mine subsidence ENGINEERING CONSULTANTS

ILLAWARRA METALLURGICAL COAL:

Appin – Area 9 – Longwall 904

End of Panel Subsidence Monitoring Review Report for Appin Longwall 904

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MSEC448 (Rev. B) – Appin Colliery – Longwalls 901 to 904 – Subsidence Predictions and Impact Assessments for Natural Features and Surface Infrastructure in Support of the Extraction Plan (June 2012)

MSEC829 (Rev. A) – Appin Colliery – Longwalls 902 to 904 – The Effects of the Proposed Modified Longwalls 902 to 904 on Previous Subsidence Predictions and Impact Assessments (May 2016)

MSEC1005 (Rev. A) – Appin Colliery – Area 9 – The Effects of the Proposed Modified Commencing Ends of Longwalls 903 and 904 at Appin Colliery on the Subsidence Predictions and Impact Assessments (December 2018)

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

Introduction to Longwall Mining and Subsidence (Revision A)

General Discussion of Mine Subsidence Ground Movements (Revision A)

Mine Subsidence Damage to Building Structures (Revision A)

CONTENTS

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Tables

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Figures

Figures are prefixed by the number of the section or the letter of the appendix in which they are presented.

Drawings

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

Drawing No.	***Description***	***Rev.***
MSEC1285-01	General layout and monitoring lines	A
MSEC1285-02	Natural features	A
MSEC1285-03	Built features	A
MSEC1285-04	Vectors of incremental horizontal movement due to LW904	A

1.1. Introduction

Illawarra Metallurgical Coal (IMC) has approval for the mining of Longwalls 901 to 904 (LW901 to LW904) in Area 9 at Appin Colliery. IMC has now completed the mining of LW904 which is the fourth longwall in the series. The location of the longwalls in Area 9 are shown in Drawing No. MSEC1285-01, in Appendix A. A summary of the commencement and finishing dates for the longwalls in Area 9 is provided in Table 1.1.

Table 1.1 Commencement and finishing dates for the longwalls in Area 9

Longwall	Commencement date	Finishing date
LW901	19 January 2016	8 September 2017
LW902	12 May 2018	3 April 2019
LW903	1 November 2019	7 April 2021
LW904	20 May 2021	9 August 2022

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IMC to prepare subsidence predictions and impact assessments for LW901 to LW904. Report No. MSEC448 (Rev. B) was issued in June 2012 in support of the Extraction Plan Application for these longwalls. The Department of Planning and Environment (DPE) granted approval for the Extraction Plan on 10 September 2014.

IMC subsequently shortened the commencing (i.e. western) and finishing (i.e. eastern) ends of LW904 by 1425 m and 50 m, respectively, from the extents indicated in the Extraction Plan Application. Reports Nos. MSEC829 (Rev. A), MSEC1005 (Rev. A) and MSEC1138 (Rev. A) were issued in May 2016, December 2018 and December 2020, respectively, in support of the applications for these modifications. The modified commencing and finishing ends of LW904 were approved by the DPE on 21 March 2019 and 19 March 2021, respectively.

LW904 was completed at chainage -59.4 m approximately 2 m short of the approved finishing end of -61 m. The as-extracted overall void length of LW904 including the installation heading is 2038 m.

This End of Panel subsidence review report provides the following information:

- comparisons between the measured and predicted subsidence effects at the monitoring lines and monitoring points in Appin Area 9 resulting from the mining of LW904; and
- comparisons between the observed and assessed impacts on the natural and built features within the mining area resulting from the mining of LW904.

Further details on the observed and assessed impacts for natural features due to the mining of LW904 are provided in the associated reports by other consultants. The observations provided in this report should be read in conjunction with those and all other relevant reports.

Chapter 2 of this report describes the locations of the ground monitoring lines and monitoring points that were surveyed during the mining of LW904. That section also provides comparisons between the measured and predicted movements resulting from the mining of this longwall.

Chapter 3 of this report describes the natural and built features near LW904. That section also provides comparisons between the observed and assessed impacts for these features due to the mining of this longwall. Further discussions on the observed and assessed impacts for the natural features are provided in the associated reports by other consultants.

Appendix A includes all drawings associated with this report.

1.2. Mining geometry

The layout of the longwalls in Area 9 at Appin Colliery is shown in Drawing No. MSEC1285-01, in Appendix A. A summary of the as-extracted dimensions for LW901 to LW904 is provided in Table 1.2.

Table 1.2 Mining geometry of the as-extracted longwalls in Area 9

Location	Longwall	Overall void length including installation heading (m)	Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
Area 9	LW901	2028	305	-
	LW902	2153	305	45
	LW903	2297	305	45
	LW904	2038	325	45

The mined lengths of the longwalls excluding the installation headings are approximately 9 m shorter than the overall void lengths provided in Table 1.2. The longwall face widths excluding the first workings are approximately 294 m for LW901 to LW903 and 314 m for LW904.

The longwalls in Area 9 at Appin Colliery are being mined in the Bulli Seam, from the west towards the east, i.e. towards the main headings. The natural surface and the seam levels along the centreline of LW904 are illustrated in Fig. 1.1.

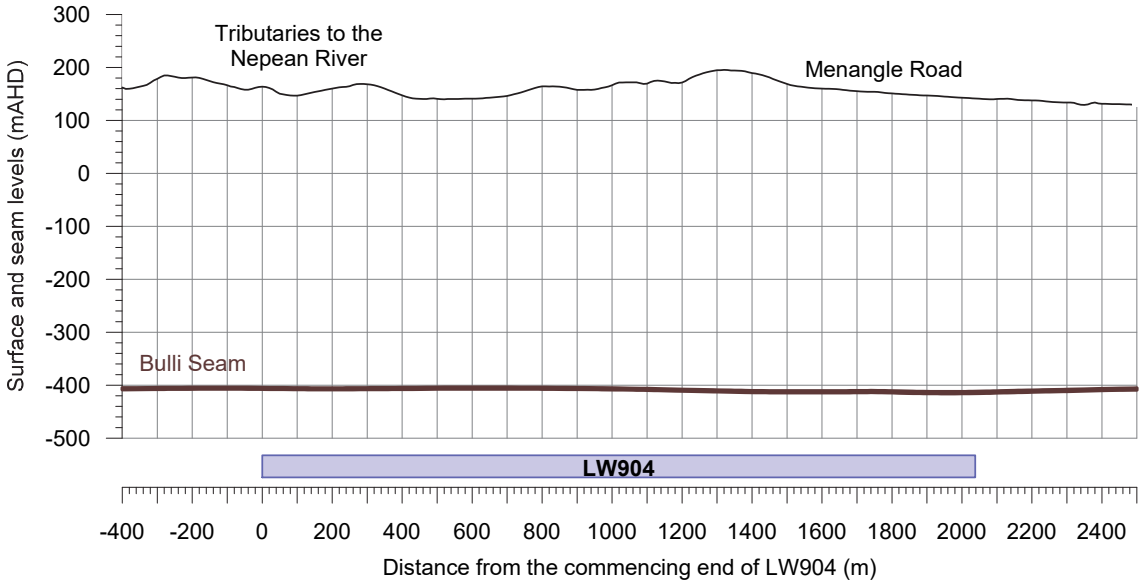

Fig. 1.1 Surface and seam levels along the centreline of LW904

The natural surface above the mining area generally falls from the north towards the south. The natural drainage lines above the western end of LW904 flow into the Nepean River which is more than 1 km south of the longwall tailgate. The drainage lines above the eastern end of LW904 flow into Harris Creek which is more than 600 m east of the finishing end of the longwall. Razorback Range is located on the northern side of LW904 and the toe of this range is partially located above the longwall.

The depth of cover to the Bulli Seam directly above LW904 varies between a minimum of 535 m above the tailgate towards the commencing (i.e. western) end of the longwall, and a maximum of 630 m above the maingate near the mid-length of the longwall. The seam floor within the mining area generally dips from the south to the north, with an average dip approximately 2 %, or 1 in 50.

The thickness of the Bulli Seam varies between 2.7 m and 3.0 m within the extents of LW904. IMC mined the full thickness of the seam.

1.3. Predicted mine subsidence effects

The predicted mine subsidence effects for LW904 are provided in Reports Nos. MSEC448, MSEC829, MSE1005 and MSEC1138 which supported the Extraction Plan and Modification Applications. The predicted conventional subsidence effects have been obtained using the Incremental Profile Method (IPM) based on the standard prediction curves for the Southern Coalfield Bulli Coal Seam.

A summary of the maximum predicted incremental vertical subsidence, tilt and curvatures due to LW901 to LW904 is provided in Table 1.3. The values provided in this table are the additional movements due to the mining of each of the longwalls.

Table 1.3 Maximum predicted incremental vertical subsidence, tilt and curvature due to each of LW901 to LW904

Longwall	Maximum predicted incremental vertical subsidence (mm)	Maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (km^{-1})	Maximum predicted incremental sagging curvature (km^{-1})
LW901	625	4.5	0.04	0.10
LW902	825	6.5	0.08	0.15
LW903	850	6.0	0.06	0.12
LW904	875	6.0	0.06	0.10

A summary of the maximum predicted total vertical subsidence, tilt and curvatures after the mining of LW901 to LW904 is provided in Table 1.4. The values provided in this table are the accumulated movements due to the mining of all longwalls.

Table 1.4 Maximum predicted total vertical subsidence, tilt and curvature after the mining of LW901 to LW904

Longwall	Maximum predicted total vertical subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
LW901 to LW904	1300	6.5	0.08	0.16

The maximum predicted total tilt after the mining of LW904 is 6.5 mm/m (i.e. 0.65 %, or 1 in 154). The maximum predicted total curvatures are 0.08 km^{-1} hogging and 0.16 km^{-1} sagging and represent minimum radii of curvature of 13 km and 6 km, respectively.

The predicted conventional (i.e. typical) strains, based on applying a factor of 15 to the predicted conventional curvatures (and rounding to the nearest 0.5 mm/m), are 1.5 mm/m tensile and 2.5 mm/m compressive. However, the measured strains can exceed these conventional values due to irregular movements or localised effects.

The predicted strains (including the potential for non-conventional anomalous movement) for the longwalls in Area 9 were determined using a statistical analysis of ground monitoring data from Appin and other nearby collieries. The maximum predicted strains are 1.0 mm/m tensile and 1.7 mm/m compressive based on the 95 % confidence levels, and 1.7 mm/m tensile and 3.4 mm/m compressive based on the 99 % confidence levels.

The predicted valley-related effects along the streams have been determined using the methods outlined in ACARP Research Project No. C9067, which were published in the handbook entitled "*Management Information Handbook on the Undermining of Cliffs, Gorges and River Systems*", issued in September 2002. Details on the ACARP 2002 Prediction Method are provided in the background report entitled "*General Discussion on Mine Subsidence Ground Movements*" which can be obtained from *www.minesubsidence.com*.

2.1. Introduction

The mine subsidence effects due to the mining of LW904 were monitored using ground monitoring lines, ground monitoring points and other systems including the following:

- Main Southern Railway, including monitoring associated with the track, embankments, cuttings, culverts and Douglas Park Station;
- Early warning monitoring lines;
- Camden Road monitoring line;
- Menangle Road monitoring line;
- Telstra optical fibre cable monitoring line;
- Nepean River closure lines;
- Harris Creek Cliff Line closure lines;
- Blades Bridge monitoring points;
- Far-field monitoring points;
- Nepean Twin Bridges monitoring points and bridge joint monitoring;
- Moreton Park Road Bridge South monitoring points; and
- ALS / LiDAR surveys.

The locations of the ground monitoring lines and ground monitoring points are shown in Drawing No. MSEC1285-01, in Appendix A. Comparisons between the measured and predicted subsidence effects at these monitoring lines and points are provided in the following sections. The predicted subsidence effects have been obtained using the IPM based on the standard prediction curves for the Southern Coalfield Bulli Coal Seam.

2.2. Main Southern Railway

The Main Southern Railway crosses directly above the previously mined LW901, as shown in Drawings Nos. MSEC1285-01 to MSEC1285-03, in Appendix A. Monitoring associated with the railway includes the:

- Global Navigation Satellite System (GNSS) monitoring along the railway;
- ARTC monitoring line;
- embankment monitoring points;
- cutting monitoring points;
- culvert monitoring points; and
- Douglas Park Station monitoring points.

IMC and the Australian Rail Track Corporation (ARTC) agreed to cease automated track monitoring along the railway during the mining of LW904. GNSS units were, however, installed along the railway to provide a continuous monitoring presence along the railway.

The monitoring results and discussions are provided in weekly subsidence monitoring review reports for the railway (Reports Nos. MSEC1178-R01 to MSEC1178-R68), which were issued during the mining of LW904, between May 2021 and September 2022.

A summary of the monitoring results for the Main Southern Railway is provided in the following sections.

2.2.1. GNSS monitoring and ARTC monitoring line

The ARTC monitoring line follows the Main Southern Railway directly above the previously mined LW901. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the ARTC monitoring line during LW904 is provided in Table 2.1.

Table 2.1 Survey dates for the ARTC monitoring line during LW904

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Start and end of LW904, with 3D survey at 1000 m extraction	26 September 2017 (end of LW901) 20 May 2019 (end of LW902) 19 May 2021 (end of LW903) 15 Nov 2021 16 Aug 2022 (end of LW904)	As per approved LW905 monitoring program

The measured and predicted incremental vertical subsidence along the ARTC monitoring line due to the mining of LW904 only are illustrated in Fig. 2.1. Measurements from the GNSS units along the rail corridor are also plotted in the figure.

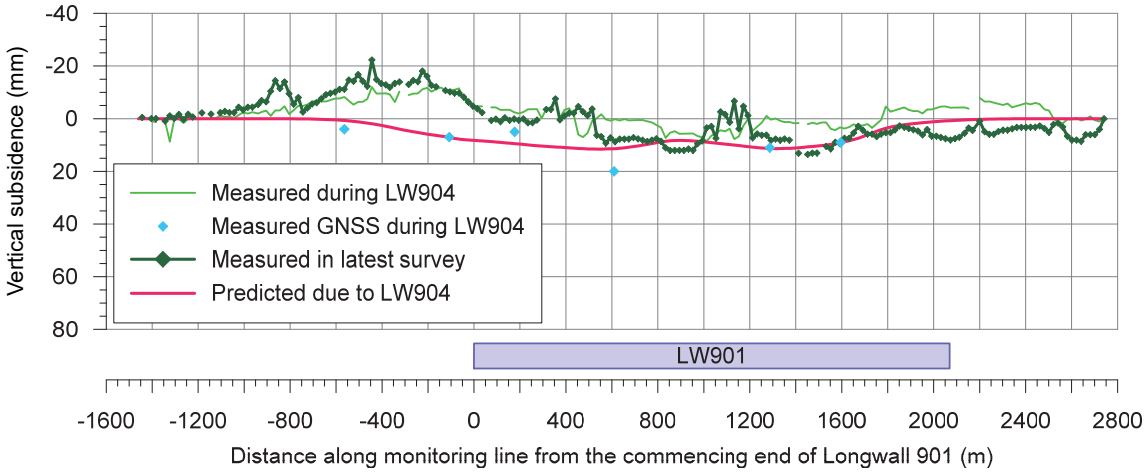

Fig. 2.1 Measured and predicted incremental vertical subsidence along the ARTC line due to the mining of LW904 only

The maximum measured and predicted incremental vertical subsidence occur directly above the existing LW901 where the monitoring line is located closest to the active LW904. There is some variability in the measured profile which could be partly due to localised movements of the survey marks. Low-level uplift was observed west of the commencing end of LW901; however, this movement is in the order of survey tolerance for absolute level, or may reflect swelling of soils following heavy rainfall events. In comparison, the GNSS units did not measure uplift at these locations.

There was, however, reasonable correlation between changes in height measured by the GNSS units and the results from the ground surveys.

A summary of the maximum measured and predicted incremental vertical subsidence, tilt and strain for the ARTC monitoring line is provided in Table 2.2. The values are the maximum additional movements due to the mining of LW904 only.

Table 2.2 Maximum measured and predicted incremental subsidence effects for the ARTC monitoring line due to the mining of LW904 only

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm)	Maximum incremental tensile strain (mm/m)	Maximum incremental compressive strain (mm/m)
Measured	14	0.5	0.4	0.3
Predicted	< 20	< 0.5	*- Refer to discussions below -*	

The accuracies of the measured relative eastings, northings and levels along the ARTC monitoring line are in the order of ±5 mm. The accuracies of the measured absolute eastings, northings and levels are in the order of ±10 mm. The accuracies of the measured strains are in the order of ±0.25 mm/m.

The maximum measured incremental vertical subsidence of 14 mm is consistent with the maximum predicted value of less than 20 mm. It is noted one of the GNSS units recorded subsidence of almost 20 mm, as shown in Fig. 2.1.

The maximum measured incremental tilt of 0.5 mm/m is similar to but greater than the maximum predicted value of less than 0.5 mm/m. However, the greatest measured tilts are localised movements where there is localised variability in the measured vertical subsidence profile along the monitoring line. Away from these locations, the measured macro/global tilt is similar to that predicted.

The maximum measured strains are 0.4 mm/m tensile and 0.3 mm/m compressive which are similar to the order of survey tolerance. That is, the strains were not measurable outside of the survey tolerance.

The vectors of horizontal movement along the ARTC monitoring line are shown in Drawing No. MSEC1285-04. Discussions on these movements have been included in Section 2.9.

2.2.2. Embankment monitoring points

Embankment monitoring points in Appin Area 9 are located at railway chainages 74.7 km, 75.7 km and 76.2 km. The embankment at 74.7 km is located directly above the previously mined LW901 and the embankments at 75.7 km and 76.2 km are located at minimum distances of approximately 0.3 km and 0.7 km, respectively, to the west of the previously mined LW902.

The subsidence effects at the embankments were measured by IMC using 3D ground monitoring lines along the crests and toes. Only minor differential vertical and horizontal movements were measured along the embankments, typically similar to the order of survey tolerance. No adverse impacts were observed along the embankments.

2.2.3. Cutting monitoring points

Cuttings in Appin Area 9 are located at railway chainages 74.0 km and 75.3 km. Both cuttings are located directly above the previously mined LW901. The cuttings at 74.0 km and 75.3 km are located at minimum distances of approximately 200 m and 50 m to the south of the previously mined LW902.

The subsidence effects at the cuttings were measured by IMC using 3D ground monitoring lines along their crests and toes. Minor changes were observed during the mining of LW904, with no adverse impacts observed on the cuttings themselves.

2.2.4. Culvert monitoring points

The culvert monitoring points in Appin Area 9 are located at the crossing of Harris Creek and on the embankments at railway chainages 74.7 km and 75.7 km. The culvert at 74.7 km is located directly above the previously mined LW901 and the culvert at 75.7 km is located at a distance of approximately 400 m to the west of the previously mined LW902.

The subsidence effects at the culvert monitoring points were measured by IMC using 3D ground monitoring lines along their main axes. Only minor differential vertical and horizontal movements were measured along the culverts, typically similar to the order of survey tolerance.

2.2.5. Douglas Park Station monitoring points

Douglas Park Station is located immediately to the east of the finishing end of the previously mined LW901 and south of the finishing end of the previously mined LW902. The subsidence effects at the station platform were measured by IMC using 3D ground monitoring points along its length. Only minor differential vertical and horizontal movements were measured along the platform, typically similar to the order of survey tolerance.

2.3. Camden Road monitoring line

The Camden Road monitoring line is located to the east of LW904 at a minimum distance of approximately 640 m from the longwall finishing end. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Camden Road monitoring line during LW904 is provided in Table 2.3.

Table 2.3 Survey dates for the Camden Road monitoring line during LW904

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Final survey after the completion of LW904	3 October 2017 (end of LW901) 6 May 2019 (end of LW902) 29 April 2021 (end of LW903) 12 August 2022 (end of LW904)	As per approved LW905 monitoring program

The measured incremental vertical subsidence along the Camden Road monitoring line due to the mining of LW904 only is illustrated in Fig. 2.2. Positive values are net downward movements and negative values are net uplift.

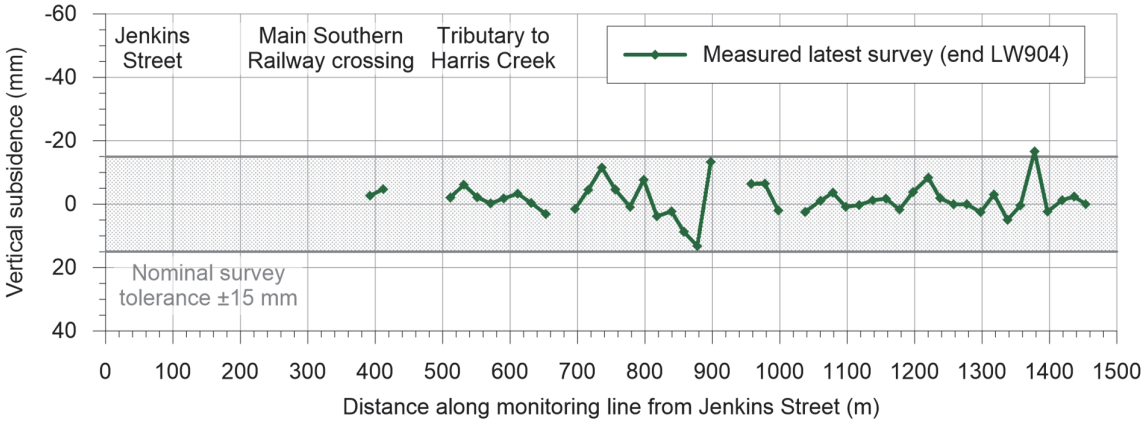

Fig. 2.2 Measured incremental vertical subsidence along the Camden Road line due to the mining of LW904 only

The measured incremental vertical subsidence (i.e. net downward movement) along the Camden Road monitoring line due to LW904 is less than 15 mm and, therefore, is in the order of survey tolerance for absolute level. The measured incremental strains are typically less than 0.3 mm/m tensile and compressive and, therefore, are similar to the order of survey tolerance.

The vectors of horizontal movement along the Camden Road monitoring line are shown in Drawing No. MSEC1285-04. Discussions on these movements have been included in Section 2.9.

2.4. Menangle Road monitoring line

The Menangle Road monitoring line follows the alignment of that road and it crosses above the western end of the previously mined LW903 and above the eastern end of LW904. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Menangle Road monitoring line during LW904 is provided in Table 2.4.

Table 2.4 Survey dates for the Menangle Road monitoring line during LW904

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to active subsidence; weekly 2D and monthly 3D surveys from longwall chainage of 200 m; and final survey after completion of LW904	3 May 2018 (base survey) 16 May 2019 (end of LW902) 13 May 2021 (end of LW903) 8 July 2021, then approximate weekly surveys to 11 August 2022 (end of LW904)	As per approved LW905 monitoring program

The measured and predicted total vertical subsidence along the Menangle Road monitoring line due to the mining of LW902 to LW904 are illustrated in Fig. 2.3. The movements measured during the mining of LW902, LW903 and LW904 are shown by the blue, khaki and green lines, respectively. It is noted that the monitoring line was extended east of Mark MR9081 (i.e. approximate distance of 1600 m), with a baseline survey completed on 9 January 2020 and, therefore, there is a survey discontinuity in the results at that location.

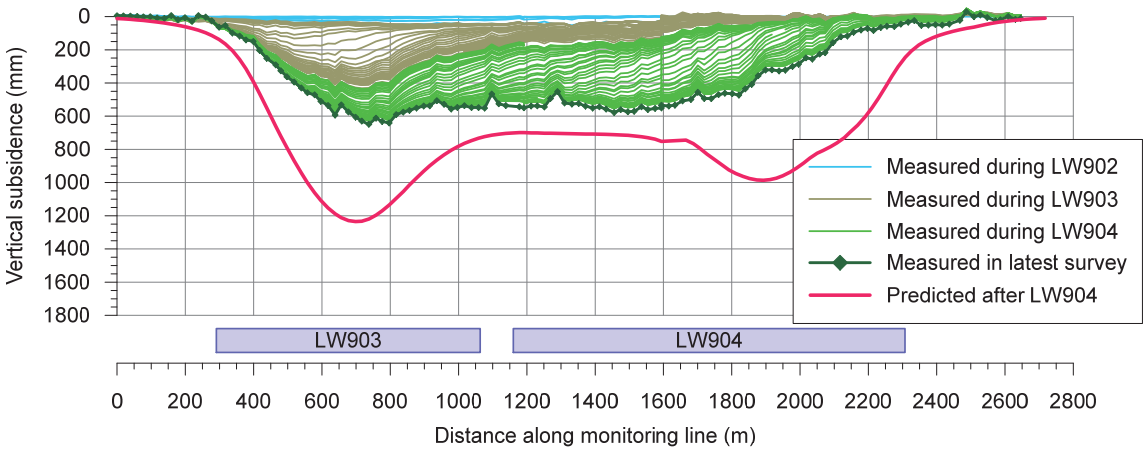

Fig. 2.3 Measured and predicted total vertical subsidence along the Menangle Road monitoring line due to the mining of LW902 to LW904

The maximum measured and predicted total vertical subsidence occurs directly above LW903 with slightly less subsidence above LW904. Only low-level subsidence was measured outside the mining area which is less than that predicted.

A summary of the maximum measured and predicted total vertical subsidence, tilt and strain for the Menangle Road monitoring line is provided in Table 2.5. The values are the maximum accumulated movements due to the mining of LW902 to LW904.

Table 2.5 Maximum measured and predicted total subsidence effects for the Menangle Road monitoring line due to the mining of LW902 to LW904

Type	Maximum total vertical subsidence (mm)	Maximum total tilt (mm)	Maximum total tensile strain (mm/m)	Maximum total compressive strain (mm/m)
Measured	649	4.1	1.6	4.8
Predicted	1250	4.2	*- Refer to discussions below -*	

The accuracies of the measured relative eastings, northings and levels along the Menangle Road monitoring line are in the order of ±5 mm. The accuracies of the measured absolute eastings, northings and levels are in the order of ±10 mm. The accuracies of the measured strains are in the order of ±0.25 mm/m.

The maximum measured total vertical subsidence of 649 mm is approximately half and the maximum predicted value of 1250 mm. The maximum measured tilt of 4.1 mm/m is similar to but less than the maximum predicted value of 4.2 mm/m. The maximum measured tilt is due to the localised bump in the subsidence profile above the chain pillar between LW903 and LW904 and, therefore, it does not represent the overall/macro movements above the mining area.

The maximum measured total strains are 1.6 mm/m tensile and 4.8 mm/m compressive. The maximum predicted total conventional strains, based on applying a factor of 15 to the maximum predicted conventional curvatures, are 1.5 mm/m tensile and 2.5 mm/m compressive.

The maximum measured tensile strain is similar to the predicted value based on conventional ground movements. The maximum measured tensile strain occurs in a single survey bay and, away from that location, the measured tensile strains are otherwise less than 1.0 mm/m.

The maximum measured compressive strain is greater than the maximum predicted value based on conventional ground movements. However, it was noted in Reports Nos. MSEC448, MSEC829 and MSEC1005 that the measured strains can exceed the predicted values based on conventional movements due to anomalous ground movements or valley related effects.

The measured total strain along the Menangle Road monitoring line due to the mining of LW902 to LW904 is illustrated in Fig. 2.4. The movements measured during the mining of LW902, LW903 and LW904 are shown by the blue, khaki and green lines, respectively.

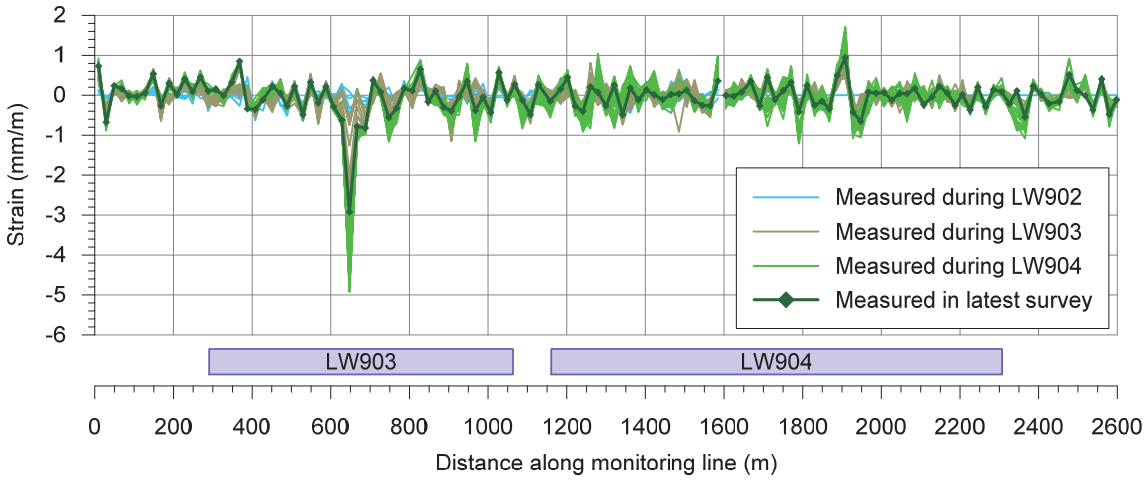

Fig. 2.4 Measured total strain along the Menangle Road monitoring line due to the mining of LW902 to LW904

The maximum measured compressive strain occurs directly above the middle of LW903. There is a drainage line close to this location and, therefore, the localised movement could include anomalous or valley-related effects. As shown in Fig. 2.5, the compressive strain developed gradually between January and February 2020 during the mining of LW903 and continued to develop during the mining of LW904.

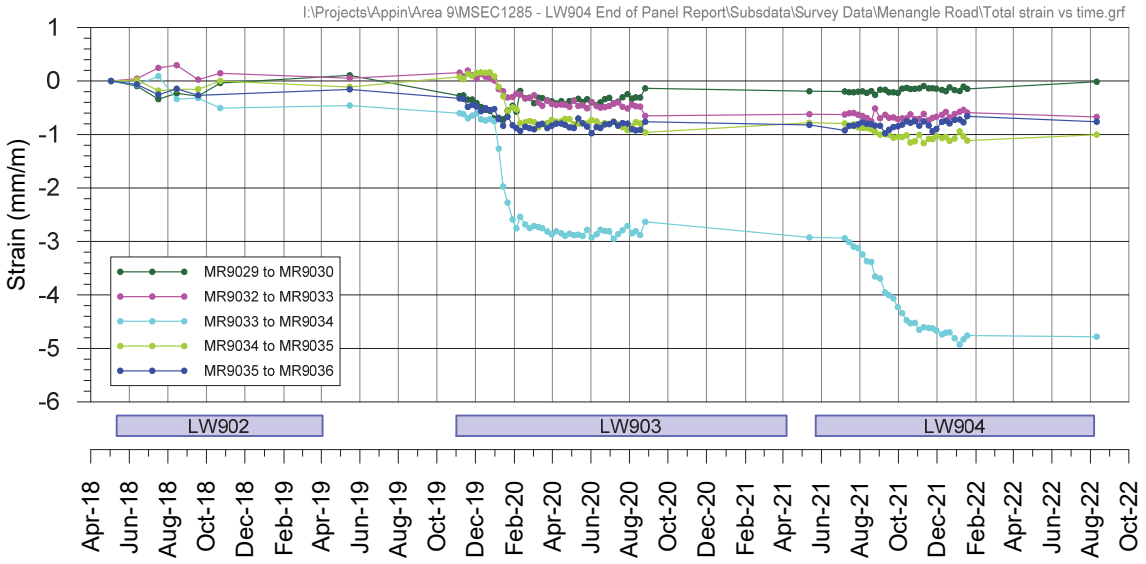

Fig. 2.5 Measured development of total strain over time along the Menangle Road monitoring line during the mining of LW902 to LW904

The 95th percentiles for the measured total strains for the survey bays located directly above the mining area are 0.8 mm/m tensile and 1.1 mm/m compressive. The maximum predicted total strains based on the 95 % confidence levels (i.e. considering the potential for anomalous movement) above the mining area are 1.0 mm/m tensile and 1.7 mm/m compressive. The measured strains based on the 95th percentiles, therefore, are less than the predicted strains based on the 95 % confidence levels.

The vectors of horizontal movement along the Menangle Road monitoring line are shown in Drawing No. MSEC1285-04. Discussions on these movements have been included in Section 2.9.

2.5. Telstra optical fibre cable line

The Telstra Optical Fibre Cable (OFC) monitoring line is located outside and adjacent to the commencing end of LW903 and south of the commencing end of LW904. The monitoring line was measured using 2D and 3D survey techniques. A summary of the survey dates for the Telstra OFC monitoring line during LW904 is provided in Table 2.6.

Table 2.6 Survey dates for the Telstra OFC monitoring line during LW904

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW904; monthly 3D surveys between 300 m and 500 m of extraction; and final survey after completion of LW904	26 September 2017 (end of LW901) 20 May 2019 (end of LW902) 13 May 2021 (end of LW903) 11 June 2021 8 July 2021 2 August 2021 2 September 2021 11 August 2022 (end of LW904)	As per approved LW905 monitoring program

The measured and predicted total vertical subsidence along the Telstra OFC monitoring line due to the mining of LW901 to LW904 is illustrated in Fig. 2.6. The movements measured during the mining of LW901, LW902, LW903 and LW904 are shown by the brown, blue, khaki and green lines, respectively.

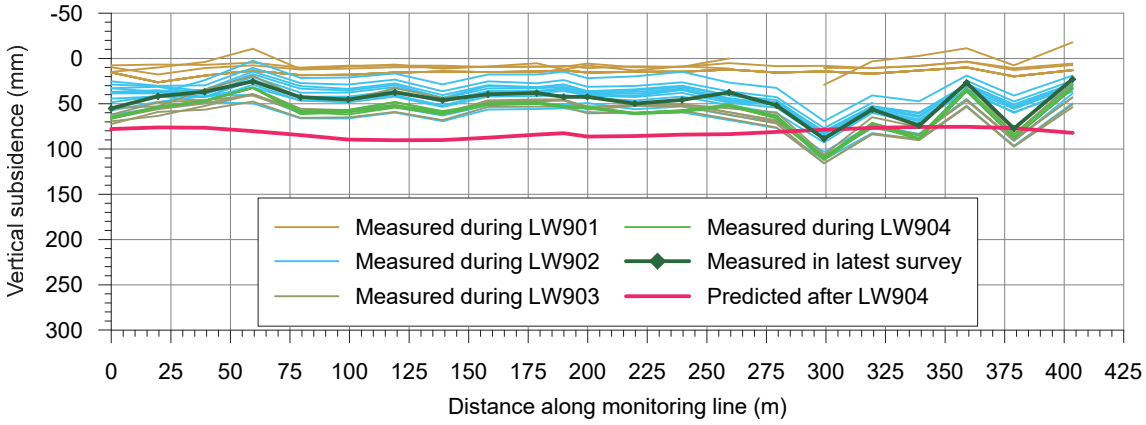

Fig. 2.6 Measured and predicted total vertical subsidence along the Telstra OFC line due to the mining of LW901 to LW904

Low level subsidence (i.e. typically less than 100 mm) was measured and predicted along the Telstra OFC monitoring line due to the mining of LW901 to LW904. The measured vertical subsidence was greater than the predicted during the mining of LW904; however, the measured subsidence later reduced and the final measured values are similar to the predicted values. While the maximum measured values are greater than the predicted values in some locations, the exceedances are within the order of accuracy of the prediction method of ±50 mm at low levels of vertical subsidence.

The measured total strain along the Telstra OFC monitoring line due to the mining of LW901 to LW904 is illustrated in Fig. 2.7. The movements measured during the mining of LW901, LW902, LW903 and LW904 are shown by the brown, blue, khaki and green lines, respectively.

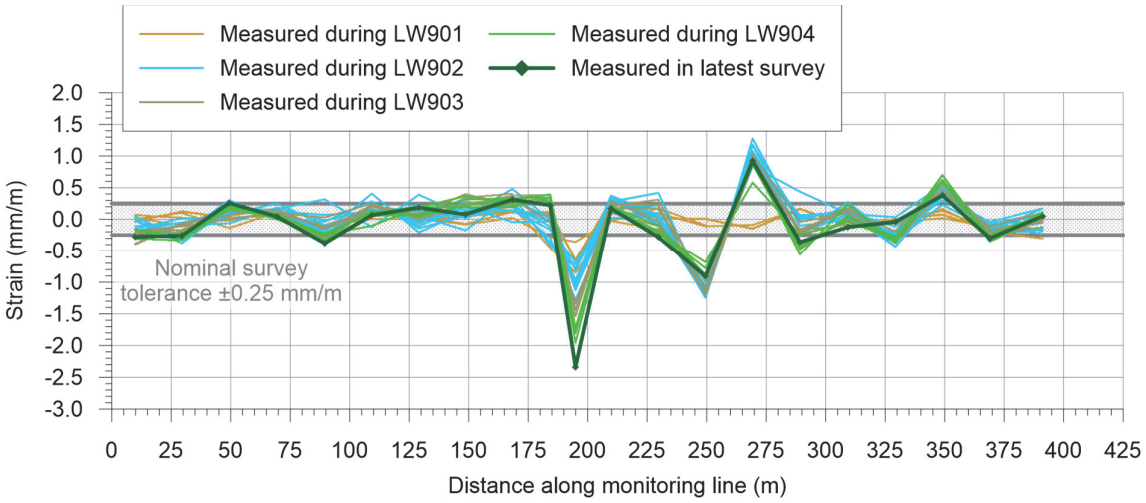

Fig. 2.7 Measured total strain along the Telstra OFC line due to the mining of LW901 to LW904

The maximum measured total strains are 0.9 mm/m tensile and 2.3 mm/m compressive. The maximum predicted total conventional strains, based on applying a factor of 15 to the maximum predicted conventional curvatures, are less than 0.5 mm/m tensile and compressive. The maximum measured strains are therefore greater than the maximum predicted values based on conventional ground movements. However, it was noted in Reports Nos. MSEC448, MSEC829 and MSEC1005 that the measured strains can exceed the predicted values based on conventional movements due to anomalous ground movements or valley related effects.

The 95th percentiles for the measured total strains along the Telstra OFC monitoring line are 0.7 mm/m tensile and 1.2 mm/m compressive. The maximum predicted total strains based on the 95 % confidence levels (i.e. considering the potential for anomalous movement) outside the mining area are 0.6 mm/m tensile and 0.5 mm/m compressive. The measured tensile strain based on the 95th percentile, therefore, is similar to the predicted strain based on the 95 % confidence level. The measured compressive strain is greater than the predicted value; however, the is partly due to the limited sample size, i.e. 21 survey bays. The monitoring line also crosses a small drainage line and, therefore, could also include valley-related effects.

The vectors of horizontal movement along the Telstra OFC monitoring line are shown in Drawing No. MSEC1285-04. Discussions on these movements have been included in Section 2.9.

2.6. Nepean River closure lines

The Nepean River is located 1.1 km south-west of LW904 at its closest point. The Nepean River 9A to 9J closure lines (Nep X 9A-Line to Nep X 9J-Line) are 2D monitoring lines across the Nepean River Valley, apart from the Nep X 9E-Line which is across Allens Creek near the confluence with the Nepean River. The monitoring lines each comprise two survey prisms on either side of the valley, with lengths varying between 110 m and 225 m.

The Nep X 9I and Nep X 9J-Line were measured during and at the end of LW904. The other closure lines were measured at the end of LW904 only. A summary of the survey dates for the Nepean River closure lines during LW904 is provided in Table 2.7.

Table 2.7 Survey dates for the Nepean River closure lines during LW904

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Final survey after the completion of LW904	11 September 2017 (end of LW901) 16 April 2019 (end of LW902) 7 May 2021 (end of LW903) 2 June 2021 then monthly to 29 July 2022 (Nep X 9I-Line and 9J-Line only); and then 10 August 2022 (end of LW904 for Nep X 9A-Line, 9C-Line, 9F-Line, 9G-Line, 9H-Line, 9I-Line and 9J-Line)	As per approved LW905 monitoring program

The development of the measured incremental closure at the Nep X 9I-Line and 9J-Line during the mining of LW904 is illustrated in Fig. 2.8. The incremental movements were in the order of survey tolerance of ±3 mm. That is, the mining-related movements were not measurable outside of the survey tolerance.

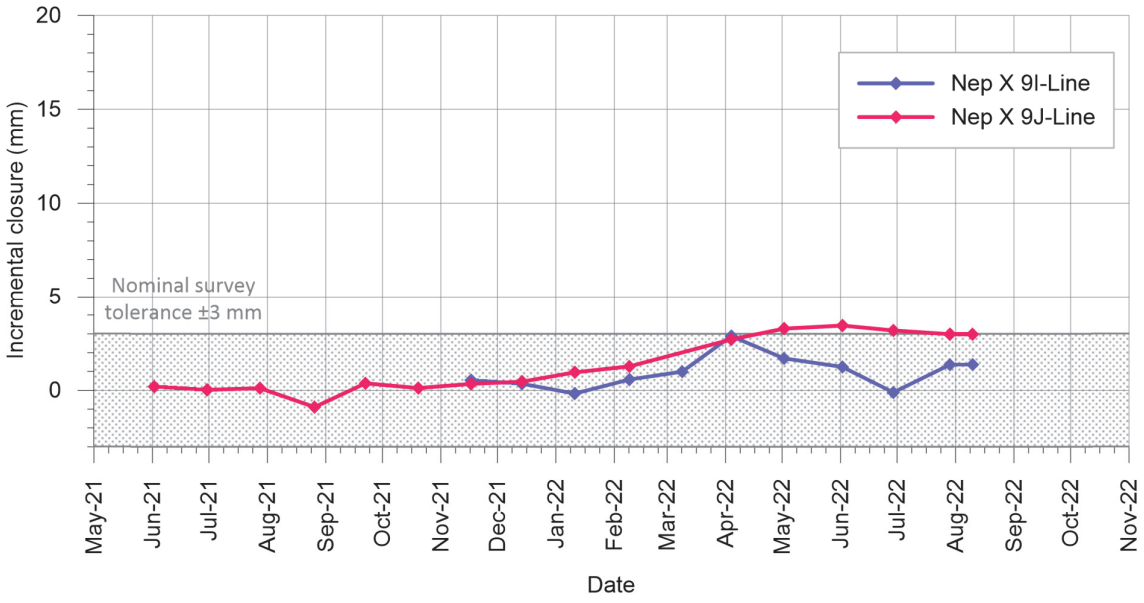

Fig. 2.8 Development of measured incremental closure at the Nep X 9I-Line and 9J-Line during LW904

A summary of the measured incremental closure movements for each of the Nepean River closure lines is provided in Table 2.8. The values are the additional movements due to the mining of LW904 only based on the final survey carried out on 10 August 2022.

Table 2.8 Measured incremental closures for the Nepean River lines due to LW904 only

Location	Measured incremental closure (mm)	Predicted incremental closure (mm)
Nep X 9A-Line	0	< ±10 (survey tolerance based on reflectorless EDM)
Nep X 9B-Line	*(not measured)*	
Nep X 9C-Line	-6 (opening)	
Nep X 9D-Line	*(not measured)*	< ±3 (survey tolerance)
Nep X 9E-Line	*(not measured)*	
Nep X 9F-Line	-1 (opening)	
Nep X 9G-Line	0	
Nep X 9H-Line	1	
Nep X 9I-Line	1	
Nep X 9J-Line	3	

The measured incremental movements at the Nepean River closure lines due to the mining of LW904 only are in the order of survey tolerance and, therefore, the mining-related movements are not measurable.

2.7. Harris Creek Cliff Line closure lines

The Harris Creek Cliff Line (HCCL) is located approximately 1.6 km south of the finishing end of LW904 at its closest point. The HCCL A-Line to E-Line are 2D monitoring lines across the valley of Harris Creek. The monitoring lines each comprise two survey prisms on either side of the valley, with lengths varying between 60 m and 110 m. A summary of the survey dates for the HCCL closure lines during LW904 is provided in Table 2.9.

Table 2.9 Survey dates for the HCCL closure lines during LW904

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW904; monthly surveys during mining; and final survey after completion of LW904	10 April 2018 (end of LW901) 7 June 2019 (end of LW902) 11 May 2021 (end of LW903) 21 June 2021 and then approximate monthly surveys to 19 September 2022 (end of LW904)	As per approved LW905 monitoring program

The development of the measured incremental movements for the HCCL closure lines due to the mining of LW904 is illustrated in Fig. 2.9. Positive values represent net closure and negative values represent net opening.

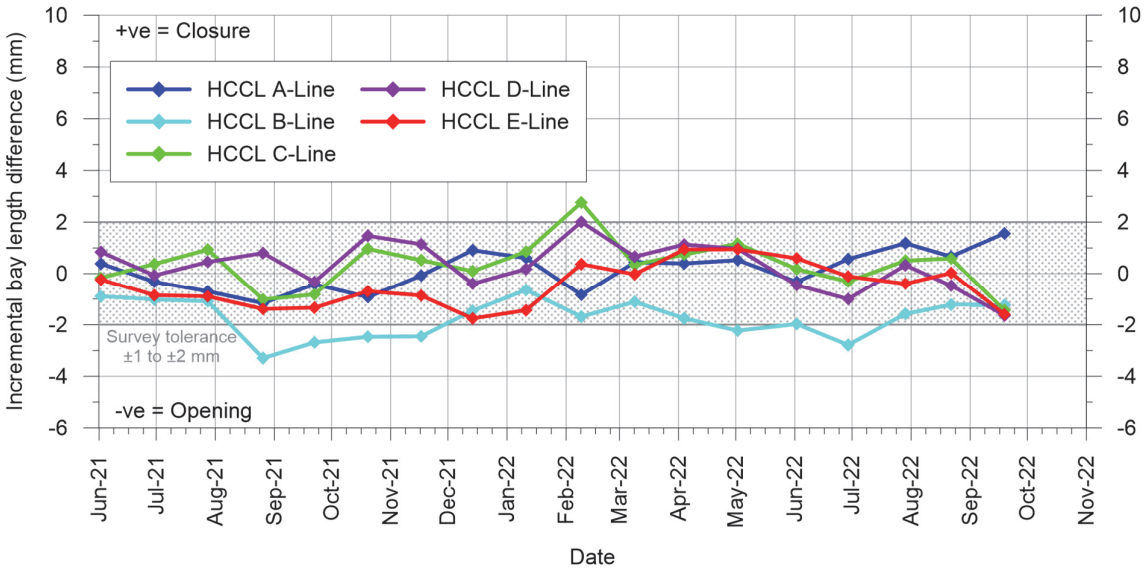

Fig. 2.9 Development of measured incremental movements for the HCCL closure lines due to the mining of LW904

The measured incremental movements in the final survey are less than ±2 mm. These movements were therefore in the order of the nominal tolerance for survey accuracy and environmental effects. That is, the mining-related movements were not measurable outside of the nominal tolerance. There are transient movements slightly greater than ±2 mm that are likely to include survey accuracy and environmental effects.

The development of the measured total closure for the HCCL closure lines due to the mining of LW901 to LW904 is illustrated in Fig. 2.10. Positive values represent net closure and negative values represent net opening.

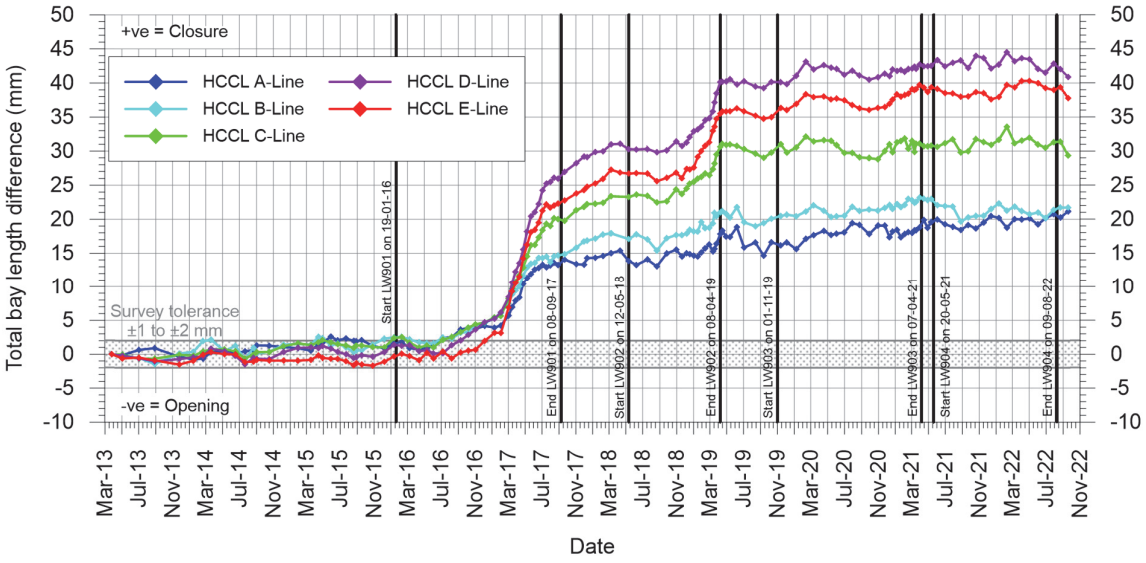

Fig. 2.10 Development of measured total closure for the HCCL due to the mining of LW901 to LW904

A summary of the measured and predicted total closure movements for each of the HCCL closure lines is provided in Table 2.10. The values are the maximum accumulated movements due to the mining of LW901 to LW904.

Table 2.10 Measured and predicted total closure for the HCCL closure lines due to LW901 to LW904

Location	Measured total closure (mm)	Predicted total closure (mm)
HCCL A-Line	21	50
HCCL B-Line	22	
HCCL C-Line	29	
HCCL D-Line	41	
HCCL E-Line	38	

The maximum measured total closure due to the mining of LW901 to LW904 is 41 mm at the HCCL D-Line. The greatest closures have developed towards the southern end of the cliffline (i.e. towards the confluence with the Nepean River) and generally reduce towards the northern end. The total closure movements measured after the completion of LW904 are less than the maximum predicted value of 50 mm.

2.8. Blades Bridge monitoring points

Blades Bridge crosses Harris Creek and it is located approximately 1.6 km south of the finishing end of LW904 at its closest point. The horizontal distance across Blades Bridge has been measured using two prisms fixed to the bridge abutments, located on its northern side. A summary of the survey dates for Blades Bridge during LW904 is provided in Table 2.11.

Table 2.11 Survey dates for Blades Bridge during LW904

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW904; monthly surveys during mining; and final survey after completion of LW904	11 May 2018 (end of LW901) 7 June 2019 (end of LW902) 11 May 2021 (end of LW903) 21 June 2021 and then approximate monthly surveys to 19 September 2022 (end of LW904)	As per approved LW905 monitoring program

The measured incremental movement at Blades Bridge due to the mining of LW904 only is illustrated in Fig. 2.11. The measured movement at the nearby HCCL A-Line is also shown in this figure for comparison.

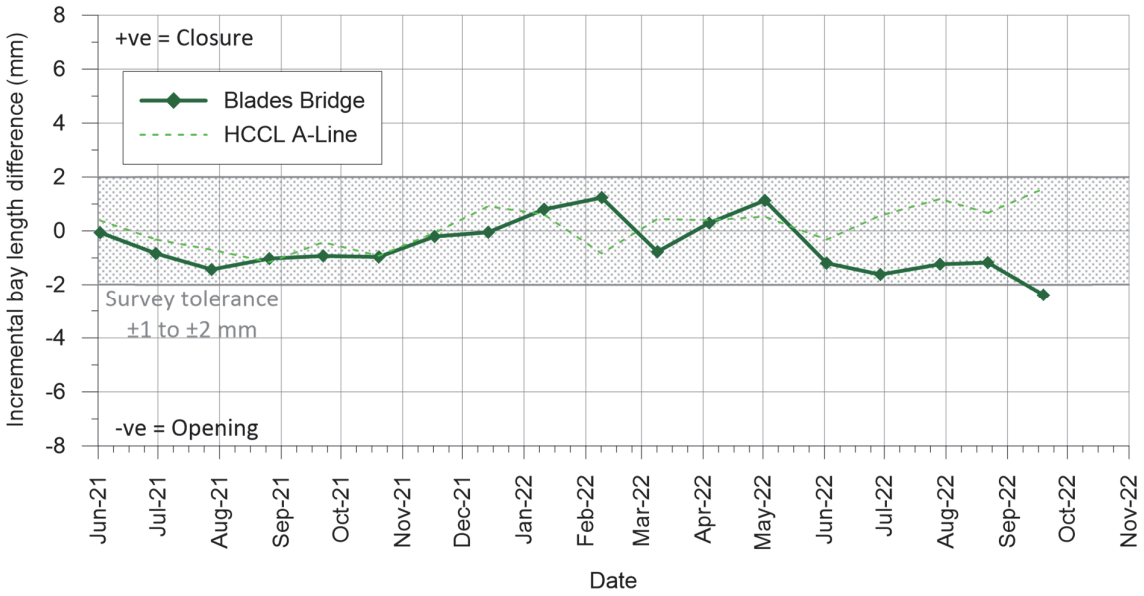

Fig. 2.11 Measured incremental closure at Blades Bridge due to the mining of LW904 only

The measured incremental closure at Blades Bridge due to the mining of LW904 only is -2 mm (opening). The final incremental movement at the completion of LW904 is similar the order of survey tolerance and, therefore, it is not measurable.

2.9. Far-field monitoring points

The far-field horizontal movements in Area 9 have been measured by IMC using the Appin Area 9 (AA9) far-field marks and along the ARTC, Camden Road, Menangle Road and Telstra OFC monitoring lines. Infrastructure along the Main Southern Railway were also measured in absolute 3D, including at the culverts, cuttings and embankments.

The survey dates for the AA9 far-field marks during the mining of LW904 are provided in Table 2.12. The survey dates for the ARTC, Camden Road and Telstra OFC monitoring lines are provided in Sections 2.2, 2.3 and 2.5, respectively.

Table 2.12 Survey dates for the AA9 far-field marks for LW904

Mining phase commitments	Mining phase survey dates	Post mining phase commitments
Base survey prior to the commencement of LW904; monthly surveys during mining; and final survey after completion of LW904	12 September 2017 (end of LW901) 2 May 2019 (end of LW902) 7 May 2021 (end of LW903) 23 July 2021 and then monthly surveys to 19 August 2022 (end of LW904)	As per approved LW905 monitoring program

The measured incremental horizontal movement vectors for the AA9 far-field marks and the ARTC, Camden Road, Menangle Road, Telstra OFC, Early Warning, and Steep Slopes monitoring lines are shown in Drawing No. MSEC1285-04. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of ±10 mm.

The vectors of incremental horizontal movement are generally orientated towards the mining area. The greatest movements occur directly above the mining area and along Razorback Range to the north of the mining area.

A comparison between the measured incremental far-field horizontal movements due to the mining of LW904 and those measured elsewhere in the Southern Coalfield is provided in Fig. 2.12. The x-axis represents the distance from the active longwall.

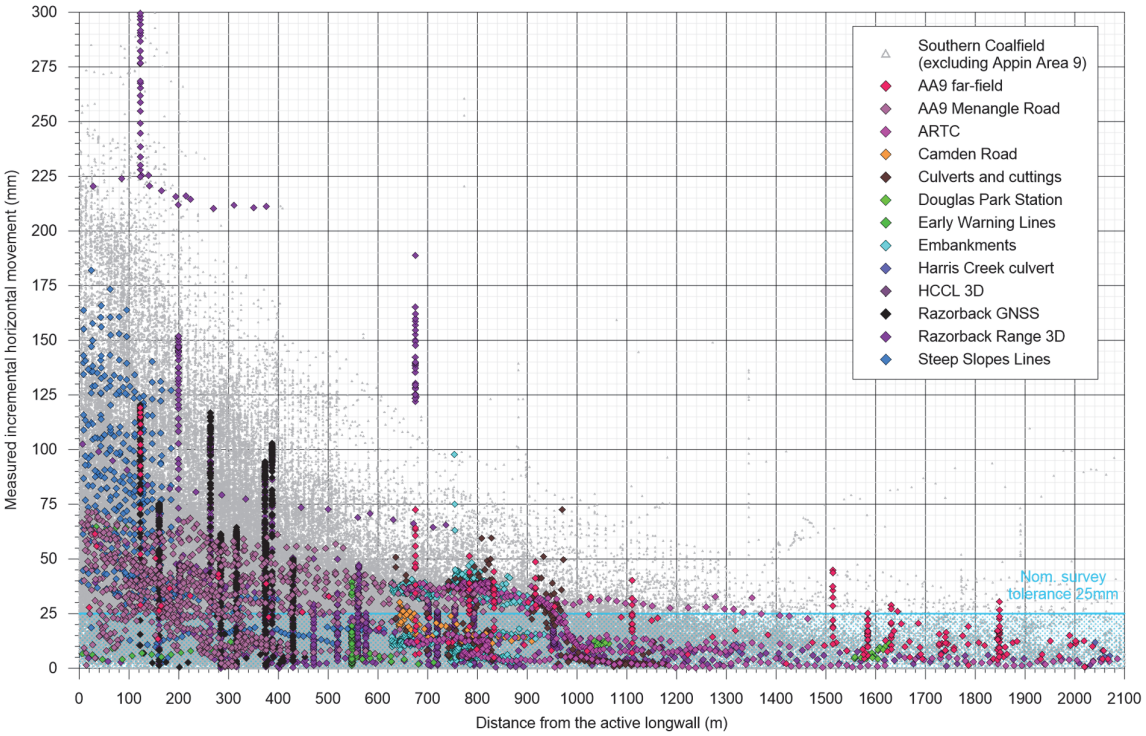

Fig. 2.12 Measured incremental far-field horizontal movements due to the mining of LW904

The measured incremental horizontal movements due to the mining of LW904 (i.e. coloured diamonds in Fig. 2.12) are generally within the range of movements that have been measured elsewhere in the Southern Coalfield (i.e. grey diamonds in that figure) at similar distances from the active longwall.

The incremental horizontal movements measured at some of the Razorback Range 3D marks (i.e. purple diamonds in Fig. 2.12); however, are greater than the movements typically measured elsewhere in the Southern Coalfield. These higher movements occurred at survey marks located on the side of Razorback Range where localised landslips occurred after prolonged periods of heavy rainfall.

The maximum measured incremental horizontal movement due to the mining of LW904 (excluding the marks affected by the localised landslips) is 150 mm on the side of Razorback Range. The horizontal movements at distances greater than approximately 1 km from LW904 are generally less than 25 mm and, therefore, are in the order of survey tolerance for absolute position. There are some marks with movements greater than survey tolerance which were also influenced by the concurrent mining in Appin Area 7.

2.10. Nepean Twin Bridges monitoring points

The Nepean Twin Bridges are located approximately 2 km south of the finishing end of LW904. These bridges experienced far-field movements due to the mining in Appin Area 9 and the concurrent mining in the adjacent Appin Area 7. The monitoring associated with the Nepean Twin Bridges included:

- absolute 3D monitoring points;
- relative 3D monitoring points;
- inclinometer monitoring;
- bridge joint monitoring; and
- visual monitoring.

Descriptions of the monitoring results are provided in the following sections.

2.10.1. Absolute 3D monitoring points

The absolute 3D horizontal movements at the Nepean Twin Bridges have been monitored at Marks DPBN and DPBS, which are located at the northern and southern ends, respectively, of the twin bridges. These marks were measured as part of the far-field monitoring, as described in Section 2.9.

The absolute horizontal movements at Marks DPBN and DPBS have been measured since 15 October 2007 during the mining in Appin Area 7 and during the mining of LW901 to LW904 in Area 9. The development of total horizontal movements for these marks, plotted from the start of April 2014, is shown in Fig. 2.13.

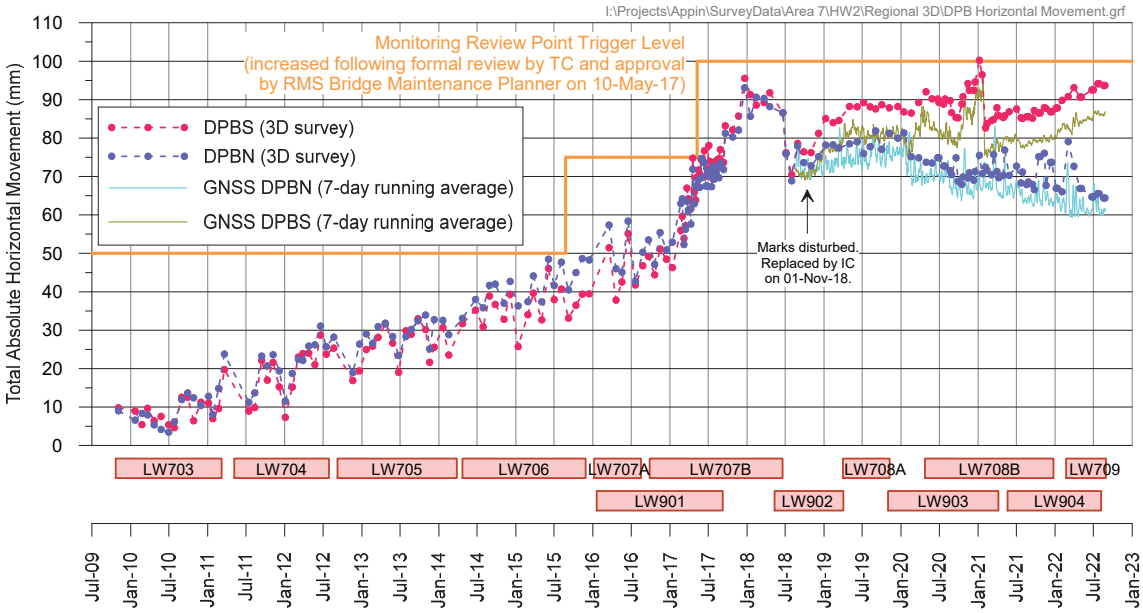

Fig. 2.13 Measured total absolute movements at Marks DPBN and DPBS due to the concurrent mining in Appin Areas 7 and 9

Global Navigation Satellite System (GNSS) units were installed at the ends of the Nepean Twin Bridges in late 2018 and they replaced the fixed survey marks DPBN and DPBS. The results have been overlaid with absolute 3D ground surveys in Fig. 2.13. Greater variation was initially observed at DPBS. A site inspection found that the results were influenced by heavy vegetation growth, which, when removed, returned readings to previously observed trends.

The vectors of incremental horizontal movement at Marks DPBN and DPBS are shown in Drawing No. MSEC1285-04, in Appendix A. The measured incremental horizontal movements at Marks DPBN and DPBS, at the completion of LW904, are 13 mm and 8 mm, respectively. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of measurement tolerance for absolute position of ±20 mm. The orientations of the vectors are therefore not reliable since the magnitudes are not measurable.

The absolute horizontal movements at Marks DPBN and DPBS remained below the Monitoring Review Point Trigger, as shown in Fig. 2.13. A summary of the maximum measured absolute horizontal movements at Marks DPBN and DPBS, measured on 19 August 2022 after the completion of LW904, is provided in Table 2.13.

Table 2.13 Measured absolute movements and trigger for the Nepean Twin Bridges

Location	Maximum measured absolute horizontal movement (mm)	Level 1 Trigger (mm)
Marks DPBN and DPBS	94	100

The maximum measured absolute horizontal movement at Marks DPBN and DPBS was less than the Level 1 Trigger at the completion of LW904.

The 2D horizontal distance across the Nepean River valley at the Nepean Twin Bridges has also been measured using the Marks DPBN and DPBS. The measured total valley closure at the Nepean Twin Bridges is illustrated in Fig. 2.14. The nominal survey accuracy is ±3 mm.

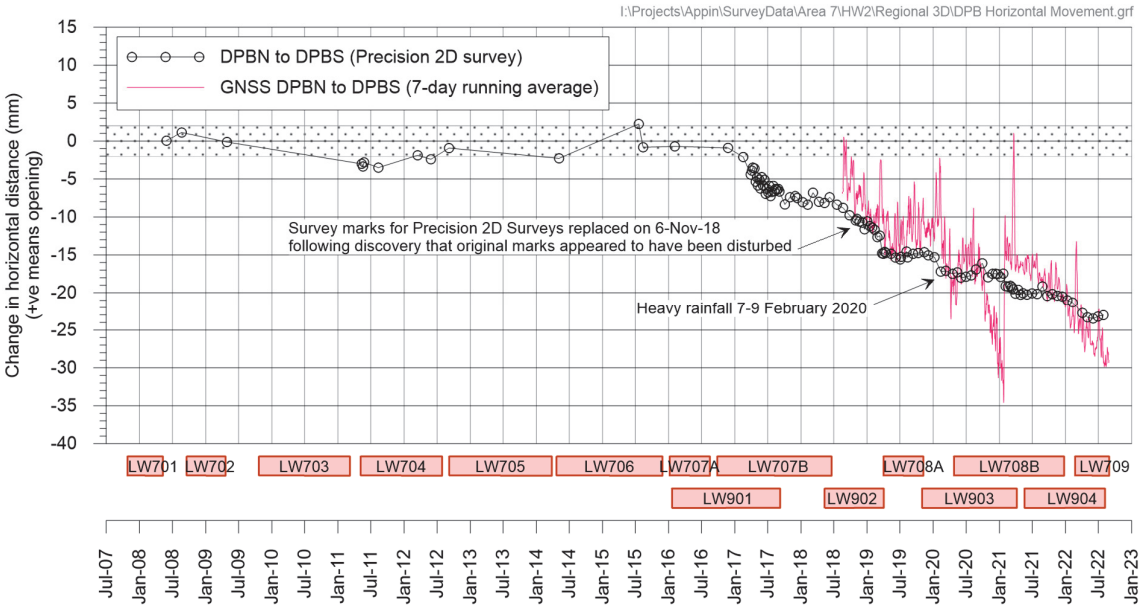

Fig. 2.14 Measured total valley closure at the Nepean Twin Bridges

The measured incremental closure at the completion of LW904 was 3 mm. The results of the GNSS units have been overlaid with the absolute 3D and precision 2D survey results in in Fig. 2.14. There appears to be reasonable agreement between the results, though greater variation is observed from the GNSS units, even when a 7-day running average is displayed.

2.10.2. Relative 3D monitoring points

The subsidence effects of the Nepean Twin Bridges were measured by IMC using relative 3D marks fixed directly to the bridges' structure. The locations of the monitoring points on the Southbound and Northbound carriageways of the bridges are shown in Fig. 2.15 and Fig. 2.16 (Source: IMC).

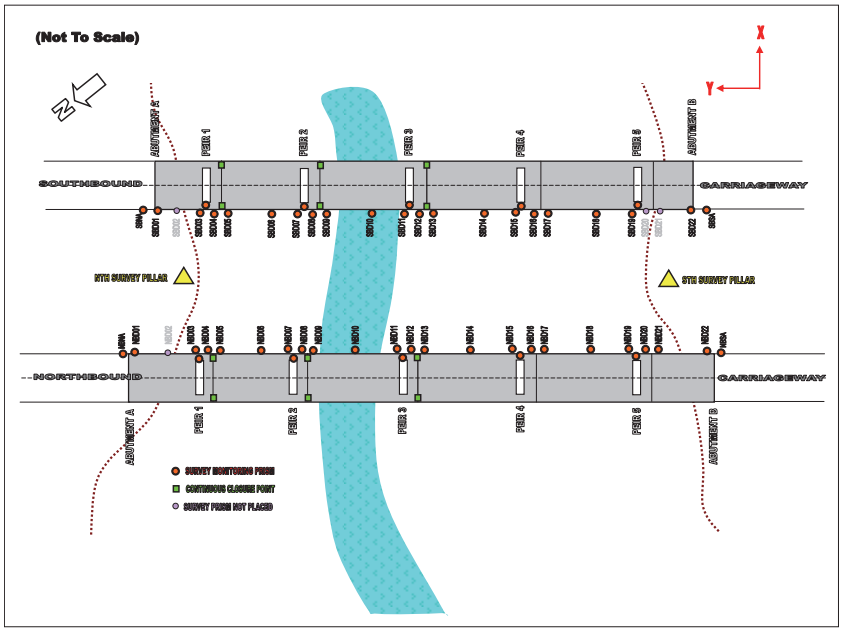

Fig. 2.15 Plan of the relative 3D monitoring points on the Nepean Twin Bridges (Source: IMC)

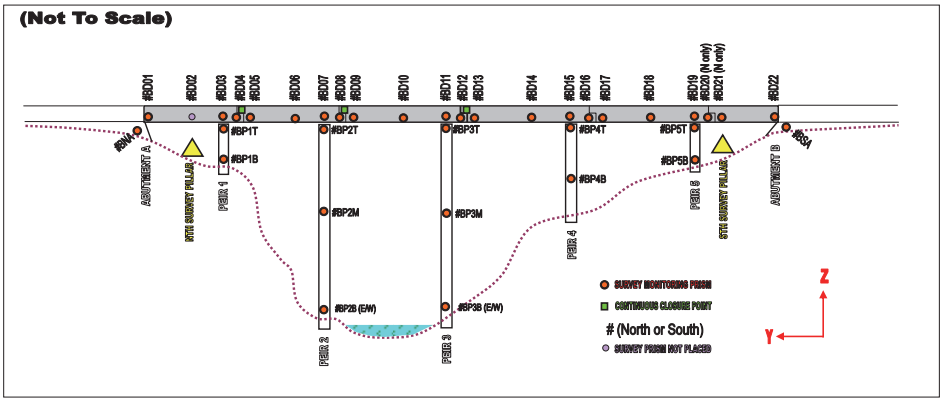

Fig. 2.16 Elevation of the relative 3D monitoring points on the Nepean Twin Bridges (Source: IMC)

The changes in horizontal distance between the piers and abutments of the Nepean Twin Bridges have been measured since 15 October 2007 during mining in Appin Area 7 and continued during LW901 to LW904 in Area 9. The development of total changes in horizontal distance between the marks, plotted from 2007, is shown in Fig. 2.17. The nominal survey accuracy is ±2 mm.

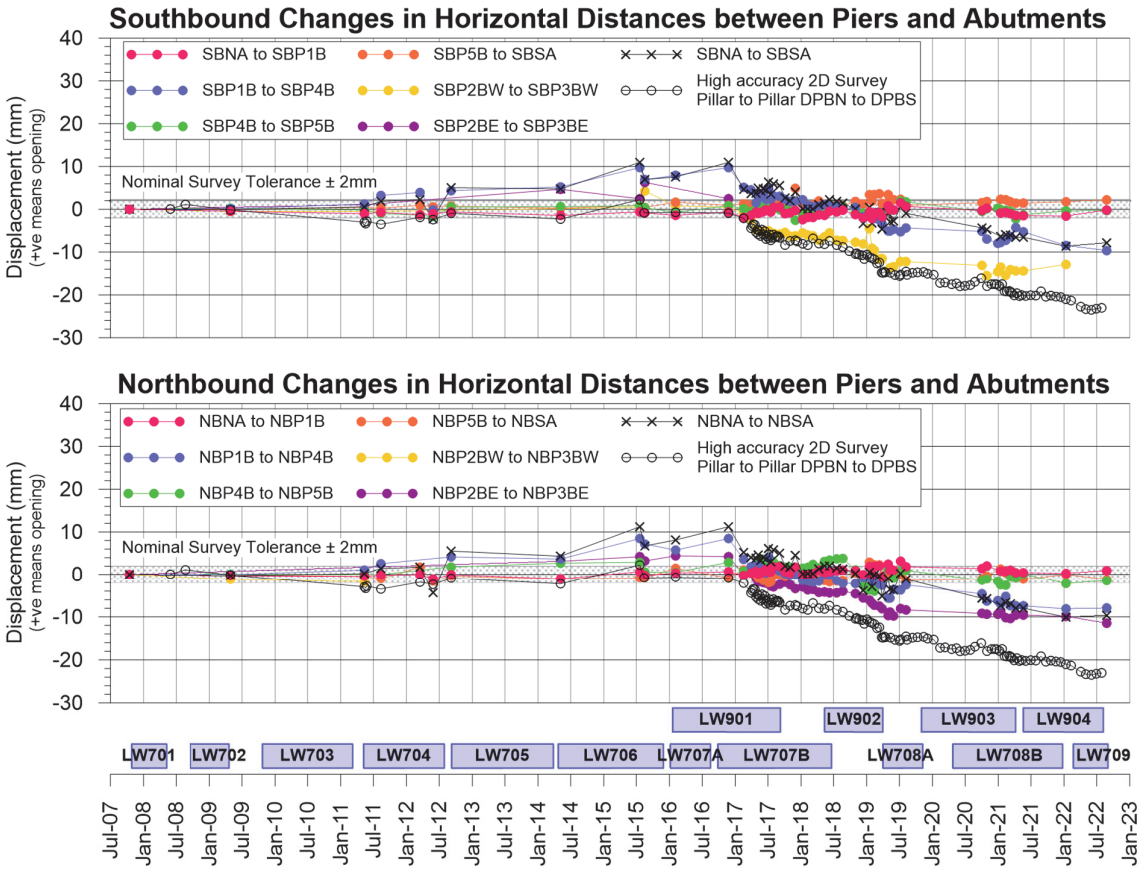

Fig. 2.17 Measured total changes in horizontal distance between the piers and abutments of the Nepean Twin Bridges

It can be seen that the total closure measured across the ends of the bridges has concentrated between Piers 2 and 3 at the bases of the bridges. Very little incremental changes in the distances were measured between the piers and abutments during the mining of LW904.

The measured changes in the lateral direction of the base of the Southbound and Northbound Bridges are close to survey tolerance, as shown in Fig. 2.18. It is noted that a lateral shift was observed in the positions of the base of Piers 2 and 3 relative to the upper levels of the bridges at the end of mining of LW902, with a small recovery measured during the mining of LW904. Minimal change in lateral alignment has been observed in the bridge deck.

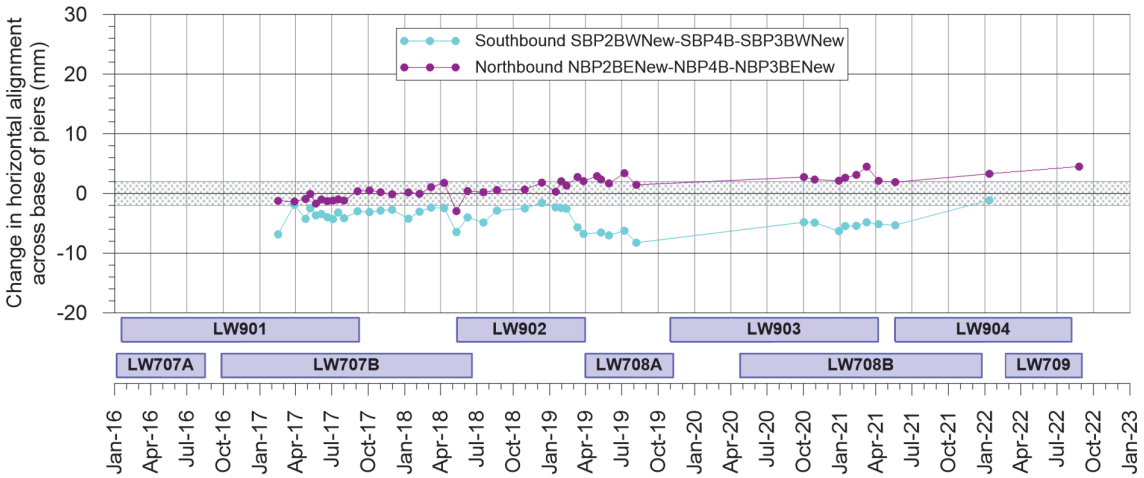

Fig. 2.18 Changes in horizontal alignment across the base of the piers

2.10.3. Inclinometer monitoring

The differential movements at the inclinometer and Shape Accelerometer Array (SAA) at Site PSM6, located near the Nepean Twin Bridges, were monitored during the extraction of LW904 and the concurrent mining in the adjacent Appin Area 7. The inclinometers were installed and maintained by Pells Sullivan and Meynink (PSM), measured by IMC and the results interpreted by PSM. PSM6 was unfortunately lost due to flooding in the Nepean River, with the last readings taken in February 2022.

Further details on the inclinometers and the results are provided in the monitoring reports by PSM, numbers PSM883-420L (dated 9 April 2021) through to PSM883-471L (dated 5 September 2022).

Before the commencement of LW903, PSM advised in September 2019 that differential movements in inclinometer PSM6 was approaching the 5 mm trigger level. The Technical Committee reviewed the monitoring results on 11 September 2019 and agreed to increase the trigger level from 5 mm to 10 mm on the basis that the observed shear displacements are at a depth of 25.25 m below ground, which has an insignificant effect on the Bridges.

The TARP for the Nepean Twin Bridges, which was developed by the RMS chaired Technical Committee, provided a trigger for differential movements at the inclinometers. A summary of the Level 1 Trigger and the maximum measured total differential movements at the inclinometers, at any time during the extraction of LW904, is provided in Table 2.14.

Table 2.14 Measured differential movements and trigger for the Nepean Twin Bridges inclinometers

Type	Maximum measured differential movement (mm)	Level 1 Trigger (mm)
Differential movement	5.67 (PSM6 – RST) 3.82 (PSM6 – SAA)	10

The measured differential movements at PSM6 did not exceed the revised Level 1 Trigger during the mining of LW904. The observed movements are at a depth of 25.25 m. Minor changes have been measured since the completion of LW904.

2.10.4. Joint monitoring

Differential movements across the movement joints in the Nepean Twin Bridges were measured by PSM during the mining of LW904 and the concurrent mining in the adjacent Appin Area 7. The bridge movement joints are referred to as Joint 1 (adjacent to Pier 1), Joint 2 (adjacent to Pier 2) and Joint 3 (main expansion joint adjacent to Pier 3).

The bridge joint monitoring readings commenced on 29 November 2007 (during the mining of LW701 in Appin Area 7) and measurements have been taken at 5 or 10-minute intervals. Further details on the bridge joint monitoring and the results are provided in monitoring reports by PSM, numbers PSM883-420L (dated 9 April 2021) through to PSM883-471L (dated 5 September 2022).

The TARP for the Nepean Twin Bridges, which was developed by the RMS chaired Technical Committee, provided a trigger for the differential movements across the bridge movement joints. A summary of the Level 1 Triggers and the maximum measured differential movements across the bridge movement joints, at any time during the extraction of LW904, is provided in Table 2.15.

Table 2.15 Measured differential movements and triggers for the Nepean Twin Bridges joints

Type	Maximum measured differential movement across bridge joint (mm)	Level 1 Trigger (mm)
Joint 1 (northern joint)	+0.19 (northbound carriageway) +0.52 (southbound carriageway)	2
Joint 2 (middle joint)	-0.80 (northbound carriageway) -0.41 (southbound carriageway)	2
Joint 3 (main expansion joint)	-4.11 (northbound carriageway) -1.25 (southbound carriageway)	10

The measured differential movements at the bridge joints did not exceed the Level 1 Triggers during the mining of LW904.

2.11. Moreton Park Road Bridge (South) monitoring points

Moreton Park Road Bridge (South) is located approximately 1.5 km south-east of the finishing end of LW904. The bridge has experienced far-field movements due to the mining in Area 9 and the concurrent mining in the adjacent Appin Area 7. The monitoring associated with Moreton Park Road Bridge (South) included the following:

- absolute 3D monitoring points;
- relative 3D monitoring points; and
- visual monitoring.

Descriptions of the monitoring results are provided in the following sections.

2.11.1. Absolute 3D monitoring points

The absolute 3D horizontal movements at Moreton Road Bridge South have been monitored at Marks MPBE and MPBW, which are located adjacent to the eastern and western ends, respectively, of the bridge. These marks were measured as part of the far-field monitoring, as described in Section 2.9.

The vectors of incremental horizontal movement at Marks MPBE and MPBW are shown in Drawing No. MSEC1285-04, in Appendix A. The accuracies of the measured absolute positions (i.e. eastings and northings) are in the order of ±20 mm. The measured incremental horizontal movement at Marks MPBE and MPBW, at the completion of LW904, were less than 2 mm. The measured movements, therefore, are in the order of survey tolerance.

The absolute horizontal movements at Marks MPBE and MPBW have been measured since 15 October 2007 during the mining in Appin Area 7 and during the mining of LW901 to LW904 in Area 9. The development of total horizontal movements for these marks, plotted since the start of 2010, is shown in Fig. 2.19.

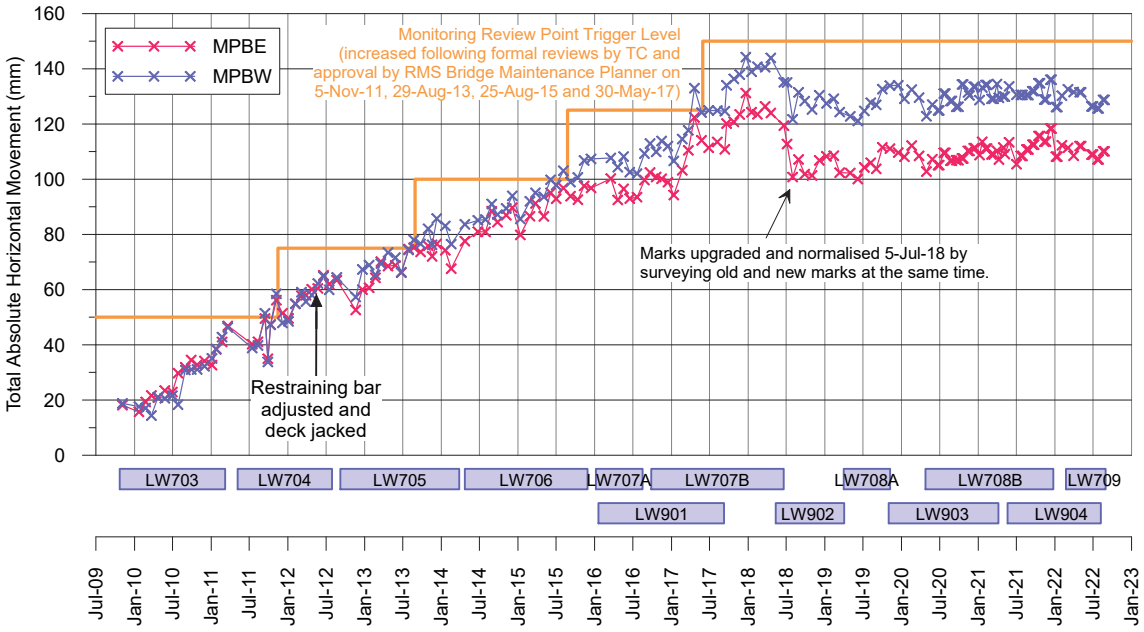

Fig. 2.19 Measured total absolute movements at Marks MPBE and MPBW due to the concurrent mining in Appin Areas 7 and 9

The absolute horizontal movements at Marks MPBE and MPBW did not exceed the Monitoring Review Point Trigger during the mining of LW904, as shown in Fig. 2.19.

A summary of the maximum measured absolute horizontal movements at Marks MPBE and MPBW, measured on 19 August 2022 after the completion of LW904, is provided in Table 2.16.

Table 2.16 Measured absolute movements and trigger for Moreton Road Bridge (South)

Location	Maximum measured absolute horizontal movement (mm)	Level 1 Trigger (mm)
Marks MPBE and MPBW	129	150

The maximum measured absolute horizontal movement at Marks MPBE and MPBW was less than the Level 1 Trigger at the completion of LW904.

2.11.2. Relative 3D monitoring points

The mine subsidence movements of the Moreton Park Road Bridge (South) were measured by IMC using relative 3D marks fixed directly to the bridge structure. The locations of the monitoring points on the bridges are shown in Fig. 2.20 and Fig. 2.21 (Source: IMC).

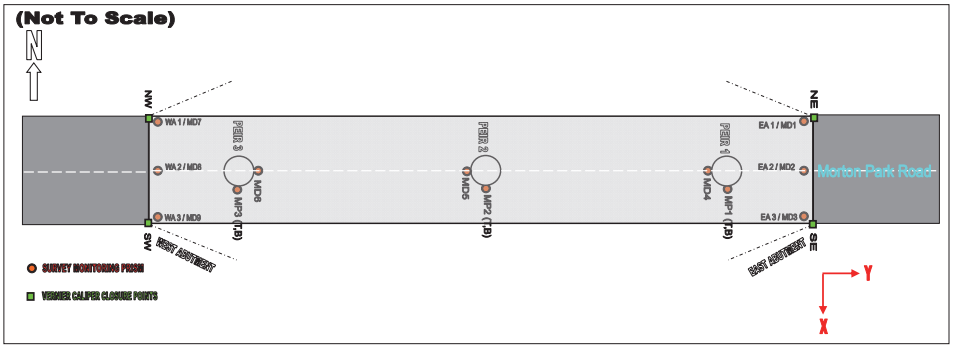

Fig. 2.20 Plan of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IMC)

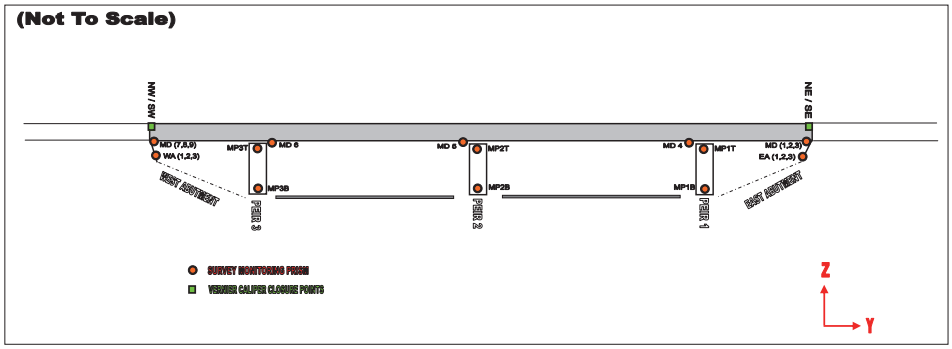

Fig. 2.21 Elevation of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IMC)

The changes in horizontal distance between the bridge abutments have been measured since 15 October 2007 during the mining in Appin Area 7 and during the mining LW901 to LW904 in Area 9. Marks have been established on the eastern abutment (EA1 to EA3) and on the western abutment (WA1 to WA3). The development of total changes in horizontal distance between the abutments, plotted since 2007 is shown in Fig. 2.22. The nominal survey accuracy is ±2 mm.

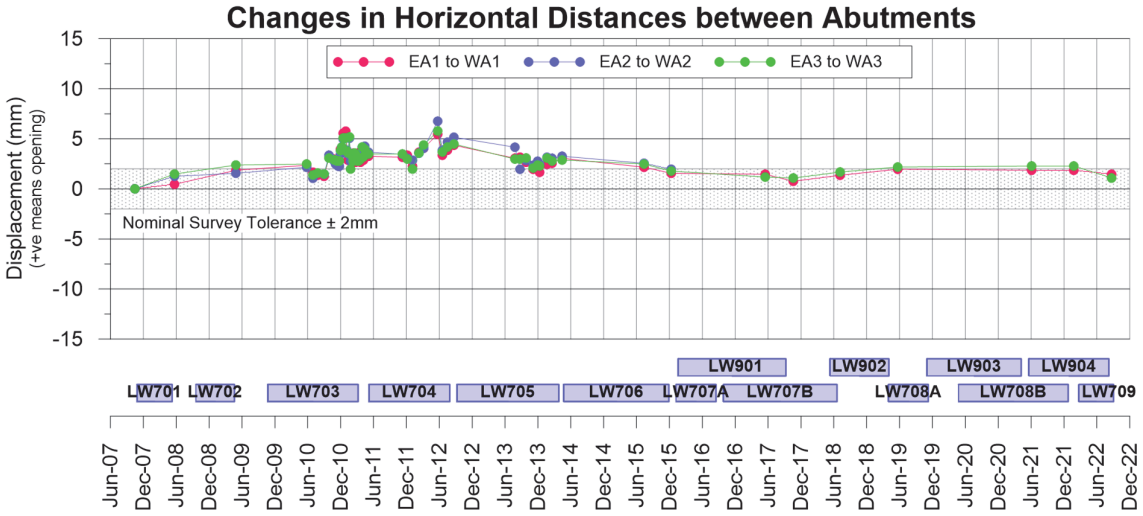

Fig. 2.22 Measured total changes in horizontal distance between the abutments of Moreton Park Road Bridge (South)

The total changes in horizontal distance between the bridge abutments were less than ±2 mm at the completion of LW904. The total measured movements, therefore, were in the order of survey tolerance at the completion of the longwall.

2.12. ALS / LiDAR surveys

The changes in surface level due to the mining in Area 9 have been measured using Airbourne Laser Scan (ALS) / Light Detection and Ranging (LiDAR) surveys.

ALS surveys have been carried out in June 2007 (before the commencement of LW901), in November 2017 (after the completion of LW901), in late-March 2019 (around the completion of LW902), in mid-April 2021 (after the completion of LW903) and in mid-September 2022 (after the completion of LW904).

The measured incremental changes in surface level due to the mining of LW904 only are shown in Fig. 2.23. These contours have been determined by taking the differences between the surface levels measured before and after the mining of this longwall. The data located outside the predicted limit of vertical subsidence (i.e. incremental 20 mm subsidence contour) have been removed for clarity.

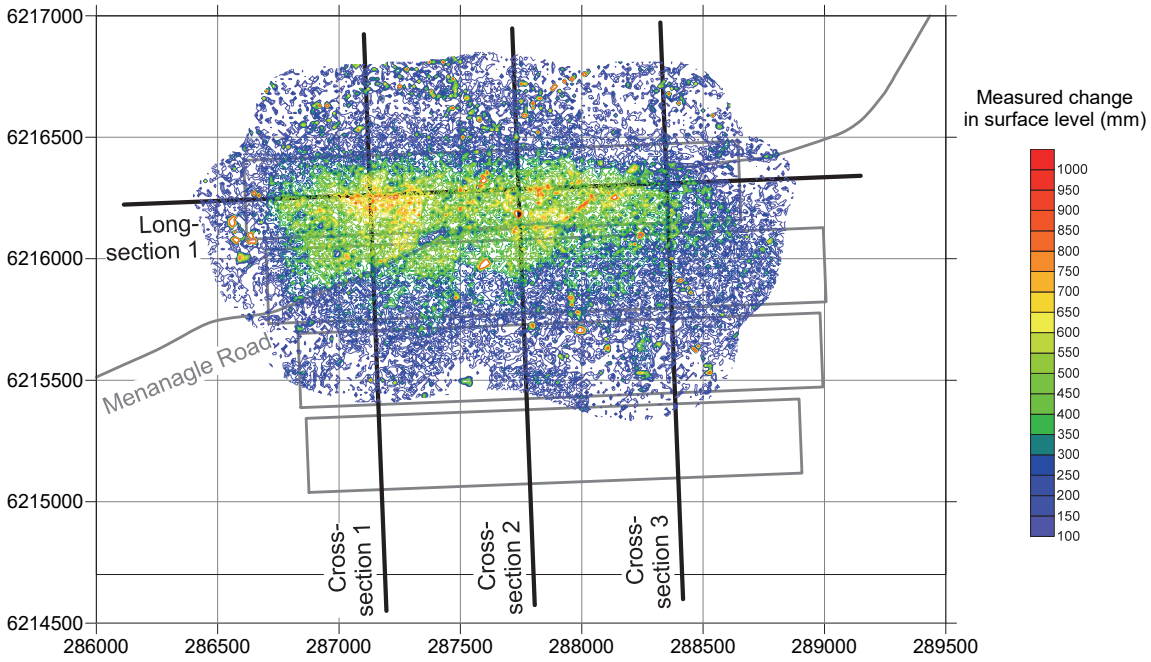

Fig. 2.23 Measured incremental changes in surface level due to the mining LW904 only

The LiDAR surveys after LW903 and LW904 have an accuracy for absolute level in the order of ±100 mm. The accuracy of the measured incremental changes in surface level (i.e. the difference between these two surveys) due to the mining of LW904, therefore, is in the order of ±200 mm.

The measured total changes in surface level due to the mining of LW901 to LW904 are shown in Fig. 2.24. These contours have been determined by taking the differences between the surface levels measured before the commencement of LW901 and after the completion of LW904. The data located outside the predicted limit of vertical subsidence (i.e. total 20 mm subsidence contour) have been removed for clarity.

The LiDAR survey before LW901 has a lower point density and is affected more by vegetation compared with the more recent surveys. Hence, there is more variability in the measured total changes in surface level due to the mining of LW901 to LW904 and the accuracy is in the order of ±250 mm or greater.

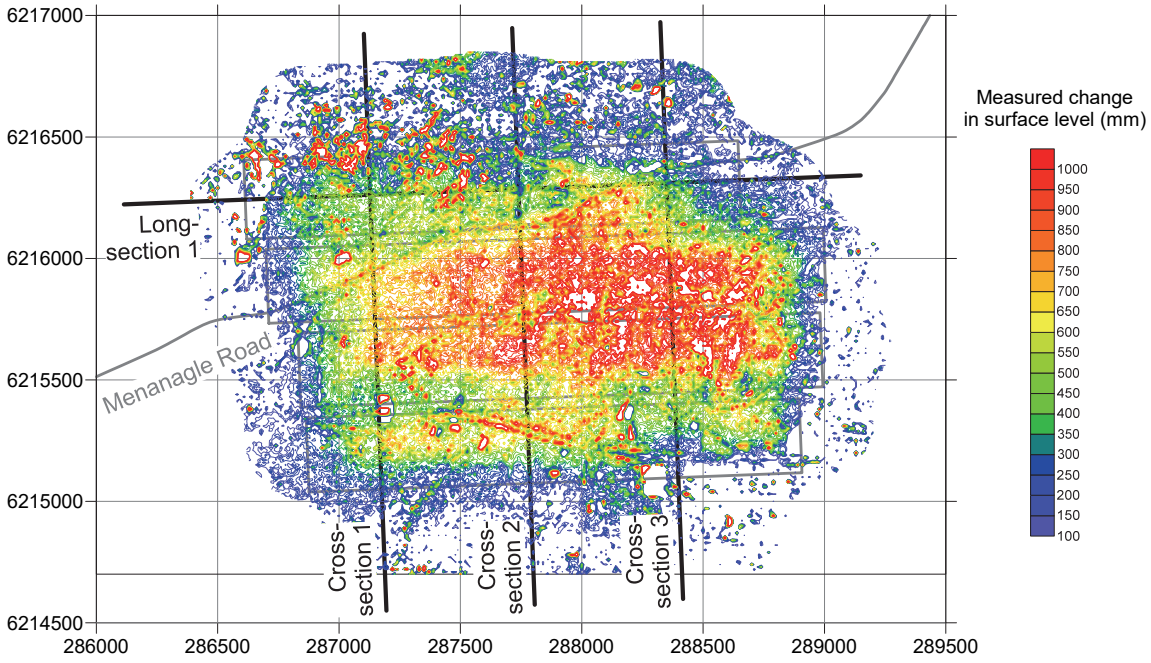

Fig. 2.24 Measured total changes in surface level due to the mining of LW901 to LW904

The contours of the measured changes in surface level, developed from the LiDAR surveys, show the changes in the heights of points at fixed positions in space (i.e. eastings and northings). This differs from traditional subsidence contours that include both the vertical and horizontal components of the movements of points fixed to the surface. Horizontal movements are usually included in the subsidence profiles, as traditional ground monitoring data is based on the movements of survey marks that are fixed to the ground.

The contours can contain artefacts (i.e. locally increased or decreased movements), particularly in the locations of steeply incised terrain. These artefacts can be seen in Fig. 2.23 and Fig. 2.24 as the areas of dark red contours outside the extents of the mined longwalls, such as along Razorback Range to the north of the mining area.

The change in surface level at a fixed position in space (i.e. easting and northing), therefore, can be large in the locations of steep slopes and does not provide a true indication of the actual vertical subsidence at a point on the ground. However, where the ground is reasonably flat, the contours of the measured changes in surface level should provide a good indication of the actual vertical subsidence.

The comparisons of the measured changes in surface level and the predicted vertical subsidence along Cross-sections 1 to 3 and Long-section 1 are provided in Fig. 2.25 to Fig. 2.28. The locations of these sections are indicated in Fig. 2.23 and Fig. 2.24. The predicted profiles of vertical subsidence have been derived from the predicted subsidence contours illustrated in Report No. MSEC1005 which includes the approved modifications to the longwall commencing and finishing ends.

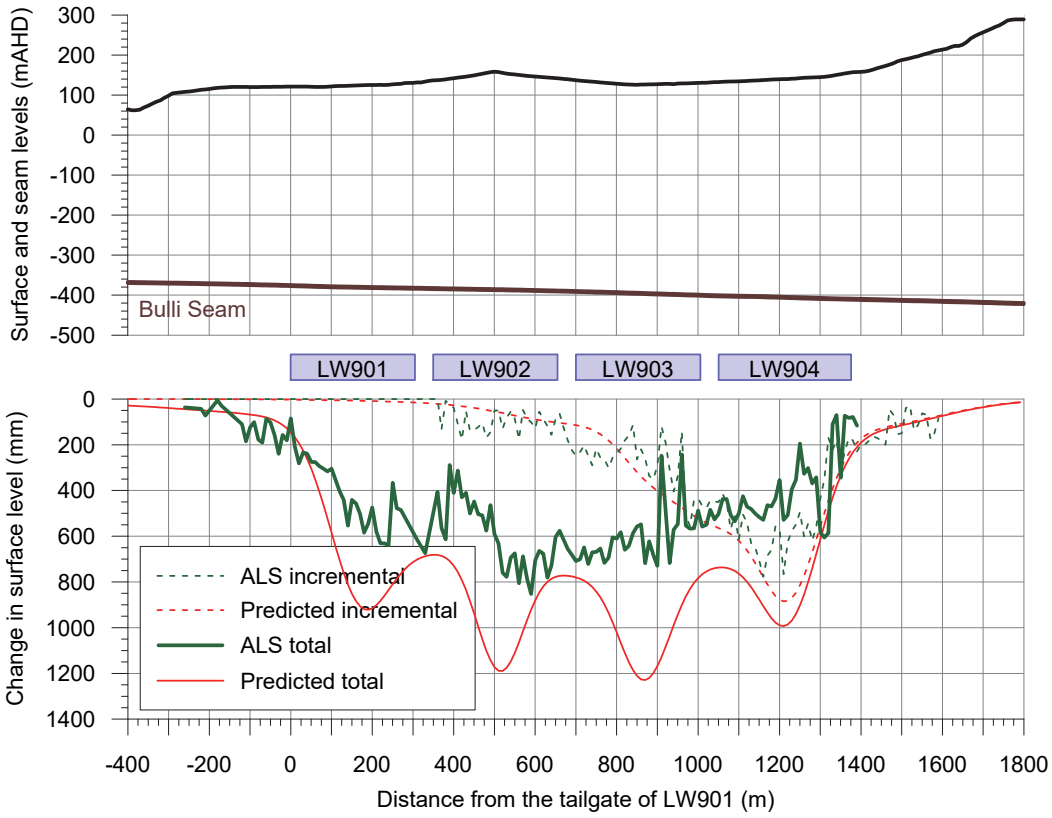

Fig. 2.25 Measured changes in surface level and predicted vertical subsidence along Cross-section 1

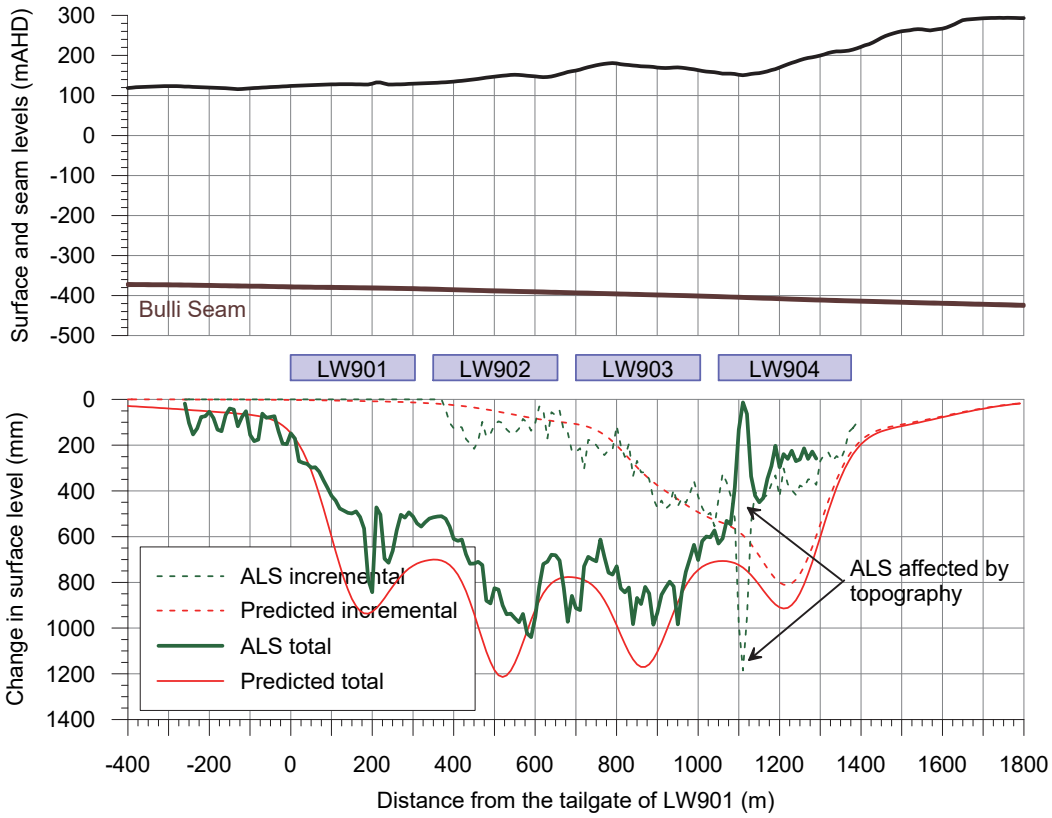

Fig. 2.26 Measured changes in surface level and predicted vertical subsidence along Cross-section 2

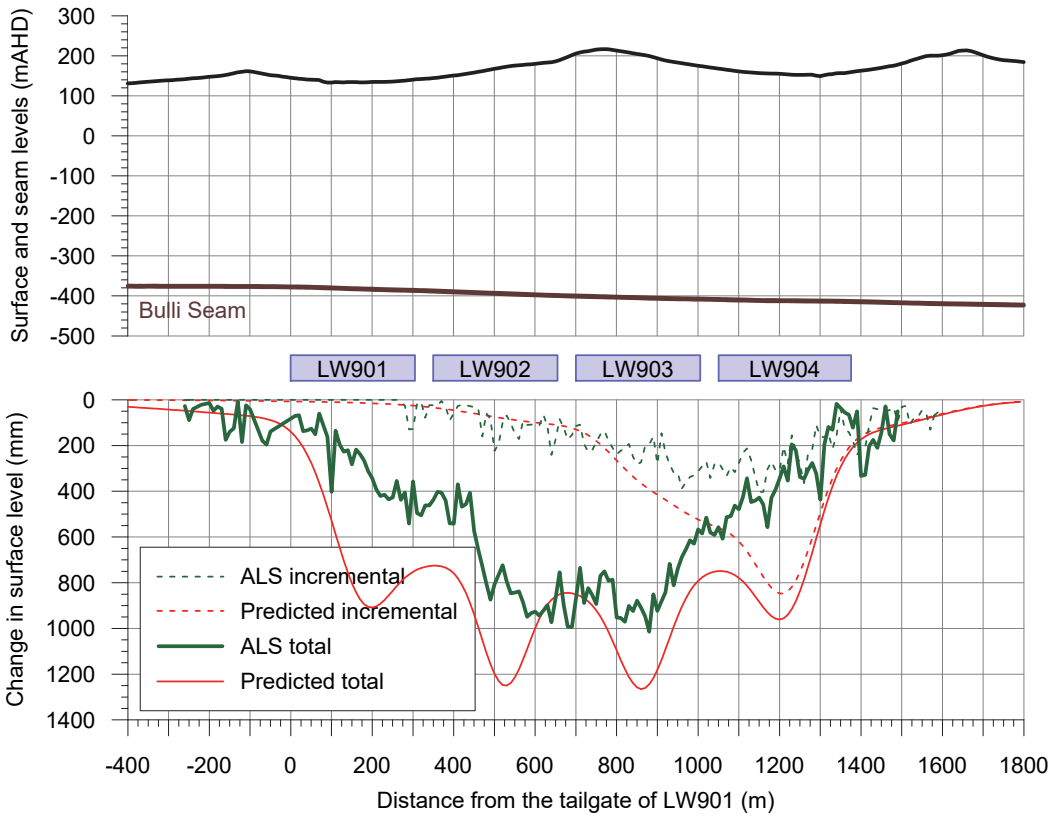

Fig. 2.27 Measured changes in surface level and predicted vertical subsidence along Cross-section 3

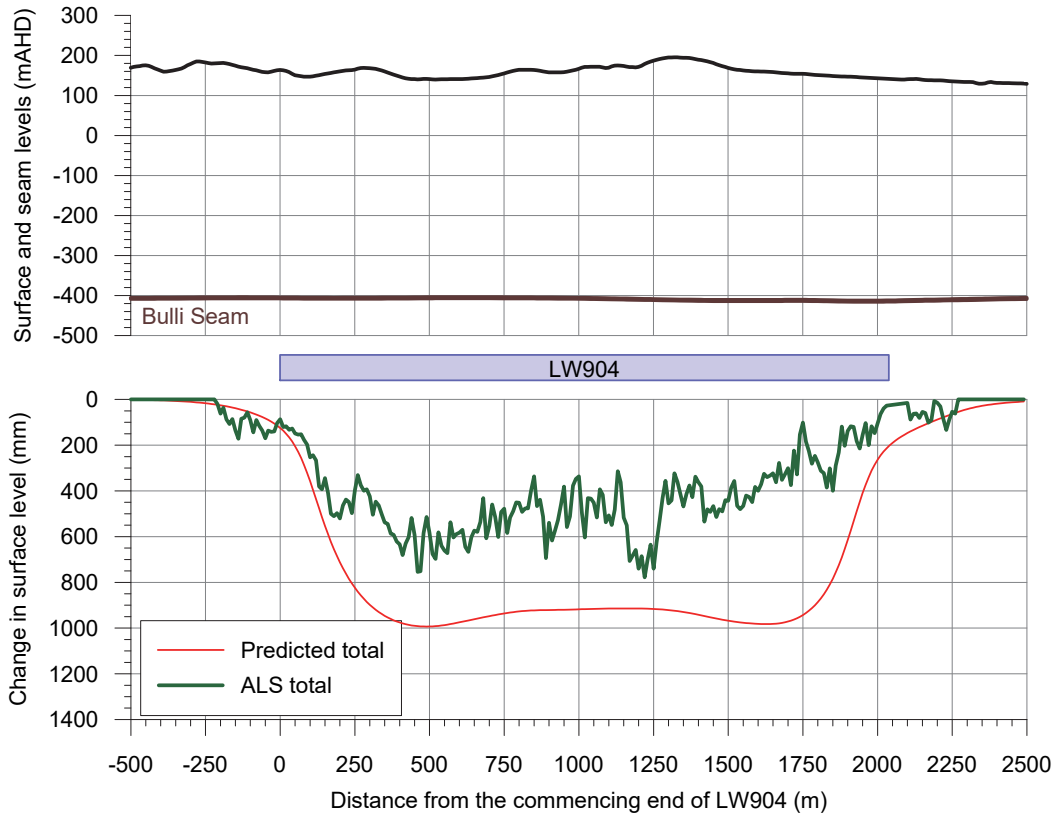

Fig. 2.28 Measured changes in surface level and predicted vertical subsidence along Long-section 1

The profiles of the measured incremental changes in surface level (i.e. dashed lines) reasonably match the predicted profiles of incremental vertical subsidence along each of the cross-sections and long-section. There is more variability in the measured total changes in surface level (i.e. solid lines) due to the lower accuracy of the LiDAR survey before LW901.

The maximum measured changes in surface level above each of the longwalls are generally similar to or less than the maximum predicted values. There are localised areas where the measured movements exceed the predictions; however, these are likely due to artefacts within the LiDAR surveys.

There are localised areas outside of the longwalls where the measured changes in surface level exceed the predicted vertical subsidence. However, these are artefacts of the LiDAR surveys and are not real movements. Elsewhere, the low-level movements are in the order of accuracy of the measurement method.

It is considered that the ground movements measured using the LiDAR surveys are consistent with the predictions provided in Reports Nos. MSEC448, MSEC829 and MSEC1050.

3.1. Natural features

The natural features in the vicinity LW904 are shown in Drawing No. MSEC1285-02, in Appendix A, and include:

- Nepean River – located 1.1 km south-west of LW904 at its closest point;
- Harris Creek – upper reaches located 675 m east of LW904 at its closest point;
- tributaries to the Nepean River and Harris Creek – upper reaches located directly above LW904;
- cliffs along the Nepean River and Harris Creek – located at minimum distances of 1.0 km and 1.6 km, respectively, from LW904;
- rock outcrops – located along Razorback Range north of LW904; and
- steep slopes – located directly above and north of LW904.

The MSEC assessed impacts for the natural features resulting from the mining of LW901 to LW904 are provided in Reports Nos. MSEC448, MSEC829 and MSEC1005, which supported the Extraction Plan and Modification Applications. More detailed assessments for the natural features are also provided in other consultants' reports on the project.

Comparisons between the MSEC assessments and the reported impacts for the natural features listed above, resulting from the mining of LW904, are provided in Table 3.1. The impacts are based on those recorded by the IMC Environmental Field Team and are described in the accompanying Landscape Report entitled "*Appin Mine Longwall 904 Landscape Report 2022*".

Table 3.1 Assessed and reported impacts for the natural features due to LW904

Natural feature	MSEC assessed impacts	Reported impacts
Nepean River	Unlikely that increased **ponding**, **flooding** or **changes in stream alignment** would occur	No reported impacts
	Minor **fracturing** of the bedrock within or beyond 400 m of the longwalls	No visible fracturing observed; however, the flooded river valley and sediment profile limits observations of the river bed
	Unlikely that **surface water flow diversions** would occur	No reported impacts
	Likely that **gas emissions** would develop along the river	Gas release zone (Level 1 impact according to the TARP) was observed at one site (AA9_LW904_001) on 10 August 2021, during the mining of LW904, near the confluence of the Nepean River and Cataract River. This gas release zone was not active during the site visit on 5 September 2022. Several other gas release zones observed during previous longwalls remain active. Refer to the IMC Landscape Report
	Water quality – refer to the surface water report by HGEO **Terrestrial ecology** – no reported impacts, refer to the IMC Landscape Report	
Harris Creek	Adverse impacts unlikely	No reported impacts
Tributaries to the Nepean River	Unlikely that increased **ponding**, **flooding** or **scouring** would occur	No reported impacts
	Cracking of natural surface soils and **fracturing** of exposed bedrock directly above the longwalls. Minor fracturing could occur within 400 m of the longwalls	No reported impacts
	Unlikely that **surface water flow diversions** would occur	No reported impacts

Natural feature	MSEC assessed impacts	Reported impacts
Cliffs along the Nepean River	Rock falls could occur close to mining area (LW901 to LW904), representing less than 0.5 % of the total face area within the mining domain	No reported impacts
Cliffs along Harris Creek	Likelihood of mining-induced rock falls considered to be extremely low	No reported mining-related impacts. Minor rock falls were observed during mining that were considered to be associated with existing instabilities and after heavy rainfall
Other cliffs and rock outcrops	Fracturing of exposed bedrock which could result in **rockfalls** where the rock is marginally stable	No reported mining-related impacts. A section of rock from the discontinuous cliffline along Razorback Range north of LW904 become detached after heavy rainfall, not related to mining
Steep slopes	Surface **cracking** typically between 25 mm and 50 mm, with localised cracking in the order of 100 mm to 150 mm directly above the longwalls	No reported mining-related impacts. Several shallow slides reported along Razorback Range after heavy rainfall, not related to mining

No mining-related physical impacts (i.e. surface cracking, rock fracturing, etc.) for the natural features were reported during the mining of LW904. One new gas release zone was observed along the Nepean River and other gas release zones remained active during mining of this longwall. Impacts not related to mining included minor rockfalls along Harris Creek Cliff Line and Razorback Range and several shallow slides along Razorback Range which occurred after heavy rainfall periods and are associated with existing or natural instabilities.

The reported impacts on the natural features due to the mining of LW904 are therefore less than the MSEC assessments provided in Reports Nos. MSEC448, MSEC829 and MSEC1005. Further assessments of natural features have been provided by other specialist consultants, and these are described in the relevant reports attached to the *End of Panel* report.

3.2. Built features

The built features in the vicinity LW904 are shown in Drawing No. MSEC1285-03, in Appendix A, and include the:

- Main Southern Railway and associated infrastructure;
- Camden and Menangle Roads;
- Nepean Twin Bridges;
- Moreton Road Bridge (South) and Blades Bridge;
- Water and sewer pipelines;
- 66 kV and 11 kV powerlines;
- Optical fibre and copper telecommunications cables;
- survey control marks;
- heritage sites (railway cottage); and
- houses and associated structures.

The MSEC assessed impacts for the built features resulting from the mining of LW901 to LW904 are provided in Reports Nos. MSEC448, MSEC829 and MSEC1005, which supported the Extraction Plan and Modification Applications. Comparisons between the MSEC assessments and the reported impacts for the built features listed above, resulting from the mining of LW904, are provided in Table 3.2.

Table 3.2 Assessed and reported impacts for the built features due to LW904

Built feature	MSEC assessed impacts	Reported impacts
Main Southern Railway	No impacts on the safety or serviceability of the railway after the implementation of the monitoring and management strategies	No reported impacts on safety or serviceability
Menangle Road	Minor cracking and localised heaving of the road surface directly above the mining area	Localised mining-related heaving of road surface observed near Marks MR9033, MR9049, MR9054, MR9064 to MR9065 and MR9069 to MR9070. A bump and minor cracking of the road pavement developed within the cutting between Marks MR9085 and MR9086. Minor deterioration of road pavement between Marks MR9090 and MR9097. The impacts developed gradually during the mining of LW904
Camden Road	Impacts unlikely	No reported impacts
Nepean Twin Bridges	Impacts unlikely after the implementation of the preventive, monitoring and management strategies	No reported impacts
Moreton Park Road Bridge (South) and Blades Bridge	Impacts unlikely	No reported impacts
Water and sewer pipelines	Minor leakages could occur	No reported impacts
66 kV and 11 kV powerlines	Minor impacts possible requiring some adjustments of cables and poles	No reported impacts
Optical fibre and copper telecommunications cables	Impacts unlikely with the implementation of monitoring and management strategies	No reported impacts
Survey control marks	Vertical and horizontal movements which could require re-establishment	No reported damage to survey control marks. The marks to be re-established after completion of mining
Business establishments	Adverse impacts unlikely	No reported impacts
Rural structures	Minor impacts on rural structures located directly above longwalls	IMC reported very slight to slight wall and floor cracking of two garages (Property Refs. N14 and N16)
Pools	Assessed impacts for approximately 15 % of pools above the mining area including cracking and loss of water	IMC reported impacts for one pool (Property Ref. H14) including cracking of pool shell and pool surrounds and leaking of water
Farm dams	Incidence of impact (cracking and leakage) expected to be extremely low	No reported impacts
Groundwater bores	Impacts likely including lowering of piezometric surface, blockage and change in groundwater quality	Refer to the groundwater assessment and the IMC Landscape Report
Aboriginal heritage sites	Adverse impacts unlikely	No Aboriginal heritage sites located within the Study Area for LW904
Heritage sites	Adverse impacts unlikely	No reported impacts
Houses	Remain safe and serviceable, assessed impacts: 92 % for no claim or Category R0, 6 % for Category R1 or R2, 2 % for Category R3 or R4, and < 0.5 % for Category R5	Houses have remained in safe and serviceable conditions No mining-related impacts reported for the houses along Gibraltar Drive at the top of Razorback Range (Property Refs. O02, O17 and O18). IMC reported minor impacts not related to mining including very slight internal wall cracking, movements of the driveway, retaining walls and poly tanks IMC reported very slight to slight internal and external wall cracking (Category R1 and R2) for three houses (Property Refs. N11, N14 and N15)

Localised mining-related heaving and cracking of the road pavement along Menangle Road was reported during the mining of LW904. These impacts developed gradually and they did not affect safety or serviceability of the road. There were also several existing and non-mining related defects along Menangle Road including potholes, slumping and deterioration due to heavy rainfall and traffic loads. The road pavement was re-sheeted in several locations to maintain ride quality. Examples of the mining-related impacts observed along Menangle Road during the mining of LW904 are provided in Fig. 3.1 to Fig. 3.3.

IMC reported that there was very slight to slight cracking in two rural structures and cracking and loss of water from one pool. The assessed impacts were potential for minor impacts on rural structures and potential impacts on approximately 15 % of pools including cracking and loss of water.

IMC reported very slight to slight wall cracking (Categories R1 and R2) for three houses during the mining of LW904. This cracking could be due to mining, natural ground movements, or both. The End of Panel reports for the previously mined longwalls in Area 9 state that there were three claims submitted to SA NSW relating to the houses for each of LW901 to LW903, i.e. 9 claims in total, for very slight to slight impacts (Categories R1 and R2).

MSEC therefore understands that there have been 12 (reported or claimed) Category R1 and R2 impacts for houses during the mining of LW901 to LW904. There is a total of 251 houses located within the Study Area for these longwalls. The rate of Category R1 and R2 impacts therefore represents approximately 5 % of the houses within the Study Area and it is similar to but slightly less than the assessed rate of 6 %. MSEC understands that there have been no moderate or greater impacts (Category R3 to R5) during the mining of LW901 to LW904.

The recorded mining-related impacts on the built features due to the mining of LW904 are similar to or less than the MSEC assessments provided in Reports Nos. MSEC448, MSEC829 and MSEC1005. The built features and infrastructure were maintained in safe and serviceable conditions during mining with the implementation of the monitoring and management strategies.

Fig. 3.1 Broad rise in pavement along Menangle Road between Marks MR9064 and MR9065 (Source: SLR, photograph taken on 20 July 2022)

Fig. 3.2 Slight bump in pavement along Menangle Road between Marks MR9068 and MR9069 after completion of resurfacing works (Source: SLR, photograph taken on 20 July 2022)

Fig. 3.3 Slight rise in pavement along Menangle Road between Marks MR9068 and MR9069 after completion of resurfacing works (Source: SLR, photograph taken on 20 July 2022)

APPENDIX A. DRAWINGS

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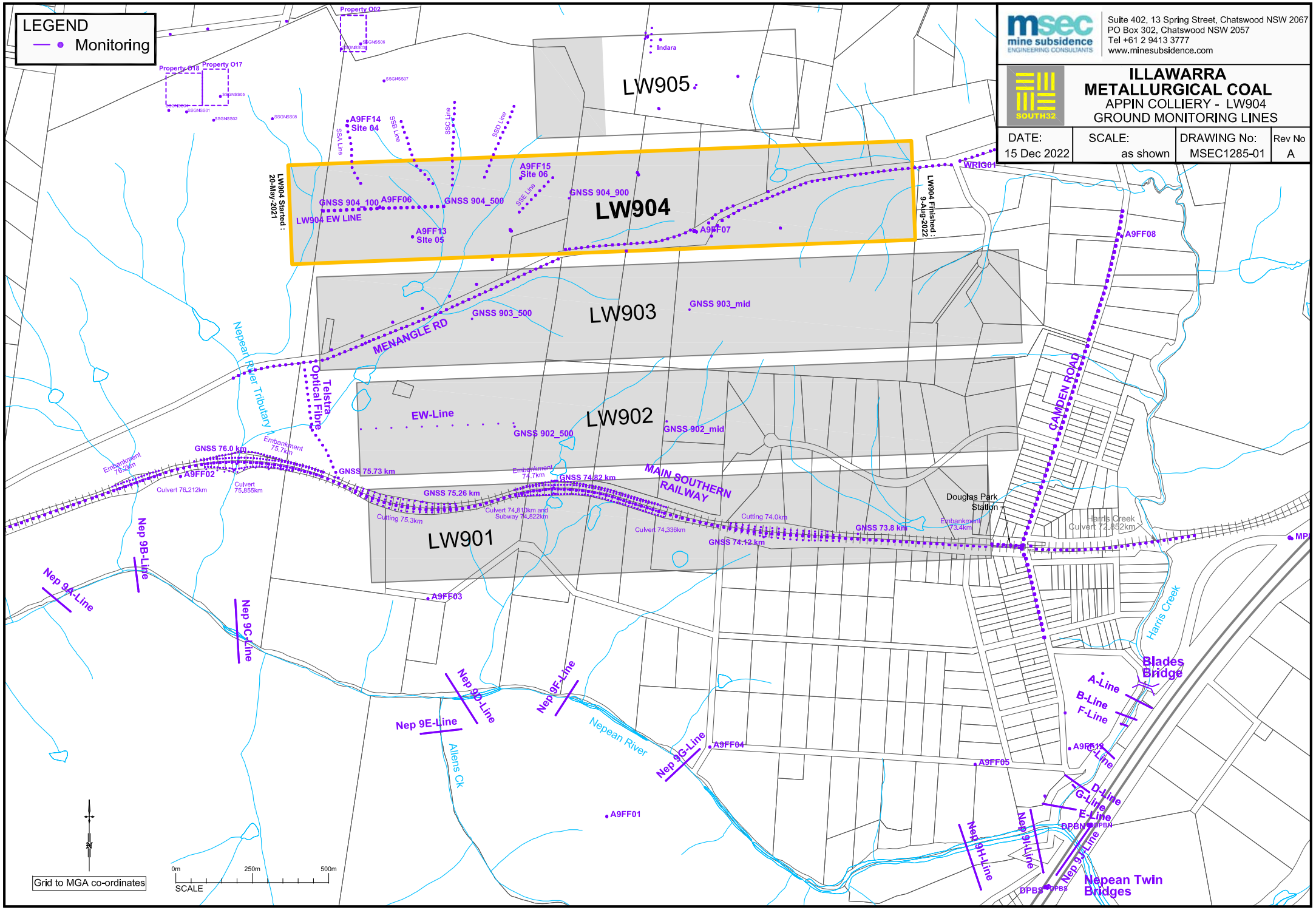

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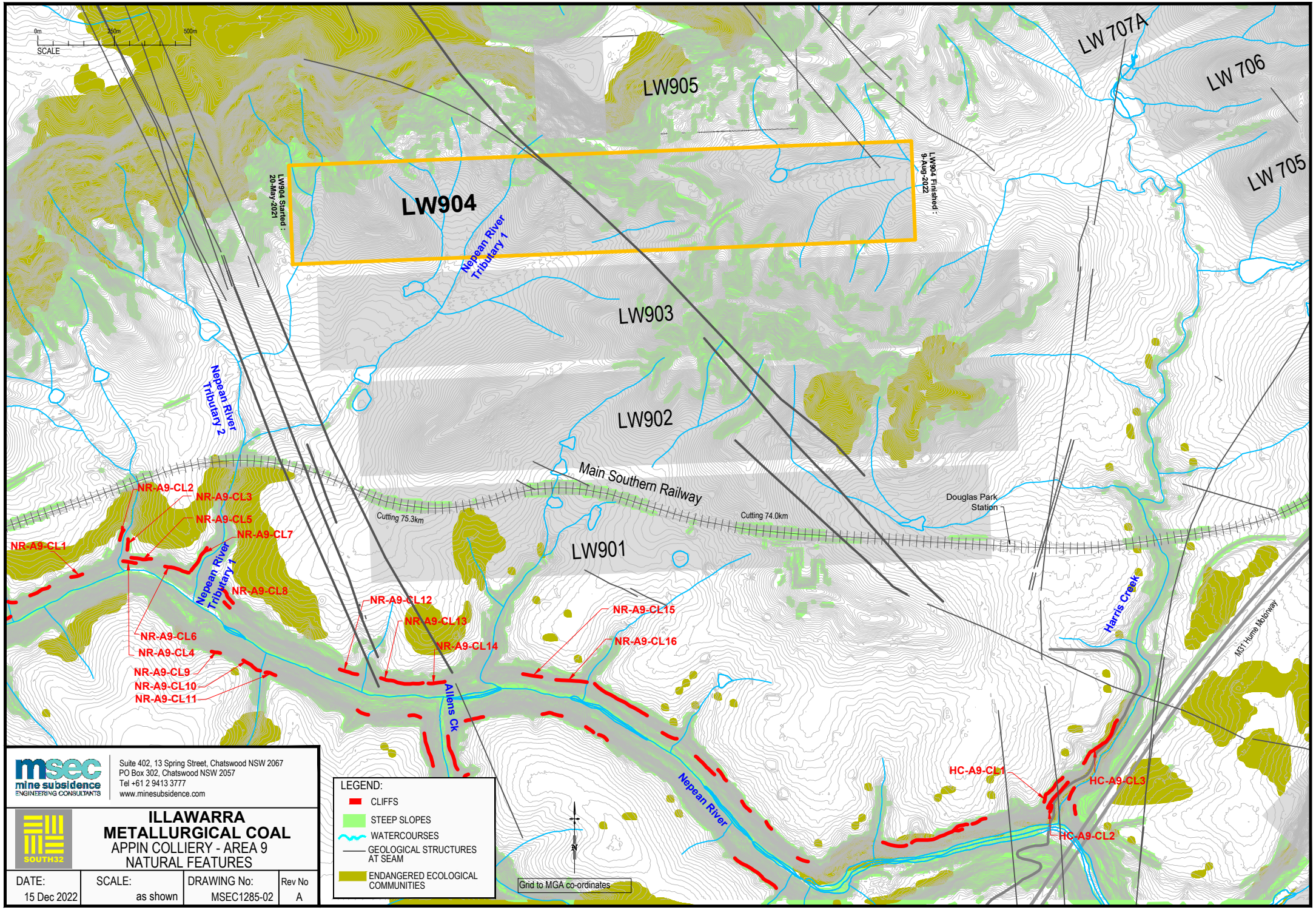

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SOUTH32

ILLAWARRA METALLURGICAL COAL

APPIN COLLIERY - AREA 9

NATURAL FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
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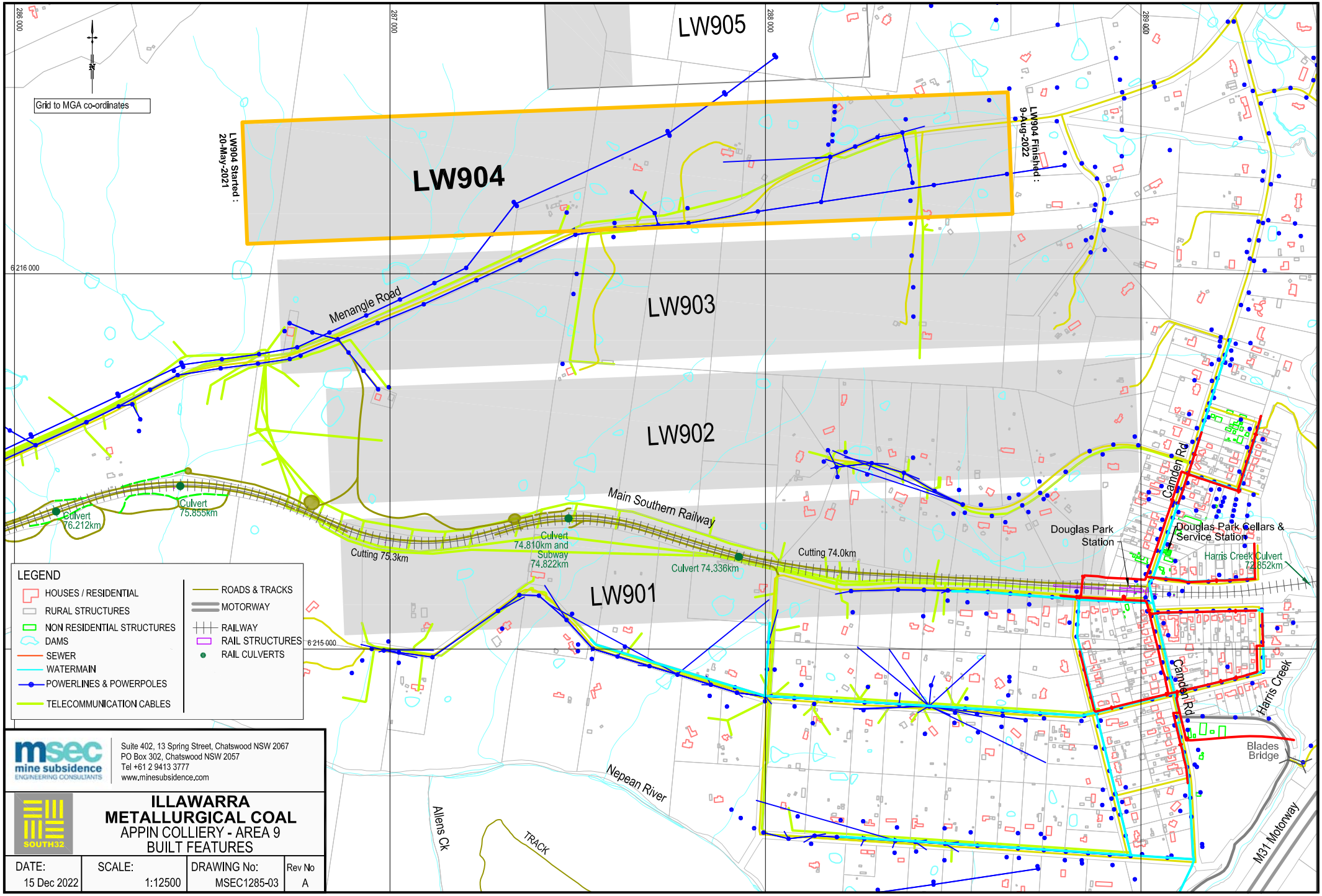

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BUILT FEATURES

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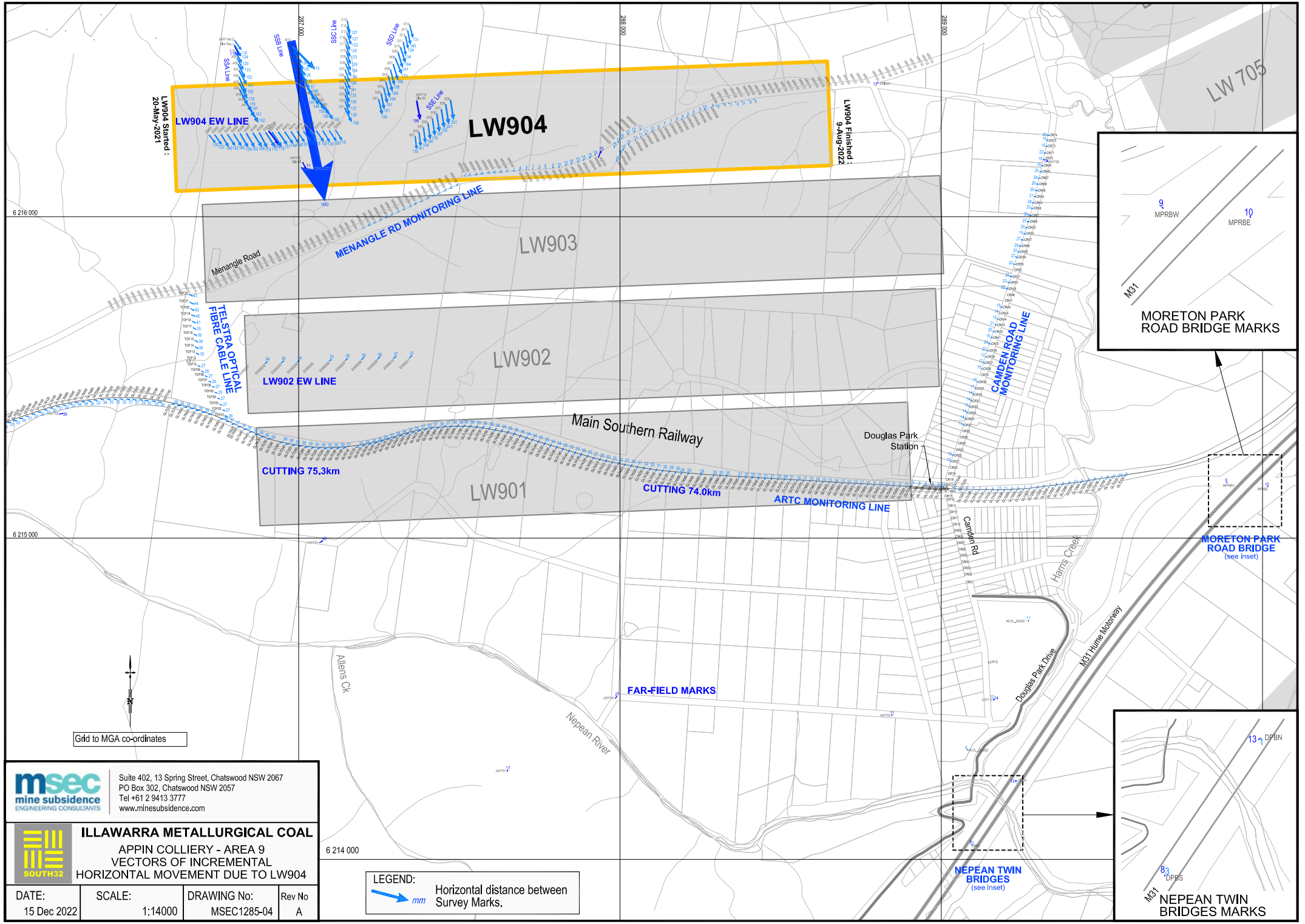

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APPIN COLLIERY - AREA 9
VECTORS OF INCREMENTAL
HORIZONTAL MOVEMENT DUE TO LW904

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15 Dec 2022	1:14000	MSEC1285-04	A

LEGEND:
mm Horizontal distance between Survey Marks.