built as a sump, hence the risk of a dam break failure is considered minimal. The Manual specifies for a significant hazard category a 1:20 AEP event (5 percent AEP)

Model (operational) rules allow for the MAW in the overburden MAW dams to be pumped, when available, directly into the north central MAW dam, henceforth ensuring that the allocated DSA volume is available within in each dam on the 1 November each year. A hazard assessment for all dams on site will be required during future design stages. Note that for dams without an actual catchment, like the MAW transfer dams, allowing for the DSA will be a matter of increasing the storage depth.

8.7 Flood management

8.7.1 Hydraulic modelling

Hydraulic modelling to determine water levels resulting from flood flows has been undertaken for the existing (pre-development) and post-development condition using one-dimensional (HEC-RAS) hydraulic modelling software to simulate minor waterways and two-dimensional (TUFLOW) hydraulic modelling software to model the more complex Carmichael River floodplain. Both of these packages are recognised as industry standard within Australia and are appropriate for modelling flood extents for this study.

Hydraulic modelling was undertaken for the 10, 50, 100 and 1,000 year ARI design events with a model time step of five seconds. The modelling determined that there would be:

- Change in local flood levels (higher in some regions, lower in others) as a result of watercourse diversions or temporarily restricted flows during construction. This would be a localised effect and not expected to impact outside of the construction area
- Confinement of the Carmichael River to the corridor between the flood levees during Project operation. The contraction of the floodplain would cause an insignificant increase in flood extent upstream of the MLA for any of the simulated flood events. This outcome reflects the relative distance of the contraction from the western MLA boundary.

A detailed description of flood management is provided in SEIS Volume 4 Appendix K4 Flooding and Diversion Drain Assessment.

8.7.2 Flood management

To manage flood impacts from the Project (Mine), the following are measures are proposed:

- Levee banks are proposed in various locations to reduce the risk of flood waters entering pits and to assist with the separation of mine affected areas. These controls will reduce the amount of MAW and SAW produced
- Design criteria have been established for diversion drains required to redirect surface water away from mine affected areas. The purpose of these diversion drains is to both provide flood immunity to the site and to minimise the volume of mine-affected water requiring treatment before discharge
- The Project (Mine) design includes provision for a haul road and conveyor crossing of the Carmichael River. This crossing links the southern parts of the mine to the mine infrastructure in the northern area. Given that the crossing of the Carmichael River has the potential to have a large impact on the existing flood regime, particularly flood levels, a preliminary design of the crossing was undertaken using a hydraulic model to inform the design and demonstrate that potential hydraulic impacts could be addressed through design

Carmichael River levee design criteria

The following criteria were adopted for the Carmichael River levees at this stage of the design:

- The alignment of the flood protection levees along the northern and southern sides of the Carmichael River corridor has been based on the available corridor provided in the mine plan
- The flood protection levees along the northern and southern sides of the Carmichael River corridor, and the levees along the northern and southern external diversion drains, have been designed with crest levels set at the 1,000 year ARI flood level, with an additional 600 mm of freeboard
- For the purposes of this design stage, the batter slopes on the levees have been set at one vertical to five horizontal, and a 6 m top width of levee. Further assessment and consideration of the geotechnical engineering issues and design refinement will be required at a later stage

Diversion drains

Diversion drains are categorised as follows:

- External diversions drains - These are located outside of the mine affected area (but within the MLA) and are constructed in phases depending upon mining activity and to last for the life of the mining activity in that area. They will also be maintained and integrated into the rehabilitation plan for the mine site. A case study design for one of these external diversion drains is described below in order to demonstrate indicative sizing. Sizing of the remainder of the proposed external diversion drains will be required in further stages of design
- Internal diversion drains and bunds - These are located within the MLA and are constructed as required to provide required flood mitigation. These will require relocation or replacement as the mine plan advances to allow for the progression of the open cut

mining footprint and to ultimately ensure alignment and compliance with final landform and drainage requirements. The diversion drains are expected to remain after the mine operations have ceased. Due to the open cut pits and waste rock stockpiles the natural waterways cannot be restored. It is also expected that the diversion drains will develop their own environmental values during the many years they will be required that would be destroyed by reinstating the previous natural waterway.

External diversion drain design criteria

The external diversion drains are to be designed in accordance with the following drainage design criteria:

- The design must accommodate the 100 year ARI flow with an additional 600 mm freeboard; no allowance for climate change (higher rainfall intensities) as derived using the hydraulic models previously described
- The design considers expected subsidence (MSEC, 2013)
- The maximum flow velocity in the diversion drains to be no greater than 2.5 m/s velocity for the 50 year ARI event (DERM, 2011)
- No greater than 80 N/m^2 shear stress for the 50 year ARI event (DERM, 2011)
- No greater than 220 watt/ m^2 stream power for the 50 year ARI event (DERM, 2011)
- Drain banks to have 1:5 slope
- Where the mine pits are potentially at risk of inundation from the diversion drains, diversion bunds will be constructed along the eastern side of the drain to provide for 1,000 year ARI flood immunity for the pit from flood waters originating from the diversions drains. These are sized according to the 1,000 year ARI peak flood level, plus 600 mm freeboard.

Haul roads and conveyor crossing

The Project (Mine) design includes provision for a haul road and conveyor crossing of the Carmichael River. This crossing links the southern parts of the mine to the mine infrastructure in the northern area. Given that the crossing of the Carmichael River has the potential to have a large impact on the existing flood regime, particularly flood levels, a preliminary design of the crossing was undertaken using the hydraulic model to inform the design and demonstrate that potential hydraulic impacts could be addressed through design.

The mine plan indicates that the crossing would take the form of a causeway, thus having a low flood immunity standard and would be overtopped by large floods. Preliminary analysis of a causeway, suggests a large number of culverts would be required to provide 50 year ARI flood immunity and that providing a bridge instead may prove to be an appropriate alternative.

River crossing design criteria

The haul road and conveyor crossing has been designed in accordance with the following design criteria:

- 50 year ARI flood immunity for the haul road and conveyor crossing, with 600 mm freeboard for the haul road
- Haul road width of 40 m

- Conveyor/s to be located on the same structure as the haul road crossing therefore not requiring separate hydraulic analysis
- Velocity of flows under bridge less than 5 m/s
- Allowance for passage of flow through natural minor channels on the flood plain, where possible
- Assumptions adopted for the preliminary design including:
  - Piers to support the bridge have a pile cap base of 2 m diameter and are 1 m in diameter above the pile cap
  - The soffit level of the bridge will be approximately 0.5 m above the 50 year ARI flood to allow for debris passage
  - In the absence of a defined limit to afflux, it has been assumed that 600 mm at the upstream side of the crossing is acceptable.

9. Offsite infrastructure

9.1 Offsite infrastructure

The offsite infrastructure comprises (see Figure 32):

- Workers accommodation village
- Airport
- Industrial development area
- Water supply infrastructure

9.2 Mine Workers accommodation village

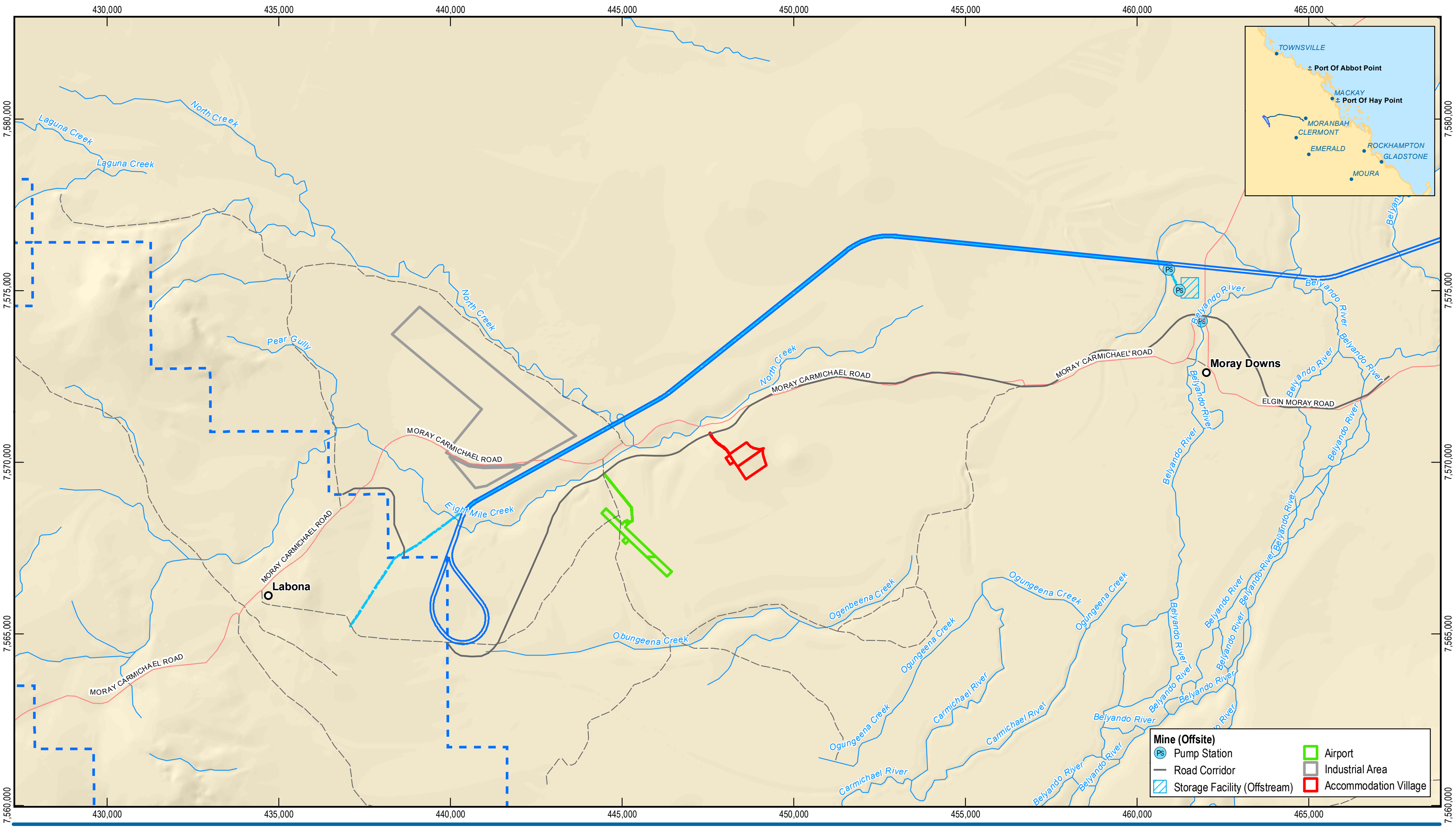
The workers accommodation village will be purpose built to accommodate the workforce for the construction and operation of the Project. The design has been developed in a staged manner where the accommodation can grow in accordance with demand, whilst ensuring that each stage is appropriately serviced in terms of facilities and infrastructure. For full details, please refer to Volume 1 Chapter 4 (Approvals) and Volume 4 Appendices C1 and C4 (Offsite Infrastructure).

The workers accommodation village design is based on the utilisation of a ‘module unit’ that provides 48 bedrooms in a three sided two storey low-set format. There are to be in total 49 modules wrapped around a central spine of communal facilities for the exclusive use of future residents. The central spine communal facilities are to be of more traditional construction materials, whereas the modules are to be lightweight and relocatable. The workers accommodation village has also been designed such that in can be constructed in a number a stages, whilst ensuring key services and facilities are appropriately provided in sequence and in accordance with the scale and anticipated demand of future residents.

The design philosophy and key aspects of the planned workers accommodation village can be characterised as follows:

- Reception / site management offices;
- Medical clinic
- Kitchen / dining room;
- 3,500 accommodation rooms;
- Laundries associated with each accommodation cluster
- Informal recreation facilities such as barbeques / shelters associated with each accommodation cluster
- Bulk linen stores
- Amenities rooms
- Recreation facilities
- Gymnasiums

- Commercial laundry
- Maintenance shed
- Hazardous materials & chemical storage
- Car parking
- Sewerage infrastructure
- Power infrastructure



1:150,000 (at A4)

0 2.5 5

Kilometres

Map Projection: Universal Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 55

N

LEGEND

- Homestead
- Local Road
- Track
- Watercourse
- Rail Corridor
- Water Supply Pipeline
- Mine (Onsite)

Adani Mining Pty Ltd
Carmichael Coal Mine and Rail Project SEIS

Job Number	41-26422
Revision	B
Date	14-10-2013

Offsite Infrastructure

Figure 32

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Level 9, 145 Ann St Brisbane QLD 4000 T +61 7 3316 3000 F +61 7 3316 3333 E bnemail@ghd.com W www.ghd.com

Data source: DME: EPC1690 (2010)/EPC1080 (2011); DNRM: Bioregion Boundary (2011); © Commonwealth of Australia (Geoscience Australia): Watercourse, Tracks (2007); Adani: Alignment Opt11 Rev 2 (SP1 and 2)(2013), Offsite Infrastructure (2013). Created by: AJ

9.3 Airport

A dedicated airport will support the Project to facilitate FIFO operation and general access to other regional and national centres.

In the Environmental Impact Statement (December 2012), the siting of the airport was located to the north of the rail line and close to the boundary of the mining tenure. Further studies since that time have been undertaken, and a number of factors have led to the change in location to the south of the rail line, nearer to the worker accommodation village. The factors leading to the revised location are:

- Responding to submissions from stakeholders, such as the Isaac Regional Council who expressed concerns regarding potential bird strike as a result of the location of the airport;
- Further ecological studies of offsite infrastructure which has shown that the southern location requires less clearing and is further away from sensitive fauna habitat, such as the Black-throated finch;
- Safer operating conditions through improved connectivity between the airstrip and the worker accommodation village
- Improved immunity from flooding

Airport has been strategically selected to ensure that it is conveniently located in relation to both the accommodation village and mine, whilst ensuring that take-off and landing approach paths are offset from the accommodation village to minimise potential noise disturbance and disruption.

The design philosophy of key aspects of the planned airport can be characterised as follows:

- A 2,250 m x 30 m asphalt runway strip
- Apron of dimension 100 m x 70 m
- Multi-function terminal building (circa 800 m^2) providing security, amenities, café and departure lounge functions
- Security fencing and stock proof fencing
- Inclusion of appropriate visual, navigation and lighting aids
- Car and bus parking for up to 62 cars and 4 buses
- Passenger set down and pick up area
- Ancillary emergency fuel storage of up to 500 m
- Aerodrome Rescue and Fire Fighting Services (AFRRS) facilities

When operational, the airport has been designed and planned to accommodate aircraft with a maximum capacity of 150 persons. Flights are programmed to occur on Tuesdays, Wednesdays and Sundays.

Currently it is planned that during the early and mid-phases of the mine, between 10 and 13 flights per week will occur. In the latter part of the mines operation (post 2060), flights are generally expected to decline from eight (8) to one (1) flight per week. When operating at maximum capacity (in the early-mid phases) it is envisaged that up to 701 flights per annum could be processed through the airport.

Importantly, all aspects in relation to certification and aeronautical industry compliance of the proposed airport fall outside the scope of this current material change of use and operational works application and are to be dealt with separately.

9.4 Industrial development area

An industrial area will be established as part of the off-site infrastructure to provide for servicing and maintenance of the mine, offsite infrastructure and rail construction and operation. Facilities may include, but not limited to:

- vehicle and equipment fabrication and maintenance workshops
- concrete batching plant
- hot mix bituminous plant
- bulk fuel storage
- vehicle wash areas
- warehouse and storage
- office and administration buildings

The industrial area will be located on a land parcel approximately 4 km to the east of the EPC 1080 lease directly to the north of the proposed rail alignment. The industrial area is located in this position to allow access to a rail siding for use in supply logistics to the mine development.

The proposed rail siding area is situated at the western end of the Project (Rail) alignment. As the Project (Rail) alignment is a single line with a rail siding area for multiple trains, the intent of the rail siding is to improve the functioning and operation of the new rail line proposed to service the planned mine. The rail line will be used for a number of ancillary purposes such as fuel delivery. The rail line is envisaged as a single line with rail sidings as an effective mechanism to enable a number of trains to utilise the line without impacting on each other at the western end of the line.

Given the large length of the coal trains that could be ultimately utilising this proposed rail line, a siding of minimum dimension 2.5 – 3 km was highlighted as being required. Further, it was also advised that the best location for any such siding (apart from being adjacent to the proposed rail line) would be interlocked with the above-mentioned industrial area such that the full potential of the proposed rail line could be achieved and managed in a coordinated manner.

9.5 Offsite water infrastructure

9.5.1 Extraction

A key source of water supply to the mine will be a flood water harvester on the Belyando River. The extraction system will pump water from the river into an off-site storage then supply water to the mine via a trunk main pipeline. The extraction from the Belyando will be triggered by flood events over 200 ML/d, stored in an off-stream storage and used to meet mine water demands when onsite and groundwater (off and onsite) supplies are exhausted. The amount of water sought, and operation of the water harvester, is presented in Table 16. The location of the water harvester will be directly downstream of the confluence of the Belyando River with the

Carmichael River (approximately 70 km Adopted Middle Thread Distance (AMTD) Belyando River).

Table 16 Proposed water harvesting extraction

Extraction location	Max. volumetric limit per annum	Average volumetric extraction per annum	Pump size	Trigger (start and cease to pump)
Approximately 70 km AMTD Belyando River	12,500 ML/a	10,000 ML/a	400 ML/day	200 ML/day

9.5.2 Required infrastructure

To support the proposed water extractions, a number of pump stations, storages and pipelines will need to be constructed. As mentioned earlier, the water is proposed to be extracted from the Belyando River which at the proposed extraction point, runs through the property (Lot 662 on PH1491) on which Adani own the property leases. All associated infrastructure will be located within the bounds of the property. Appendix B in this submission provides an overall layout plan of the infrastructure, and concept for several of the pump stations. The recommended infrastructure design was described in the EIS, with the key changes since then being the removal of the pump stations and in stream storage extractions on North and Obungeena Creeks.

Belyando River pump station

The pump station will be located on the western bank of the existing storage formed by the causeway for the Moray Carmichael Road entering the Moray Downs Property from the east, within the Belyando Creek. The pump station will consist of 5 No. centrifugal, wet well submersible pumps, with one pump on standby. The pumps will be located within a three sided reinforced concrete structure, which will protect the pumps from flood flows and debris. The pumps will also be protected by a bar screen on the open face and roof of the wet well. This bar screen will be removed when maintenance is required. A channel will be dug perpendicularly to the river at invert level to provide a pump sump.

The pipe fittings within the pump station will be ductile iron, with a gate valve, check valve and dismantling joint on each pump discharge pipeline. Once underground, the discharge pipeline will transition to HDPE via a stub flange and backing ring, before splitting to twin pipelines to the storage dam. Both pipelines will contain a gate valve to allow for isolation for maintenance.

The electrical infrastructure will be housed on a steel platform supported on the pump station walls, above the defined floodplain level. Gate valve spindles will also extend to the platform to allow for operation during flood conditions. Access to the platform will be via a steel staircase, for which the design is to be confirmed.

Due to the size of the pumps and the location within the flood plain, no permanent pump lifting equipment will be provided at the pump station site. Lifting arrangements for maintenance and replacement will need to be made on site.

Offsite storage

Flow will be extracted from the storage via a dry well with submersible pumps located adjacent to the storage at ground level. The suction pipes will pass through the storage wall. The storage will be both above and below existing ground levels.

10. Mine decommissioning and rehabilitation

The operational life of the Project (Mine) is over 60 years, therefore a general overview of decommissioning and rehabilitation is provided based on current legislative requirements, noting that such requirements may be different at the time of decommission and rehabilitation.

The general objective required for the rehabilitation of areas disturbed by mining is that the final land form is:

- safe to humans and wildlife
- non-polluting
- stable
- able to sustain an agreed post-mining land use

Details of rehabilitation approaches are provided in SEIS Volume 4 Appendix R1 and R2.

11. References

Boughton, 2004, Australian Water Balance Model (AWBM)

DERM, 2012, Manual for Assessing Hazard Categories and Hydraulic Performance of Dams

GoldSim modelling software, 2013, GoldSim Technology Group

MSEC, 2013, Carmichael Project – Revised Subsidence Prediction and Subsidence Impact Assessment Report.

National Uniform Drillers Licensing Committee, 2011. Available from http://adia.com.au/resources/waterwell-sector/water-bore-construction/ (Accessed 18.10.2013).

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Document Status

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		Name	Signature	Name	Signature	Date
A	J Elkhoury J Keane	J Keane		J Keane		01/08/2013
0	M Goodall	J Keane		J Keane		

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ADANI MINING PTY LTD:

Carmichael Project – Revised Subsidence Assessment

In Support of the Environmental Impact Statement

DOCUMENT REGISTER

Revision	Description	Author	Checker	Date
01	Draft Issue	PLD	AAW/PA	26 Jun 2013
A	Final Issue	PLD	AAW/PA	26 Jul 2013

Report produced to:- Provide predicted revised subsidence movements and impact assessments at the proposed Carmichael Project In support of the EIS.

Associated reports:- MSEC575 (Revision A – October 2012) – Adani Mining Pty Ltd, Carmichael Project – Subsidence Prediction and Subsidence Impact Assessment Report, In Support of the Environmental Impact Statement.

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

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

EXECUTIVE SUMMARY

Adani Mining Pty Ltd (Adani, the Proponent) proposes to commence a greenfield underground coal mine in Central Queensland in the Galilee Basin.

Adani commenced an Environmental Impact Statement (EIS) process for the Carmichael Coal Mine and Rail Project (the Project) in 2010. On 26 November 2010, the Queensland (Qld) Office of the Coordinator General declared the Project a 'significant project' and the Project was referred to the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPaC) (referral No. 2010/5736). The Project was assessed to be a controlled action on the 6 January 2011 under section 75 and section 87 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The controlling provisions for the Project include:

- World Heritage properties (sections 12 & 15A)
- National Heritage places (sections 15B & 15C)
- Wetlands (Ramsar) (sections 16 & 17B)
- Listed threatened species and communities (sections 18 & 18A)
- Listed migratory species (sections 20 & 20A)
- The Great Barrier Reef Marine Park (GBRMP) (sections 24B & 24C).

The Qld Government's EIS process has been accredited for the assessment under Part 8 of the EPBC Act in accordance with the bilateral agreement between the Commonwealth of Australia and the State of Queensland.

The Proponent prepared an EIS in accordance with the Terms of Reference (ToR) issued by the Qld Coordinator-General in May 2011 (Qld Government, 2011). The EIS process is managed under section 26(1) (a) of the *State Development and Public Works Act 1971* (SDPWO Act), which is administered by the Qld Government's Department of State Development, Infrastructure and Planning (DSDIP).

The EIS, submitted in December 2012, assessed the environmental, social and economic impacts associated with developing a 60 million tonne (product) per annum (Mtpa) thermal coal mine in the northern Galilee Basin, approximately 160 kilometres (km) north-west of Clermont, Central Queensland, Australia. Coal from the Project will be transported by rail to the existing Goonyella and Newlands rail systems, operated by Aurizon Operations Limited (Aurizon). The coal will be exported via the Port of Hay Point and the Point of Abbot Point over the 60 year (90 years in the EIS) mine life.

Project components are as follows:

- The Project (Mine): a greenfield coal mine over EPC 1690 and the eastern portion of EPC 1080, which includes both open cut and underground mining, on mine infrastructure and associated mine processing facilities (the Mine) and the Mine (offsite) infrastructure including a workers accommodation village and associated facilities, a permanent airport site, an industrial area and water supply infrastructure
- The Project (Rail): a greenfield rail line connecting the mine to the existing Goonyella and Newlands rail systems to provide for the export of coal via the Port of Hay Point (Dudgeon Point expansion) and the Port of Abbot Point, respectively including
  - Rail (west): a 120 kilometre (km) dual gauge portion running west from the Mine site east to Diamond Creek
  - Rail (east): a 69 km narrow gauge portion running east from Diamond Creek connecting to the Goonyella rail system south of Moranbah.
  - Quarries: The use of five (5) local quarries to extract quarry materials for construction and operational purposes.

The underground component of the mine will extract coal using longwall mining methods in two seams over an approximate extent of 45 kilometres north to south with conceptual longwall lengths up to approximately 6 kilometres. Cutting heights are approximately 2.75 metres in the upper seam and 3.25 metres in the lower seam. Proposed longwall panel void widths are approximately 310 metres. The proposed multi-seam panel offsets and mains are proposed to be in a staggered arrangement.

The proposed 110 longwall panels, are located within the mining lease and are shown in Drawings Nos MSEC627-01, MSEC627-02 and MSEC627-03. These drawings also show the project Study Area, which is defined as the surface area that is likely to be affected by the conventional subsidence movements resulting from the proposed extraction of the Proposed Longwalls.

The target seams for the proposed longwalls are the AB1 Seam and D1 Seam. The AB1 seam floor contours, seam thickness contours and depth of cover contours are shown in Drawings Nos MSEC627-05, MSEC627-07 and MSEC627-09, respectively in Appendix D. The D1 seam floor contours, seam thickness contours and depth of cover contours are shown in Drawings Nos MSEC627-06, MSEC627-08 and MSEC627-10, respectively in Appendix D. The seams dip towards the west within the proposed mining area at approximately 2 to 4 degrees, as shown in Drawings Nos. MSEC627-05 and MSEC627-06.

The depth of cover to the AB1 seam varies within the proposed mining area from approximately 120 metres above Longwalls ABLW101S and ABLW501S to 440 metres above Longwalls ABLW107S and ABLW207, as shown in Drawing No. MSEC627-09. The thickness of the AB1 and D1 seams varies from approximately 4 metres to 11.5 metres as shown in Drawings Nos MSEC627-07 and MSEC627-08. There is limited data available on the D1 seam in the south of Mine Area 5. The proposed extraction height for all longwalls is 2.75 metres in the AB1 Seam and 3.25 metres in the D1 Seam.

The majority of the land above the proposed mining area is undeveloped, with sparse vegetation. The land is understood to be used for grazing. As can be noted from the surface level contours, shown in Drawing No. MSEC627-04, the surface areas above the proposed longwalls are relatively flat. The features near the Study Area include Carmichael River that flows towards the east, small tributaries that flow to the Carmichael River, two unsealed roads, and various boundary fences.

The maximum predicted total subsidence for the proposed longwalls after extraction in the AB1 seam is 2625 mm and the maximum predicted total subsidence for the proposed longwalls after extraction in the AB1 and D1 seams is 5550 mm. The predicted subsidence parameters are summarised in Table 4.1 and Table 4.2 and the predicted subsidence contours are shown in Drawings Nos MSEC627-13 and MSEC627-14.

The assessments in this report indicate that the levels of impact that have been assessed on the natural features and items of surface infrastructure can all be managed by the preparation and implementation of management strategies. It is expected that where sufficient depth of cover and thickness of Triassic and and/or Tertiary deposits are present, there will be a low risk of direct hydraulic connection from the surface to the seam. It should also be noted, however, that more detailed assessments of some natural features and items of surface infrastructure have been undertaken by other consultants, and the findings in this report should be read in conjunction with the findings in all other relevant reports.

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

CONTENTS

LIST OF TABLES, FIGURES AND DRAWINGS

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.

The following figures are included in Appendix C of this report.

Drawings

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

1.0 INTRODUCTION

1.1. Background

Mine Subsidence Engineering Consultants was commissioned by Adani Mining Pty Ltd (Adani, the Proponent) to complete a Revised Subsidence Prediction and an Impact Assessment for the Carmichael Project (the 'project') as part of the Environmental Impact Statement (EIS).

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  - Rail (east): a 69 km narrow gauge portion running east from Diamond Creek connecting to the Goonyella rail system south of Moranbah.
  - Quarries: The use of five (5) local quarries to extract quarry materials for construction and operational purposes.

The underground component of the mine will extract coal using longwall mining methods in two seams immediately adjacent to the open cut pits and will be mined over an approximate extent of 45 kilometres north west to south east with conceptual longwall lengths up to approximately 6 kilometres. Two seams are proposed to be extracted. The upper seam is named AB1 seam and has a proposed cutting height of 2.75 metres. The lower seam is named D1 seam and has a proposed cutting height of 3.25 metres. Proposed longwall panel void widths are approximately 310 metres. The proposed multi-seam panel offsets and mains are proposed to be a staggered arrangement.

MSEC previously prepared a subsidence prediction and impact assessment report (MSEC525) in October 2012 for a longwall layout that included a total of 98 proposed longwall panels. The proposed longwall layout has since been revised to a total of 110 longwall panels, referred to in this report as the Proposed Longwalls, in a revised configuration and a south easterly extension.

The proposed longwalls are arranged in five mining areas within the mining lease and are shown in Drawings Nos. MSEC627-01, MSEC627-02 and MSEC627-03. These drawings also show the project Study Area, which is defined as the surface area that is likely to be affected by the conventional subsidence movements resulting from the proposed extraction of the Proposed Longwalls.

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

Chapter 2 defines the Study Area and provides a summary of the natural features and items of surface infrastructure within the Study Area.

Chapter 3 includes overviews of longwall mining, the development of mine subsidence and the methods used to predict mine subsidence movements. Descriptions of conventional and non-conventional mine subsidence parameters and the uncertainties in subsidence predictions are also provided in this chapter.

Chapter 4 provides the maximum predicted subsidence parameters resulting from the extraction of the Proposed Longwalls.

Chapter 5 provides the subsidence impact assessments on surface and sub-surface cracking. Discussions on the likely height of the fractured zone and hydraulic connectivity and the Great Artesian Basin are also provided in this chapter.

Chapter 6 provides mine subsidence impact assessment on the other natural features, items of infrastructure and built developments.

1.2. Mining Geometry

The layout of the Proposed Longwalls is shown in Drawing Nos. MSEC627-01, MSEC627-02 and MSEC627-03 in Appendix D.

The widths of the longwalls are approximately 310 metres, rib to rib. The majority of the chain pillars between the longwall panels are approximately 35 metres solid. Some pillar widths for longwalls in the D1 Seam with shallow cover are approximately 25 metres solid and longwalls greater than approximately 5km in length have two solid pillars of approximately 35 metres with three headings. A summary of the approximate longwall dimensions is provided in Table 1.1

The schedule of extraction for each 5 years of mine operation (rounded up to each fully extracted longwall panel) is presented in Drawings Nos. MSEC627-16 to MSEC627-25.

Table 1.1 Geometry of the Proposed Longwalls

Longwalls in AB1 Seam	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)	Longwalls in D1 Seam	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
Mine 1 North							
				DLW101N	2246	311	-
				DLW102N	2566	311	24
				DLW103N	2886	311	24
ABLW101N	3336	311	-	DLW104N	3220	311	24
ABLW102N	3663	311	34	DLW105N	3531	311	34
ABLW103N	3996	311	34	DLW106N	3860	311	34
ABLW104N	4328	311	34	DLW107N	4190	311	34
ABLW105N	4660	311	34	DLW108N	4519	311	34
ABLW106N	4992	311	34	DLW109N	4849	311	34
ABLW107N	5325	311	74	DLW110N	5179	311	74
Mine 1 South							
				DLW101S	1927	311	-
				DLW102S	1912	311	24
				DLW103S	1904	311	24
ABLW101S	1911	311	-	DLW104S	1939	311	24
ABLW102S	1851	311	34	DLW105S	1878	311	34
ABLW103S	1791	311	34	DLW106S	1815	311	34
ABLW104S	1728	311	34	DLW107S	1749	311	34
ABLW105S	1719	311	74	DLW108S	1740	311	74
ABLW106S	5790	311	74	DLW109S	5795	311	74
ABLW107S	5782	311	74	DLW110S	5788	311	74

Longwalls in AB1 Seam	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)	Longwalls in D1 Seam	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
Mine 2							
ABLW201	5139	311	-	DLW201	5155	311	-
ABLW202	5105	311	34	DLW202	5120	311	34
ABLW203	5070	311	34	DLW203	5084	311	34
ABLW204	4845	311	34	DLW204	4875	311	34
ABLW205	4464	311	34	DLW205	4574	311	34
ABLW206	4083	311	34	DLW206	4189	311	34
ABLW207	3702	311	34	DLW207	3774	311	34
Mine 3 North							
ABLW301N	3839	311	-	DLW301N	3839	311	-
ABLW302N	3781	311	34	DLW302N	3781	311	34
ABLW303N	3723	311	34	DLW303N	3723	311	34
ABLW304N	3668	311	34	DLW304N	3669	311	34
ABLW305N	1645	311	34	DLW305N	1713	311	34
Mine 3 South							
ABLW301S	3044	311	-	DLW301S	3046	311	-
ABLW302S	2560	311	34	DLW302S	2562	311	34
ABLW303S	2351	311	34	DLW303S	2352	311	34
ABLW304S	2262	311	34	DLW304S	2263	311	34
ABLW305S	2149	311	34	DLW305S	2150	311	34
ABLW306S	1110	311	34	DLW306S	1110	311	34
Mine 4							
ABLW401	4821	311	-	DLW401	4848	311	-
ABLW402	4839	311	34	DLW402	4865	311	34
ABLW403	4858	311	34	DLW403	4881	311	34
ABLW404	4876	311	34	DLW404	4898	311	34
ABLW405	4894	311	34	DLW405	4915	311	34
ABLW406	4912	311	34	DLW406	4931	311	34
ABLW407	4930	311	34	DLW407	4948	311	34
Mine 5 North							
ABLW501N	4205	311	-	DLW501N	4166	311	-
ABLW502N	4233	311	34	DLW502N	4190	311	34
ABLW503N	4261	311	34	DLW503N	4214	311	34
Mine 5 South							
				DLW501S	3571	311	-
				DLW502S	3411	311	24
				DLW503S	3251	311	24
				DLW504S	3090	311	24
ABLW501S	2250	311	-	DLW505S	2925	311	24
ABLW502S	2957	311	24	DLW506S	2760	311	34
ABLW503S	2783	311	34	DLW507S	2595	311	34
ABLW504S	2609	311	34	DLW508S	2430	311	34
ABLW505S	2435	311	34	DLW509S	2265	311	34
ABLW506S	2261	311	34	DLW510S	2099	311	34
ABLW507S	2087	311	34	DLW511S	1936	311	34
ABLW508S	1913	311	34	DLW512S	1752	311	34

1.3. Surface Topography

The surface level contours in the vicinity of the proposed longwalls are shown in Drawing No. MSEC627-04.

The surface topography within the Project Area consists of low-lying gently sloping plains of generally less than 2% gradient. The Carmichael River is the regional drainage line in the area, which flows towards the east in the southern part of the mining lease area. The proposed longwalls have been set back from the Carmichael River and the closest longwall is approximately 655 metres from the river.

As shown in Drawing No. MSEC627-04, the lowest elevation above the footprint of the Proposed Longwalls is approximately 228 metres AHD, near the Carmichael River. The highest point is at approximately 346 metres AHD above the proposed Longwall ABLW104N.

1.4. Seam Level Information

The principal coal-bearing formations at the project are the Bandanna Formation and Colinlea Sandstone. Within the Bandanna Formation and Colinlea Sandstone there are seven significant coal seam groups (AB, B, C, D1, D2/D3, E, and F).

The target seams for the proposed longwalls are the AB1 Seam and D1 Seam.

The seam floor contours, seam thickness contours and depth of cover contours for the AB1 Seam are shown in Drawings Nos. MSEC627-05, MSEC627-07 and MSEC627-09, respectively, in Appendix D. The seam floor contours, seam thickness contours and depth of cover contours for the D1 Seam are shown in Drawings Nos. MSEC627-06, MSEC627-08 and MSEC627-10, respectively, in Appendix D.

The seams dip towards the west within the proposed mining area at approximately 2 to 4 degrees, as is shown on Drawings Nos. MSEC627-05 and MSEC627-06.

The depth of cover to the AB1 seam varies within the proposed mining area from approximately 120 metres above Longwalls ABLW101S and ABLW501S to 440 metres above Longwalls ABLW107S and ABLW207, as is shown on Drawings No. MSEC627-09.

The thickness of the AB1 and D1 seams varies from approximately 4 metres to 11.5 metres as is shown in Drawings Nos. MSEC627-07 and MSEC627-08. There is limited data available on the D1 seam in the south of Mine Area 5. The proposed extraction height for all longwalls is 2.75 metres in the AB1 Seam and 3.25 metres in the D1 Seam.

The interburden thickness between the AB1 and D1 seams varies from approximately 70 metres to 130 metres.

1.5. Overburden Geology

The surface lithology within the Project Area can be seen in Fig. 1.1, which shows the proposed longwalls, the Project Area, the Study Area and the exploration bore collar locations overlaid on the 1:250,000 Surface geology map published by Geosciences Australia.

A typical stratigraphic section is provided in Fig. 1.2.

The regional and local geology are described in a coal resource estimate report by Xenith Consulting Pty Ltd (Xenith, 2009) and provide the following descriptions:

"*The Galilee Basin is an intracratonic basin that covers approximately 247,000 km^2 in central Queensland. The maximum stratigraphic thickness is 2800 m and ranges from Late Carboniferous to Middle Triassic in age. The basin fill accumulated in alluvial plain environments and contains thick, widespread coal seams of Permian Age. Permo-Triassic rocks are only exposed along the eastern margin of the basin with the remainder covered by fill of the Jurassic-Cretaceious Eromanga Basin. (Leblang, 2005)."*

"The majority of the lease area is mantled by a sequence of sediments of Tertiary age. The Tertiary ranges in thickness from 45m to 100m, comprising red and yellow, clayey mudstone and soft sandstone.

The formation overlies the Permo-Triassic sequence unconformably."

"The Triassic sequence in this area consists of the Dunda Beds and underlying Rewan Formation with thicknesses of up to 200m of Triassic sediments penetrated in the deepest drill holes in the West of the lease. The Dunda Beds consist of yellow to red-brown, medium-grained, quartz sandstones with minor mudstone interbeds. The Rewan Formation comprises interbedded grey-green, fine to medium-grained, lithic sandstone and grey-green mudstone."

Data provided by Adani Mining indicate the depth of Tertiary sediments above the proposed longwalls varies up to approximately 70 metres maximum depth. Contours of the depth of Tertiary sediments are provided in Drawing No. MSEC627-11. The depth of weathering above the proposed longwalls varies from approximately 20 metres to 100 metres. Contours of the depth of weathering are provided in Drawing No. MSEC627-12.

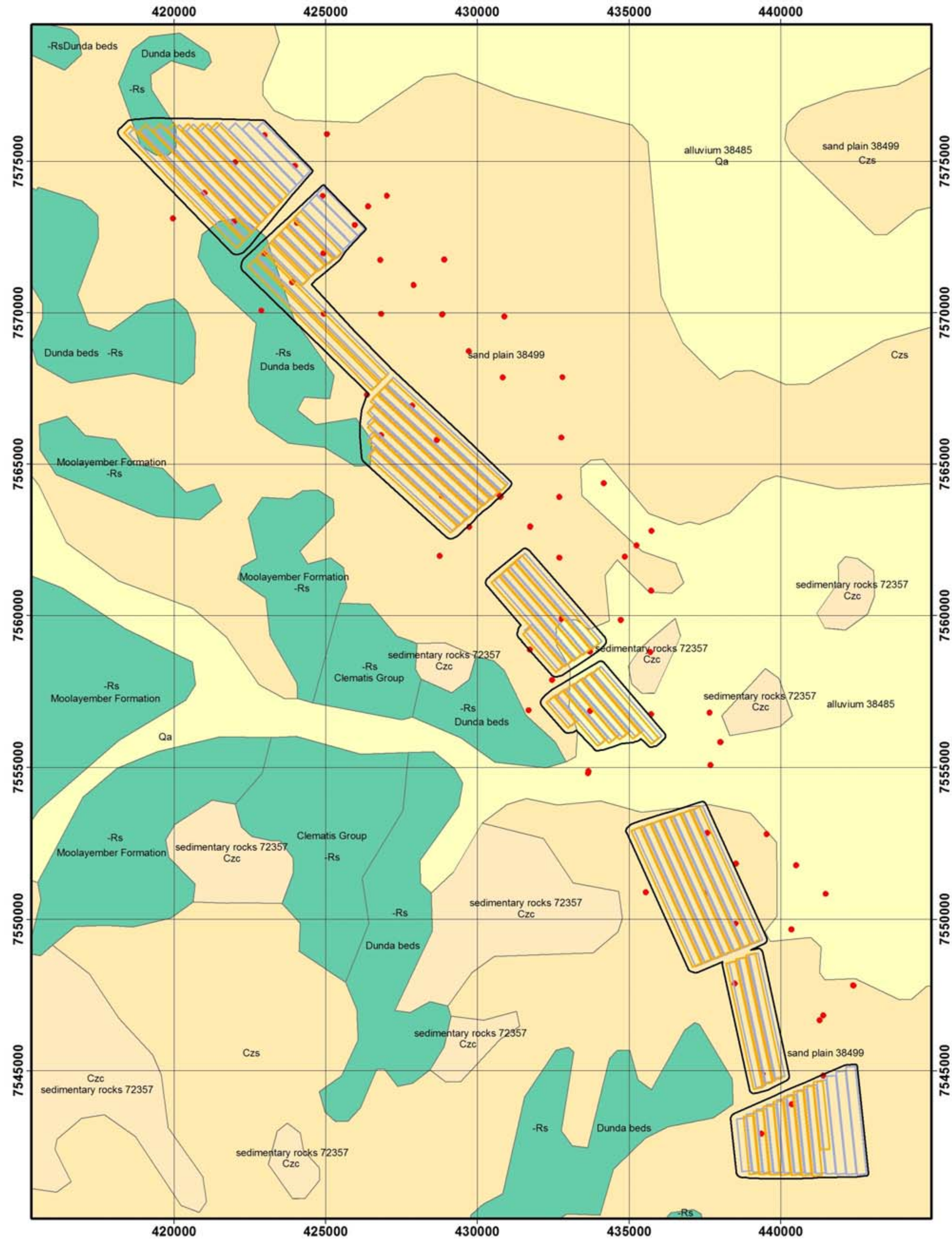


Fig. 1.1 1:250,000 Surface geology (Published by Geosciences Australia)

(Legend: (Rs) Triassic sandstone siltstone mudstone conglomerate, (Czc) Cenozoic consolidated siliclastic rocks, (Czs) Cenozoic sand plain, (Qa) Quaternary channel and flood plan alluvium gravel sand silt clay)

Age		Lithology	Stratigraphy	Thickness
Tertiary		Clays / Mudstones		40 - 100m
Triassic		Mudstone / Siltstone	Rewan Formation	
Late Permian		Sandstone	Bandanna Formation	
		COAL - AB Seam		12 - 18m Resource Seam
		Sandstone / Siltstone		10m
		COAL - B splits		1 - 2m
		Siltstone / Mudstone		60 - 70m
		COAL - C Seam (carbonaceous)		3 - 4m
		Siltstone / Sandstone	Colinlea Sandstone	2 - 20m
		COAL - D1 Seam		4 - 6m Resource Seam
		Sandstone		5 - 30m
		COAL D2/D3 Seam		8 - 10m Resource Seam
		Siltstone / Mudstone		10 - 20m
		COAL - E Seam		1 - 3m Resource Seam
		Sandstone / Siltstone		5 - 10m
		COAL - F Seam		1 - 5m Resource Seam
Early Permian		Sandstone		

Fig. 1.2 Stratigraphic Column of the project lease area (source: Linc Energy Ltd, Galilee Project – MDLa 372, Insitu Coal Resource Estimate, Nov 2009, provided by Adani Mining)

2.1. Definition of the Study Area

The Study Area is defined as the surface area that is likely to be affected by the conventional subsidence movements resulting from the proposed extraction of the Proposed Longwalls. The extent of the Study Area has been determined by a 26.5 degree angle of draw around the extent of the proposed longwalls. The 26.5 degree angle of draw provides an approximate position of the limit of subsidence, which is taken as 20 mm of vertical subsidence. Drawing No. MSEC627-01 shows the project Study Area.

The areas that lie outside the Study Area are expected to experience far-field movements. These movements are small and unlikely to result in impacts on the great majority of surface and sub-surface features. Some features, such as a large bridge, may be sensitive to differential far-field movements and these are discussed later in this report.

2.2. Overview of the Natural Features and Items of Surface Infrastructure within the Study Area

The major natural features and items of surface infrastructure within the Study Area can be seen in the Drawing No. MSEC627-13. The proposed longwalls have been overlaid on the 1:250,000 Topographic Map of the area, published by Geosciences Australia, which is presented in Fig. 2.1.

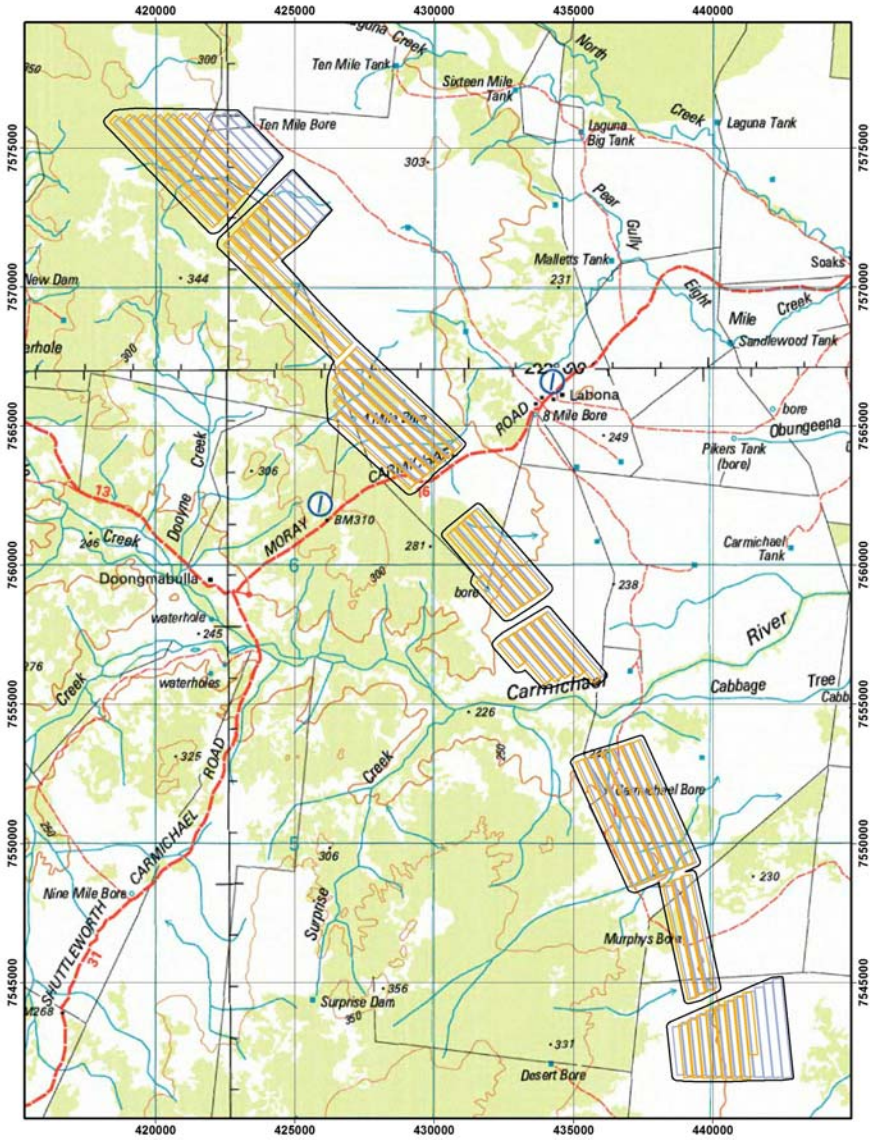


Fig. 2.1 1:250,000 Topographic Map (Published by Geosciences Australia)

The majority of the land above the proposed mining area is undeveloped, with sparse vegetation. The land is understood to be used for grazing. As can be noted from the surface level contours, shown in Drawing No. MSEC627-04, the surface areas above the proposed longwalls are relatively flat with varying surface level contours ranging from 228 metres AHD to 346 metres AHD. The features near the Study Area include Carmichael River that flows towards the east, small tributaries that flow to the Carmichael River, two unsealed roads, and various boundary fences.

3.1. Introduction

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

3.2. Overview of Coal Mining Methods

3.2.1. Bord and Pillar First Workings

Bord and pillar first workings comprise a series of self supporting roadways (or bords) within the coal seam leaving a grid of pillars which are designed to be long term stable. These first workings are extracted using continuous miners which are remote-controlled, track-mounted, electrically powered coal cutting and loading machines that can be used to form mine roadways and extract coal pillars. This method of extraction is commonly undertaken to form main headings within underground coal mines and to form the development headings around proposed longwall panels. This method of extraction is sometimes undertaken as the primary extraction method for a coal mine where the depths of cover are very shallow, or where the surface subsidence has to be limited so as to minimise the potential impacts on surface features.

The widths of the roadways are typically limited to around 5.5 metres to 6.0 metres, which reduces the likelihood of roof falls and minimises the load on the pillars. In order for the roadways to remain stable for the life of the mine, the roof and often the sides of the roadways have to be supported using mesh and anchors. The widths of pillars which are designed to be long term stable are typically a minimum of the depth of cover divided by 10 (i.e. H/10) or three times the pillar height (i.e. 3T), whichever is greater. Wider pillars may be required where the roof or floor is weak.

As the depth of cover increases, the widths of the pillars also increase in order to carry the extra weight of the overburden, resulting in less coal resource being recovered. Because of these issues, it is generally uneconomic to use bord and pillar first workings as the primary production method at depths of cover in the order of 200 metres or greater. Bord and pillar first workings, however, are used successfully at shallower depths of cover, or where the surface subsidence has to be limited so as to protect the surface features.

The proposed first workings for this project have typical roadway widths of 5 metres and typical pillar widths of 35 metres. The depth of cover above the proposed first workings varies between 120 metres and 440 metres.

The subsidence observed at the surface above bord and pillar first workings mostly results from the compression of the coal pillars and the strata above and below the seam due to the weight of overburden. Where the pillars have been designed to be long term stable, the vertical subsidence observed at the surface is typically less than 20 mm. As natural or seasonal variations in the surface levels, due to the wetting and drying of the surface soils, have been measured in the order of 20 mm, or even greater, vertical subsidence of less than 20 mm is usually defined as negligible.

3.2.2. Longwall Mining

Longwall mining is a method used to extract large rectangular panels (i.e. blocks) of coal, typically 150 metres to 400 metres wide and 1 kilometre to 5 kilometres long. The coal is progressively mined by a shearer that shaves off slices of coal up to 1 metre thick from the longwall face, under the protection of hydraulic supports, until all the panel is fully extracted. While the technology has changed considerably over the years, the basic idea of longwall mining is to maintain a safe working space for the miners along a wide coal face whilst removing all of the coal and allowing the roof and overlying rock to collapse into the void behind. The Carmichael Project proposes to extract all underground panels using longwall mining techniques.

Firstly a large rectangular panel or pillar is initially formed using continuous miners or road headers. Gate roads are first driven all around the large rectangular pillar before longwall mining begins. The gate road along one long side of the panel is called the maingate where fresh air and mine workers are carried to the face and the extracted coal is conveyed along conveyors. The gate road on the other side of the panel is called the tailgate where air is carried away from the face and also provides a secondary means of egress.

A number of hydraulic jacks, called powered roof supports, chocks or shields, provide support to the roof along the coalface at one end of the longwall panel. Each chock or shield is typically 1.75 metres wide and the supports are placed in a long line, side by side, for the full width of the coal face. An individual support can weigh 30 tonnes to 40 tonnes, can extend to a maximum cutting height of up to 6 metres and can support 1,000 tonnes to 1,250 tonnes of the overlying strata weight. Each chock can hydraulically advance itself around 1 metre forward after each slice of coal is extracted.

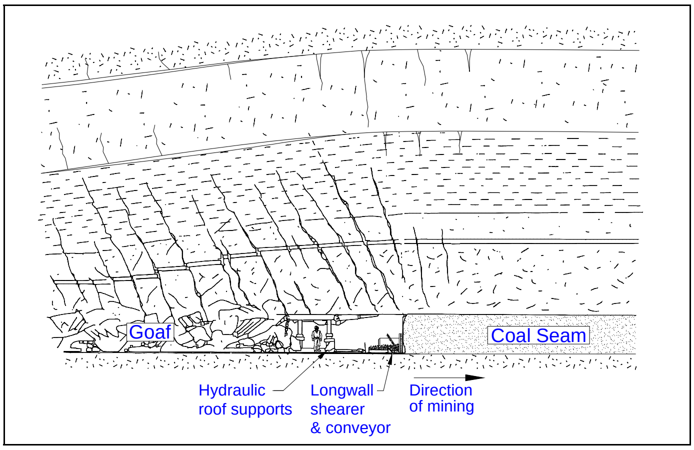


Fig. 3.1 Cross-section along the Length of a Typical Longwall at the Coal Face and a photograph of a typical Shearer, Conveyor and Hydraulic Support Chocks

Fig. 3.2 An Operating Longwall Face

Note: The following features can be seen: coal seam under extraction, the coal shearer, the face conveyor and system of self-advancing hydraulic roof supports ('chocks' or 'shields').

The coal is cut in slices from the coalface by a shearer and the coal falls onto an armoured face conveyor (AFC), which is placed in front of the powered roof supports, and carries the coal from the longwall face to the maingate. From here it is loaded onto a network of conveyor belts for transport to the surface. At the maingate, the coal is often reduced in size in a crusher and loaded onto the first conveyor belt by the beam stage loader (BSL). As the shearer removes the coal, the AFC is snaked over behind the shearer and the powered roof supports move forward into the newly created cavity.

As the longwall face progresses through the seam, the overlying roof strata falls into the mined void (goaf) and the subsidence process of the overburden strata commences. The collapsed roof strata comprises loose blocks and can contain large voids depending on the loading and compaction that follows. Immediately above the mined void and the collapsed zone, the strata can remain relatively intact and bends into the void, resulting in new vertical factures, opening up of existing vertical fractures and bed separation. The strata layers above that bend and shear with the amount of strata sagging, fracturing and bed separation reducing towards the surface.

The basic idea behind longwall mining was developed many years ago, but it has only been in the last thirty years that mining equipment has become powerful and reliable enough to successfully and safely extract large longwall blocks. Safety, productivity and cost considerations dictate that longwall mining is now the major, viable, high production method of coal mining adopted in the majority of Australian underground coal mines that operate at depths greater than about 300 metres.

Longwall mining has a better level of resource recovery when compared to the bord and pillar extraction method, has less need for roof support consumables, has higher volume coal clearance systems and has minimal manual handling. In addition, the safety of the miners is enhanced by the fact that they are always under the hydraulic roof supports when they are extracting coal.

It takes two longwall development heading panels to delineate the first longwall block. Thereafter, only one set of longwall gateroads needs to be driven for each new adjacent longwall panel because the new panel also makes use of one of the gateroads left over from the previous panel. The interpanel pillars that separate each gateroad are known as chain pillars.

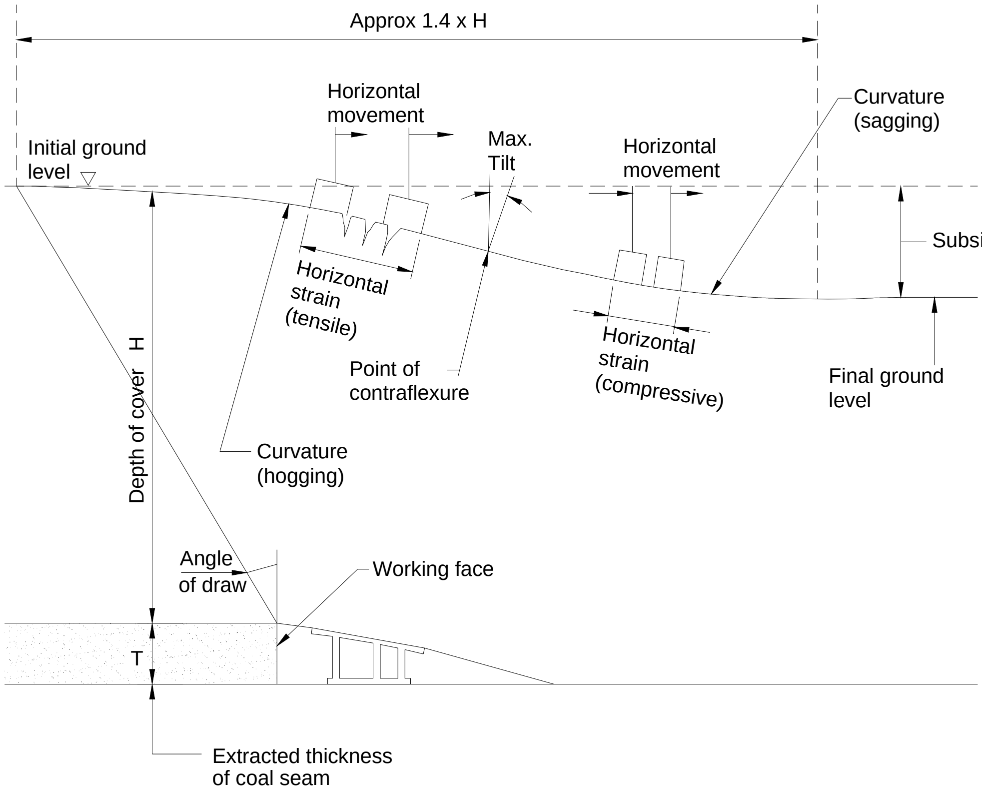
Longwall extraction operations effectively result in the formation of very wide and very long excavations separated by a single or double row of relatively narrow chain pillars. Longwall mining therefore involves both first workings and second workings. The mains development and gateroads are first workings, which result in no measurable subsidence at the surface, and the longwall panels are a type of second workings. As with pillar extraction, significant subsidence and resulting disturbance of the subsurface and surface may occur, depending on the mining layout.

3.3. Overview of Conventional Subsidence Parameters

The normal ground movements resulting from the extraction of pillars or longwalls 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 longwall goaf edges, can be greater than the vertical subsidence. Subsidence is usually expressed in units of *millimetres (mm)*.
  The magnitude of the maximum vertical subsidence at the surface will vary depending on a number of factors including the longwall panel and pillar widths, the chain pillar stability, the presence of nearby previously extracted mined panels, the depth of cover, the extracted seam thickness, the geology of the strata layers between the surface and coal seam and on the geology of the strata layers in the floor below the seam.
- **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)*.
  When the surface subsides in the shape of a trough over a mined panel, it curves inwards towards the centre of the trough and outwards near the perimeter of the trough. This behaviour is referred to as curvature. Curvature in an outwards direction results in the ground 'stretching' or 'hogging' and is referred to as convex curvature. Curvature in an inwards direction over the centre of a mined panel causes the ground to sag and move closer together and is referred to as concave curvature
  Hence curvature results in points on the surface moving in both a vertical direction and a horizontal direction as they subside into a subsidence trough. Curvature is calculated at a point from three pegs and hence has a direction.
  Curvature is convex or 'hogging' over the goaf edges and concave or 'sagging' toward the bottom of the subsidence trough. The convention usually adopted is for convex curvature to be positive and concave

curvature to be negative.



- **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 distance between two points increases and **Compressive Strains** occur when the distance between two points decreases. So that ground strains can be compared between different locations, they are typically measured over bay lengths that are equal to the depth of cover between the surface and seam divided by 20.

  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 Displacement**, or the horizontal component of subsidence, is often greatest near the point of maximum tilt and declines to zero at the limit of subsidence and at the point of maximum subsidence. Horizontal displacement is usually expressed in millimetres.
  Early researchers and mine subsidence surveyors did not measure or predict the horizontal displacements as they were far more difficult to measure or predict accurately. Modern survey methods measure the easting, northing and reduced level of pegs at each epoch from which the actual mining induced horizontal movements and directions can be determined.
  Horizontal displacements include remote or regional or far field horizontal displacements and they are caused by several mechanisms, as discussed later,

- **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 also been measured across the monitoring line (i.e. shear deformations) and vice versa.

- **Angle of draw** is a term used to describe the extent of the spread of subsidence beyond the mined panel edges. Most of the observed subsidence occurs over the mined panels with lower subsidence values being observed tampering to zero at some point beyond the edges of the mined panels, i.e. over the solid unmined coal areas.
  The observed angle of draw is the inclination or angle in degrees from the vertical of the line connecting the goaf edge of the workings to a point on the surface beyond the edge of the panel where 20mm subsidence has been observed at the surface. Observed angles of draw in NSW generally range from 10 to 30 degrees, however, wide variations are recorded due to many factors. This limit or cut off of measuring to 20mm was chosen to determine the observed angle of draw because natural ground movements of more

than 20mm are commonly observed due to changing moisture and climatic conditions and it is generally accepted that vertical subsidence movements of less than 20 mm will have negligible impact on surface infrastructure.

For designing mine layouts to protect surface features, the predicted angle of draw can be assumed to be 26½ degrees from the edge of the extraction, i.e. a point on the surface at a distance of half the depth of cover from the longwall goaf edges, where local data is not available. Where local data exists and it can be shown that the local angle of draw is generally less than 26½ degrees, then, the lower angle of draw can usually be used.

The actual observed angles of draw seem to be dependent on many factors including, the magnitude of the maximum subsidence, the depth of cover, the geology of the overburden, the magnitude of in-situ horizontal stress, the presence and proximity of nearby previously extracted panels, the dip of the strata, and the presence and proximity of faults, dykes and other geological structures.

- ***Residual*** subsidence is defined as the additional, time-dependent subsidence that develops after mining is completed or moved sufficiently far enough away from the affected area. As a general guide, active subsidence forms 90 to 95 % of the total subsidence in most cases, and this occurs when mining is within the area of influence of the point.

  There is limited information to determine residual subsidence precisely because observations of long term residual subsidence require dedication on the part of the observers to continue monitoring very small changes in subsidence over a long period of time. Long term subsidence monitoring at Metropolitan Colliery in NSW has measured average rates of subsidence of 3 to 7 mm per year. As the rate of subsidence development reduces asymptotically to miniscule levels, survey accuracy and the shrinking and swelling of the soil due to changes in moisture content form a large proportion of the measured changes.

The **incremental** subsidence, tilts, curvatures and strains are the additional parameters which result from the extraction of each longwall. Since observed incremental movements were derived or extracted by subtracting increments from the total, transient or cummulative profiles, then, it is valid to add predicted incremental profiles to obtain the cummulative, transient, total or final profiles. The **total** subsidence, tilts, curvatures and strains are the final parameters at the completion of a series of longwalls (i.e. Longwalls 101 to 411). The **travelling** tilts, curvatures and strains are the transient movements as the longwall extraction face mines directly beneath a given point. It is important to realise that the travelling tilts, curvatures and strains can be larger than the final tilts, curvatures and strains. Often the direction of the travelling tilts, curvatures and strains are different from the final tilts, curvatures and strains.

A cross-section through a typical single longwall panel showing typical profiles of systematic subsidence, tilt, curvature and strain is provided in Fig. 3.3.

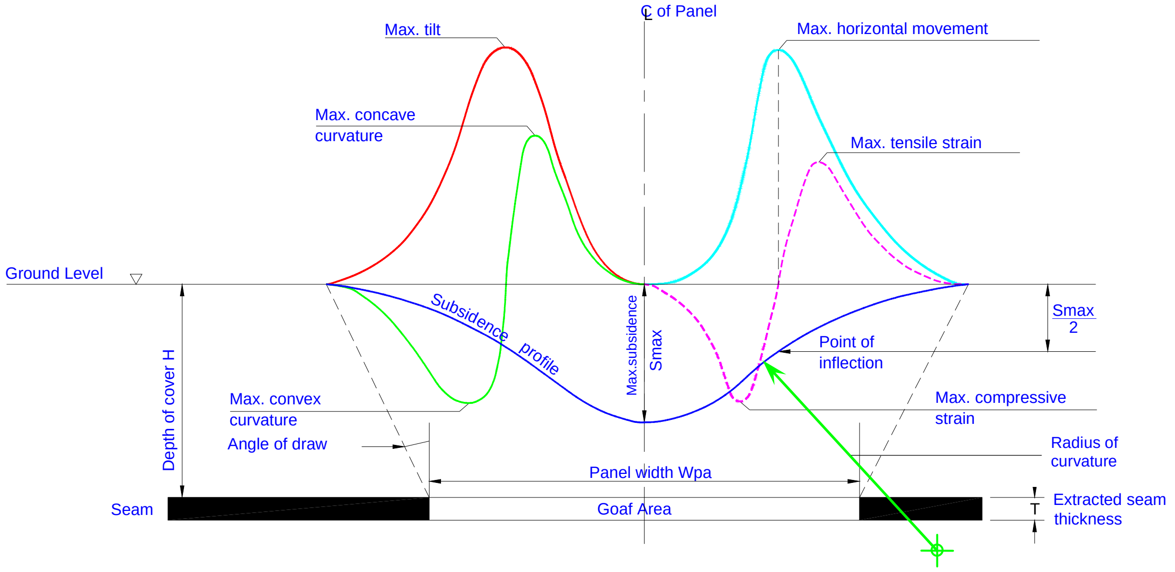


Fig. 3.3 Typical Profiles of Conventional Subsidence Parameter for a Single Longwall Panel

Conventional and Non-Conventional Subsidence Parameters, Effects, Impacts and Consequences

Some new subsidence terms and definitions were first published in an Independent Inquiry report entitled "*Strategic Review of Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield*", (Southern Coalfields Inquiry Report), which was published in July 2008. "*Impacts of Potential Underground Coal Mining in the Wyong Local Government Area Strategic Review*", which was also published in July 2008. This terminology was expanded by the same authors in the "*The Metropolitan Coal Project PAC Inquiry Report",* 2009. The new terms and definitions draw a distinction between subsidence effects, subsidence impacts, environmental consequences,

consequences, secondary consequences, conventional effects and non-conventional effects. These new terms are detailed and referenced below;

- "***Conventional*** *or general model of surface subsidence is based on the presence of straightforward and uniform site conditions, including:*
  - the surface topography is relatively flat and the seam is level,
  - the surrounding rock mass is relatively uniform and free of major geological disturbances or dissimilarities,
  - the mine workings are laid out on a regular pattern." [Section 4.1.3 - Southern Coalfields Inquiry Report].
  "***Conventional*** *surface subsidence effects and their impacts are well understood and are readily and reasonably predictable by a variety of established method."* [Section 6 - Southern Coalfields Inquiry Report].
  *"The various subsidence parameters associated with this **conventional**, or general, model of subsidence behaviour are sometimes referred to as the systematic components of subsidence, whist those associated with site-specific behaviours are referred to as non-systematic. This distinction in subsidence behaviour can be misleading since most site specific features also respond to undermining in a systematic manner. This Inquiry has maintained the convention of treating subsidence outcomes based on the **conventional** model of subsidence behaviour as being the standard or norm, and then adapting these to take account of variations created by the effects of the presence of specific natural features*". [Section 4.1.2 - Southern Coalfields Inquiry Report].
  "Conventional *behaviour refers to the manner in which the surface responds to subsidence effects when the topography is flat, the coal seam is level and the geology is uniform and free of structural disturbances."* [Section 2.8 - Wyong Inquiry Report].
  *"In **conventional** subsidence circumstances, a number of empirical, analytical and numerical subsidence prediction techniques are capable of producing reasonably accurate predictions of vertical displacement, typically within ±150 mm. The more noteworthy of these are the incremental subsidence prediction technique, the influence function technique and a number of numerical modelling codes. However, the accuracy of any subsidence prediction technique should never be taken for granted. All depend to some extent on input parameters being representative of the specific site conditions."* [Section 2.8.6.1 - Wyong Inquiry Report].
  "Particular care has to be taken when predicting subsidence for a greenfields site due to a lack of site specific data. A number of panels need to be extracted before subsidence prediction models can be properly calibrated and validated." [Section 2.8.6.1 - Wyong Inquiry Report].

- *"Where conventional conditions are not met, surface subsidence effects may vary from those that would be predicted using the conventional model. Such subsidence effects are generally known as '**non-conventional'**,"* [Section 4.1.3 - Southern Coalfields Inquiry Report]
  "*Prediction of some of the subsidence effects on specific features, such as valley closure, uplift and upsidence and far-field horizontal displacements, is being carried out by a number of specialist consultants and research institutions in NSW, although the science of such prediction, and hence its reliability, is at a far earlier stage than the prediction of **conventional** subsidence effects."* [Section 4.3.2 - Southern Coalfields Inquiry Report]
  *"A number of the site conditions which are associated with **non-conventional** subsidence effects are present in the Southern Coalfield, in particular, valleys and gorges, locally-steep topography and geological features including faults and dykes"* [Section 6 - Southern Coalfields Inquiry Report].
  "*The understanding of **non-conventional** surface subsidence effects (especially far-field horizontal movements, valley closure, upsidence and other topographical effects) is not as advanced. Both valley closure and upsidence are difficult to predict. Upsidence is a highly variable factor, particularly at the local scale, and is less predictable than valley closure. However, there is a rapidly developing database of **non-conventional** surface subsidence impacts in the Southern Coalfield which is being used to develop improved prediction. It is the Panel's view that these techniques are less advanced, and less reliable than those used for **conventional** subsidence."* [Section 6 - Southern Coalfields Inquiry Report]
  *"Since unpredicted impacts of subsidence on rivers and significant streams in the Southern Coalfield first came to public attention, the coal mining industry has made significant advances in its understanding of and ability to predict **non-conventional** subsidence effects. The level of understanding which has resulted from this work leads this field internationally."* [Section 6 - Southern Coalfields Inquiry Report].
  *"Coal mining companies should place more emphasis on identifying local major geological disturbances or discontinuities (especially faults and dykes) which may lead to **non-conventional** subsidence effects, and on accurately predicting the resultant so-called 'anomalous' subsidence impacts" ."* [Section 6 - Southern Coalfields Inquiry Report]
  Non-Conventional Surface Subsidence Effects; *The more common site specific variations to the conventional model of surface subsidence encountered in New South Wales that can affect surface subsidence relate to;*
  - *steep topography;*
  - *valleys and gorges;*
  - *far-field horizontal movements;*
  - *massive overburden strata; and*
  - *pillar foundation settlement or failure.* [Section 2.8.3 - Wyong Inquiry Report].

- *"**Subsidence effects**: the deformation of the ground mass surrounding a mine due to the mining activity. The term is a broad one, and includes all mining-induced ground movements, including both vertical and horizontal displacement, tilt, strain and curvature."* [Glossary Section - Southern Coalfields Inquiry Report]. *"The term '**subsidence effects'** is* used to describe *subsidence itself – i.e. deformation of the ground mass caused by mining, including all mining-induced ground movements such as vertical and horizontal displacements and curvature as measured by tilts and strains."* [Section 2.8 - Wyong Inquiry Report].

- ***"Subsidence impacts:*** *the physical changes to the ground and its surface caused by **subsidence effects.** These impacts are principally tensile and shear cracking of the rock mass and localised buckling of strata caused by valley closure and upsidence but also include subsidence depressions or troughs."* [Glossary Section - Southern Coalfields Inquiry Report]. *"The term **'subsidence impacts'** is used to describe the physical changes to the ground and its surface that may be caused by these subsidence effects. These impacts are principally surface depressions, tensile and shear cracking of the rock mass and localised buckling of strata caused by valley closure and upsidence."* [Section 2.8 - Wyong Inquiry Report].

- **"*Environmental consequences:*** *the environmental consequences of **subsidence impacts,** including loss of surface flows to the subsurface, loss of standing pools, adverse water quality impacts, development of iron bacterial mats, cliff falls, rock falls, damage to Aboriginal heritage sites, impacts on aquatic ecology, ponding, etc*." [Glossary Section - Southern Coalfields Inquiry Report]. *"The **environmental consequences** of these impacts may include ponding, loss of groundwater, loss of surface flows to the subsurface, adverse water quality impacts, impacts on aquatic ecology, cliff falls, rock falls etc."* [Section 2.8 - Wyong Inquiry Report] *"The Southern Coalfield Inquiry defined the terms **subsidence impact**, **subsidence effect** and **environmental consequence** in respect of subsidence and natural features. The Panel has extended the use of these terms to also include man-made structures and surface modifications. The term **effect** describes subsidence itself. Any physical change to the fabric or structure of the ground, its surface, or man-made features is described as an **impact**. The term **consequence** is used to describe any change in the amenity or function of a feature that arises from an **impact**. In turn, some **consequences** may give rise to secondary **consequences**."* [Section 3.2.1 - The Metropolitan Coal Project PAC Inquiry Report, 2009].

- *"**Consequences** related to natural features are referred to as **environmental consequences**. By way of example, tensile strain due to the ground surface being 'stretched' as a result of undermining is an **effect**, a crack resulting from the tensile strain is an **impact**, loss of water down the crack is a **consequence**, and the drying of a water dependent ecosystem as a result of this loss of water is a **secondary consequence**. The latter two are included under **environmental consequences** in some contexts."* [Section 3.2.1 - The Metropolitan Coal Project PAC Inquiry Report, 2009].

3.4. Vertical Subsidence Movements

The magnitude of the maximum vertical subsidence at the surface will vary depending on a number of factors including the longwall panel and pillar widths, the chain pillar stability, the presence of nearby previously extracted mined panels, the depth of cover, the extracted seam thickness, the geology of the strata layers between the surface and coal seam and on the geology of the strata layers in the floor below the seam.

The maximum subsidence observed normally where there are strong and massive conglomerate and sandstone strata units present, is typically between 55 % and 60 % of the extracted seam thickness, for single seam extractions, which is lower than the 65% of the extracted seam thickness for overburdens where there are fewer massive strong units. These maximum subsidence percentages would be observed where ever the widths of the panels are supercritical, i.e. greater than 1.4 times the depths of cover. Lower levels of subsidence would be observed where the panels are sub-critical and unmined coal left in chain pillars reduces the levels of the observed subsidence.

Techniques for predicting surface subsidence effects can be classified under three categories, namely empirical, analytical/numerical and hybrid methods. Empirical techniques are based on the back analysis of previous field outcomes. Reliability of outcomes is dependent, therefore, on the overall size and representativeness of the database and considerable care is required if the techniques are applied to conditions that are outside of this database. The more common empirical prediction methods are:

- ***Graphical***, which involves plotting suites of curves showing relationships between various parameters and subsidence outcomes;
- ***Upper Bound***, which involves constructing an envelope over measured maximum or worse case outcomes and predicting on the basis of that envelope;
- ***Profile Function***, which attempts to define the shape of the vertical displacement curve by a mathematical equation and is confined in general to single (isolated) excavations; and
- ***Incremental Profile Method***, which involves constructing the overall vertical displacement profile by summing the incremental vertical displacement that occurs each time a panel is extracted.

Analytical techniques are based on applying mathematical solutions derived from first principles to calculate how the rock mass will behave when an excavation is made within it. Most of the mathematical formulae have been known for decades; however, until the advent of computers, they could only be solved for very simple, two dimensional mining layouts. Advances in computational power now enables more complex mathematical equations to be solved, thereby enabling more detailed mining layouts, geological and geotechnical conditions and ground behaviour mechanisms to be analysed. Such analysis has now come to be known as mathematical modelling, numerical analysis or computer modelling. No one mathematical model is currently capable of fully describing rock behaviour and so numerical models still require a database for calibration purposes. Modelled outcomes need to be accepted with caution, especially at greenfield sites.

A number of techniques are capable of producing reasonably accurate predictions of vertical displacement, typically within ±150 mm. The accuracy of any subsidence prediction technique depends to a large extent on input parameters being representative of the specific site conditions. Particular care has to be taken when predicting subsidence for a greenfields site due to a lack of site specific data. A number of panels need to be extracted before subsidence prediction models can be properly calibrated and validated.

3.5. Horizontal Subsidence Movements

The predictions of mining induced horizontal movements are not as accurate as the predictions of vertical movements. Studies have shown that the magnitudes of the absolute horizontal displacements can be estimated in the Newcastle Coalfields, from the predicted tilt profiles, by applying a tilt-to-horizontal displacement factor of 10, and it is generally assumed that these movements are generally directed towards the centre of the mined longwall panel, as shown in Fig. 3.4.

Considering the relationship between mining induced bending curvature of a surface strata layer and horizontal strain on the surface, it can be deduced that a tilt-to-horizontal displacement factor of 10, equates to the bending in a surface strata beam of 30 metres depth bending about its centre line. This general rule is considered approximate only since the observed mining-induced horizontal movements showed considerable scatter in magnitude from these estimates and, the observed movements are not always directed towards the centre of the mined panel. It was recognised that applying this factor was more accurate for predicting the maximum value of horizontal movements over a panel than in predicting the lower values of mining-induced horizontal movements and it was accepted that many other variables had also been found to influence mining induced horizontal movements.

The understanding of mining induced horizontal ground movements is improving with improvements in the monitoring techniques to measure the magnitude, direction, and lateral extent of mining induced horizontal ground movements. The early subsidence monitoring involved the two dimensional measurement of vertical displacement and differential horizontal movements in one direction. Improvements in three dimensional monitoring, stress change monitoring, high resolution surveying techniques, GPS technology and satellite based differential interferometry using synthetic aperture radar (DinSAR) are providing a much better basis for understanding the extent and the mechanics of the mining induced horizontal ground movements.

With the development of accurate three dimensional surveying techniques, horizontal mining induced movements are now routinely observed to extend well beyond measureable vertical subsidence movements and the distances defined by the 26.5 degree angle of draw. It has now been found that the magnitude of mining-induced horizontal movements and the direction of these horizontal movements are controlled by a complex interaction of multiple factors, including the magnitude of the vertical subsidence, the presence of previously extracted panels, the depth of cover, the location of the peg relative to the extracted voids, the surface topography, the strata thicknesses and geology and the magnitude and direction of the in-situ horizontal stresses.

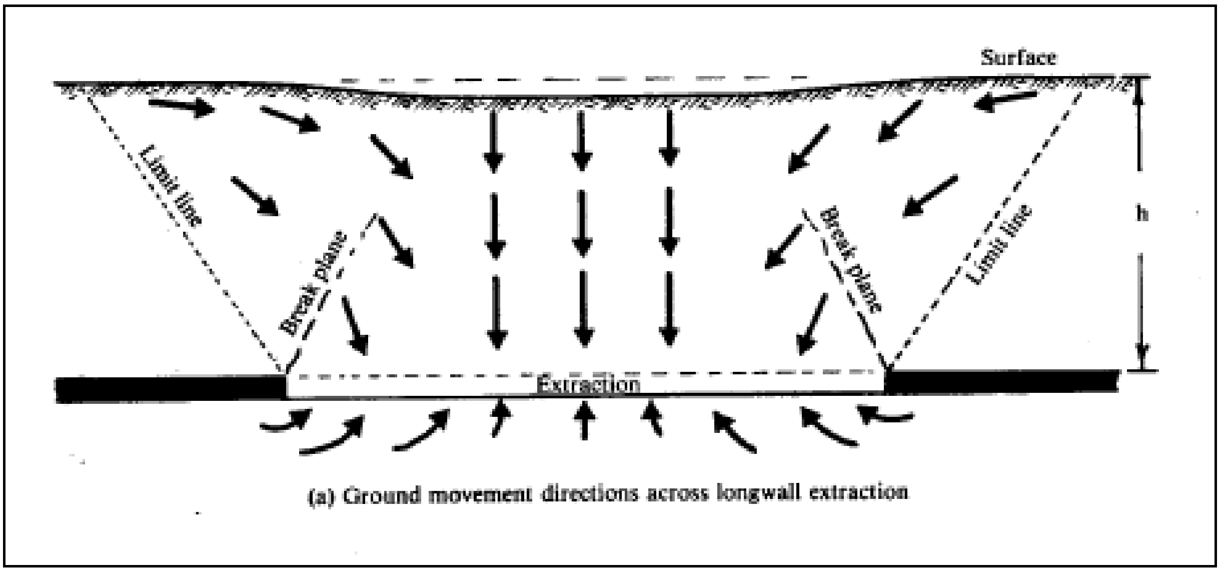


Fig. 3.4 Normal Mining Induced Movements above an Extracted Area (after Whittaker, Reddish and Fitzpatrick, 1985)

Before year 2000, it was not common to have survey control for mine subsidence monitoring only extending about one depth of cover or a few hundred metres from the edges of the approaching longwall goaf because of the challenges associated with maintaining survey accuracy over large distances. Now an array of bench marks is established around the area being subsided with far more accurate equipment and surveying techniques. Anderson et al (2007) describe the current use of concentric networks of survey control remote from mining and located on all sides of the mining areas. While it took some years before GPS technology became readily available and was able to be routinely used for subsidence monitoring at a high enough resolution, the effect has been profound. After survey control was established all around a mining area it became apparent that there was a need for reconciliation of small horizontal movements at either end of these early subsidence lines.

In flat terrain the vertical subsidence movements that are observed directly over extracted longwall panels are generally greater than the horizontal ground movements. The magnitude of the observed horizontal movements over the extracted panels represent about 30% of the vertical movements and the pegs are observed to move in changing directions with time as a longwall face first approaches, passes underneath and then moves beyond a point.

Mining induced horizontal movements have been recorded in all directions but typically they occur in the direction toward the active mining activity and, in non-conventional conditions of steep terrain, additional down slope movements are common. Outside the longwall panel boundaries though the mining induced horizontal ground movements are often found to be greater than the vertical ground movements at those points. Near the edge of the panel, the mining induced horizontal ground movements are typically observed to be about twice the magnitude of the observed vertical movements at that peg. In areas further away and beyond the boundaries of the project area, the horizontal ground movements tend to be many times the magnitude of the observed vertical subsidence movements. Small uniform horizontal movements have been measured kilometres from the edges of some panels in certain conditions. These small mining induced horizontal ground movements are called far field movements and these regional, remote or far field movements tend to be small, uniform and have low associated tilts and strains.

The three main mechanisms have been recognised to contribute to the observed magnitude and direction of the mining induced horizontal ground movements and the measured movements are a combination of all three of these mechanisms in greater or lesser proportions depending on the site conditions:

- Conventional horizontal movement that occurs generally toward the subsidence trough associated with the bending curvature of the overburden strata beams directly over an extracted longwall panel, typically, estimated with tilt-horizontal movement factors of 10 to 15 depending on geological conditions,
- Stress relief of the overburden strata toward the extracted panel, which are very dependent on the levels of in-situ horizontal stress that are locked in the various overburden layers, the goaf height relative to the depth of cover and extent of interlocking or friction resistance between these layers, and
- Horizontal movements toward topographic low points in a downslope direction, (i.e. steep slope and valley closure movements, which include vertical and horizontal components), caused by in-situ stress relief and re-distribution, by strata dilation along vertical joints/fractures and by block rotation mechanism within the overburden.

Although the prediction of vertical subsidence can be undertaken with reasonable accuracy the prediction of mining-induced horizontal ground movements is far less accurate when based on tilt-horizontal movement factors only. Previous studies have shown that this horizontal ground displacement prediction method is only approximate and, whilst it tends to be conservative where the tilts are high, it tends to underestimate the horizontal movements where the tilts are low. When comparing the predicted and observed horizontal movements over many longwalls, it becomes apparent that these approximate horizontal movement predictions are most accurate in conventional conditions, i.e. above simple mine layouts with consistent geological conditions and uniform extracted coal seam thicknesses under flat surface terrains.

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

The observed far-field horizontal movements beyond the normal vertical subsidence limits of the extracted panels also tend to be higher than the predicted horizontal movements using the above approximate horizontal ground displacement prediction method because these far field horizontal movements are generated by the stress relief mechanism rather than the bending curvature of the overburden strata beams.

With ongoing monitoring, analysis and research of subsidence induced ground movements, an improved understanding of the influence of the various mechanisms that affect the observed mining induced horizontal displacements is continually being developed and more accurate horizontal movements may be predicted in the future by combining the predicted horizontal displacements from the varying components from each of these mechanisms.

As described previously, normal strains are the differential horizontal movements of the ground. Conventional ground strains can, therefore, be estimated by multiplying the ground curvature by the same factor used to determine absolute horizontal movement from tilt. That is, for the proposed longwalls the maximum conventional ground strains can be estimated by applying a factor of 10 to the maximum conventional curvatures. However, like the prediction of horizontal movement, it should be noted that these horizontal strain predictions are not as accurate as the vertical predictions of subsidence and tilt.

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

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

3.6. Far-field Movements

As discussed above, far field movements are the measured horizontal movements at pegs located beyond the longwall panel edges and over solid unmined coal areas that were generated by the release of in-situ horizontal stress.

Far-field horizontal movements tend to be small bodily movements towards the extracted goaf area. The measured far field movements at pegs that are located beyond the longwall panel edges and over solid unmined coal areas are often much greater than the observed vertical movements at those pegs. An empirical database of observed horizontal movements has been developed which confirms this.

For example, at the location beyond the panel edges, where the predicted conventional vertical subsidence value is 20 mm, i.e. at a distance of about half of the depth of cover from the panel edges, horizontal movements of up to 100 mm have been observed, with an average observed horizontal movement of approximately 40 mm.

These far field horizontal movements are higher than the vertical movements beyond the longwall panel edges and over solid unmined coal since these movements are derived from two components. First there is the mining induced horizontal movement component caused by the mining induced bending curvature of the strata beds into the goaf areas plus, there is an additional component caused by a relief of the in situ horizontal compressive stresses in the strata around the longwalls. Further away from the longwalls, the observed far field horizontal movements are believed to be predominantly a result of the in-situ stress relief mechanism. Before mining these in situ stresses, which are generally compressive in all directions, are in equilibrium or balance. When mining occurs, the equilibrium is disturbed and the stresses achieve a new balance by shearing through the weaker strata units allowing the strata to move or expand towards the goaf areas, where the confining stresses have been relieved.

When large horizontal displacements are measured outside a longwall extraction area, they are more likely to be a result of far-field movements than a result of the mining induced curvature mechanism. Far-field horizontal movements have been observed at considerable distances from extracted longwalls. Such stress relief movements are becoming more predictable and also occur whenever significant excavations occur at the surface or underground. The methods used to predict far-field horizontal movements have continued to develop in recent years using the current and available 3D monitoring data and the confidence levels in these predictions continue to improve.

Far-field horizontal movements tend to be bodily movements towards the extracted goaf area and are accompanied by very low levels of strain. As such, these movements generally do not result in impacts on natural features or built environments, except where they are experienced by large structures which are very sensitive to differential horizontal movements.

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

Far-field horizontal movements and the method used to predict such movements are described further in Section 4.4.

3.7. 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 longwall extraction are easy to identify where longwalls are regular in shape, the extracted coal seams are relatively uniform in thickness, the geological conditions are consistent and surface topography is relatively flat.

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

Irregular subsidence movements are occasionally observed at the deeper 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 mechanisms.

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

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

Irregular ground movements are commonly observed in shallow mining situations where the collapsed zone that develops above the extracted longwalls extends up to or near the surface. These types of irregular movements are generally only observed where the depths of cover are less than 100 metres and where the longwalls are supercritical.

The minimum depth of cover directly above the proposed longwalls is 80 metres, which occurs at the north western end of the proposed Longwall 201. The longwalls with depths of cover less than approximately 220 metres are supercritical and, therefore, blocky subsidence movements could occur resulting in larger cracking and stepping at the surface.

3.7.2. 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 strains.

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 have been 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.

3.7.3. Non-conventional Subsidence Movements due to Steep Topography

Non-conventional movements can also result from down slope movements where longwalls are extracted beneath steep slopes. In these cases, elevated tensile strains develop near the tops 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 sides of the steep slopes and compression ridges at the bottoms of the steep slopes.

3.7.4. Valley Related Movements

The streams within the Study Area may be subjected to valley related movements which are commonly observed as a result of longwall mining at deep mines in NSW. Valley bulging movements are a natural phenomenon, resulting from the formation and ongoing development of the valley, as illustrated in Fig. 3.5. The potential for these natural movements are influenced by the geomorphology of the valley.

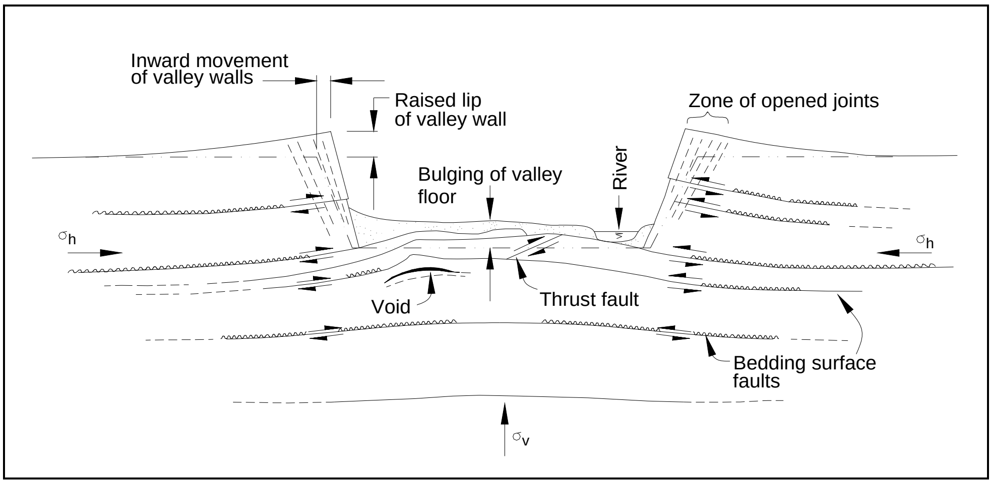


Fig. 3.5 Valley Formation in Flat-Lying Sedimentary Rocks (after Patton and Hendren 1972)

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 downslope 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 only 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.

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

Valley related movements have not been reported in the available mine subsidence observed data from the Bowen Basin coal fields. The reasons for this are varied and include the following:

- Longwall mining in the Bowen Basin has typically occurred at relatively shallow depths of cover, where the large conventional subsidence movements can mask any valley related movements that may occur.
- The ground surface in the Bowen Basin typically includes Quaternary and Tertiary sedimentary deposits, which can mask any valley related movements that may have occurred in the bedrock beneath.
- The terrain in many parts of the Bowen Basin is relatively flat. The magnitude of mining-induced valley related movements is influenced by the depth of the valley. In the case of the proposed Carmichael Project, the valley depths are relatively shallow and appear to be incised within the alluvial deposits, whilst, the valley sites where substantial valley related movements have been observed in NSW are much deeper and wider and are incised in sandstone valleys and gorges.
- There has been limited monitoring for valley related movements in the Bowen Basin as it is difficult to install fixed survey pegs in alluvial river beds.

Predictions of valley related movements have not been provided for the project for the reasons above. While the depth of cover to some areas of the proposed mining area are similar to those in deep mines in NSW, it is considered likely that any valley related movements at the surface will be small because of the generally flat terrain, and presence of Tertiary sedimentary deposits at the proposed project.

3.8. The Incremental Profile Method

The predicted conventional subsidence parameters for the proposed longwalls were determined using the Incremental Profile Method, which was developed by MSEC, formerly known as Waddington Kay and Associates. The method is an empirical model based on a large database of observed monitoring data that essentially involves two steps; first the prediction of incremental subsidence profiles over each longwall based on the local seam thicknesses, the incremental panel and pillar widths, the presence of adjacent previously mined panels and the local depths of cover. The second step is the addition of all the incremental subsidence profiles to form the total subsidence profiles over the series of longwalls.

It has been shown, by predicting the subsidence movements using this two step process, that more accurate and more site specific subsidence parameters can be derived than otherwise obtained using methods that attempt to predict the total subsidence profiles in one step.

The empirical database that has been used to develop and calibrate the Incremental Profile Method includes mine subsidence ground monitoring data from mines and collieries gathered by MSEC from the Southern, Western, Newcastle and Hunter Coalfields of New South Wales and from the Bowen Basin in Queensland, including: Angus Place, Appin, Awaba, Austar, Baal Bone, Bellambi, Beltana, Blakefield South, Bulga, Bulli, Burwood, Carborough Downs, Chain Valley, Central, Clarence, Coalcliff, Cook, Cooranbong, Cordeaux, Corrimal, Cumnock, Dartbrook, Delta, Dendrobium, Donaldson, 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, Southern, Springvale, Stockton Borehole, Teralba, Tahmoor, Tower, Wambo, Wallarah, Western Main, Ulan, United, West Cliff, West Wallsend, and Wyee.

Further details on the Incremental Profile Method are provided in the background report entitled *General Discussion on Mine Subsidence Ground Movements* which can be obtained from the MSEC website at *www.minesubsidence.com*.

3.9. Testing and Calibration of the Incremental Profile Method

3.9.1. Available Subsidence Monitoring Data

The proposed Carmichael Project is a Greenfield site. There is therefore no monitoring data available from this site or from nearby collieries for calibration of the Incremental Profile Method model.

Cook Colliery is located in Queensland within the Bowen Basin and is approximately 330 kilometres to the south east of the proposed Carmichael Project. The Castor seam was extracted at Cook Colliery and the Castor Seam is an upper seam within the Rangal Coal Measures, which are directly correlative to the Bandanna Formation. The AB1 seam is the upper coal seam within the Bandanna Formation. Both formations are overlain by the Rewan Formation Triassic sequence.

It is therefore anticipated that the goafing characteristics of the overburden materials of the Rewan Formation at the Carmichael Project will be similar to those of the overburden materials of the Rewan Formation at Cook Colliery. Therefore the subsidence monitoring data from Cook Colliery can provide a sound basis to calibrate the IPM model for the Carmichael Project. Extensive data from the monitoring of subsidence movements over panels in the Castor Seam at Cook Colliery has been obtained and Caledon Coal Pty Ltd has kindly granted permission to use this data for calibration of our Incremental Profile Method Model.

At Cook Colliery the Castor Seam panels were mined using varying partial extraction systems and longwall panels with varying panel widths. Few of the partially extracted panels in the Castor Seam were supercritical in width. In some cases the partially extracted panels at Cook Colliery only included wide stable pillars whilst, at other panels, the partial extraction system mined up to 85% of the panel area leaving stooks and thin remnant pillars that would readily fail when undermined by the proposed Argo Seam longwalls. Whilst most of the Castor Seam panels were extracted using partial extractions systems with continuous miners, six of the Castor Seam panels were extracted by longwalls.

The longwall panel widths in the Castor Seam were not supercritical as their widths, (172 to 205 metres), represented between 0.73 to 1.32 times the depths of cover, (i.e. sub-critical width range). The extracted seam thickness in the Castor Seam workings ranged from 2.8 to 3 metres.

The initial mine subsidence monitoring and prediction advice for Cook Colliery was published by Bill Kapp (1980). Kapp advised;

> "*Subsidence movements at Cook Colliery, as well as geological sections at Cook and Leichhardt Collieries, suggest that subsidence behaviour at Blackwater would approach that of United Kingdom strata rather than the Newcastle and Southern Coalfields of N.S.W*.
>
> *The crowding of the subsidence contours along the western edge of extraction is noteworthy. At this depth a geological anomaly might be suspected, but with no such evidence, the initial large deformation of the main strata is the likely cause. Such steep profiles over the start of an area of extraction have been observed in the Southern Coalfield, N.S.W.*
>
> *The limit angle at Cook Colliery ranges from 15.3 ^{o} to 21.5 ^{o} and the mean is 19.6 ^{o}.*
>
> *Although present data is used as a guide in forecasting, further subsidence monitoring work over extraction areas is needed to improve the confidence of forecasting subsidence, slope changes, curvatures and strains. In further work, strains should be measured directly."*

The following Figs. 3.5 and 3.6 show the monitoring layouts and the observed subsidence results over the One West Panel, Castor Seam at Cook Colliery.

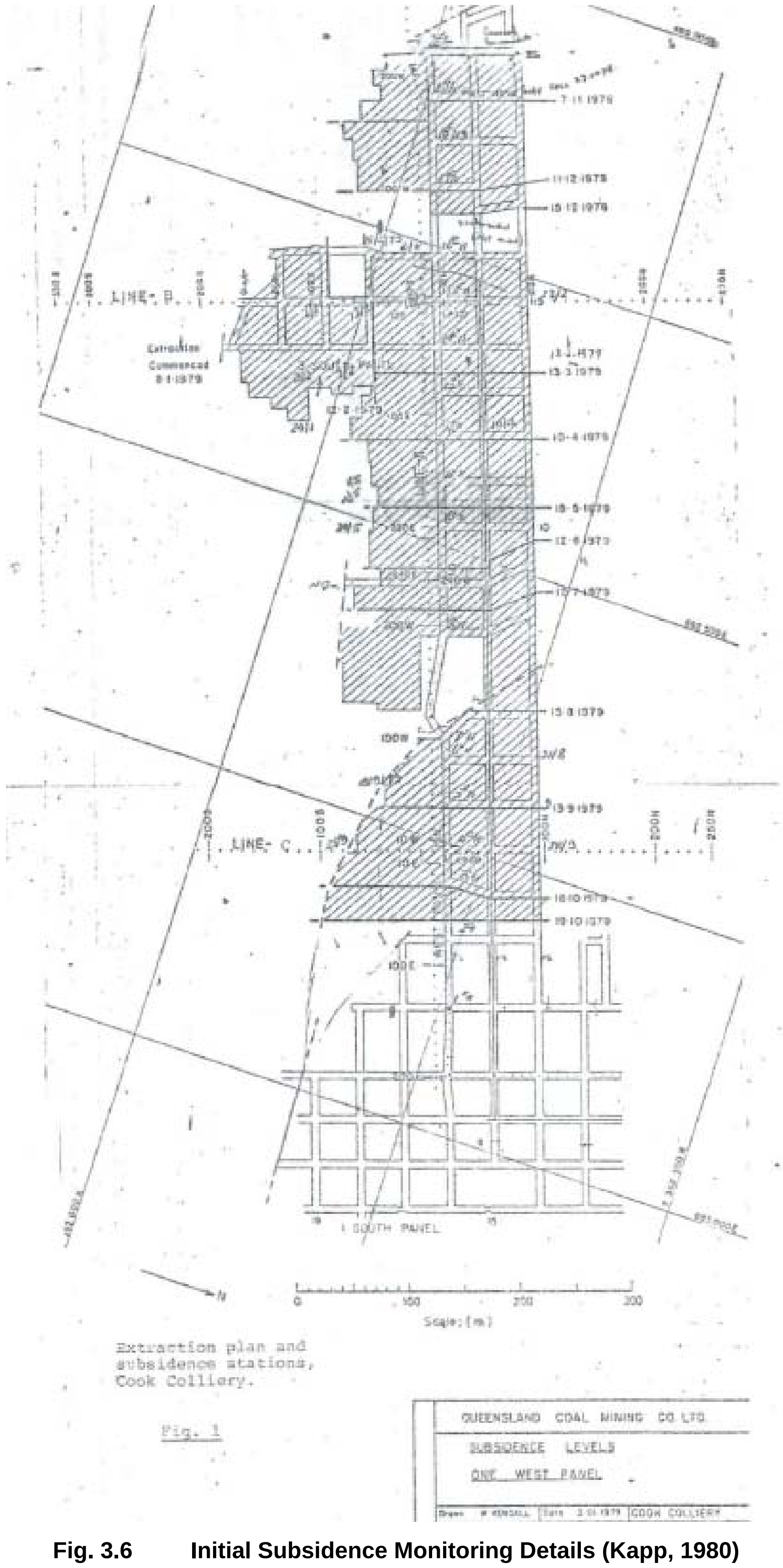


Fig. 3.6 Initial Subsidence Monitoring Details (Kapp, 1980)

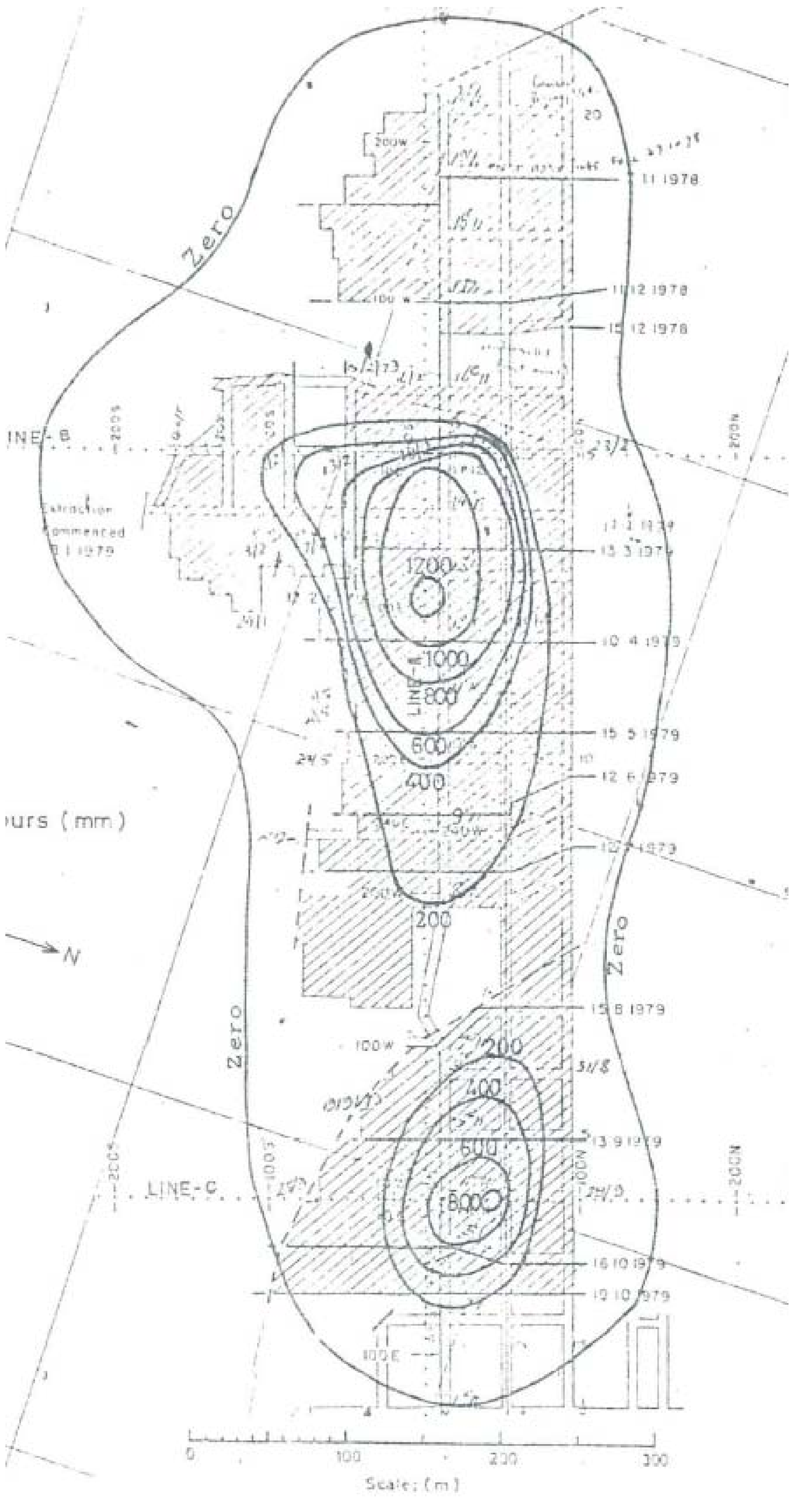


Fig. 3.7 Initial Subsidence Monitoring Results (Kapp, 1980)

Further details of subsidence monitoring over Cook Colliery were published in June 1993 by ACIRL following a NERRDP funded research project title "*Improved Methods of Subsidence Engineering*" that was prepared by Peter Willey, Peter Hornby, Steve Ditton, Giles Pucket and Greg McNally. This project followed detailed subsidence monitoring that was undertaken by the Colliery over Longwalls 1 to 4 as a result of extraction of the Castor Longwalls 1 to 4.

Willey, et al, (1993) advised;

> *"A subsidence monitoring program was established over Longwall 4 at Cook Colliery. The monitoring consisted of measurements of mining induced movements both on the surface and between the seam and the surface. Cook Colliery was chosen as the site for the program for a number of reasons:*
>
> > ** The overburden is composed of a sequence of laminates and thin sandstone layers with one massive sandstone layer overlying the Aries Seam "*(Fig. 3.8 below). *"This is in contrast to the large amount of massive sandstones and conglomerates found in the Newcastle and Southern Coalfields of New South Wales.*
> >
> > ** There were no previous workings above the extraction panel.*
> >
> > ** The surface terrain is relatively flat virtually eliminating topographic effect on subsidence. Also, surveying is quicker and therefore cheaper over flat ground.*
> >
> > ** Management and staff at CRQ Ltd gave a large amount of assistance particularly with the drilling of boreholes and the initial survey layout."*

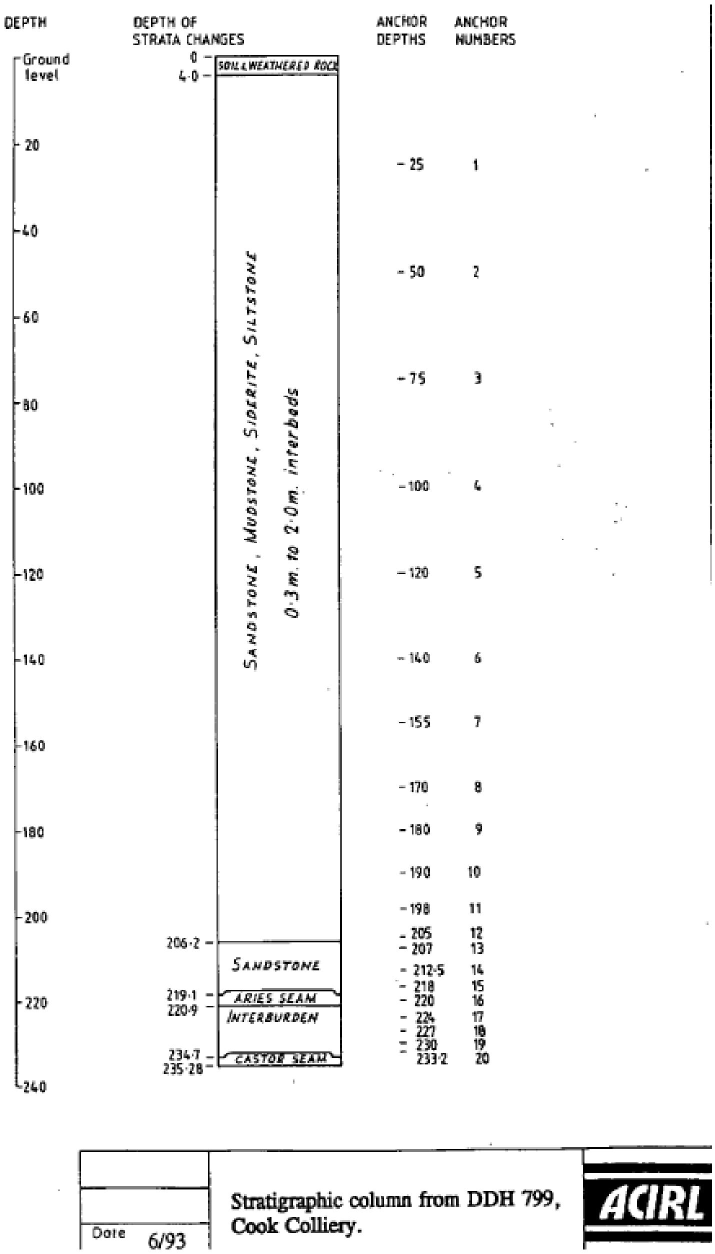


Fig. 3.8 Stratigraphic Column near Castor Seam Longwall 4 (Willey, et al, 1993)

"Longwall 4 is 168m wide and extracted an average of 2.9m of the Castor Seam at a depth of about 235m below the surface. Vertical subsidence above Longwalls 1 and 2, each 168m wide, was about 1.6 to 1.9m. Subsidence above Longwall 3 was in order of 1.7 to 2.0 but this panel was 200m wide. Surface strains had not been measured over any of the first three longwalls. Maximum subsidence over Longwall 4 was 1.7m as shown in the figures below and Table below summarises the mining details for Longwall 4."

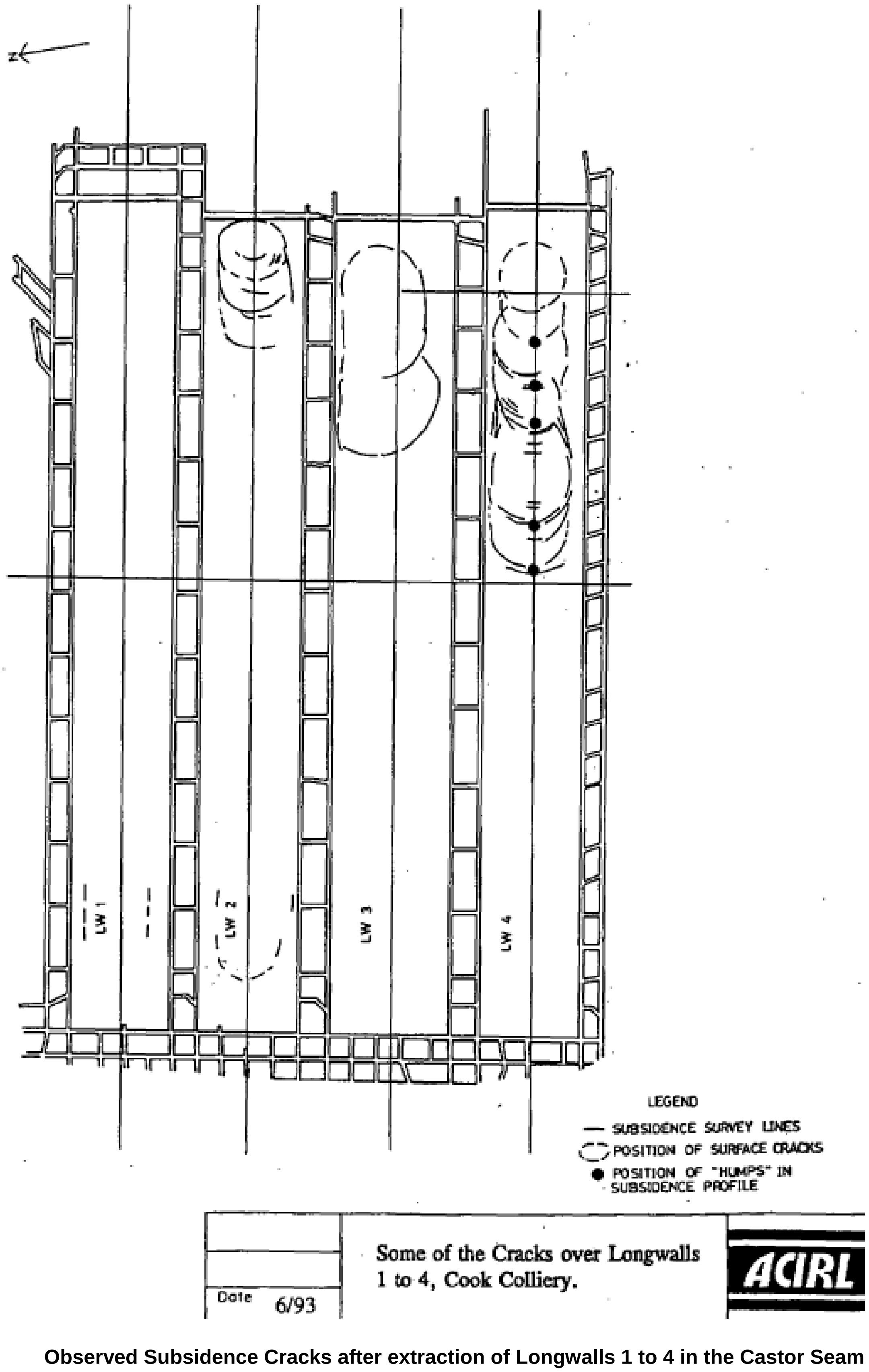


Fig. 3.9 Observed Subsidence Cracks after extraction of Longwalls 1 to 4 in the Castor Seam at Cook Colliery (ACIRL)

Summary of the Mining Details for Longwall 4, Cook Colliery

SEAM	Castor	
EXTRACTION THICKNESS	2.9m	
PANEL WIDTH	168m	
CHAIN PILLAR WIDTH	25 to 38m	
PANEL LENGTH	1320m	
DEPTH OF COVER	235m	
PREVIOUS WORKINGS	Nil	
GEOLOGY (From DDH 799)	0 to 206m	Interbedded sandstones, mudstones, siderite and siltstone.
	206 to 219m	Massive Sandstone
	219 to 221m	Aries Seam
	221 to 235m	Interburden
	235 to 238m	Castor Seam

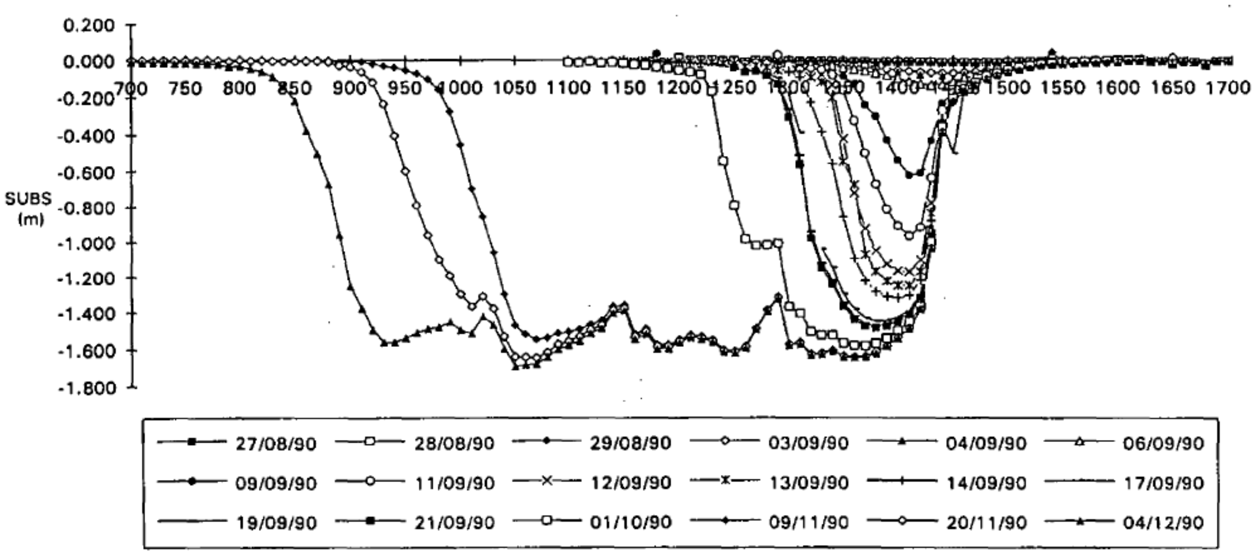


Fig. 3.10 Centreline Subsidence Profile, Castor Seam Longwall 4 (Willey, et al, 1993)

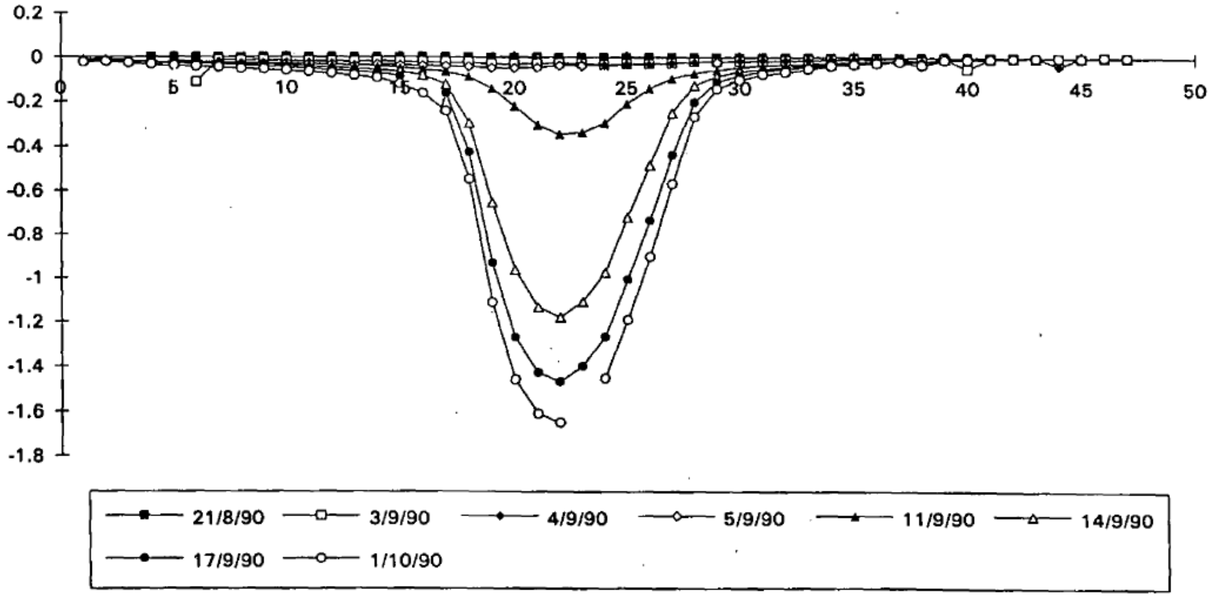


Fig. 3.11 Crossline Subsidence Profile, Castor Seam Longwall 4 (Willey et al 1993)

"The Figure below is a map of the surface cracks over Longwall 4. High points on the longwall centreline coincide with these cracks and, of course, high tensile strains. The maximum tensile strain measured over 10m baylengths was 20mm/m but generally they were less than 10mm/m. These were associated with surface cracks up to 200mm across. Compressive strains reached 12mm/m and were more consistent with values of 7 to 10mm/m being common. "

The maximum tilt was 65mm/m although most tilts were below 20mm/m.

Curvatures were quite tight getting up to 2.5km $^{-1}$ (radius = 0.4km) regularly and as tight as 4.78km $^{-1}$ (radius=0.209km) near the start of the longwall.

The most striking feature of the centreline subsidence plot over LW4 is the way in which the subsidence fluctuates between about 1.35m and 1.7m over a relatively short distance. This fluctuation produces the tight curvatures.

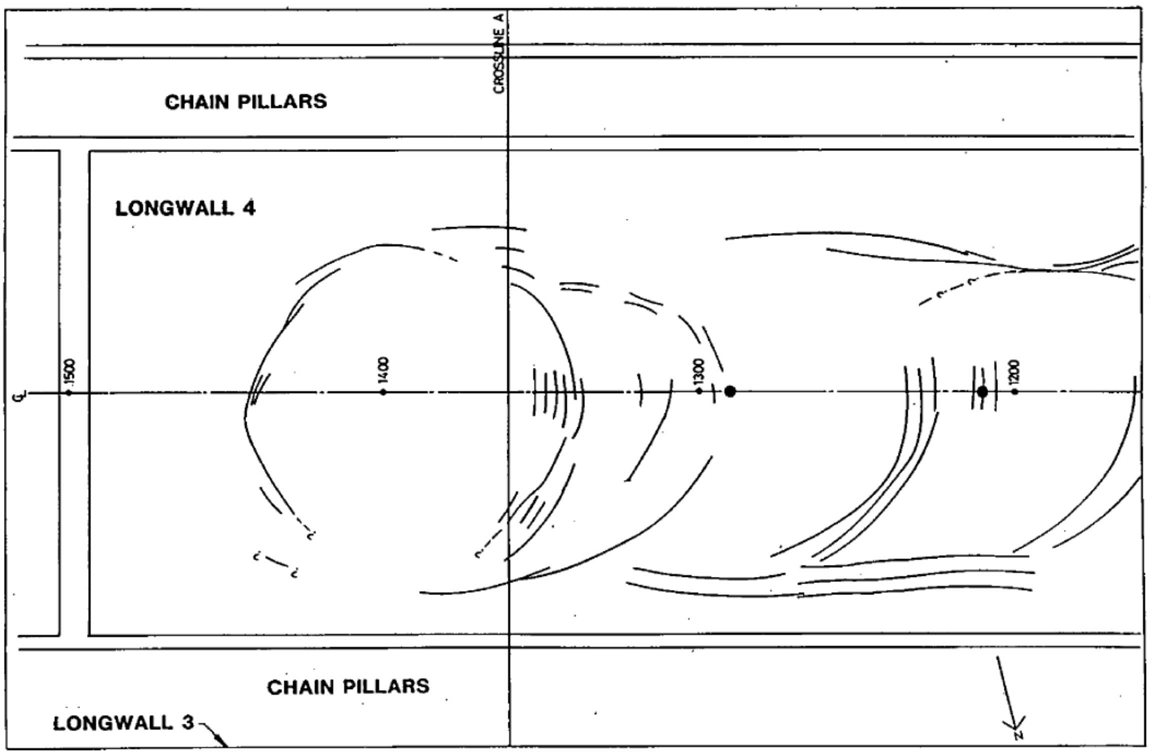


Fig. 3.12 Survey Pegs and Surface Cracks over Castor Seam Longwall 4 (Willey et al 1993)

*"The surface crack pattern first developed in a circle of about 40m diameter centred near peg 1380. These cracks first appeared when the longwall face was under pegs 1250 to 1300 and coincided with major goaf falls underground. Major cracks continued to appear as the longwall retreated producing the arcuate pattern shown in the above Figures." (*Figs. 3.8 and 3.11 above).

"The spacing between major crack groups was generally between 50 and 100m. A feasible explanation for this phenomenon was that the massive sandstone layer above the Aries Seam was driven to failure at regular intervals by the retreating longwall. Monitoring of chock loadings during this period supports this view with cyclic loadings being recorded every 10 to 15m or so of face advance (Frith and Stewart, 1993, in press).

*Results from the borehole extensometer " (*Fig. 3.12 below)," *were somewhat ambiguous. When the longwall face was about 20m before the borehole the cables attached to Anchors 16 to 20 broke. This was probably due to shearing along the interface between the Aries Seam and the overlying massive sandstone at a depth of 219m. Anchors 4, 9 and 10 also broke at about this time and it is thought that their cables were caught on the broken cables from Anchors 16 to 20. Other cables broke later leaving only 8 working. This Figure shows the movements of the surviving anchors as the longwall face retreated."*

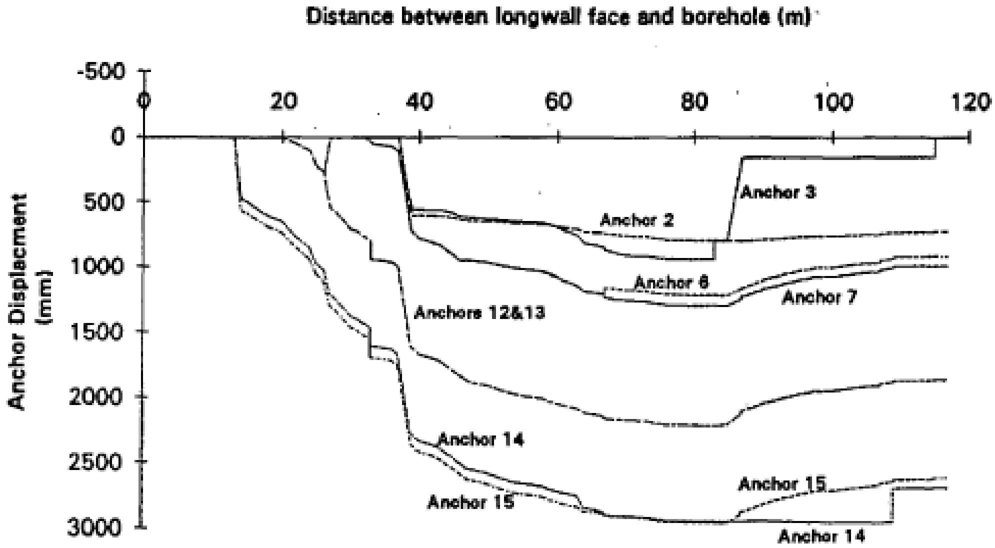


Fig. 3.13 Crossline Subsidence Profile, Castor Seam Longwall 4 (Willey et al 1993)

Further details of the observed levels of monitored subsidence over Cook Colliery were published in December 2005 by Galvin & Associates in a report titled "*Longwall Mining Considerations at Cook Colliery*." Galvin advised;

"Surface cracking and surface subsidence measurements confirmed that the area had subsided regionally. It was reported that surface subsidence almost equated to the amount of coal extracted. That is, surface subsidence approximated mining height x areal extraction. Typically, in Australian conditions, maximum surface subsidence approximates 60% of the extracted volume of coal and somewhat less in partially extracted panels. Two reasons that could account for the high level of recorded subsidence over 502 panel are:

I. The area extracted was greater than that shown on the plan,
2. The superincumbent strata have very good caving properties.

Investigations that I have previously undertaken at the adjacent and now closed Laleham Colliery confirmed that significantly higher levels of subsidence occur in this mining region than experienced in other Australian mining regions. The caving angle is also steeper, resulting in a lower angle of draw. Both of these factors contribute to lower abutment stress and a smaller abutment stress zone around the perimeter of caved workings."

Based on the above published papers on subsidence monitoring at Cook Colliery, high levels of subsidence can be observed at Cook Colliery because the overburden is composed of a sequence of laminates and thin sandstone layers. This can be compared and contrasted against the large amount of massive sandstones and conglomerates found in the Newcastle and Southern Coalfields of New South Wales. It is noteworthy that Bill Kapp advised that; "*Subsidence movements at Cook Colliery, as well as geological sections at Cook and Leichhardt Collieries, suggest that subsidence behaviour at Blackwater would approach that of United Kingdom strata rather than the Newcastle and Southern Coalfields of N.S.W*."

Detailed mine subsidence monitoring was undertaken along and across each of the Castor Longwalls 1 to 6, and hard copies of these monitoring results were provided by Caledon. Figs 3.13 to 3.15 show some of this monitoring and Figs. 3.9 and 3.10 show the monitoring data published by ACIRL along and across Castor Seam Longwall 4. All this subsidence monitoring data has now been entered into the MSEC mine subsidence survey data base.

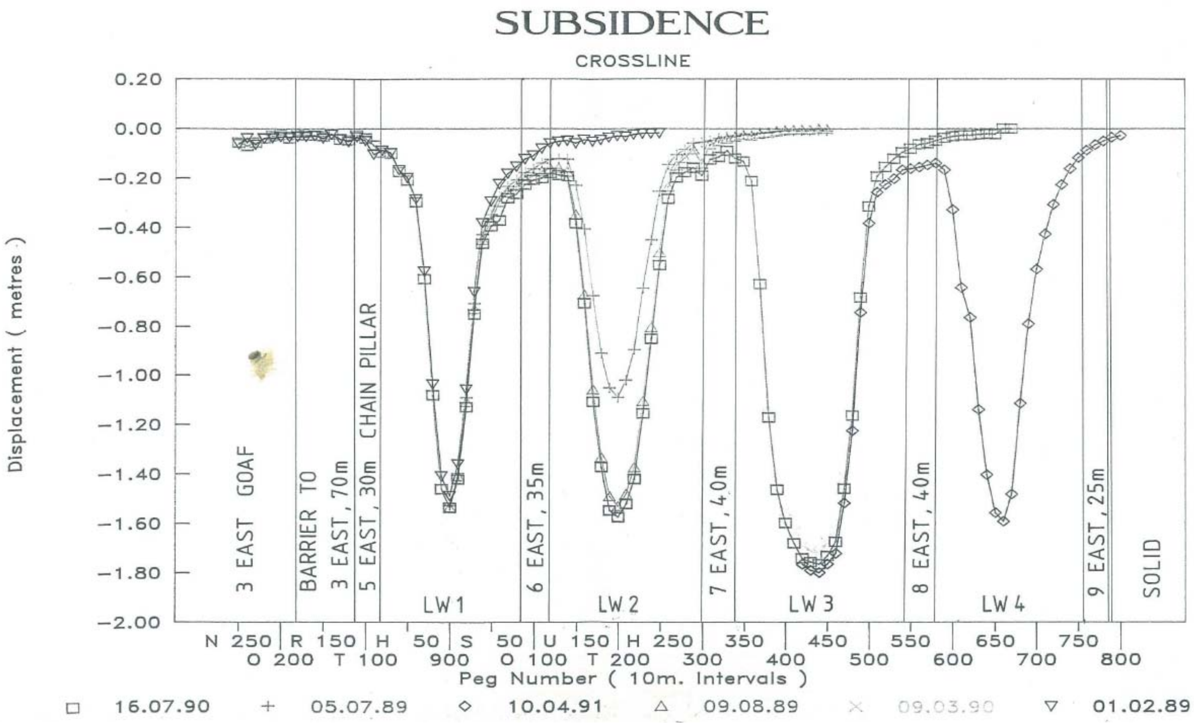


Fig. 3.14 Crossline Subsidence Profile, Castor Seam Longwalls 1 to 4 (Cook)

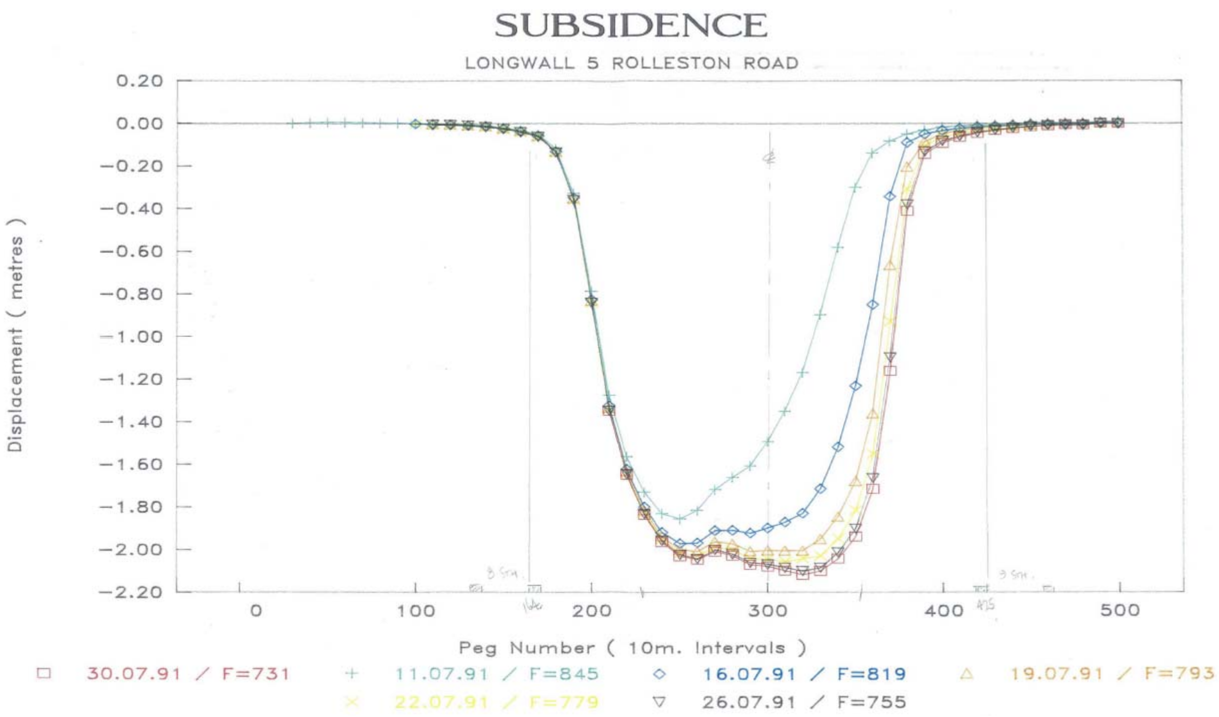


Fig. 3.15 Rolleston Road Subsidence Profile, Castor Seam Longwall 5 (Cook)

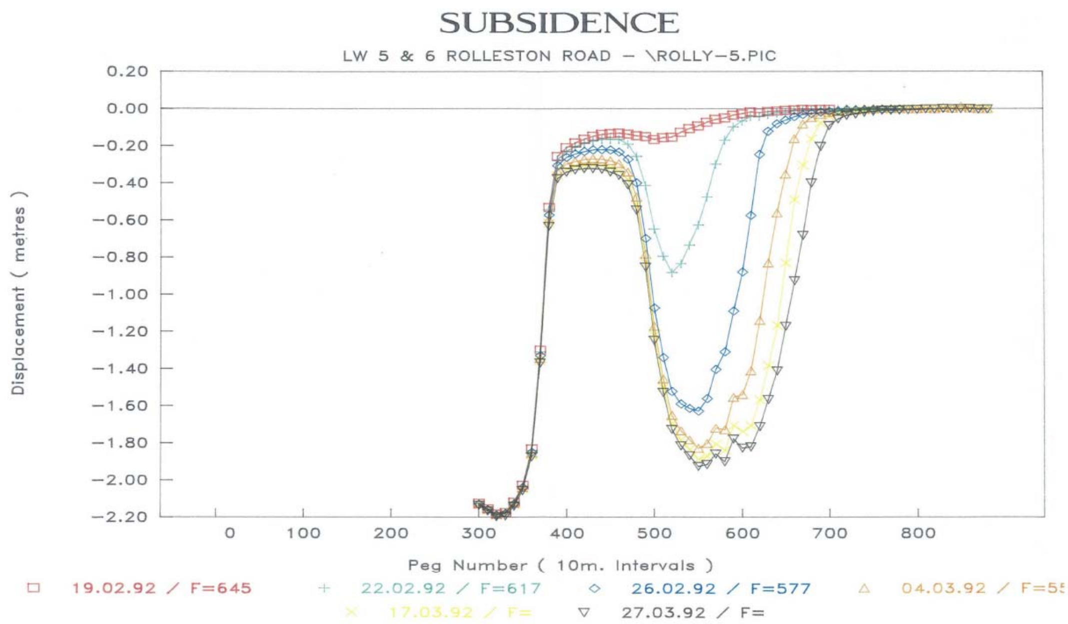


Fig. 3.16 Rolleston Road Subsidence Profile, Castor Seam Longwalls 5 and 6 (Cook)

3.9.2. Calibration for Local Single-seam Mining Conditions

The MSEC Standard Incremental Profile Method (IPM) model was initially used to predict mine subsidence movements for the single-seam conditions over the Castor Seam panels at Cook Colliery along the available subsidence monitoring lines. Comparisons were then undertaken between the observed and predicted subsidence movements using single-seam conditions over the Castor Seam Longwalls 1 to 4.

The following figures, Fig. 3.16 to 3.19, show the observed subsidence profiles, the initial standard IPM predictions and the new calibrated predictions over the Castor Seam Longwalls 1 to 4.

These comparisons indicated that the standard IPM prediction model provides subsidence predictions that were lower in magnitude and the shape of the subsidence profiles resulted in tilts and curvatures that were also less than those that were observed after the survey monitoring, see particularly Fig. 3.19.

This initial review/comparison confirmed the previous advice from Kapp (1980), Willey (1995) and Galvin (2005) that the lack of any massive strata units and the presence of thinly bedded claystone and siltstone laminates at Cook Colliery results in very steep caving angles, high compaction or low bulking of the goafed material and much higher than expected levels of subsidence compared to other Australian mining regions.

Based on these initial predictions and comparisons against the observed subsidence monitoring results, a calibrated IPM model was developed to better predict the single-seam subsidence at Cook Colliery for panels of similar panel widths and depths of cover at Castor Seam Longwalls 1 to 4.

In essence the adjusted model uses the Standard MSEC IPM prediction curves, but, the panel width-to-depth-of-cover (W/H) ratio used in the model is twice the actual panel W/H ratios at Cook Colliery – in order to get the shape of the profiles to match the actual steep observed subsidence profiles and, then, the predicted subsidence profiles values are increased to obtain a reasonable match between observed and predicted subsidence magnitudes.

It can be seen from the above figures, that the observed profiles of subsidence, tilt and curvature along these monitoring lines at Cook Colliery, (i.e. the blue coloured lines on Figs 3.16 to 3.19), reasonably match those predicted using the standard Incremental Profile Method (i.e. the solid red coloured lines on Figs 3.16 to 3.19). In some locations, there are small lateral shifts between the observed and predicted profiles, which could be the result of surface dip, seam dip, or variations in the overburden geology.

It should be recognised that this geological calibration is based on panel widths of 172 metres to 200 metres and depths of cover between 215 metres and 235 metres. The depths of cover above the proposed longwalls at the Carmichael Project vary from less than 100 metres to more than 500 metres and the proposed void widths are 310 metres.

The calibration of the IPM model for the Cook Colliery data has resulted in a significant increase in the maximum predicted subsidence over the uncalibrated model.

While this provides a level of conservatism when compared to monitoring data from other collieries, it will be necessary to review predicted subsidence parameters at the commencement of mining at the Carmichael Project to consider the need for additional further modification to the prediction model.

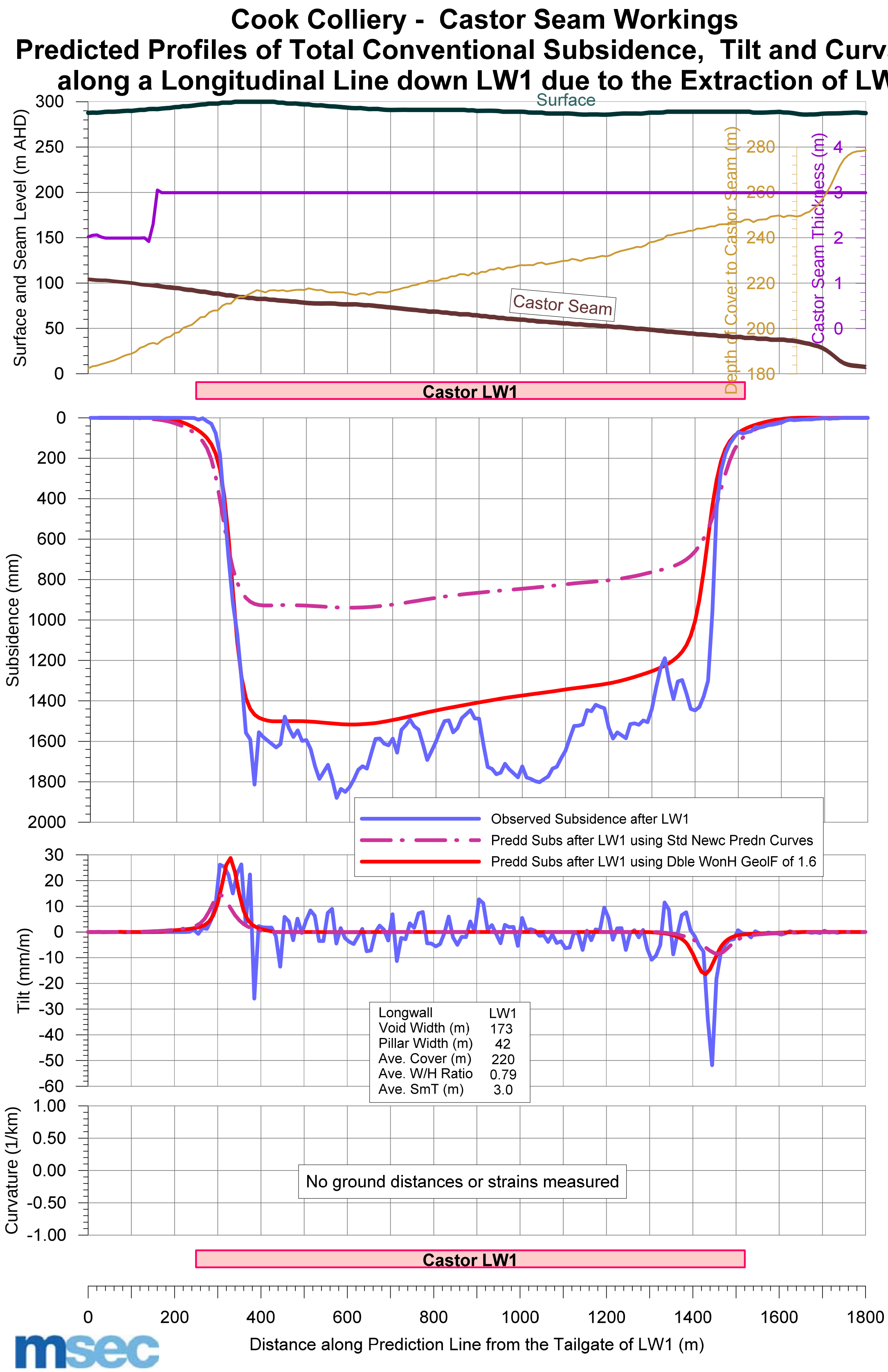


Fig. 3.17 Comparison of Observed and Predicted Subsidence, Tilt and Curvature along Castor LW1 Longitudinal Line

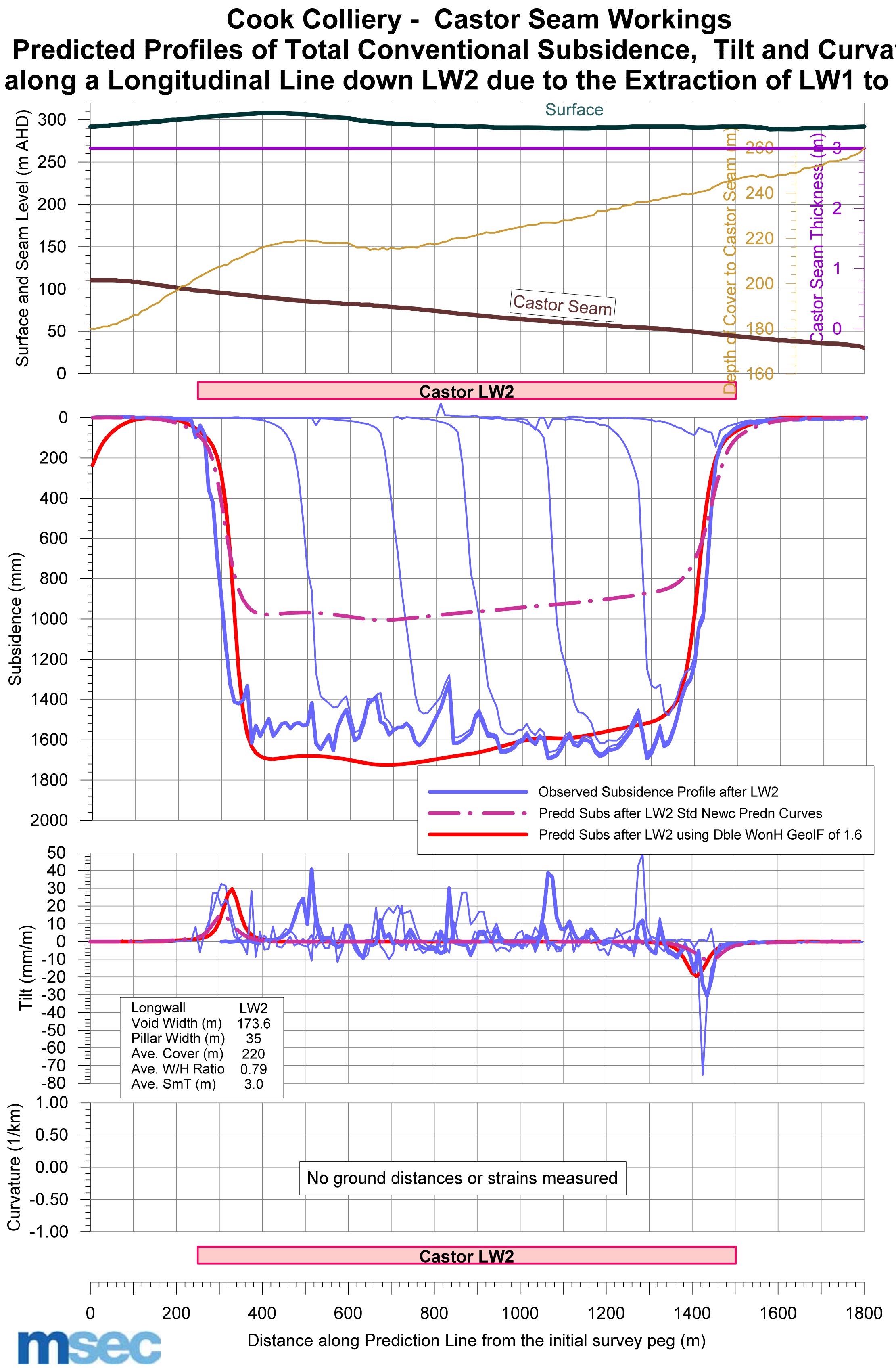


Fig. 3.18 Comparison of Observed and Predicted Subsidence, Tilt and Curvature along Castor LW2 Longitudinal Line

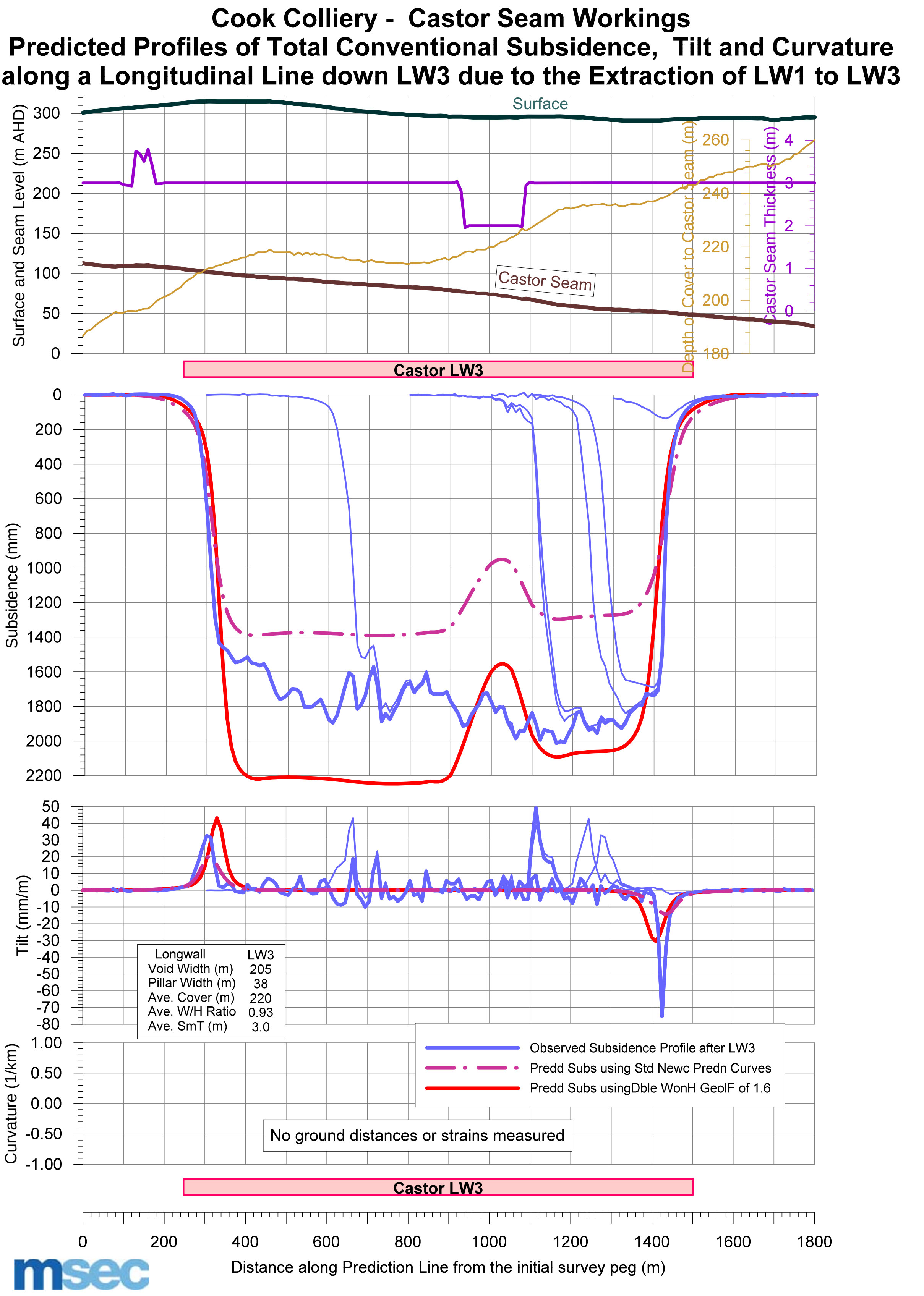


Fig. 3.19 Comparison of Observed and Predicted Subsidence, Tilt and Curvature along Castor LW3 Longitudinal Line

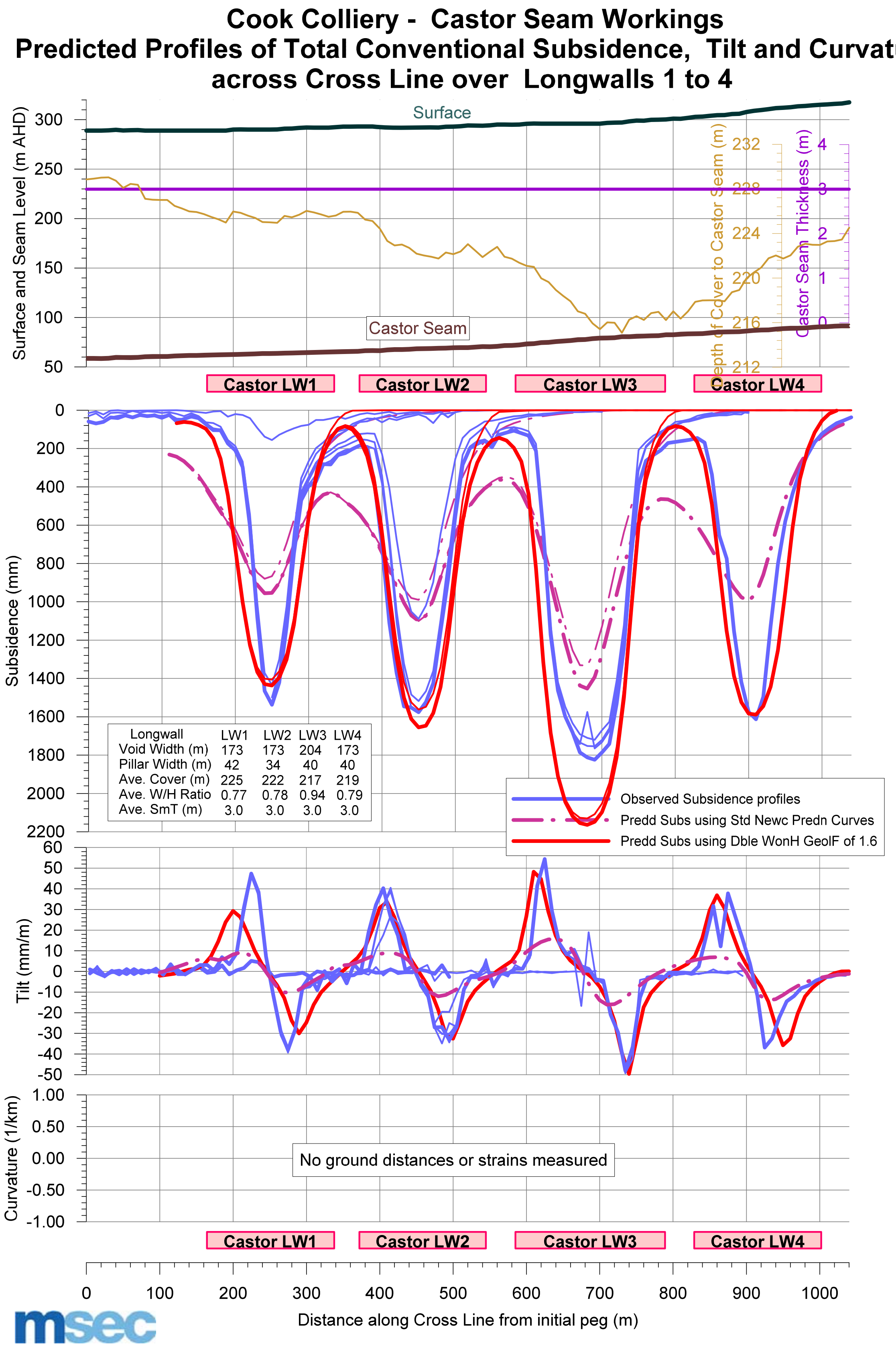


Fig. 3.20 Comparison of Observed and Predicted Subsidence, Tilt and Curvature along Castor LW1 to LW4 cross lines

3.9.3. Calibration for Multi-Seam Mining Conditions

The magnitudes of the available observed multi-seam subsidence cases are higher than equivalent single-seam cases and the observed shapes of these multi-seam subsidence profiles are much more complicated, because of the additional mining and complex geological factors involved in multi-seam cases, including;

- the extent and magnitude of the subsidence experienced after the previously mined panels, i.e. the extent of mining induced voids within the seam and the overlying strata that occurred when the previous workings were extracted,
- the likelihood of re-working and settlement of the mining induced voids within the previously mined workings.
- the local geological conditions in both seams,
- whether the interburden thickness is small resulting in high interaction with the overlying goafs and pillars, or, so large that little interaction occurs,
- the stability of the stooks, remnant pillars and chain pillars in the previously mined seam,
- the ratio between the extracted seam thickness of the previously mined panels compared to the extracted seam thickness in the panels of the currently mined seam, plus,
- the proximity of the previously extracted workings and longwalls within the lower seam.

Based on the observed monitoring data after the extraction of longwalls under or above longwalls at Sigma, Liddell and Cumnock Collieries, as well as observed monitoring data at a number of other Collieries in the NSW Coalfields and in the UK, it was recommended in the paper by Li et al (2007 & 2010) that the additional maximum subsidence resulting from multi-seam mining can be estimated from the following equation:-

$$S_2 = a_2 T_2 \qquad \text{(Li e al, 2010)}$$

where $$a_2 = (a_m - a_1)(T_1 / T_2) + a_m$$

a_1 = Maximum subsidence resulting from the extraction of the upper seam (single-seam conditions) as a proportion of the extracted seam thickness

a_m = Maximum total subsidence resulting from the extraction of the upper seam (single-seam conditions) plus the extraction of the lower seam (multi-seam conditions) as a proportion of total extracted seam thickness of both seams

T_1 = Extracted seam thickness in upper seam

T_2 = Extracted seam thickness in lower seam

Guidance was provided in these papers by Li et al (2007 & 2010) on an upper bound "a_m" value for cases involving longwalls under longwalls, but it appears that these recommendations are only relevant for a limited range of panel widths, depths of cover, interburden thicknesses and seam thicknesses.

The IPM model of predicting mine subsidence has been used successfully to back predict and to predict the subsidence ground movements for various longwall panels in multi-seam conditions for both longwall under longwall cases as well as for longwall under bord and pillar and partial extraction cases. The IPM model for multi-seam subsidence prediction is based on calibrating the predicted single-seam predictions by various multi-seam factors.

The multi-seam factors vary depending on the predicted subsidence as proportions of the extracted seam thicknesses of the overlying and underlying seams, the actual seam thicknesses of the overlying and underlying seams and the interburden thickness between the overlying and underlying seams. The multi-seam factors are the greatest for the cases where the interburden thicknesses are the lowest and where the proportions of subsidence to the extracted seam thicknesses in the overlying and underlying seams were the lowest.

The multi-seam factor for the proposed longwalls at the Carmichael Project in the D1 Seam, based on an interburden thickness between 70 and 130 metres resulted in an incremental subsidence of 95% of extracted seam thickness for a single longwall based on multi-seam conditions.

Shapes of the Multi-seam Subsidence Profiles

It has been found from past longwall mining experience that the shapes of multi-seam subsidence profiles depend on, amongst other factors, the depths of cover, interburden thickness, extraction heights and the relative locations between the longwalls within each seam.

In the cases where the chain pillars within the lower seam are located directly beneath the chain pillars, or stable remnant pillars, within the overlying seam, which are referred to as *Stacked Cases,* the observed subsidence profiles are steeper and more localised above the longwalls when compared with those for similar single-seam conditions. In the cases where the chain pillars, or stable remnant pillars, within the lower seam are offset from the chain pillars within the overlying seam, which are referred to as *Staggered Cases*, as is the case at the Carmichael

Project, the subsidence profiles are flatter and extend further when compared with those for similar single-seam conditions.

The observed subsidence profiles for multi-seam cases are typically wider than those observed for single-seam cases, as shown in Fig. 3.21, which result from the reactivation of the goafs and chain pillars in the overlying seam. In this figure, the observed multi-seam profiles are shown in black and the observed single-seam profiles are shown in cyan and red. It should be noted, that the observed multi-seam profiles shown in this figure are based primarily on cases where the longwalls extracted in the underlying seam were offset, or staggered to the previously extracted longwalls in the overlying seam.

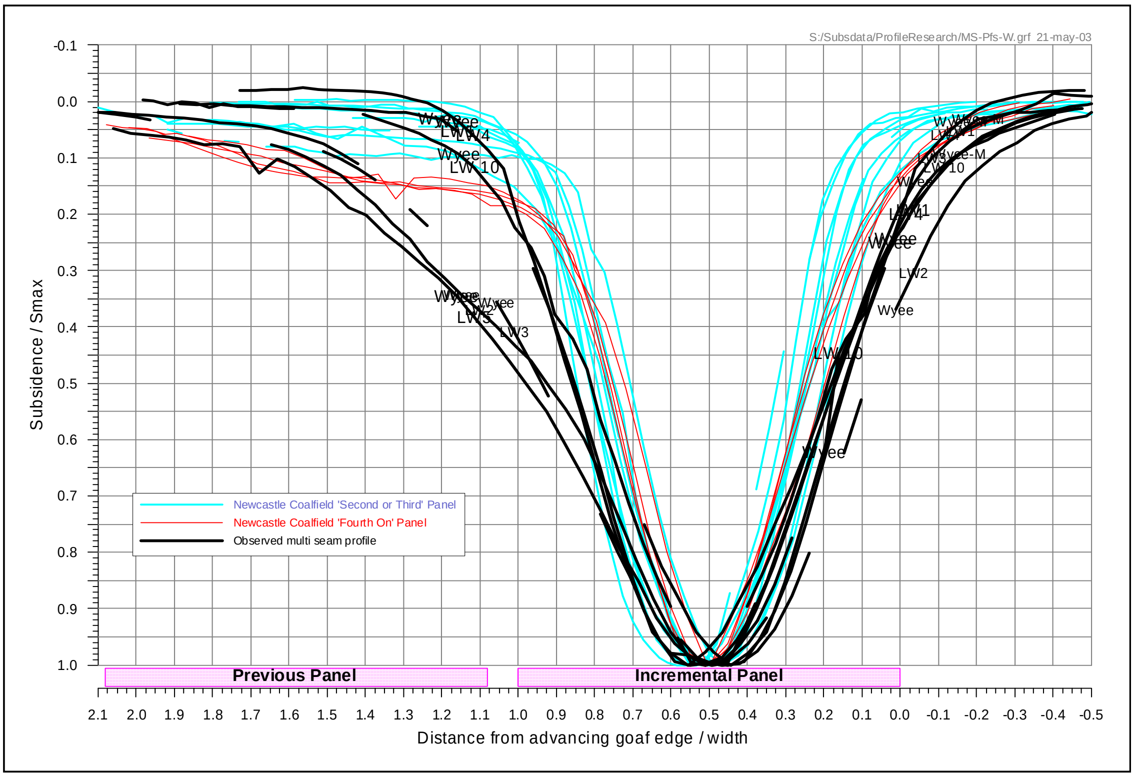


Fig. 3.21 Comparison between Single and Multi-Seam Incremental Subsidence Profiles

3.10. Reliability of the Predicted Conventional Subsidence Parameters

The Incremental Profile Method has been tested and calibrated against observed monitoring data at Cook Colliery. It has been found that there is a reasonable correlation between observed and predicted subsidence, where the prediction model generally produces conservative results.

The Incremental Profile Method is based upon a large database of observed subsidence movements and has been found, in most cases, to give reasonable, if not, conservative predictions of maximum subsidence, tilt and curvature. The following quotations from the NSW government inquiry report titled "*The Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield - Strategic Review*", State of New South Wales through the NSW Department of Planning (DOP, 2008) provides an overview of the available mine subsidence prediction techniques, including the Incremental Profile Method, and have concluded;

"Techniques for predicting surface subsidence effects can be classified under three categories, namely empirical, analytical/numerical and hybrid methods. Empirical techniques are based on the back analysis of previous field outcomes. Reliability of outcomes is dependent, therefore, on the overall size and representativeness of the database and considerable care is required if the techniques are applied to conditions that are outside of this database. The more common empirical prediction methods are:"

*"1. **Graphical**, which involves plotting suites of curves showing relationships between various parameters and subsidence outcomes;"*

*"2. **Upper Bound**, which involves constructing an envelope over measured maximum or worse case outcomes and predicting on the basis of that envelope;"*

*"3. **Profile Function**, which attempts to define the shape of the vertical displacement curve by a mathematical equation and is confined in general to single (isolated) excavations; and"*

*"4. **Incremental Profile Method**, which involves constructing the overall vertical displacement profile by summing the incremental vertical displacement that occurs each time a panel is extracted"*

...

"A number of techniques are capable of producing reasonably accurate predictions of vertical displacement, typically within ±150 mm. The more noteworthy of these are the incremental subsidence prediction technique, the influence function technique and a number of numerical modelling codes. However, the accuracy of any subsidence prediction technique should never be taken for granted. All depend to some extent on input parameters being representative of the specific site conditions. Particular care has to be taken when predicting subsidence for a greenfields site due to a lack of site specific data. A number of panels need to be extracted before subsidence prediction models can be properly calibrated and validated."

....

*"**Incremental Profile Method**: It has been known for decades that, in theory, the vertical surface displacement profile over mine workings at any point in time can be constructed by summing the increments of vertical displacement arising from the mining of each panel making up those workings. The Australian coal mining industry has provided considerable research funding over the last decade to effectively 'reverse engineer' the subsidence prediction process by utilising the large databases of subsidence information relating to the Southern Coalfield and the Newcastle Coalfield in NSW to define the characteristic shape for each increment of vertical displacement resulting from a mining operation. Once the vertical displacement profile has been created, it can be used to calculate tilt, curvature and strain in the same manner as that described for the profile function technique. This prediction technique offers a number of benefits over other empirical techniques because variations in depth, seam thickness and seam dip can be taken into account, as well as the influence of multiple mining panels - and subsidence predictions can be produced at any nominated point on the surface."*

The prediction of the conventional subsidence parameters at a specific point is more difficult than providing the prediction of the maximum likely subsidence movements. The predicted subsidence profiles obtained using the Incremental Profile Method 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. However, 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, with the observed parameters being less than those predicted in other locations.

The prediction of multi-seam subsidence at a point is more difficult to achieve accurately than single-seam cases and is subject to more complex and variable factors.

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, tensile strains have been observed where compressive strains were predicted, and vice versa.

The following reasons contribute to why ground 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 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.
- 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 insitu horizontal stress, the far-field movement mechanisms or valley related movements. Where the mining induced curvatures are low and the ground movements due to the release of insitu stress, i.e. far field, slope and valley related movements, are high, then the ratio of horizontal movement to tilt or the ratio of strain to curvature can be much higher than those predicted using a strain to curvature ratio of 10 or 15.
- Where a thick surface layer of soil, clay or rock exists, the underlying movements in the bedrock are often transferred to the surface at reduced levels and the measured strains are, therefore, more evenly distributed and hence more systematic in nature than they would be if they were measured at rockhead.
- Strain measurements can sometimes give a false impression of the state of stress in the ground. For example:-
    - buckling of the near-surface strata can result in localised cracking and apparent tensile strain in areas where overall, the ground is in fact being compressed, because the actual values of the measured strains are dependent on the locations of the survey pegs.
    - where 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. For example, it is difficult to measure variations in bay lengths more accurately than ±5 mm, especially where tripods have to be set over sunken survey marks. Over a typical bay length of 20 metres, surveying error variations of ±0.25 mm/m are commonly seen in the observed strain data.
- 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.
- It is also recognised that the ground movements above a longwall panel can be affected by the gradient of the coal seam, the direction of mining and the presence of faults and dykes 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. Further discussions on irregular movements are provided in Section 4.5.

For the above reasons, rather than adopting one relationship between mining induced curvature and strain for the predictions of strain, the strain predictions provided in this report are based on a statistical analysis of measured strains, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.3.

The Incremental Profile Method approach therefore allows site specific appropriate predictions of subsidence, tilt and strains for each natural feature or item of infrastructure and provides a more realistic assessment of the mining induced impacts than by predicting the maximum predicted parameters at every point, which would be overly conservative and would yield an excessively overstated assessment of the potential subsidence impacts.

4.0 PREDICTED SUBSIDENCE PARAMETERS FOR THE PROPOSED LONGWALLS

4.1. Introduction

The following sections provide the maximum predicted conventional subsidence parameters resulting from the extraction of the Proposed Longwalls in the AB1 and D1 Seams.

The predicted maximum subsidence, tilt and curvature have been determined using the Incremental Profile Method, with prediction curves that have been calibrated based on observed subsidence data from Cook Colliery as discussed in Section 3.9.

The maximum predicted subsidence parameters and the predicted subsidence contours provided in this report describe and show the conventional movements and do not include valley related upsidence and closure movements, nor the effects of faults and other geological structures.

4.2. Maximum Predicted Conventional Subsidence, Tilt and Curvature

A summary of the maximum predicted values of incremental conventional subsidence, tilt and curvature, due to the extraction of each of the proposed longwalls, 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 Longwalls

Maximum Predicted Incremental Conventional Parameters in AB1 Seam					Maximum Predicted Incremental Conventional Parameters in D1 Seam				
Longwall	Subsidence	Tilt	Hogging Curvature	Sagging Curvature	Longwall	Subsidence	Tilt	Hogging Curvature	Sagging Curvature
-	-	-	-	-	DLW101N	2925	95	>5.00	>5.00
-	-	-	-	-	DLW102N	2925	70	3.28	3.25
-	-	-	-	-	DLW103N	2925	55	1.62	1.66
ABLW101N	2475	60	2.38	2.61	DLW104N	3025	45	1.02	1.05
ABLW102N	2475	45	1.41	1.49	DLW105N	2875	35	0.67	0.68
ABLW103N	2425	35	0.85	0.86	DLW106N	2625	25	0.42	0.58
ABLW104N	2325	25	0.54	0.54	DLW107N	2275	20	0.26	0.55
ABLW105N	2175	20	0.36	0.49	DLW108N	1975	15	0.16	0.45
ABLW106N	2050	20	0.42	0.53	DLW109N	1800	15	0.11	0.31
ABLW107N	1850	15	0.32	0.47	DLW110N	1375	10	0.07	0.19
-	-	-	-	-	DLW101S	2925	>100	>5.00	>5.00
-	-	-	-	-	DLW102S	2925	>100	>5.00	>5.00
-	-	-	-	-	DLW103S	2925	75	3.18	3.65
ABLW101S	2475	90	>5.00	>5.00	DLW104S	3075	55	1.74	1.82
ABLW102S	2475	60	2.58	2.85	DLW105S	3025	45	1.02	1.04
ABLW103S	2475	45	1.29	1.38	DLW106S	2825	35	0.63	0.65
ABLW104S	2400	35	0.75	0.79	DLW107S	2525	25	0.38	0.58
ABLW105S	2200	25	0.45	0.48	DLW108S	2075	20	0.22	0.51
ABLW106S	2350	30	0.61	0.65	DLW109S	2275	20	0.31	0.54
ABLW107S	2200	25	0.42	0.51	DLW110S	2025	15	0.20	0.49
ABLW201	2475	55	2.12	2.32	DLW201	3050	45	1.20	1.23
ABLW202	2475	45	1.33	1.39	DLW202	2975	40	0.94	0.99
ABLW203	2450	35	0.89	0.95	DLW203	2875	35	0.68	0.70
ABLW204	2350	30	0.64	0.66	DLW204	2675	30	0.50	0.58
ABLW205	2225	25	0.47	0.49	DLW205	2400	20	0.33	0.57
ABLW206	2050	20	0.40	0.49	DLW206	2100	15	0.22	0.51
ABLW207	1825	15	0.25	0.46	DLW207	1875	15	0.15	0.36
ABLW301N	2425	35	0.86	0.89	DLW301N	2675	30	0.51	0.58
ABLW302N	2375	30	0.64	0.67	DLW302N	2575	25	0.40	0.59
ABLW303N	2300	25	0.52	0.53	DLW303N	2425	20	0.32	0.57
ABLW304N	2225	25	0.46	0.49	DLW304N	2275	20	0.26	0.56
ABLW305N	2125	20	0.37	0.48	DLW305N	2150	20	0.22	0.53
ABLW301S	2475	45	1.31	1.37	DLW301S	2900	35	0.77	0.81
ABLW302S	2425	35	0.83	0.86	DLW302S	2725	30	0.53	0.59
ABLW303S	2350	30	0.64	0.65	DLW303S	2500	25	0.38	0.58
ABLW304S	2300	25	0.54	0.55	DLW304S	2350	20	0.30	0.57
ABLW305S	2225	25	0.46	0.49	DLW305S	2200	20	0.24	0.54
ABLW306S	2050	20	0.39	0.49	DLW306S	1975	15	0.18	0.45
ABLW401	2475	45	1.61	1.61	DLW401	2925	35	0.76	0.81
ABLW402	2475	40	1.26	1.25	DLW402	2875	35	0.65	0.66
ABLW403	2475	40	0.98	1.03	DLW403	2800	30	0.56	0.62
ABLW404	2425	35	0.80	0.84	DLW404	2675	30	0.49	0.59

Maximum Predicted Incremental Conventional Parameters in AB1 Seam					Maximum Predicted Incremental Conventional Parameters in D1 Seam				
Longwall	Subsidence	Tilt	Hogging Curvature	Sagging Curvature	Longwall	Subsidence	Tilt	Hogging Curvature	Sagging Curvature
ABLW405	2375	30	0.62	0.67	DLW405	2525	25	0.37	0.58
ABLW406	2325	25	0.54	0.55	DLW406	2375	20	0.27	0.57
ABLW407	2250	25	0.46	0.49	DLW407	2225	20	0.23	0.55
ABLW501N	2475	40	1.20	1.24	DLW501N	2725	30	0.56	0.60
ABLW502N	2450	35	0.91	0.94	DLW502N	2650	25	0.47	0.58
ABLW503N	2400	30	0.72	0.75	DLW503N	2525	25	0.38	0.58
-	-	-	-	-	DLW501S	2925	>100	>5.00	>5.00
-	-	-	-	-	DLW502S	2925	80	3.71	4.48
-	-	-	-	-	DLW503S	2925	70	2.82	3.07
ABLW501S	2475	>100	>5.00	>5.00	DLW504S	3075	60	1.94	2.14
ABLW502S	2475	85	4.65	>5.00	DLW505S	3075	55	1.56	1.59
ABLW503S	2475	65	2.91	3.45	DLW506S	3075	45	1.16	1.24
ABLW504S	2475	55	2.02	2.24	DLW507S	3000	40	0.90	0.95
ABLW505S	2475	45	1.42	1.54	DLW508S	2900	35	0.72	0.75
ABLW506S	2475	40	1.11	1.11	DLW509S	2800	30	0.59	0.63
ABLW507S	2425	35	0.82	0.87	DLW510S	2675	30	0.49	0.59
ABLW508S	2375	30	0.67	0.68	DLW511S	2525	25	0.37	0.58
-	-	-	-	-	DLW512S	2300	20	0.29	0.56

The predicted total conventional subsidence contours, resulting from the extraction of the Proposed Longwalls, in the AB1 seam and D1 seam are shown in Drawings Nos MSEC627-14 and MSEC627-15 respectively, in Appendix D. The predicted total conventional subsidence contours for the Proposed Longwalls after each 5 years of scheduled mine operation (rounded up to the nearest fully extracted longwall panel) are presented in Drawings Nos. MSEC627-26 to and MSEC627-34, in Appendix D. A summary of the maximum predicted values of total conventional subsidence, tilt and curvature, after the extraction of each of the Proposed Longwalls, is provided in Table 4.2.

Table 4.2 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature after the Extraction of the Proposed Longwalls

Maximum Predicted Total Conventional Parameters in AB1 Seam					Maximum Predicted Total Conventional Parameters in D1 Seam				
Longwall	Subsidence	Tilt	Hogging Curvature	Sagging Curvature	Longwall	Subsidence	Tilt	Hogging Curvature	Sagging Curvature
ABLW101N to ABLW107N	2575	55	2.28	2.52	DLW101N to DLW110N	5225	95	>5.00	>5.00
ABLW101s to ABLW107S	2625	95	3.93	3.26	DLW101S to DLW110S	5550	>100	>5.00	>5.00
ABLW201 to ABLW207	2575	55	2.13	2.22	DLW201 to DLW207	5175	95	3.06	3.02
ABLW301N to ABLW305N	2425	35	0.86	0.89	DLW301N to DLW305N	4100	50	1.15	1.07
ABLW301S to ABLW306S	2600	45	1.38	1.42	DLW301S to DLW306S	4650	70	1.66	1.82
ABLW401 to ABLW407	2575	45	1.60	1.62	DLW401 to DLW407	5000	70	1.84	1.92
ABLW501N to ABLW503N	2575	40	1.16	1.21	DLW501N to DLW503N	4650	50	1.26	1.28
ABLW501S to ABLW508S	2625	>100	>5.00	>5.00	DLW501S to DLW512S	5450	>100	>5.00	>5.00

The predicted total tilts provided in the above table are the maxima after the completion of the proposed longwalls. The predicted curvatures provided in the above table are the maxima during or after the extraction of the proposed longwalls.

The maximum predicted conventional tilt is greater than 100 mm/m (i.e. 10 %), which represents a change in grade of greater than 1 in 10. The maximum predicted conventional curvatures are both greater than 5.0 km^{-1}, which represent a minimum radius of curvature of less than 200 metres.

The predicted conventional subsidence parameters vary across the Study Area as a result of, amongst other factors, variations in the longwall geometry, depths of cover and extraction height. To illustrate this variation, the predicted profiles of conventional subsidence, tilt and curvature have been determined along Prediction Lines 1 to 9, the locations of which are shown in Drawings Nos MSEC627-14 and MSEC627-15.

The predicted profiles of conventional subsidence, tilt and curvature along the Prediction Lines 1 to 9, resulting from the extraction of the proposed longwalls, are shown in Fig. C01 to Fig. C09, respectively, in Appendix C. The predicted total profiles along the prediction lines, after the extraction of each of the proposed longwalls, are shown as solid red lines. The range of predicted curvatures, in any direction to the prediction lines, at any time during or after the extraction of the proposed longwalls, are shown by the grey shading. The predicted profiles of subsidence, tilt and curvature presented in Fig. C01 to Fig. C09, in Appendix C include profiles after each 5 years of scheduled mine operation (rounded up to the nearest fully extracted longwall panel).

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, the depth of bedrock and, in this case, multi-seam mining conditions. 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, for single-seam mining conditions, applying a constant factor to the predicted maximum curvatures provides an approximate prediction for the predicted maximum normal or conventional strains, even though it is recognised that this prediction method does not account for horizontal movements due to the release of insitu horizontal stress, the far-field movement mechanisms or valley related movements. 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 Hunter Coalfield of NSW, it has been found that a factor of 10 provides a reasonable relationship between the predicted maximum curvatures and the predicted maximum conventional strains for single-seam conditions. 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.

It is not simple to provide a similar relationship between curvature and strain for multi-seam mining conditions, since there is very limited empirical data to establish this relationship and such a relationship would not account for horizontal movements due to the release of insitu horizontal stress, the far-field movement mechanisms or valley related movements. In addition to this, localised strains also develop in multi-seam mining conditions, as the result of remobilising the existing goaf and chain pillars in the overlying seam, which are also not directly related to curvature.

The observed data from Cook Colliery which was used for calibration of the prediction model did not include strain measurements. The expected magnitudes of strain for multi-seam mining conditions have therefore been based on the observed strains for multi-seam mining in the Hunter Coalfield of NSW. The maximum observed tensile and compressive strains along eight monitoring lines for a longwall mined directly beneath existing longwalls are provided in Table 4.3.

Table 4.3 Maximum Observed Strains for the Monitoring Lines above Multi-seam mining in the Hunter Coalfield

Monitoring Line	Depth of Cover (m)	Extraction Height (m)	Interburden Thickness between Seams (m)	Maximum Observed Tensile Strain (mm/m)	Maximum Observed Compressive Strain (mm/m)
1	190 ~ 220	2.8	75 ~ 80	13	10
2	170 ~ 180	2.5	70 ~ 75	18	14
3	190 ~ 220	2.8	75 ~ 80	6	2
4	165 ~ 175	2.7	75 ~ 80	7	8
5	150 ~ 220	2.5 ~ 3.2	70 ~ 90	3	4
6	170 ~ 210	2.3 ~ 2.9	70 ~ 80	11	19
7	180 ~ 210	2.1 ~ 2.9	75	5	19
8	190 ~ 210	2.9	75	23	11

It can be seen from the above table, that the maximum observed tensile strain was 23 mm/m and the maximum observed compressive strain was 19 mm/m. It is noted, that lines 3 and 5 were located outside the extents of the longwall and, therefore, the strains measured along these lines were less than those measured along the other lines.

4.3.1. Analysis of Strains in Survey Bays

For features that are in discrete locations it is appropriate to assess the frequency of the observed maximum strains for individual survey bays.

The monitoring lines discussed above have been analysed to determine the maximum observed tensile and compressive strains in the survey bays located directly above multi-seam longwall extraction, at any time during the extraction of the longwall. A number of probability distribution functions were fitted to the empirical data. It was found that a *Generalised Pareto Distribution (GPD)* provided a reasonable fit to the raw strain data.

The histograms of the maximum observed tensile and compressive strains for the monitoring lines measured during multi-seam longwall mining, is provided in Fig. 4.1. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

The averages of the maximum strains that the individual survey bays experienced at any time during mining were 1.7 mm/m tensile and 2.6 mm/m compressive. The maximum strains that any survey bay experience at any time during mining were 23 mm/m tensile and 19 mm/m compressive.

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 the longwall 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 strains that the individual survey bays experienced at any time during mining were 7 mm/m tensile and 9 mm/m compressive. The 99 % confidence levels for the maximum strains that the individual survey bays experienced at any time during mining were 14 mm/m tensile and 13 mm/m compressive.

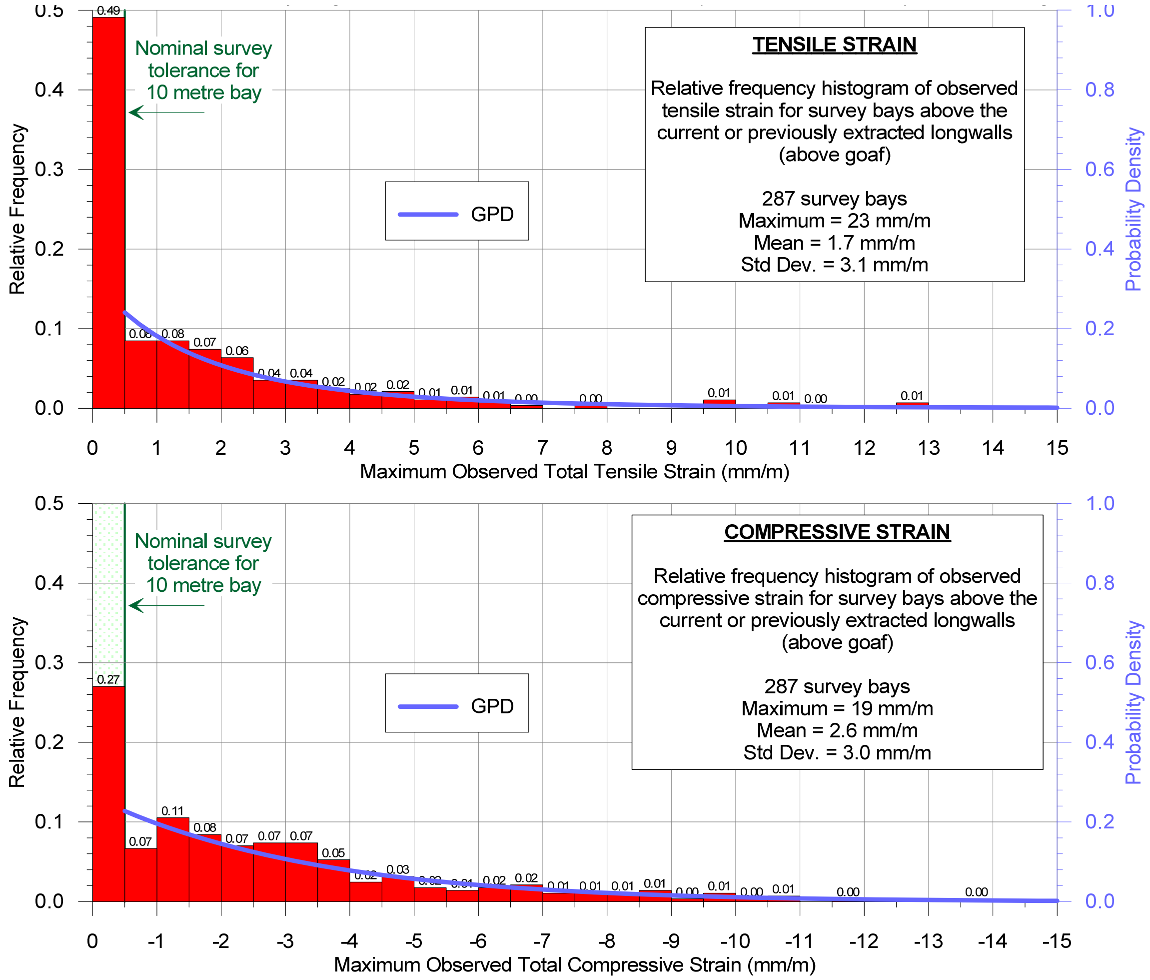


Fig. 4.1 Distributions of the Measured Maximum Tensile and Compressive Strains for Survey Bays Located Directly Above Multi-seam Longwall Mining

4.3.2. Analysis of Strains along Whole Monitoring Lines

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

Four of the eight monitoring lines (i.e. 50 %) had recorded maximum total tensile strains greater than 10 mm/m, two of the eight monitoring lines (i.e. 25 %) had recorded maximum total tensile strains greater than 15 mm/m and one of the eight monitoring lines (13 %) had recorded maximum total tensile strain greater than 20 mm/m.

Also, four of the eight monitoring lines (i.e. 50 %) had recorded maximum total compressive strains greater than 10 mm/m, two of the eight monitoring lines (i.e. 25 %) had recorded maximum compressive strains greater than 15 mm/m and none of the monitoring lines (i.e. 0 %) had recorded maximum total compressive strain greater than 20 mm/m.

4.4. Predicted Far-field Horizontal Movements

As discussed in Section 3.6, in addition to the conventional subsidence movements that have been predicted above and adjacent to the proposed longwalls, it is also likely that far-field horizontal movements will be experienced during the extraction of the proposed longwalls.

An empirical database of observed incremental far-field horizontal movements has been compiled using monitoring data primarily from the NSW Coalfields. The far-field horizontal movements resulting from longwall mining were generally observed to be orientated towards the extracted longwall. 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 longwall, are provided in Fig. 4.2. The confidence levels, based on fitted GPD's, have also been shown in this figure to illustrate the spread of the data.

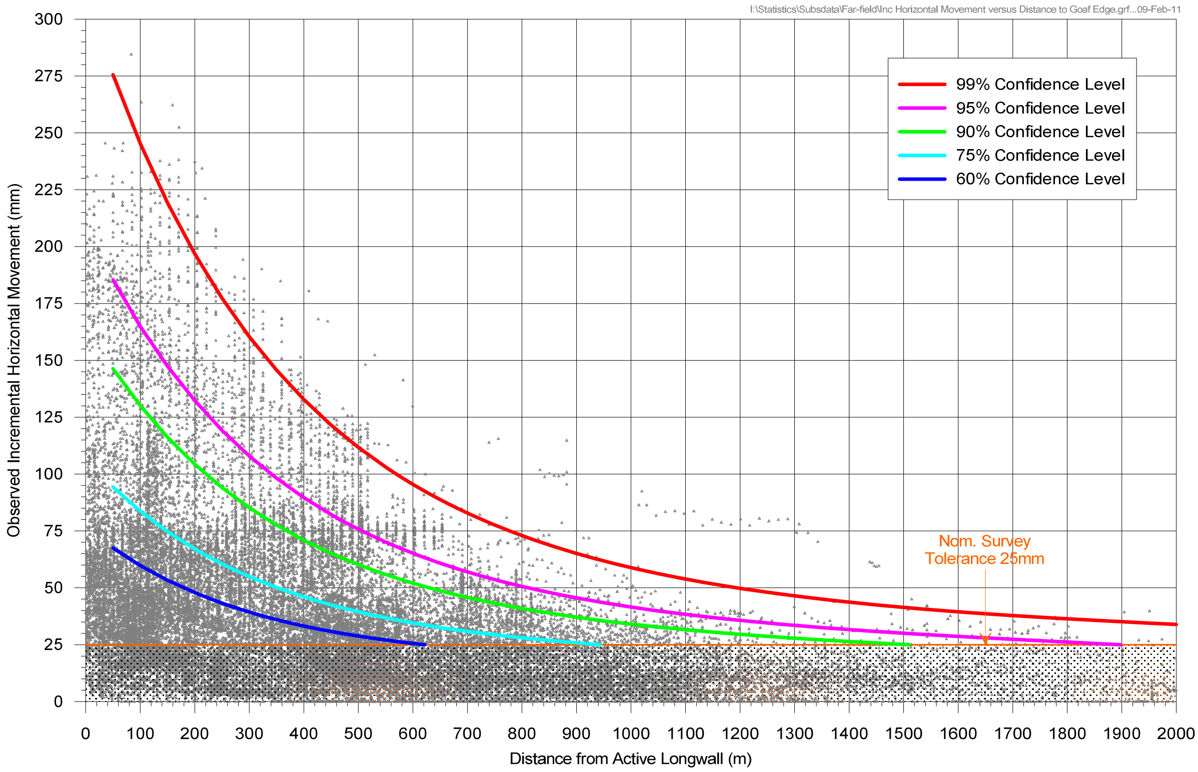


Fig. 4.2 Observed Incremental Far-Field Horizontal Movements

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

The predicted far-field horizontal movements resulting from the extraction of the proposed longwalls are very small and could only be detected by precise surveys. Such movements tend to be bodily movements towards the extracted goaf area, and are accompanied by very low levels of strain, which are generally less than the order of survey tolerance (i.e. less than 0.3 mm/m). The impacts of far-field horizontal movements on the natural features and items of surface infrastructure within the proposed longwalls is not expected to be significant, except where they occur at large structures which are sensitive to small differential movements.

We are not aware of far-field horizontal movement data in Queensland and cannot therefore include this information in the data set. It is anticipated that the magnitude of far field horizontal movements will be less than those in NSW at equivalent depths of cover because of the presence of the Quaternary and Tertiary deposits at the surface.

4.5. Non-Conventional Ground Movements

It is likely non-conventional ground movements will occur within the Study Area, due to near surface geological conditions, which were discussed in Section 3.7. 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 statistical analysis of measured strains from previous longwall mining, including both conventional and non-conventional anomalous strains, which is discussed in Section 4.3.

5.1. Mining Induced Surface Deformation

Longwall mining can result in surface cracking, heaving, buckling, humping and stepping at the surface. The prediction of surface cracking widths, depths and spacings is more difficult than the predictions of subsidence, tilt and curvature. This is because the sizes and extents of surface deformations are influenced by many factors, including mine subsidence movements, which are dependent on:

- mine geometry;
- depth of cover;
- extracted seam thickness;
- the presence of valleys and steep surface topography and the location relative to the extracted longwall goaf edges;
- local variations in the near surface geology;
- the locations of pre-existing natural joints at bedrock;
- the presence and plasticity of any soils that overlie the bedrock; and
- the depth of the surface bedrock unit.

The surface crack widths and frequencies of the cracks are also dependent upon the pre-existing jointing patterns in the bedrock. Large natural joint spacing can lead to concentrations of strain and possibly the development of fissures at rockhead, which are not necessarily coincident with the joints.

Fractures and joints in sedimentary strata occur naturally during the formation of the strata and from subsequent erosion and weathering processes. Longwall mining can result in additional fracturing in the bedrock, which initially tends to occur in the tensile zones, but fractures can also occur due to buckling of the surface beds in the compressive zones. Because of the difficulties in predicting surface cracking, instead of providing site specific crack width predictions, areas of cracking and severity of cracking can be assessed based on the general geological profiles and zones of the predicted subsidence parameters.

As subsidence occurs, surface cracks will generally appear in the tensile zone, i.e. within 0.1 to 0.4 times the depth of cover from the longwall perimeters. Most of the cracks will occur within a radius of approximately 0.1 times the depth of cover from the longwall perimeters. The cracks will generally be parallel to the longitudinal edges of the longwalls (except at the ends where they follow the contours of subsidence).

At shallow depths of cover, it is also likely that transient surface cracks will occur above and parallel to the moving extraction face, i.e. at right angles to the longitudinal edges of the longwall, as the subsidence trough develops. This cracking, however, tends to be transient, since the tensile phase of the travelling wave, which causes the cracks to open up, is generally followed by a compressive phase, which partially recloses them. It has been observed in the past, however, that shearing also occurs and the surface cracks which are opened during the tensile phase of the travelling wave cannot fully close during the compressive phase, and can result in formation of compressive ridges at the surface.

The incidence of surface cracking is dependent on the location relative to the extracted longwall goaf 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 main factors contributing to surface cracking would be the depth of cover to the extracted seam, the thickness and characteristics of the surface strata layer, the magnitude of the mining induced subsidence, the presence of pre-existing joints or faults and surface topography changes. Shearing cracks are usually observed at very shallow depths and localised shearing cracks through thin surface strata layers are commonly observed in the beds of valley floors. Many of the observed mining induced surface cracks are located within the areas of highest mining induced tensile stress which indicates that the mining induced bending curvature is a principal cause. Hence it is concluded that the observed surface cracks are formed through a combination of several mechanisms and factors, with the depth of cover determining which mechanism predominates. The largest surface crack widths and step heights are expected to occur where the predicted ground strains are the greatest, in the locations of the shallowest depths of cover as well as in the locations of the natural joints.

At shallow depths of cover, i.e. approximately 200 metres or less, such as those which are present above the north eastern end side of Mine 1 and the eastern side of Mine 5, surface cracking and heaving can potentially occur in any location above the extracted longwalls. The larger and more permanent cracks, however, are usually located in the final tensile zones around the perimeters of the longwalls. Open fractures and heaving, however, can also occur due to the buckling of surface beds that are subject to compressive strains. An example of crack patterns that develop in shallow depths of cover is shown in Fig. 5.1 below.

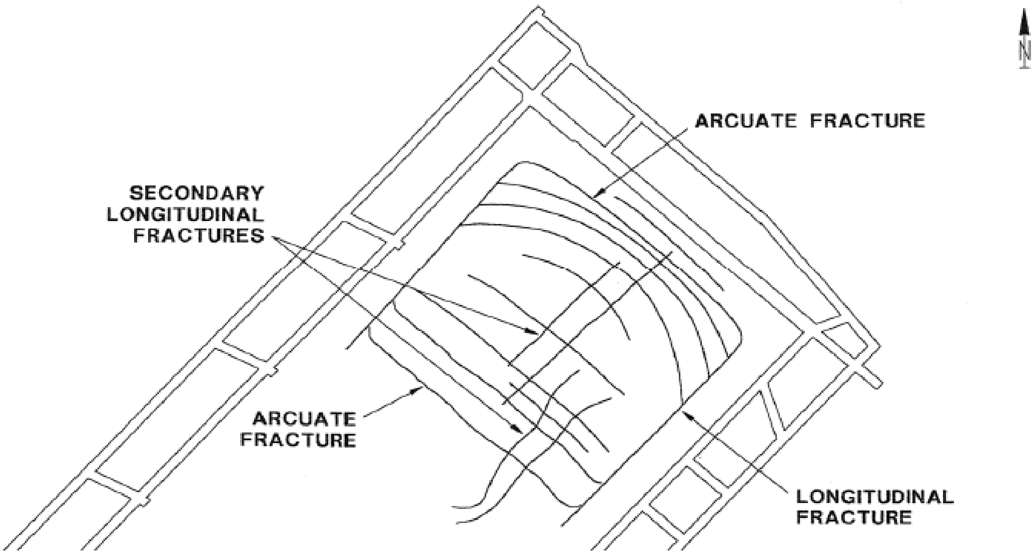


Fig. 5.1 Survey of Major Fracture Pattern at Approx. 110m Cover (Source: Klenowski, ACARP C5016, 2000)

Over previously mined longwalls, typical surface crack widths up to the order of 100 mm and step heights in the order of 100 mm have been commonly observed at shallow depths of cover, say less than 200 metres. Larger crack widths have been observed with shallow depths of cover where thicker seams are extracted, near steep terrain or where thick massive strata beams are present. These larger tensile cracks tend to be isolated and located around the perimeters of the longwalls and along the tops of steep slopes, due to down slope movements resulting from the extraction of the proposed longwalls. The typical surface cracks and these larger isolated cracks can normally be easily identified and remediated to prevent loss of surface water – Klenowski (ACARP C5016, 2000).

5.1.1. Observed Cracking

The following photographic records that were obtained from Longwall operations in the Bowen Basin provide guidelines to the nature and extent of cracking that might occur above the proposed longwalls at the Carmichael Project.

Fig. 5.2 Very large crack above longwall commencing at approx. 180 m cover, where the surface crack has been eroded by water

Fig. 5.3 Step in ground across longwall centreline at approx. 180 m cover

Fig. 5.4 Large crack and possible step across longwall centreline (crack appears to have been eroded)

Fig. 5.5 Series of long cracks along longwall tailgate at approx. 250m cover

Fig. 5.6 Typical crack along longwall commencing at approx. 300m cover

Fig. 5.7 Typical crack along Longwall commencing end at approx. 300m cover

5.1.2. Observations of Surface Cracking in NSW at higher depths of cover and within multi-seam mining

Experience in NSW and Queensland has found that the severity and frequency of surface cracking reduces as the depth of cover to the extraction increases.

Most of the mining-induced surface cracking that is observed in NSW occurs where the depths of cover are less than 200 metres. Mining at depths of cover greater than about 400 metres in NSW results in few surface cracks being observed, and in plateau areas away from valleys, easily repaired surface cracking can occur in isolated locations only, as shown in Fig. 5.8.

Localised cracking is often observed in exposed bedrock areas within valley floor areas in NSW. At the Carmichael Project, however, the beds of the creeks and rivers above the proposed longwalls consist of deep alluvial beds and the type of cracks that are observed in bedrock in NSW are not expected.

Cracking is expected to occur within the banks and beds of the undermined watercourses at Carmichael Project and these cracks are prone to erosion if they are not repaired. Please refer to other reports in the EIS for the project on mitigation and remediation plans for mining beneath the major watercourses.

Fig. 5.8 Photographs of Surface Cracking on sides of steep sloping areas in the NSW Southern Coalfield with greater than 400 metres cover

Fig. 5.9 Photographs of Surface Cracking above multi-seam longwall extraction in the Hunter Coalfield around 200m cover

5.1.3. Potential surface cracking at Carmichael Project

It has been observed that the severity and frequency of cracking is generally greater where the depth of cover is shallow and when panel widths are increased.

The surface cracking observations obtained from other collieries were used to correlate observed cracking with mining induced hogging curvature. The predicted final mining-induced hogging curvature after the mining of all previously extracted longwalls was chosen for the correlation as it shows how the ground bends into the centre of the longwall panel. Curvature is a good indicator for surface cracking as zones of tensile strains are commonly found where hogging curvature occurs.

Predicted final hogging curvatures after the mining of the proposed longwalls in the AB1 seam at the Carmichael Project are shown in Fig. 5.10 and predicted additional final hogging curvatures after the mining of the proposed longwalls in the D1 seam are shown in Fig. 5.11. The colour scale demonstrates the variation in the magnitude of predicted curvature above the panels due to varying depths of cover and panel width. The same colour scale has been used in both figures to allow a direct comparison to be made. The variations in predicted hogging curvature are due to the changing depths of cover. In addition to the plotted final curvature contours, it should be noted that as the longwall face travels along each panel, a travelling transient curvature wave is applied along the panel that subjects the central areas of the panel to travelling curvatures that are of similar magnitudes as the plotted final curvatures. For reasons of clarity, predicted travelling or transient tensile strains that develop as each longwall travels from one end to the other have not been shown. Predicted sagging curvatures, where compressive buckling may occur, have also not been shown.

There is limited data available on the depth of surface tensile cracking. It is believed that the depth of cracking is a function of the mechanisms that are causing the tensile and shearing stresses, i.e. whether the surface cracking is being caused by the shearing stresses in shallow depths of cover, local variations of geology – particularly the presence of natural jointing, faulting and dykes, mining induced curvatures, release of in-situ horizontal stresses, downslope movements or valley related movements.

In many cases researchers have excavated downwards at observed surface cracks to assess how deep the cracks extend. From the surface most of the observed cracks generally are thicker on the surface and taper down to thinner widths with depth. This may suggest that these cracks were formed by mining induced bending curvature rather than shearing which usually results in a uniform crack thickness. Where bending is the main mechanism, the surface cracks will extend down to approximately the depth of the neutral axis of the surface strata layer. That is the depths of these surface cracks will vary from place to place depending on the thickness of the top surface strata layer.

Available literature suggests surface cracking depths in areas of hogging curvature can extend to depths in the order of 5 to 10 metres but greater depths may occur depending on the geological setting, the depths of cover and the mine subsidence parameters.

It is recommended that visual monitoring be carried out during the mining period to assess the degree of surface cracking and to coordinate remediation works as needed. Please refer to advice in the EIS for the surface cracking rehabilitation plan.

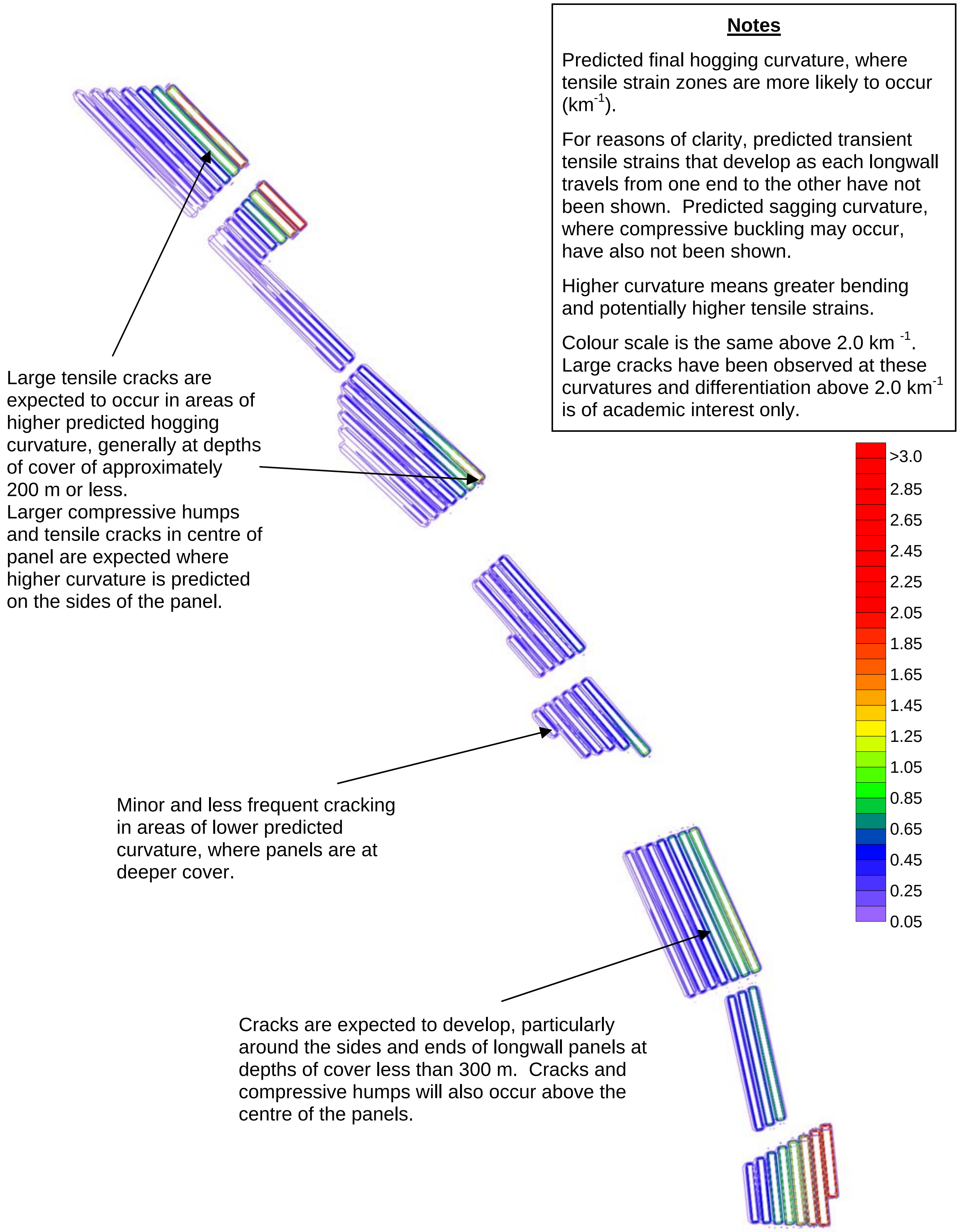


Fig. 5.10 Predicted final hogging curvatures (km^{-1}) due to the mining of all longwalls in the AB1 seam, accompanied by comments on potential for surface cracks

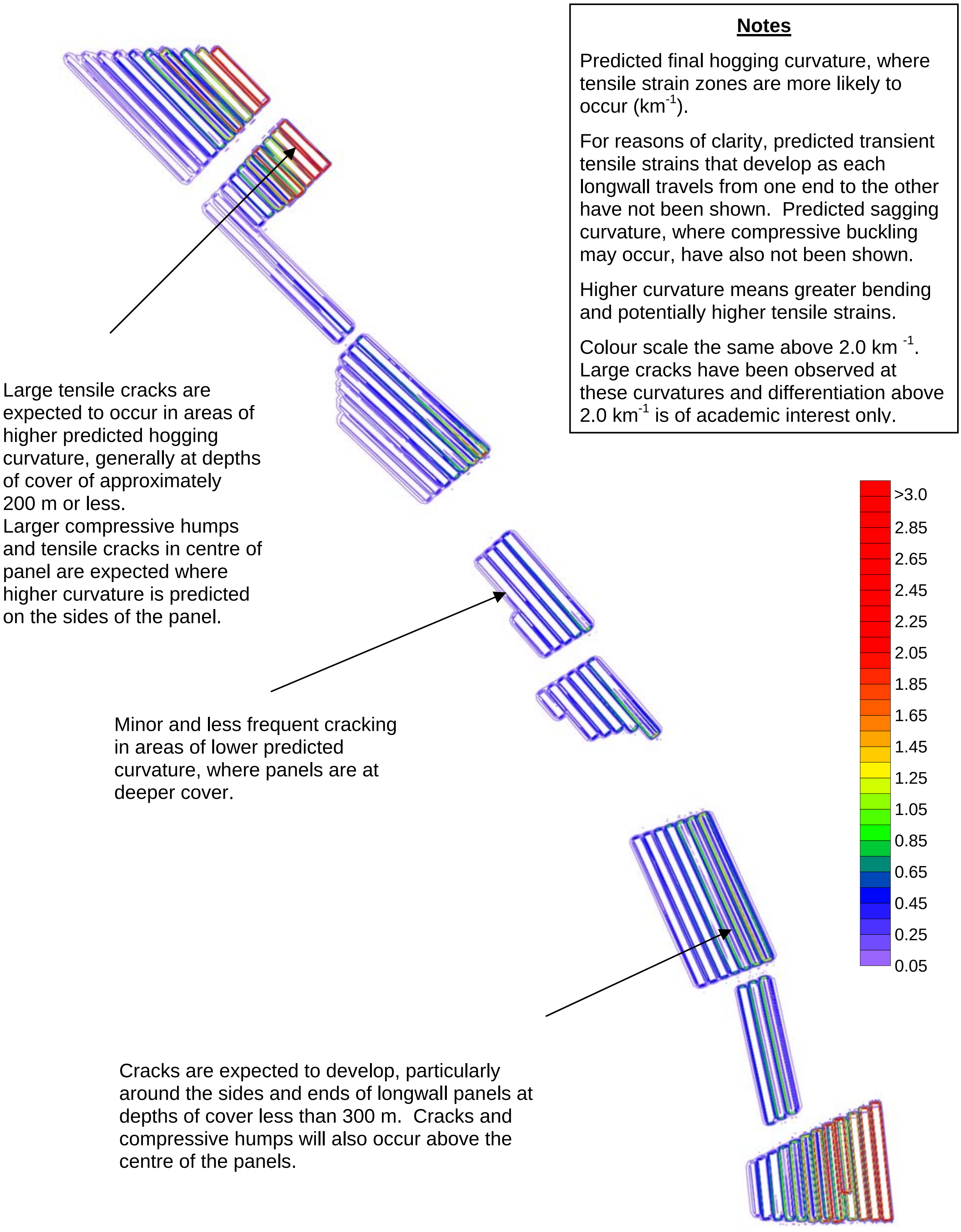


Fig. 5.11 Predicted additional final hogging curvatures (km^{-1}) due to the mining of all longwalls in the AB1 and D1 seams, accompanied by comments on potential for surface cracks

5.2. Mining Induced Sub-Surface Cracking and Effects of Cracking

5.2.1. General Background to Sub-Surface Cracking

The underground extraction of coal panels can induce vertical and horizontal mine subsidence ground movements, bedding plane separation, vertical shearing, fractures and breakages of the overlying strata, which can potentially impact on surface water and groundwater resources that are present before the coal is extracted. The extent of the mining induced strata deformation, the associated fracturing and the geology of the strata layers will dictate the effect of mining on the surface water bodies and on the aquifers.

The proposed longwall mining at the project will result in mine subsidence, bedding plane separation, shearing and additional surface cracking both at the surface and within the sub surface strata units. The extent and severity of these mining induced ground deformations will vary across the project area depending on a number of factors, including:

- depths of cover;
- widths of the longwall panels and pillars;
- extracted seam thicknesses;
- the presence of previously extracted panels;
- strata layer thicknesses;
- geology of the strata layers;
- presence of near surface geological structures;
- locations of natural jointing within the units; and
- the presence of valleys and steep surface topography.

There have been cases where mine subsidence ground movements have caused extensive cracking within watercourses at depths of cover of less than 200 metres, resulting in surface water being captured and flowing into mine workings. If the flows into the mine are small and the mine pumps can cope, then, this additional water may only be an operational problem for the mine, but, the loss of this water can seriously impact on the surface environment and the flora and fauna that are dependent on the surface and groundwater resource. There have also been instances where water from the overlying surface waters or from sub surface aquifers have drained into mines where the depths of cover above the coal seams were more than 200 metres causing closure of these mines. In contrast there are also many documented reports of successful mining under oceans, seas, lakes, dams, ponds, rivers and creeks with less than 100 metres depth of cover without any water draining into the mine.

Hence mining impacts on surface and ground water bodies are variable and, rather than assuming the best or the worst conditions, it is important to appreciate the circumstances applying to each of these cases and to understand when surface water and groundwater may connect with the mine.

The extent, severity and manner of impacts of mining on surface water resources vary between different coal mines because every situation is different. Each stream is unique in terms of its characteristics, which include flow conditions, water quality, gradients, valley depths and degree of incision, sediment and nutrient load, ecosystems, bedrock mineralogy and geomorphology.

The nature and extent of mining beneath or near these streams also varies considerably in terms of the proximity of the extraction to the stream, the size and thickness of the extraction and the depth of cover. The specific geology of each case should be closely considered as the presence or absence of strong channels or impermeable layers completely changes generalisations based on panel width or seam thickness. The complexity of factors involved requires impact assessments for mining applications near streams to be undertaken on a case by case basis by geologists, subsidence engineers, surface and ground water hydrologists.

5.2.2. Review of Literature on Mining Induced Sub-Surface Cracking and Cracking Zones

A considerable amount of mining, including longwall mining, has been undertaken over the last two centuries beneath the oceans, seas, lakes, dams, rivers, creeks and streams in Australia. The issue of hydraulic connections between the surface water bodies and the mine workings has been the subject of several inquiries and strategic reviews commissioned by State Governments (including; Wardell 1975, Reynolds 1977, Southern Coalfield NSW DoP July 2008 and Wyong NSW DoP July 2008).

Engineers, surveyors, geologists and groundwater hydrologists have published many papers on the effects of mine subsidence on surface water and groundwater resources. Varying opinions have been published regarding which subsidence parameter most influences the observed impacts, how best to determine the likely impacts of mining on water resources, and the choice of which computer programmes should be utilised in these studies. Despite these varying opinions, some basic understandings have been developing in this field and a summary of what is felt to be the important points is presented below.

The following sketch shown in Fig. 5.12, which was provided to the Wyong Strategic Review Inquiry by Wallarah Coal, illustrates the nature of cracking and the possible influence of mining for a single longwall panel. In this sketch it is shown that mining can cause cracking from the seam level up to the surface, however, above a fractured, highly connected and depressurised zone, there can be, depending on various factors, a constrained zone in which there can be disconnected cracking, increased horizontal permeability and bedding plane shear, but with negligible changes to the vertical permeability of the strata.

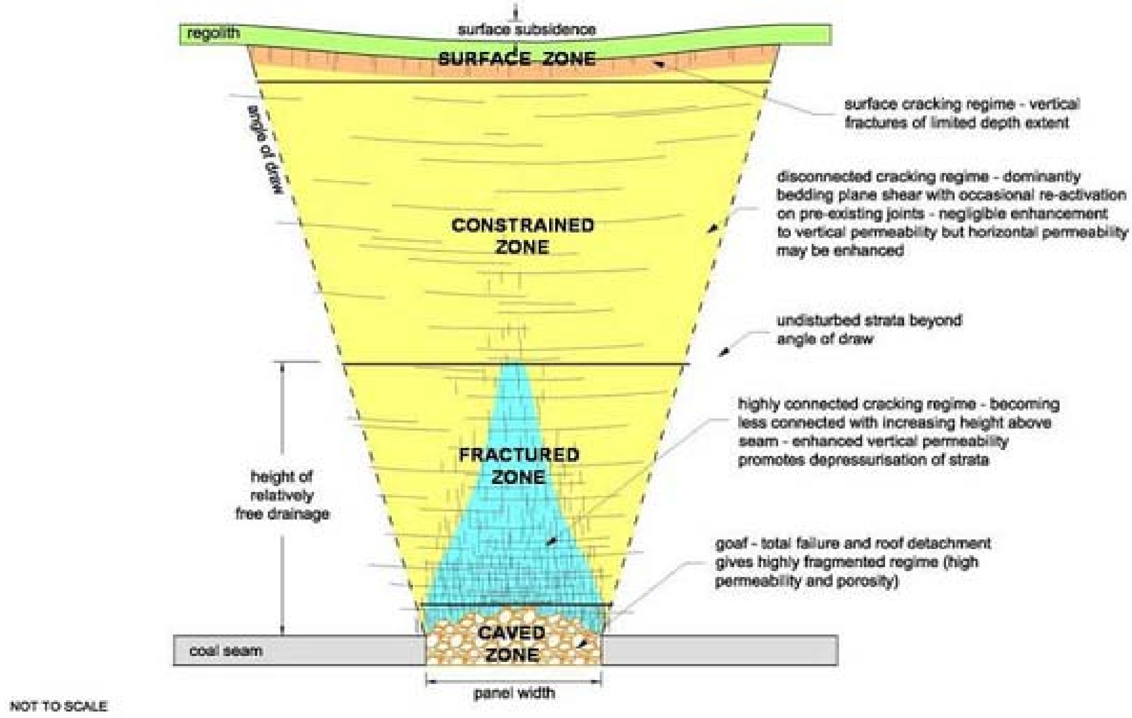


Fig. 5.12 Conceptual Model of Caving and the Nature of Fracturing above a Mine Excavation (Source: Adapted from Wyong Areas Coal Joint Venture)

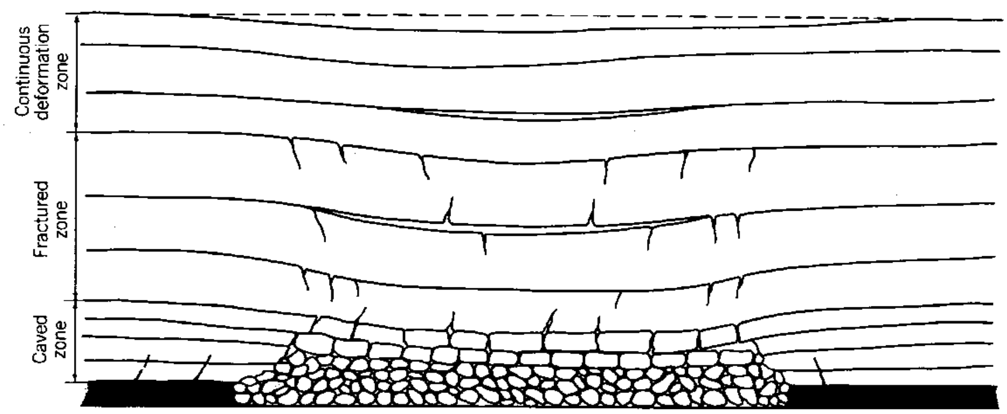


Fig. 5.13 Zones in the Overburden According to Peng and Chiang (1984)

Many researchers have investigated and reported on the influence of underground mining on water bodies and on aquifers that are affected by mining. A common approach in these studies is to divide the strata above the longwall into a number of zones, as shown in Fig. 5.13, with different deformation characteristics, in order to explain the various observed findings. This approach is good, but, the difficulty comes when one tries to assign "typical" extents of the various zones, as this is dependent on many variables.

5.2.3. Review of Literature on Height of Fracturing versus Height of Hydraulically Connected Fractures

The height of the free draining fractured zone is not equal to the height to the top of the highest observed mining induced fracture alone as some of the fractures higher up in the sequence may not be connected or do not drain to the mined void.

The height above the seam of the relatively free draining fractured zone is an important issue and it appears to be dependent on many factors, most notably including; the longwall panel width, the seam thickness extracted, the thicknesses and geomechanical properties of the overlying strata units, the presence of faults and natural jointing, the presence of layers of clay, claystone, shale, siltstone, mudstone, tuff and tuffaceous horizons that can restrict the vertical flow of groundwater, and, where very wide supercritical panels are being extracted, the bulking and compaction factors of the goafed material.

The height of free draining fractured zone cannot be definitively measured using borehole extensometers alone as significant bed separation, vertical dilation and increased horizontal permeability can occur above certain strata layers even though there has been no change to the vertical permeability below these layers towards the mine void.

The height of fracturing cannot be definitively determined after comparing borehole piezometers and permeability testing at selected horizons before and after mining alone either as significant bed separation, vertical dilation and increased horizontal permeability can occur above certain strata layers even though there is no change to the vertical permeability below these layers towards the mine void.

Instead of just having a borehole extensometer or just having borehole piezometers and permeability testing, it appears that it is best to have pre-mining groundwater condition information over a long period, a borehole sub-surface strata extensometer, and post mining permeability and piezometric level measurements when assessing the mining induced heights of fracturing. Usually researchers find cases where either a sub-surface strata extensometer was used or cases where piezometric level measurements or cases where pre-mining and post mining permeability testing was undertaken. There are few cases in the published literature where all this data is available for a site.

Seedsman & Dawkins (ACARP C13009, 2006) advise that an early empirical hydrogeological model for strata above longwalls was developed by Kendorski et al (1979) and the zones were defined by ratios of height to extraction thickness as shown in Table 5.1. Earlier work on heights of fracturing and effects on surface and groundwater was also published by Orchard and Wardell in terms of the seam thickness extracted. Holla reported on various sub-surface strata extensometer investigations including some permeability testing and Holla reported all his results in terms of the extracted seam height.

Table 5.1 Definition of Hydrogeological Zones

	Height above seam (normalized to extraction thickness	Definition
Constrained zone	> 60 t	No change in hydrogeological conditions
Dilated zone	60 t	Sagging of beds, no failure, opening of bedding surface leading to increased storativity.
Fractured zone	24t - 30t	Strata crack and settle. Fractures through individual beds, opening of bedding planes, shearing and dislocation of beds.
Caved zone	6t - 10 t	Strata fall and detach, complete disruption, broken and rubble-ized strata

Seedsman & Dawkins (ACARP C13009, 2006) advised that the Kendorski model was compatible with the inflow history from the German Creek and Oaky Creek Mines as published by Klenowski (ACARP C5016, 2000) and the Kendorski model has also been applied to the NSW Newcastle coal measures, where the overburden geologies are dominated by the presence of massive conglomerates, by Forster and Enever (1992).

An extensive groundwater testing program was conducted by Forster and Enever (1992) in the Lake Macquarie region of NSW, i.e. just south of Newcastle, which resulted in the development of a practical hydro-geological model of subsurface behaviour zones specific to this area. Forster and Enever (1992) produced the hydro-geological model, which was based on ratios of zone heights to extraction thicknesses, for supercritical longwall panels in the Great Northern Seam which has been reproduced as Fig. 5.14.

Interestingly the original model was principally based on the results from three boreholes, two at the Wyee Mine and one at Cooranbong Colliery, where the panels were very wide with high levels of subsidence. The observed heights of fracturing at the three sites were 63 metres, 40 metres and 58 metres respectively. The determination of height of fracturing was based on various geological and geotechnical evaluations of this region together with many other local permeability and piezometric tests.

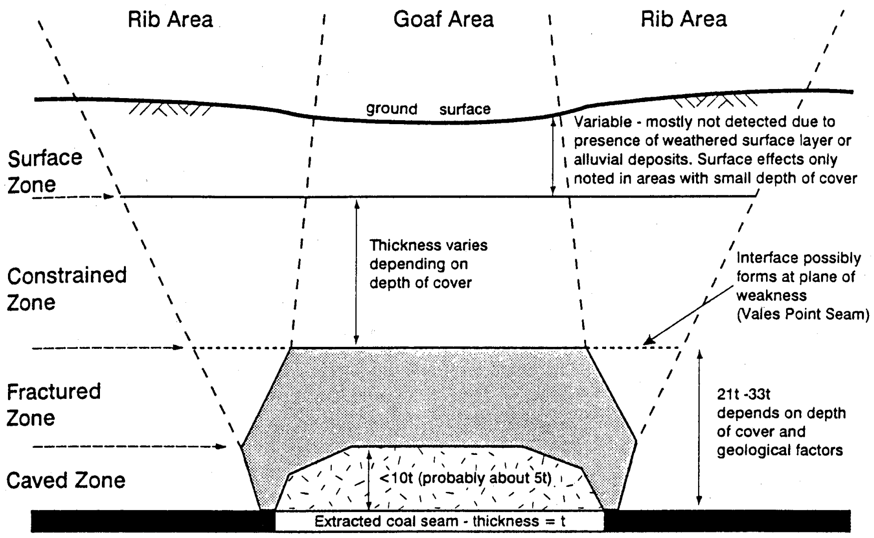


Fig. 5.14 Zones in the Overburden according to Forster (1995)

It has been subsequently deduced that the relatively low heights of fracturing in this Central Coast region of NSW, compared to other geological regions, is predominantly due to two factors, that is, the consistent presence of the strong and massive strata beams within the overburden that limit subsidence movements plus, very importantly, the presence of numerous reported layers of clay, claystone, shale, siltstone, tuff and tuffaceous horizons, between these stronger strata channels that can restrict the vertical flow of groundwater.

Forster and Enever (1992) did flag that it is not sufficient to create a constrained zone above mine workings but that this zone must also have a low natural permeability and/or contain beds of low permeable strata for it to function as a hydraulic barrier between the surface and the mine workings. The same conclusion was suggested to Mr Justice Reynolds, refer to Reynolds (1977), i.e. that the mine plans should limit panel widths to one third the depth of cover under stored waters so that the height of connective fracturing within a goaf should not go up more than one third the depth of cover and, as long as there were aquicludes or aquitards within the middle constrained zone or the surface one third of the depth of cover then loss of water from the dams should be minimal.

Exploration and instrumentation boreholes have revealed that some of the claystones and tuffs in the NSW Newcastle and Southern Coalfields have a high propensity to swell significantly and that the floor sediments of the coastal lakes can include clay rich material. The role that these materials may have played in producing successful outcomes also needs to be borne in mind.

A further extensive analysis of surface and sub-surface subsidence, cracking and groundwater data from the Newcastle region was undertaken by Ditton & Frith (ACARP C5016, 2003) and these authors developed a sub-surface fracturing model that was based predominantly on work published by Whittaker and Reddish (1989), see Fig. 5.15 below.

The Whittaker and Reddish model was developed in response to the water ingress problems associated with early longwall extraction at the Wistow Mine in Selby, UK where a longwall panel was located at 350 metres depth and experienced groundwater inflows of 121 to 136 litres/sec when sub-surface fracturing intersected a limestone aquifer that was 77 metres above the seam. This model identified the existence of two distinct zones of fracturing above super-critical width extractions (*continuous* and *discontinuous* fracturing).

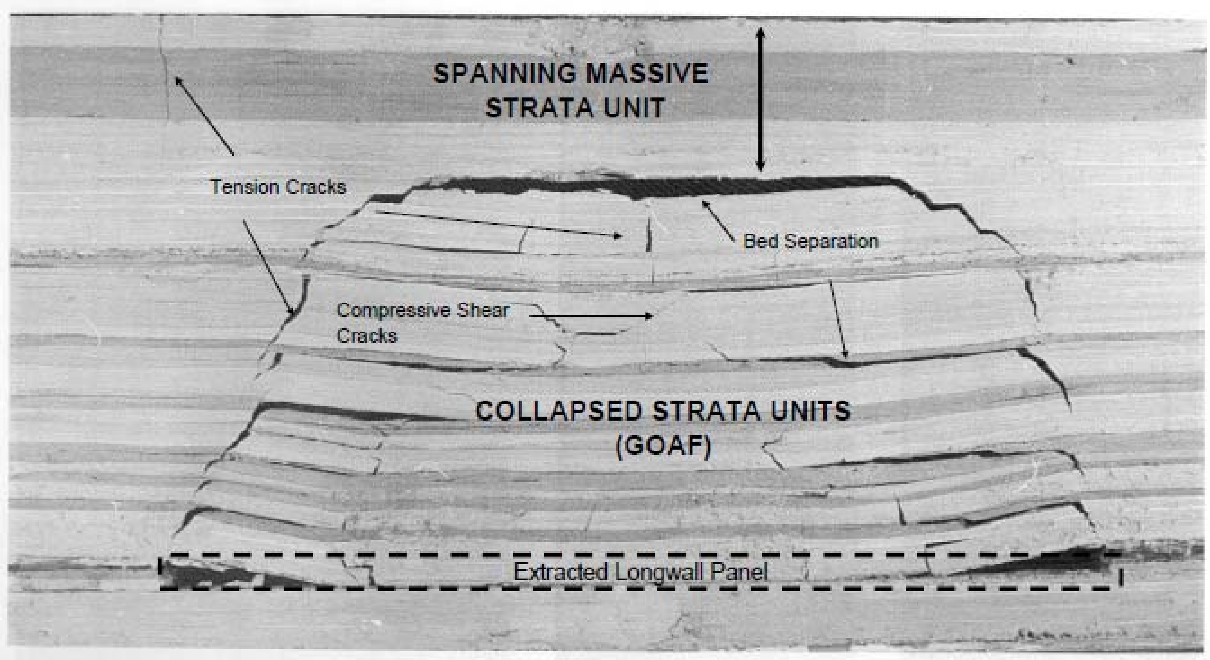


Figure 237 Physical model of caved strata above longwall extraction with strong overburden. Mining data: h = 84m; w = 118m; M = 4m.

Fig. 5.15 Overburden behaviour with strong massive units Whittaker & Reddish (1989)

The definition of the extent of *continuous* fracturing that was used in the Whittaker and Reddish model refers to the height at which a direct connection of the fractures occurs within the overburden and the workings; it represents a direct hydraulic connection for groundwater inflows. The height is very different to the potential height of fracturing which can extend higher, but, within which the remote fractures and cracks are not connected.

The definition of the extent of *discontinuous* fracturing refers to the height at which the horizontal permeability increases as a result of strata de-lamination and fracturing, i.e. a slight temporary reduction in head without full water loss or direct connections to the workings.

Most of the fracturing in the Whittaker and Reddish modelling was observed to occur close to the rib-side only as the fracturing in the overburden above the middle portion of the panel tended to close and did not appear to represent an area in which groundwater inflows into the workings would be generated.

Ditton & Frith (ACARP C5016, 2003) developed their height of fracturing model based on the following data in their Table 5.2 which they advised was derived from previously published literature.

Table 5.2 Predicted Tensile Strains and Sub-Surface Fracturing Data

Mine No. (refer to Appendix D for Mine details)	W (m)	H (m)	T (m)	S_{max} (m)	Predicted Smooth Profile Strain, E_{max} (mm/m)	a* (m)	b* (m)	A (a/H) (m)	B (b/H) (m)	a/T	S_{max}/W^2 **
1-NSW	170	185	2.0	0.99	2.8	63	163	0.34	0.88	31.5	0.034
2-NSW	250	210	3.1	1.9	2.5	40	170	0.20	0.85	12.5	0.030
3-NSW	105	75	2.8	1.27	9.4	58	64	0.77	0.85	20.7	0.115
4- QLD	205	132	2.4	1.28	3.1	21	117	0.16	0.89	8.9	0.038
5- QLD	200	142	2.8	1.40	2.9	18	127	0.13	0.89	6.4	0.035
6- QLD	205	95	3.2	1.86	9.4	55	85	0.58	0.89	17.2	0.099
7-NSW	150	350	2.7	0.28	1.0	n/m	150	n/m	0.43	n/m	0.018

Note : *- a = Distance to total drilling fluid loss above workings.
*- b = Distance to partial drilling fluid loss above workings.
**- S_{max}/W^2 = a new robust term (i.e. Overburden Curvature Index) to plot A and B against instead of tensile strain (see below for further explanation).
n/m – not measured as drilling terminated before depth was reached.

From the table above it can be seen that the highest fracturing height used in developing this Ditton & Frith (ACARP C5016, 2003) model was 63 metres above the mined seam which is less than fracture heights advised in many other published reports. For example, as listed in Table 5.3, higher fracturing heights were noted in Klenowski (ACARP C5016, 2000) for varying inflow rates into various Queensland mines. Flows varied from 140 l/sec at

70 metres cover depth to 2 l/sec at 175 metres cover depth. There is a trend of generally regular decrease in flow rate with increasing depth of cover up to 175 metres depths of cover.

Table 5.3 Maximum Recorded Inflow Rates into Longwall Mines with Increasing Cover Depths

LOCATION	DEPTH OF COVER (m)	INFLOW RATE (l/sec)	COMMENTS
Southern Colliery	70	140	
Oaky No. 1 Underground Mine	100	83	
Southern Colliery	105	50	Flooded highwall mining entries
Southern Colliery	120	45	
Southern Colliery	140	27	
Oaky No. 1 Underground Mine	150	6	
Southern Colliery	160	30	Permian rock in creek bed
Oaky No. 1 Underground Mine	160	9	
Oaky No. 1 Underground Mine	175	2	

Inflow rates from ponded water are largely a function of the amount of subsidence induced tensile strain at the base of the pond. In the case of overlying aquifers, inflow rate is a function of the amount of subsidence induced tensile strain at the base of the aquifer and the permeability of the aquifer, as drawdown occurs.

The suggested guidelines below that were included in Klenowski (ACARP C5016, 2000) apply to geotechnical environments similar to those at the Oaky Creek and German Creek Mines, with Permian rock extending from the base of the ponded water to the mining horizon. In the case of soft, plastic Permian overburden or the presence of a pond floor layer of low permeability, cohesionless alluvium in which subsidence cracks self-heal, less conservative guidelines could possibly be adopted, but only after thorough geotechnical investigations.

Klenowski (ACARP C5016, 2000) stated that for ponded water at cover depths of greater than 160 metres, remedial works will generally not be required and standard underground pumping systems should be capable of handling minor increases in flow. This is a very useful consideration for the Carmichael Project as few areas over the proposed longwalls are shallower than 160 metres.

For ponded water at cover depths ranging from 160 metres down to 120 metres, underground pumping systems should be capable of pumping a flow rate of at least 50 l/sec. For ponded water at cover depths ranging from 120 metres to 70 metres, flow rate increases from about 45 l/sec to 140 l/sec, and pre and post-subsidence remedial works are recommended, as well as the installation of large capacity, emergency, underground pumps. If pre-subsidence remedial works are not possible, underground pumping systems, capable of handling increased flows, need to be installed.

Experience has shown that it is extremely difficult to mine longwall coal when goaf water flow rates of greater than 20 l/sec occur along the face line. In such cases, dams and transportable pumping systems need to be installed in gate roads or sumps adjacent to gate roads. Where possible, mine designs should accommodate goaf water flows away from longwall faces.

While many authors seem to use seam thickness as the preferred mining parameter that influences cracking heights and dilation, such as Kendorski (1993), Forster and Enever (1992) and Ditton and Frith (ACARP C10023, 2003), many other authors have noted the importance of depth of cover, (Klenowski ACARP C5016, 2000), and others suggested that it is more logical to normalise measured fracture heights to panel width and not extraction thickness, e.g. Mills and O'Grady (1998) and Seedsman (ACARP C13009, 2006).

More recently, however, other authors such as Gale (ACARP C13013, 2008) advise that the height of the fractured zone is dependent on many factors including panel width and seam thickness, but, Gale prefers to relate the height of connective fracturing to the mining induced tensile strains and depths of cover and not to just one factor.

It has been highlighted that a thick and strong strata layer within the overburden may significantly reduce surface subsidence movements and sites with these strong strata beams would have differing heights of connective fracturing compared to sites without any strong or massive strata beams. Sites with a high number of claystone, shales and tuffaceous layers throughout the overburden, especially where these clay or tuff layers can swell and seal any minor fractures have exhibited far lower heights of connective fracturing compared to sites with mainly sandstone layers.

Accordingly, it is recognised that it may not be appropriate to use heights of cracking or connectivity models that were developed based solely on one factor, say seam thickness or geometry of the mined panel, especially if all the monitoring data was drawn from sites within one geological area, for use at other sites with differing geological conditions. It is generally considered preferable to first review the geological conditions at the site in question to assess which model would be appropriate.

While keeping the above general advice in mind, a theoretical height of a fractured zone (n.b. not necessarily with connective cracking and draining into the mine) can be approximated from the mining geometry alone, as being equal to the panel width (W) minus the span (w) divided by twice the tangent of the angle of break. This geometry only model is not proposed for general use, it is just proposed to show the influence of geometry, as illustrated in Fig. 5.16.

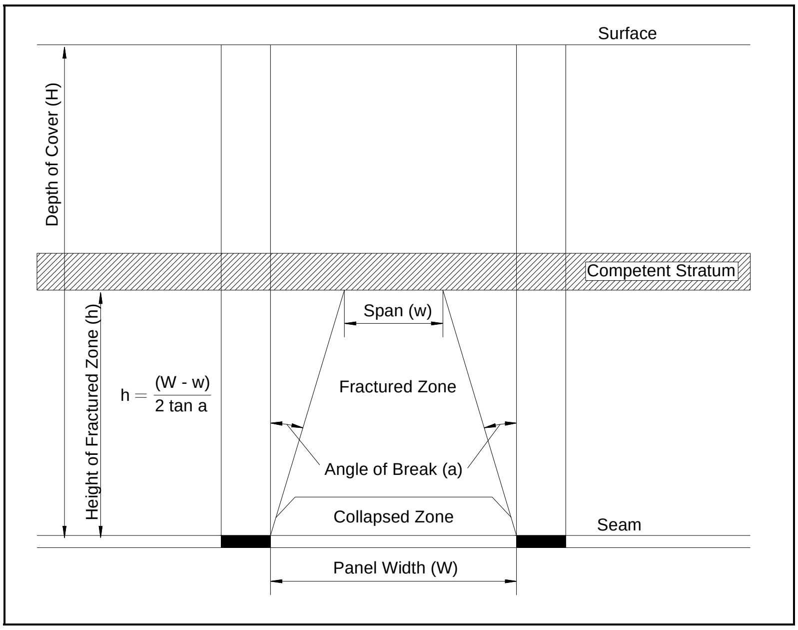


Fig. 5.16 Theoretical Model Illustrating the Development and Limit of the Fractured Zone using Geometry alone

MSEC has gathered observed borehole data on the observed fracture height of the connective draining zone sourced from a number of literature studies. The data points collected to date are shown in Fig. 5.17.

The data points are compared with the results of the theoretical geometry only model developed by MSEC, using an angle of break of 20 degrees and spanning width of 30 metres. The results are also compared with lines representing factors of 1.0 times and 1.5 times the panel width, which was suggested by Gale (ACARP C13013, 2008).

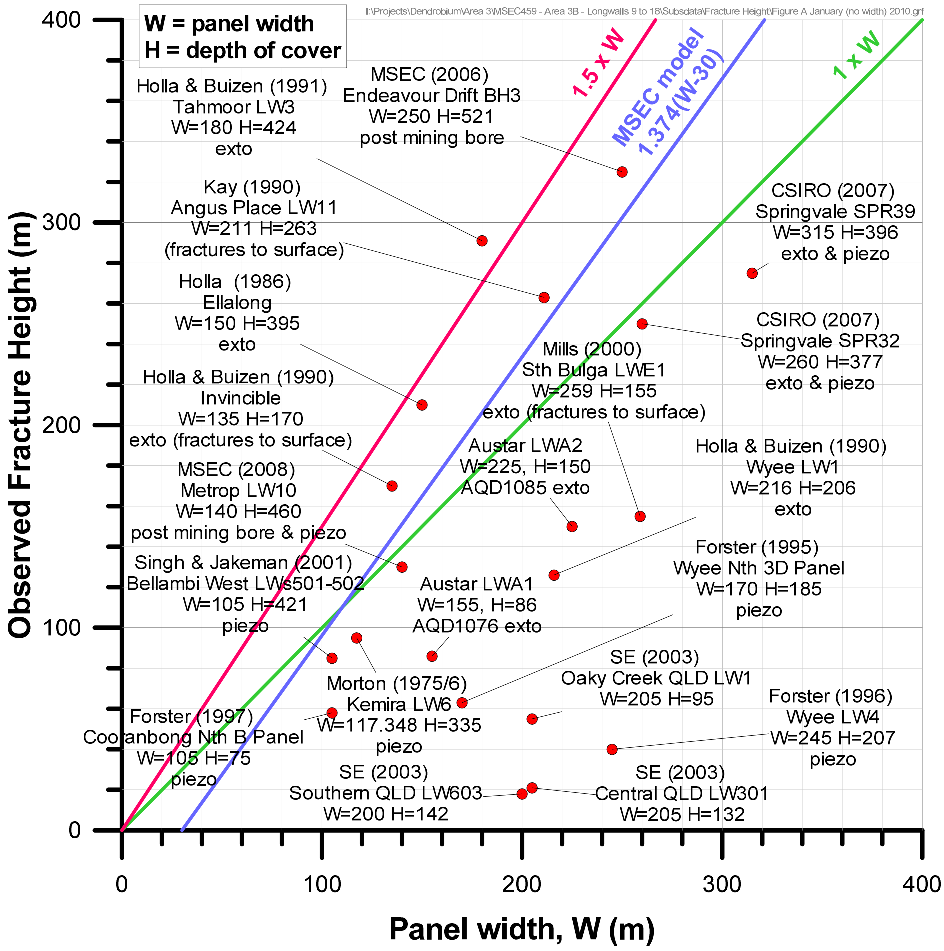


Fig. 5.17 Observed Fracture Heights versus Panel Width

It can be seen from Fig. 5.17, that the MSEC model and Gale's suggested factors of 1.0 and 1.5 provide reasonable but conservative estimates for the height of fracturing, for these available data points, but, it is accepted that both these models are generalisations and the MSEC model shown above, i.e. being based on geometry only, is not being proposed as a general model for predicting heights of fracturing or heights of hydraulically connected fracturing. It should be remembered, however, that this plot includes a wide variety of geological conditions that affect the results significantly.

It can be seen from Fig. 5.17 that the maximum panel void width is 315 metres, which is similar to the proposed panel void width of 310 metres for the Carmichael Project.

Wider panel widths of 410 metres have been extracted at Ulan Coal Mine in NSW, where the depth of cover ranges from 200 to 300 metres. The overburden strata at Ulan are predominantly sandstone with some siltstone on the top of some of the ridges and with some occasional basalt flows on some other ridges. The Environmental Assessment documents for the recently approved extension of mining at Ulan included groundwater reports that indicated that the mining induced cracking above the currently extracted 410 metre wide panels at Ulan extend up to the surface and that depressurisation of the Ulan seam, in combination with the subsidence cracking of the overlying strata from the coal seam, probably through to the surface, results in the eventual depressurisation and drainage of the saturated zone above the mine. This experience highlights the significant influence of overburden geology and panel widths on the heights of fracturing.

It is reiterated that the height of fracturing using the above MSEC model or Gale's suggested factors of 1.0 and 1.5 should not be interpreted as the height at which water loss will occur, since the heights in the database were not generally determined based on water loss, but on significant changes in vertical dilation. Gale (ACARP C13013, 2008) states that, "*Longwall mining creates additional fractures and changes the conductivity of pre-existing fractures. The height that mining related fractures may form has been established from monitoring and computational studies as being 1-1.5 times the panel width. However, the creation of these fractures alone does not necessarily imply that a direct hydraulic connection exists over this zone.*"

From the above discussions it can also be noted that previously published estimates of the height of the fracturing zone and the height of the hydraulically connected fractured zone varies widely between different studies at different locations, not only because of the varying influence of local geology, varying mined panel widths and varying depths of cover, but, also because of the method of measurement. However, it should be remembered that in some of these published cases this height of connective fracturing was determined based solely on measured sub-surface subsidence movements from borehole extensometer and, at other sites, the height of connective fracturing was determined solely from piezometer records and at other sites it was determined based on comparisons of permeability testing. In other words great care has to be taken when reading the available literature and in interpreting the published results. Ideally borehole extensometer measurements, permeability testing and piezometer records should be used to fully assess whether surface water and aquifer resources have been impacted by mining.

As this is a complex issue, MSEC understands that no simple equation can properly estimate the heights of the collapsed and fractured zones and a detailed thorough analysis should be undertaken.

Seam thickness was initially used as the factor in determining the height of fracturing for the early English models, which may be applicable for those conditions, but, the influence of seam thickness is minor for narrow panels where the strata bridges over strong chain pillars and for cases where there are extensive bed separations and voids within the goaf. The extracted seam thickness influences the height of fracturing for very wide total extraction panels as was observed in the Forster studies, but, wherever bridging occurs between chain pillars then seam thickness would be less relevant than the panel width. However where strong and massive channels bridge between the chain pillars then generalised rules using panel widths alone become less useful.

Gale (ACARP C13013, 2008) provides useful comments in assessing the likely impacts of longwall mining under water bodies. The following notes have been reproduced from this report as they represent a reasonable summary of the above discussions;

> *"In most instances, guidelines relate to inflows that would endanger underground personnel and operations. In more recent times, water inflow criteria for mines has been widened to include lesser inflows that may not impact on mine safety or operations, but have the potential to reduce water flow within streams and surface aquifers. For the purpose of this report the larger inflows relating to mining safety are defined as mine inflow and the lesser inflow relating to aquifer water loss as environmental inflow, but, guidelines can be prepared for lower values once the various government bodies specify the required environmental limits."*
>
> *"Longwall mining creates additional fractures and changes the conductivity of pre-existing fractures. The height that mining related fractures may form has been established from monitoring and computational studies as being 1-1.5 times the panel width. It is noted that the creation of these fractures alone does not necessarily imply that a direct hydraulic connection exists over this zone. In order for mine inflow to occur, the fractures created must form a connected and conductive network or zone to allow significant volumes of inflow."*
>
> *………" Overall, the data suggests that mine inflow (observed inflows) can occur for theoretical strain values above approximately 6mm/m and the severity of inflow increases as the strain increases. Strains above approximately 10mm/m are likely to be associated with significant inflow."*
>
> *"It was recognised that the empirical relationship"……"provides a broad qualitative overview of the likelihood for various levels of inflow. In order to obtain a better understanding of environmental inflow, quantification of the potential flow rates is necessary. This was achieved by estimating the hydraulic characteristics of the overburden above longwall panels over a wide range of subsidence values."*
>
> *"This was done utilising computer modelling of the overburden caving and subsidence behaviour for a range of depths and panel geometries. Back analysis of site data was also used and provided validation for the modelling outcomes."*
>
> *"Simulation of the fracture distribution and resultant hydraulic conductivity of the overburden was conducted to assess the impacts both above and adjacent to longwall panels. The impact of various levels of subsidence on the conductivity of the overburden and on the water profiles which may be maintained above the longwall panels was evaluated. Geological sections from the Hunter Valley and the Bowen Basin were modelled."*
>
> *"The modelled average conductivity correlated very well with the measured values and indicated that the modelling process had simulated the fracture and flow systems in the overburden above longwall panels, and provided a good estimate of conductivity."*
>
> *"Overall, the results indicate that the overburden above panels having theoretical tensile strains of 4mm/m has flow networks close to the in situ conductivity. This therefore provides a reasonable estimate for the onset of enhanced conductivity of the overburden."*
>
> *"It was noted that a hydraulic profile was maintained in the upper strata where the average conductivity was less than approximately 10^{-6} m/s. This indicates that flow in strata with an average conductivity less than 10^{-6} m/s is tortuous and may support a water table under the appropriate site conditions."*
>
> *"These results are summarised in Figure S1."*

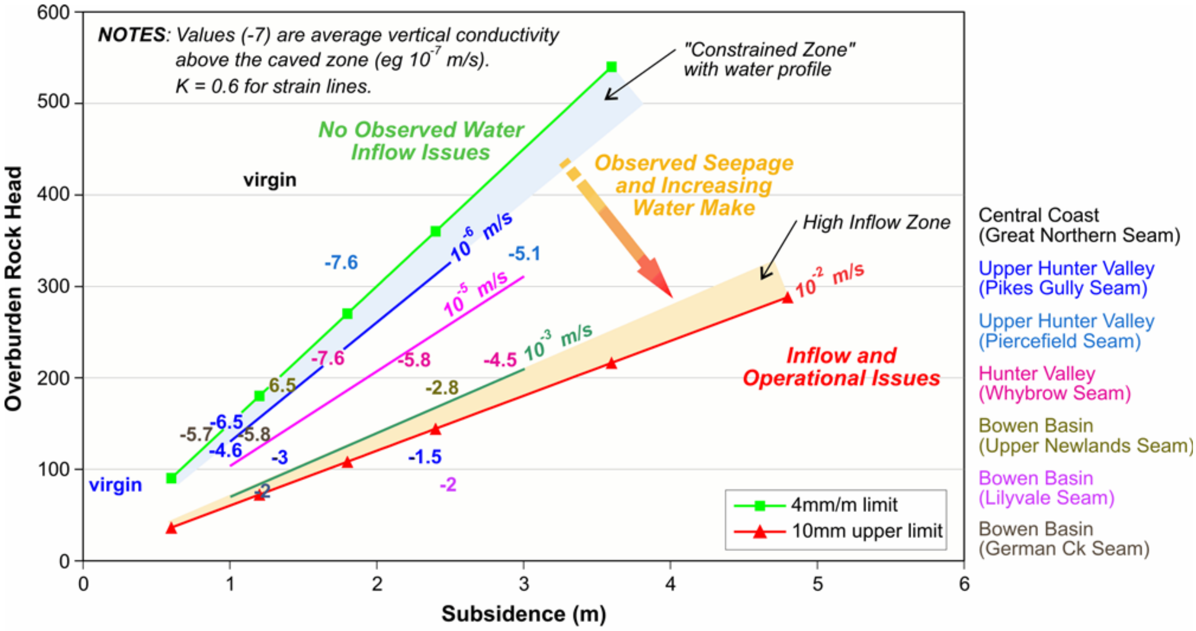


Figure S1 Average overburden conductivity characteristics relative to subsidence and depth criteria.

"In order to evaluate the potential inflow it is essential to assess the surface or aquifer conditions which would provide input into the fractured network as the nature of soils and surface topography may impact on the location and rate at which surface water may connect with the mining fractures."

"If a highly conductive fracture system above a longwall panel intersects a water saturated sand body, then the inflow rate of the system is typically controlled by the lesser conductivity of the sand and the overburden. If the fractures intersect open flowing water, then the full capacity of the fracture system will be utilised."

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

Many advances in the understanding of the issue have developed and a number of criteria have evolved over the years for assessing the likelihood of a hydraulic connection between the surface and mine workings, and the four principal ones are:

- ***Minimum Depths of Cover.*** For a given mining width, the severity of the observed subsidence impacts decreases with increasing depth of mining. Provided that the depth of mining is sufficient to support the development of a 'constrained zone', and this zone has suitable less permeable layers, i.e. aquitards or aquicludes, then surface water or groundwater are unlikely to drain into the mining excavation. (Some drainage of surface water may still occur, but, this water is likely to remain within the rocks of the 'surface zone'.)
- ***Maximum tensile strain on the surface.*** Early English studies indicated that water could be prevented from entering a mine if cracking of the surface was restricted by limiting the maximum tensile strain on the surface to between 5 mm/m and 10 mm/m, depending on the nature of the strata. It is recognised today that this rule fails to include allowance for the presence of an adequate aquitard or aquiclude layer and fails to adequately consider the behaviour of the strata in the constrained zone and hence is no longer widely used.
- ***Development of a constrained zone***. The recommendations of early government inquiries into mining under stored waters were based on development of a constrained zone and have been applied without incident at a number of sites. Panel widths were limited, say, to less than one third of the depth of cover so that a large constrained zone would result above the goafs in which it was believed that some less permeable materials could exist. The rule of thumb formulae may have been relevant at the sites being considered during those inquiries, however, checks need to be undertaken to ensure that adequate aquitard or aquiclude layers do exist above the fractured zone. Current mine planning still relies on this principle when mining directly beneath stored waters, but, we have moved away from adopting very narrow panels where field monitoring, field experience and advances in computer modelling show that wider panels can be utilised.

- ***Presence of an aquiclude or aquitard***, being a layer of highly impermeable material, such as shale, silt, clay or tuff. Experience in Australia and around the world indicates that if the right type and thickness of less permeable materials are present, unrestricted extraction may take place beneath water bodies without surface water finding its way into the workings. However if these less permeable materials are only present in the collapsed zone and highly fractured zone then these layers do not provide a seal against downward flowing water towards the mine void. Where none of these materials are present then much higher heights of connective fracturing can occur.

More recent studies have highlighted that generalised mine design recommendations should not be applied blindly and that careful consideration must always be given to site specific geology and geological features. The specific geology of each case should be closely considered as the presence or absence of strong channels or impermeable layers completely changes generalisations based on panel width or seam thickness.

It is therefore recommended that a detailed assessment by an appropriate specialist ground water consultant be undertaken at the appropriate stage to confirm, refine and further elaborate upon this preliminary assessment. One of the most important tasks of this specialist is to confirm the presence of an appropriate aquitard or aquiclude layer within the top portions of the overburden.

5.2.4. Height of fracturing and potential for hydraulic connectivity from surface water to seam at the Carmichael Project

The discussions below on the potential for hydraulic connectivity are general in nature and based on broad facts and observations that have been provided in published literature. It is reiterated that the potential for hydraulic connectivity is best undertaken on a case by case basis and it is recommended that a detailed assessment by an appropriate specialist ground water consultant be undertaken to confirm, refine and provide further details to this preliminary assessment.

The difficulty in assessing the likely height of fracturing and height of hydraulic connectivity at this project is that the geological setting for the Carmichael project is significantly different from the geological settings in almost all the published literature on subsidence, likely height of fracturing and height of hydraulic connectivity in Australia. The models published in literature have been developed for locations with predominantly sandstone overburden or using data from cases with significant sandstone overburden. The overburden at the Carmichael project predominantly includes the Rewan formation which is described as an aquitard in the GHD Hydrogeology Report (Nov 2012) and this formation is a base unit of the Great Artesian Basin. In addition, there are significant thicknesses of clay dominated materials in the tertiary age deposits.

It must be stressed that the anticipated height of fracturing does not imply that hydraulic connectivity will extend to the same height, especially since the overburden materials at the Carmichael Project contain significant thicknesses of clay, claystone, mudstone, siltstone and kaolinitic layers which behave as aquitards. Because of this geological profile, the predicted subsidence for this project is significantly greater than for normal sandstone dominated profiles. The overburden materials are not anticipated to bulk during goafing in the manner that sandstone dominated profiles do, resulting in greater subsidence, and heights of fracturing above extracted longwall panels, which could extend up higher than usually seen in sandstone dominated environments. However, because the overburden profile has a high presence of aquitard materials in the both the Rewan formation and tertiary sediments above the proposed longwalls, there is considered to be a low risk of direct hydraulic connection between the surface aquifers and extracted seams. The best anecdotal evidence of the ability of the overburden to prevent hydraulic connection from the surface to seam is at Cook Colliery, which has continued without any operational issues and has ponds formed in the subsided surface above the longwall panels. There is no data available from Cook Colliery however, in relation to fracture height assessments or permeability changes in the overburden.

A summary of the fracture zone models discussed in Section 5.2.3 and the application to the Carmichael Project is provided in Table 5.4. The results of these models are graphically represented in Fig. 5.18. It can be seen from Fig. 5.18 that the height of fracture zones and development of constrained/dilated zones based on seam thickness vary from approximately 85 metres to 120 metres. Given the geological setting and the greater predicted subsidence for the Carmichael project, it is uncertain that the fracture networks resulting from the extraction of the proposed longwalls would conform to the zones identified in the published literature. The study by Klenowski (ACARP C5016, 2000) is based on data from Oaky Creek and German Creek and suggests that remedial works are generally not required where depths of cover are greater than 160 metres.

Table 5.4 Predicted Height of Fracturing based on Published Literature

Model	Zones	Description	Height above extracted seam	Height above extracted seam at Carmichael Project (metres)
Wyong Strategic Review Inquiry (2008)	Surface Zone	Surface cracking regime – vertical fractures of limited depth extent	First 20m of the surface	20
	Constrained Zone	Disconnected cracking regime – dominantly bedding plane shear with occasional re-activation on pre-existing joints – negligible enhancement to vertical permeability but horizontal permeability may be enhanced	No information	-
	Fractured Zone	highly connected cracking regime – becoming less connected with increasing height above seam – enhanced vertical permeability promotes depressurisation of strata	No Information	-
	Caved Zone	goaf – total failure and roof detachment gives highly fragmented regime (high permeability and porosity)	3t to 10t	8 to 28
Seedsman & Dawkins (ACARP C13009, 2006) Kendorski et al (1979)	Constrained Zone	No Change in hydrogeological conditions	>60t	>165
	Dilated Zone	Sagging of beds, no failure, opening of bedding surface leading to increased storativity	60t	165
	Fractured Zone	Strata crack and settle. Fractures through individual beds, opening of bedding places, shearing and dislocation of beds	24t to 30t	66 to 83
	Caved Zone	Strata fall and detach, complete disruption, broken and rubble sized strata	6t to 10t	17 to 28
Forster (1995)	Surface Zone	Goaf Area: Horizontal compression, vertical tension, decreased vertical permeability. Rib Area: Horizontal tension, possible increased vertical permeability.	<15m thick	<15
	Constrained Zone	Goaf Area: Horizontal compression, vertical tension, no change in vertical permeability, likely increase in horizontal permeability. Rib Area: Horizontal tension, possible increased, vertical compression, some vertical permeability increase possible.	No information	
	Fractured Zone	Totally distressed, large increase in bulk permeability	21t to 33t	58 to 91
	Caved Zone	Loose caved blocks of rock	<10t	28
Guo et al (ACARP C14033, 2007)	Caving Zone	Average permeability predicted to increase by as much as 1000 to 2000 times	3t	8
	Fracture Zone	Increase of up to 50 times in vertical permeability	43t	120
	Constrained Zone	Increase of up to 2 times in vertical permeability	75t to 78t	206 to 215
	Elastic Zone	Increase of 3 to 5 times average permeability	97t to 101t	267 to 278
	Surface Zone	Increase of up to 10 times in vertical permeability		
Klenowski (ACARP C5016, 2000)		For ponded water at cover depths of greater than 160m, remedial works are generally not required and standard underground pumping systems are capable of handling minor increases in flow. For ponded water at cover depths ranging from 160m to120m, underground pumping systems should be capable of pumping a flow rate of at least 50 l/sec. For ponded water at cover depths ranging from 120m to 70m, flow rate increases from about 45 l/sec to 140 l/sec, and pre- and post-subsidence remedial works are recommended, as well as the installation of large capacity, emergency, underground pumps.		

t = extracted seam thickness / mining height

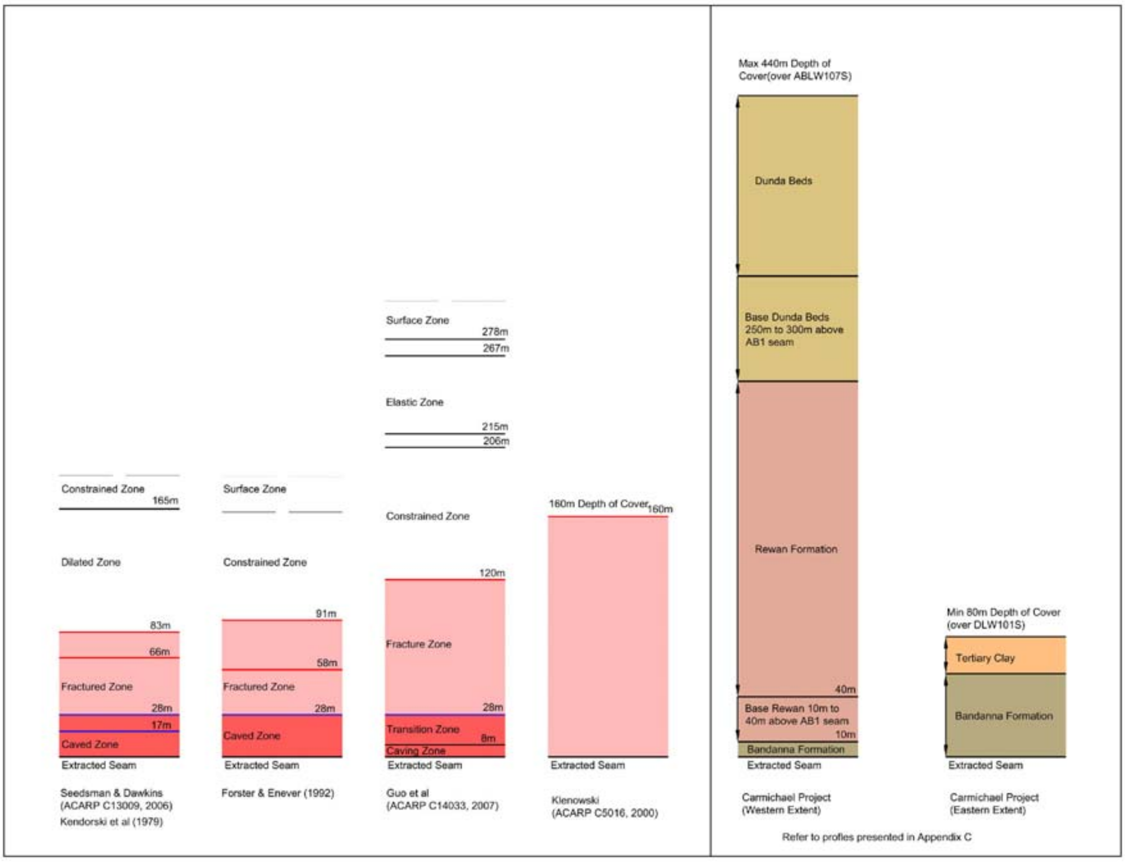


Fig. 5.18 Diagramatic Representation of Predicted Height of Fracturing based on Published Literature

The application of the model presented by Gale (ACARP C13013, 2008) for the Carmichael Project is summarised in Table 5.5 and presented graphically in Fig. 5.18. It can be seen from Table 5.5 and Fig. 5.18 that this model predicts inflow and operational issues towards the east of the Proposed Longwalls, particularly for Mine 1 and Mine 4 and 5, where depths of cover are less than about 240 metres. It should be noted that again, this model has been developed from sandstone dominated environments and the predicted subsidence and depth of cover for the Carmichael project are generally outside the range of the data used for developing the model.

Table 5.5 Average Overburden Conductivity Characteristics by Gale (ACARP C13013, 2008)

Prediction Line	Mine	Longwall	Predicted Maximum Total Subsidence at prediction line	Average Depth of Cover	Gale (2008) Average overburden conductivity characteristics based on Subsidence and depth Criteria
Prediction line 1	Mine 1 North	DLW101N	3100	120	>10^{-2} Inflow and Operational Issues
		DLW102N	3100	160	>10^{-2} Inflow and Operational Issues
		DLW103N	3000	200	10^{-3} to 10^{-2} High Inflow Zone
		ABLW101N	5300	160	>10^{-2} Inflow and Operational Issues
		ABLW102N	4800	210	>10^{-2} Inflow and Operational Issues
		ABLW103N	4200	260	>10^{-2} Inflow and Operational Issues
		ABLW104N	3600	300	10^{-4} Observed Seepage and Increasing Water Make
		ABLW105N	3400	330	10^{-5} Observed Seepage and Increasing Water Make
		ABLW106N	3100	370	10^{-5} to 10^{-6} Observed Seepage and Increasing Water Make
		ABLW107N	2600	400	<10^{-7} No observed Water Inflow Issues
Prediction line 2	Mine 1 South	DLW101S	3100	120	>10^{-2} Inflow and Operational Issues
		DLW102S	3100	160	>10^{-2} Inflow and Operational Issues
		DLW103S	3000	190	10^{-3} to 10^{-2} High Inflow Zone
		ABLW101S	5400	140	>10^{-2} Inflow and Operational Issues
		ABLW102S	5200	180	>10^{-2} Inflow and Operational Issues
		ABLW103S	4700	220	>10^{-2} Inflow and Operational Issues
		ABLW104S	4100	270	10^{-3} to 10^{-2} High Inflow Zone

Prediction Line	Mine	Longwall	Predicted Maximum Total Subsidence at prediction line	Average Depth of Cover	Gale (2008) Average overburden conductivity characteristics based on Subsidence and depth Criteria
		ABLW105S	3300	320	10^{-5} Observed Seepage and Increasing Water Make
		ABLW106S	3000	370	10^{-5} to 10^{-6} Observed Seepage and Increasing Water Make
		ABLW107S	2600	410	<10^{-7} No observed Water Inflow Issues
Prediction line 3	Mine 1 South	ABLW106S	3600	370	10^{-5} Observed Seepage and Increasing Water Make
		ABLW107S	3500	400	10^{-5} to 10^{-6} Observed Seepage and Increasing Water Make
Prediction line 4	Mine 2	ABLW201	4500	220	>10^{-2} Inflow and Operational Issues
		ABLW202	4200	240	>10^{-2} Inflow and Operational Issues
		ABLW203	3700	290	10^{-3} to 10^{-4} Observed Seepage and Increasing Water Make
		ABLW204	3300	320	10^{-4} Observed Seepage and Increasing Water Make
		ABLW205	3200	350	10^{-5} Observed Seepage and Increasing Water Make
		ABLW206	3100	380	10^{-5} to 10^{-6} Observed Seepage and Increasing Water Make
		ABLW207	2900	400	10^{-6} "Constrained Zone with water profile
Prediction line 5	Mine 3 North	ABLW301N	3900	250	10^{-2} to 10^{-3} High Inflow Zone
		ABLW302N	3500	280	10^{-3} to 10^{-4} Observed Seepage and Increasing Water Make
		ABLW303N	3300	300	10^{-4} Observed Seepage and Increasing Water Make
		ABLW304N	3100	320	10^{-5} Observed Seepage and Increasing Water Make
		ABLW305N	3100	340	10^{-5} to 10^{-6} Observed Seepage and Increasing Water Make
Prediction line 6	Mine 3 South	ABLW301S	4100	250	10^{-2} to 10^{-3} High Inflow Zone
		ABLW302S	3600	270	10^{-3} Observed Seepage and Increasing Water Make
		ABLW303S	3500	290	10^{-4} Observed Seepage and Increasing Water Make
		ABLW304S	3400	300	10^{-4} Observed Seepage and Increasing Water Make
		ABLW305S	3400	320	10^{-5} Observed Seepage and Increasing Water Make
Prediction line 7	Mine 4	ABLW401	4900	200	>10^{-2} Inflow and Operational Issues
		ABLW402	4600	220	>10^{-2} Inflow and Operational Issues
		ABLW403	4400	240	>10^{-2} Inflow and Operational Issues
		ABLW404	4000	260	10^{-2} to 10^{-3} High Inflow Zone
		ABLW405	3700	280	10^{-3} to 10^{-4} Observed Seepage and Increasing Water Make
		ABLW406	3500	290	10^{-4} Observed Seepage and Increasing Water Make
		ABLW407	3500	310	10^{-4} Observed Seepage and Increasing Water Make
Prediction line 8	Mine 5 North	ABLW501N	4600	220	>10^{-2} Inflow and Operational Issues
		ABLW502N	4300	240	>10^{-2} Inflow and Operational Issues
		ABLW503N	4100	270	10^{-2} to 10^{-3} High Inflow Zone
Prediction line 9	Mine 5 South	DLW501S	3100	130	>10^{-2} Inflow and Operational Issues
		DLW502S	3100	170	>10^{-2} Inflow and Operational Issues
		DLW503S	3000	180	>10^{-2} Inflow and Operational Issues
		ABLW501S	5400	120	>10^{-2} Inflow and Operational Issues
		ABLW502S	5300	140	>10^{-2} Inflow and Operational Issues
		ABLW503S	5100	160	>10^{-2} Inflow and Operational Issues
		ABLW504S	4800	190	>10^{-2} Inflow and Operational Issues
		ABLW505S	4400	210	>10^{-2} Inflow and Operational Issues
		ABLW506S	4300	230	>10^{-2} Inflow and Operational Issues
		ABLW507S	3800	250	10^{-3} Observed Seepage and Increasing Water Make
		ABLW508S	3600	270	10^{-3} to 10^{-4} Observed Seepage and Increasing Water Make

Prediction Line 1 - Mine 1 North

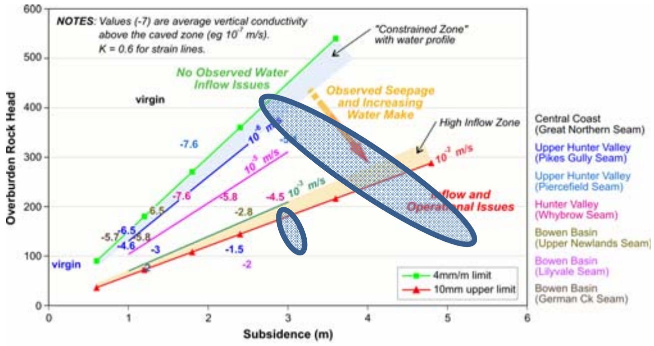


Figure S1 Average overburden conductivity characteristics relative to subsidence and depth criteria.

Prediction Line 2 - Mine 1 South

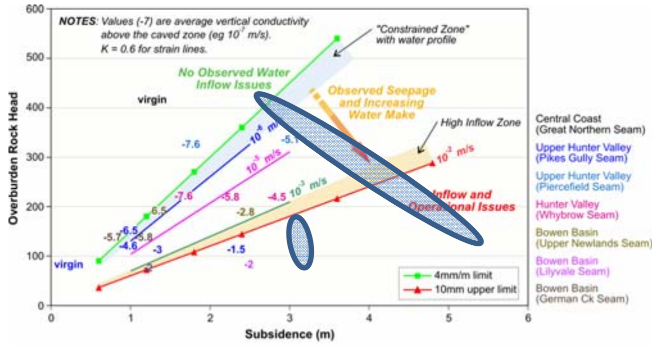


Figure S1 Average overburden conductivity characteristics relative to subsidence and depth criteria.

Prediction Line 3 - Mine 1 South

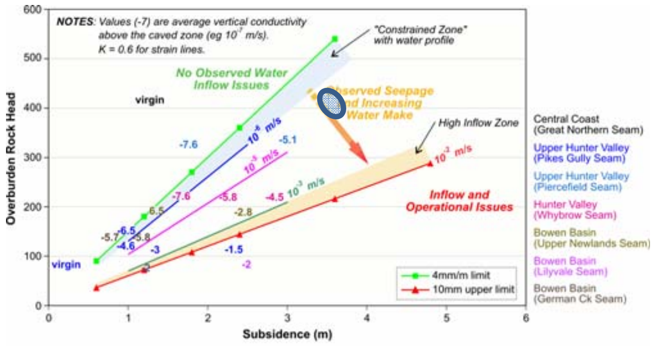


Figure S1 Average overburden conductivity characteristics relative to subsidence and depth criteria.

Prediction Line 4 - Mine 2

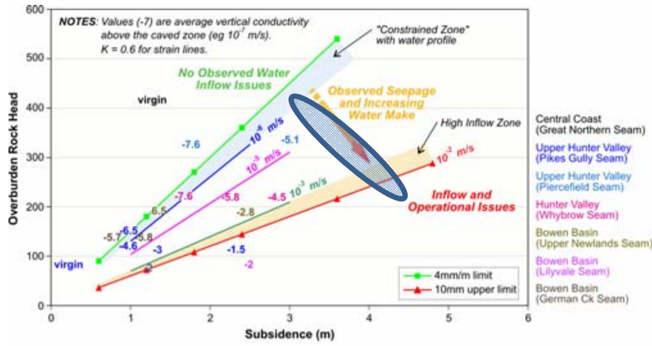


Figure S1 Average overburden conductivity characteristics relative to subsidence and depth criteria.

Prediction Line 5 - Mine 3 North

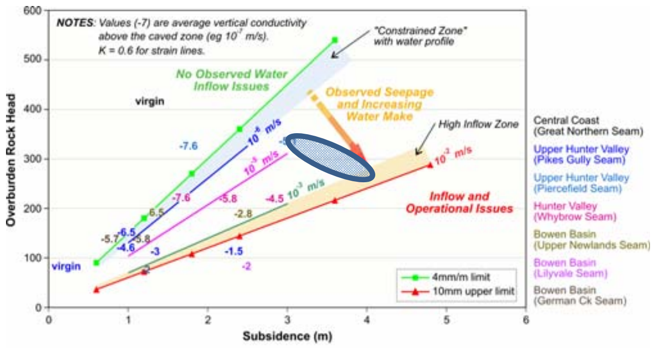


Figure S1 Average overburden conductivity characteristics relative to subsidence and depth criteria.

Prediction Line 6 - Mine 3 South

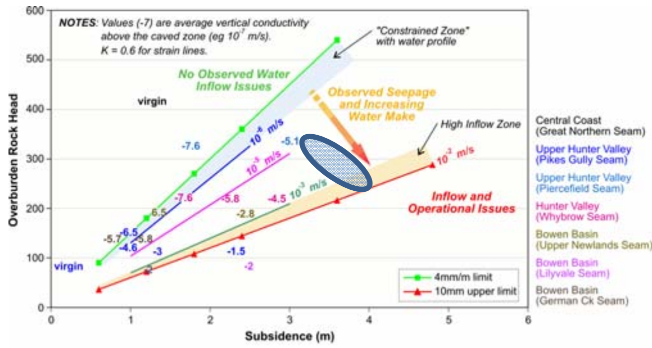


Figure S1 Average overburden conductivity characteristics relative to subsidence and depth criteria.

Fig. 5.19 Average Overburden Conductivity Characteristics by Gale (ACARP C13013, 2008)

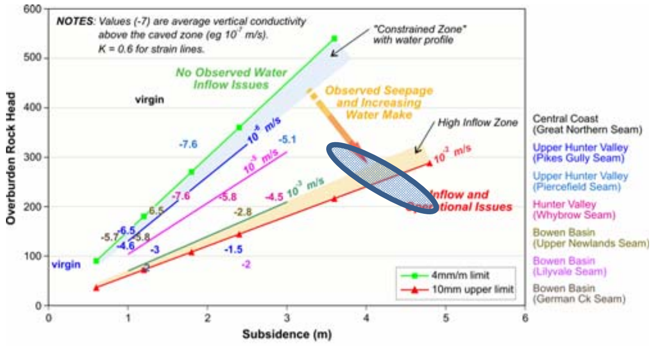
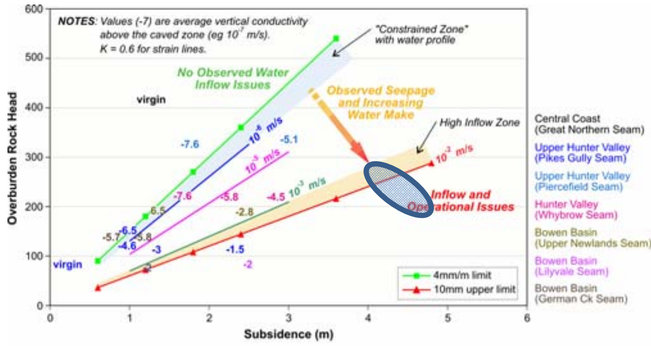
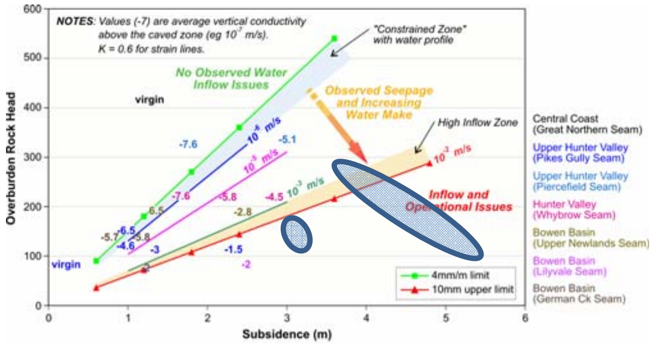
Prediction Line 7 - Mine 4	Prediction Line 8 - Mine 5 North
	
Prediction Line 9 - Mine 5 South	
	

Figure S1 Average overburden conductivity characteristics relative to subsidence and depth criteria.

Fig. 5.19 Average Overburden Conductivity Characteristics by Gale (ACARP C13013, 2008) Cont.

It can be seen from Table 5.4 and Fig. 5.18 that there is considerable variation in the estimates for height of fracturing based on different published methods. The overburden above the Proposed Longwalls at the Carmichael Project include significant thickness of Tertiary and Triassic (Rewan Formation) sediments, which are generally of low strength and poor spanning capability than those found in the coalfields of NSW, upon which many of these methods are based.

The stratigraphic column shown in Fig. 1.2 identifies a sandstone layer immediately above the AB1 seam to the base of the Rewan Formation which, given the close proximity above the AB1 seam, will form part of the goaf and is not expected to span the mined void. In addition, it has been anticipated that goafing characteristics of the overburden materials will be similar to those observed at Cook Colliery, where observed subsidence was much greater than has been observed elsewhere in the Bowen Basin and NSW Coalfields. The overburden over Cook Colliery is also mostly fine grained sediments that do not include aquifers or groundwater bearing layers. Surface cracking has been observed at Cook, however the mine is still regarded by its operators as a relatively “dry” mine, as evidenced by the presence of various mining created ponds over the subsided workings.

The heights of fracturing that are summarised in Table 5.4, above, are also based on single seam extraction. With an interburden thickness of 70 metres to 130 metres between the AB1 and D1 seams, the extraction of the D1 seam will result in fracturing to the overlying AB1 seam and reworking of the fractured zone above the AB1 seam, increasing the height of the fractured zone. As a result, it is anticipated that the height of fracturing at the Carmichael Project will be at the upper end of the range of height estimates for the various published methods and potentially even higher.

Accordingly the expected height of fracturing at the Carmichael Project, is expected to extend from the AB1 seam to the surface over much of the proposed longwall footprint. It must be stressed, however, that the anticipated height of fracturing does not imply that hydraulic connectivity will extend to the same height, especially since the overburden materials at the Carmichael Project contain layers which behave as aquicludes or aquitards. Based on the geological profiles provided in the coal resource estimate report by Xenith Consulting Pty Ltd (Xenith 2009) and the borehole logs provided by Adani Mining Pty Ltd, there are significant thicknesses of clay, claystone, mudstone, tuff, siltstone and several kaolinitic layers which may behave as aquitard or aquiclude layers.

The ability of the overburden to retard or prevent hydraulic connection at the Carmichael Project in the presence of aquiclude and aquitard materials in fractured strata is supported by the following information:

- The drilling investigation program for the Carmichael project encountered problems during drilling as a result of swelling clay in the boreholes.
- The mine hydrology report by GHD (GHD 2012) provides a calibrated model parameter for vertical hydraulic conductivity of 1 x 10^{-5}m/d in the Rewan Formation [Table 5-3]. The Rewan formation is a base confining unit for the Great Artesian Basin.
- The similarities between the overburden materials and extracted seams at Cook Colliery formed the basis for the calibration of the model for the Carmichael Project. Comments from Cook Colliery indicate that longwall mining had continued without any operational issues relating to surface to seam hydraulic connection. Ponded water has formed in the subsidence troughs above the extracted longwalls at Cook Colliery that were used for calibration of the model for the Carmichael Project as described in Section 3.9. This ponded water has been retained in the base of these troughs and the Rewan formation is the main overburden sequence between the extracted seam and the subsided surface.
- Longwalls have been successfully extracted beneath the Isaac River in the Bowen Basin at depths of cover from 170 metres to 250 metres, longwall widths of 314 metres and at an extracted seam thickness in the order of 4.5 metres. The longwalls were extracted below the river with no identifiable increase in mine dewatering rates. The extraction took place in a different geological setting, however this case demonstrates that the presence of aquiclude and aquitard materials in the overburden can prevent hydraulic connection between the surface and the extracted seam.

In the longwall extraction cases described above, the models for height of fracturing would suggest a height of fracturing up to or close to the surface, however extraction had continued without operational problems and without observed adverse impact to surface water.

It is expected that where sufficient depth of cover and thickness of Rewan formation and/or Tertiary clay are present, there will be a low risk of direct hydraulic connection from the surface to the seam. Conservatively adopting 160 metres based on Klenowski (ACARP C5016, 2000) would be considered a reasonable height for preliminary modelling of the height of direct hydraulic connection. Above this height, it is anticipated that there will be increase in the strata permeability due to fracturing through beds and bedding plane dilation, however the likelihood of hydraulic connectivity from the surface to the seam is anticipated to be low given the presence of aquiclude and aquitard materials in the overburden. Adopting increases in vertical permeability as suggested by Guo et al (ACARP C14033, 2007) would provide a reasonable basis for preliminary modelling. Assumptions should be conservative and should be verified by field measurement once mining commences. Development of a mathematical model for fracture networks would be the next stage for refinement of hydrogeological parameters prior to the commencement of underground operations.

The above assessment of hydraulic connectivity for the Carmichael project is based on the overburden descriptions provided in the coal resource estimate report (Xenith 2009) and the drilling data provided by Adani Mining for boreholes with spacings of the order of 1.5km or more. These descriptions of the overburden indicate the presence of materials that may act as aquicludes or aquitards and conclusions on connectivity are only applicable where these materials are consistently present. As discussed at the beginning of this section, it is recommended that a detailed assessment by an appropriate specialist ground water consultant be undertaken at the appropriate stage of the project on the potential for hydraulic connectivity from surface to seam. Please also refer to studies by the surface water consultant for further detailed information.

5.3. Great Artesian Basin

The proposed longwalls are located close to the eastern margin of the Great Artesian Basin (GAB) recharge beds. The Rewan formation forms the basement confining layer of the GAB and the base or bottom confined aquifer of the GAB is contained within the overlying Clematis sandstone. Hence the Clematis sandstone outcrops to the west of EPC1690 and forms part of the recharge beds at the eastern margin of the GAB.

The main sandstone aquifers and confining aquitards for the GAB are outlined in Fig. 5.20 (Great Artesian Basin Consultative Council, 1998) and a schematic representation of the GAB aquifers is presented in Fig. 5.21 (Geoscience Australia, 2010).

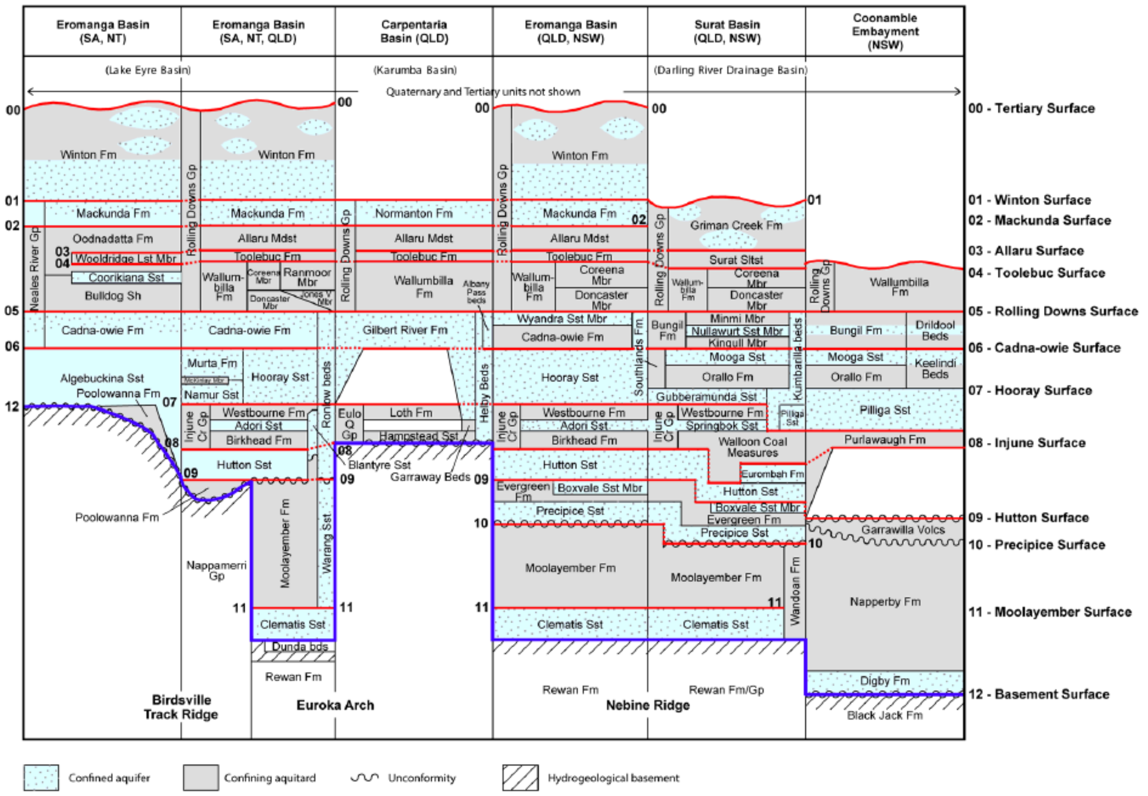


Fig. 5.20 Main Sandstone Aquifers and Confining Aquitards for the Great Artesian Basin (Source: Hydrogeochemical Baseline Mapping of the Great Artesian Basin Groundwater, Geoscience Australia, 2010)

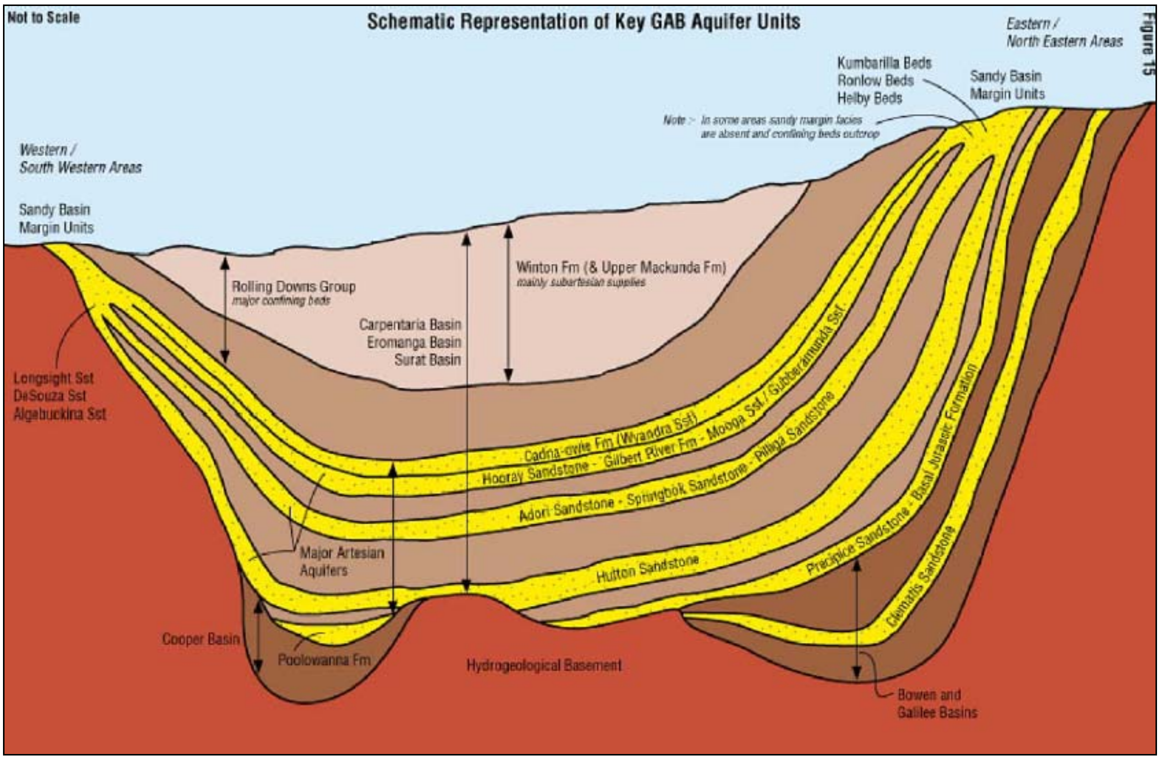


Fig. 5.21 Schematic Representation of Key GAB Aquifer Units (Source: Great Artesian Basin Resource Study, Great Artesian Basin Consultative Council, 1998)

Based on the above information and the geological information provided by Adani Mining, there are no identified GAB aquifer units outcropping within the proposed longwall footprint.

The nearest GAB aquifer unit to the proposed longwalls is the Clematis Sandstone, which is identified in the surface geological map in Fig. 1.1. The Mine Hydrology Report (GHD 2012) notes that the nearest mapped outcrop of Clematis sandstone is approximately 2 km to the west of EPC 1690. At this distance from the proposed longwalls, no measureable conventional subsidence movements and hence no impacts, are expected to result from the extraction of the proposed longwalls. It is possible, however, that the area would experience small far-field horizontal movements, which are discussed in Section 4.4.

The Mine Hydrology Report (GHD 2012) provides detailed information on the boundaries of the GAB and potential impacts on the GAB resulting from the proposed open cut and underground operations at the Carmichael Project.

6.0 POTENTIAL IMPACTS ON SURFACE INFRASTRUCTURE

A number of the major natural features and items of surface infrastructure within the Study Area can be seen in the Drawing No. MSEC627-13. The majority of the land is undeveloped, with sparse vegetation. The land is understood to be used primarily for grazing. The features within the Study Area include small tributaries that flow to the east, two unsealed roads, and boundary fences.

6.1. Streams

The locations of the watercourses in the vicinity of the proposed longwalls are shown in Drawing No. MSEC627-11, in Appendix D. There are no major creeks or streams within the Study Area.

The largest watercourse in the vicinity of the proposed longwalls is the Carmichael River, which is located outside the Study Area. The proposed longwalls have been set back from the Carmichael River and the closest longwall is approximately 655 metres from the river. A number of small tributaries are located above the proposed longwalls as shown on Drawing No. MSEC627-11. These tributaries flow generally to the north east and towards the proposed future open cut pit at the Carmichael Project.

Predicted profiles of conventional subsidence, tilt and curvature were prepared for three of the tributaries and the results are presented in Figs. C.12, C.13 and C.14 in Appendix C. In each figure, the predicted subsided surface levels along these tributaries are shown for the completion of mining in both seams.

The tributaries have shallow incisions into the surface soils. It is unlikely, therefore, that the tributaries would experience any significant valley related movements resulting from the extraction of the proposed longwalls.

The predicted subsidence and tilts are likely to be of sufficient magnitude to result in changes in the surface water flows along the drainage lines.

It can be seen from Figs. C.12, C.13 and C.14 in Appendix C that increased ponding is predicted to develop in the drainage lines directly above the proposed longwalls.

It is expected, at the magnitudes of predicted curvatures and strains, that significant fracturing and buckling would occur in the uppermost bedrock beneath the natural surface soils along the drainage lines. Surface cracking in the beds of the drainage lines would be visible at the surface where the depths of the surface soils are relatively shallow. The sizes and extents of surface cracking were discussed in Section 5.1.

It is expected, during and at the completion of mining, that earthworks would be required to manage the natural gradient along the drainage lines.

6.2. Roads

Two unsealed roads are located above the proposed longwalls, Moray Carmichael Boundary Road and Shuttleworth Carmichael Road. Predicted profiles of conventional subsidence, tilt and curvature were prepared for the two roads and the results are presented in Figs. C.10 and C.11 in Appendix C. In each figure, the predicted subsided surface levels along the roads are shown for the completion of mining in both seams.

It can be seen from Figs. C.10 and C.11 in Appendix C, that increased ponding is predicted to develop in the drainage lines directly above the proposed longwalls.

The proposed extraction will likely result in ponding, cracking, heaving, buckling and possibly steps in the pavement, which can all be repaired with minimum impact on traffic with detailed monitoring and suitable maintenance work. The potential impacts on the local road pavements can, however, be managed by the implementation of an effective subsidence management plan, with the co-operation of the relevant local or state government bodies, to ensure the safe operation of the roads during mining. Management measures will likely include proactive subsidence management of the existing pavements during mining.

6.3. Fences

Boundary fences are located across the Study Area and, therefore, are expected to experience the full range of predicted subsidence movements. A summary of the maximum predicted conventional subsidence parameters within the Study 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 Study Area would be impacted as the result of the extraction of the proposed longwalls. 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.

APPENDIX A. GLOSSARY OF TERMS AND DEFINITIONS

Glossary of Terms and Definitions

Some of the more common mining terms used in the report are defined below:-

Angle of draw	The angle of inclination from the vertical of the line connecting the goaf edge of the workings and the limit of subsidence (which is usually taken as 20 mm of subsidence).
Chain pillar	A block of coal left unmined between the longwall extraction panels.
Cover depth (H)	The depth from the surface to the top of the seam. Cover depth is normally provided as an average over the area of the panel.
Closure	**T**he reduction in the horizontal distance between the valley sides. The magnitude of closure, which is typically expressed in the units of *millimetres (mm)*, is the greatest reduction in distance between any two points on the opposing valley sides. It should be noted that the observed closure movement across a valley is the total movement resulting from various mechanisms, including conventional mining induced movements, valley closure movements, far-field effects, downhill 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.
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 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

Anderson, L., Patterson, D. and Nicholson, M. (2007). *Measuring Mine Subsidence – BHP Billiton Illawarra Coal's Diversified Approach*. Proceedings of the MSTS Mine Subsidence Technological Society 7th Triennial Conference on Mine Subsidence, pp 53-57, Nov 2007.

Deats, M.J. (1971). *A follow-up report on longwall coal mining at Durban Navigation Collieries (Pty.) Limited*. Journal of the South African Institute of Mining and Metallurgy, pp. 179-189, April 1971.

DOP (2008). *The Impacts of Underground Coal Mining on Natural Features in the Southern Coalfield - Strategic Review*", State of New South Wales through the NSW Department of Planning, 2008.

Ditton, S and Frith, R (2003) *Review of Industry Subsidence Data in Relation to the Influence of Overburden Lithology on Subsidence and an Initial Assessment of a Sub-Surface Fracturing Model for Groundwater Analysis*, ACARP Research Project No. C10023, September 2003.

Forster, I and Enever, J. (1992) Hydrogeological response of overburden strata to underground mining, Central Coast, NSW. Office of Energy Sydney.

Gale, W. (2008). *Aquifer Inflow Prediction Above Longwall Panels. , ACARP, Research Project No. C13013*

Galvin, J.M. (1981). *The Mining of South African Thick Coal Seams-An Outline of the Thesis from the Mining of South African Thick Coal Seams - Rock Mechanics and Mining Considerations*. PhD Thesis, University of Witwaterstrand, Johannesburg, 1981.

GHD (2012). *Report for Carmichael Coal Mine and Rail Project: Mine Technical Report, Hydrogeology Report, 23244-D-RP-0026, 26 March 2012, Revision B.*

Great Artesian Basin Consultative Council (1998), *Great Artesian Basin Resource Study, 36790 RSC 159545,* November 1998.

Holla, L. and Armstrong, M., (1986). *Measurement of Sub-Surface Strata Movement by Multi-wire Borehole Instrumentation*. Proc. Australian Institute of Mining and Metallurgy, 291, pp. 65-72.

Holla, L., (1991). *Reliability of Subsidence Prediction Methods for Use in Mining Decisions in New South Wales.* Conference on Reliability, Production and Control in Coal Mines, Wollongong.

Holla, L. and Barclay, E., (2000). *Mine Subsidence in the Southern Coalfield, NSW, Australia.* Published by the Department of Mineral Resources, NSW.

Holla, L. & Buizen, M., (1991). *The Ground Movement, Strata Fracturing and Changes in Permeability Due to Deep Longwall Mining*. Int. J. Rock Mech. Min. Sci. & Geomech. Abstr. Vol 28, No. 2/3, pp.207-217, 1991.

Kapp (1982). *Subsidence from Deep Longwall Mining of Coal Overlain by Massive Sandstones*. Kapp, W.A. Proc. Australasian Ins. Min. Met., 7/1 – 7/9.

Kendorski, FS, Khosla, I. and Singh, M.M. (1797) *Criteria for determining when a body of water constitutes a hazard to mining. Final Report on US BM Contract No J0285011, Engineers International Inc, 366p.*

Klenowski, G. (2000). *The Influence of Cracking on Longwall Extraction*, , ACARP Research Project No. C5016, August 2000.

Kratzsch, H., (1983). *Mining Subsidence Engineering*, Published by Springer - Verlag Berlin Heidelberg New York.

Mills, K.W. and O'Grady, P. (1998). *Impact of longwall width on overburden behaviour.* Coal Operators Conference, pp 147-155.

Mills, K.W., Waddington, A.A., and Holla, L. (2009). *Subsidence Engineering. Australasian Coal Mining Practice (Monograph Series No 12)*, Kininmonth, R.J.; Baafi, E.Y. (eds), The Australian Institute of Mining and Metallurgy (AusIMM), Carlton, Victoria, Chapter 37, pp. 874-902, 2009.

Patton and Hendron (1972). *General Report on Mass Movements*. Patton F.D. & Hendron A.J.. Proc. 2nd Intl. Congress of International Association of Engineering Geology, V-GR1-V-GR57.

Peng and Chiang (1984). *Longwall Mining*. Wiley, Peng S.S. & Chiang H.S. New York, pg 708.

Radke B.M., Ferguson, J., Cresswell, R.G., Ransley, T.R. and Habernehl, M.R. (2000) *Hydrogeochemistry and implied hydrodynamics of the Cadna-owie – Hooray Aquifer Great Artesian Basin*, Bureau of Rural Sciences, Canberra, 2000

Reid, P., (1991). *Coal Mining Beneath Dams in NSW Australia.* 1991 ASDSO Annual Conference, September 1991, San Diego, USA pp 240-245.
Report No. BHC2404C, SCT, December 2003.

Reynolds, R. G. (1977). Coal Mining under Stored Water. Supreme Court of New South Wales

Seedsman, R and Dawkins, A (2006) Techniques to Predict and Measure Subsidence and its Impacts on the Groundwater Regime Above Shallow Longwalls, ACARP Research Project No. C13009, March 2006.

Singh and Kendorski (1981). *Strata Disturbance Prediction for Mining Beneath Surface Water and Waste Impoundments*. Singh, M.M. & Kendorski, F.D. Proc. First Conference on Ground Control in Mining, West Virginia University, PP 76-89.

Kuske, T, van der Wielen, S, Dunsmore, R, Ransley T R, Draper J, and Feitz, AJ (2010). *Hydrogeochemical Baseline Mapping of the Great Artesian Basin Groundwater,* Geosciences Australia, 2010

Waddington, A.A. and Kay, D.R. (2002). *General Discussion on Mine Subsidence Ground Movements, ACARP, Research Project No. 9067*

Waddington, A.A. and Kay, D.R., (2002). *Management Information Handbook on the Undermining of Cliffs, Gorges and River Systems*. ACARP Research Projects Nos. C8005 and C9067, September 2002.

Wagner, H. and Schümann, E.H.R., (1991). *Surface effects of total coal-seam extraction by underground mining methods*. Journal of the South African Institute of Mining and Metallurgy, vol. 91, pp. 221-231, July 1991.

Wardell, K. (1975). *Mining Under Tidal Water.* , New South Wales Ministry For Mines And Power

Whittaker and Reddish (1989). *Subsidence – Occurrence, Prediction and Control.* Whittaker, B.N. and Reddish, D.J. Elsevier.

APPENDIX C. FIGURES

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 due to the Extraction of AB1 and D1 Seams

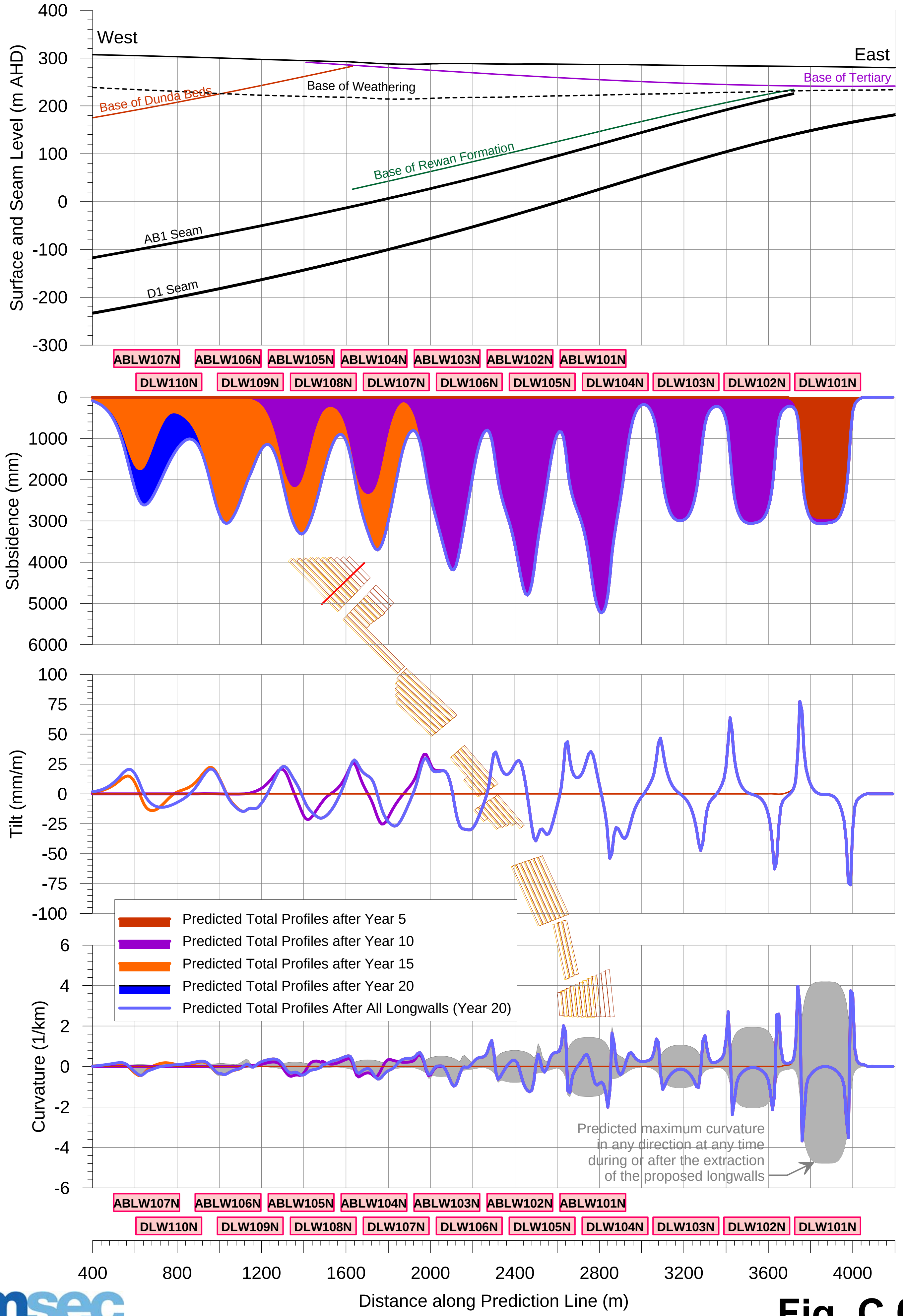


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Fig. C.01

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 due to AB1 and D1 Seams - Year 5

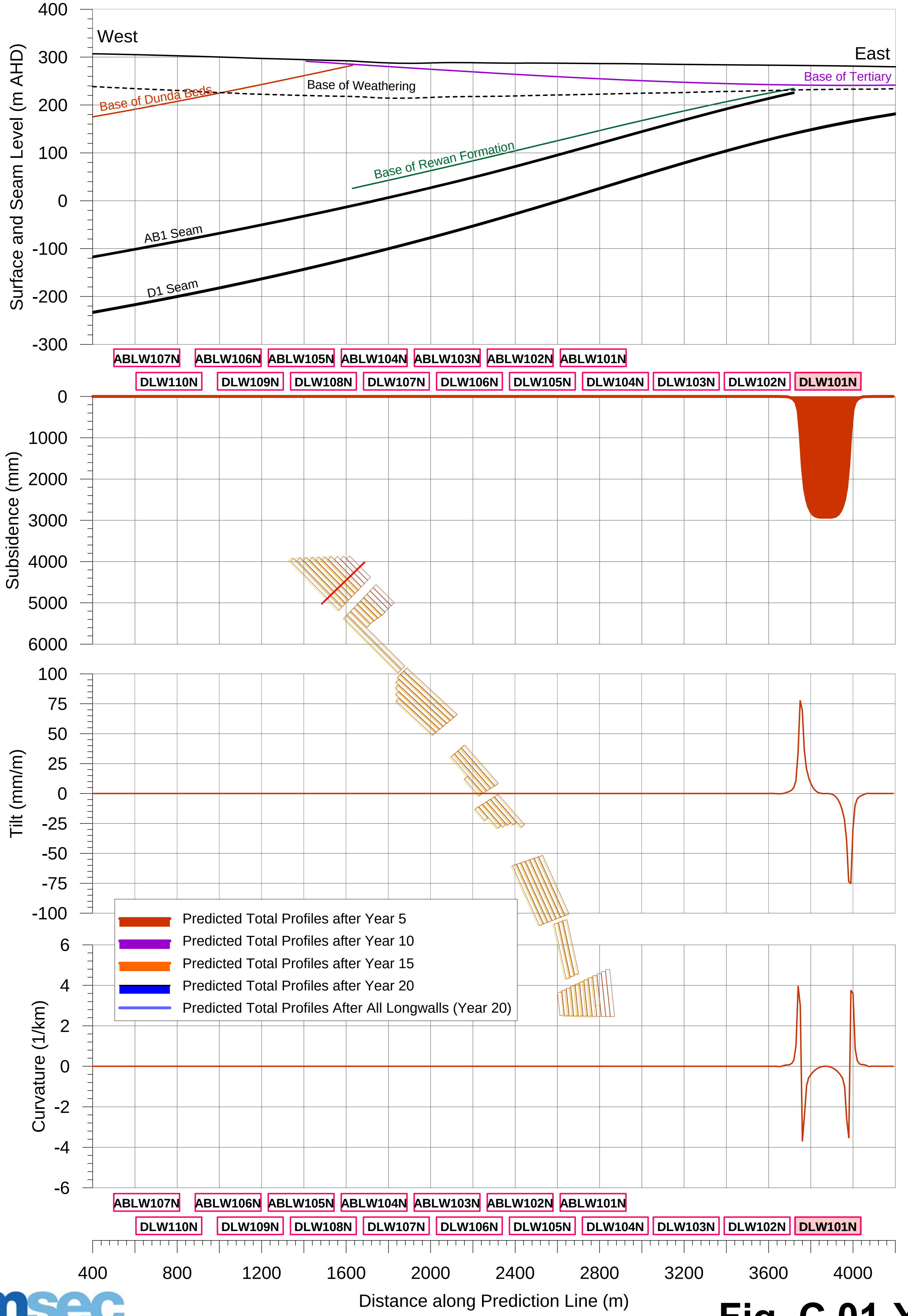

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Fig. C.01-Y5

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Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 due to AB1 and D1 Seams - Year 10

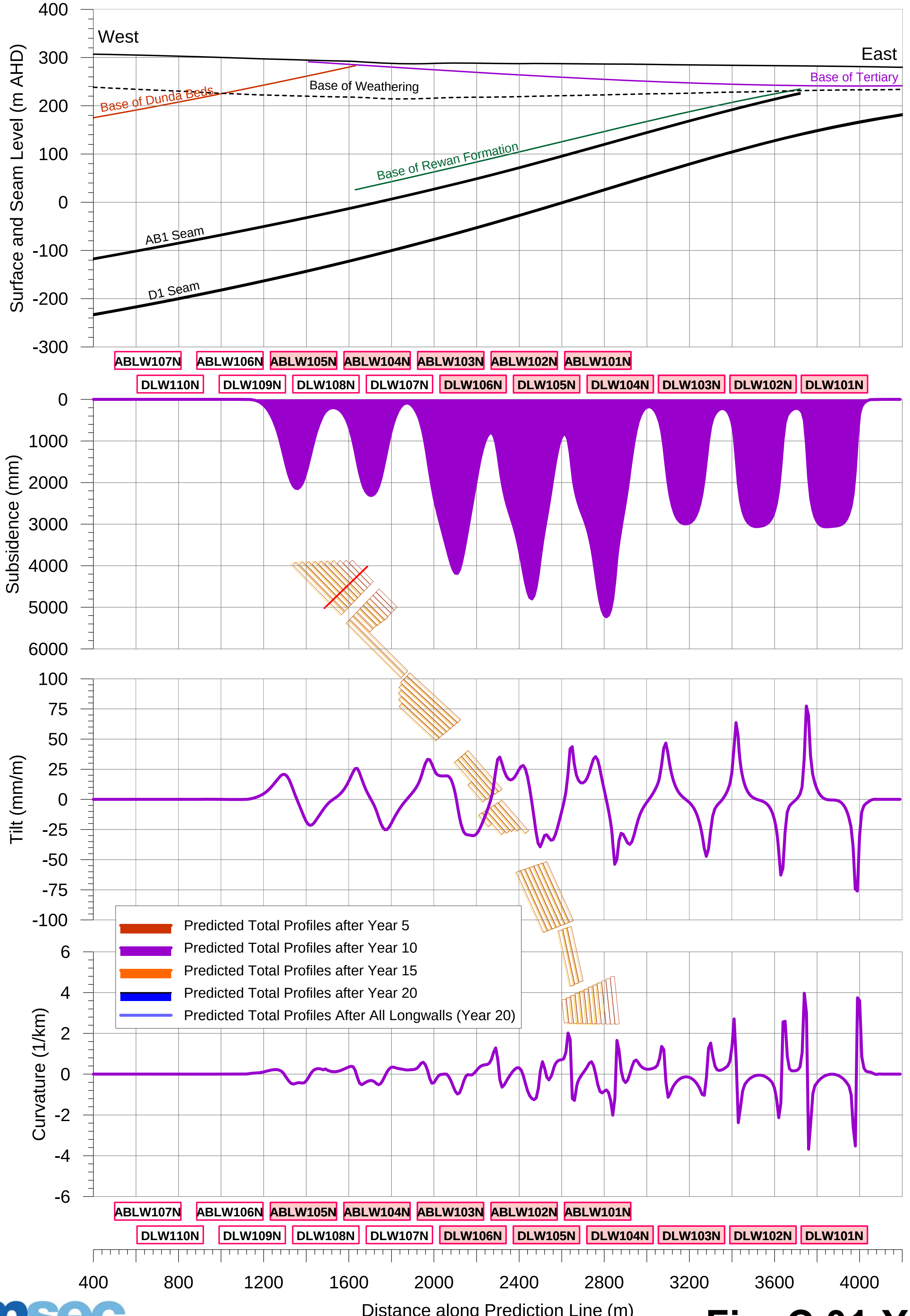

Fig. C.01-Y10

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 due to AB1 and D1 Seams - Year 15

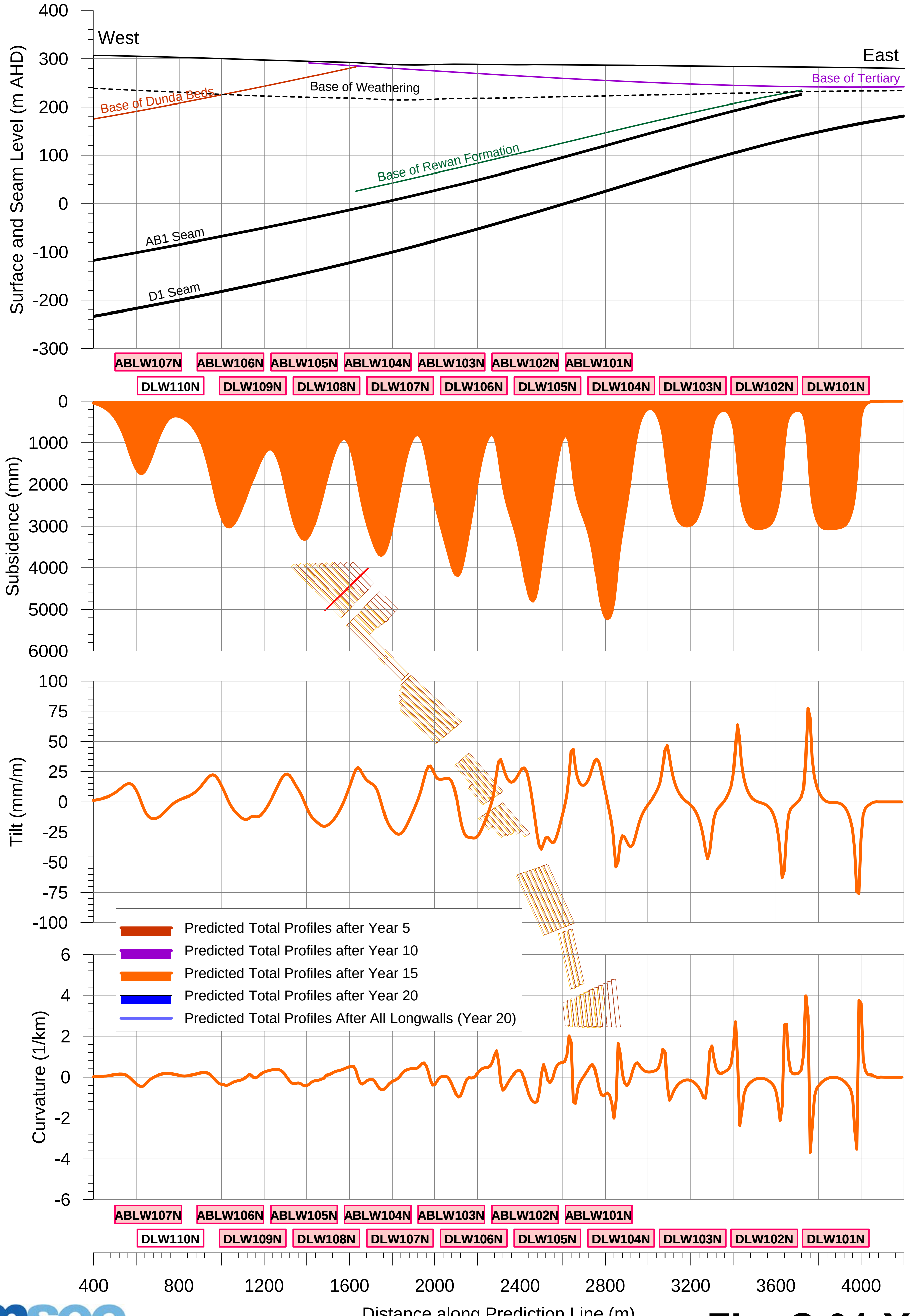

Fig. C.01-Y15

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 1 due to AB1 and D1 Seams - Year 20

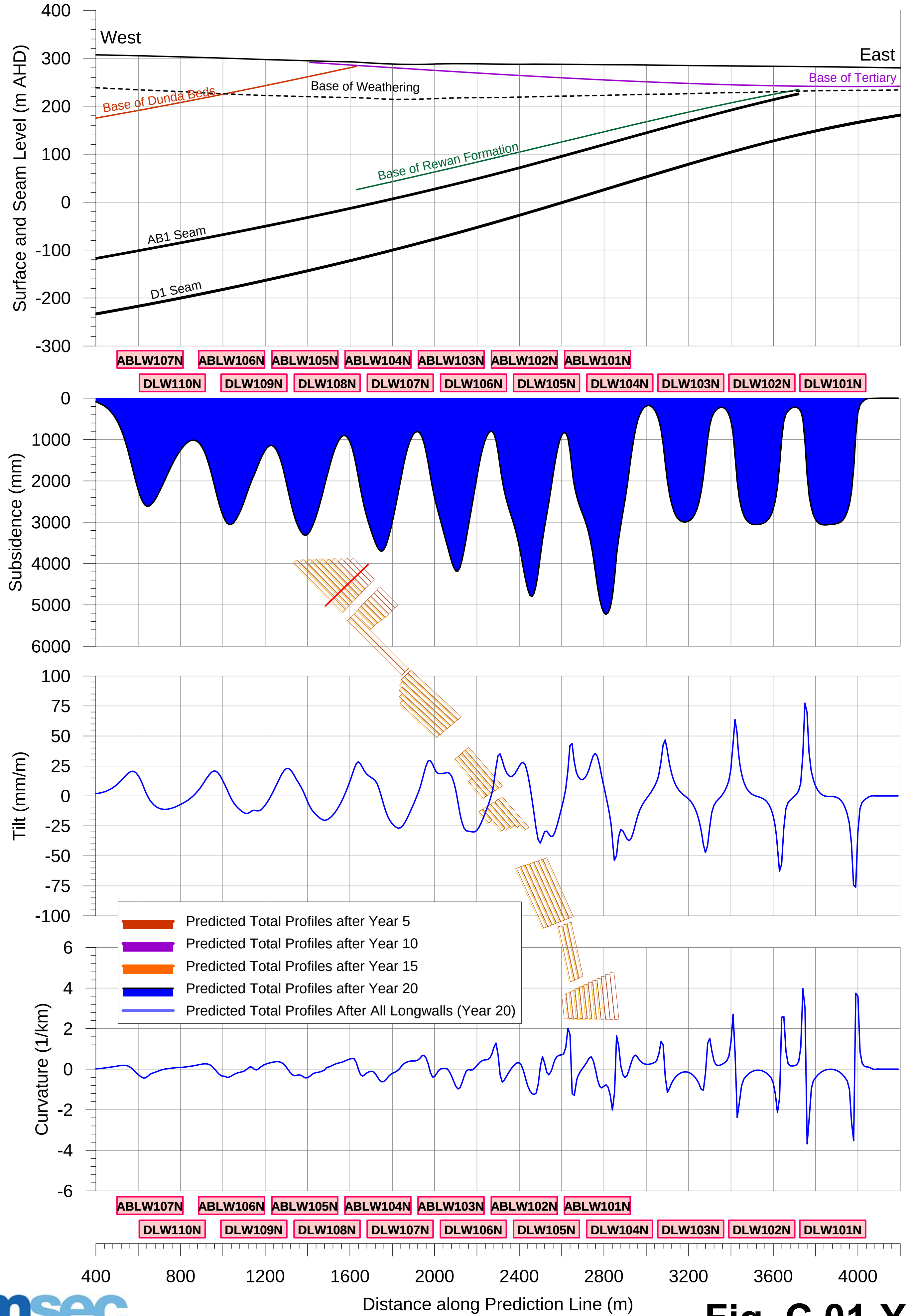

Fig. C.01-Y20

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 due to the Extraction of AB1 and D1 Seams

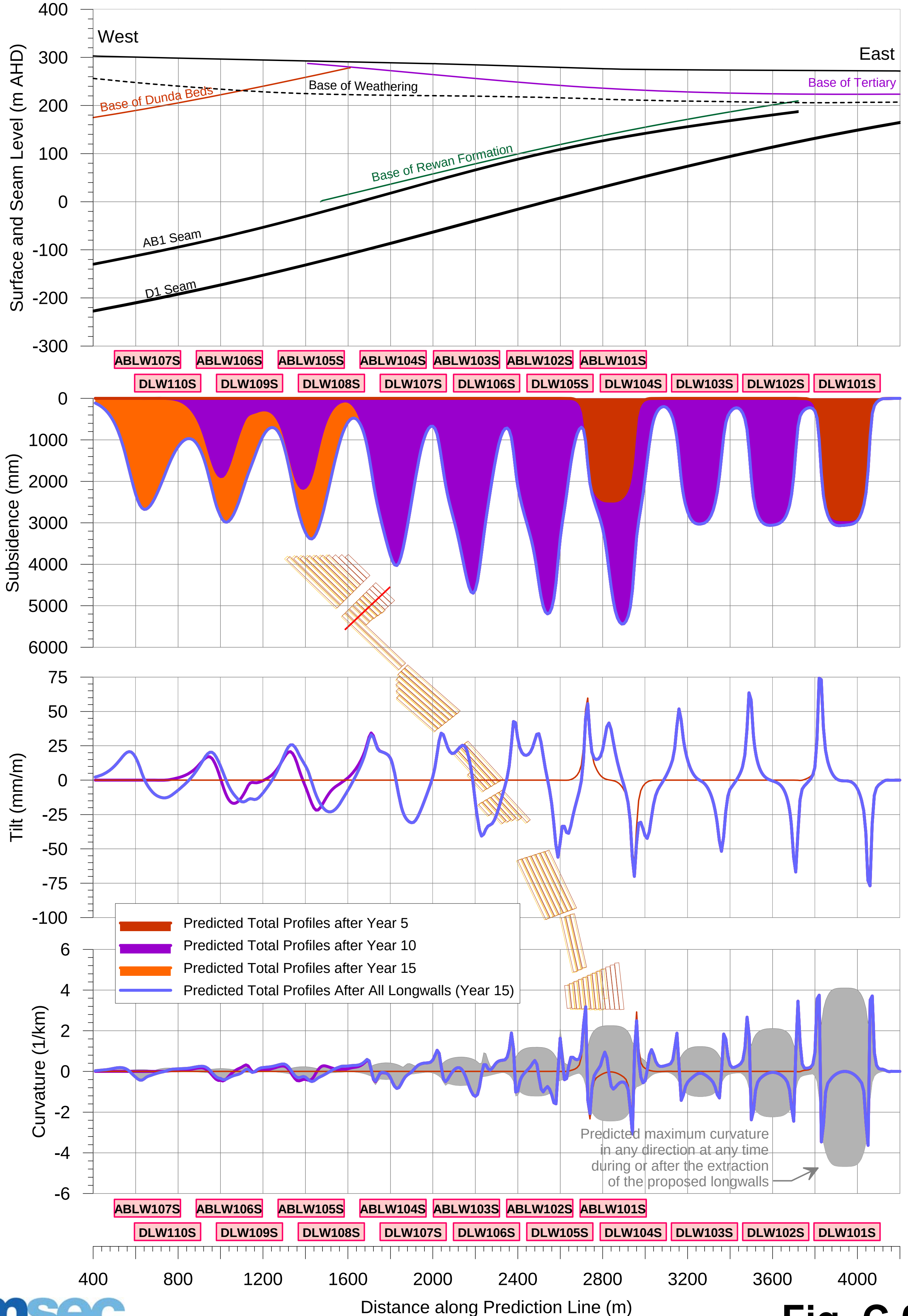

Fig. C.02

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 due to AB1 and D1 Seams - Year 5

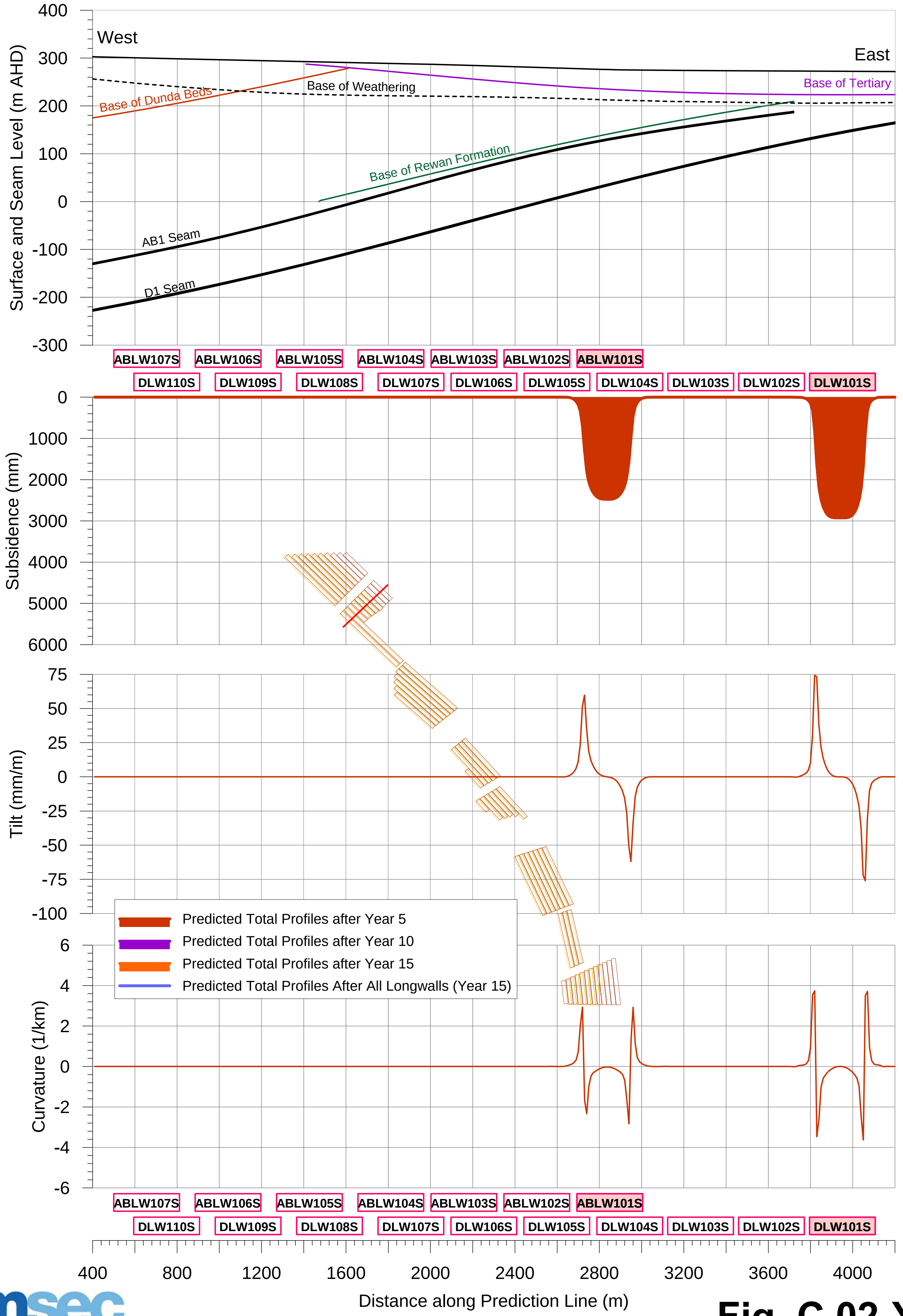

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Fig. C.02-Y5

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Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 due to AB1 and D1 Seams - Year 10

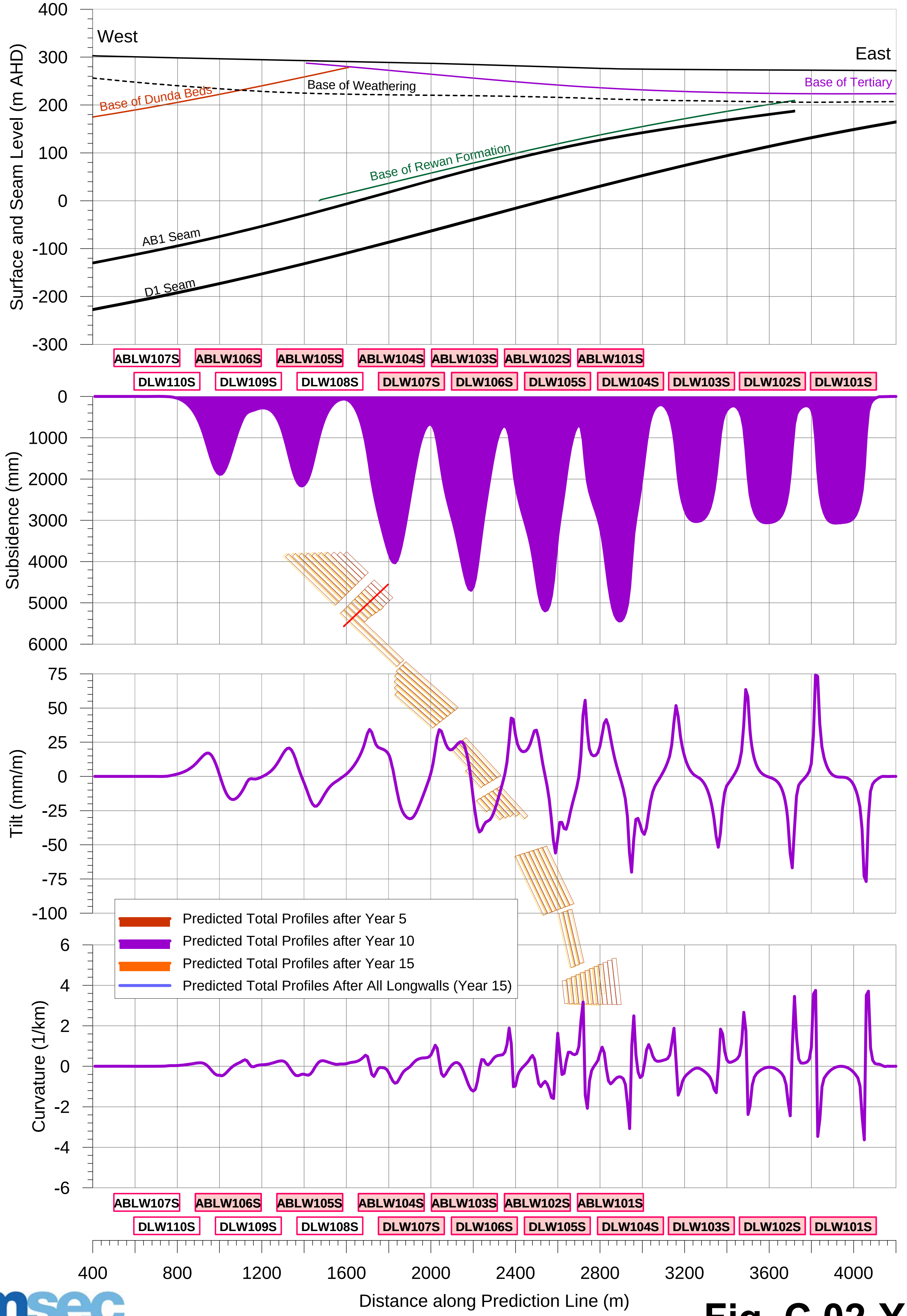

Fig. C.02-Y10

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 2 due to AB1 and D1 Seams - Year 15

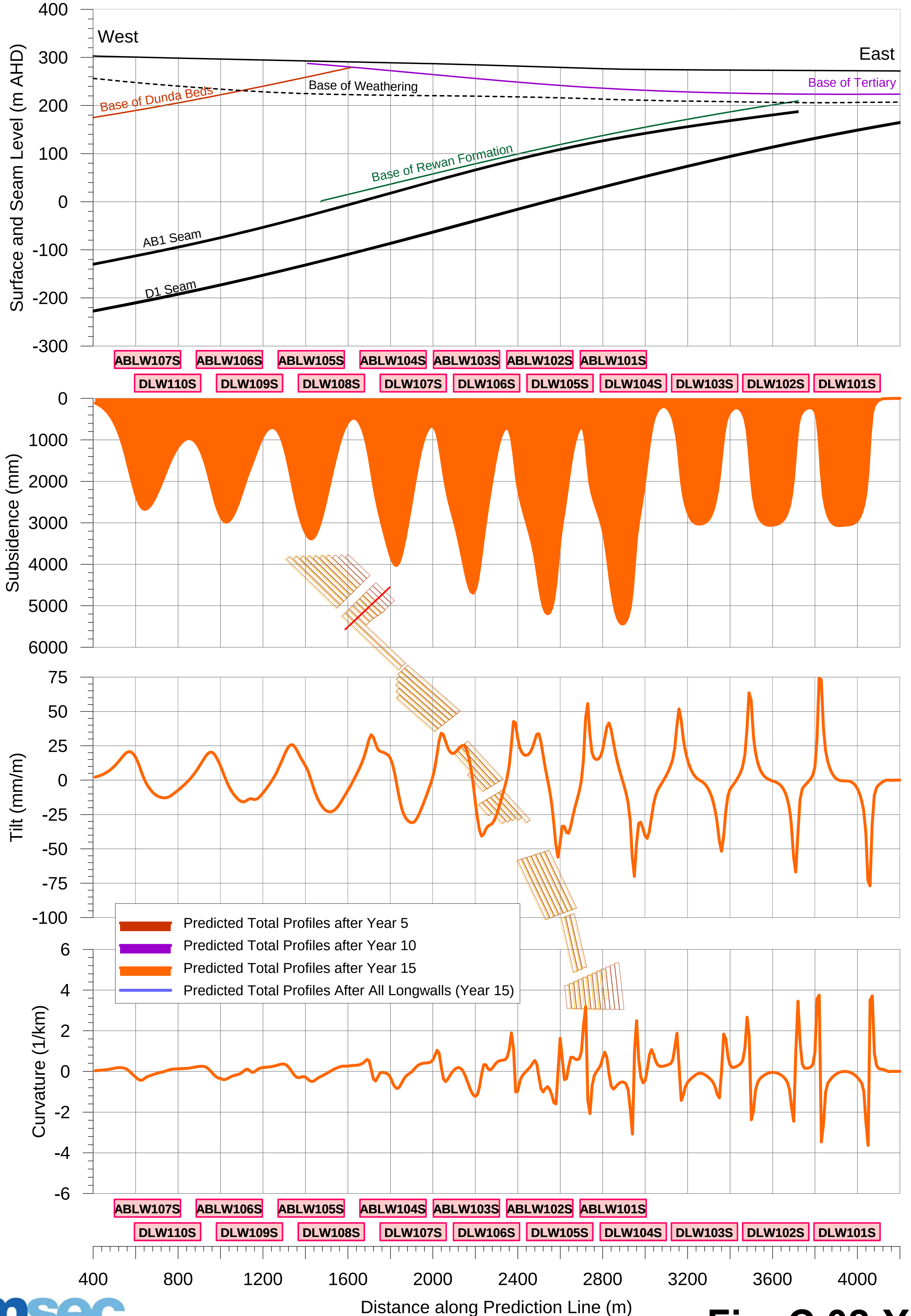

Fig. C.02-Y15

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 3 due to the Extraction of AB1 and D1 Seams

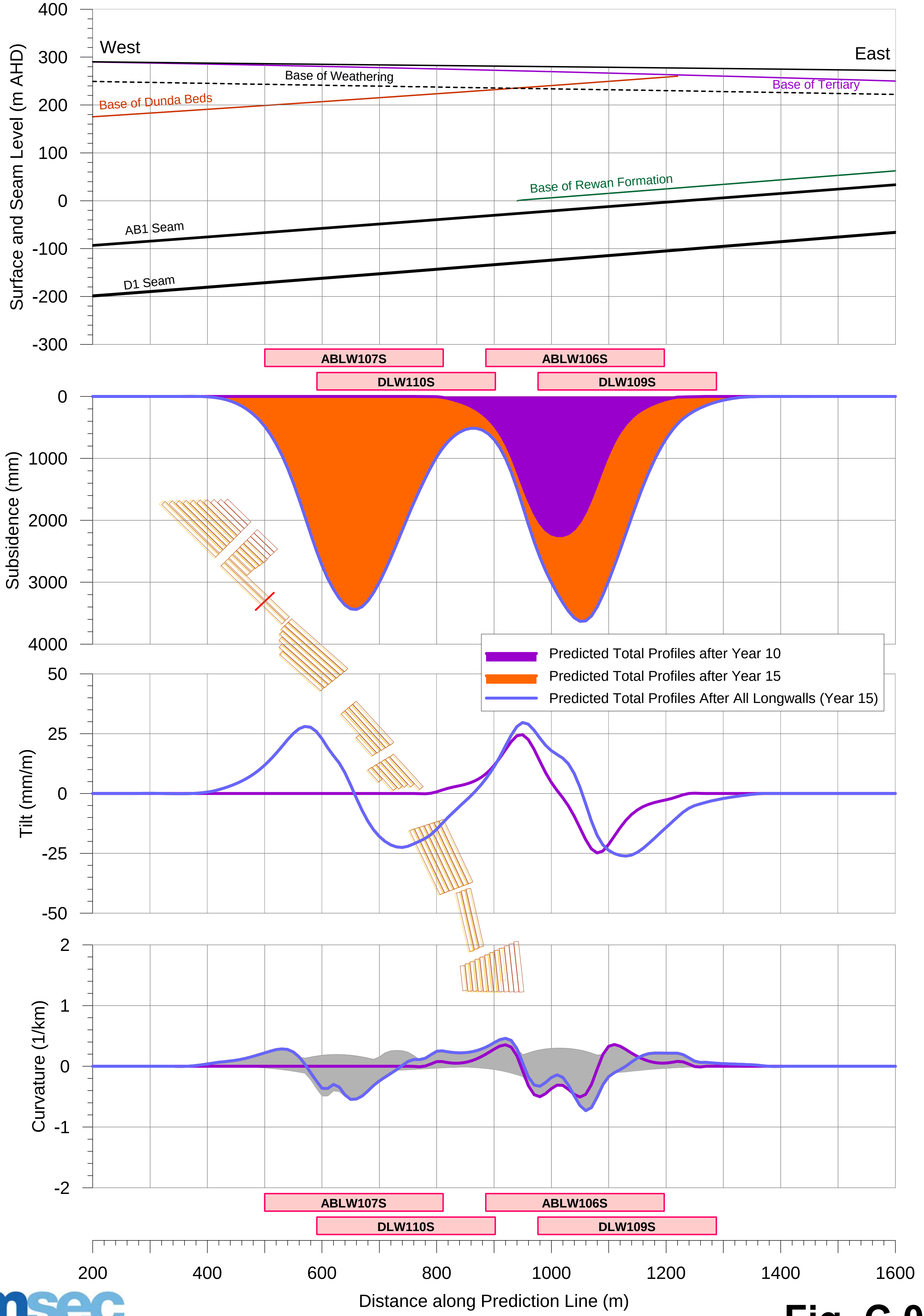

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Fig. C.03

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 3 due to AB1 and D1 Seams - Year 10

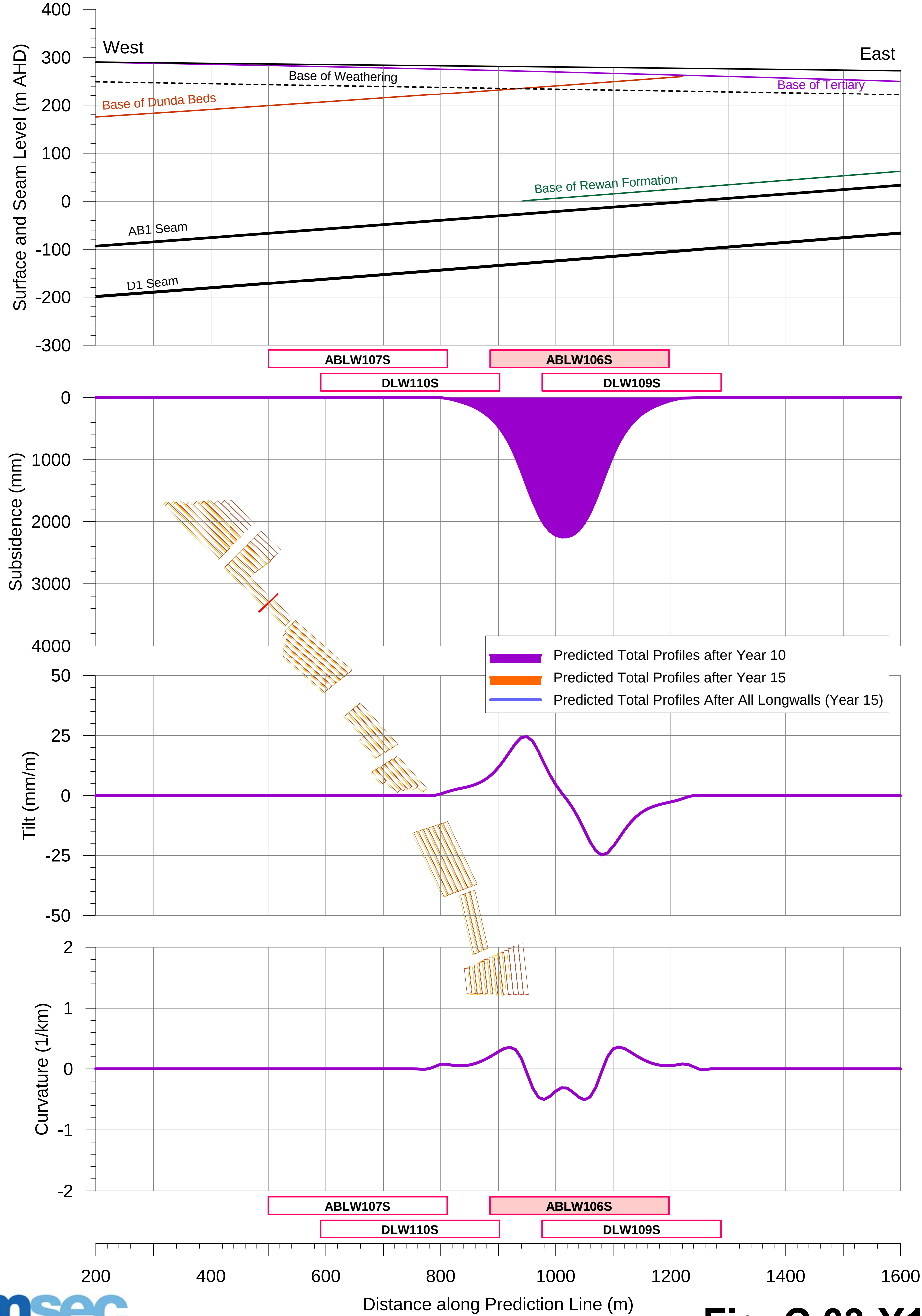

Fig. C.03-Y10

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 3 due to AB1 and D1 Seams - Year 15

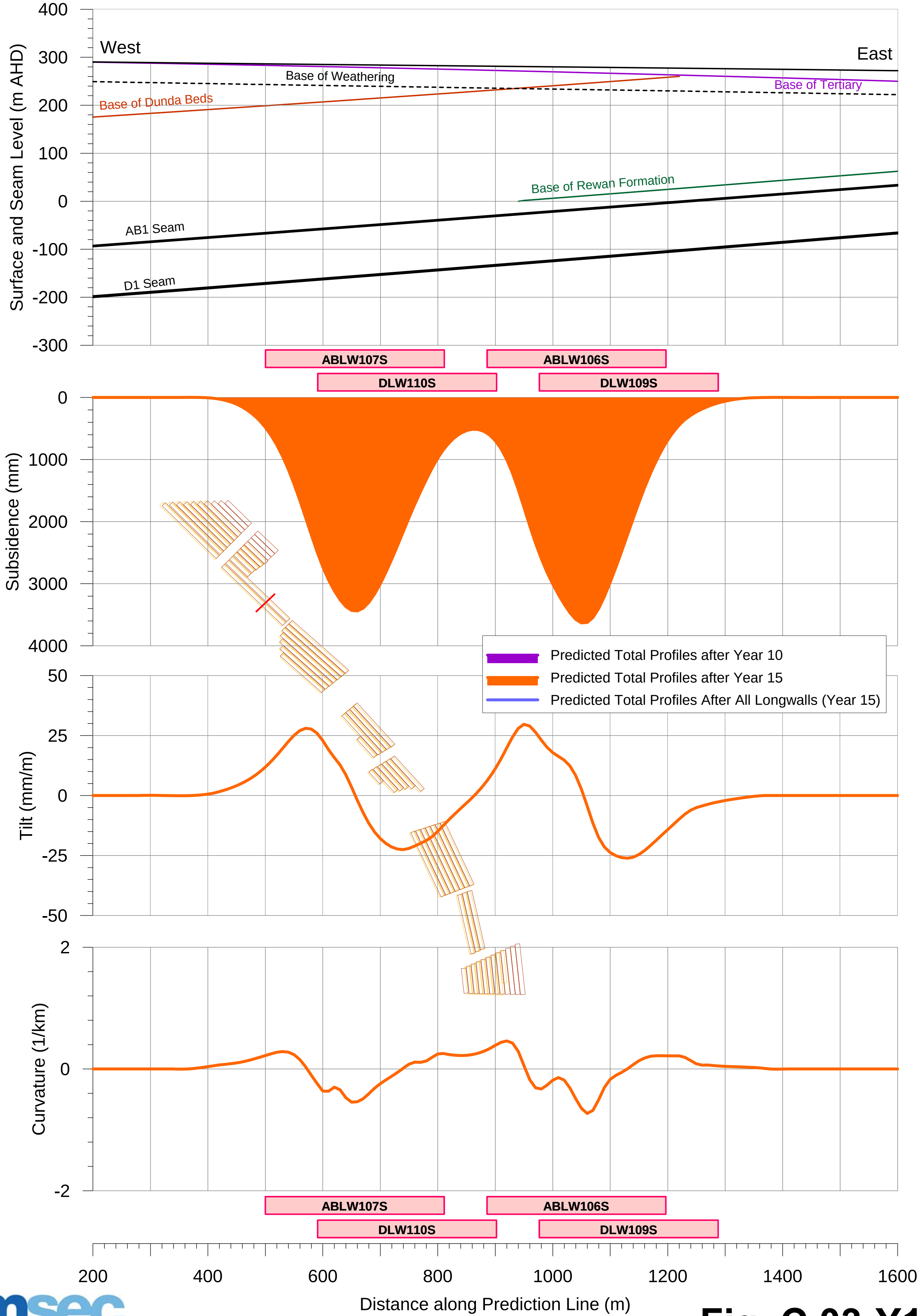

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Fig. C.03-Y15

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 4 due to the Extraction of AB1 and D1 Seams

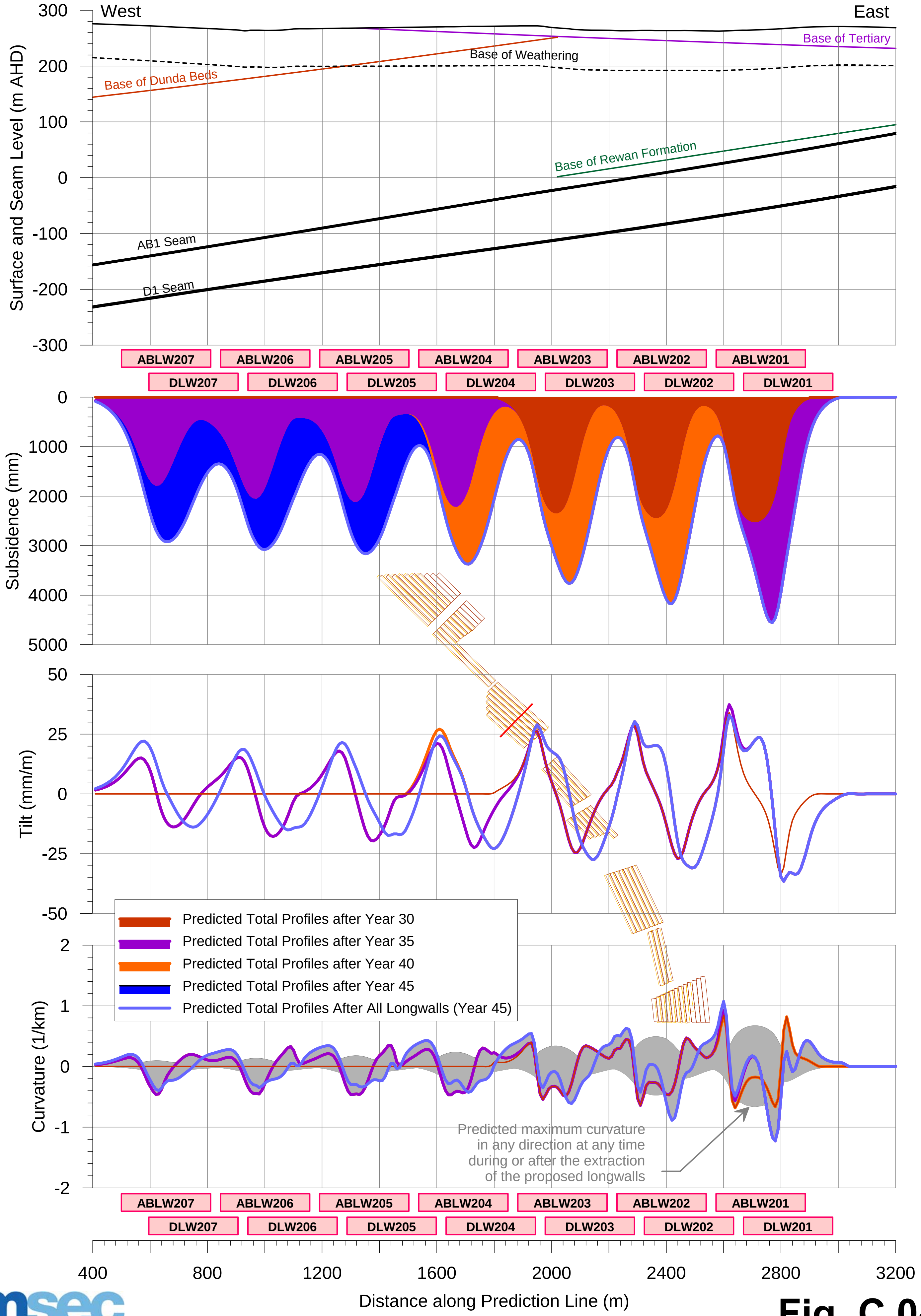

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Fig. C.04

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 4 due to AB1 and D1 Seams - Year 30

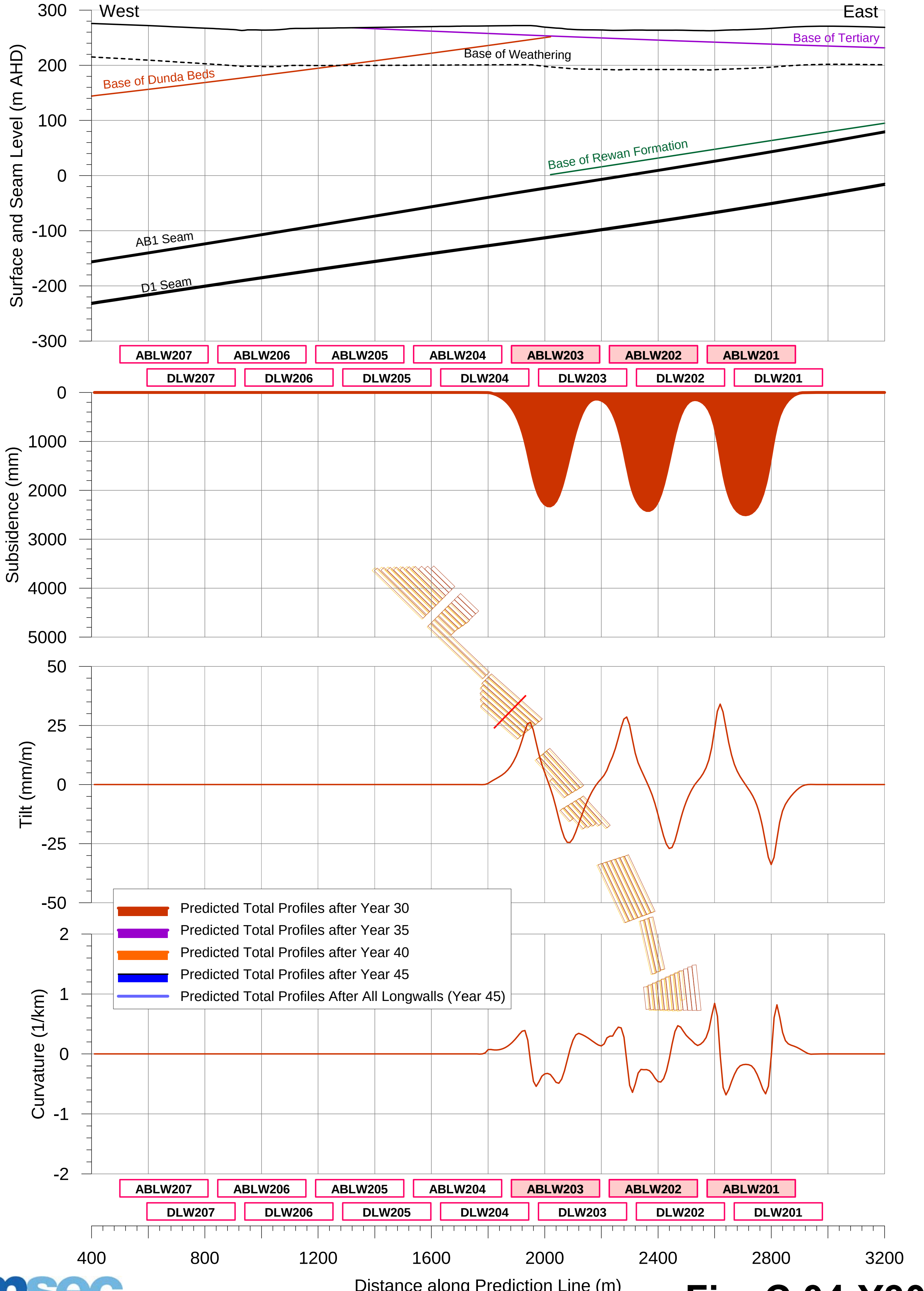

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Fig. C.04-Y30

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 4 due to AB1 and D1 Seams - Year 35

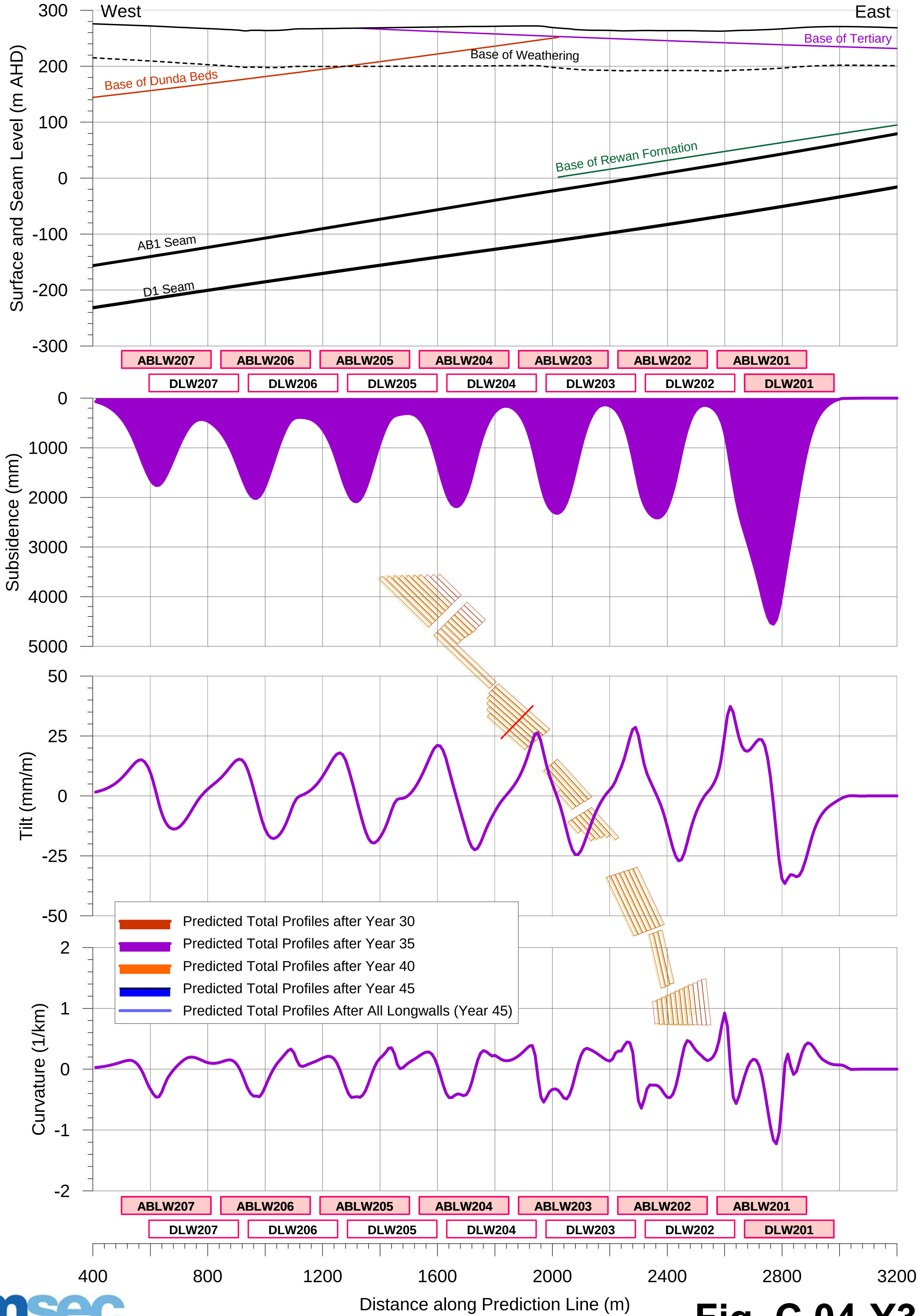

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Fig. C.04-Y35

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Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 4 due to AB1 and D1 Seams - Year 40

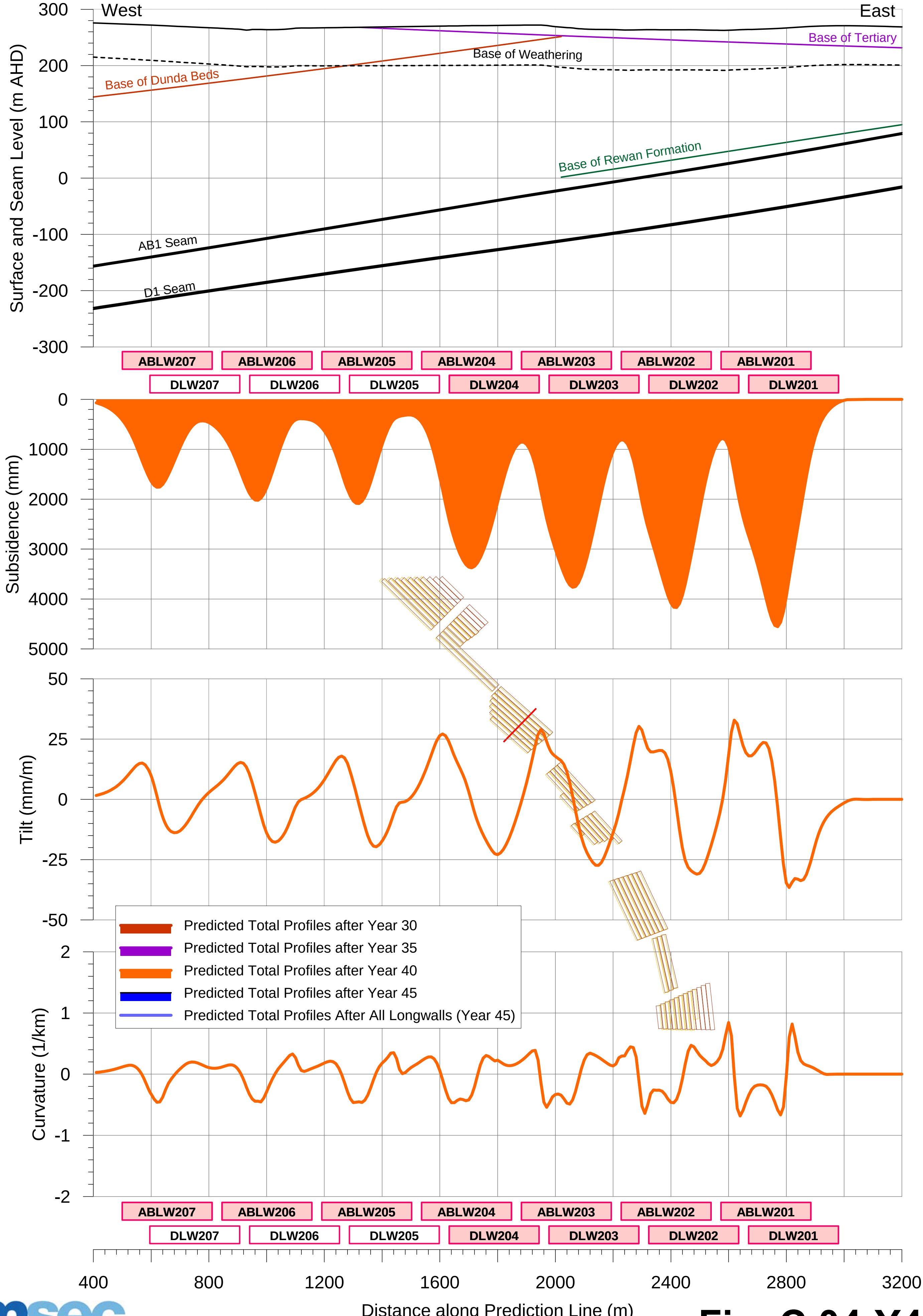

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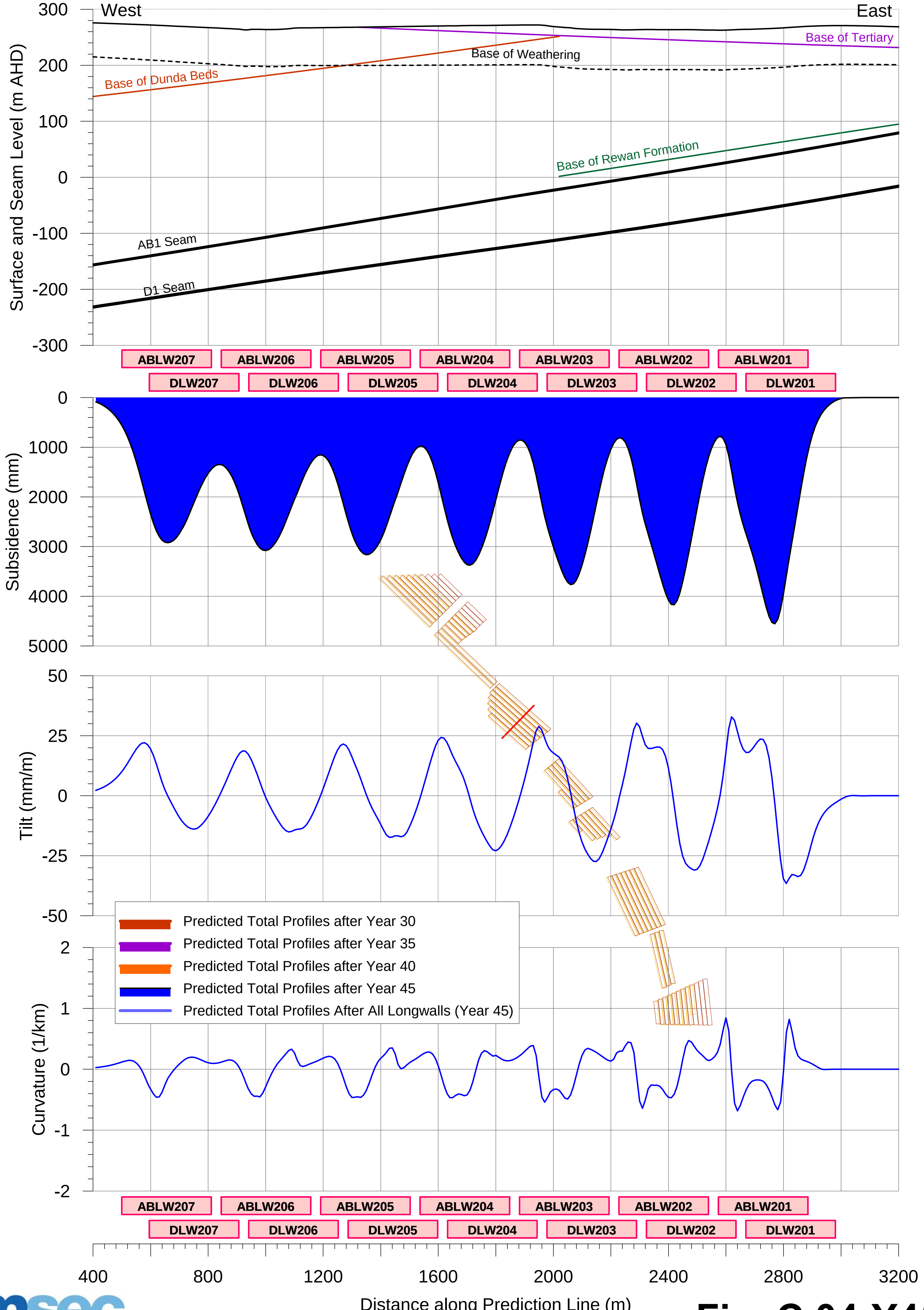
Fig. C.04-Y40

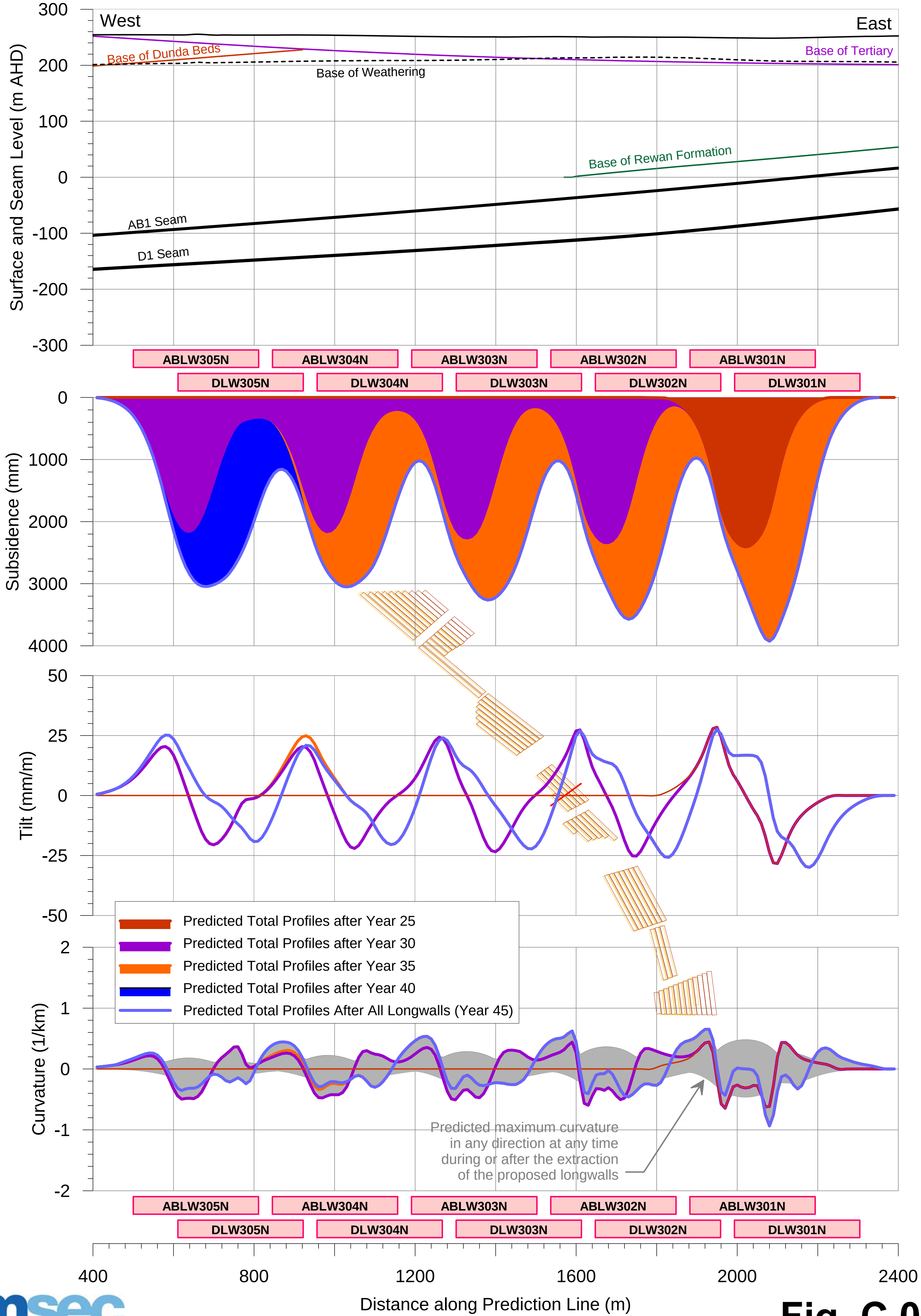
Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 4 due to AB1 and D1 Seams - Year 45



msec

Fig. C.04-Y45

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 5 due to the Extraction of AB1 and D1 Seams



msec

Fig. C.05

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 5 due to AB1 and D1 Seams - Year 25

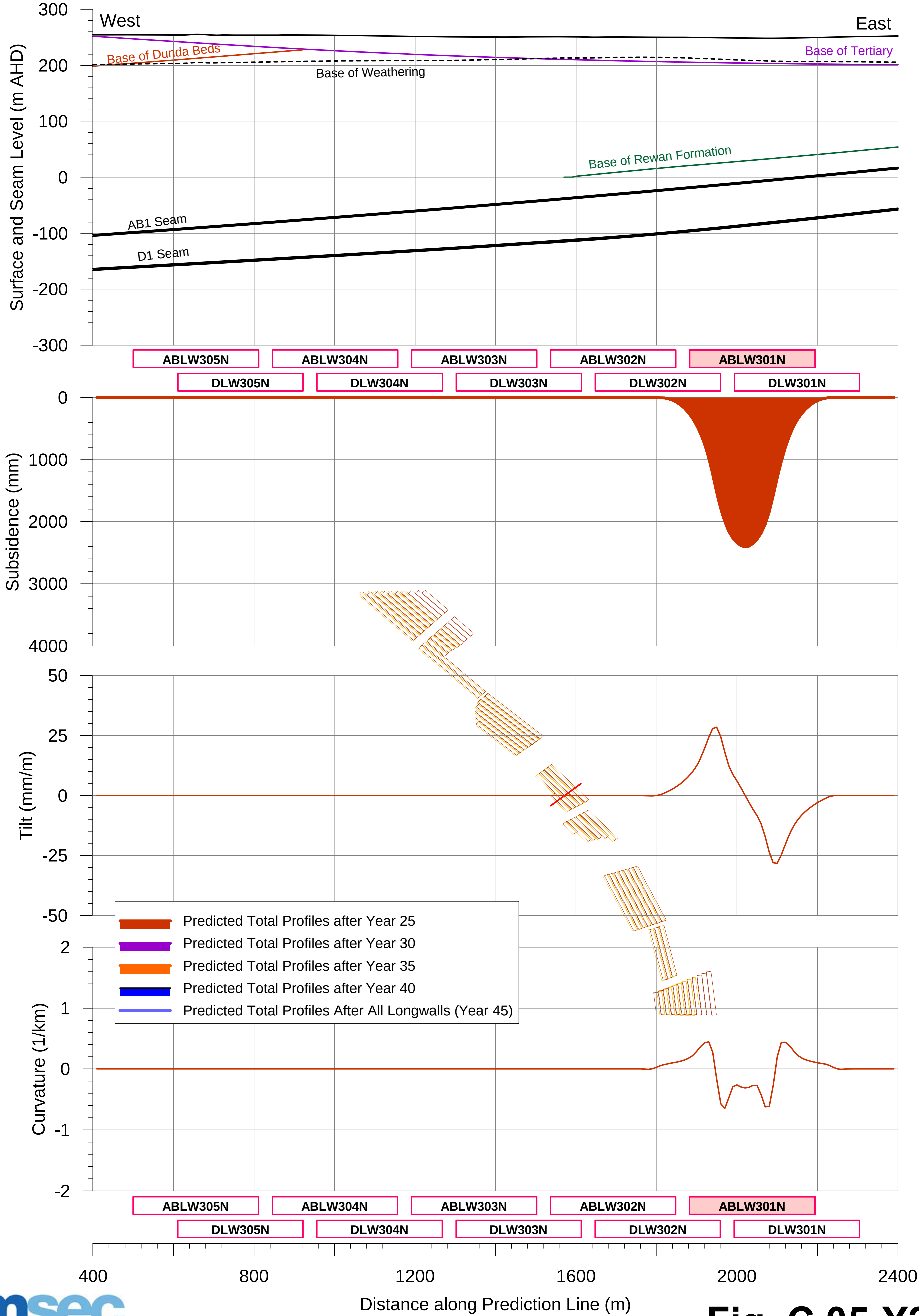


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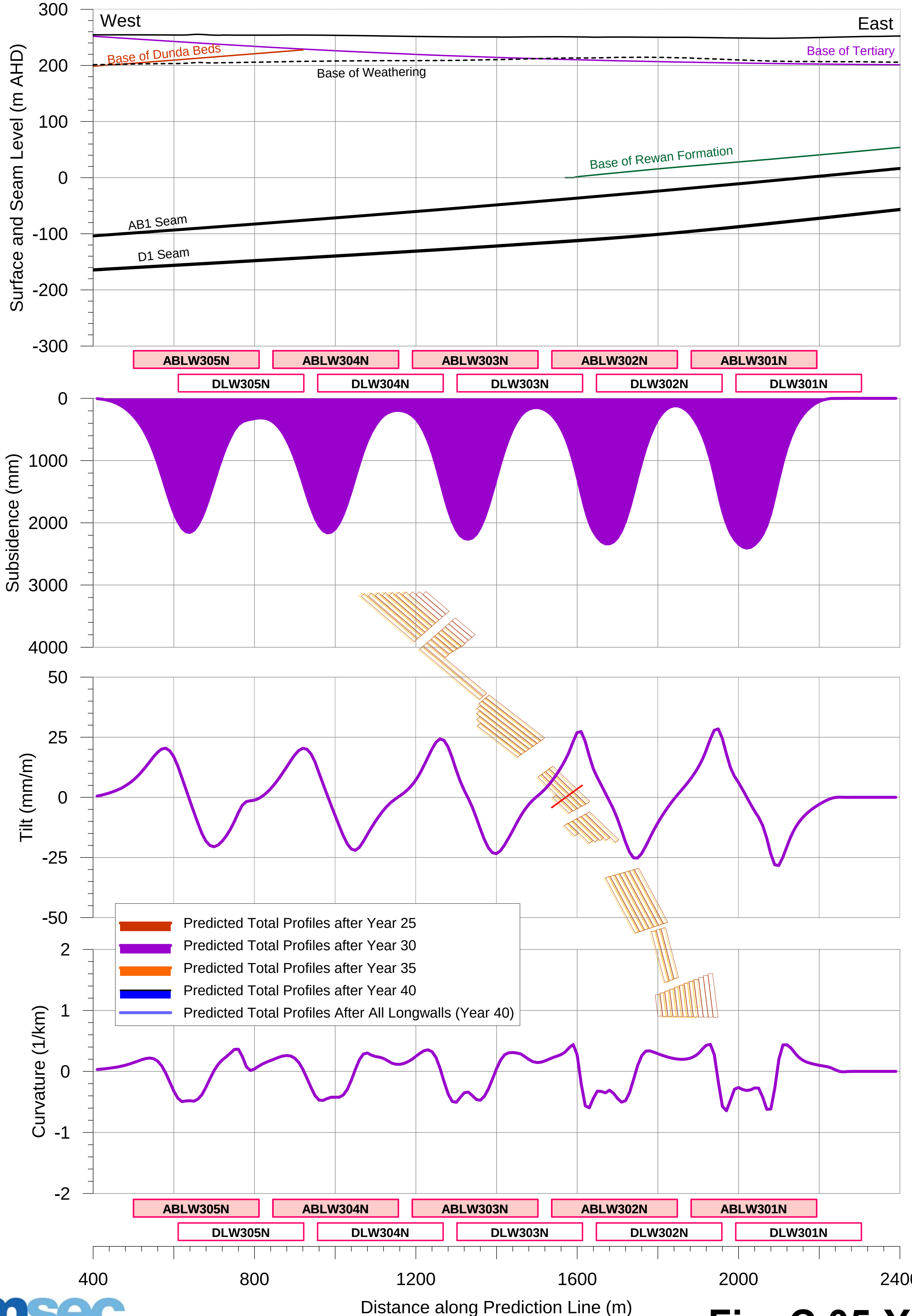
Fig. C.05-Y25

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 5 due to AB1 and D1 Seams - Year 30



msec

Fig. C.05-Y30

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 5 due to AB1 and D1 Seams - Year 35

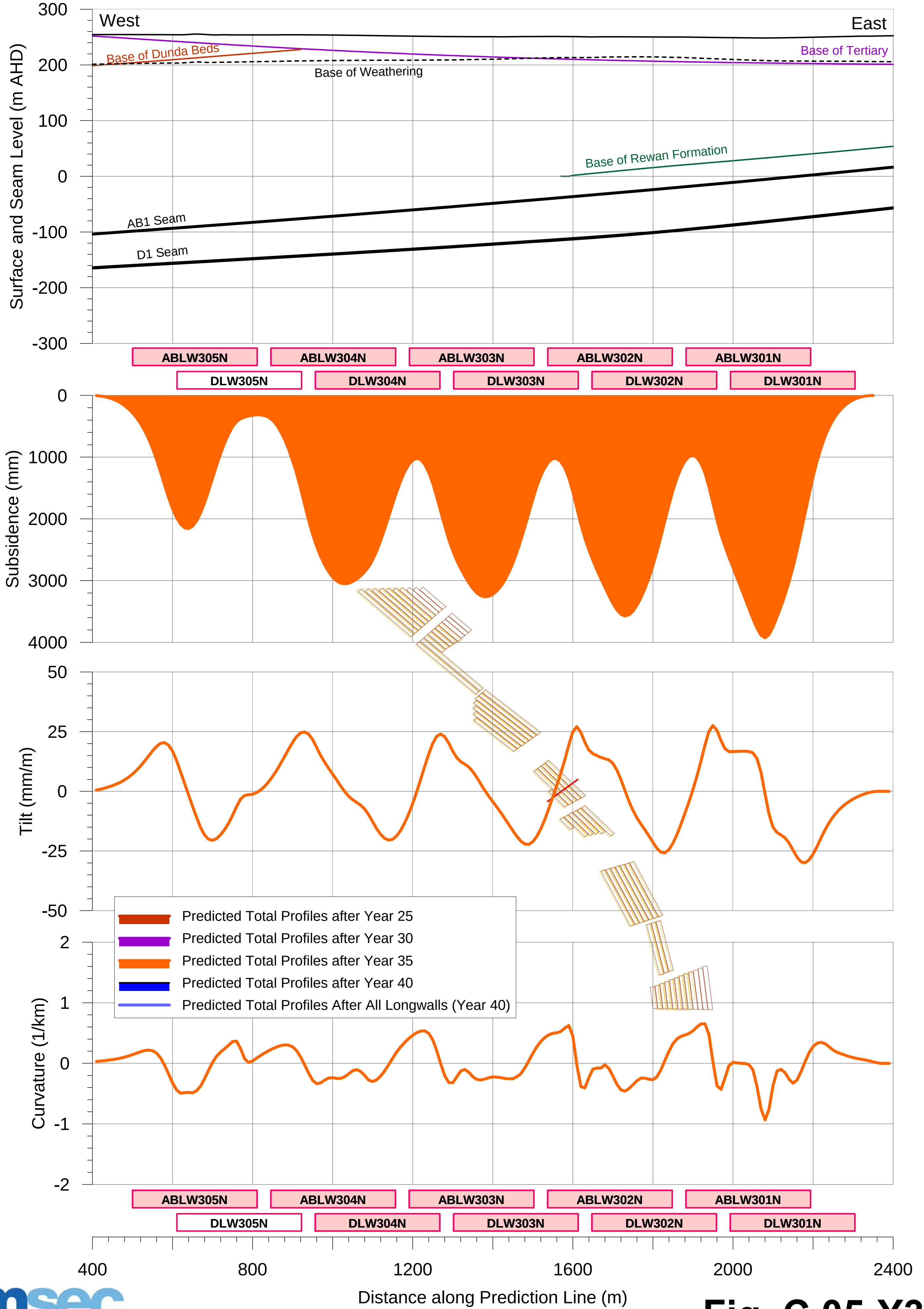


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Fig. C.05-Y35

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 5 due to AB1 and D1 Seams - Year 40

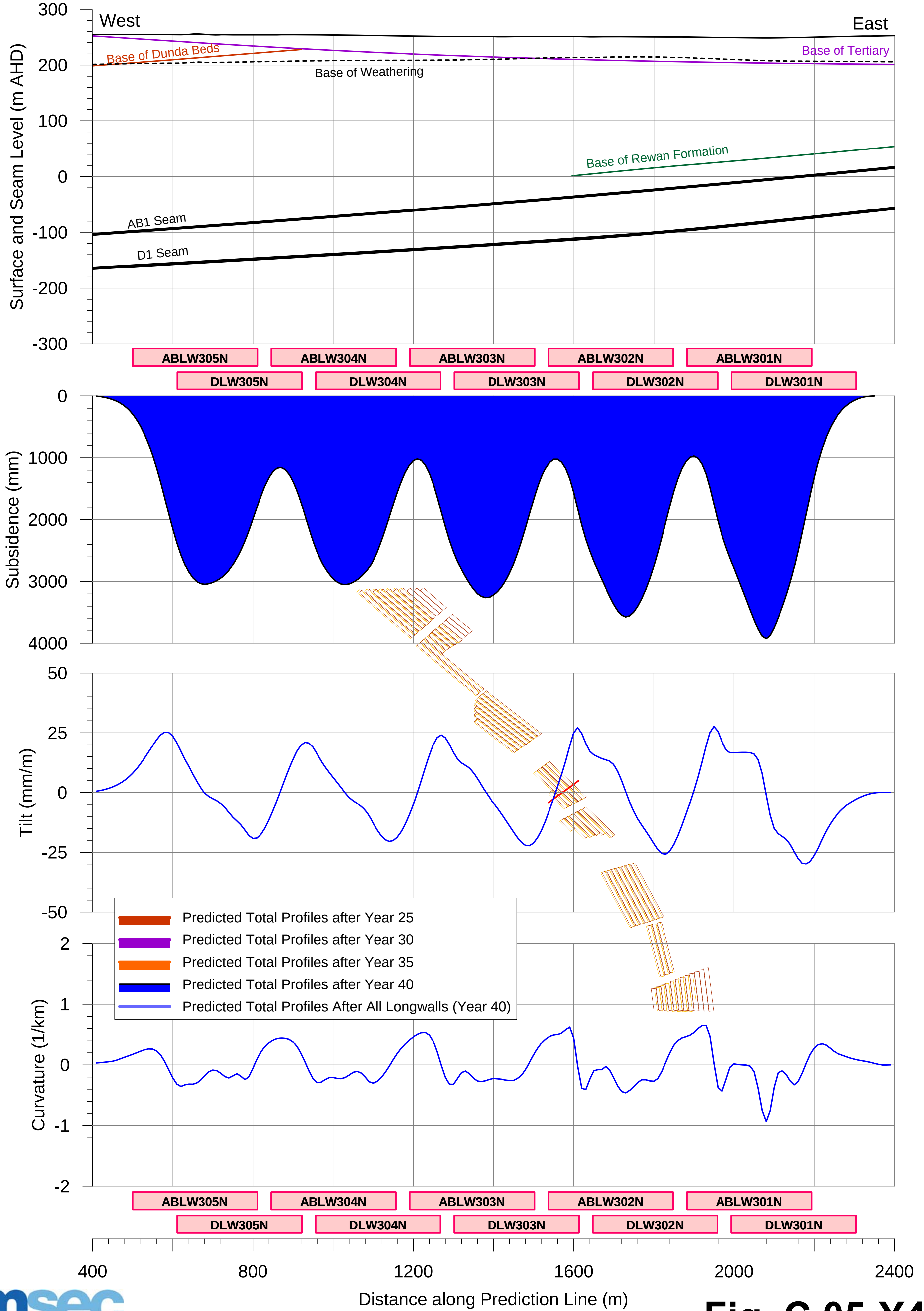

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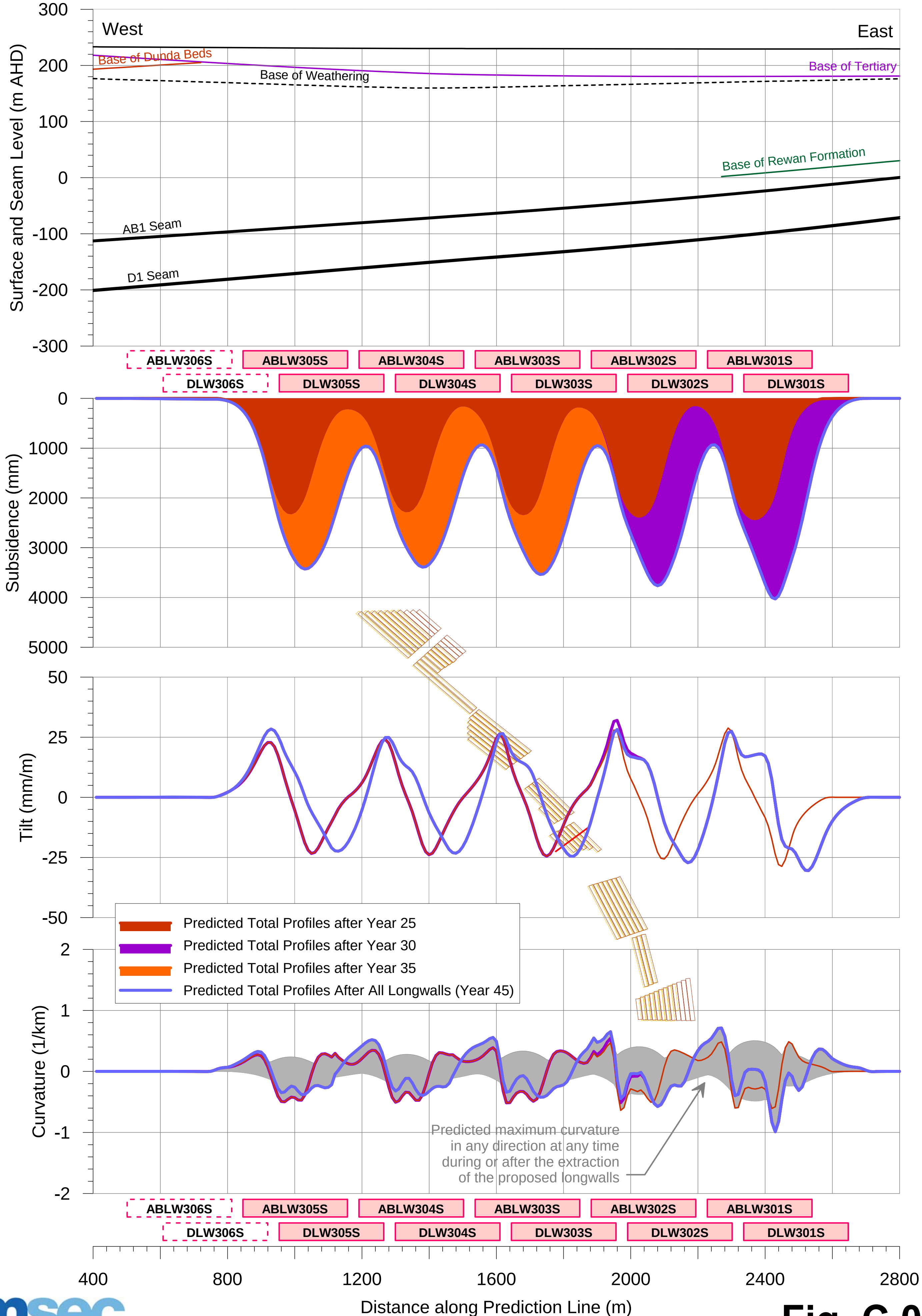
Fig. C.05-Y40

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 6 due to the Extraction of AB1 and D1 Seams



msec

Fig. C.06

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 6 due to AB1 and D1 Seams - Year 25

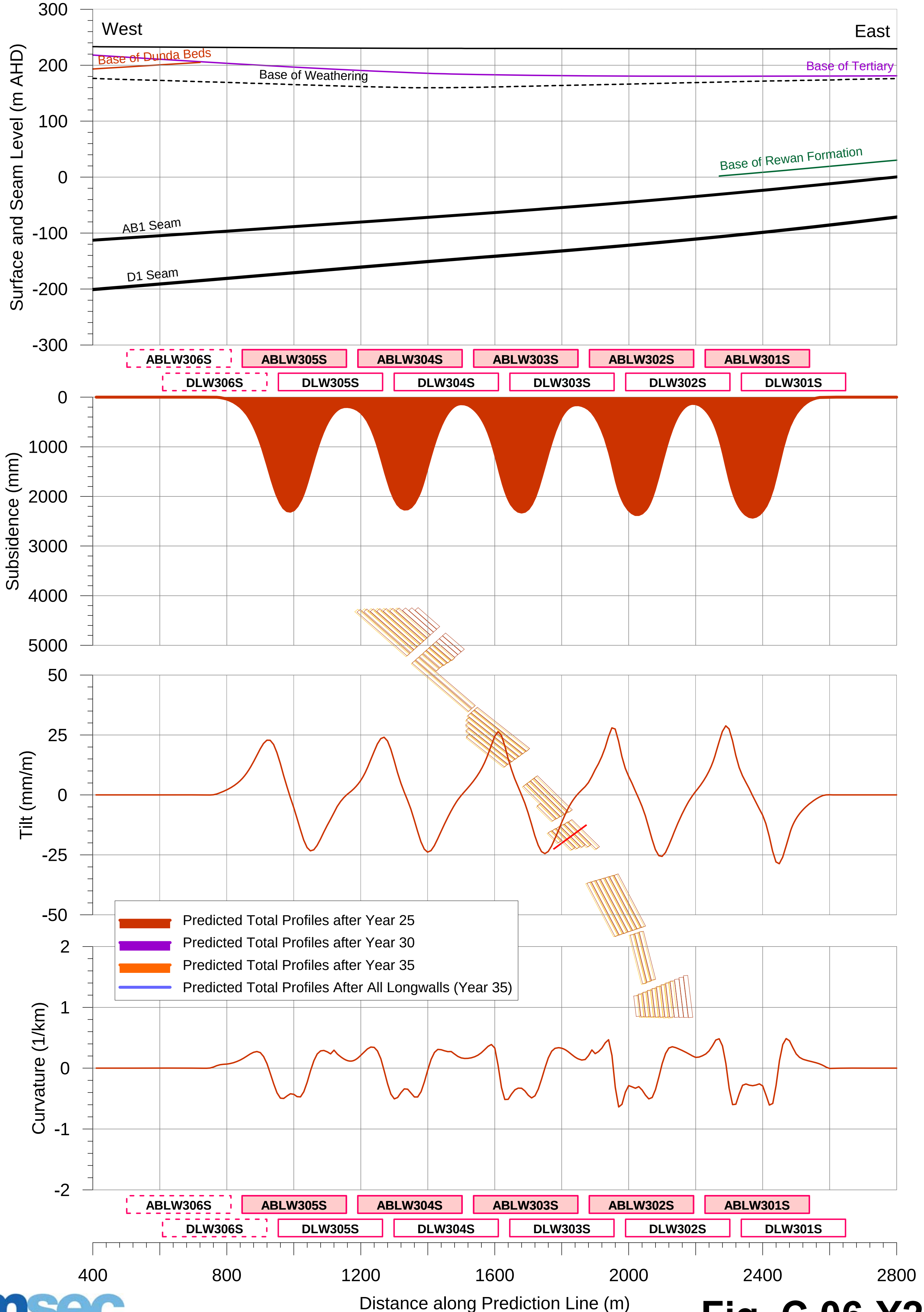


Fig. C.06-Y25

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 6 due to AB1 and D1 Seams - Year 30

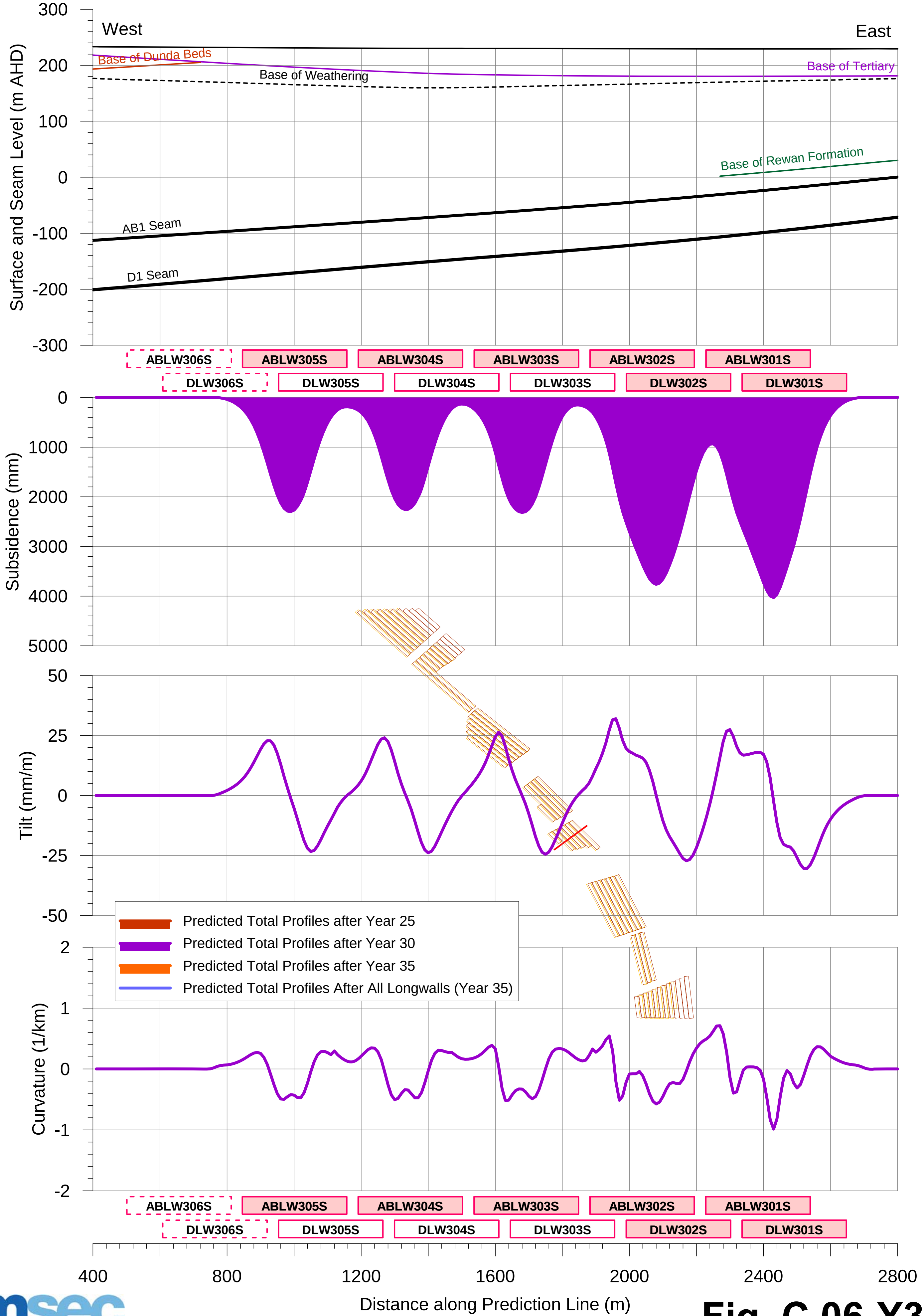


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Fig. C.06-Y30

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 6 due to AB1 and D1 Seams - Year 35

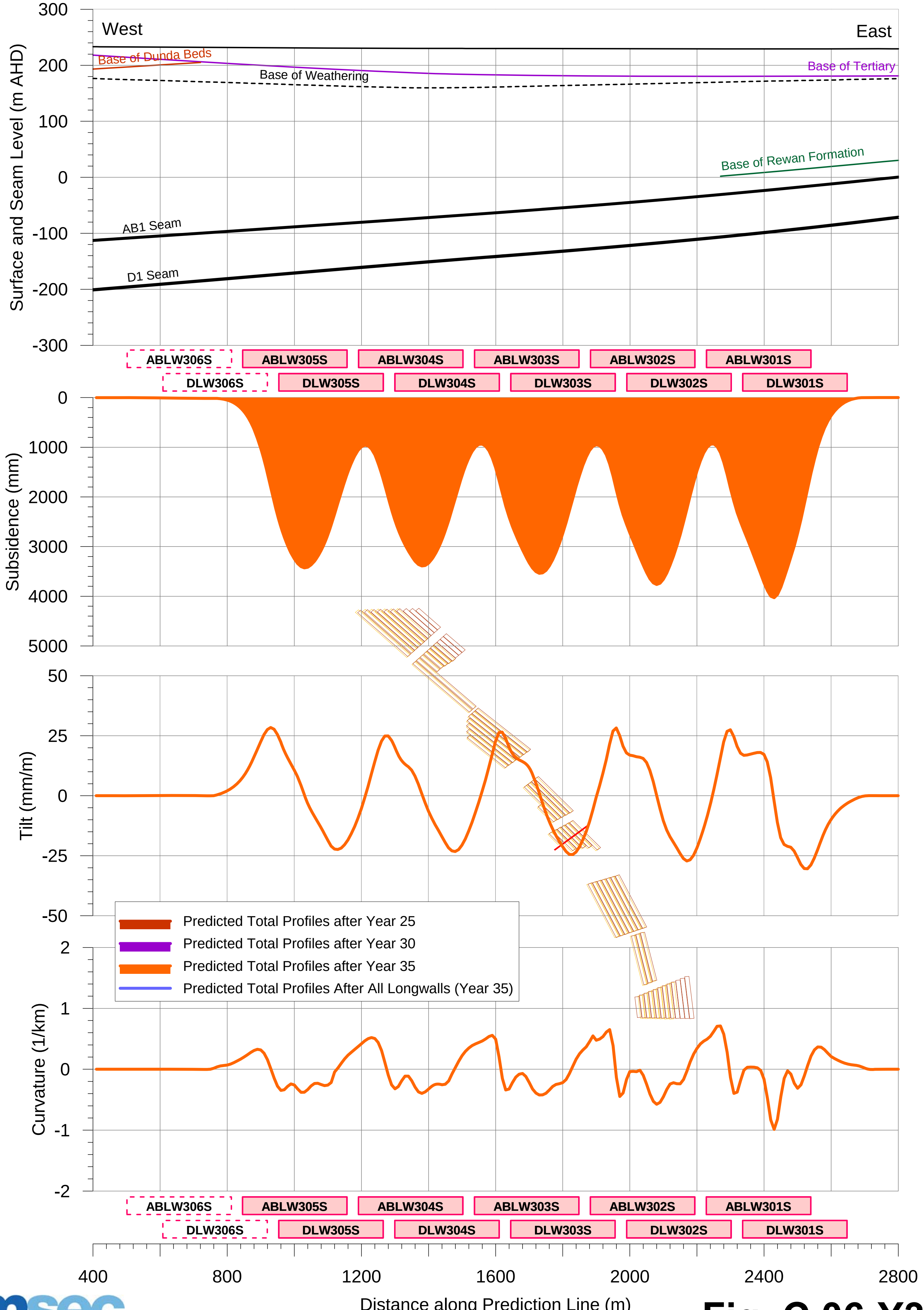

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Fig. C.06-Y35

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 7 due to the Extraction of AB1 and D1 Seams

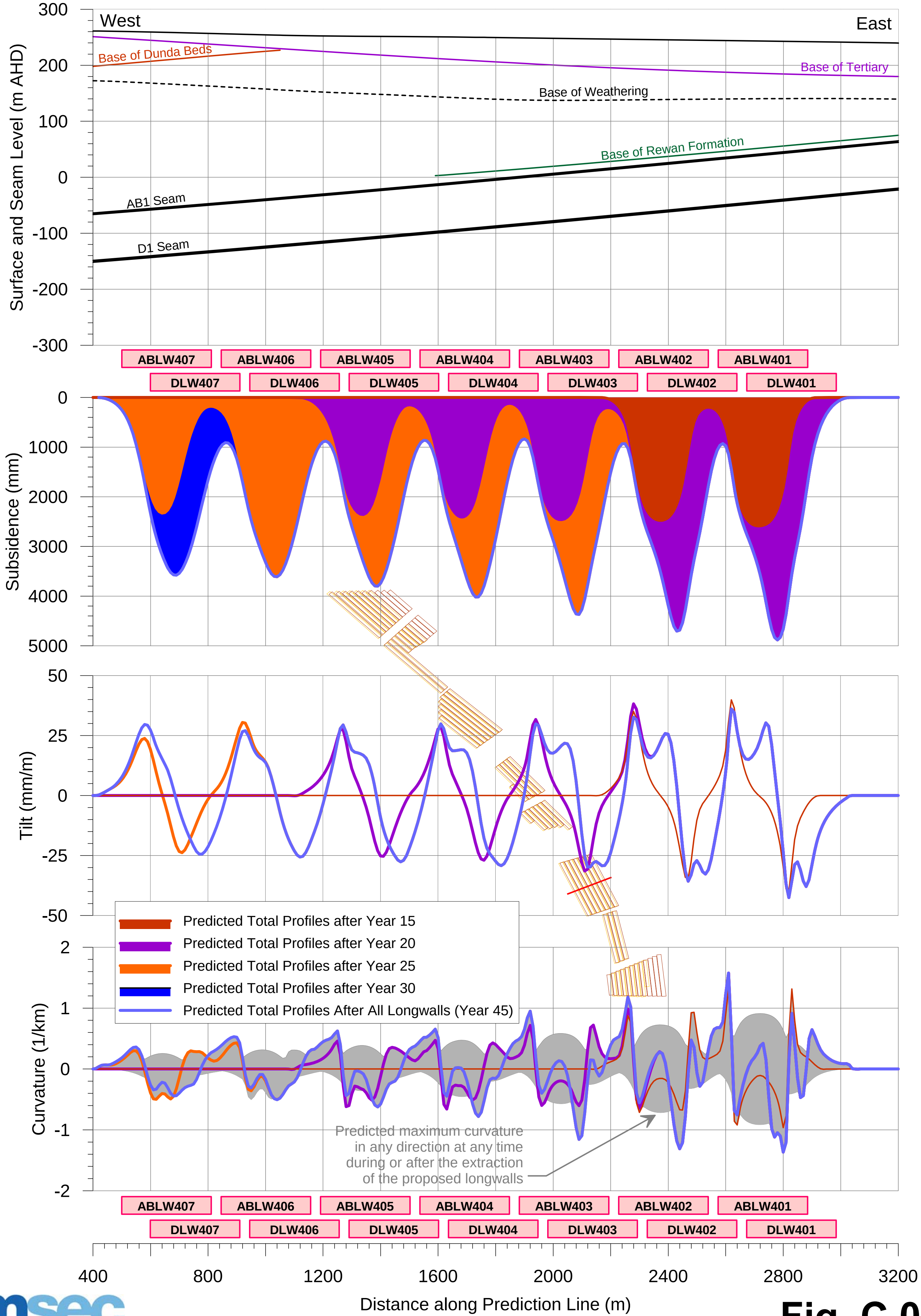

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Fig. C.07

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 7 due to AB1 and D1 Seams - Year 15

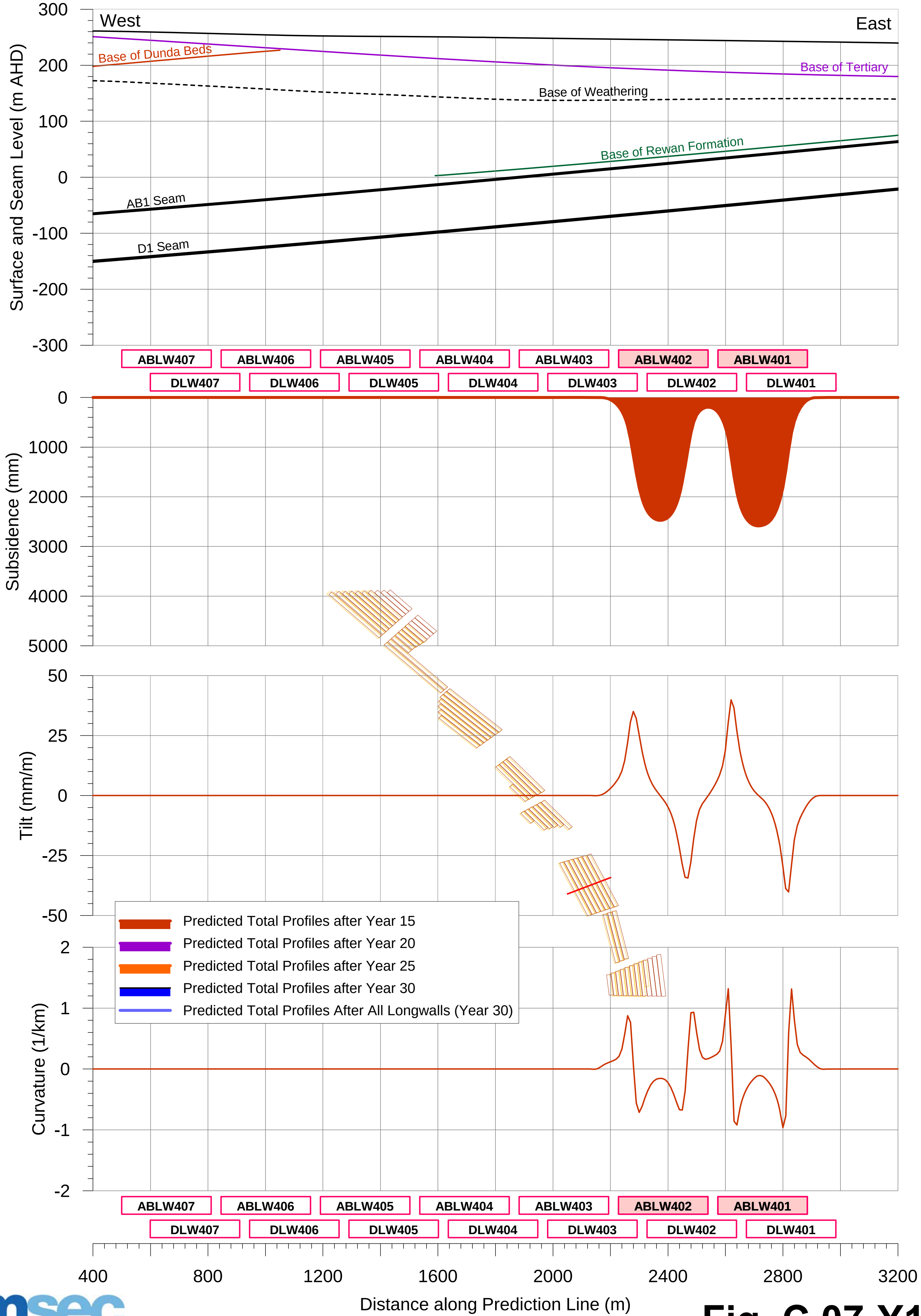

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Fig. C.07-Y15

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 7 due to AB1 and D1 Seams - Year 20

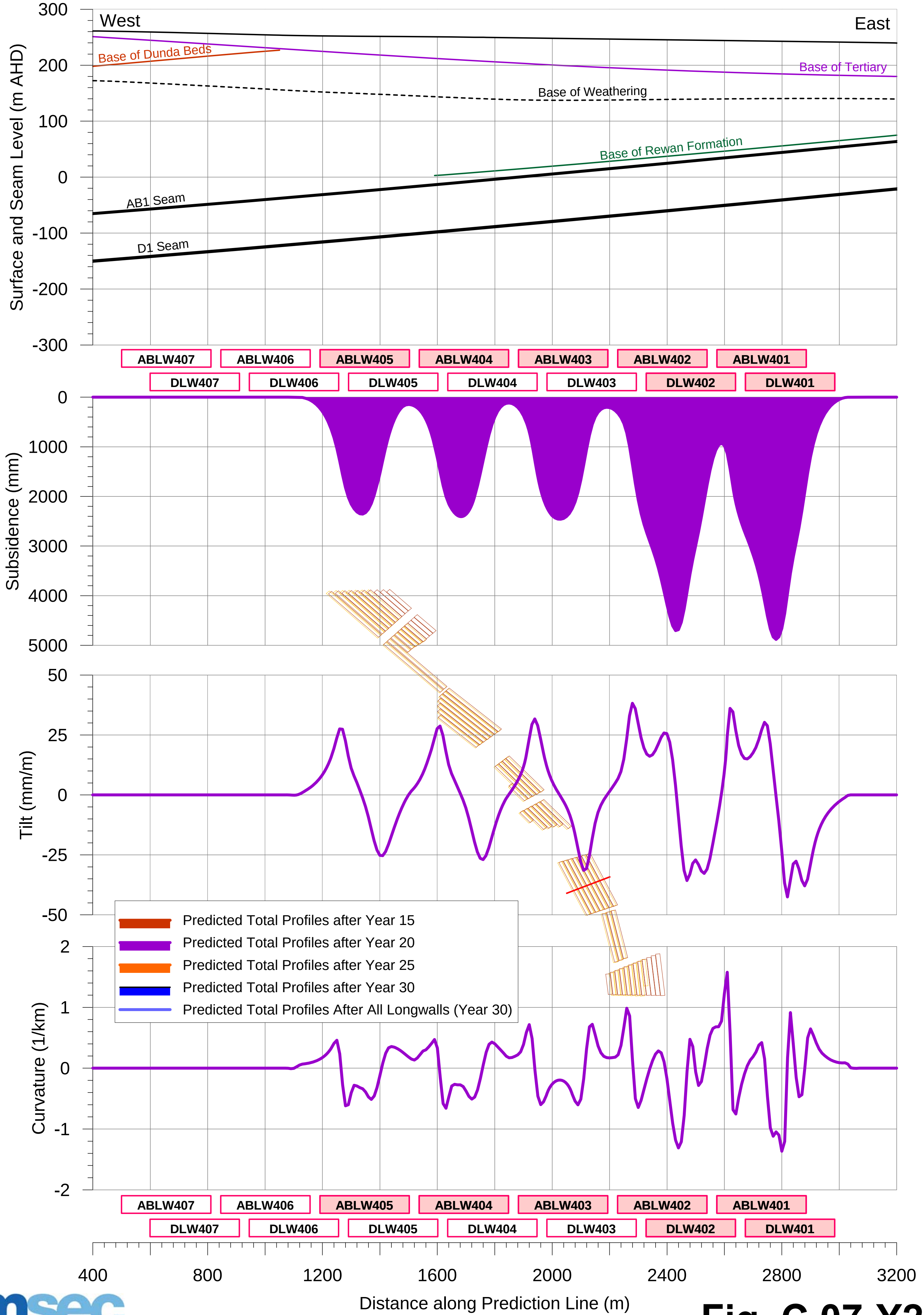

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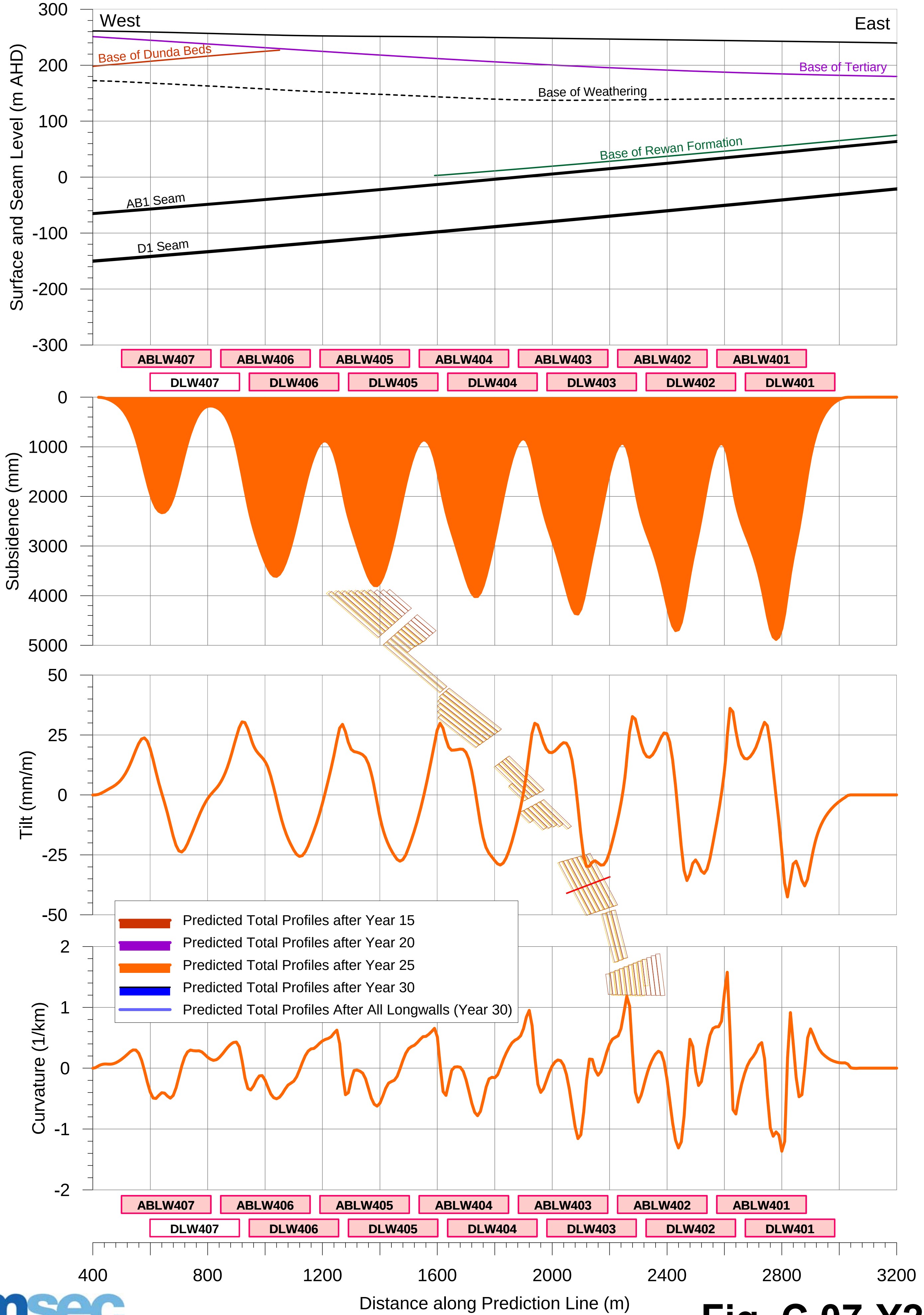
Fig. C.07-Y20

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 7 due to AB1 and D1 Seams - Year 25



msec

Fig. C.07-Y25

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 7 due to AB1 and D1 Seams - Year 30

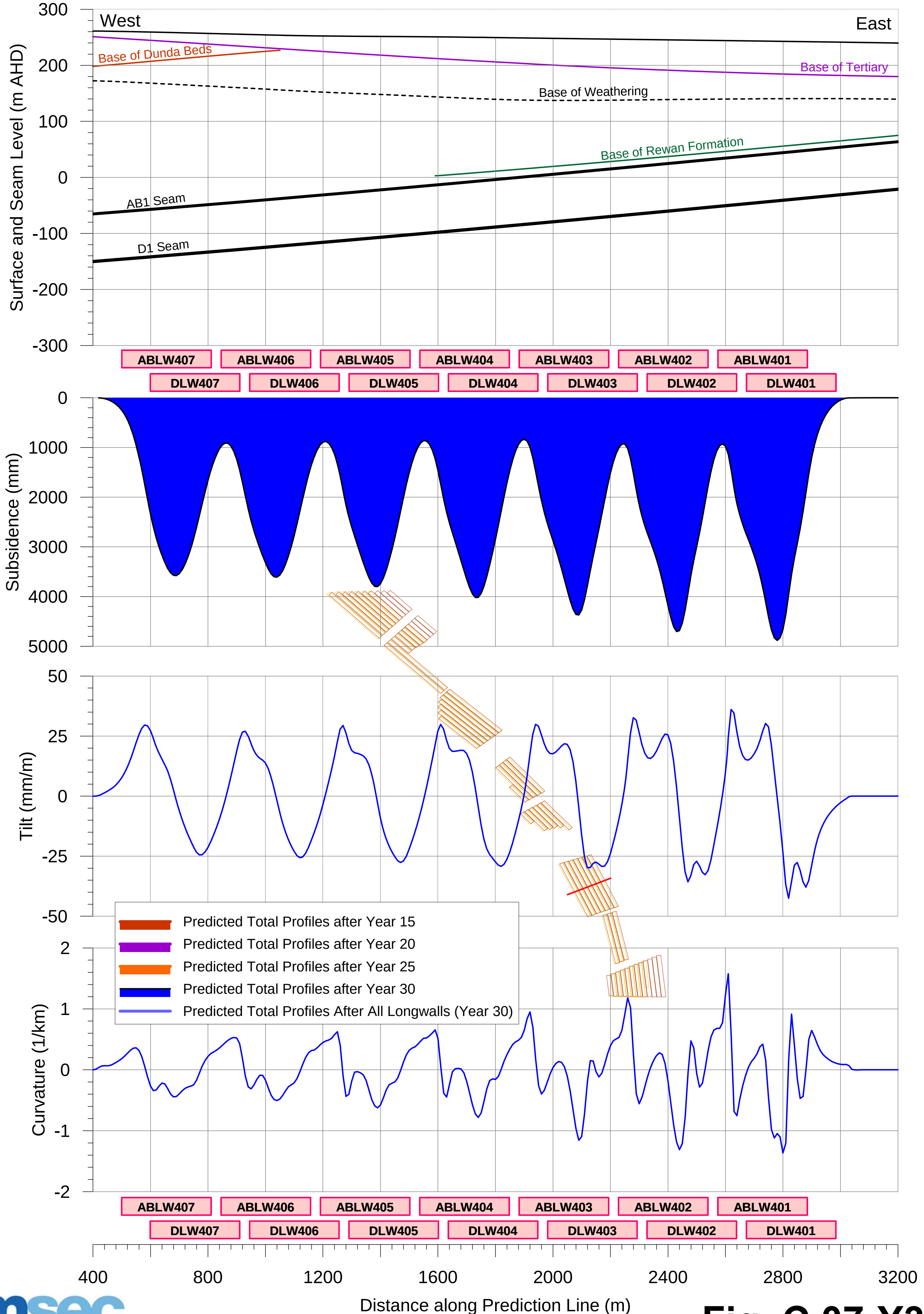


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Fig. C.07-Y30

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 8 due to the Extraction of AB1 and D1 Seams

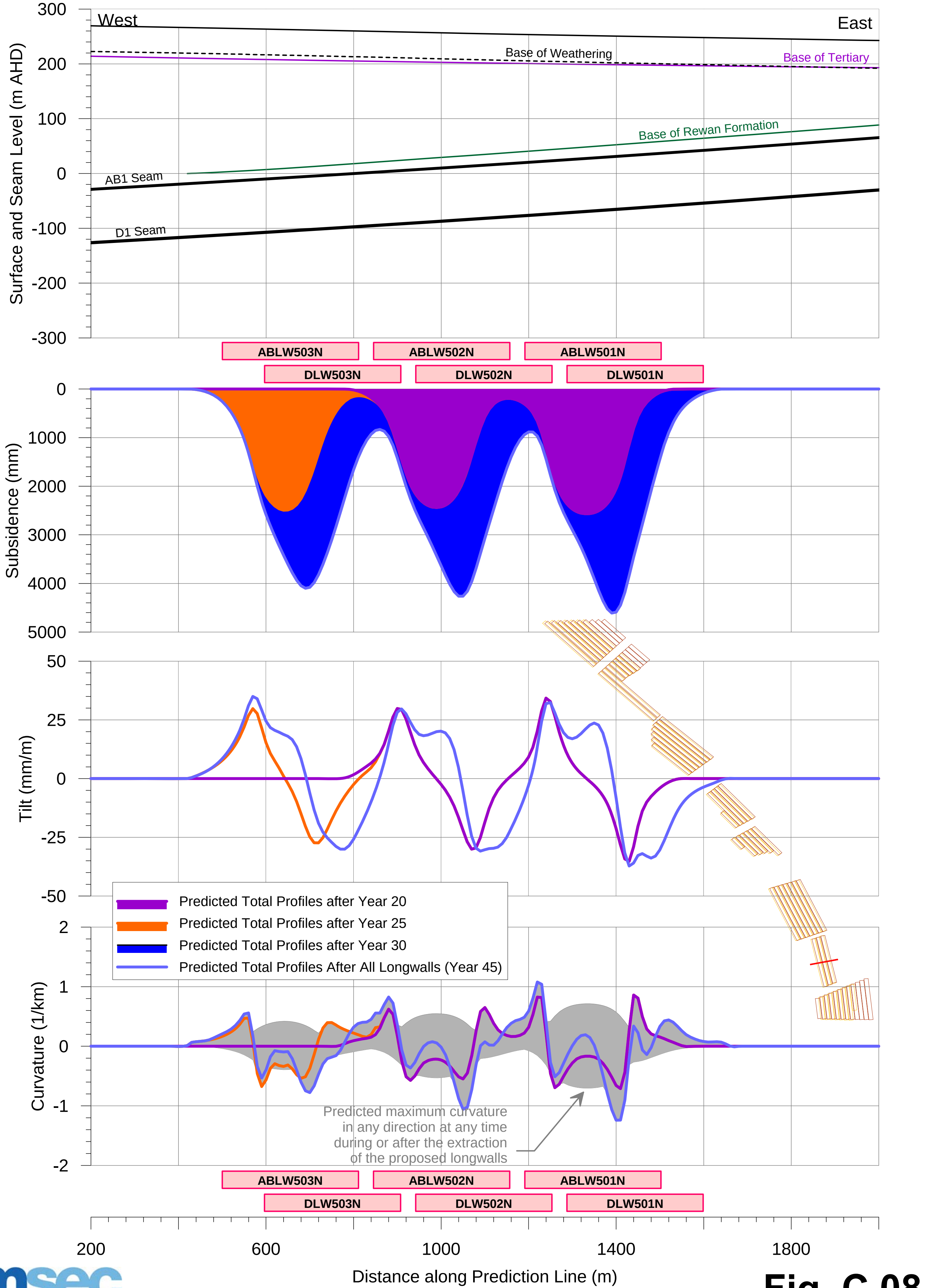

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Fig. C.08

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 8 due to AB1 and D1 Seams - Year 20

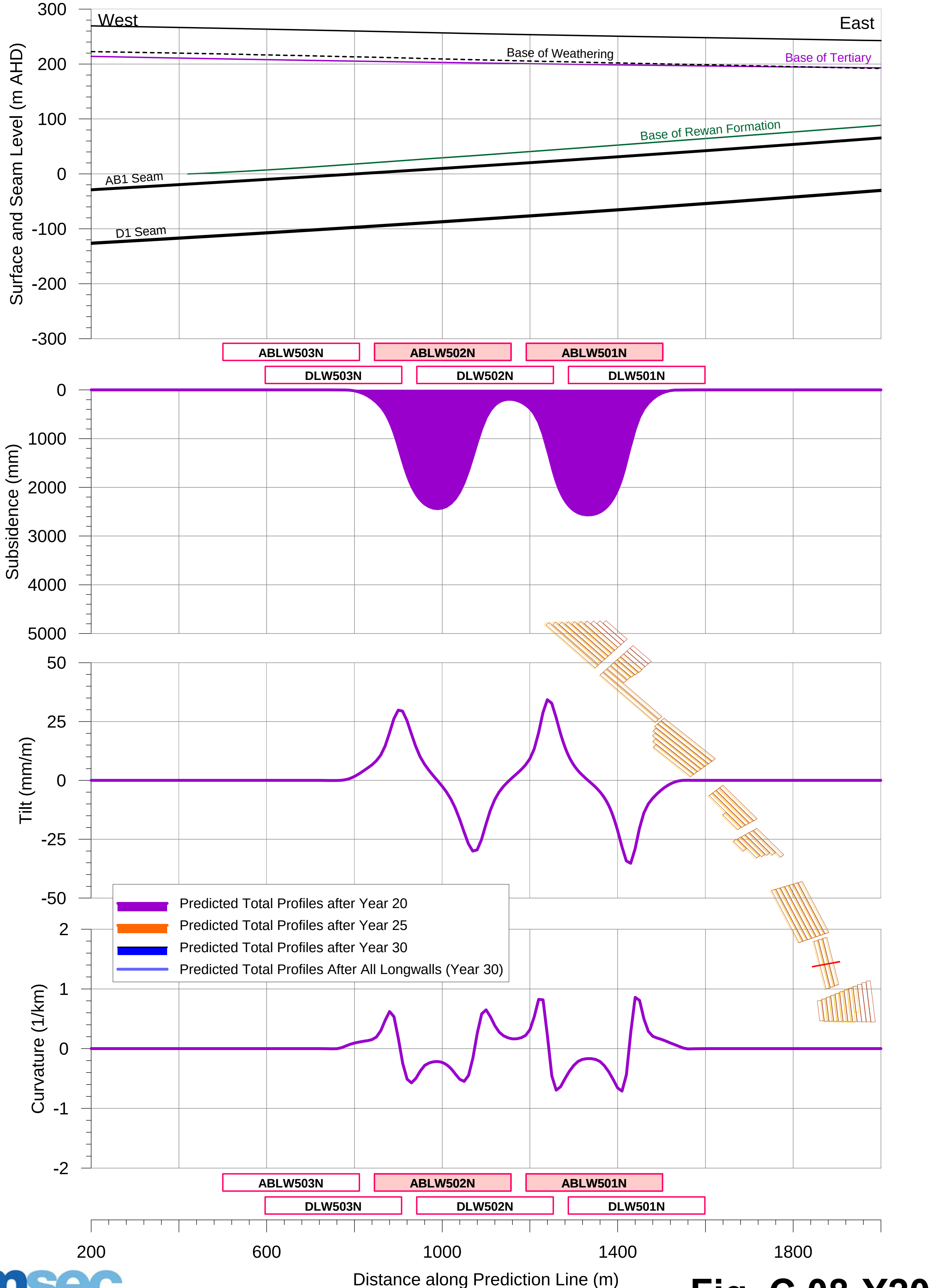

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Fig. C.08-Y20

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 8 due to AB1 and D1 Seams - Year 25

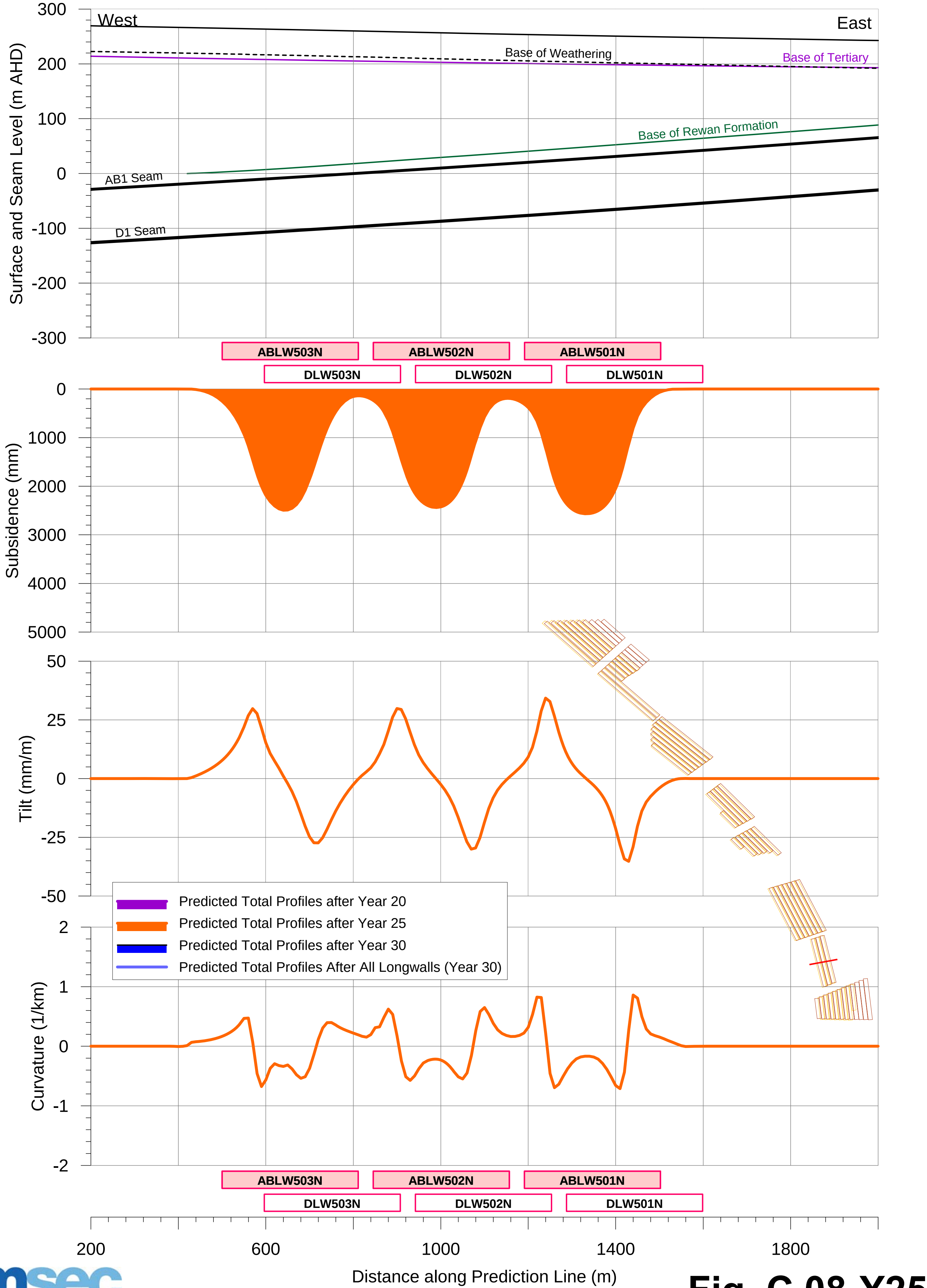
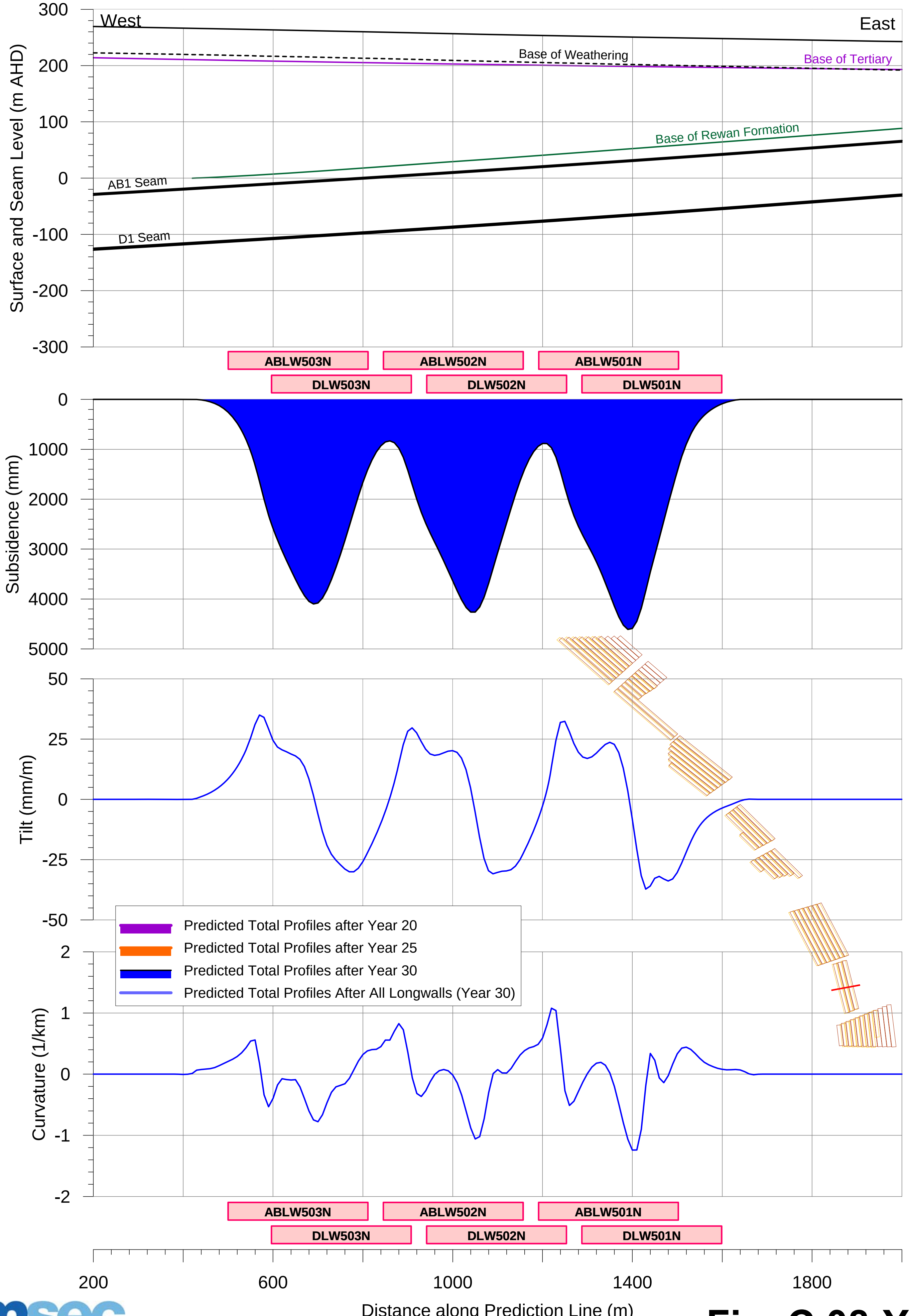


Fig. C.08-Y25

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 8 due to AB1 and D1 Seams - Year 30



msec

Fig. C.08-Y30

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 9 due to the Extraction of AB1 and D1 Seams

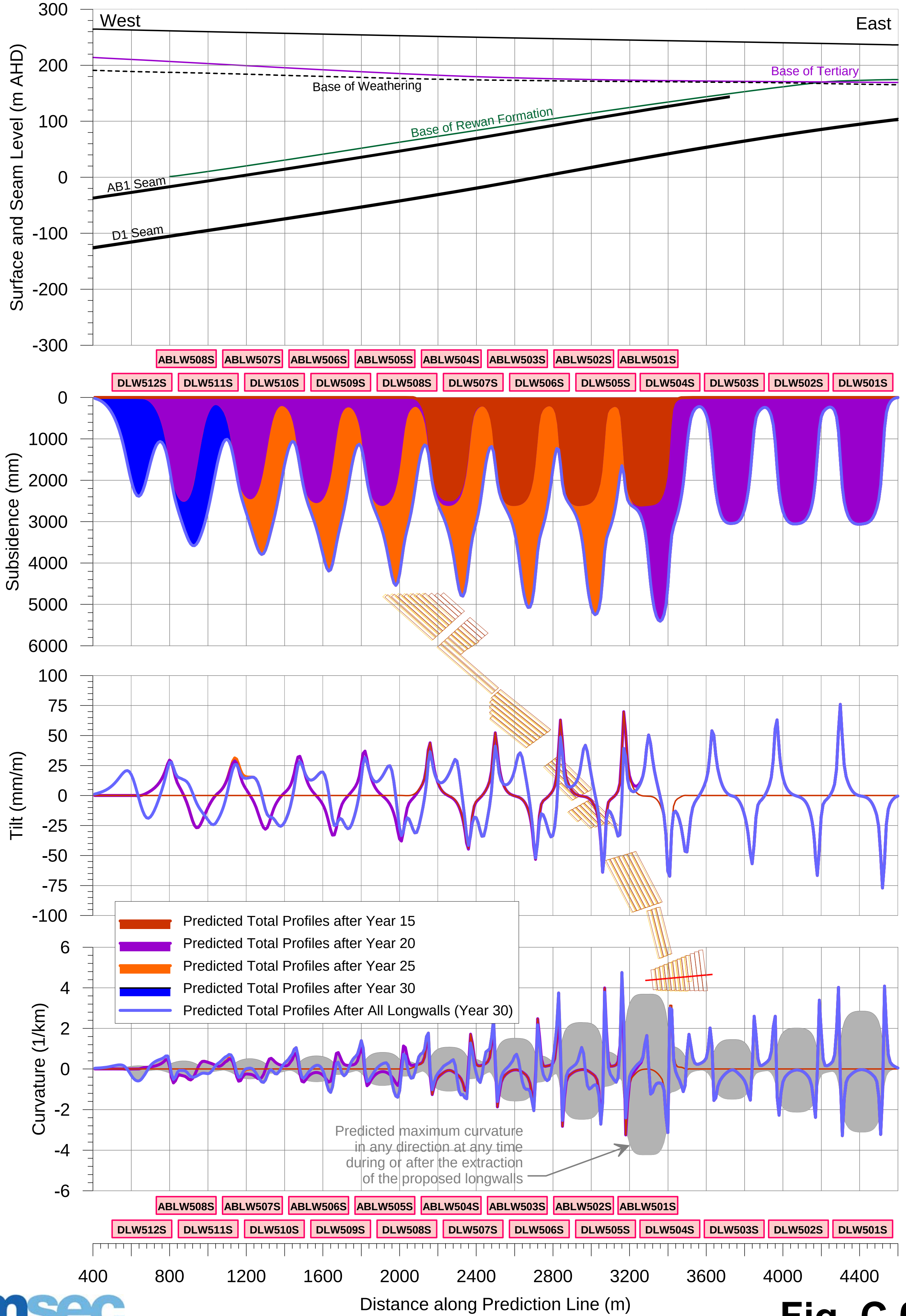


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Fig. C.09

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 9 due to AB1 and D1 Seams - Year 15

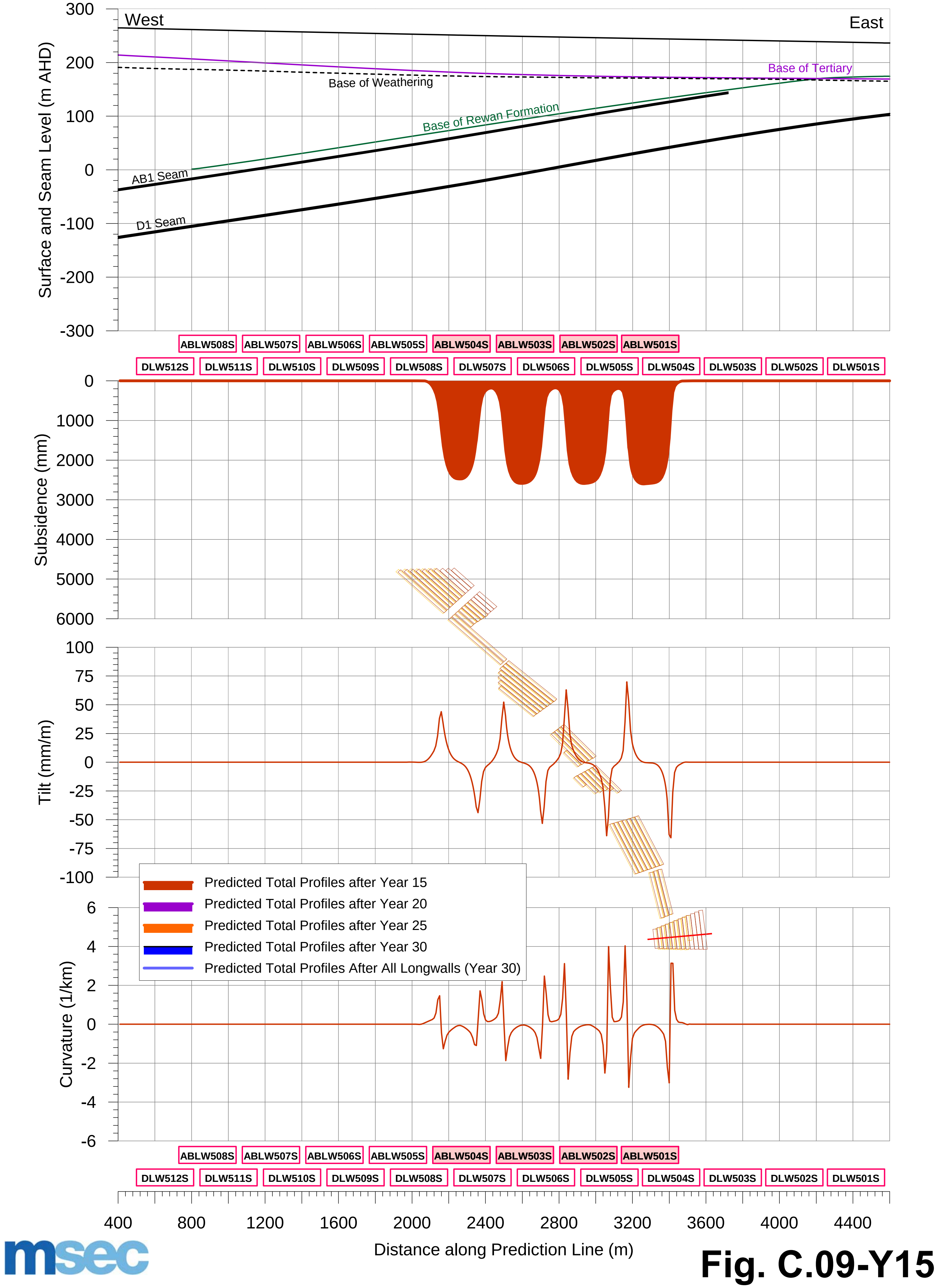
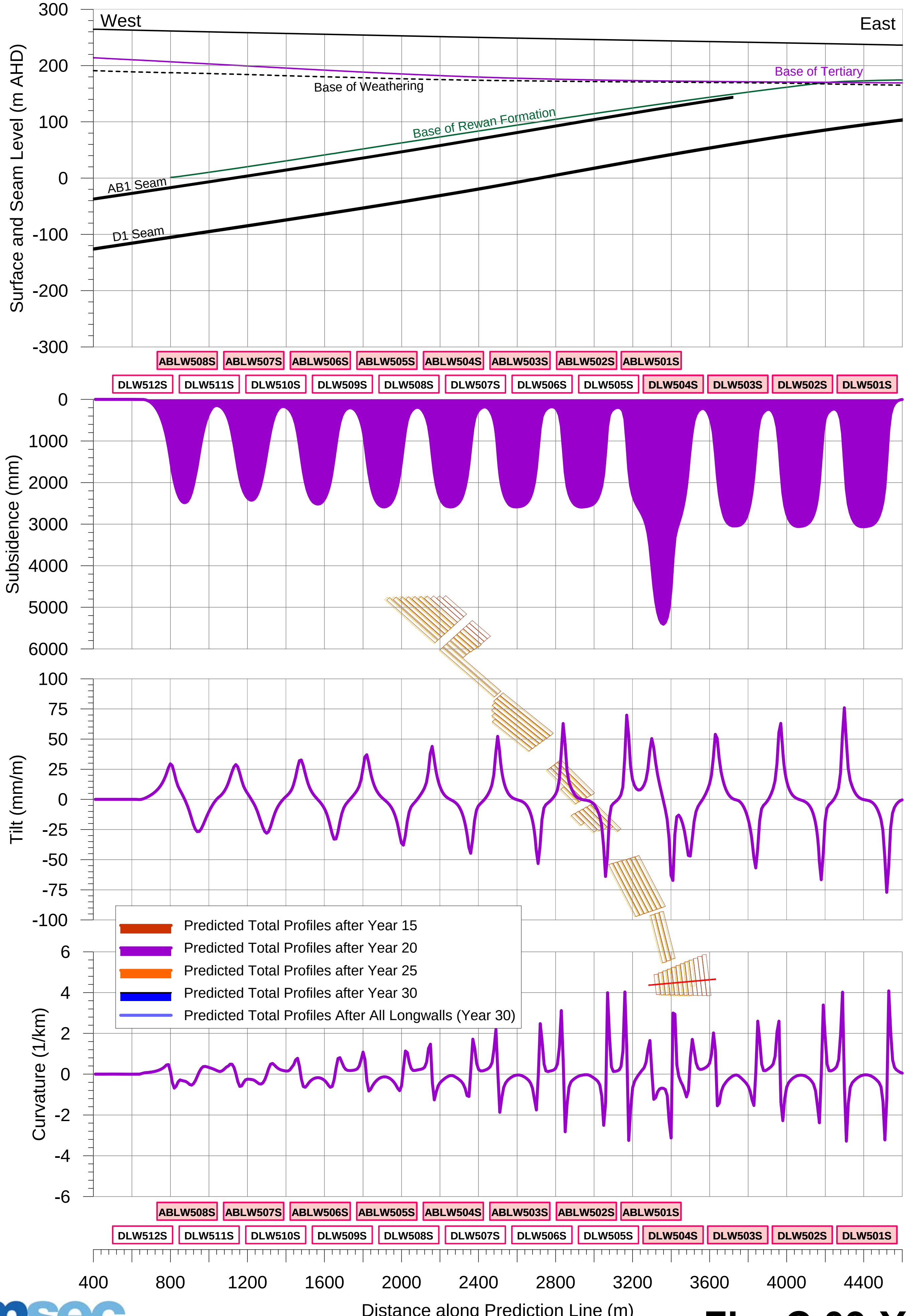


Fig. C.09-Y15

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 9 due to AB1 and D1 Seams - Year 20



msec

Fig. C.09-Y20

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 9 due to AB1 and D1 Seams - Year 25

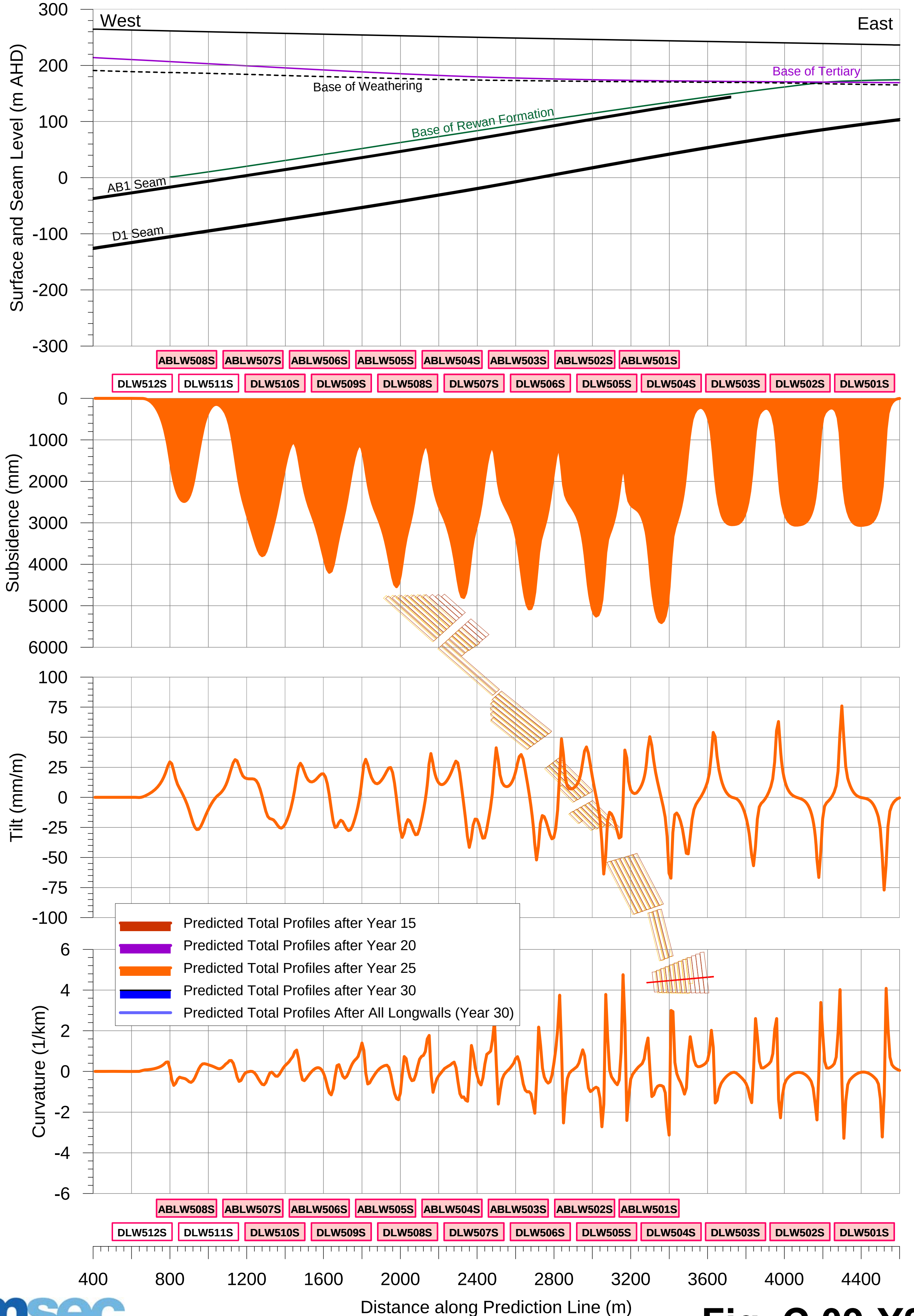


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Fig. C.09-Y25

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Prediction Line 9 due to AB1 and D1 Seams - Year 30

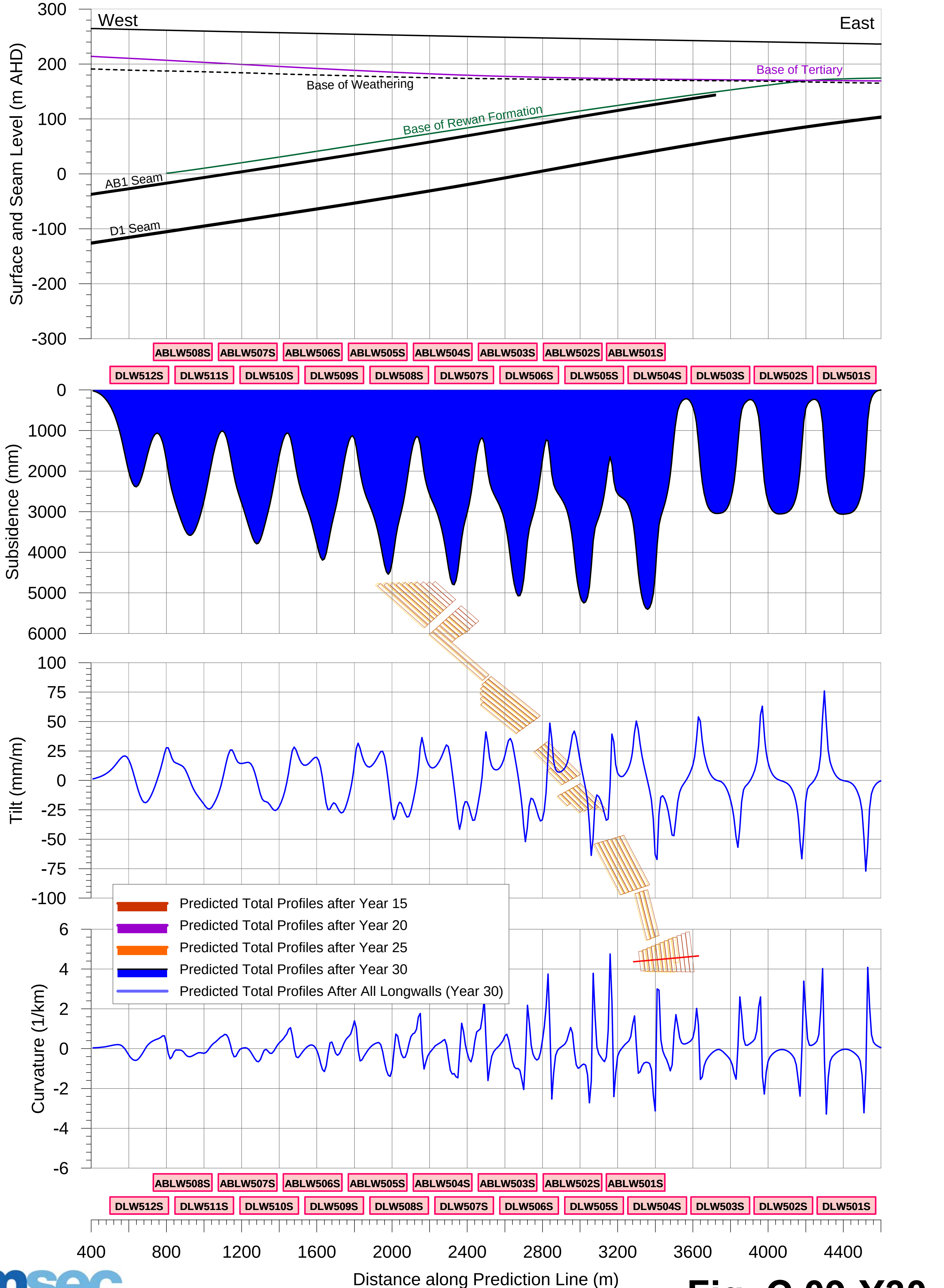

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Fig. C.09-Y30

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Moray Carmichael Boudnary Rd due to AB1 and D1 Seams

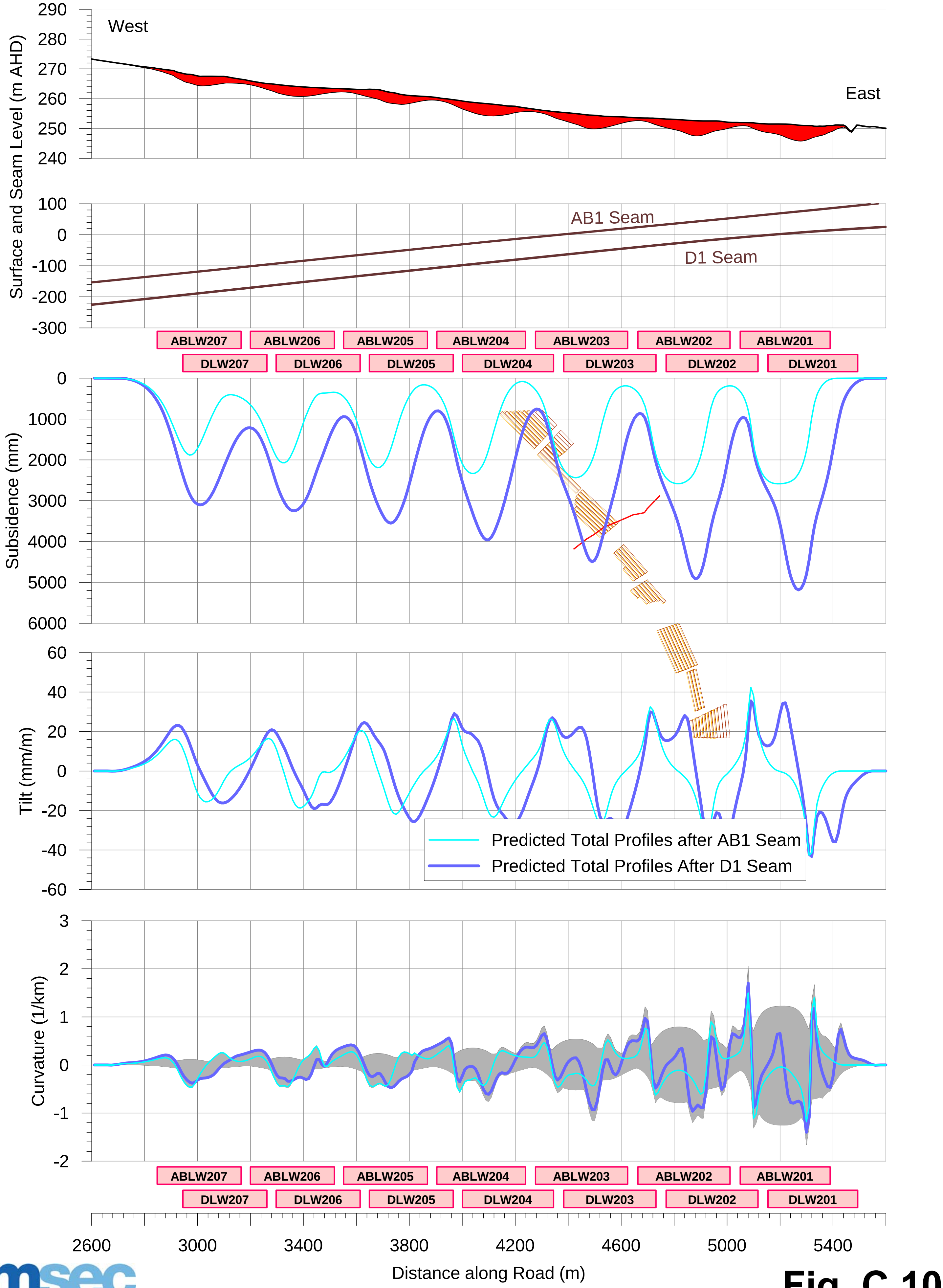

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Fig. C.10

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Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Shuttleworth Carmichael Rd due to the Extraction of AB1 and D1 Seams

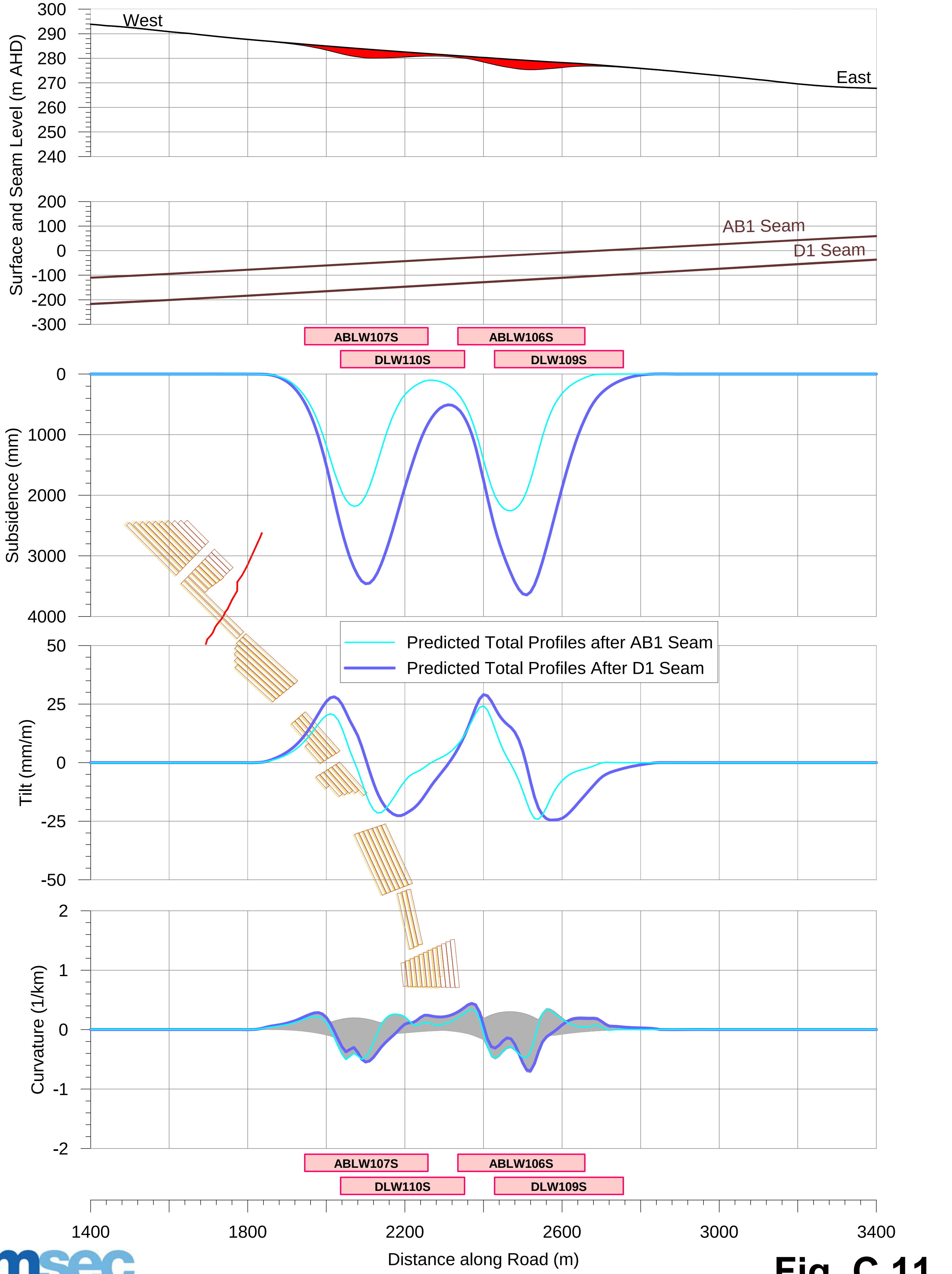
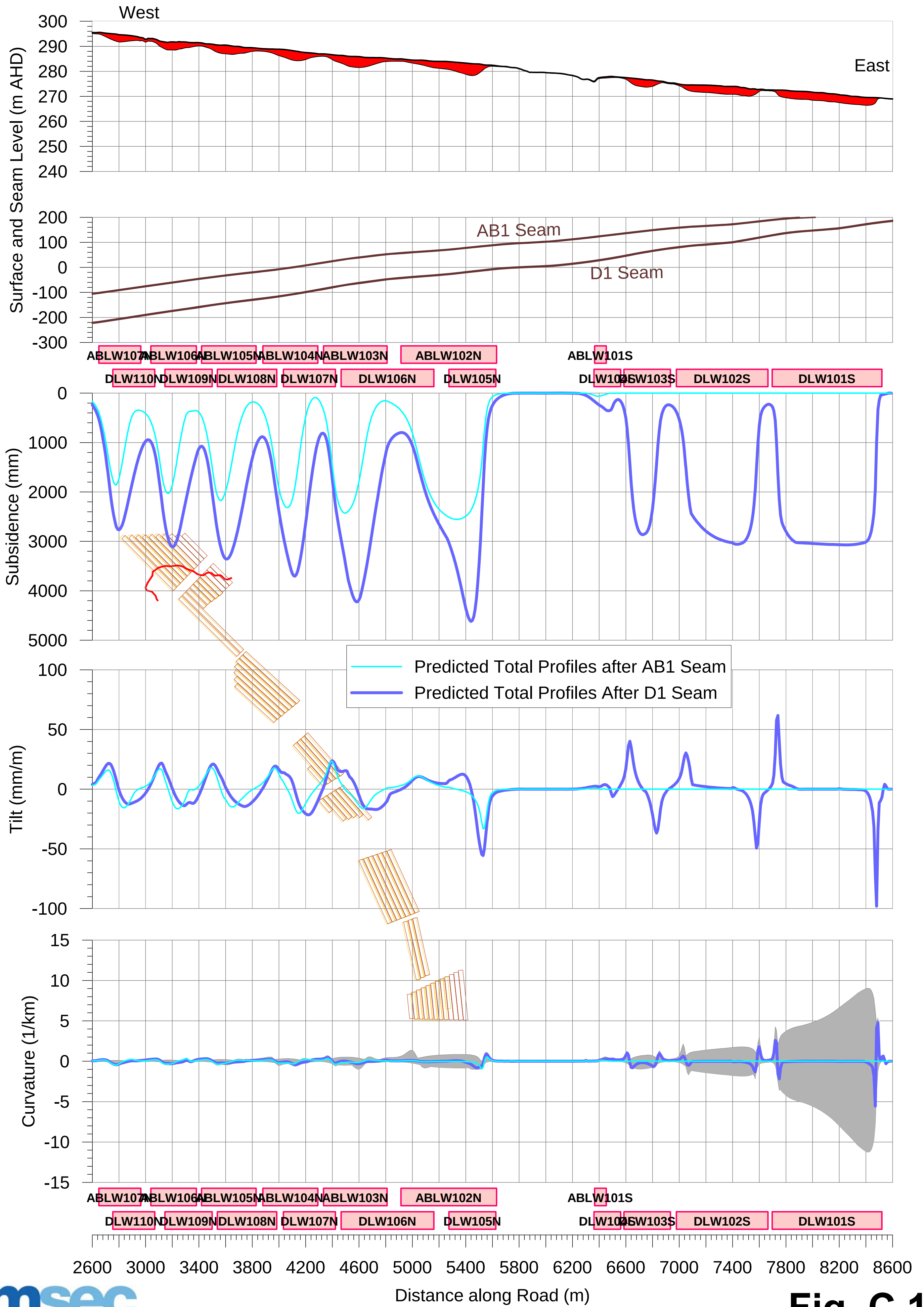


Fig. C.11

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Tributary 1 due to the Extraction of AB1 and D1 Seams



msec

Fig. C.12

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Tributary 2 due to the Extraction of AB1 and D1 Seams

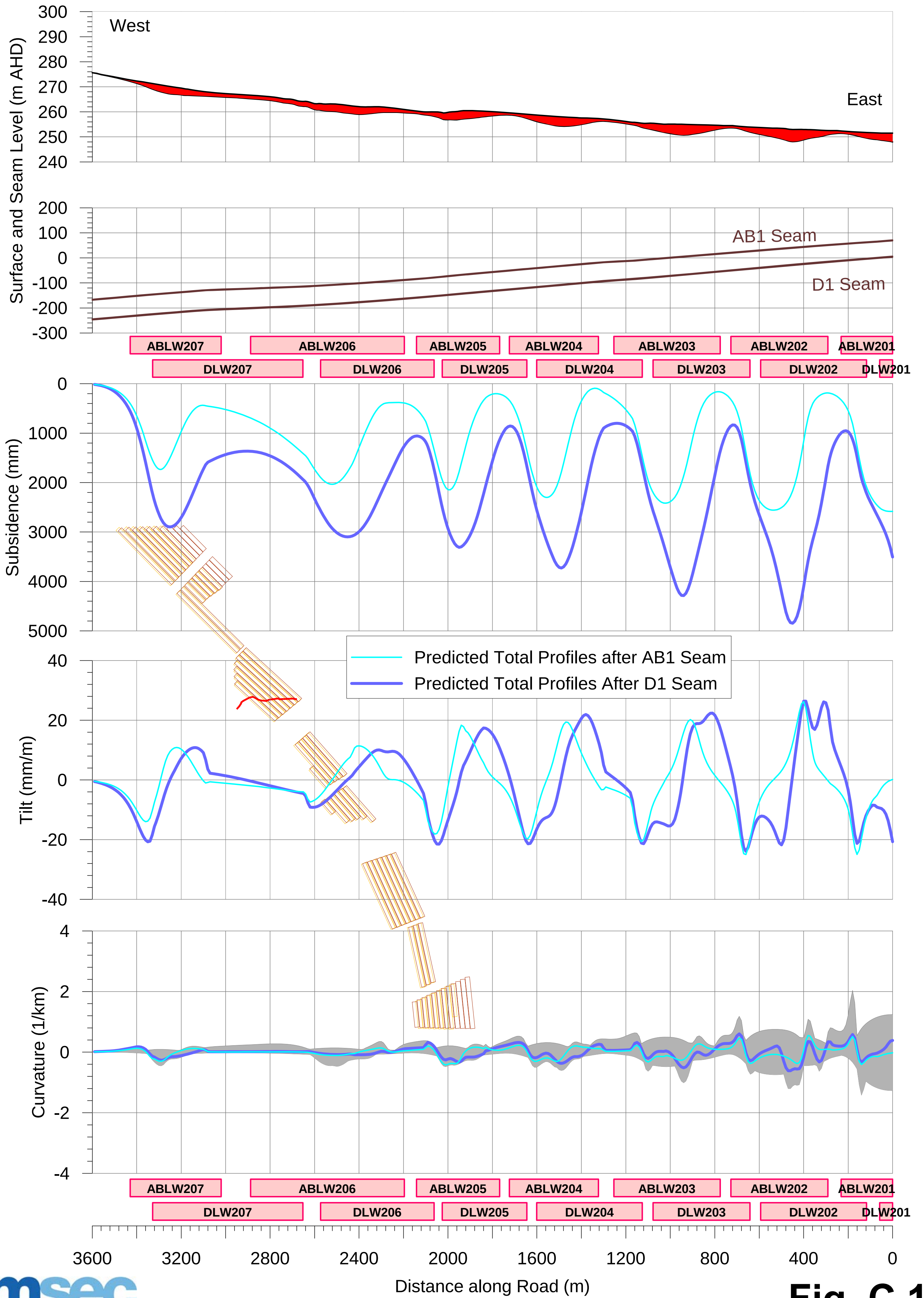


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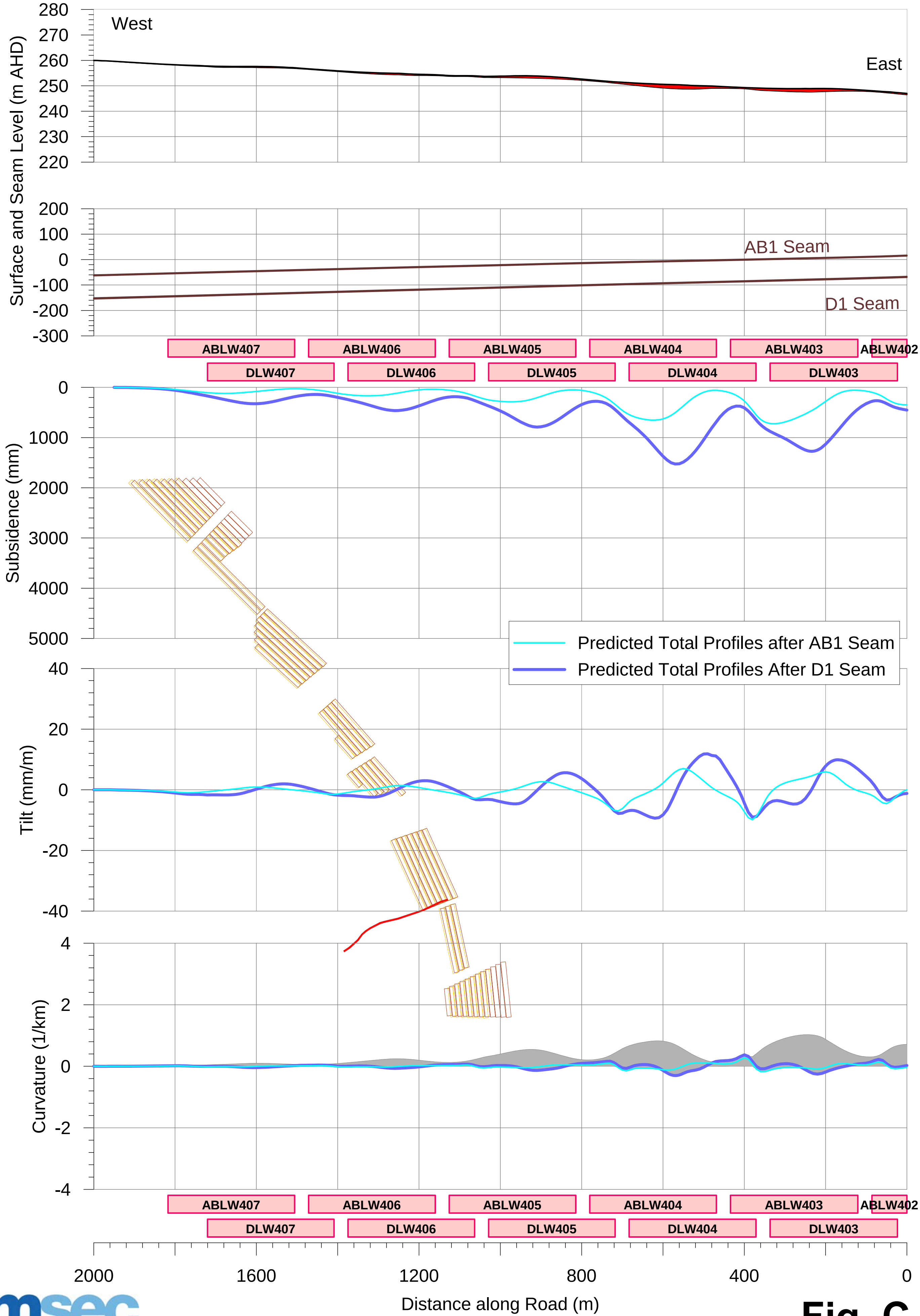
Fig. C.13

Predicted Profiles of Conventional Subsidence, Tilt and Curvature along Tributary 3 due to the Extraction of AB1 and D1 Seams



msec

Fig. C.14

APPENDIX D.   DRAWINGS

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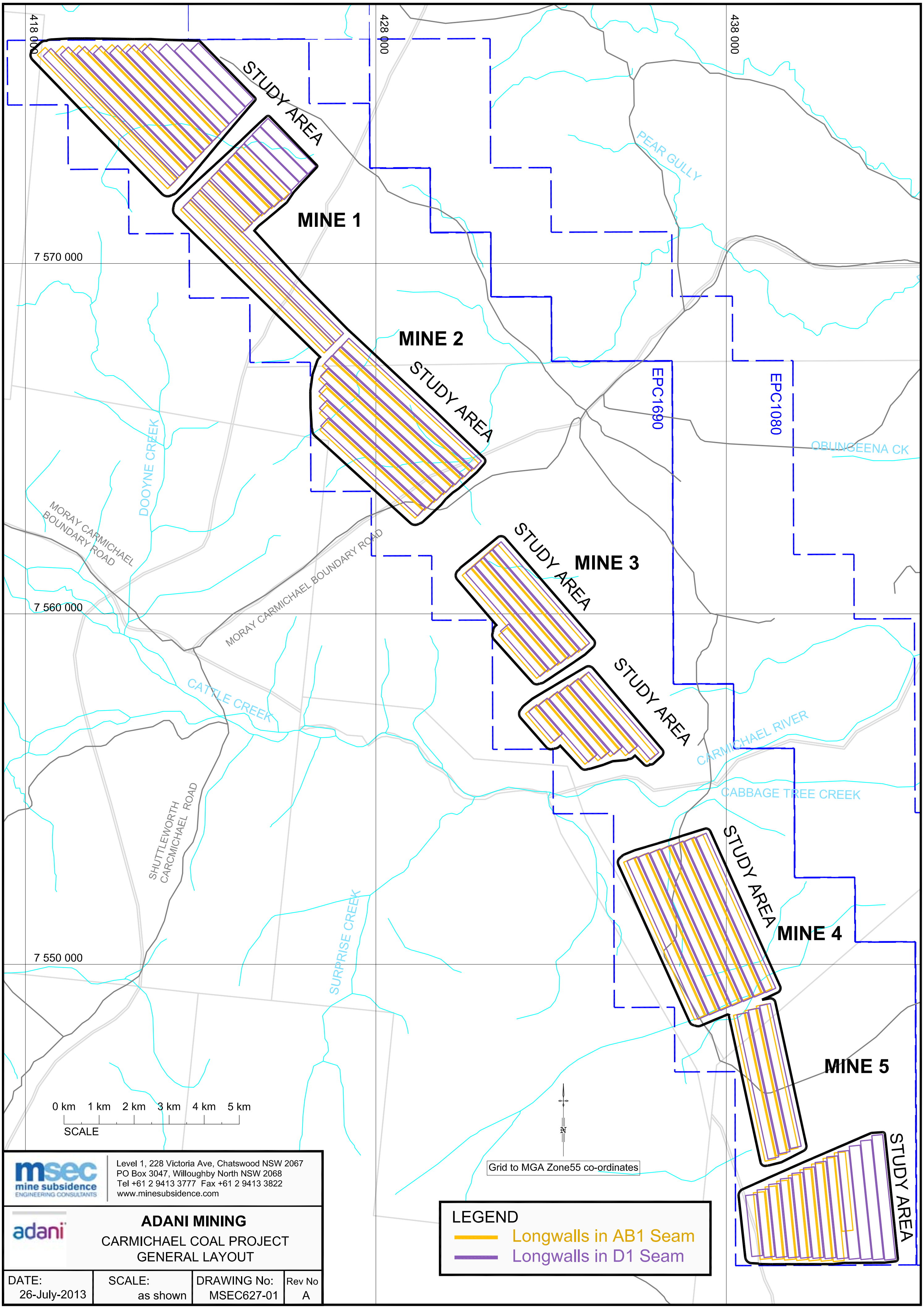

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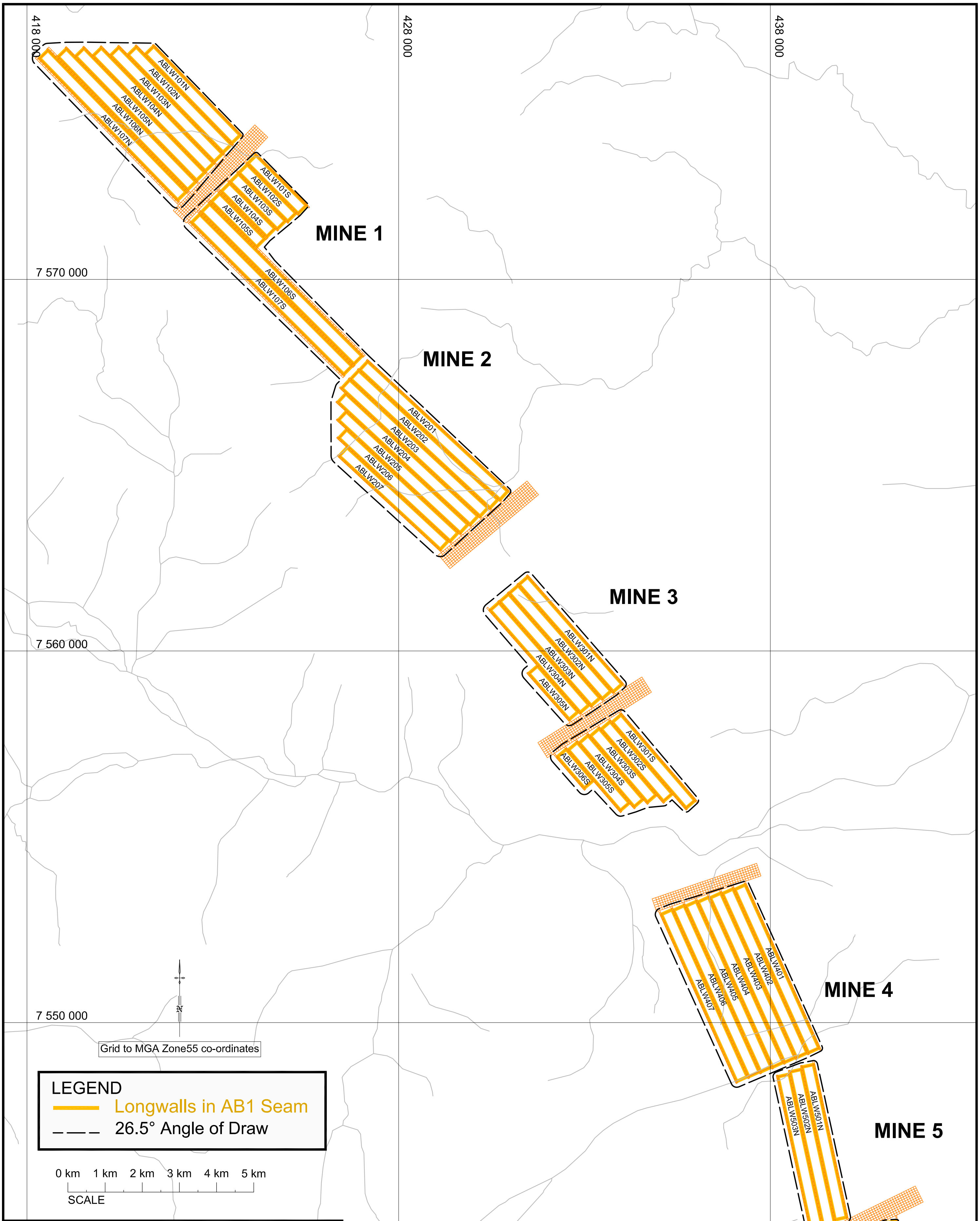

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CARMICHAEL COAL PROJECT
LONGWALL LAYOUT IN AB1 SEAM

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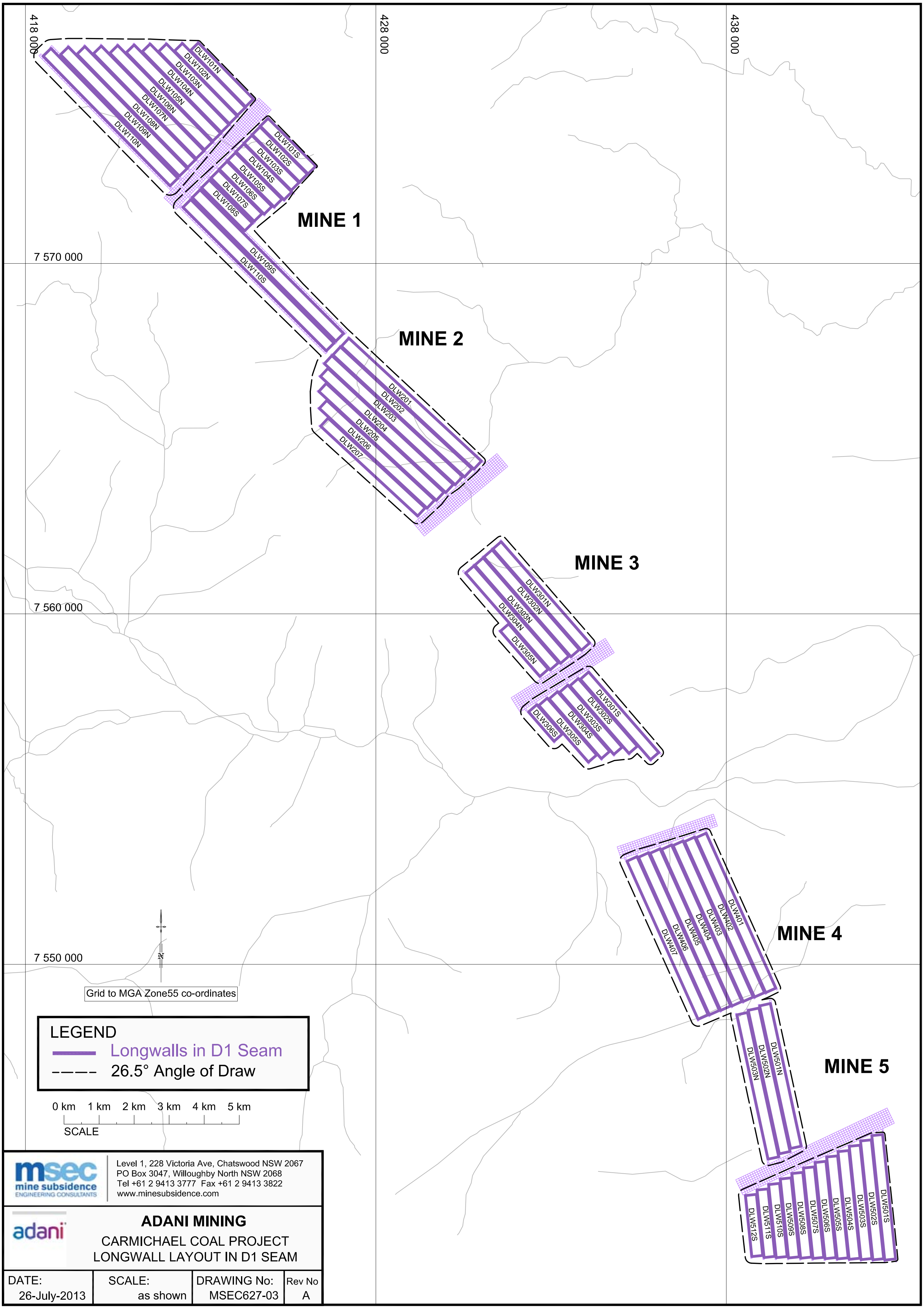

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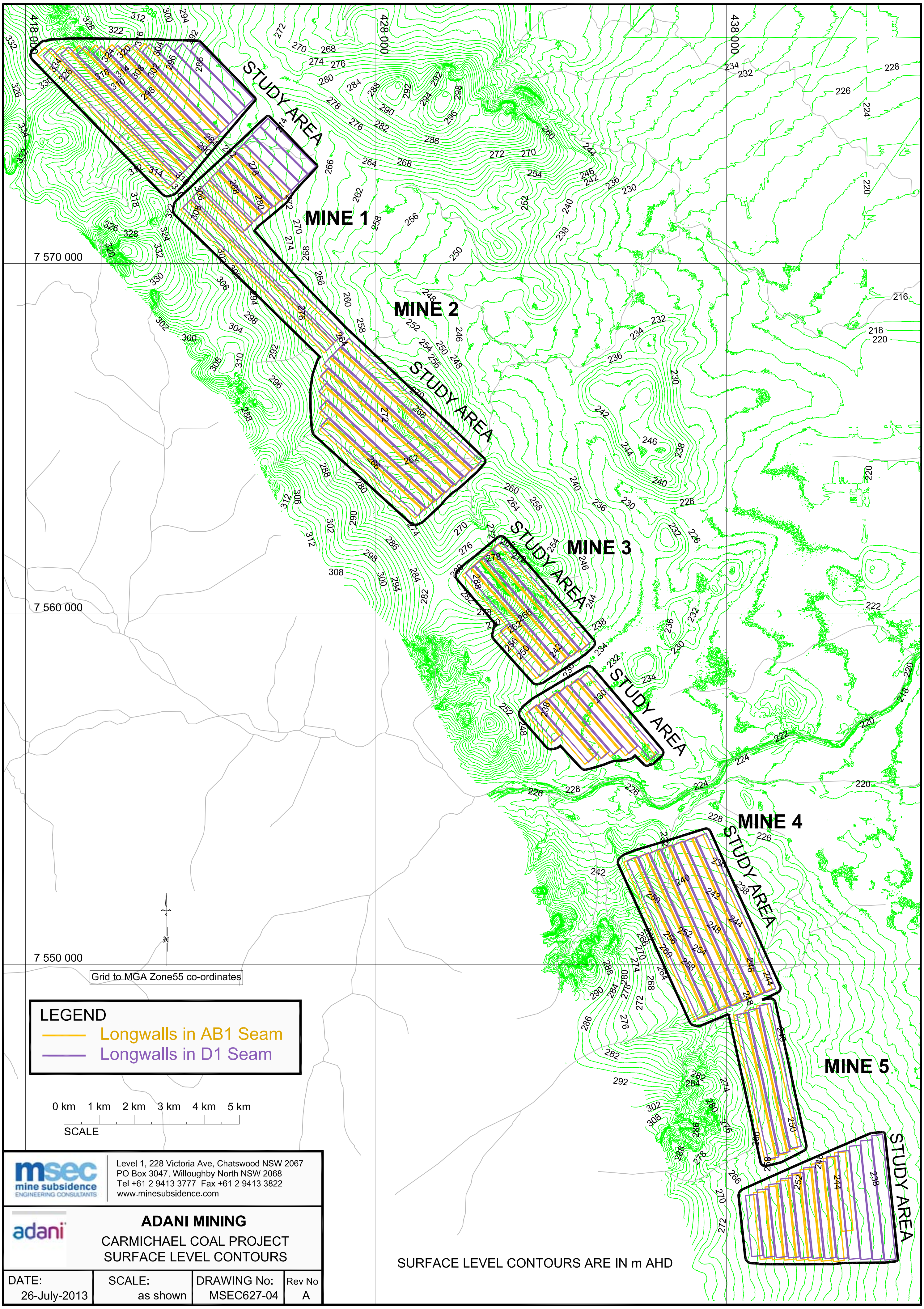

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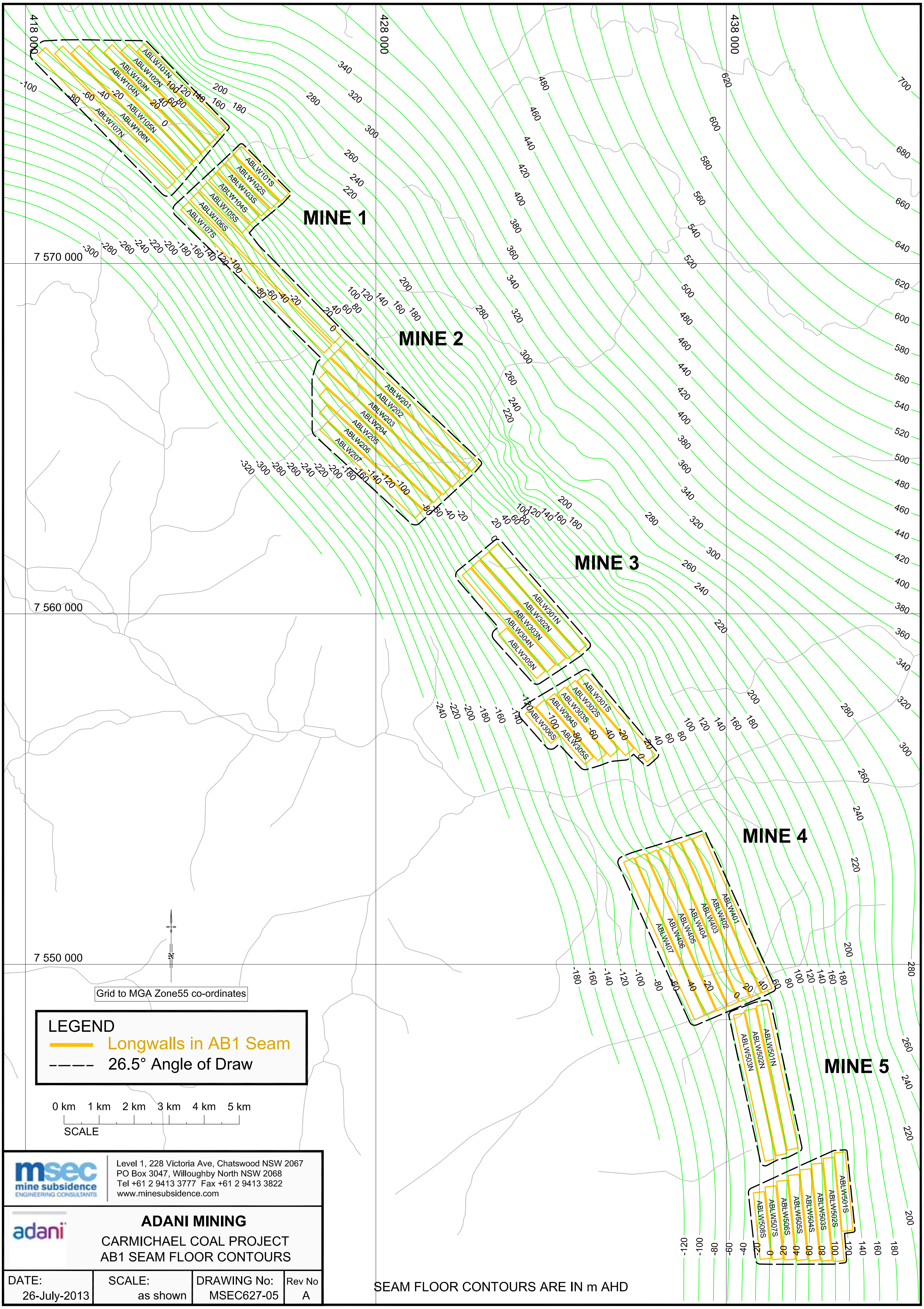

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AB1 SEAM FLOOR CONTOURS

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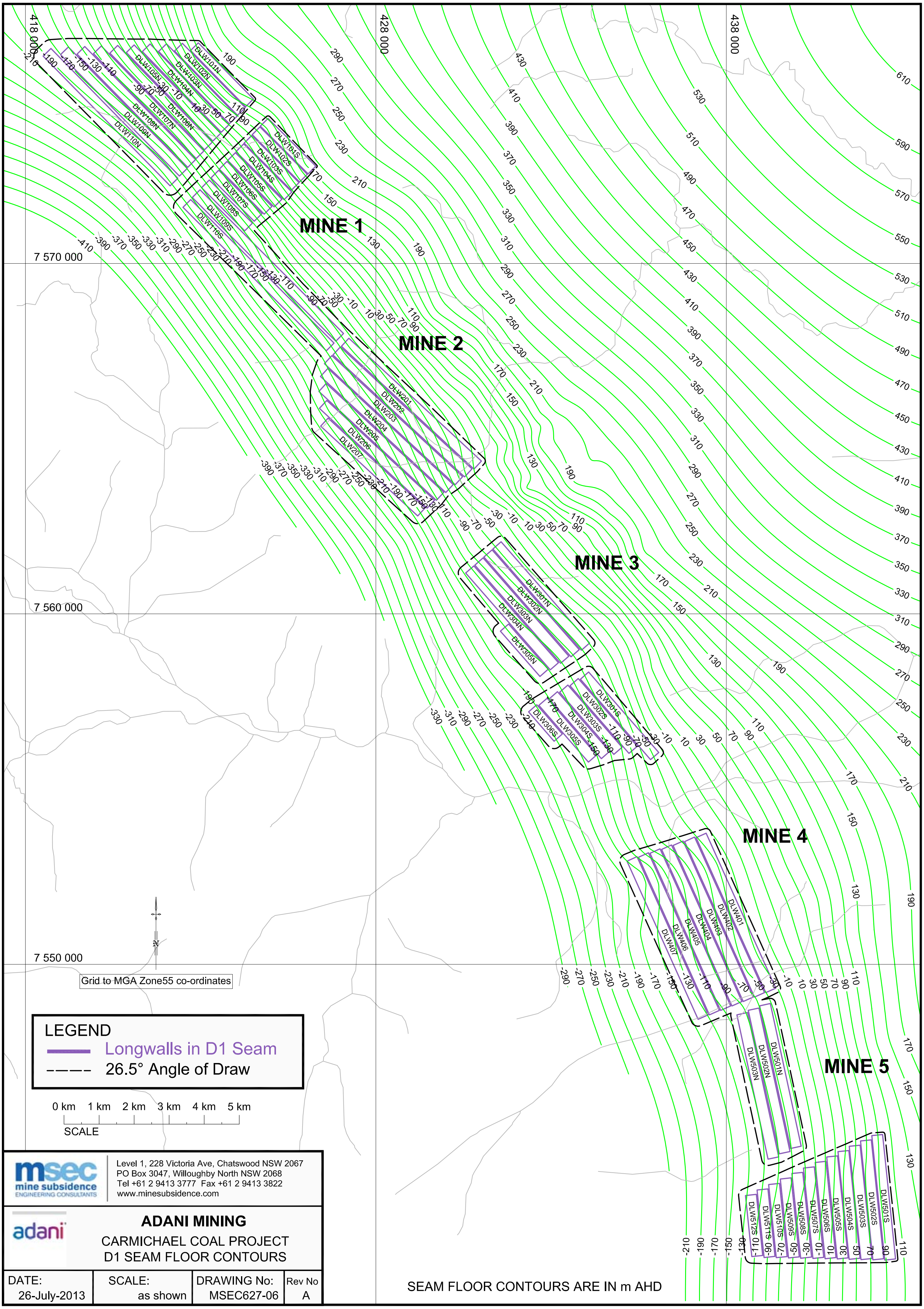

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D1 SEAM FLOOR CONTOURS

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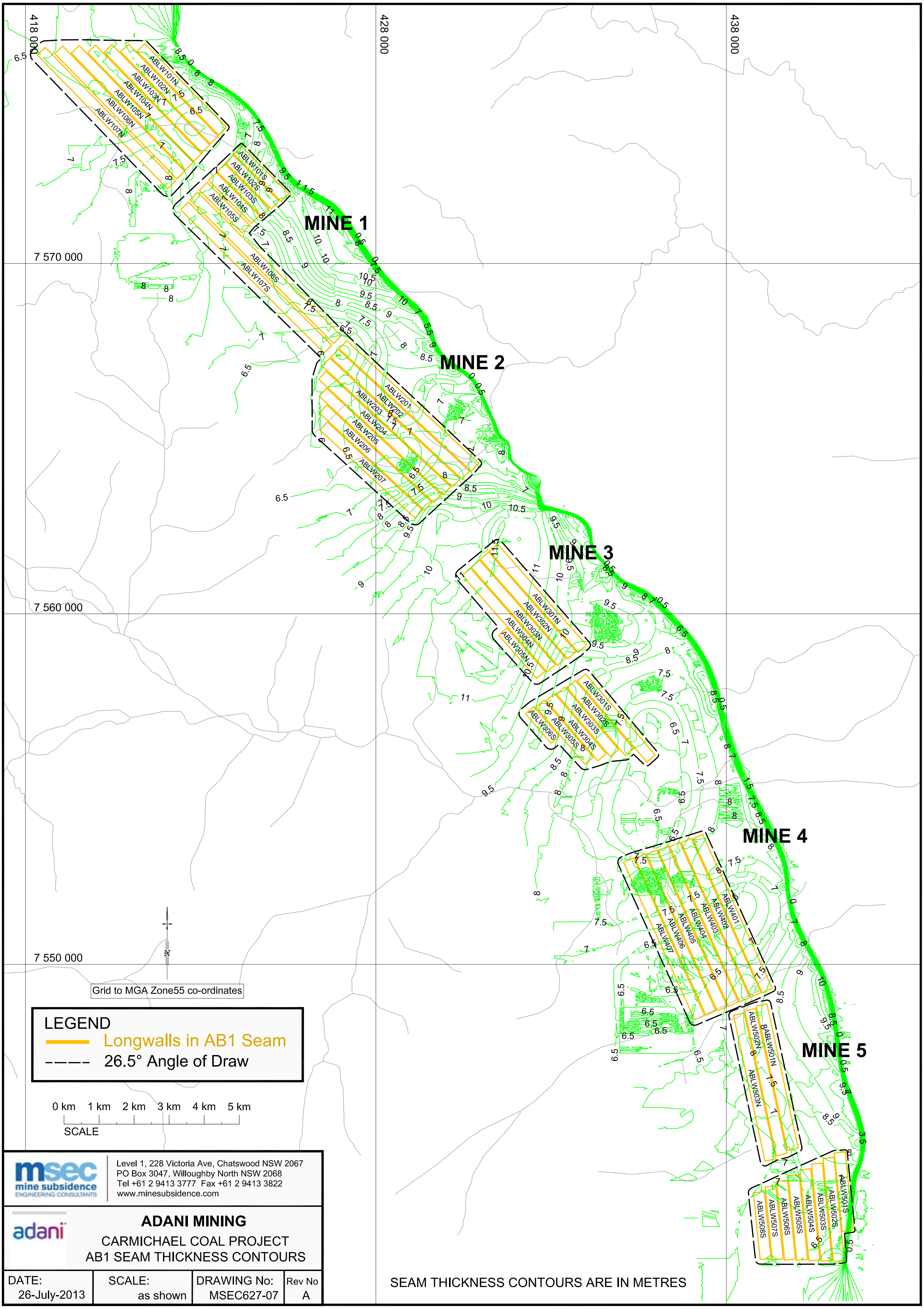

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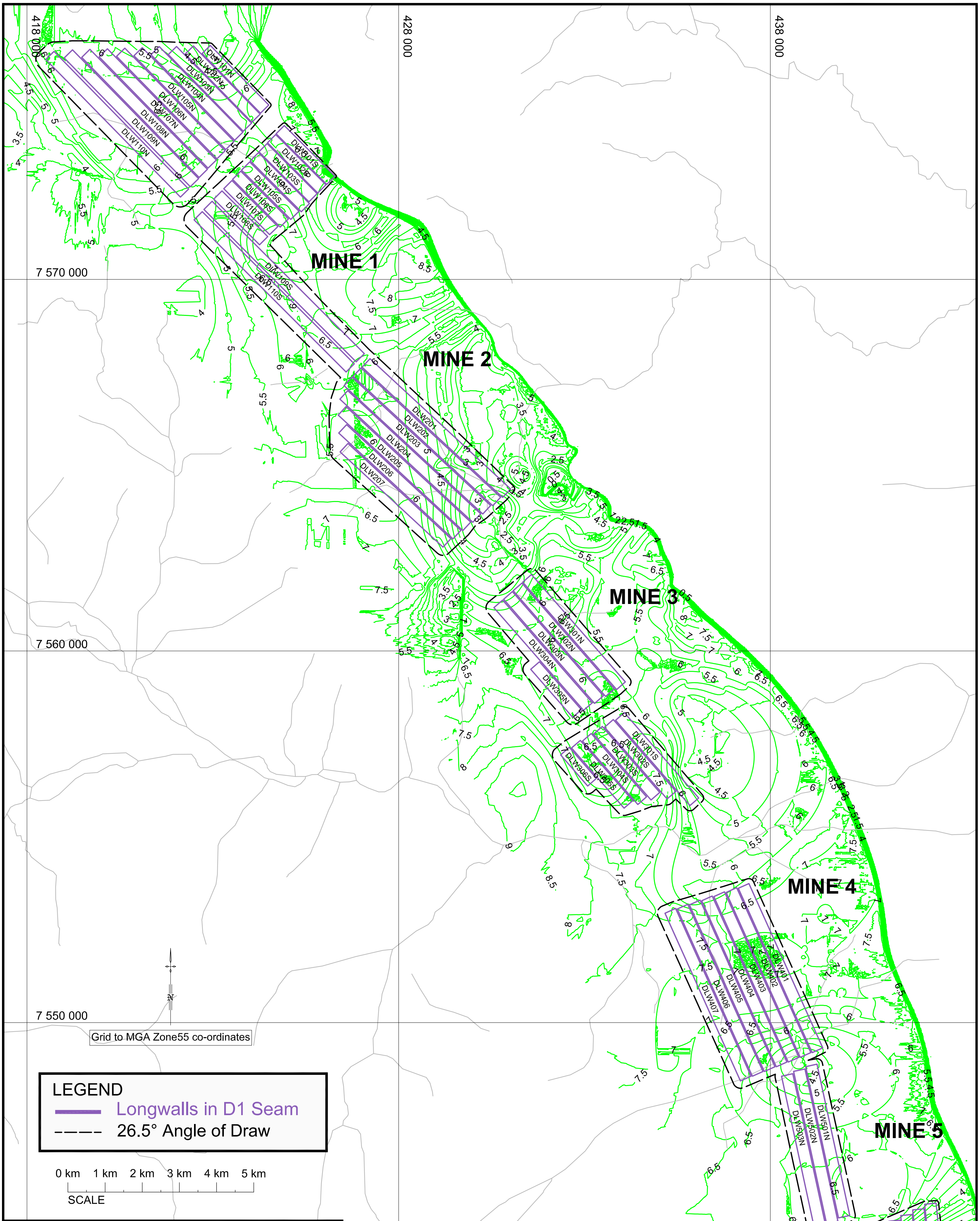

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D1 SEAM THICKNESS CONTOURS

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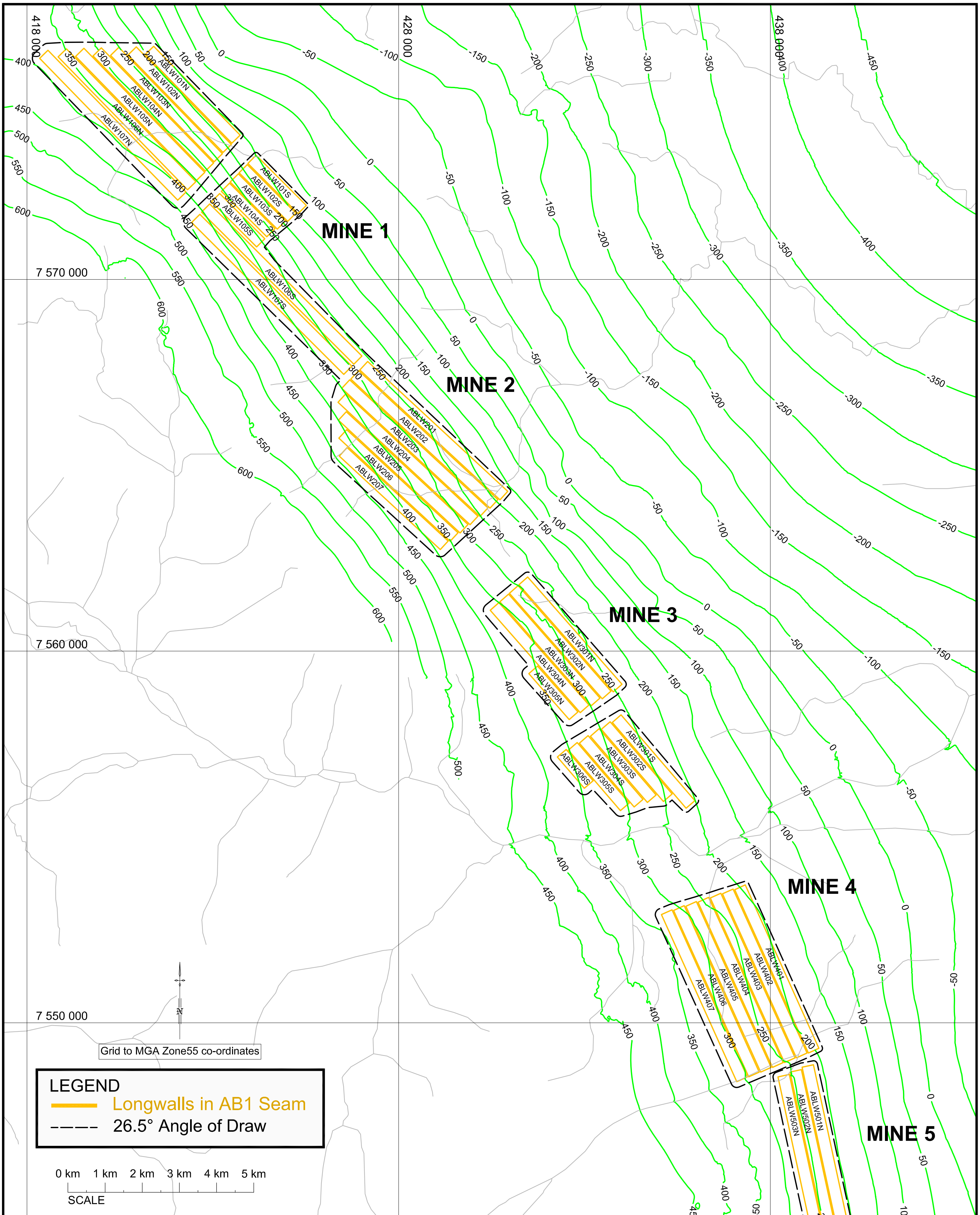
SEAM THICKNESS CONTOURS ARE IN METRES



LEGEND
Longwalls in AB1 Seam
26.5° Angle of Draw

0 km 1 km 2 km 3 km 4 km 5 km
SCALE

DEPTH OF COVER CONTOURS ARE IN METRES

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AB1 DEPTH OF COVER CONTOURS

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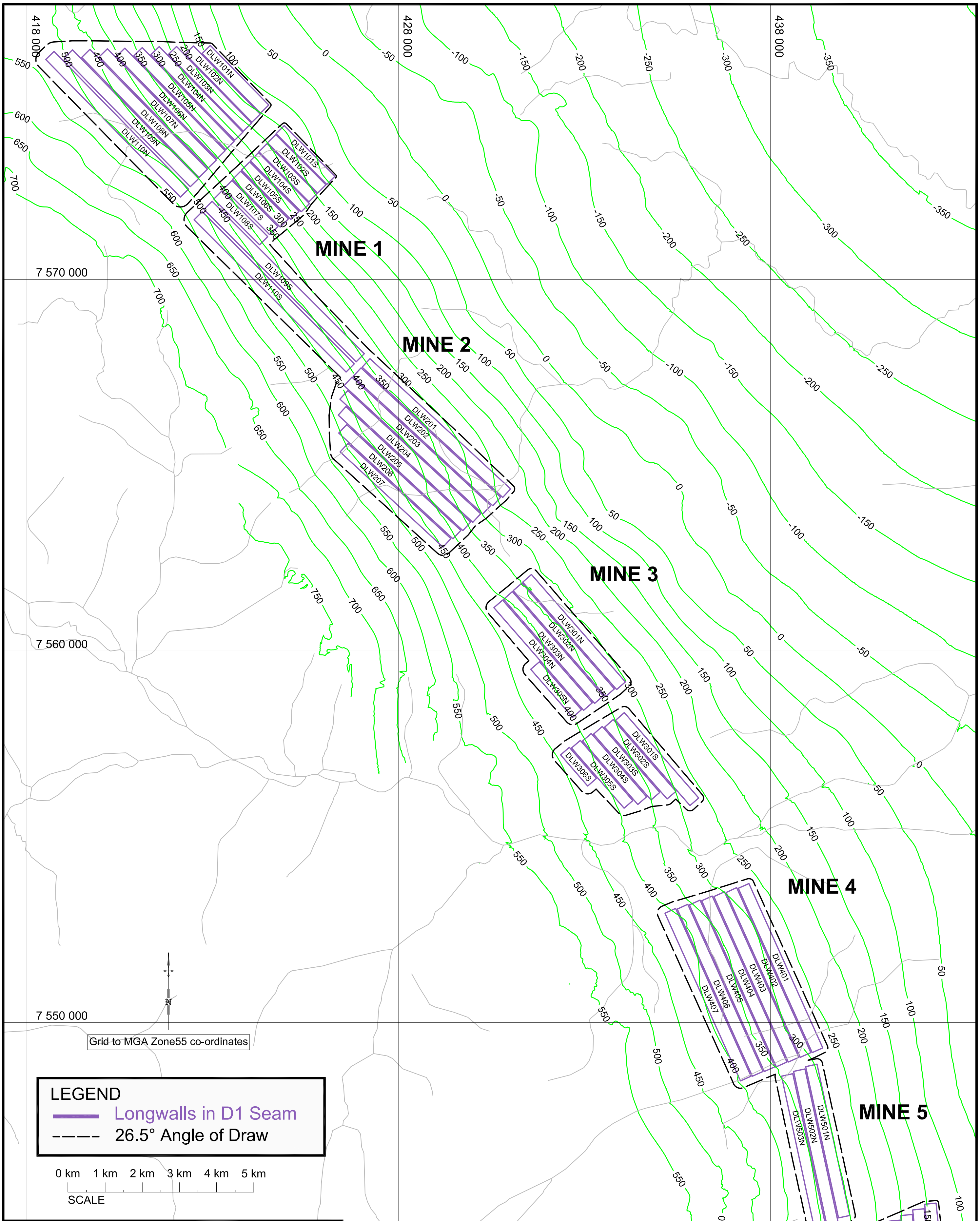

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D1 DEPTH OF COVER CONTOURS

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DEPTH OF COVER CONTOURS ARE IN METRES

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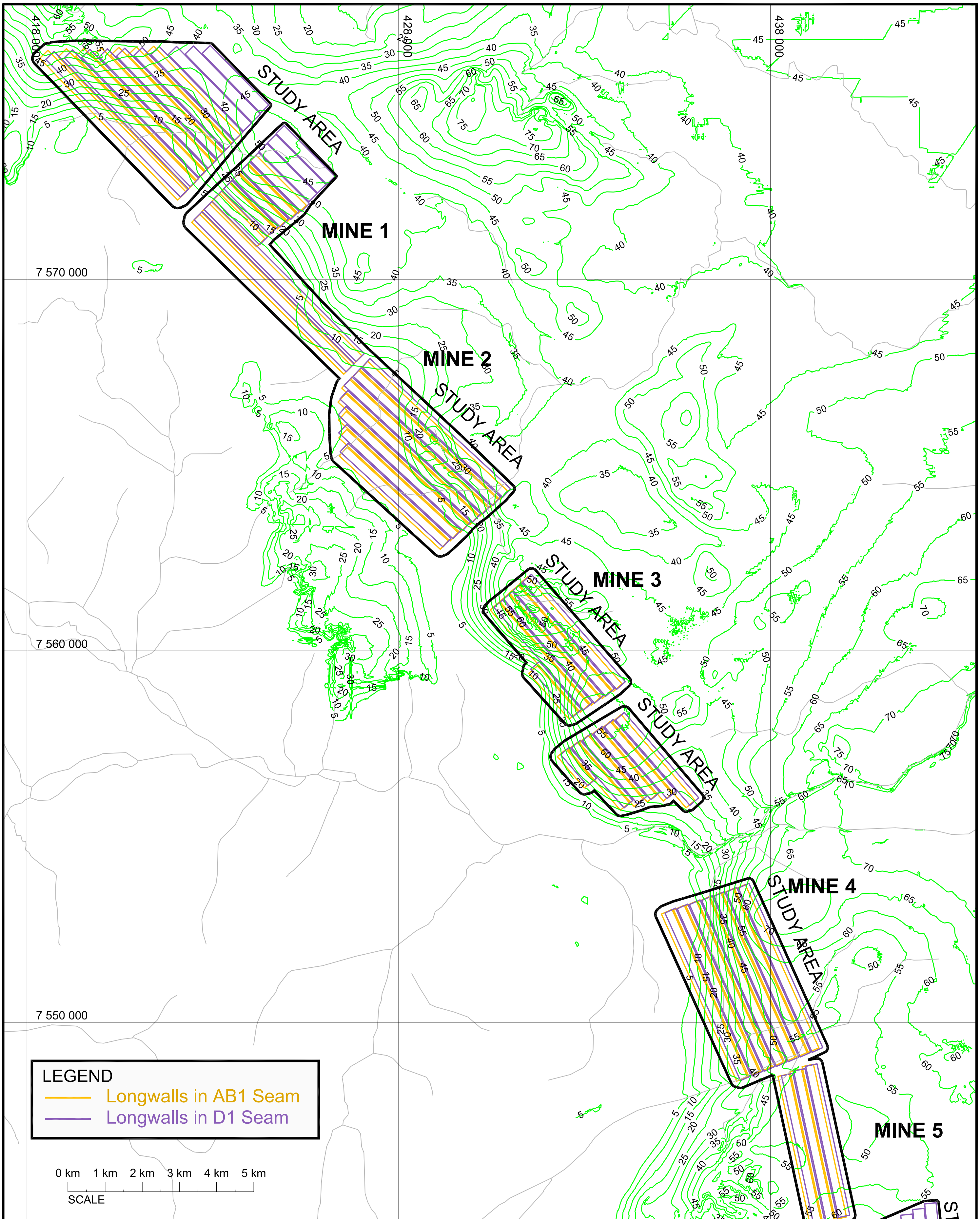

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DEPTH OF BASE OF TERTIARY

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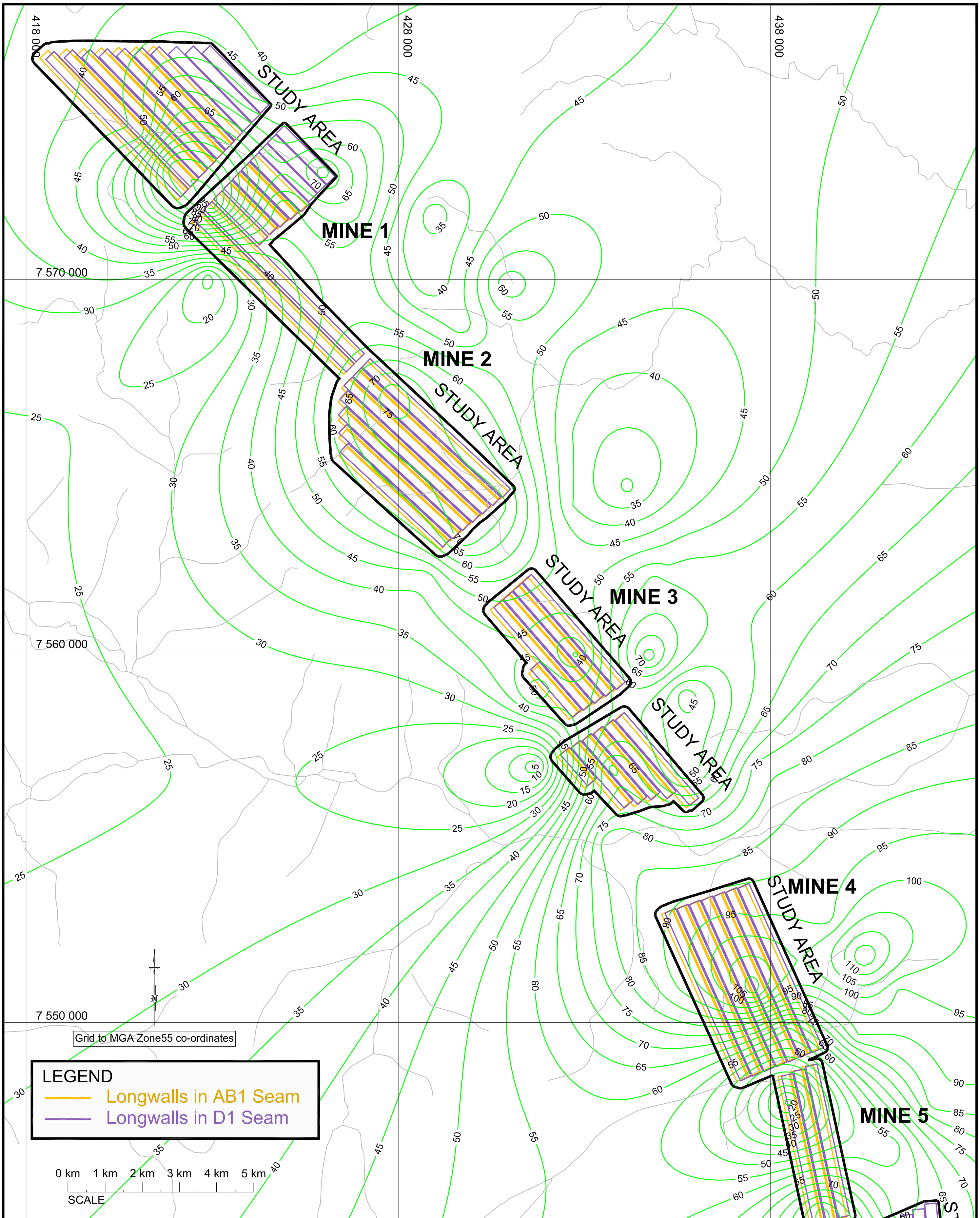

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DEPTH OF BASE OF WEATHERING

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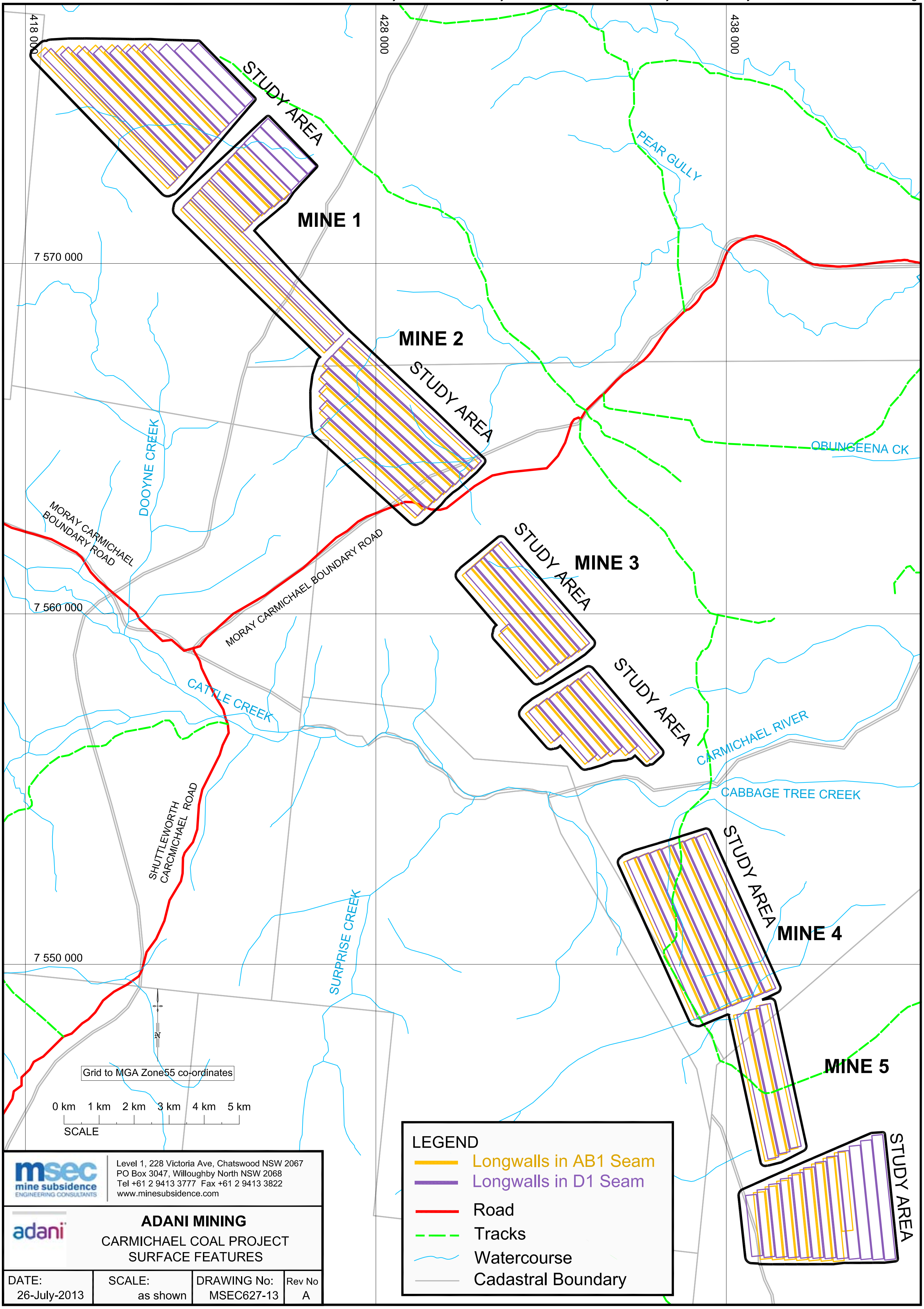

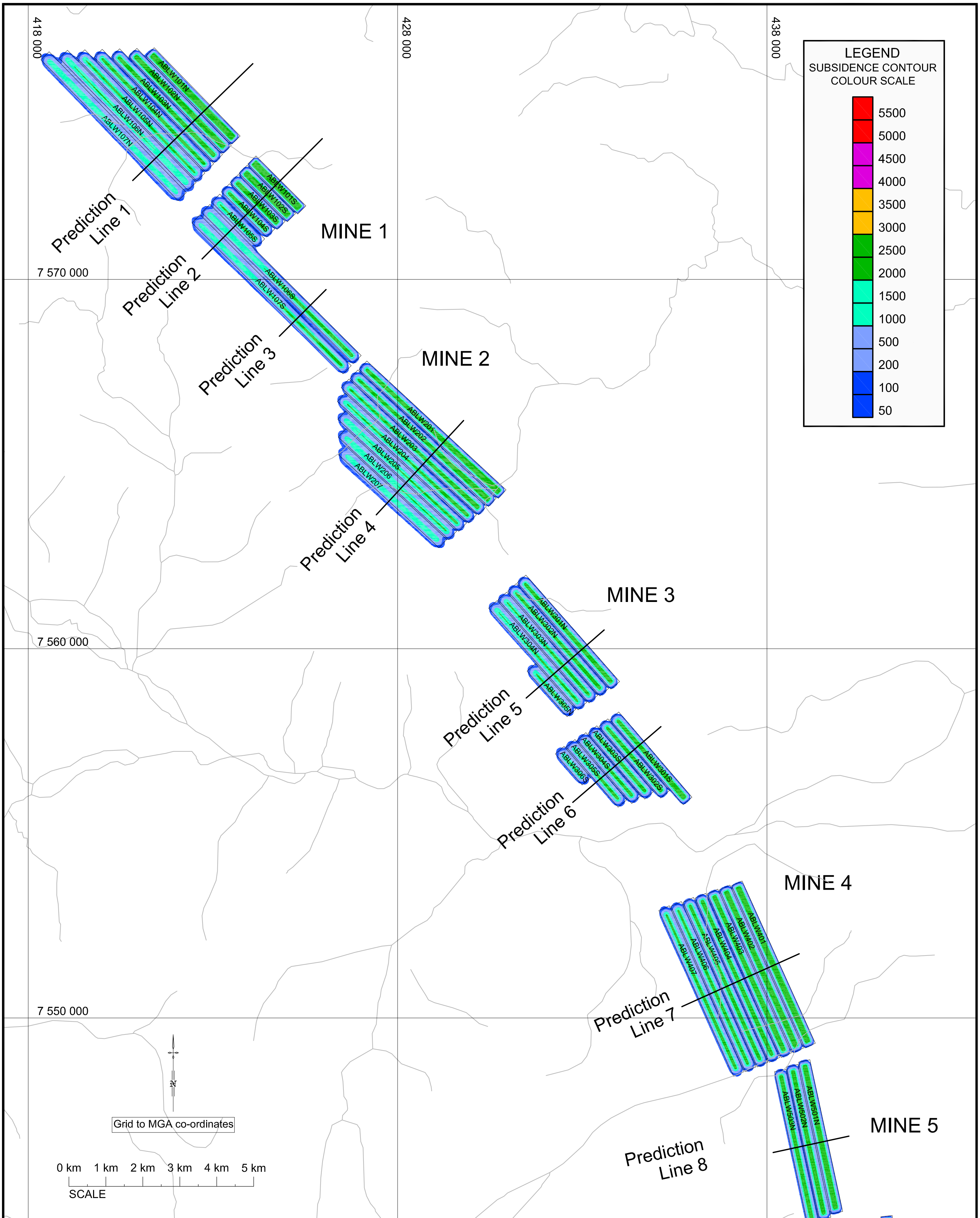

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PREDICTED TOTAL SUBSIDENCE
AFTER AB1

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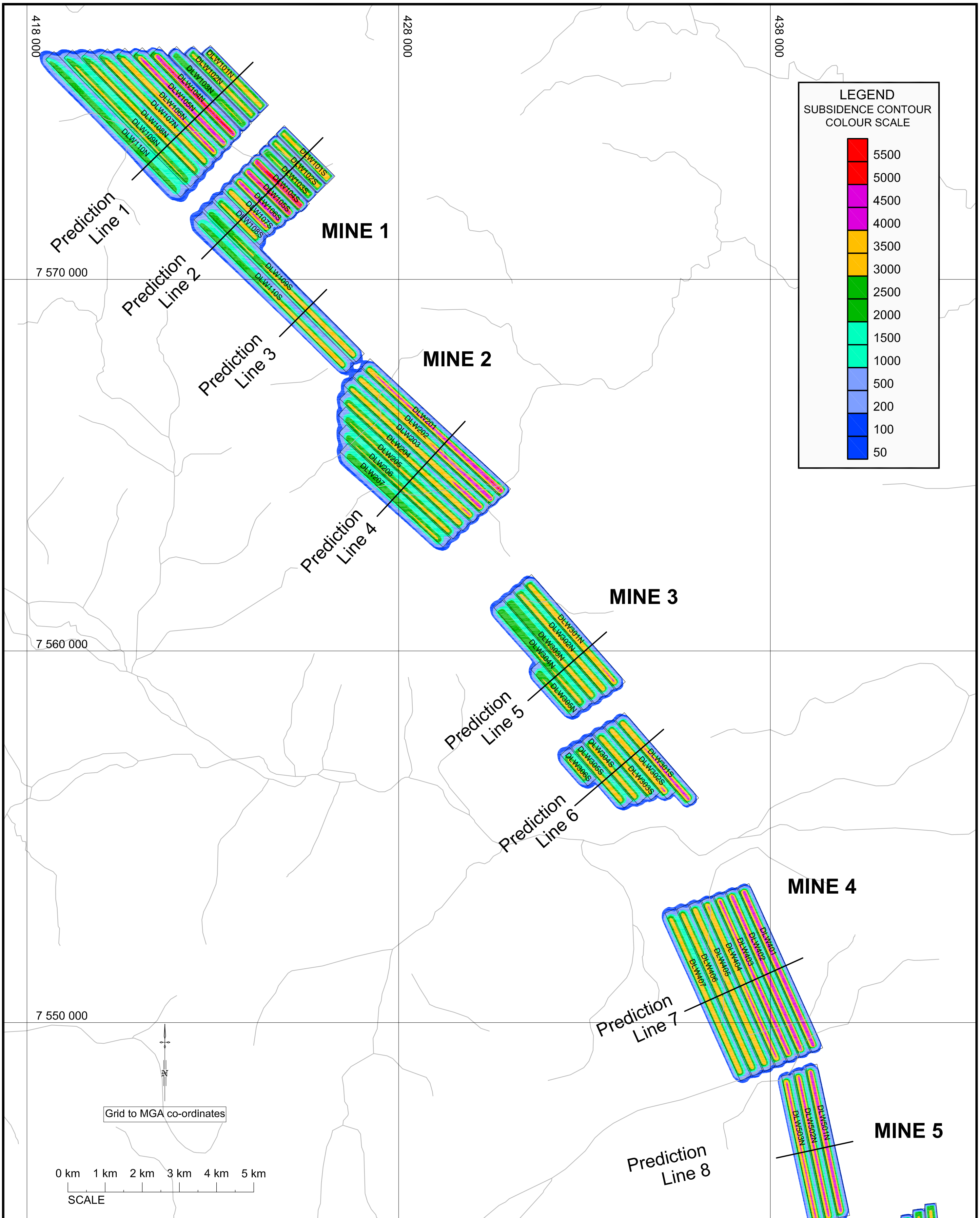

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PREDICTED TOTAL SUBSIDENCE
AFTER D1

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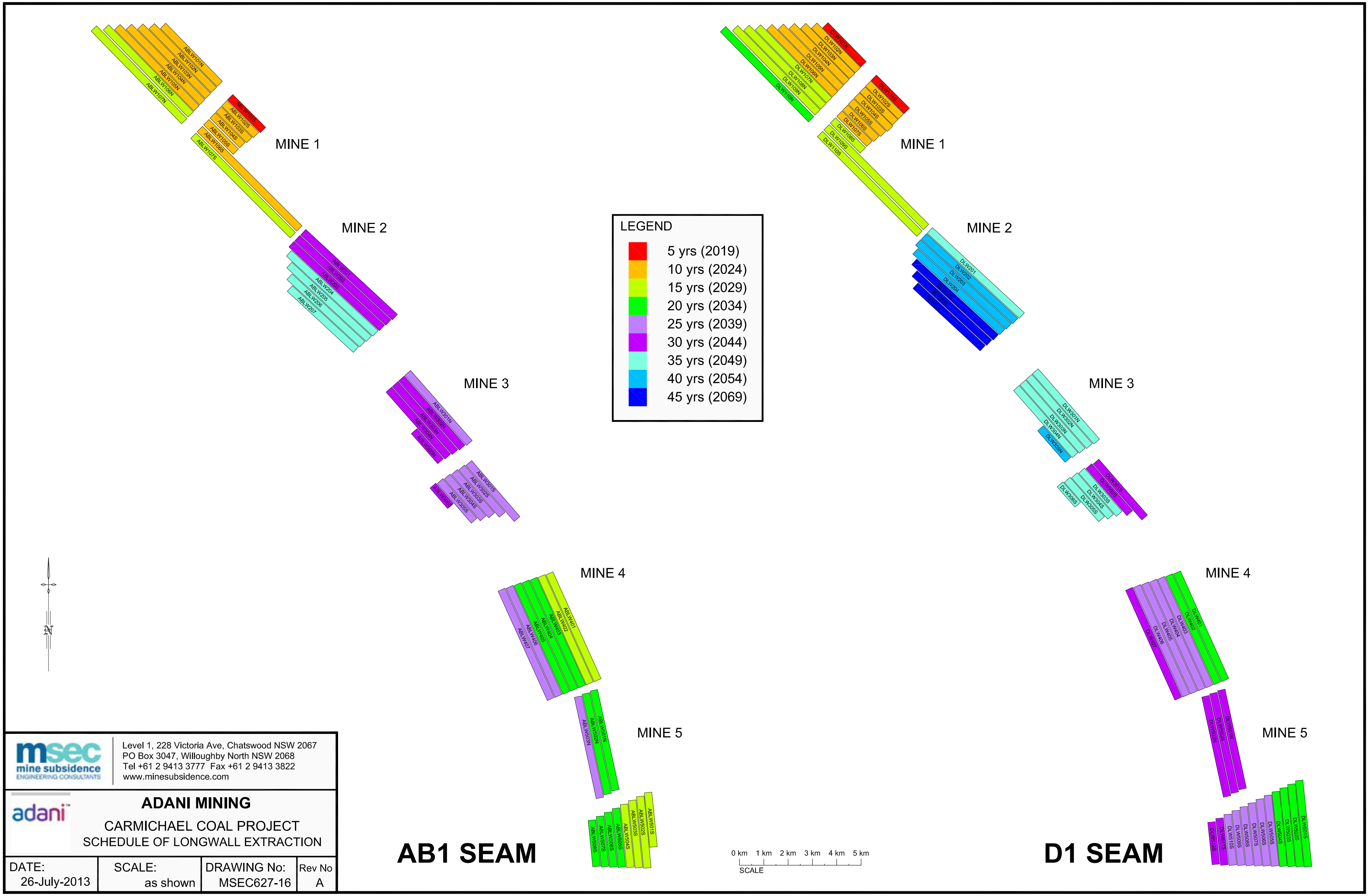

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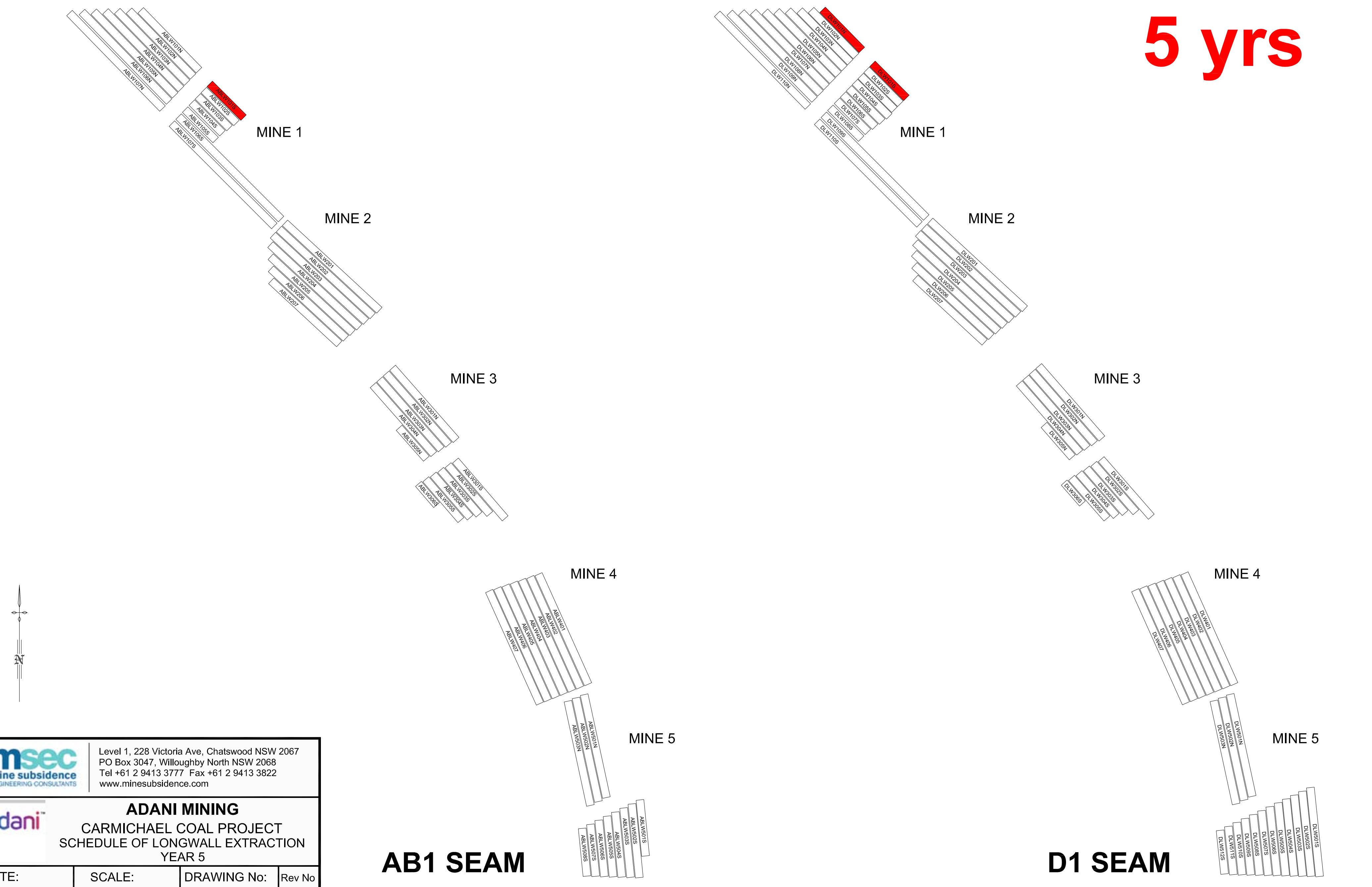

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SCHEDULE OF LONGWALL EXTRACTION
YEAR 5

DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-17	A

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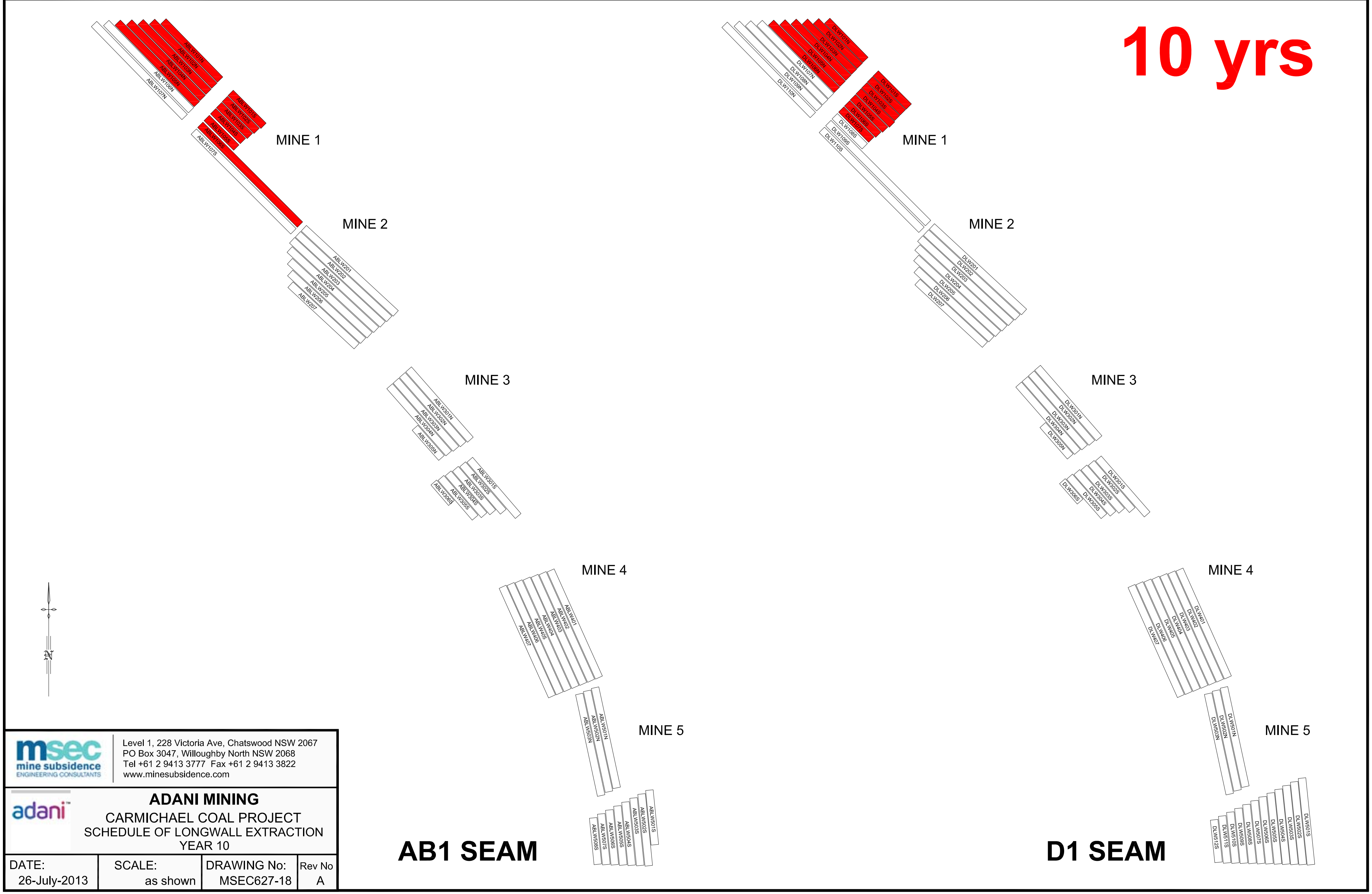

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YEAR 10

DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-18	A

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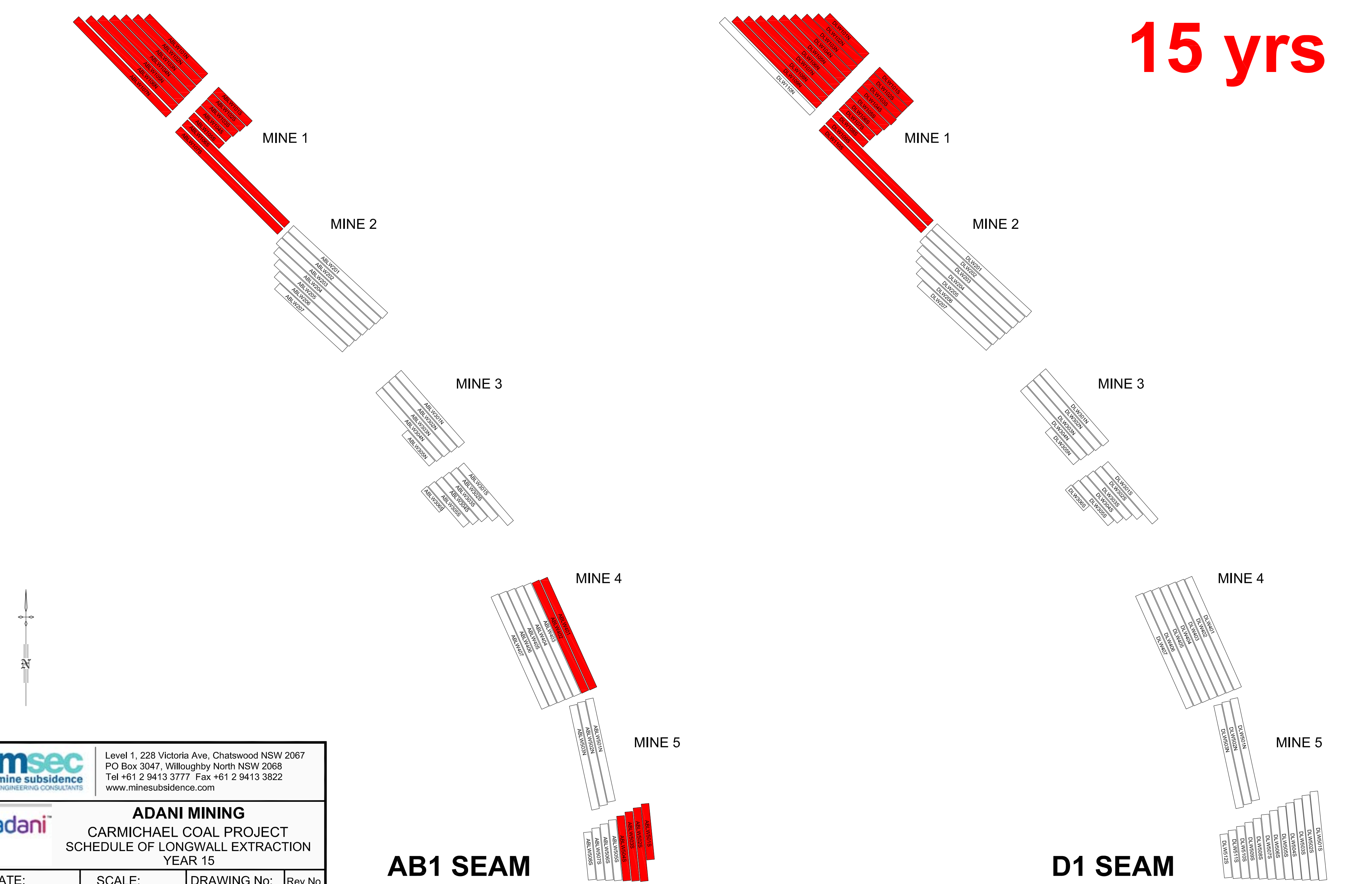

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SCHEDULE OF LONGWALL EXTRACTION
YEAR 15

DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-19	A

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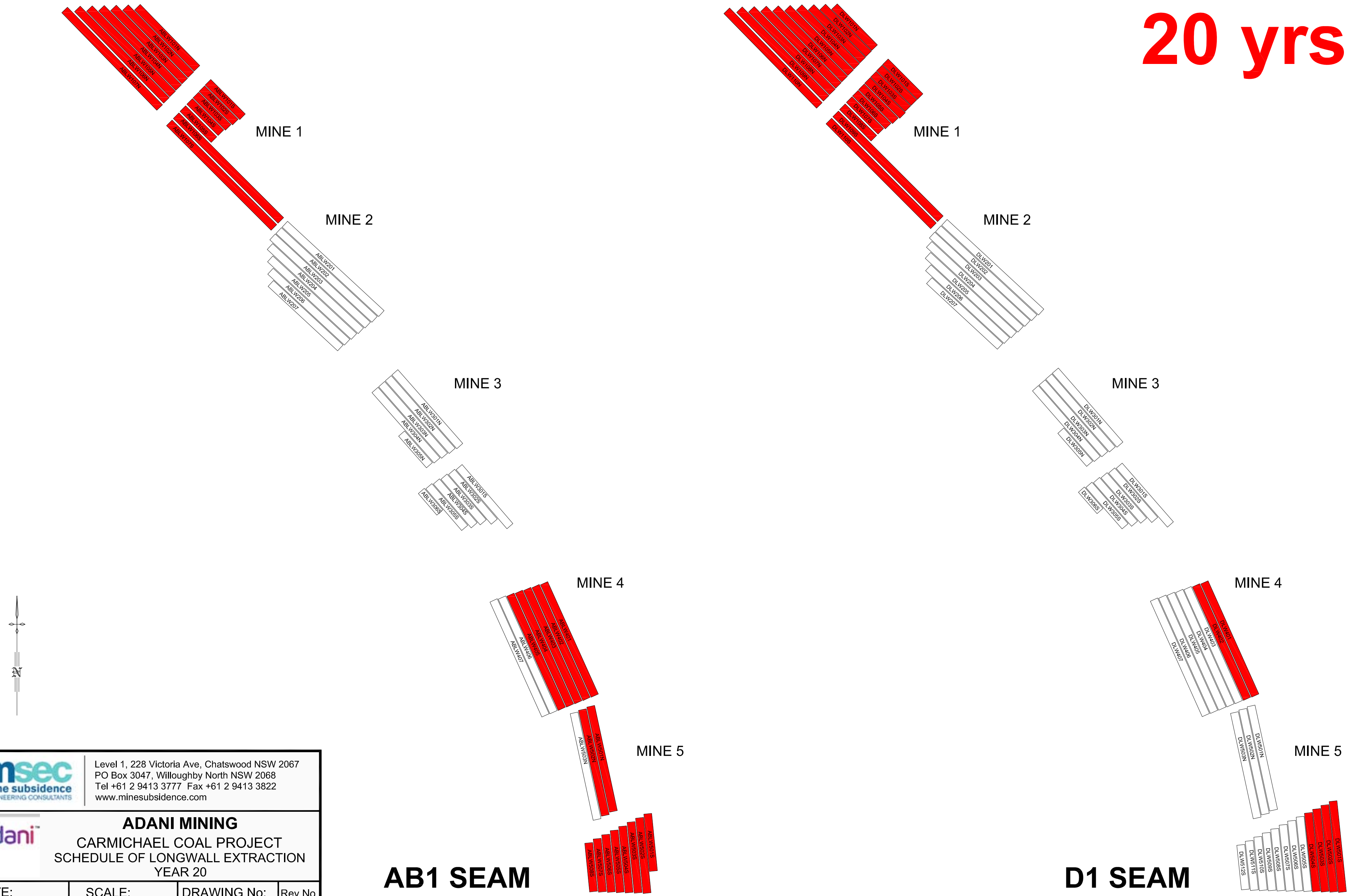

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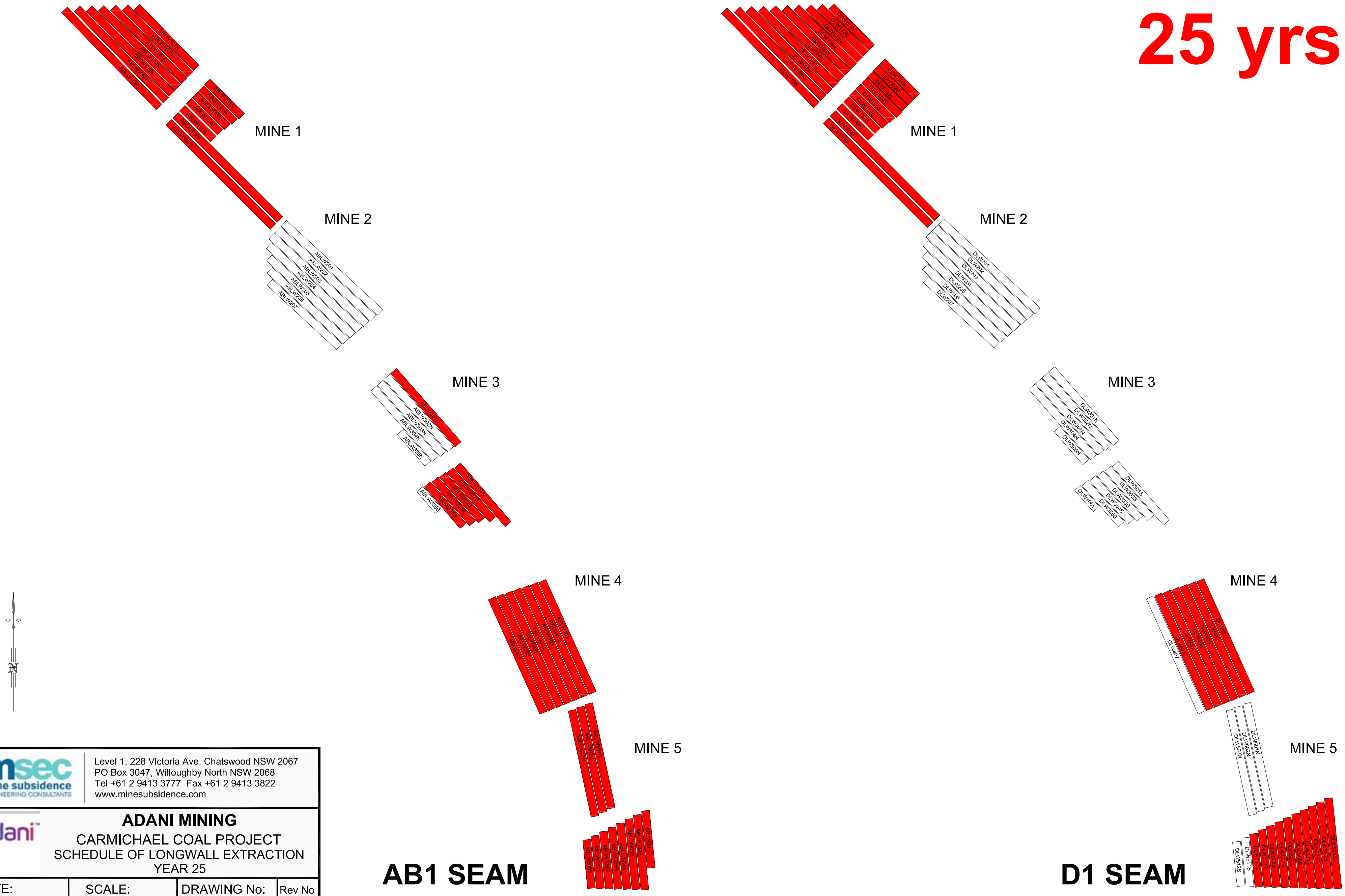
YEAR 20

DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-20	A



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YEAR 25

DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-21	A

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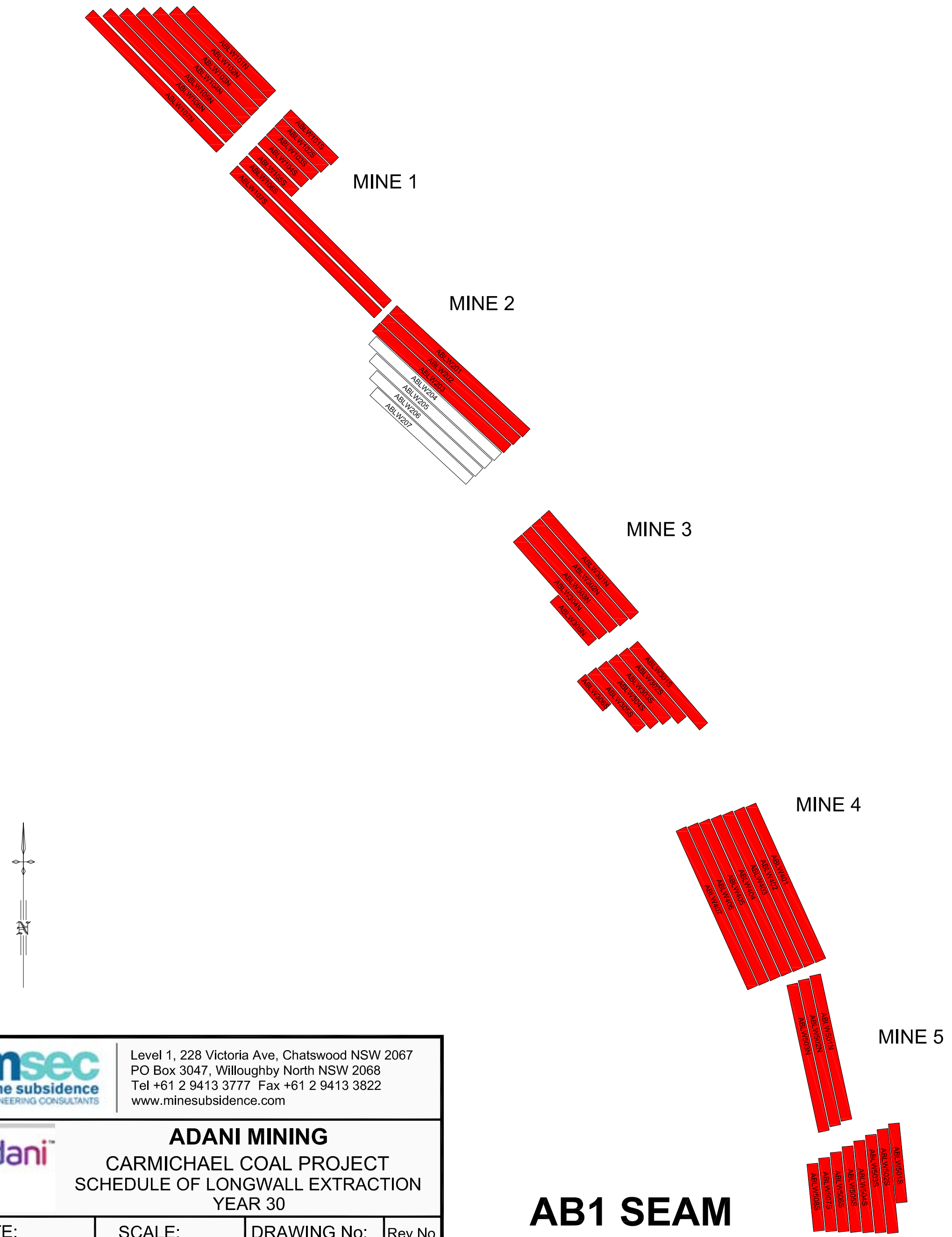

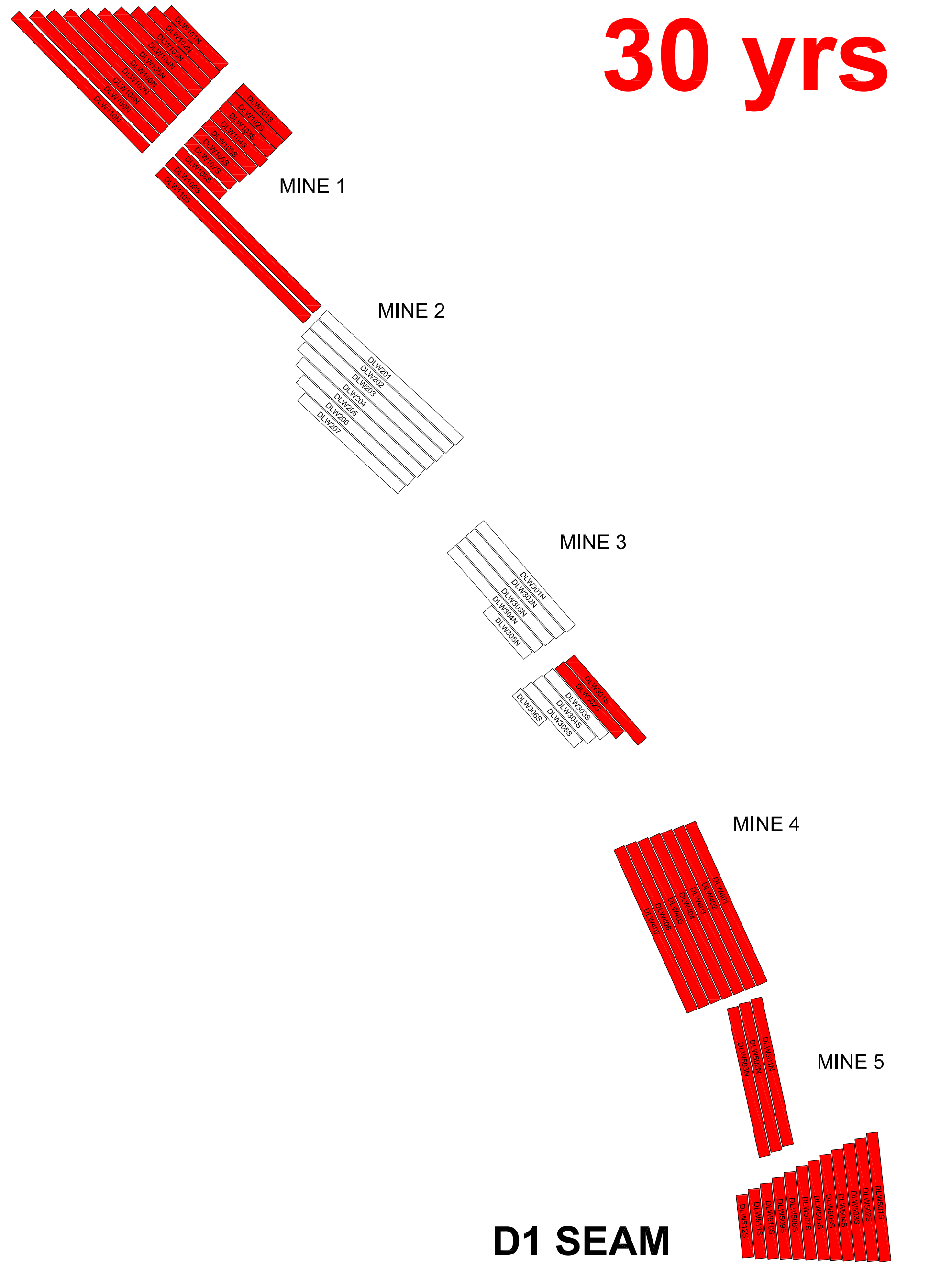

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YEAR 30

DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-22	A

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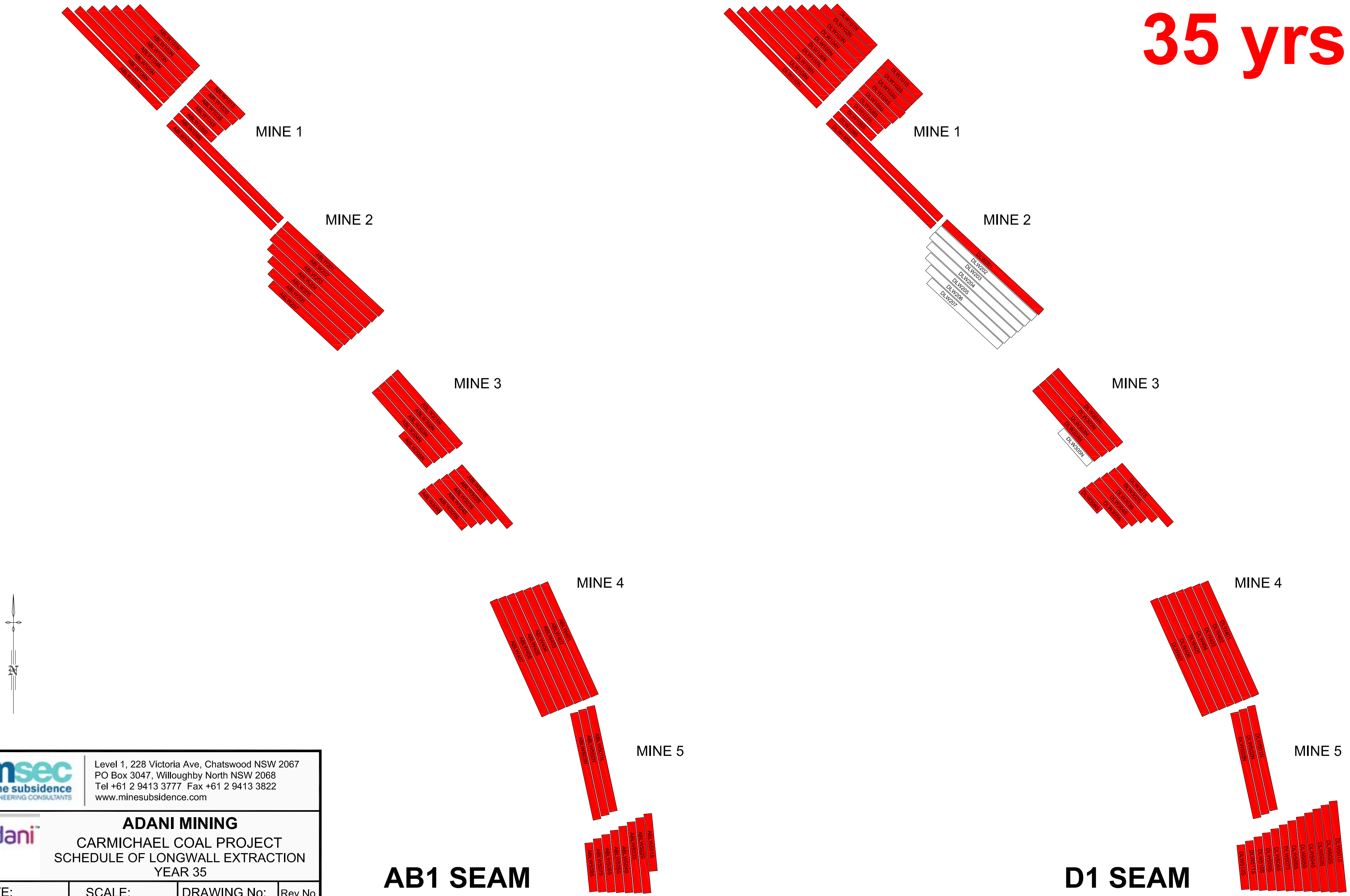

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YEAR 35

DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-23	A

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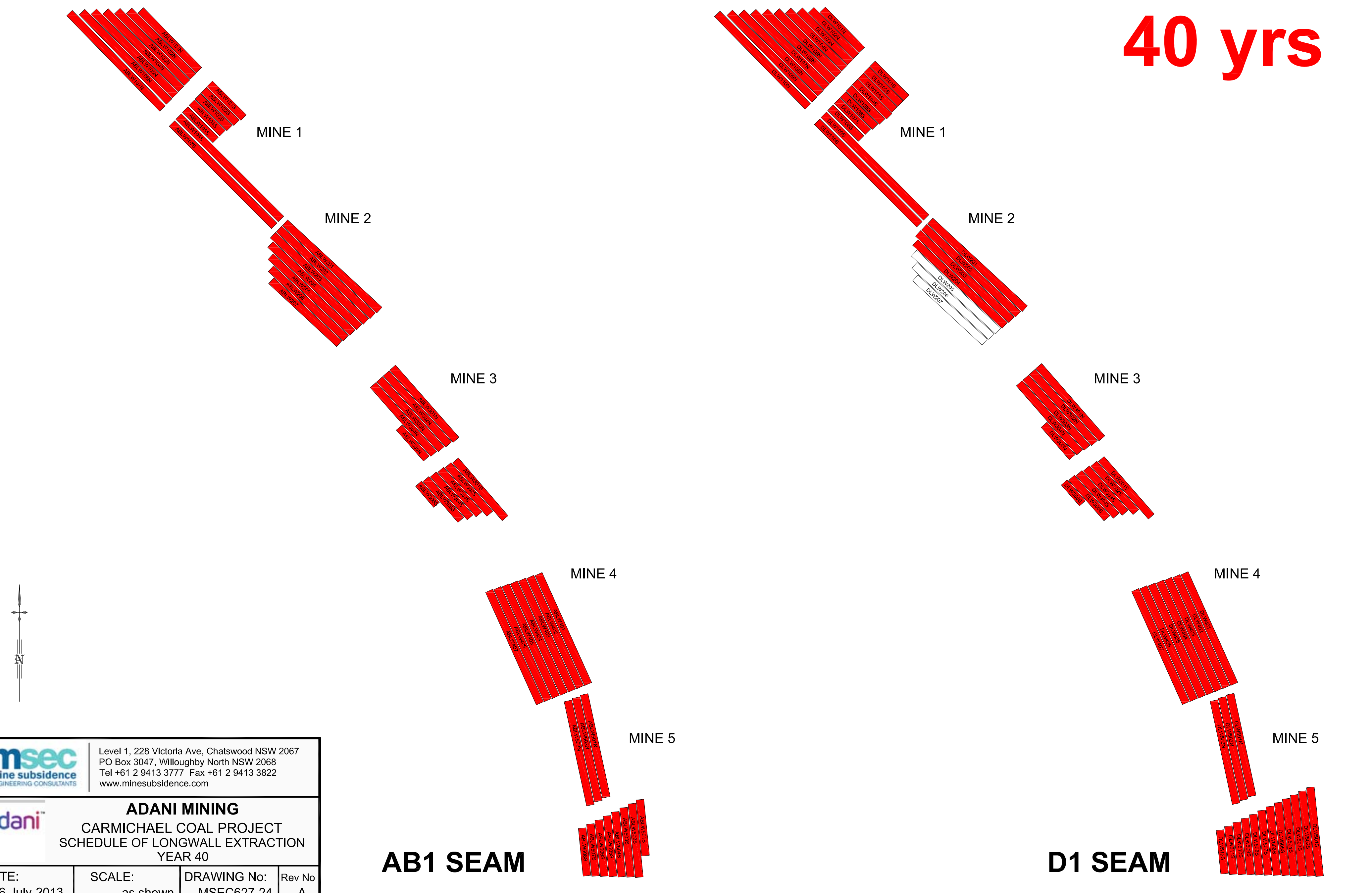

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YEAR 40

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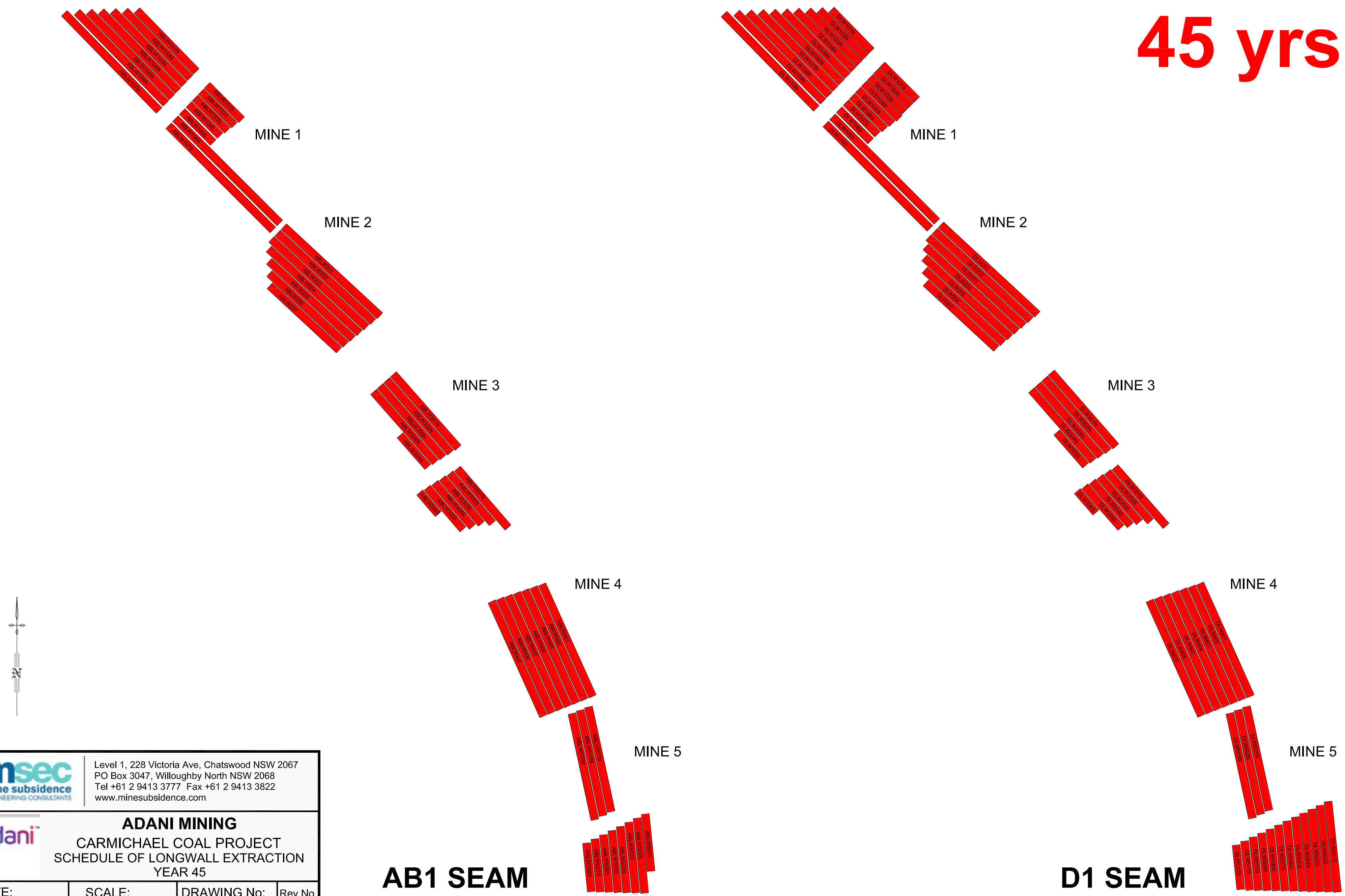
26-July-2013	as shown	MSEC627-24	A



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YEAR 45

DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-25	A

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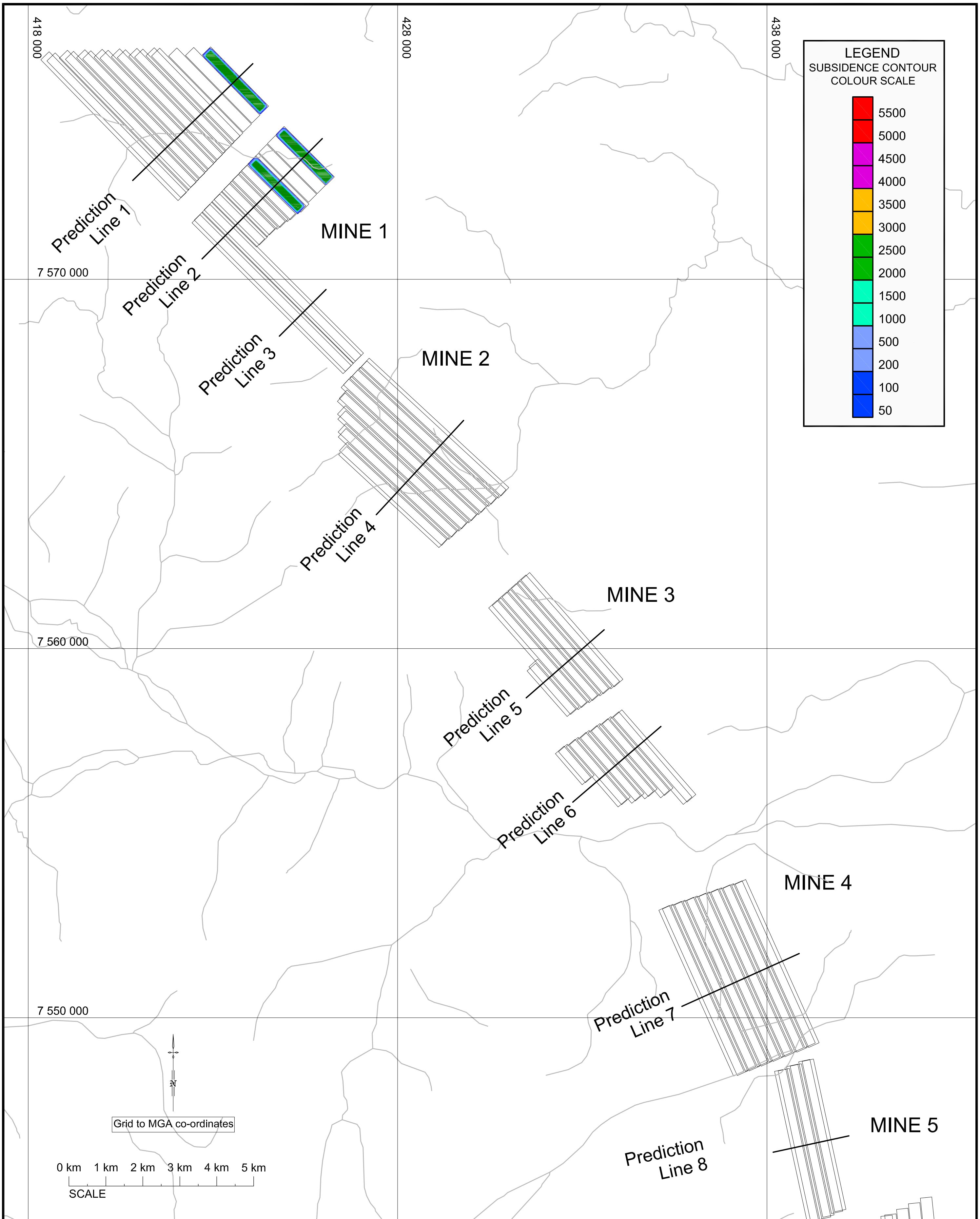

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AFTER AB1 & D1 SEAMS - YEAR 5

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26-July-2013	as shown	MSEC627-26	A

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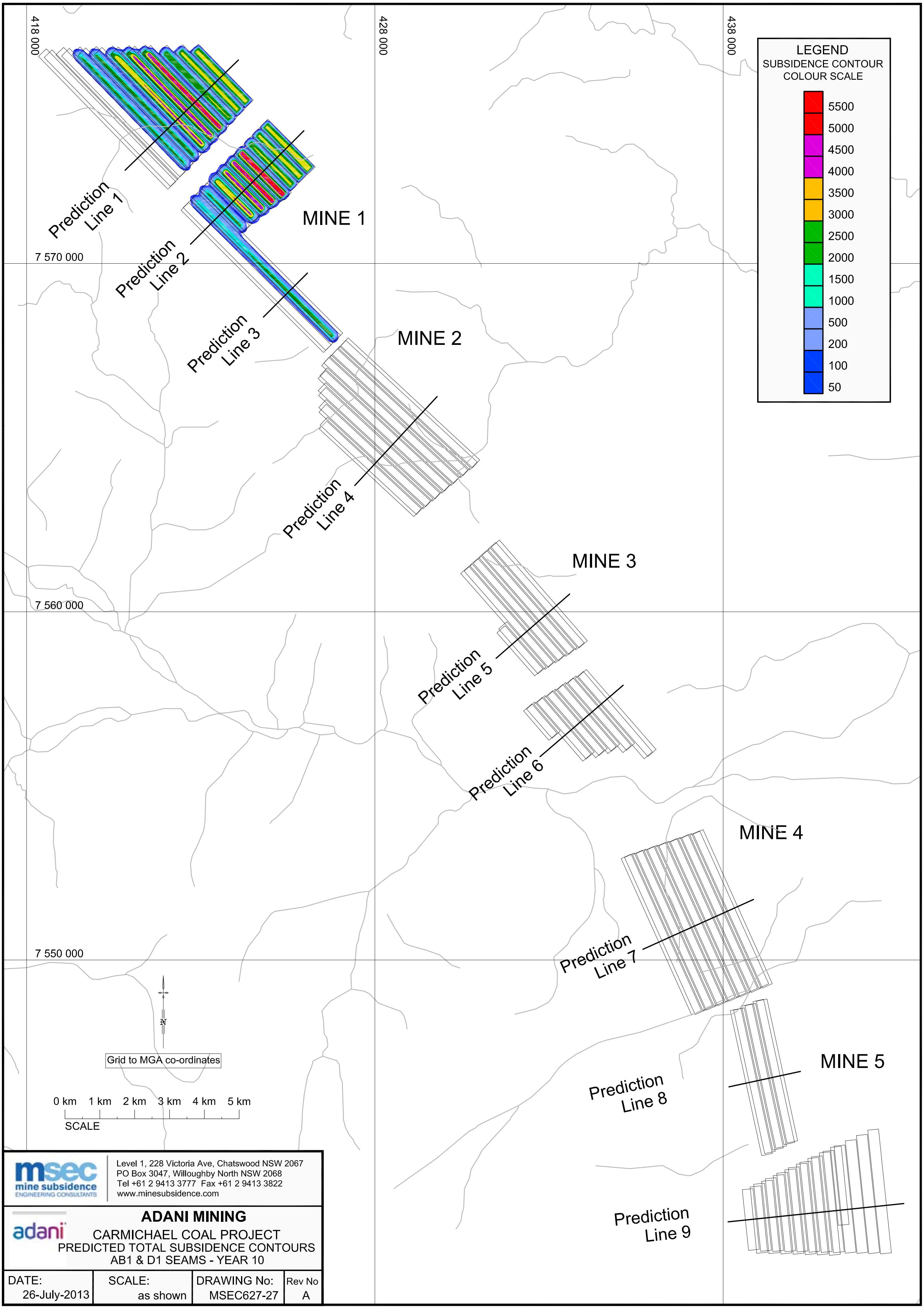

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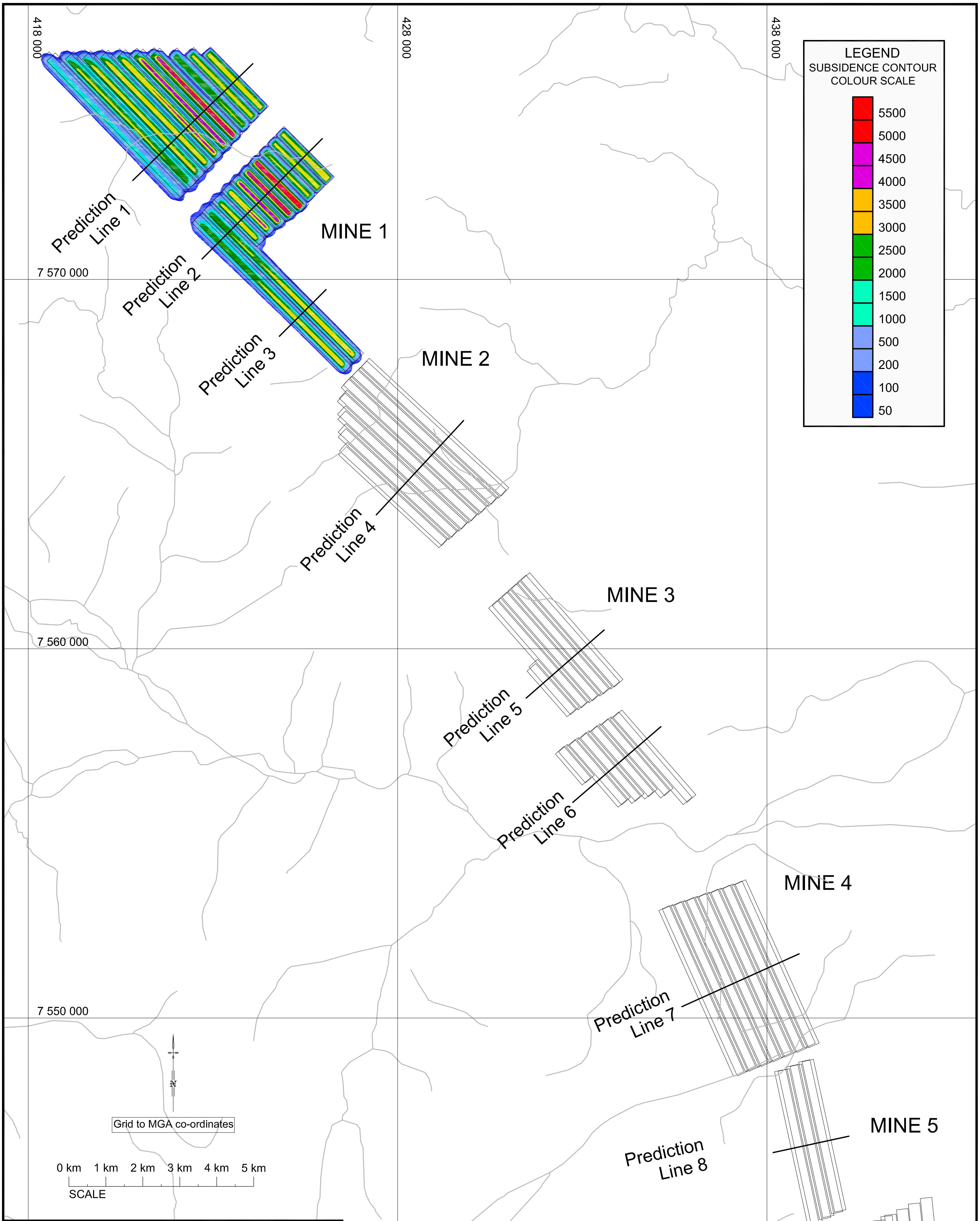

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DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-28	A

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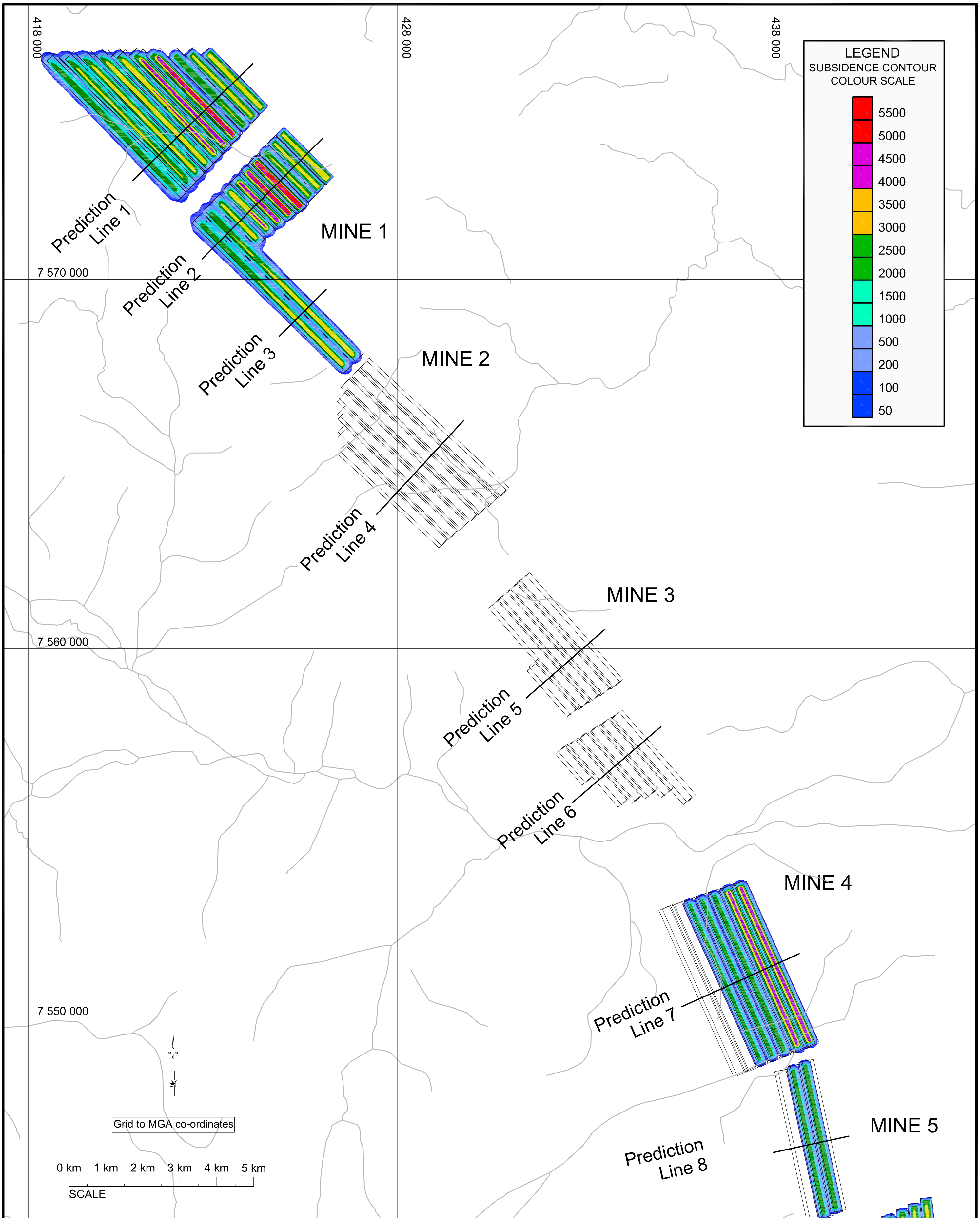

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AFTER AB1 & D1 SEAMS - YEAR 20

DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-29	A

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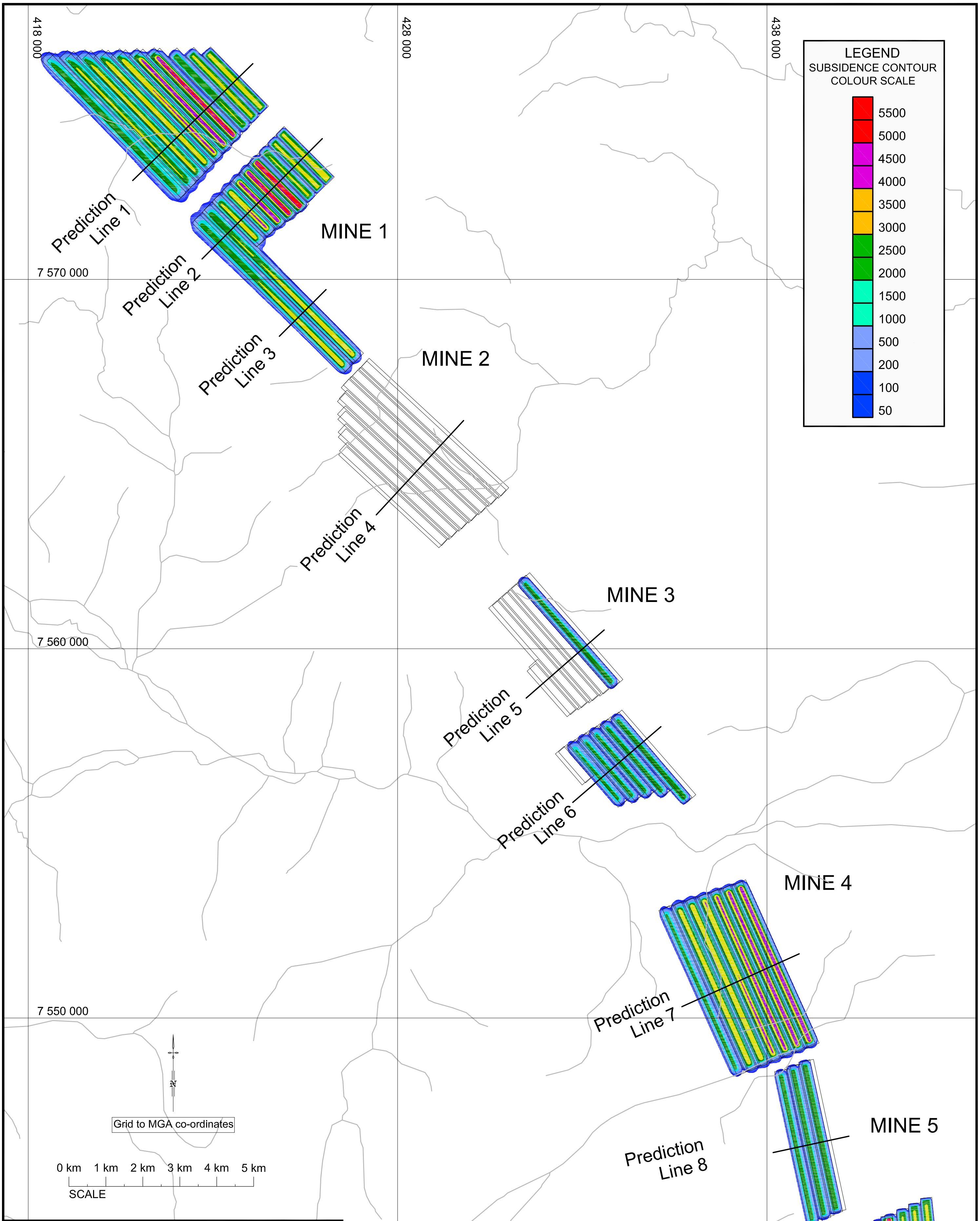

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26-July-2013	as shown	MSEC627-30	A

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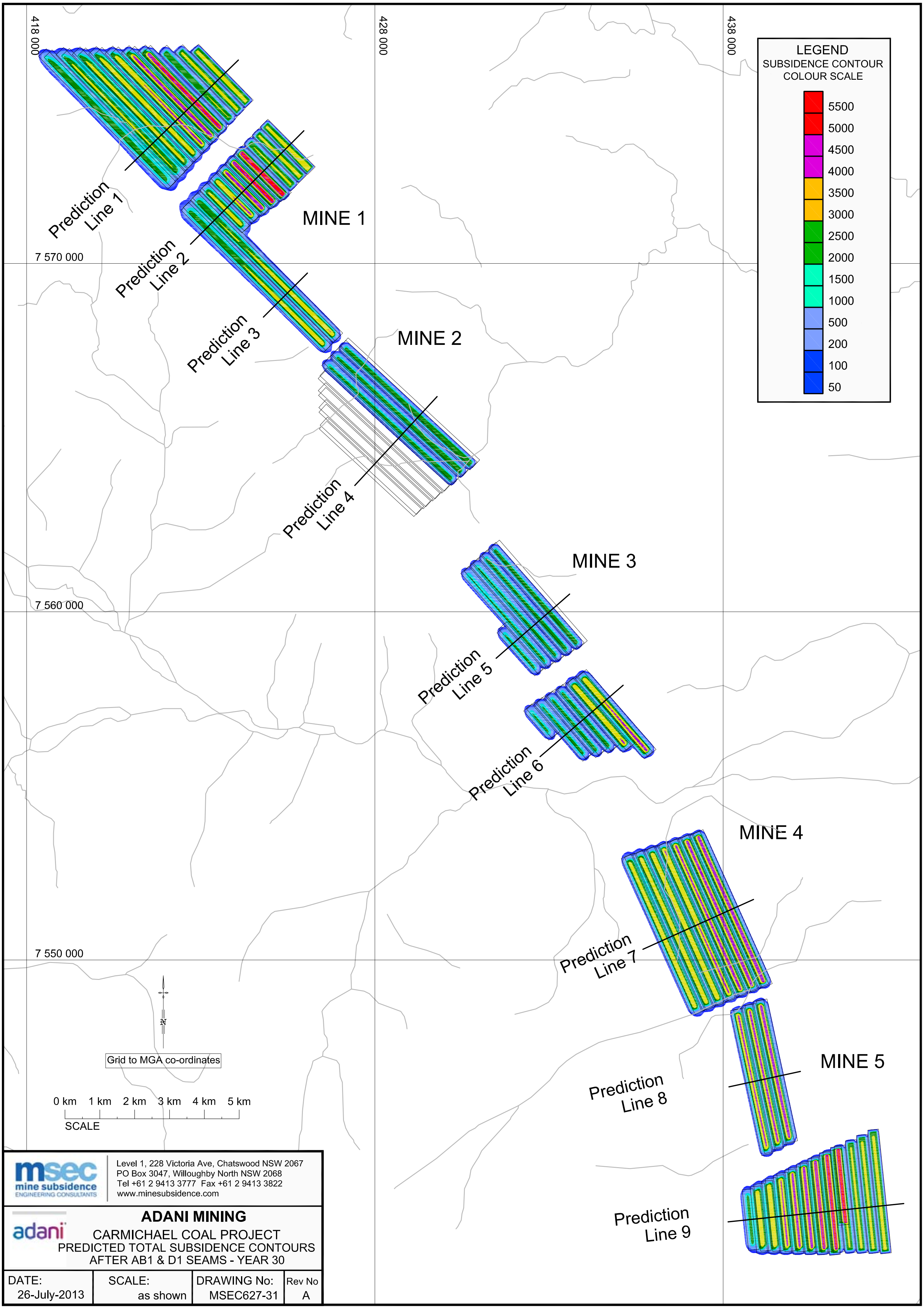

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AFTER AB1 & D1 SEAMS - YEAR 30

DATE:	SCALE:	DRAWING No:	Rev No
26-July-2013	as shown	MSEC627-31	A

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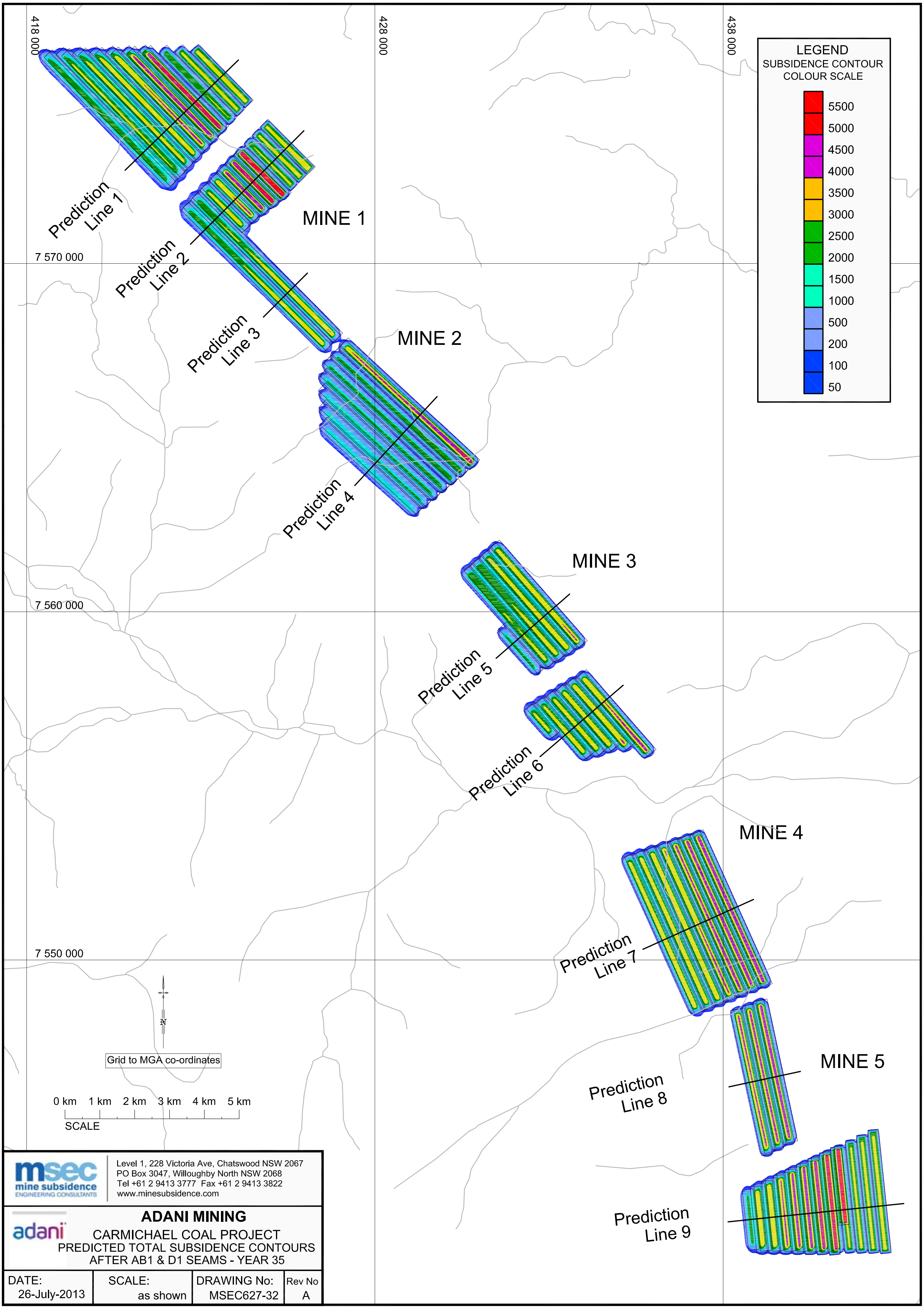

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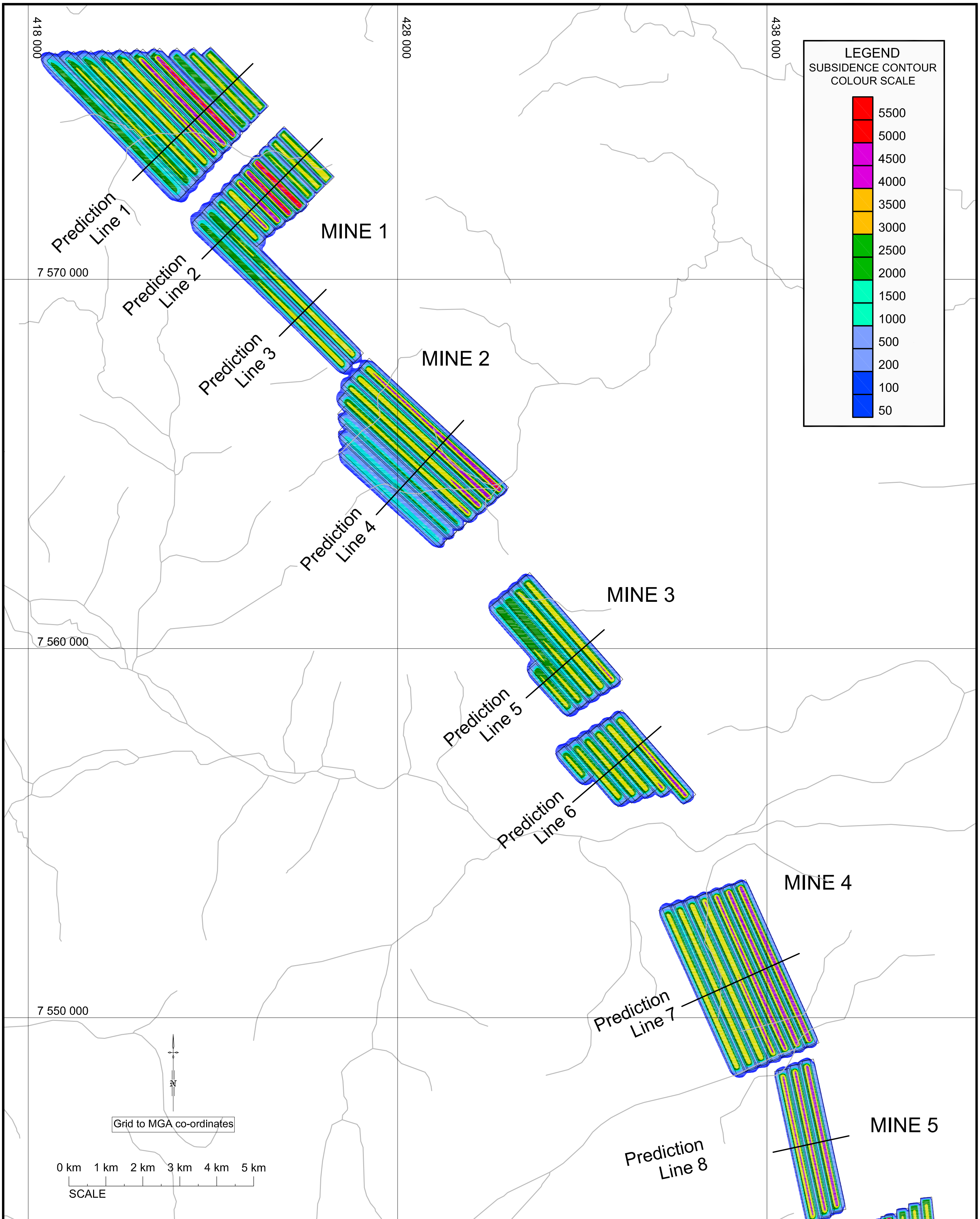

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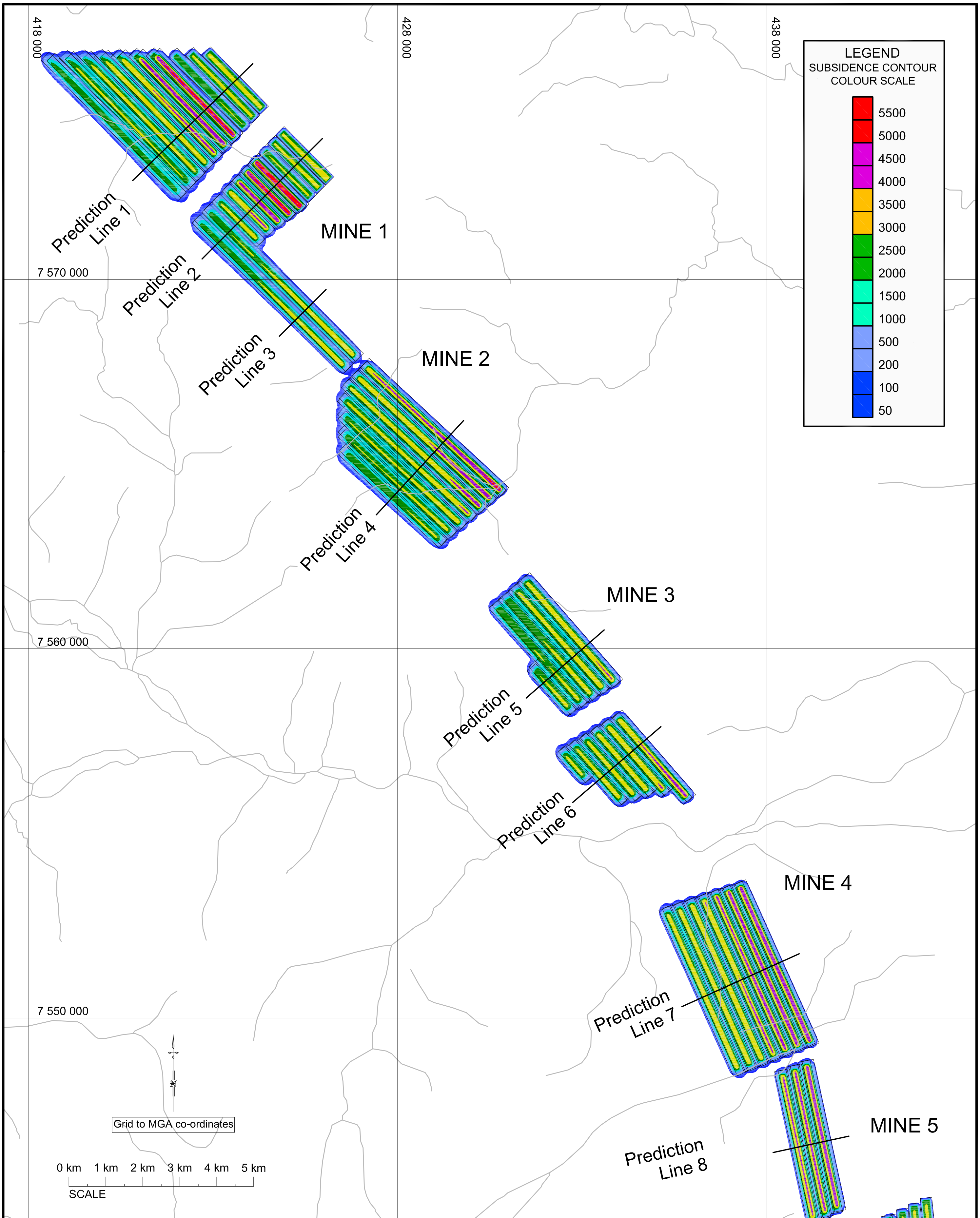

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26-July-2013	as shown	MSEC627-34	A