mine subsidence ENGINEERING CONSULTANTS

ILLAWARRA METALLURGICAL COAL:

Appin Colliery – Longwalls 708A and 708B

End of Panel Subsidence Monitoring Report for Appin Longwalls 708A and 708B

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Previous reports:

MSEC342 (Rev. C) – The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Surface Infrastructure Resulting from the Extraction of Proposed Longwalls 705 to 710 at Appin Colliery in Support of the SMP Application.

MSEC825 (Rev. A) – The Effects of the Proposed Coal Blocks in Longwalls 707 and 708 on Previous Subsidence Predictions and Impact Assessments

MSEC1125-01 to MSEC1125-60 – Subsidence Monitoring Review Reports for the Main Southern Railway, issued during the extraction of Longwall 708B between September 2020 and January 2022.

MSEC1126-01 to MSEC1126-69 – Subsidence Monitoring Review Reports for the M31 Hume Motorway, issued during the extraction of Longwall 708B between August 2020 and March 2022.

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)

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

Drawings

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

Drawing No.	*Description*	*Revision*
MSEC1250-01	General layout and monitoring lines	A
MSEC1250-02	Natural features	A
MSEC1250-03	Built features	A

1.1. Introduction

Illawarra Metallurgical Coal (IMC) has completed the mining of Longwalls 708A and 708B (LW708A and LW708B) in Area 7 at Appin Colliery, which is located in the Southern Coalfield of New South Wales. The locations of the longwalls in Area 7 are shown in Drawing No. MSEC1250-01, in Appendix B. A summary of the commencement and finishing dates of these longwalls is provided in Table 1.1.

Table 1.1 Commencement and finishing dates for LW708A and LW708B

Longwall	Commencement date (first shear)	Finishing date (break of chain)
LW708A	2 April 2019	8 November 2019
LW708B	24 April 2020	3 January 2022

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IMC to prepare subsidence predictions and impact assessments for Longwalls 705 to 710 (LW705 to LW710) in Appin Area 7. Report No. MSEC342 (Rev. C) was issued in June 2008 and that report supported the Subsidence Management Plan (SMP) Application for LW705 to LW710.

The SMP Application had LW708 as a single full-length longwall; however, a coal block was later introduced in a Modification Application creating two shorter panels to avoid mining through a zone of geological structures. Report No. MSEC825 (Rev. A) was issued in April 2016 and that supported the Modification Application for LW708A and LW708B.

The Department of Planning, Industry and Environment (DPIE) granted IMC approval for the extraction of the modified LW708A and LW708B on 9 June 2016.

The finishing (i.e. eastern) end of LW708B was subsequently extended by 94 m. Report No. MSEC1133 (Rev. B) was issued in October 2020 in support of that modification. DPIE granted IMC approval for the extended finishing end of LW708B on 23 November 2020.

In accordance with Section 18 of the SMP Approval Conditions for LW705 to LW710, this report provides:

- comparisons between the measured and predicted subsidence effects at the monitoring lines and points due to the mining of LW708A and LW708B; and
- comparisons between the observed and assessed impacts on the natural and built features due to the mining of LW708A and LW708B.

Further details on the observed and assessed impacts for some natural features, due to the mining of LW708A and LW708B, are provided in the reports by other consultants. The discussions 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 points that were measured during the mining of LW708A and LW708B. This chapter also provides comparisons between the measured and predicted movements due to the mining of these longwalls.

Chapter 3 of this report describes the natural and built features near LW708A and LW708B. This chapter also provides comparisons between the observed and assessed impacts for these surface features due to the mining of these longwalls. Further discussions on the observed and assessed impacts for some natural features are provided in the reports by other consultants.

Appendices A and B include all of the figures and drawings associated with this report.

1.2. Mining geometry

The layout of the longwalls in Area 7 is shown in Drawing No. MSEC1250-01, in Appendix B. A summary of the as-extracted dimensions for LW702 to LW708B is provided in Table 1.2.

Table 1.2 Mining geometry of the as-extracted longwalls

Location	Longwall	Overall void length including installation heading (m)	Overall void width including first workings (m)	Overall tailgate chain pillar width (m)
Area 7	LW702	980	325	-
	LW703	2075	325	45
	LW704	2325	325	45
	LW705	2835	325	45
	LW706	3055	325	45
	LW707A	1035	325	45
	LW707B	2070	325	45
	LW708A	1200	325	45
	LW708B	2260	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 lengths of longwall extraction, therefore, are approximately 1191 m for LW708A and 2251 m for LW708B. The longwall face widths excluding the first workings are approximately 314 m. The length of the coal block between LW708A and LW708B is 160 m.

The longwalls in Area 7 have been extracted from the Bulli Seam. LW708A and LW708B have been mined from the west towards the east, i.e. towards the Nepean River. The natural surface and seam levels along the centreline of LW708A and LW708B are illustrated in Fig. 1.1.

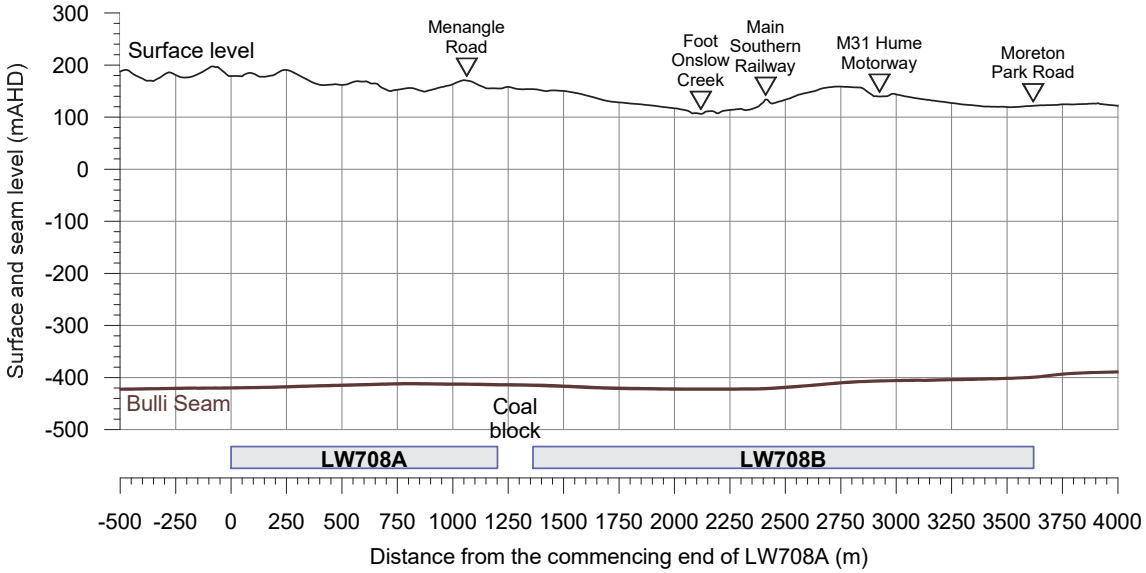


Fig. 1.1 Surface and seam levels along the centrelines of LW708A and LW708B

The depth of cover to the Bulli Seam varies between a minimum of 515 m above the finishing (i.e. eastern) end of LW708B and a maximum of 620 m near the commencing (i.e. western) end of LW708A. The seam thickness varies between 2.6 m and 3.4 m within the extents of these longwalls. IMC extracted the full thickness of the Bulli Seam.

2.1. Introduction

The mine subsidence effects due to the mining of LW708A and LW708B were monitored along several monitoring lines and monitoring points including the:

- Nepean River closure lines;
- Moreton Park Road monitoring line;
- Menangle Road monitoring line;
- M31 Hume Motorway East and West Lines;
- FBG monitoring along the M31 Hume Motorway;
- slot closure monitoring along the M31 Hume Motorway;
- ARTC monitoring line, strain gauges and tilt sensors;
- ARTC embankment points;
- highway cutting points;
- Partridge VC Rest Area monitoring points;
- absolute far-field 3D monitoring points adjacent to the Douglas Park Twin Bridges and Moreton Park Road Bridge (South);
- relative 3D monitoring points on the Douglas Park Twin Bridges and Moreton Park Road Bridge (South);
- inclinometer monitoring near the Douglas Park Twin Bridges;
- bridge joint monitoring on the Douglas Park Twin Bridges;
- visual monitoring of the M31 Hume Motorway, Moreton Park Road, Menangle Road, Douglas Park Twin Bridges and Moreton Park Road Bridge (South);
- monitoring lines at WaterNSW infrastructure; and
- Telstra monitoring line.

The locations of these monitoring lines and monitoring points are shown in Drawing No. MSEC1250-01, in Appendix B. Comparisons between the measured and predicted subsidence effects at these monitoring lines and points are provided in the following sections. The predicted subsidence parameters have been obtained using the Incremental Profile Method (IPM). This method was used to predict the subsidence effects that were presented in Reports Nos. MSEC342, MSEC825 and MSEC1133.

2.2. Nepean River closure lines

The closure movements across the Nepean River valley were measured by IMC using 2D survey techniques along three monitoring lines during the mining of LW708B. The monitoring lines comprise the Nep X Q-Line, Nep X R-Line and Nep X S-Line.

The locations of the Nepean River closure lines are shown in Drawing No. MSEC1250-01, in Appendix B. A summary of the survey dates during LW708B is provided in Table 2.1.

Table 2.1 Survey dates for the Nepean River closure lines for LW708B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly surveys from the commencement of LW708B and then at the completion of the longwall	16 April 2014 (end of LW705) 30 November 2015 (end of LW706) 2 August 2018 (end of LW707B) 24 September 2021 20 October 2021 18 November 2021 16 December 2021 11 January 2022 (end of LW708B)	As required under the LW709 monitoring program

The monitoring lines each comprise two survey marks, with the marks located on either side of the Nepean River. The lines therefore measure the closure between the valley sides. Survey marks could not be located near the base of the valley due to the difficult terrain. The upsidence in the base of the valley, therefore, could not be measured.

The development of total closure for the Nepean River closure lines, due to the mining of LW702 to LW708B, is illustrated in Fig. 2.1. The base survey for the Nep X R-Line was carried out during the mining of LW706 and the base survey for Nep X S-Line was carried out before the mining of LW708B.

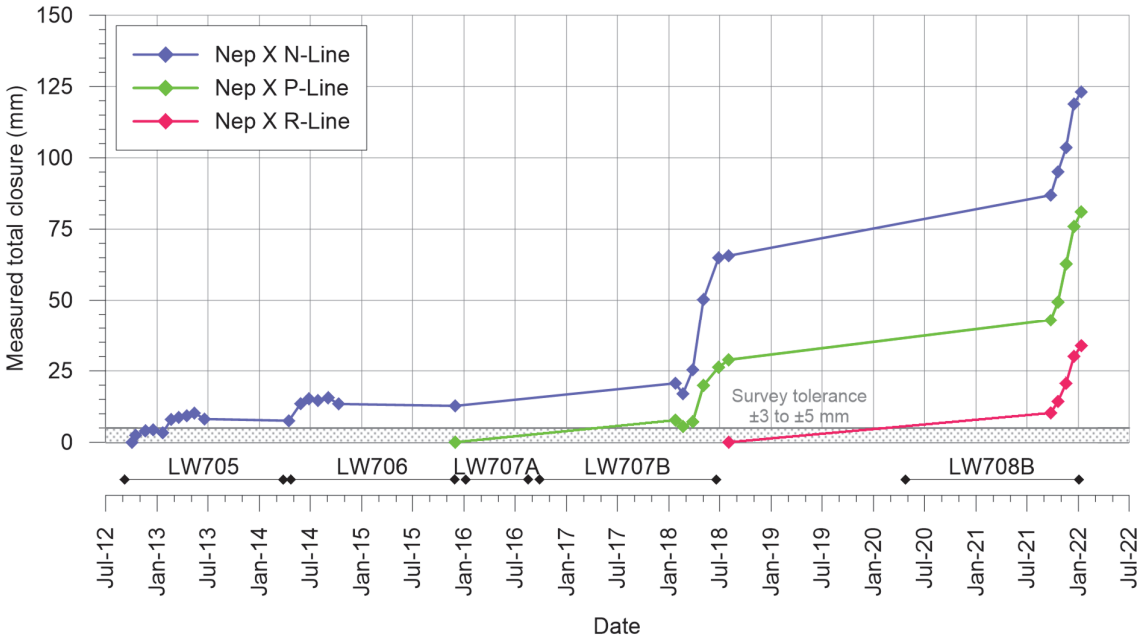


Fig. 2.1 Development of total closure for the Nepean River closure lines

A summary of the maximum measured and maximum predicted total closure movements for each of the Nepean River closure lines is provided in Table 2.2. The predicted total closures consider the modified eastern ends of LW705, LW706 and LW707B and LW708B.

Table 2.2 Measured and predicted total closure at the Nepean River closure lines after LW708B

Location	Longwalls	Measured total closure (mm)	Predicted total closure (mm)
Nep X Q-Line	LW705 to LW708B	123	100
Nep X R-Line	LW707B and LW708B	81	70
Nep X S-Line	LW708B only	33	40

The accuracies of the measured closure movements are in the order of ±5 mm.

The measured total closures at the Nep X Q-Line and Nep X R-Line are greater than the predicted total values. The exceedances of 23 mm for the Nep X Q-Line and 11 mm for the Nep X R-Line represent 23 % and 16 %, respectively, and therefore they are in the order of accuracy of the predictive method for valley closure of ±25 %. The measured total closure for the Nep X S-Line is less than the predicted total value.

It is considered that the closure movements measured using the Nepean River closure lines are consistent with the predictions provided in Reports Nos. MSEC342, MSEC825 and MSEC1133.

2.3. Moreton Park Road monitoring line

The mine subsidence effects along Moreton Park Road were measured by IMC using a 3D monitoring line. The location of the Moreton Park Road monitoring line is shown in Drawing No. MSEC1250-01, in Appendix B. A summary of the survey dates during the extraction of LW708B is provided in Table 2.3.

Table 2.3 Survey dates for the Moreton Park Road monitoring line during LW708B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Start of LW708B, and then monthly after 3100 m extraction and then at the completion of the longwall	28 June 2018 (end of LW707B) 9 June 2021, then monthly surveys to 1 October 2021, then weekly surveys to 21 January 2022 28 January 2022 (end of LW708B)	As required under the LW709 monitoring program

The profiles of measured and predicted incremental vertical subsidence, tilt and strain along the Moreton Park Road monitoring line, due to the mining of LW708B, are shown in Fig. A.01, in Appendix A. The predictions are based on the as-extracted lengths of the longwalls as presented in Report No. MSEC1133.

The incremental vertical subsidence measured directly above LW708B is less than that predicted. While the incremental vertical subsidence (i.e. due to LW708B only) measured above the previously extracted LW705, LW706 and LW707B is greater than predicted, the total vertical subsidence (i.e. due to LW702 to LW708B) measured above these longwalls is less than predicted.

A summary of the maximum measured and predicted incremental vertical subsidence, tilt and strains for the Moreton Park Road monitoring line is provided in Table 2.4. The values represent the additional movements due to the mining of LW708B only.

Table 2.4 Maximum measured and predicted incremental vertical subsidence, tilt and strain along the Moreton Park Road monitoring line due to LW708B only

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm/m)	Maximum incremental tensile strain (mm/m)	Maximum incremental comp. strain (mm/m)
Measured	98	1.0	0.7	0.6
Predicted	230	1.0	*- Refer to discussions below -*	

The accuracies of the measured relative eastings, northings and levels along the Moreton Park Road monitoring line are in the order of ±3 mm to ±5 mm. The accuracies of the measured absolute eastings, northings and levels along monitoring line are in the order of ±15 mm. The accuracies of the measured strains along the monitoring line are in the order of ±0.25 mm/m.

The maximum measured incremental vertical subsidence and tilt along the Moreton Park Road monitoring line, due to the mining of LW708B only, are the same as, or less than, the predicted values. Only low-level incremental movements developed along the monitoring line due to the mining of LW708B as it crosses above the finishing end of that longwall.

The maximum measured incremental strains are 0.7 mm/m tensile and 0.7 mm/m compressive. No localised or irregular ground movements occurred due to the mining of LW708B. The measured strains are less than the maximum predicted strains based on conventional ground movements of 1 mm/m tensile and 2 mm/m compressive.

It is considered that the ground movements measured using the Moreton Park Road monitoring line are consistent with the predictions provided in Reports Nos. MSEC342, MSEC825 and MSEC1133.

2.4. Menangle Road monitoring line

The mine subsidence effects along Menangle Road were measured by IMC using a 3D monitoring line. The location of the Menangle Road monitoring line is shown in Drawing No. MSEC1250-01, in Appendix B. A summary of the survey dates during the extraction of LW708A and LW708B is provided in Table 2.5.

Table 2.5 Survey dates for the Menangle Road monitoring line during LW708A

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Weekly during the mining of LW708A, monthly during the mining of LW708B and then at the completion of the longwall	6 October 2016 (end of LW707A) 19 March 2019 8 May 2019, then nominally weekly to 20 November 2019 (end of LW708A) 28 May 2020, then monthly to 26 November 2020 7 February 2022 (end of LW708B)	As required under the LW709 monitoring program

The profiles of measured and predicted incremental vertical subsidence, tilt and strain along the Menangle Road monitoring line, due to the mining of LW708A, are shown in Fig. A.02, in Appendix A. The predictions are based on the as-extracted lengths of the longwalls as presented in Report No. MSEC1133.

The profile of measured incremental vertical subsidence reasonably matches the predicted profile along the Menangle Road monitoring line. Localised upsidence has occurred where the monitoring line crosses a tributary to Harris Creek. It also appears that an irregular movement (i.e. localised uplift) has occurred along the monitoring line near the top of the hill above LW707A.

The measured profile of incremental tilt also reasonably matches the predicted profile. However, there is a localised irregularity in the measured tilt profile where upsidence has developed at the tributary crossing. Similarly, a localised compressive strain has also developed in this location.

A summary of the maximum measured and predicted incremental vertical subsidence, tilt and strains for the Menangle Road monitoring line is provided in Table 2.6. The values represent the additional movements due to the mining of LW708A only.

Table 2.6 Maximum measured and predicted incremental vertical subsidence, tilt and strain along the Menangle Road monitoring line due to LW708A only

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm/m)	Maximum incremental tensile strain (mm/m)	Maximum incremental comp. strain (mm/m)
Measured	410	4.8*	0.7*	5.0*
Predicted	725	4.0	*- Refer to discussions below -*	

Note: * denotes that the maximum measured tilt and strains occur due to irregular ground movements.

The accuracies of the measured relative eastings, northings and levels along the Menangle Road monitoring line are in the order of ±3 mm to ±5 mm. The accuracies of the measured absolute eastings, northings and levels along monitoring line are in the order of ±15 mm. The accuracies of the measured strains along the monitoring line are in the order of ±0.25 mm/m.

The maximum measured incremental vertical subsidence of 410 mm is approximately half of the maximum predicted incremental vertical subsidence of 725 mm. The monitoring line is located close to the finishing end of LW708A and, therefore, the end effects from that longwall could have reduced the subsidence more than that predicted.

The maximum measured incremental tilt of 4.8 mm/m occurs in the location of upsidence at the tributary to Harris Creek. The profile of predicted tilt does not include the localised movements due to valley-related effects. Away from this localised irregular movement, the maximum measured tilt is 2.8 mm/m and it is less than the maximum predicted value of 4.0 mm/m.

The maximum measured incremental compressive strain is 5.0 mm/m at the tributary to Harris Creek due to the valley-related closure effects. Elsewhere, the maximum measured incremental strains are 0.7 mm/m tensile and 1.3 mm/m compressive. The measured strains away from the irregular ground movements are less than the maximum predicted strains based on conventional ground movements of 1 mm/m tensile and 2 mm/m compressive.

It is considered that the ground movements measured using the Menangle Road monitoring line are consistent with the predictions provided in Reports Nos. MSEC342, MSEC825 and MSEC1133.

2.5. M31 Hume Motorway

The M31 Hume Motorway crosses directly above LW708B as shown in Drawings Nos. MSEC1250-01 and MSEC1250-03, in Appendix B. The monitoring associated with the motorway for LW708B included the:

- M31 East and West Lines;
- highway cutting points; and
- FBG and slot closure monitoring.

The monitoring results and discussions were provided in the weekly subsidence monitoring review reports for the motorway (MSEC1126-01 to MSEC1126-69), which were issued during the mining of LW708B between August 2020 and March 2022.

A summary of the monitoring results for the M31 Hume Motorway is provided in the following sections.

2.5.1. M31 East and M31 West Lines

The mine subsidence effects along the M31 Hume Motorway were measured by IMC using two 3D monitoring lines, being the M31 East Line and M31 West Line. The locations of these monitoring lines are shown in Drawing No. MSEC1250-01, in Appendix B. A summary of the survey dates during the extraction of LW708B is provided in Table 2.7.

Table 2.7 Survey dates for the M31 East Line and M31 West Line during LW708B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Survey full length of monitoring lines at start and end of LW708B, then monthly 3D surveys after 2400 m of extraction until one month after completion of LW708B, plus weekly focused 2D surveys after 2650 m of extraction until one month after completion of LW708B	4 November 2020, then monthly to the 28 January 2021, and then weekly to the 20 December 2021, and then fortnightly to the 31 January 2022 28 February 2022 (end of LW708B)	As required under the LW709 monitoring program

The profiles of measured and predicted incremental vertical subsidence, tilt and strain along the M31 East Line and M31 West Line, due to the mining of LW708B, are shown in Figs. A.03 and A.04, respectively, in Appendix A. The predictions are based on the as-extracted lengths of the longwalls as presented in Report No. MSEC1133.

The profiles of measured incremental vertical subsidence reasonably match the predicted profiles on the maingate side; however, the vertical subsidence measured above the chain pillar and adjacent longwalls are less than those predicted. This behaviour is similar to that observed for the previously extracted longwalls in Area 7.

A summary of the maximum measured and predicted incremental vertical subsidence, tilt and strains along the M31 East Line and M31 West Line is provided in Table 2.8. The values represent the additional movements due to the mining of LW708B only.

Table 2.8 Maximum measured and predicted incremental vertical subsidence, tilt and strain along the M31 East Line and M31 West Line due to LW708B only

Location	Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm/m)	Maximum incremental tensile strain (mm/m)	Maximum incremental comp. strain (mm/m)
M31 East Line	Measured	654	5.9	0.9	3.8
	Predicted	850	5.5	*- Refer to discussions below -*	
M31 West Line	Measured	813	6.2	1.0	1.7
	Predicted	850	5.5	*- Refer to discussions below -*	

The accuracies of the measured relative eastings, northings and levels along the M31 East and West Lines are in the order of ±5 mm. The accuracies of the measured absolute eastings, northings and levels along the monitoring lines are in the order of ±10 mm. The accuracies of the measured strains along the monitoring lines are in the order of ±0.25 mm/m.

The maximum measured incremental vertical subsidence along the M31 East and M31 West Lines of 654 mm and 813 mm, respectively, are less than the maximum predicted value of 850 mm. The maximum measured vertical subsidence along these monitoring lines was located slightly closer to the longwall maingate than the predicted locations.

The maximum measured incremental tilts of 5.9 mm/m for the M31 East Line and 6.2 mm/m for the M31 West Line are slightly greater than the maximum predicted value of 5.5 mm/m. The maximum measured tilt for the M31 East Line is due to a localised irregular movement and the predicted profile does not include anomalous movements. The maximum measured tilt along the M31 West Line is due to the slightly lower subsidence measured above the longwall maingate resulting in a slightly steeper profile.

The maximum measured incremental compressive strains along the M31 East Line are 3.8 mm/m and 3.4 mm/m. These strains are associated with bumps in the measured vertical subsidence profile and lateral misalignment indicating that non-conventional movements have developed at these locations. The maximum measured compressive strains are within the expected range when considering the potential for localised anomalous movements of up to 5.5 mm/m for 97 % of the measured cases.

Elsewhere, the maximum measured strains along the M31 East Line and M31 West Line are 1.0 mm/m tensile and 1.7 mm/m compressive. These strains are similar to or less than the maximum predicted strains based on regular ground movements of 1 mm/m tensile and 2 mm/m compressive.

It is considered that the ground movements measured using the M31 East Line and M31 West Line are consistent with the predictions provided in Reports Nos. MSEC342, MSEC825 and MSEC1133.

2.5.2. FBG and slot displacement monitoring

FBG monitoring

Temperature and strain Fibre Bragg Grating (FBG) sensors were installed in the top 50 mm of asphalt along each carriageway within the outside shoulder. The sensors are spaced every 10 m and the temperature and strain were measured every 15 minutes during the mining of LW708B.

The temperature compensated FBG strains exceeded the trigger levels in the management plan at two locations on the southbound carriageway and one location on the northbound carriageway during the mining of LW708B.

FBG187.3 on the Southbound pavement exceeded the Blue trigger on 5 May 2021. A small hump was observed to gradually formed in the pavement across the travel lanes at this location. Existing cracks in the deceleration lane to the Rest Area were also deteriorating slightly. Compressive strains continued to gradually increase to 2.8 mm/m at this location until December 2021. Average pavement strains over 20 metres, 30 metres and 40 metres increased above the Blue trigger level due solely to readings from this single FBG, with very little change observed at adjacent FBGs. The Technical Committee reviewed the monitoring results on a weekly to twice weekly frequency, in conjunction with slot displacement readings, ground surveys and visual inspections. It was agreed to progressively increase the trigger level as the results were localised to one single FBG and there were no immediate concerns with the pavement. The pavement was resurfaced in September 2021.

FBG193.2 on the Southbound pavement exceeded the Blue trigger on 10 August 2021. A small hump was observed to gradually formed in the pavement across the travel lanes at this location. The observed strain was also localised to a single FBG. The cause of the compressive strains may have been linked to closure of a slot in the Rest Area deceleration lane. The Technical Committee reviewed the monitoring results on a weekly to twice weekly frequency, in conjunction with slot displacement readings, ground surveys and visual inspections. Compressive strains continued to gradually increase to 1.1 mm/m at this location until September 2021, when the cable was broken during resurfacing works. The Technical Committee agreed on 14 September that there was sufficient redundancy available to continue monitoring ongoing changes at this location without reinstating FBGs, using a combination of ground surveys, slot monitoring and visual inspections.

FBG194.3 on the Northbound pavement previously experienced high tensile strains, when the pavement was resurfaced in September 2021. After the resurfacing, pavement strains continued to gradually reduce and continued into compression, exceeding the Blue trigger on 2 November 2021 until it stopped compressing at 2.9 mm/m in February 2022. The observed strains was also localised to a single FBG. Average pavement strains over 20 metres and 30 metres increased above the Blue trigger level due solely to readings from this single FBG, with very little change observed at adjacent FBGs. The Technical Committee reviewed the monitoring results on a weekly to twice weekly frequency, in conjunction with slot displacement readings, ground surveys and visual inspections. It was agreed to progressively increase the trigger level as the results were localised to one single FBG and there were no immediate concerns with the pavement.

The M31 Hume Motorway remained safe and serviceable during the above events.

Slot displacement monitoring

Displacement sensors were installed in each pavement slot and were measured every 5 minutes during the mining of LW708B. The slot displacements did not exceed the management plan trigger levels for closure at any stage during the mining of LW708B. As slot R189 approached the trigger level of 60 mm, the Technical Committee agreed to increase the trigger to 70 mm. The maximum measured closure of the slots located directly above LW708B was 28 mm at SB191, 51 mm at NB190 and 67 mm at R189.

2.6. Main Southern Railway

The Main Southern Railway crosses directly above LW708B as shown in Drawings Nos. MSEC1250-01 and MSEC1250-03, in Appendix B. The monitoring associated with the railway for LW708B included the:

- ARTC 3D ground monitoring line;
- ARTC 3D embankment monitoring points;
- railway cutting points; and
- strain gauges.

The monitoring results and discussions were provided in the weekly subsidence monitoring review reports for the railway (MSEC1125-01 to MSEC1125-60), which were issued during the extraction of LW708B between September 2020 and January 2022.

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

2.6.1. ARTC Line

The mine subsidence effects along the Main Southern Railway were measured by IMC using a 3D ground monitoring line, referred to as the ARTC Line. The location of the monitoring line is shown in Drawing No. MSEC1250-01, in Appendix B. A summary of the survey dates during the extraction of LW708B is provided in Table 2.9.

Table 2.9 Survey dates for the ARTC Line during LW708B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Start and end of LW708B, with monthly 3D surveys after 1985 m of extraction, plus weekly 2D focused surveys after 2185 m of extraction	12 August 2020, 7 September 2020, then weekly to the 21 September 2021, then monthly to the 7 December 2021, 10 January 2022 (end LW708B)	As required under the LW709 monitoring program

The profiles of measured and predicted incremental vertical subsidence, tilt and strain along the ARTC Line, due to the mining of LW708B, are shown in Fig. A.05 in Appendix A. The predictions are based on the as-extracted lengths of the longwalls as presented in Report No. MSEC1133.

The profile of measured incremental vertical subsidence reasonably matches the predicted profile on the maingate side; however, the vertical subsidence measured above the chain pillar and adjacent longwalls is less than that predicted. This behaviour is similar to that observed for the previously extracted longwalls in Area 7.

A summary of the maximum measured and predicted incremental vertical subsidence, tilt and strains along the ARTC Line is provided in Table 2.10. The values represent the additional movements due to the mining of LW708B only.

Table 2.10 Maximum measured and predicted incremental vertical subsidence, tilt and strain along the ARTC Line due to LW708B only

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm/m)	Maximum incremental tensile strain (mm/m)	Maximum incremental comp. strain (mm/m)
Measured	990	7.8	1.7	5.5
Predicted	900	5.6	*- Refer to discussions below -*	

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

The maximum measured incremental vertical subsidence along the ARTC Line of 990 mm is greater than the maximum predicted value of 900 mm. The exceedance of 90 mm represents 10 % of the maximum predicted vertical subsidence and, therefore, it is within the order of accuracy of prediction methods for vertical subsidence of ±15 % to ±25 %.

The maximum measured incremental tilt of 7.8 mm/m is slightly greater than the maximum predicted value of 5.6 mm/m. The measured tilt is greater than that predicted adjacent to the maingate of LW708B due to the higher subsidence that developed directly above the longwall.

The maximum measured incremental strains along the ARTC Line are 1.7 mm/m tensile and 5.5 mm/m compressive.

It is considered that the ground movements measured using the ARTC Line are consistent with the predictions provided in Reports Nos. MSEC342, MSEC825 and MSEC1133.

2.6.2. Automated track monitoring

Rail stress transducers

Rail stress transducers are located along all four rails of the railway track, spaced every 25 m to 60 m. They measured the changes in rail strain every 5 minutes during the extraction of LW708B. While some false alarms were triggered during mining, due to malfunction or damage to transducers, the actual stress readings did not exceed the trigger levels.

Expansion switch displacement sensors

Displacement sensors have been installed at each expansion switch. Measurements were recorded every 5 minutes during the extraction of LW708B. While some low level (Blue) alarms were triggered during mining, responses had already been planned in anticipation of the alarms.

2.6.3. Embankment monitoring

The mine subsidence effects along and across the Embankment at 69.0 km were measured by IMC during the mining of LW708B. A summary of the survey dates during the extraction of LW708B are provided in Table 2.11.

Table 2.11 Survey dates for the Embankment at 69.0 km during LW708B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly absolute 3D surveys after 1985 m of extraction, plus weekly local 3D surveys after 2185 m of extraction	12 August 2020, 7 September 2020, then weekly to the 22 June 2021, then monthly to the 7 December 2021, 10 January 2022 (end LW708B)	As required under the LW709 monitoring program

The profiles of measured incremental vertical subsidence, tilt and strain along the Embankment at 69.0 km, due to the mining of LW708B, are shown in Figs. A.06 to A.09, in Appendix A.

The accuracies of the measured relative eastings, northings and levels along the Embankment lines are in the order of ±5 mm. The accuracies of the measured absolute eastings, northings and levels along the monitoring lines are in the order of ±10 mm. The accuracies of the measured strains along the monitoring lines are typically in the order of ±0.15 mm/m, where bay lengths are around 20 m.

The findings are similar to those for the ARTC Line, which are discussed in Section 2.6.1. The main ground monitoring line along the railway corridor is located on the crest of the embankment on the Down side.

2.6.4. Culverts

The mine subsidence effects along the railway culvert at 69.0 km were measured by IMC using a 3D ground monitoring line, referred to as the ARTC 69.0 km Culvert. The location of the monitoring line is shown in Drawing No. MSEC1250-01, in Appendix B. The measured changes in horizontal distance along the invert of the ARTC 69.0 km Culvert is shown in Fig. 2.2.

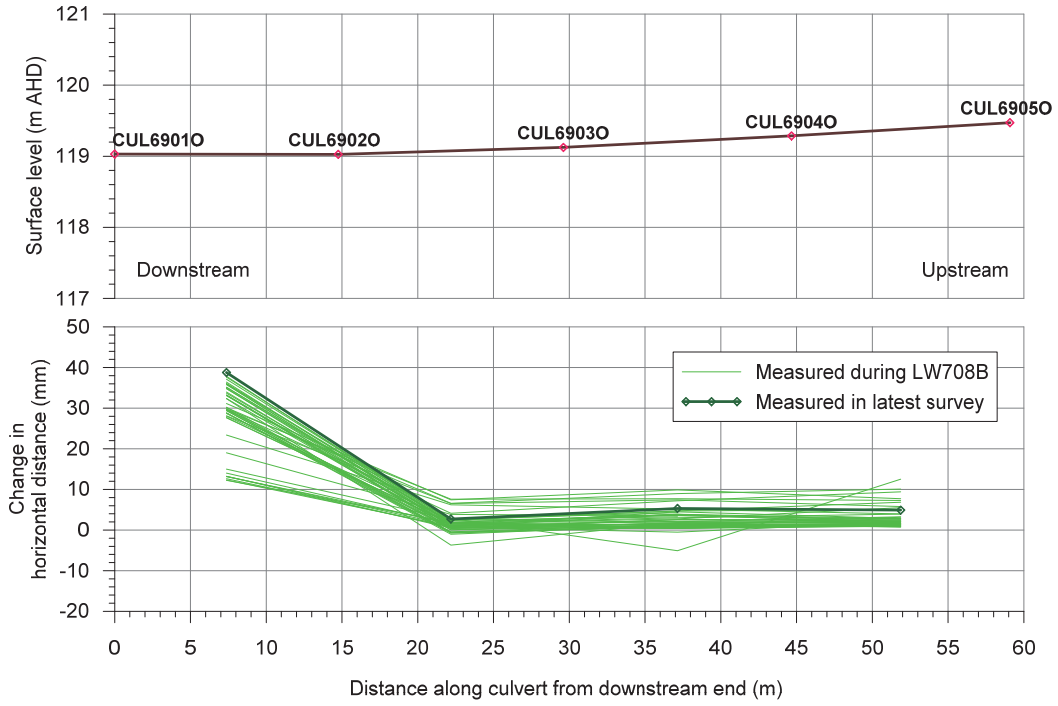


Fig. 2.2 Measured incremental changes in horizontal distance along the invert of the ARTC 69.0 km Culvert during to LW708B

2.7. Highway Cutting 2

The Highway Cutting 2 Points were measured by IMC during the extraction of LW708B. The 3D monitoring points are located on the cuttings along the M31 Hume Motorway. The locations of these monitoring points are shown in Drawing No. MSEC1250-01 in Appendix B. A summary of the survey dates during the extraction of LW708B is provided in Table 2.12.

Table 2.12 Survey dates for the Highway Cutting 2 Points during LW708B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly 3D surveys after 2400 m of extraction until one month after completion of LW708B, plus weekly focused 2D surveys after 2650 m of extraction until one month after completion of LW708B	4 November 2020, then monthly to the 28 January 2021, and then weekly to the 20 December 2021, 4 January 2022 31 January 2022 (end of LW708B)	As required under the LW709 monitoring program

The final measured absolute incremental horizontal movements at the Highway Cutting 2 Points, after the completion of LW708B, are shown in Fig. 2.3.

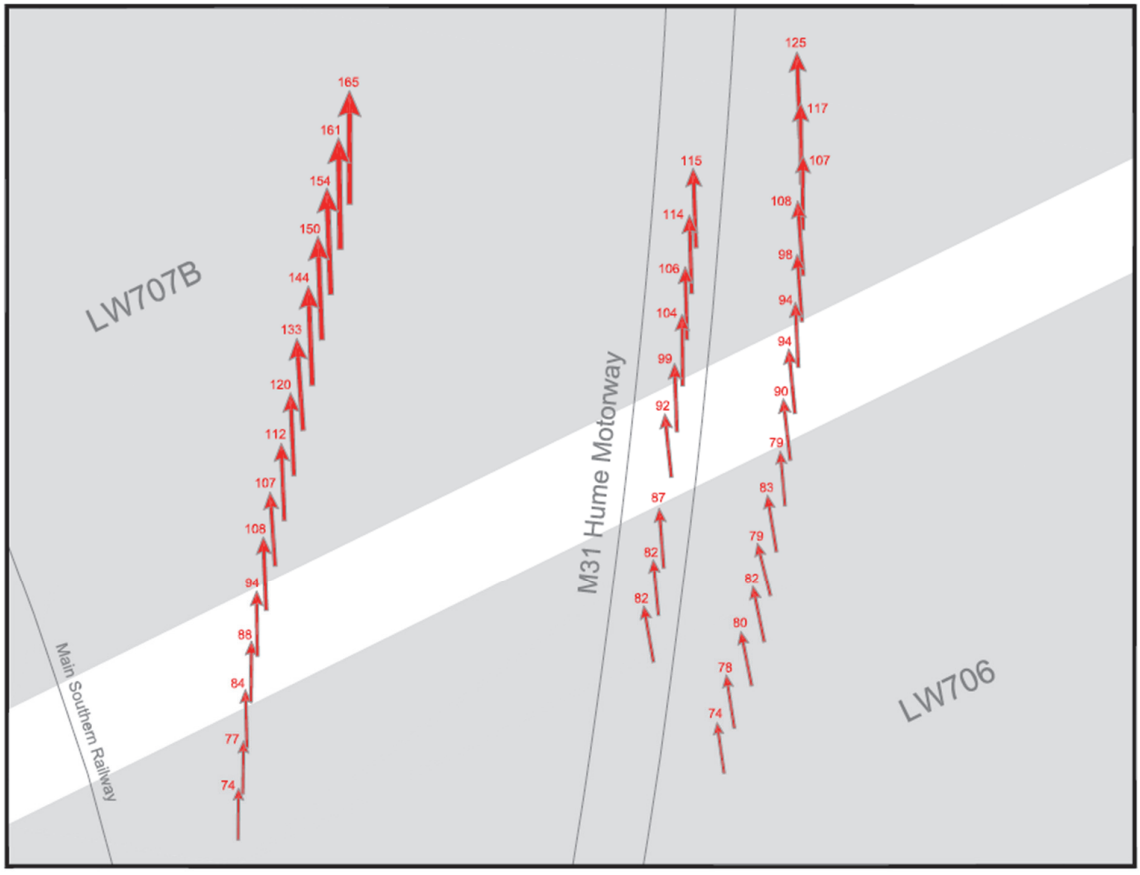


Fig. 2.3 Measured absolute incremental horizontal movements at the Highway Cutting 2 Points due to LW708B

A summary of the maximum measured absolute incremental horizontal movements at the cutting monitoring points is provided in Table 2.13. The values represent the additional movements due to the mining of LW708B only.

Table 2.13 Maximum measured absolute incremental horizontal movements at the Highway Cutting 2 Points due to LW708B only

Longwall	Location	Maximum measured incremental horizontal movement (mm)
LW708B	W144 to W158	165
	G101 to G110	115
	E146R to E160R	125

The accuracies of the measured eastings and northings at the 3D monitoring points are in the order ±5 mm.

The measured incremental horizontal movements are greatest at the northern end of the cutting and reduce relatively uniformly towards the southern end of the cutting. The orientations of the vectors are generally towards the north in the directly of LW708B. The Highway Cutting 2 Points indicate that the ground has moved uniformly and that there are no irregular or localised movements.

2.8. Partridge VC Rest Area

The Partridge VC Rest Area points were measured by IMC during the extraction of LW708B. The locations of these monitoring points are shown in Drawing No. MSEC1250-01, in Appendix B. A summary of the survey dates during the extraction of LW708B is provided in Table 2.14.

Table 2.14 Survey dates for the Partridge VC Rest Area monitoring points during LW708B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly 3D surveys after 2400 m of extraction until one month after completion of LW708B, plus weekly focused 2D surveys after 2650 m of extraction until one month after completion of LW708B	4 November 2020, then monthly to the 28 January 2021, and then weekly to the 20 December 2021, 4 January 2022 31 January 2022 (end of LW708B)	As required under the LW709 monitoring program

The maximum measured total vertical subsidence at the Partridge VC Rest Area after the mining of LW708B is 1154 mm. The measured strains are generally less than 1 mm/m tension and compression. Mark AM03 was observed to move relative to the adjacent pegs, with a compressive strain of 1.3 mm/m measured between Marks AM03 and E168 and a compressive strain of 1.6 mm/m measured between Marks AM03 and E170. Impacts were observed in this location to the concrete footpath, kerbs and unreinforced concrete mattress forming the spillway at the southern end of the Rest Area.

2.9. Far-field 3D marks

The far-field mine subsidence effects were measured by IMC using a number of 3D marks in the vicinity of LW708A and LW708B. The locations of these monitoring points are shown in Drawing No. MSEC1250-01, in Appendix B. A summary of the survey dates during the extraction of LW708A and LW708B is provided in Table 2.15.

Table 2.15 Survey dates for the far-field 3D marks during LW708A and LW708B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Start and end of LW708A and LW708B, with monthly surveys during mining after 300 metres of extraction	7 June 2019, then monthly to 2 October 2019, and 7 November 2019 (end of LW708A) 23 June 2020, and then monthly to 16 December 2021, and 12 January 2022 (end of LW708B)	As required under the LW709 monitoring program

The final measured absolute incremental horizontal movements at the far-field 3D marks, due to the mining of both LW708A and LW708B, are shown in Fig. 2.4. It is noted that these movements include the effects from the concurrent mining in Area 9.

Fig. 2.4 Measured absolute incremental horizontal movements at the far-field 3D marks due to the mining of LW708A and LW708B

A summary of the maximum measured incremental horizontal movements at the far-field 3D marks is provided in Table 2.16. The values represent the additional movements during the mining of LW708A and LW708B.

Table 2.16 Maximum measured incremental horizontal movements at the far-field 3D marks during the mining of LW708A and LW708B

Longwalls	Location	Maximum measured incremental horizontal movement (mm)
LW708A and LW708B (with concurrent mining in Area 9)	BURRELL1	92
	BURRELL2	85
	CR1	64
	DOUGLAS	64
	DPBN	12
	DPBS	15
	FR1	63
	MPR STN27	53
	MPRBE	25
	MPRBNE	23
	MPRBNW	25
	MPRBW	22
	MPRN	45
	MR1	222
	MR2	86

The accuracies of the measured eastings and northings at the far-field 3D marks are in the order ±5 mm and, therefore, the accuracies of the measured absolute horizontal movements are in the order of ±7 mm.

The maximum measured incremental horizontal movement is 222 mm at MR1. However, that mark is located above the active LW904 and, therefore, its movement is due to the concurrent mining in Area 9. Elsewhere, the maximum measured incremental horizontal movement is 92 mm at Burrell1 located north-west of Area 7 and north of Area 9.

The final measured incremental horizontal movements for the far-field 3D marks (i.e. black diamonds), ARTC line (i.e. green diamonds), M31 West Line (i.e. cyan diamonds), M31 East Line (i.e. blue diamonds) and the cutting marks (i.e. orange diamonds), during the mining of LW708A and LW708B, versus the distance from the active longwall are shown in Fig. 2.5. The measured incremental horizontal movements elsewhere in the Southern Coalfield (i.e. grey triangles) are also shown in this figure for comparison.

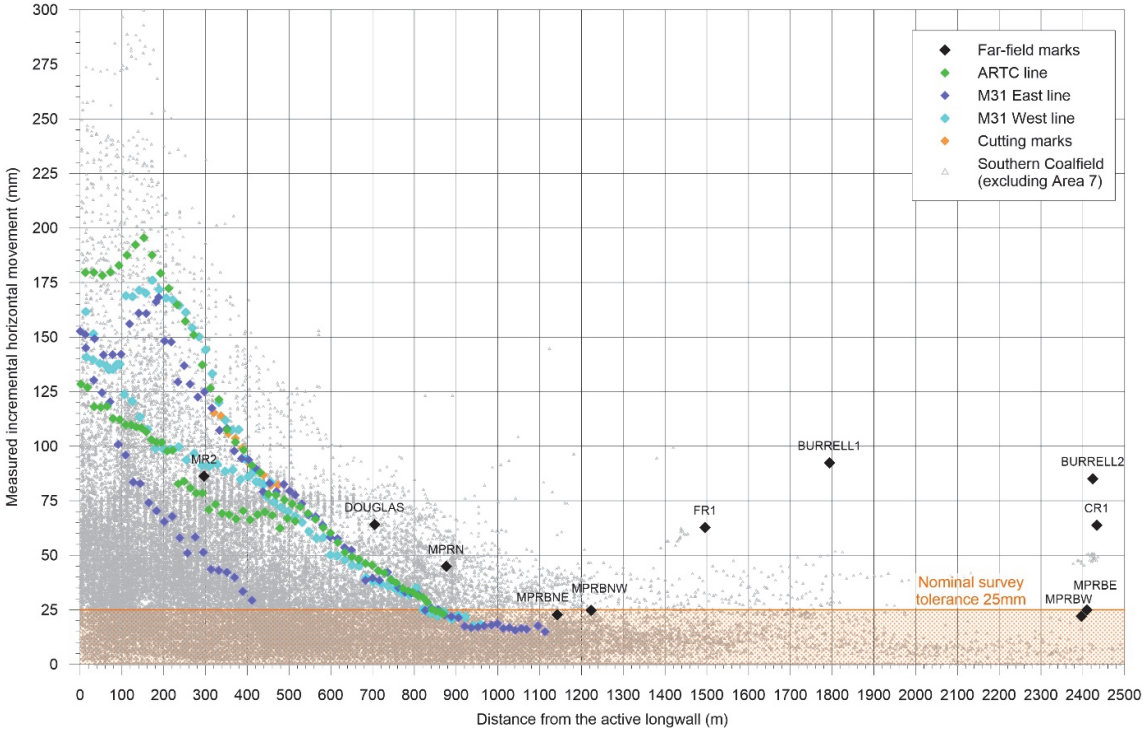


Fig. 2.5 Measured incremental horizontal movements versus distance from the active longwall

The incremental horizontal movements measured at BURRELL1, BURRELL2 and CR1 are greater than those typically measured at similar distances elsewhere in the Southern Coalfield. It is possible that the concurrent mining in Areas 7 and 9 have contributed to the higher levels of movement. Elsewhere, the measured incremental horizontal movements at the other far-field 3D marks and monitoring lines are similar to those typically measured in the Southern Coalfield.

2.10. Douglas Park Twin Bridges over the Nepean River

The Douglas Park Twin Bridges are located approximately 2.8 km south of the commencing (i.e. western) end of LW708A. The locations of these bridges are shown in Drawing No. MSEC1250-01, in Appendix B, where the M31 Hume Motorway crosses the Nepean River. The monitoring associated with the Douglas Park Twin Bridges for LW708A and LW708B included the:

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

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

2.10.1. Absolute 3D monitoring for the Douglas Park Twin Bridges

The absolute 3D horizontal movements at the Douglas Park Twin Bridges were monitored by IMC at Marks DPBN and DPBS. These two marks are located at the northern and southern ends of the bridges, as shown in Drawing No. MSEC1250-01, in Appendix B.

Marks DPBN and DPBS were measured as part of the far-field 3D surveys, which is discussed in Section 2.9. The measured incremental absolute horizontal movements at these marks are illustrated in Fig. 2.4. The measured movements are similar to the order of survey tolerance and, therefore, the orientations of the incremental vectors are not reliable.

A summary of the maximum measured incremental and total absolute horizontal movements at Marks DPBN and DPBS is provided in Table 2.17.

Table 2.17 Maximum measured absolute horizontal movements at Marks DPBN and DPBS

Mark	Maximum measured incremental horizontal movement due to LW708A and LW708B (mm)	Maximum measured total horizontal movement due to LW701 to LW708B (mm)
DPBN	12	79
DPBS	15	91

The development of the total absolute horizontal movements at Marks DPBN and DPBS, during the mining of LW703 to LW708B and concurrent mining in the adjacent Area 9, is shown in Fig. 2.6. The development of the relative horizontal distance between these two marks is illustrated in Fig. 2.7.

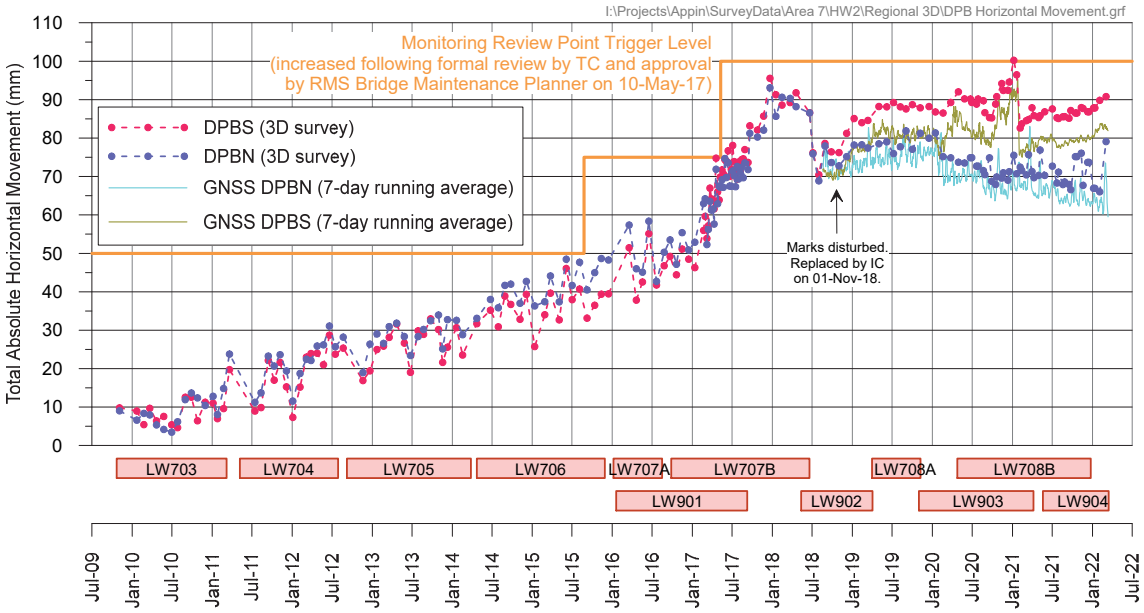


Fig. 2.6 Development of the absolute horizontal movements at Marks DPBN and DPBS

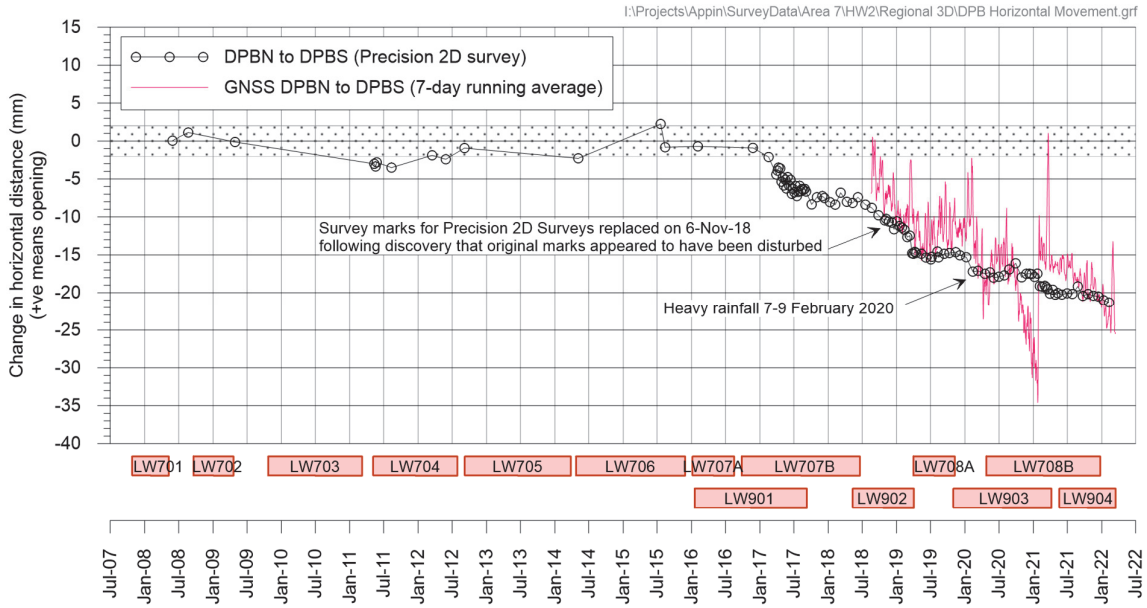


Fig. 2.7 Development of the relative horizontal movement between Marks DPBN and DPBS

The Trigger Action Response Plan (TARP) for the Douglas Park Twin Bridges, developed by the RMS chaired Technical Committee, provided triggers for absolute and relative horizontal movements of Marks DPBN and DPBS.

The Level 1 trigger of 100 mm for the absolute total horizontal movement, was agreed by the Technical Committee on the 10 May 2017, during the extraction of LW707B. No changes were made to the Level 1 trigger during the mining of LW708B. Very little change in horizontal distance was observed between the ends of the Bridges during the mining of LW708B, 903 and 904.

A summary of the measured horizontal movements at Marks DPBN and DPBS, during the mining of LW708A and LW708B, and the Level 1 triggers is provided in Table 2.18.

Table 2.18 Maximum measured horizontal movements at Marks DPBN and DPBS during the extraction of LW708A and LW708B and the Level 1 triggers

Type	Maximum measured horizontal movement (mm)	Level 1 trigger (mm)
Absolute horizontal movement of Marks DPBN and DPBS	91	100

The maximum measured total horizontal movements of Marks DPBN and DPBS were less than the Level 1 trigger during the extraction of LW708A and LW708B.

2.10.2. Relative 3D monitoring for the Douglas Park Twin Bridges

The mine subsidence effects at the Douglas Park Twin Bridges were measured by IMC using relative 3D marks fixed directly to the bridge structure. The locations of the monitoring points on the Southbound and Northbound carriageways of the bridges are shown in Fig. 2.8 and Fig. 2.9 (Source: IMC).

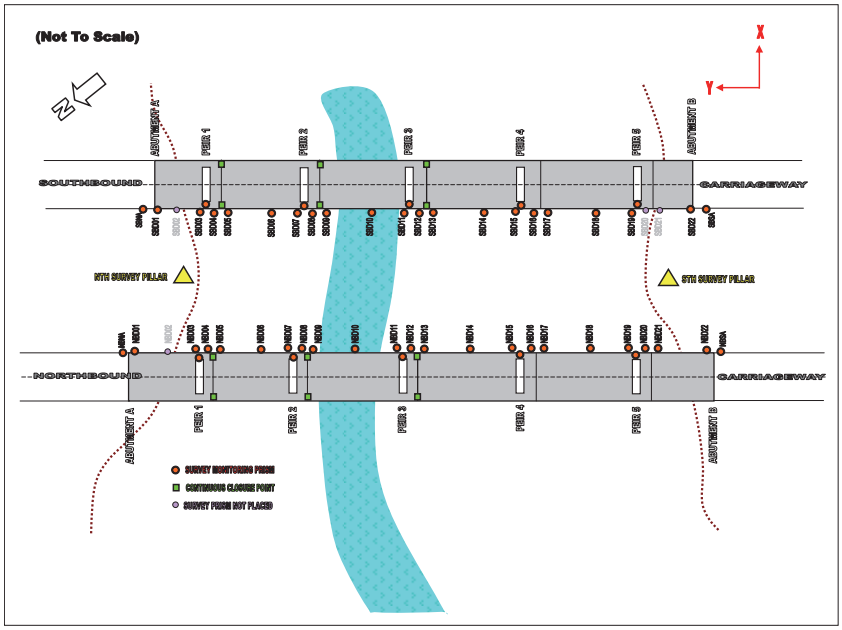


Fig. 2.8 Plan of the relative 3D monitoring points on the Douglas Park Twin Bridges (Source: IMC)

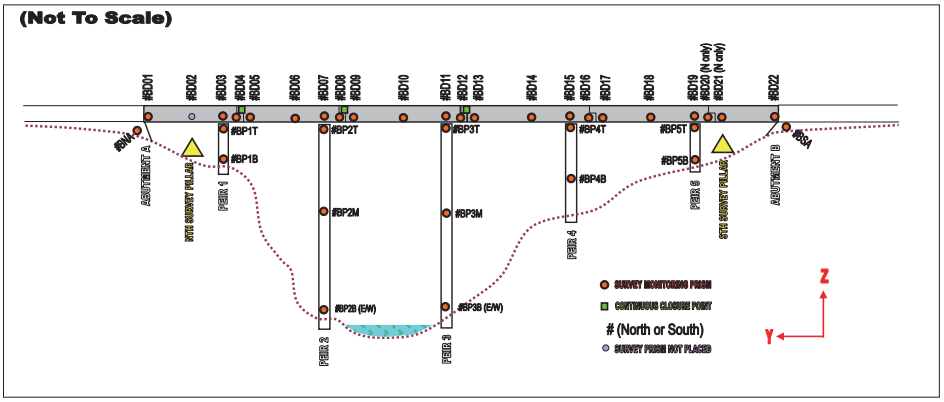


Fig. 2.9 Elevation of the relative 3D monitoring points on the Douglas Park Twin Bridges (Source: IMC)

The changes in horizontal distance between the piers and abutments of the Douglas Park Twin Bridges have been measured during mining in Area 7, since the 15 October 2007, and during the concurrent mining in Area 9. The development of the total changes in horizontal distance between the marks, plotted from the commencement of LW701, is shown in Fig. 2.10. The nominal survey accuracy is ±2 mm.

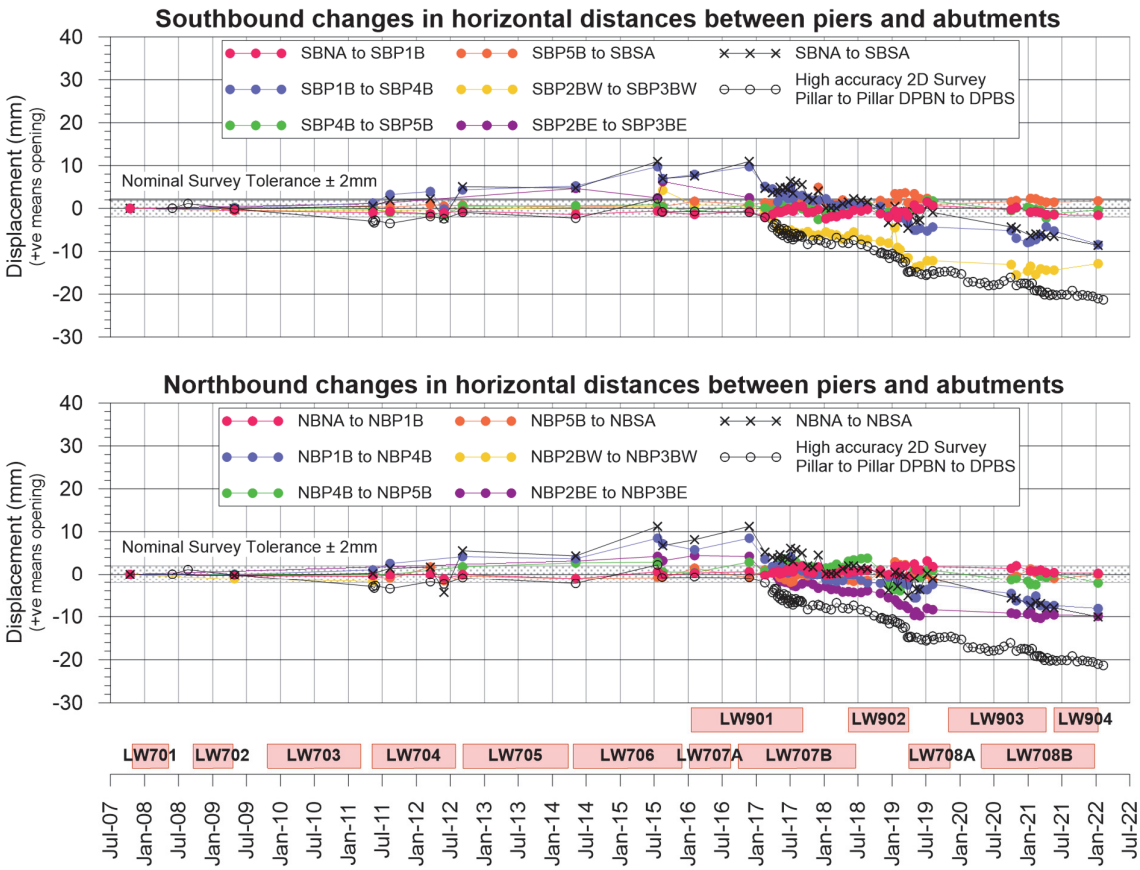


Fig. 2.10 Measured total changes in horizontal distance between the piers and abutments of the Douglas Park Twin Bridges

The total changes in horizontal distance between the abutments and piers at the completion of LW708B were generally less than ±5 mm and, therefore, were similar to the order of survey tolerance. The total changes between SBNA and SBSA, between SBP2BW and SPB3BW and between NBNA and NBSA were between 6 mm and 8 mm.

2.10.3. Inclinometer near the Douglas Park Twin Bridges

The differential movements at the manual (RST) and Shape Array Accelerometer (SAA) inclinometers at Site PSM6, located near the Douglas Park Twin Bridges, were monitored during the extraction of LW708A and LW708B and the concurrent mining in Area 9. The inclinometer was installed and maintained by Pells Sullivan and Meynink (PSM), measured by IMC and the results interpreted by PSM.

The inclinometers comprise boreholes with plastic casings that allow probes to measure the differential tilt or inclination over the lengths of the boreholes. Further details on the inclinometers and the results were provided in the monitoring reports by PSM numbers PSM883-405L through PSM883-466L.

The TARP for the Douglas Park Twin Bridges, which was developed by the RMS chaired Technical Committee, provided a trigger for differential movements at the inclinometers. A summary of the maximum measured total differential movements at the inclinometers, during the extraction of LW708A and LW708B, and the Level 1 trigger is provided in Table 2.19.

Table 2.19 Maximum measured total differential movements at the inclinometers during the extraction of LW708A and LW708B and the Level 1 trigger

Type	Maximum measured differential movement (mm)	Level 1 trigger (mm)
Differential movement	5.7 (PSM6)	10

The measured differential movements at the inclinometers at Site PSM6 did not exceed the Level 1 trigger during the extraction of LW708A and LW708B.

2.10.4. Joint monitoring for the Douglas Park Twin Bridges

The differential movements across the movement joints in the Douglas Park Twin Bridges were measured by PSM during the extraction of LW708A and LW708B. 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 locations of these joints are shown in Fig. 2.8.

The bridge joint monitoring readings commenced on the 29 November 2007 (during the mining of LW701) and measurements have since been taken at 5 or 10 minute intervals. Further details on the bridge joint monitors and the results are provided in the monitoring reports by PSM numbers PSM883-405L through PSM883-466L.

The TARP for the Douglas Park 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 maximum measured differential movements across the bridge movement joints, during the extraction of LW708A and LW708B, and the Level 1 triggers is provided in Table 2.20.

Table 2.20 Measured differential movements and triggers for the Douglas Park Twin Bridges joints

Location	Maximum measured differential movement across bridge joint (mm)	Level 1 trigger (mm)
Joint 1 (Northern joint)	-0.6 (Northbound Carriageway) +0.4 (Southbound Carriageway)	2
Joint 2 (Middle joint)	-0.7 (Northbound Carriageway) -0.3 (Southbound Carriageway)	2
Joint 3 (Main expansion joint)	-3.7 (Northbound Carriageway) -0.8 (Southbound Carriageway)	10

The measured differential movements at the bridge joints did not exceed the Level 1 triggers during the extraction of LW708A and LW708B.

2.11. Moreton Park Road Bridge (South) monitoring points

Moreton Park Road Bridge (South) is located approximately 2.1 km southeast of the commencing (i.e. western) end of LW708A, as shown in Drawings Nos. MSEC1250-01 and MSEC1250-03, in Appendix B. The monitoring associated with Moreton Park Road Bridge (South) for LW708A and LW708B included the:

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

The descriptions of the monitoring results are provided in the following sections.

2.11.1. Absolute 3D monitoring points for the Moreton Park Road Bridge (South)

The absolute 3D horizontal movements at the Moreton Park Road Bridge (South) were monitored by IMC at Marks MPBE and MPBW. These two marks are located adjacent to the eastern and western ends of the bridge, as shown in Drawing No. MSEC1250-01, in Appendix B.

The surveys for Marks MPBE and MPBW were carried out as part of the far-field 3D surveys, which is discussed in Section 2.9. The maximum measured absolute incremental horizontal movements at Marks MPBE and MPBW, after the mining of LW708A and LW708B, are 25 mm and 22 mm, respectively, as shown in Fig. 2.4.

The TARP for the Moreton Park Road Bridge (South), which was developed by the RMS chaired Technical Committee, provided triggers for the absolute horizontal movements of the far-field 3D Points MPBE and MPBW.

The Level 1 trigger of 150 mm for the total absolute horizontal movement, was agreed by the Technical Committee on the 30 May 2017, during the extraction of LW707B. No changes were made to the Level 1 trigger during the mining of LW708B.

The development of the total absolute horizontal movement at Marks MPBE and MPBW is shown in Fig. 2.11.

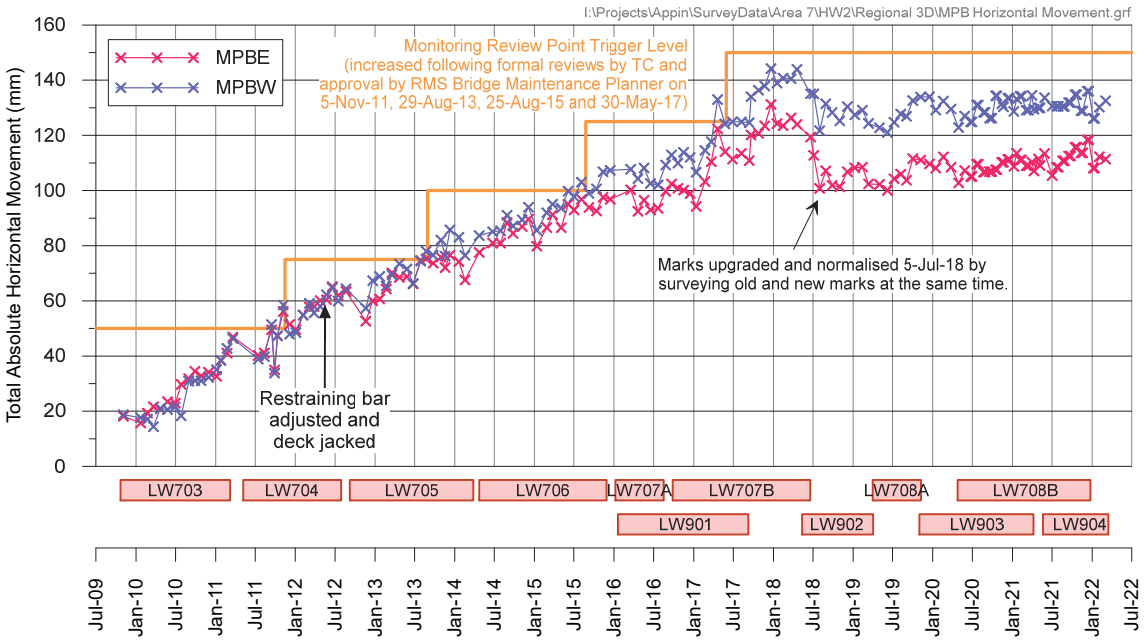


Fig. 2.11 Development of absolute horizontal movement at Marks MPBE and MPBW

A summary of the maximum measured total absolute horizontal movements at Marks MPBE and MPBW, during the extraction of LW708A and LW708B, and the Level 1 trigger is provided in Table 2.21.

Table 2.21 Maximum measured total absolute horizontal movements at Marks MPBE and MPBW during LW708A and L7W708B and the Level 1 trigger

Location	Maximum measured absolute horizontal movement (mm)	Level 1 Trigger (mm)
Marks MPBE and MPBW	111 (MPBE) 133 (MPBW)	150

The maximum measured total absolute horizontal movements at Marks MPBE and MPBW were less than the Level 1 trigger at the completion of LW708B.

2.11.2. Relative 3D monitoring points for the Moreton Park Road Bridge (South)

The mine subsidence effects 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. 2.12 and Fig. 2.13 (Source: IMC).

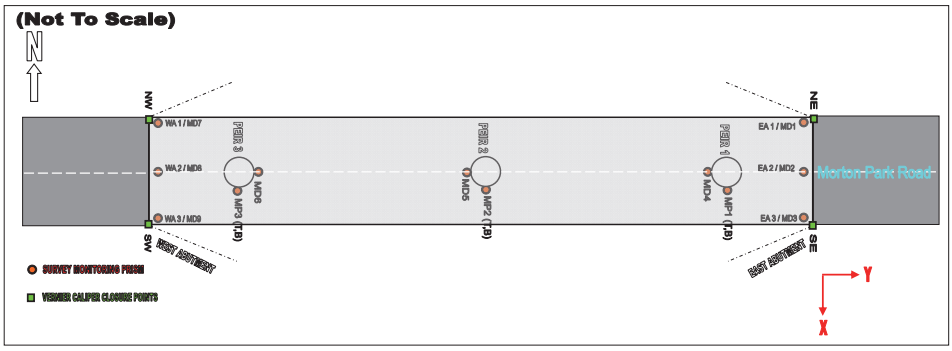


Fig. 2.12 Plan of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IMC)

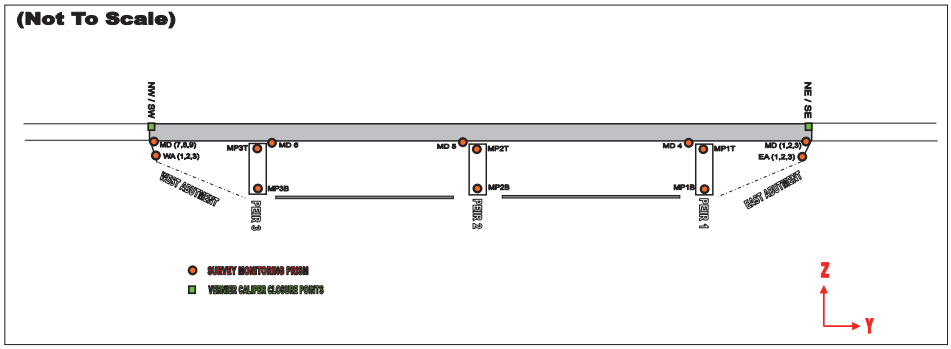


Fig. 2.13 Elevation of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IMC)

The changes in horizontal distance between the bridge abutments have been measured during mining in Area 7, since 15 October 2007, and during the concurrent mining in Area 9. Marks have been established on the eastern abutment (EA1 to EA3) and on the western abutment (WA1 to WA3). Mark EA2 was destroyed in May 2017. The development of the total changes in the horizontal distance between the abutments, during the extraction of LW701 to LW708B, are illustrated in Fig. 2.14. The nominal survey accuracy is ±2 mm.

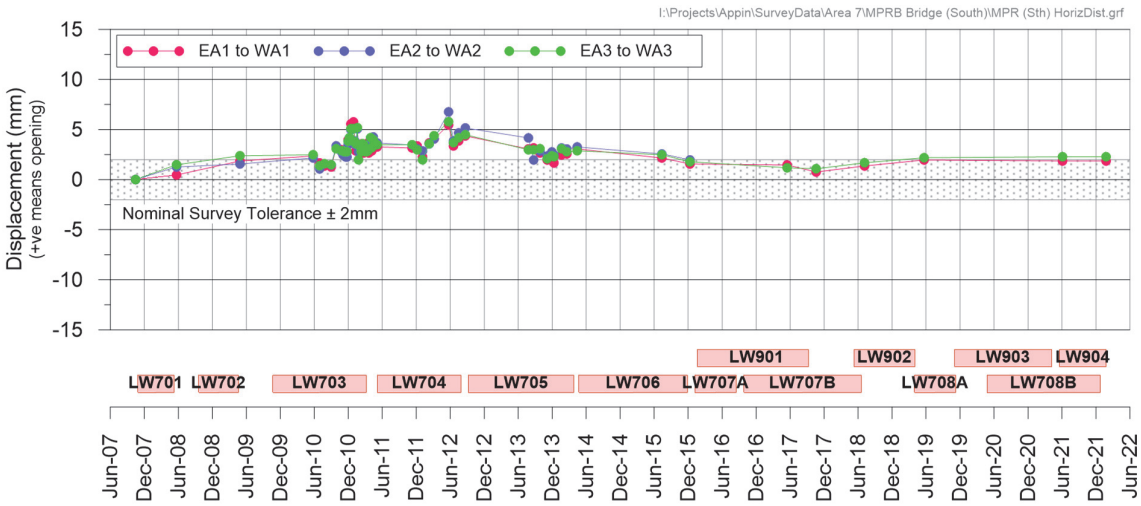


Fig. 2.14 Measured changes in the total horizontal distances between the abutments

There was a small amount of abutment spreading, in the order of +5 mm, that developed during the previous extraction of LW703 to LW705. The results vary slightly between surveys and the cause is thought to be related to changes in moisture and/or temperature. Minor changes have been observed during LW706 to LW708B.

The measured total changes in horizontal distance between the bridge abutments were +2 mm at the completion of LW708B. The total measured movements, therefore, were similar to the order of survey tolerance at the completion of this longwall.

2.12. WaterNSW Infrastructure

The WaterNSW infrastructure that is located near the mining in Area 7 includes the: Upper Canal, Devines Tunnel, wrought iron aqueducts, bridges and concrete aqueducts. The locations of the WaterNSW infrastructure are shown in Drawing No. MSEC1250-01, in Appendix B.

2.12.1. Wrought iron aqueducts and bridges

The movements at the Ousedale Creek, Mallaty Creek, Leafs Gully and Nepean Creek Aqueducts were monitored by IMC using local 3D surveys. A summary of the maximum measured incremental net subsidence, net uplift and closure at the Ousedale Creek, Mallaty Creek, Leafs Gully and Nepean Creek Aqueducts, during the extraction of LW708A and LW708B, is provided in Table 2.22.

It is noted that the net vertical movements have been taken at the marks at the bases of the structures only (i.e. the marks closest to the ground) and do not include the marks on the aqueduct pipes or at the tops of the structures which were influenced by the changes in water flows through the aqueducts, especially prior to and after canal shutdowns. The closure or opening movements have been taken as the changes in distance between the headwalls.

Table 2.22 Maximum measured incremental net subsidence, net uplift and closure at the wrought iron aqueducts during the mining of LW708A and LW708B

Location	Maximum measured incremental net subsidence (mm)	Maximum measured incremental net uplift (mm)	Maximum measured incremental closure (mm)
Ousedale Creek Aqueduct	< 2	< 2	< 2
Mallaty Creek Aqueduct	< 2	< 2	< 2
Leafs Gully Aqueduct	< 2	3	+2 (opening)
Nepean Creek Aqueduct	< 2	< 2	-2 (closure)

The survey tolerances for net subsidence, net uplift, closure and opening are approximately 2 mm.

The maximum measured incremental net subsidence and uplift at the aqueducts and bridges, during the mining of LW708A and LW708B, were similar to the order of survey tolerance, i.e. not measurable. There may be very low-level uplift at the Leafs Gully Aqueduct of +3 mm; however, this is likely to be predominately due to survey tolerance or other environmental effects.

The incremental changes in the distances between the aqueduct headwalls, during the mining of LW708A and LW708B, were +2 mm (opening) at the Leafs Creek Aqueduct, -2 mm (closure) at the Nepean Creek Aqueduct and less than ±2 mm at the Ousedale and Mallaty Creek Aqueducts. These movements are similar to the order of survey tolerance, i.e. not measurable.

2.12.2. Concrete Aqueducts C and D

The movements at Concrete Aqueducts C and D were monitored by IMC using local 3D surveys. The maximum measured incremental net vertical and horizontal movements at the Concrete Aqueducts C and D, during the mining of LW708A and LW708B, were less than ±3 mm. The measured movements, therefore, were similar to the order of survey tolerance, i.e. not measurable.

2.13. Telstra infrastructure

The mine subsidence effects along the Telstra optical fibre line were measured by IMC using a 3D ground monitoring line, referred to as the Telstra Line. The location of this monitoring line is shown in Drawing No. MSEC1250-01, in Appendix B.

The profiles of measured and predicted incremental vertical subsidence, tilt and strain along the Telstra Line, due to the mining of LW708A, are shown in Fig. A.10, in Appendix A. The predictions are based on the as-extracted lengths of the longwalls as presented in Report No. MSEC1133.

The measured profile of vertical subsidence reasonably matches the predicted profile; however, the magnitude is slightly greater than that predicted above LW705 and LW706. The measured vertical subsidence above LW707A is less than that predicted.

A summary of the maximum measured and predicted incremental vertical subsidence, tilt and strains for the Telstra Line is provided in Table 2.23. The values represent the additional movements due to the mining of LW708A only.

Table 2.23 Maximum measured and predicted incremental vertical subsidence, tilt and strain along the Telstra Line due to LW708A only

Type	Maximum incremental vertical subsidence (mm)	Maximum incremental tilt (mm/m)	Maximum incremental tensile strain (mm/m)	Maximum incremental comp. strain (mm/m)
Measured	368	2.7	0.9	0.9
Predicted	425	2.0	*- Refer to discussions below -*	

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

The maximum measured incremental vertical subsidence along the Telstra Line, due to the mining of LW708A only, is less than the maximum predicted value. The maximum measured incremental tilt is slightly greater than that predicted; however, the exceedance is in the order of accuracy of the prediction method and is similar to the order of survey tolerance.

The maximum measured incremental strains are 0.9 mm/m tensile and compressive. No localised or irregular ground movements occurred due to the mining of LW708A. The measured strains are less than the maximum predicted strains based on regular ground movements of 1 mm/m tensile and 2 mm/m compressive.

3.1. Natural Features

The natural features located near LW708A and LW708B are shown in Drawing No. MSEC1250-02, in Appendix B. These features include the:

- Nepean River;
- creeks;
- cliffs and rock outcrops;
- steep slopes; and
- archaeological sites.

The MSEC assessments for the natural features, due to the mining of LW705 to LW710 are provided in Reports Nos. MSEC342, MSEC825 and MSEC1133. More detailed assessments for some natural features are also provided in other consultant's reports. Comparisons between the MSEC assessments and the observed impacts for the natural features, as listed above, are provided in Table 3.1. The observed impacts are based on those recorded by IMC Environmental Field Team and are described in the report entitled *Appin Mine Longwall 708 End of Panel Landscape Report*, dated March 2022.

Table 3.1 Summary of the MSEC assessments and the observed impacts for the natural features due to the mining of LW708A and LW708B

Natural feature	MSEC assessed impacts	Observed impacts
The Nepean River	**Minor fracturing** could occur in the bed of the river	No fracturing observed; however, the flooded valley and sediment profile limits observations of the river bed
	The potential for **surface water flow diversion** assessed as very low	No observable loss or diversion of water from the Nepean River. Refer to the accompanying Surface Water Report by HGEO for further details
	The **surface water level** is expected to remain essentially unchanged. Uplift of the banks could result in some desiccation of the banks	No observed changes in water level apart from the normal fluctuations associated with rainfall and WaterNSW discharges
	Possible that mining-induced **springs** could occur	No iron staining or iron seeps were observed in the Nepean River during the mining of LW708A and LW708B
	Possible that isolated **gas emissions** could occur	Four existing gas release zones were observed to be active during this mining period. Two gas release zones (AA7_LW701_Gas Zone 5 and AA7_LW703_Gas Zone 10) were active during the inspection carried out on January 2022. See Table 1 in Landscape Report by IMC
	Water quality – Refer to the accompanying Surface Water Report by HGEO **Terrestrial ecology** – No impacts or changes to terrestrial ecology was observed during monitoring for LW708A and LW708B. Refer to the accompanying Landscape Report by IMC	
Creeks	Potential for some **ponding**, **flooding** and **desiccation** above the longwalls	No observed adverse impacts in the monitored streams
	Fracturing could occur in the beds of the smaller creeks above the longwalls	No observed adverse impacts in the monitored streams
Cliffs and rock outcrops	Potential for **cliff instabilities** assessed as very low	No observed adverse impacts
Steep slopes	Potential for **soil slippage**	No observed adverse impacts
Aboriginal heritage sites	Low likelihood of impacts on open sites, scarred tree and shelters.	There are no applicable Aboriginal heritage sites on the Aboriginal Heritage Information Management System (AIHMS) within or adjacent to the LW708A and LW708B mining area

There were no observed adverse impacts on the natural features due to the mining of LW708A and LW708B. Some existing gas releases observed during the mining of LW708A and LW708B have continued post-mining. Further assessments of natural features have been provided by other specialist consultants on the project, which are described in the relevant reports accompanying the *End of Panel* report.

3.2. Built features

The built features located near LW708A and LW708B are shown in Drawings Nos. MSEC1250-03, in Appendix B. The features considered in this *End of Panel* report include those located within either the 35° angle of draw line from LW708A and LW708B and/or the predicted 20 mm incremental subsidence contour due to the mining of these longwalls. The built features expected to experience far-field or valley related movements and could be sensitive to these movements have also been considered. The built features include:

- Moreton Park Road and drainage culverts;
- Menangle Road and drainage culverts;
- M31 Hume Motorway and associated infrastructure;
- Main Southern Railway and associated infrastructure;
- Douglas Park Twin Bridges;
- Moreton Park Road Bridge (South);
- low voltage powerlines;
- copper telecommunications cables;
- optical fibre cables – Telstra (2 off), Optus, NextGen and Powertel;
- building structures, pools, tanks and farm dams;
- groundwater bores;
- pumps in the Nepean River;
- the Upper Canal, Cataract Tunnel and associated infrastructure; and
- survey control marks.

The MSEC assessments for the built features, due to the mining of LW705 to LW710, are provided in Reports Nos. MSEC342, MSEC825 and MSEC1133. Comparisons between the assessed and observed impacts for the built features located near LW708A and LW708B, as listed above, are provided in Table 3.2. The observed impacts are based on those recorded by IMC Environmental Field Team.

Table 3.2 Summary of the assessed and observed impacts for built features due to the mining of LW708A and LW708B

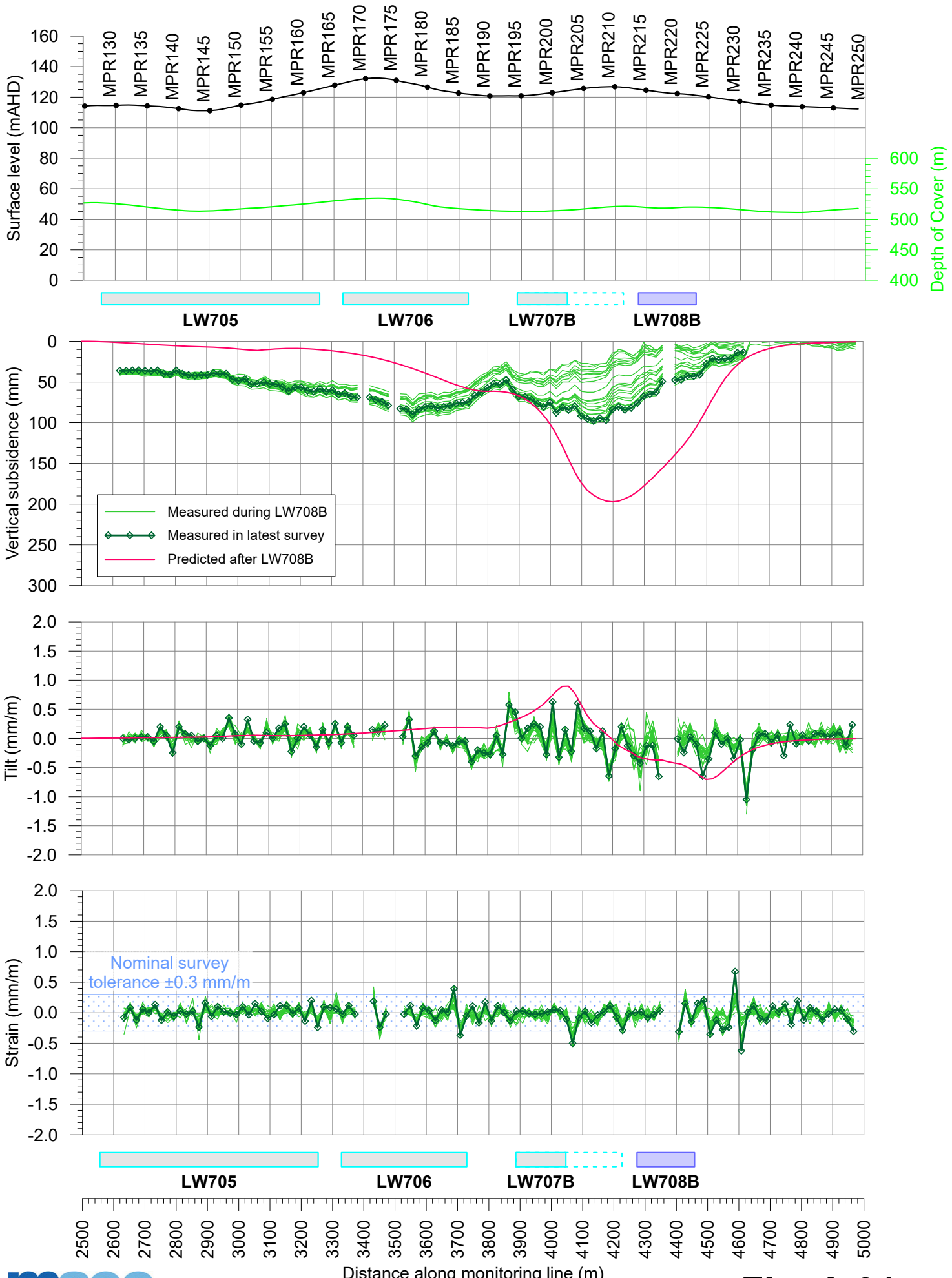
Built feature	MSEC assessed impacts	Observed impacts
Moreton Park Road	Minor cracking and localised heaving of the road surface may occur in some locations above the longwalls	Road remained safe and serviceable. No adverse impacts observed due to the mining of LW708B
Menangle Road	Minor cracking and localised heaving of the road surface may occur in some locations above the longwalls	Road remained safe and serviceable. Compressive bumps formed in the section of pavement near Marks MR7063 and MR7064 during the mining of LW708A, the pavement was repaired. Minor changes near Mark MR7053 which was resurfaced twice
M31 Hume Motorway	No impacts on the safety or serviceability of the motorway after the implementation of the management strategies	Road remained safe and serviceable. No adverse impacts to safety or serviceability. Humps formed on both carriageways during the mining of LW708B and these were remediated by re-shaping of the pavement surface as part of Management Plan responses
Main Southern Railway	No impacts on the safety or serviceability of the railway after the implementation of the management strategies	Track remained safe and serviceable. Changes in track geometry recorded during the mining of LW708B and these were remediated in accordance with the Management Plan

Built feature	MSEC assessed impacts	Observed impacts
Douglas Park Twin Bridges	Impacts unlikely after the implementation of the TARP	No adverse impacts observed due to the mining of LW708A and LW708B
Moreton Park Road Bridge (South)	Impacts unlikely after the detailed investigation, analysis and implementation of the TARP	No adverse impacts observed due to the mining of LW708A and LW708B
Low voltage powerlines	Impacts unlikely, but minor mitigation measures may be required	No adverse impacts observed due to the mining of LW708A and LW708B
Copper telecommunications cables	Impacts unlikely	No adverse impacts observed due to the mining of LW708A and LW708B
Optical fibre cables	Impacts unlikely with the implementation of the management strategies including OTDR monitoring and mitigation	No adverse impacts observed due to the mining of LW708A and LW708B
Building structures	Category A or B tilt impacts Typically Category 0 strain impacts for houses, but with 17 x Category 1 strain impacts and 8 x Category 2 strain impacts.	Building structures remained in safe and serviceable conditions. Impacts observed during the mining of LW708A and LW708B comprise 3 x Category 1 impacts and 1 x Category 5 impact. Claims that have been lodged and are being managed by Subsidence Advisory NSW (SA NSW) through the relevant legislation
Pools	Inground pools could be more susceptible to ground strains	No adverse impacts observed due to the mining of LW708A and LW708B
Water tanks	Impacts unlikely	Claims that have been lodged are being managed by SA NSW through the relevant legislation
Farm dams	Potential for minor cracking or leakage	No adverse impacts observed due to the mining of LW708A and LW708B
Heritage structures	No heritage structures located near LW708A or LW708B	No adverse impacts observed due to the mining of LW708A and LW708B
Groundwater bores	Potential for blockage or reduction in the capacity of the groundwater bores	No adverse impacts observed due to the mining of LW708A an LW708B. Refer to the accompanying Groundwater Report by HGEO
Pumps in the Nepean River	Impacts unlikely	No adverse impacts observed due to the mining of LW708A and LW708B
The Upper Canal, Cataract Tunnel and associated infrastructure	Impacts unlikely	No adverse impacts observed due to the mining of LW708A and LW708B
Survey control marks	Small fair-field horizontal movements which could require re-establishment	Small far-field horizontal movements

The observed impacts on the built features due to the mining of LW708A and LW708B were similar to or less than the assessed (i.e. predicted) impacts.

APPENDIX A. FIGURES

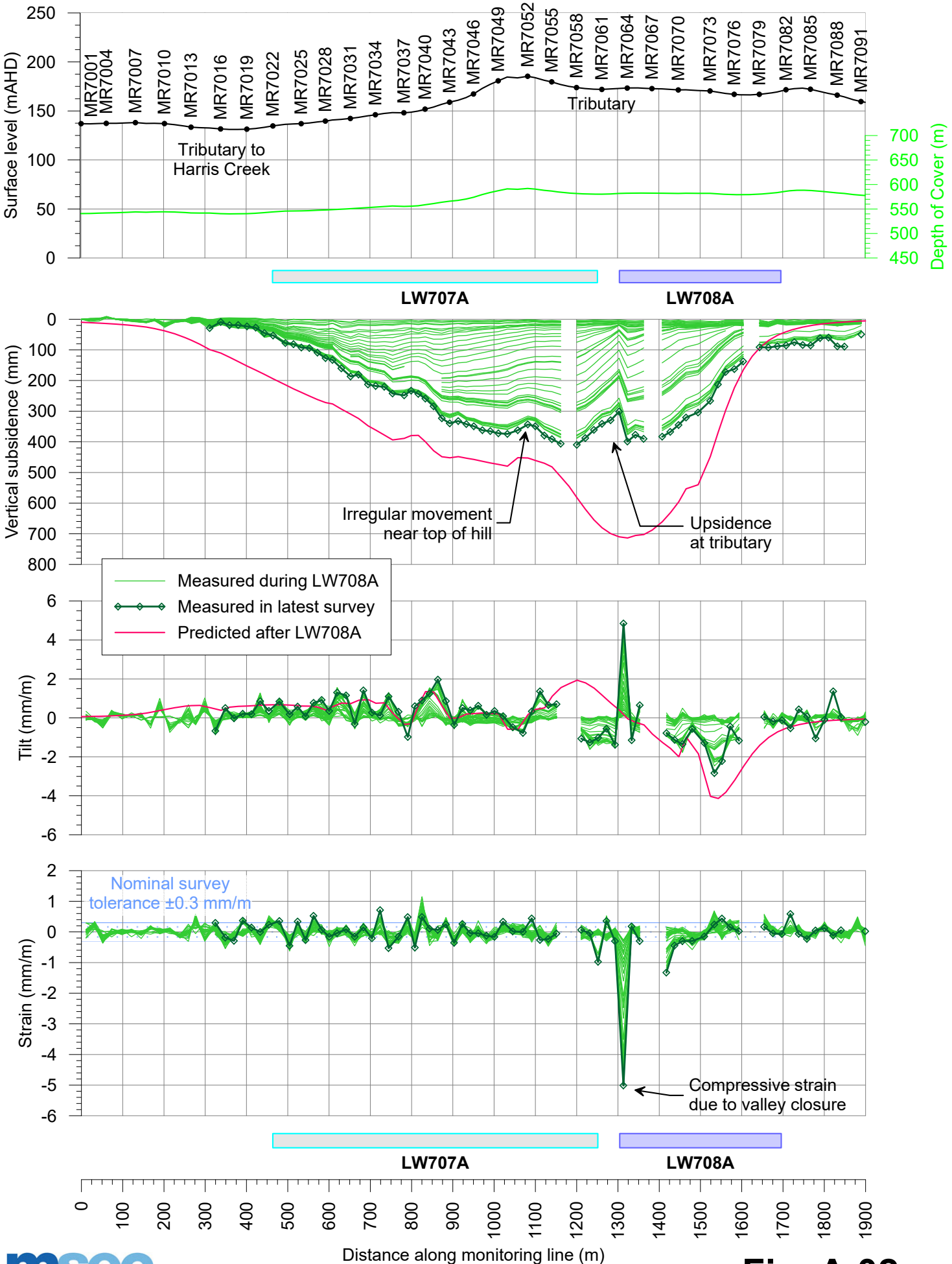
Measured and predicted profiles of incremental vertical subsidence, tilt and strain along the Moreton Park Road monitoring line due to LW708B



msec

Fig. A.01

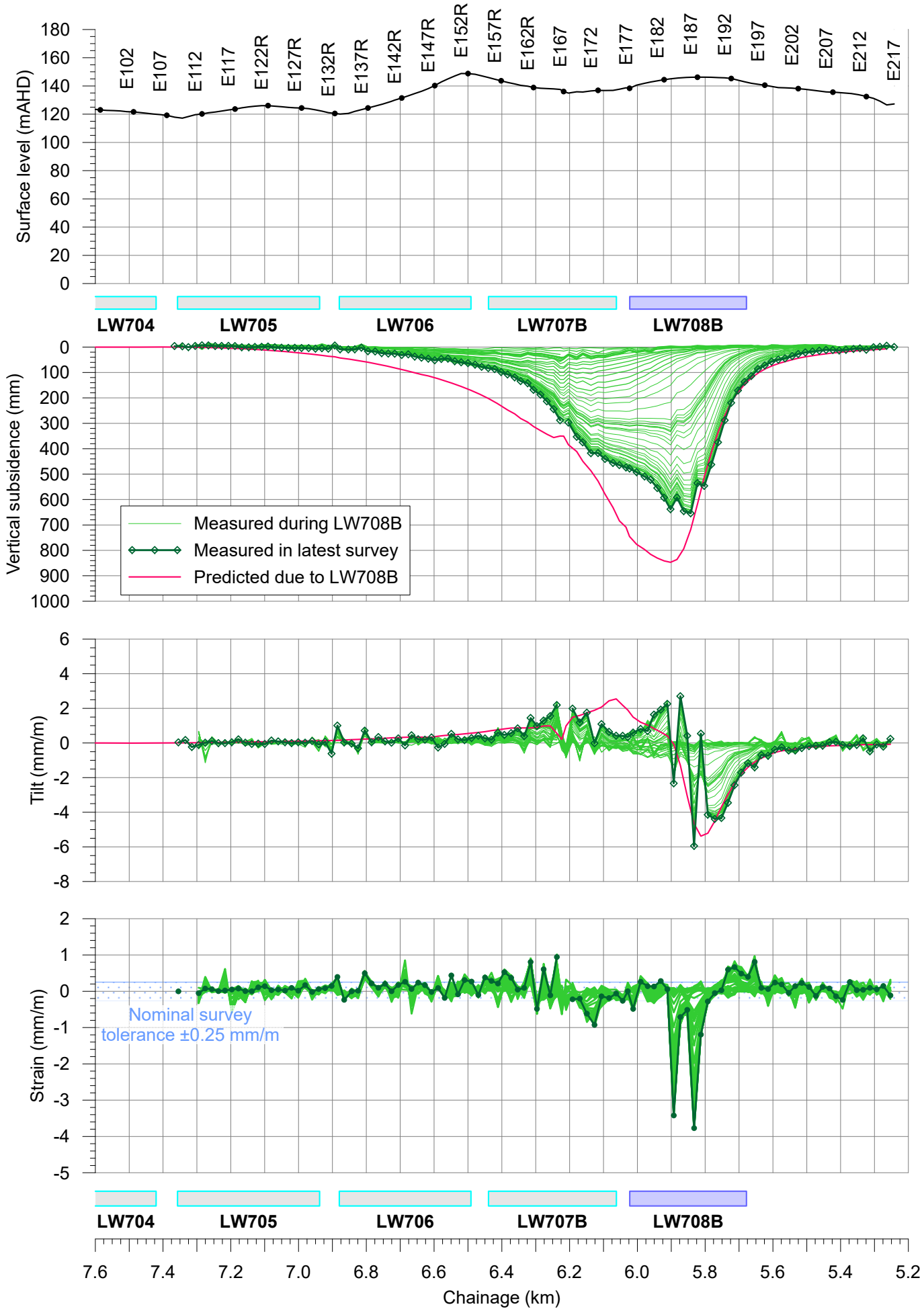
Measured and predicted profiles of incremental vertical subsidence, tilt and strain along the Menangle Road monitoring line due to LW708A



msec

Fig. A.02

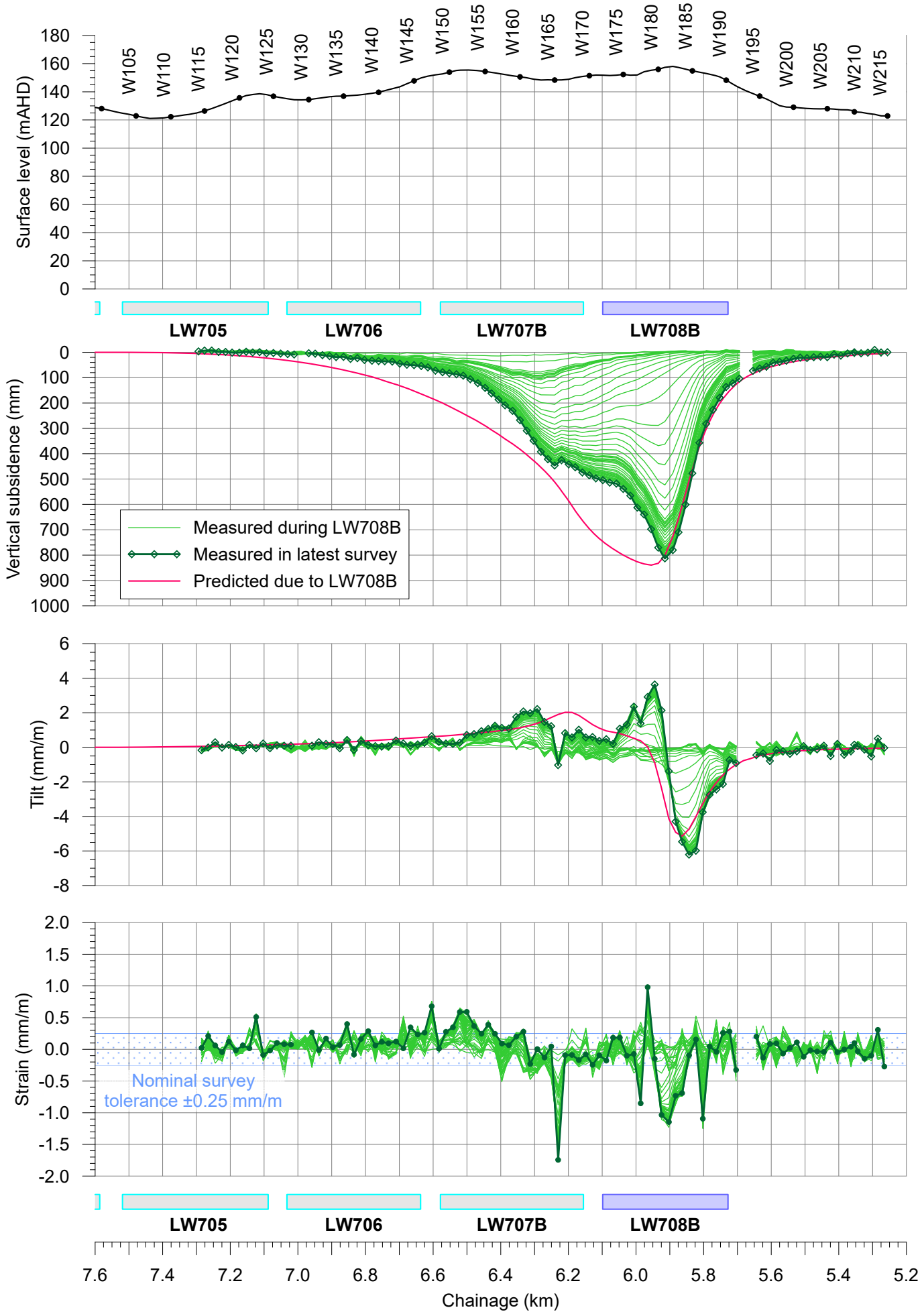
Measured and predicted profiles of incremental vertical subsidence, tilt and strain along M31 East Line due to LW708B



msec

Fig. A.03

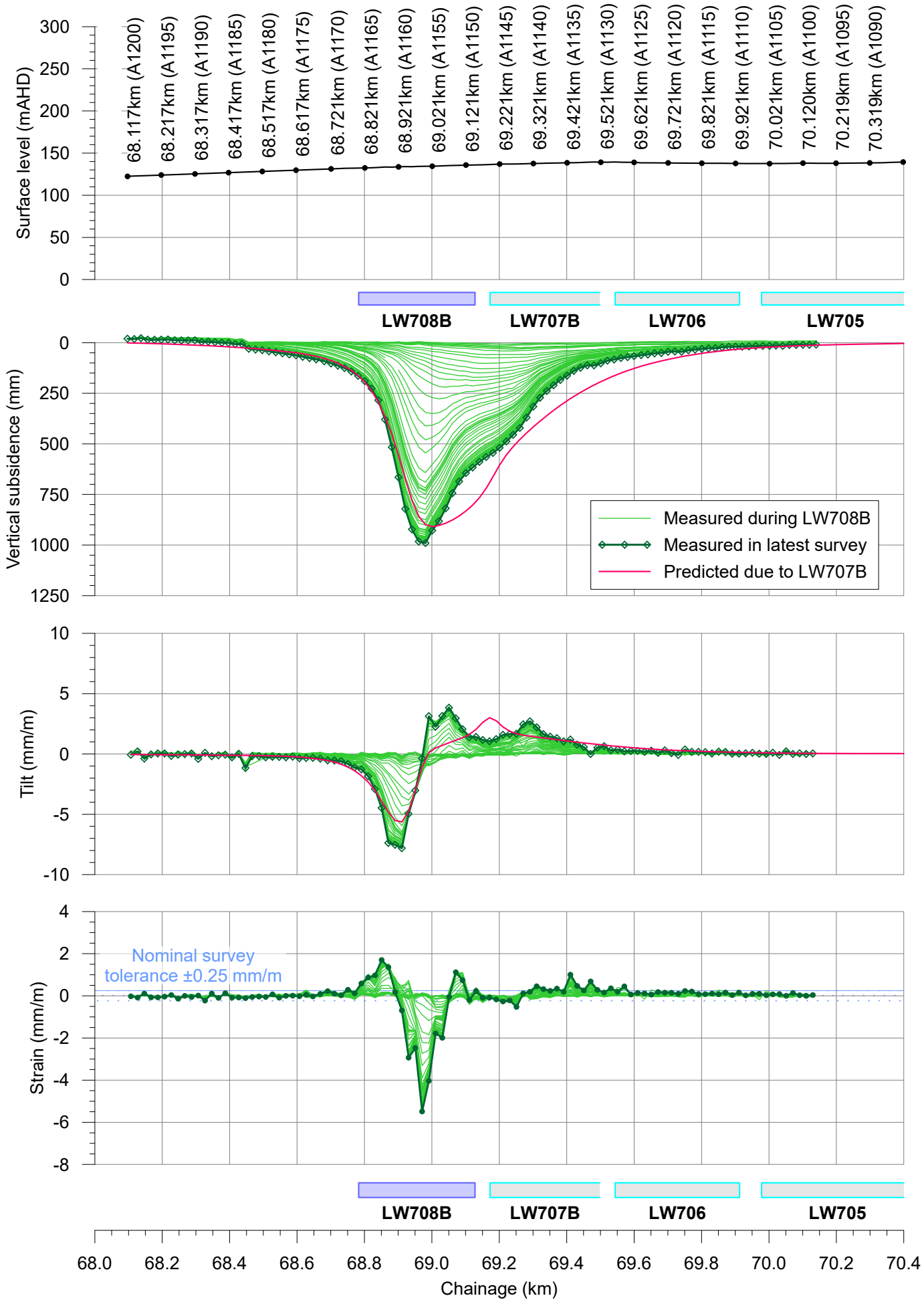
Measured and predicted profiles of incremental vertical subsidence, tilt and strain along M31 West Line due to LW708B



msec

Fig. A.04

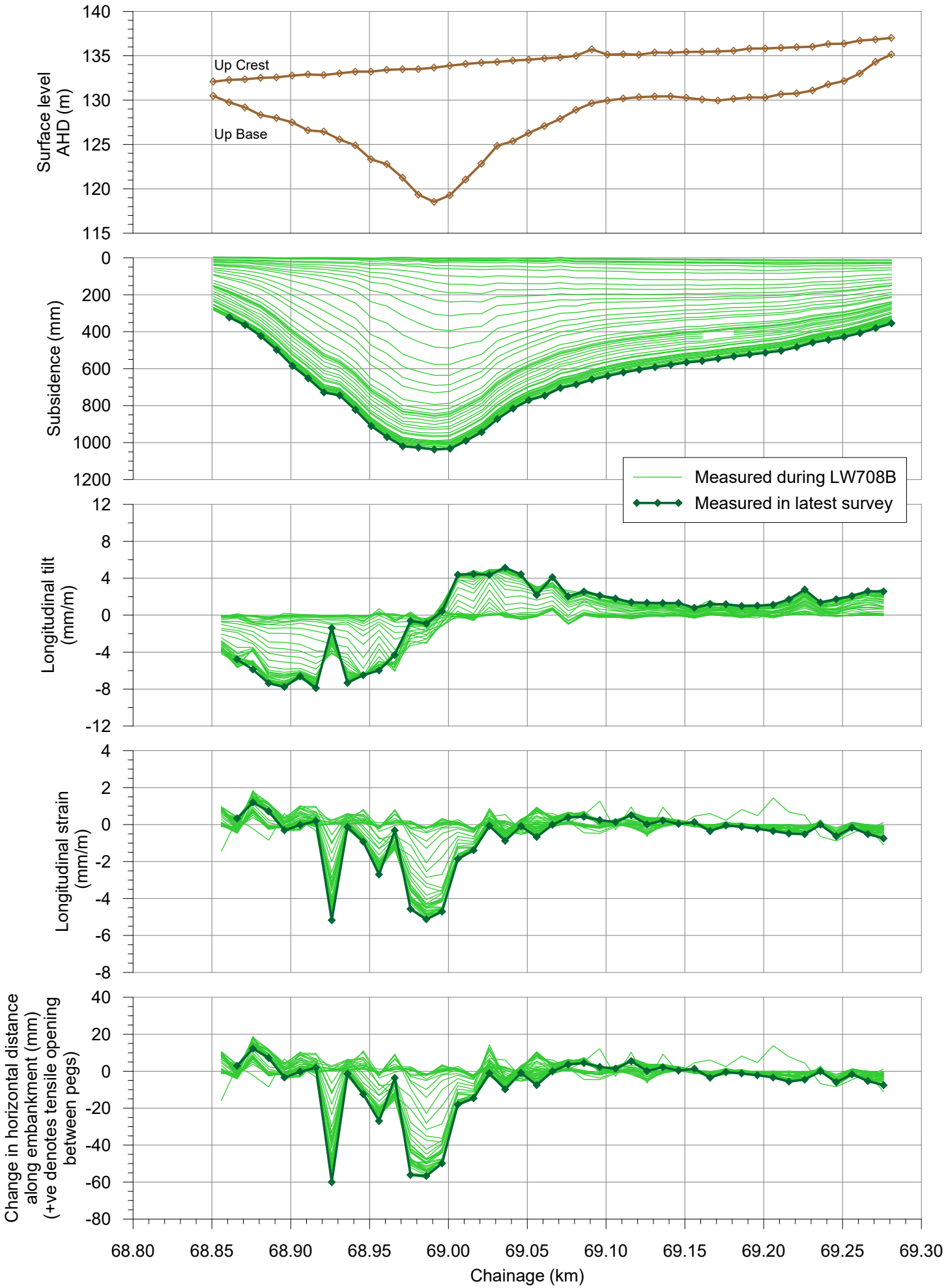
Measured and predicted profiles of incremental vertical subsidence, tilt and strain along the ARTC Line due to LW708B



msec

Fig. A.05

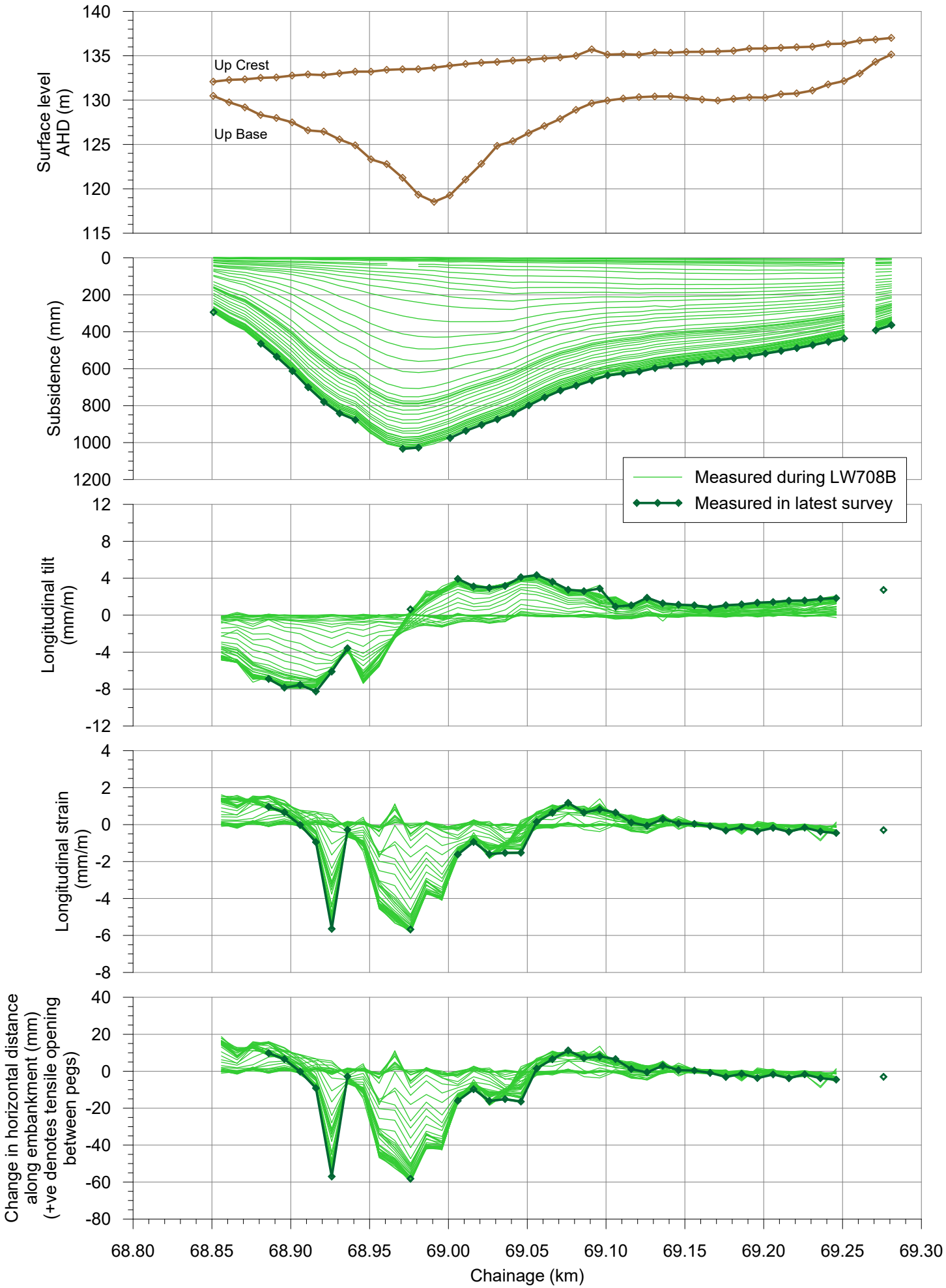
Appin Colliery - LW708B - Embankment at 69.0km
Incremental Subsidence Profiles along Up Base



msec

Fig. A.06

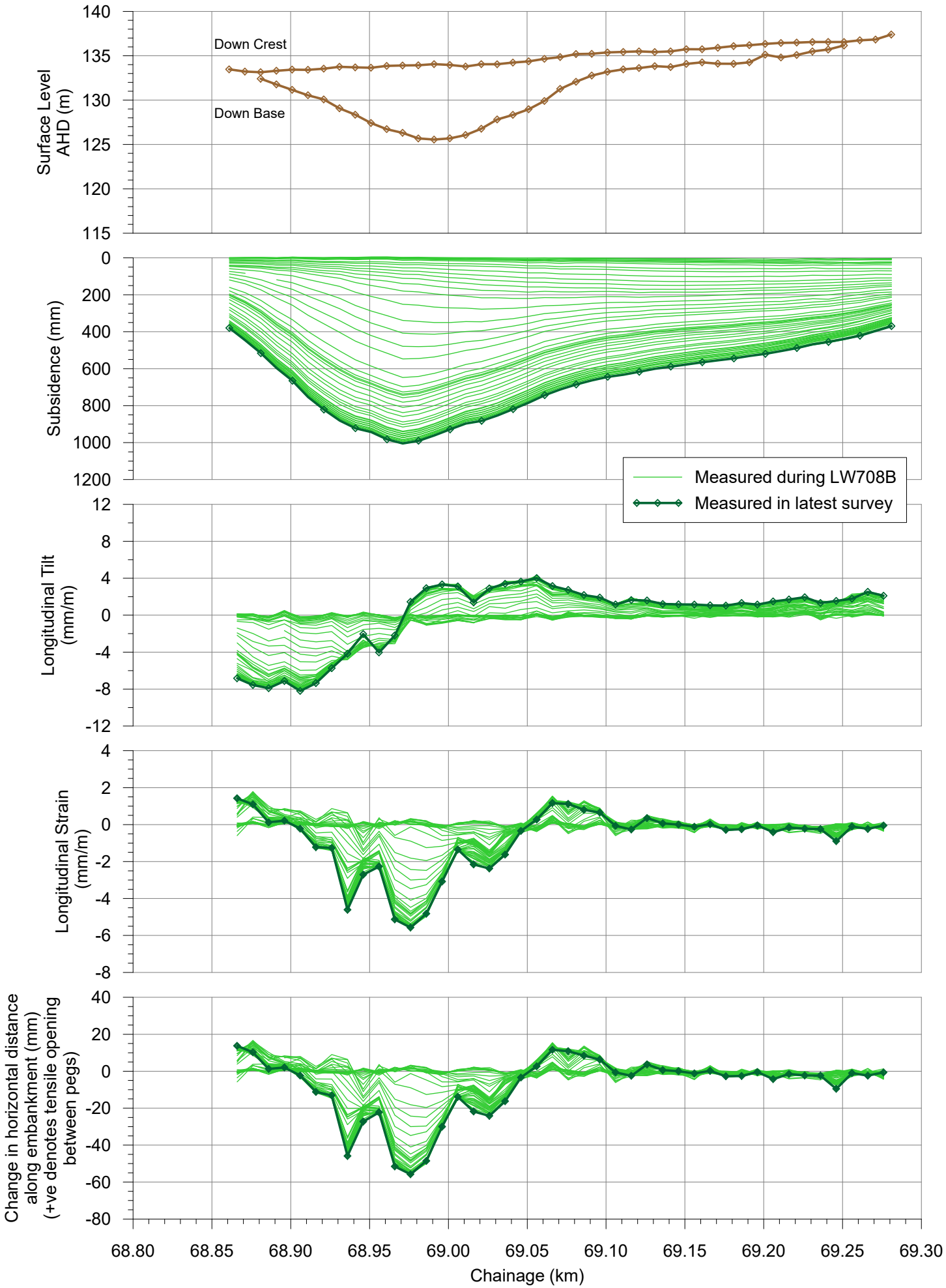
Appin Colliery - LW708B - Embankment at 69.0km
Incremental Subsidence Profiles along Up Crest



msec

Fig. A.07

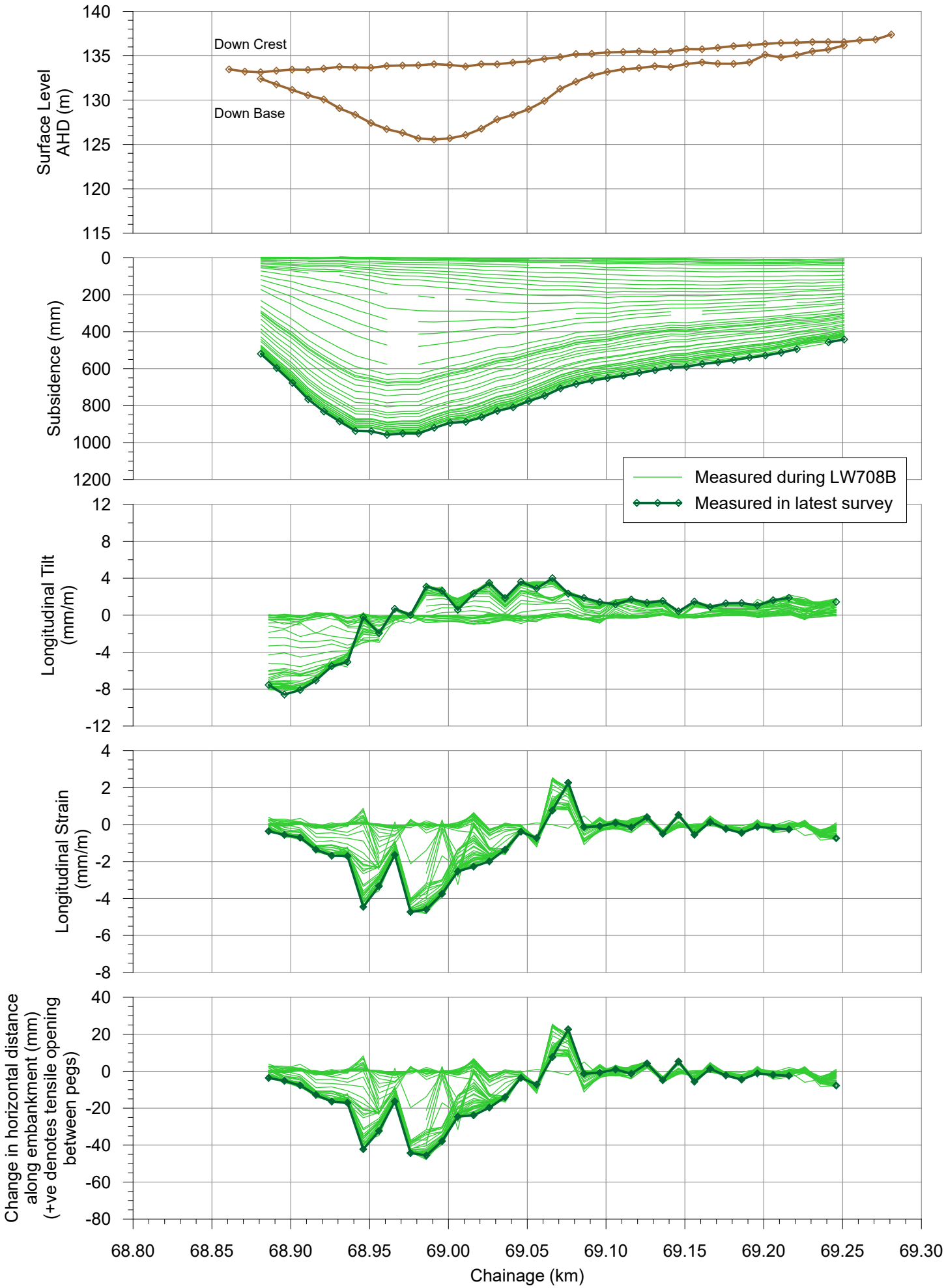
Appin Colliery - LW708B - Embankment at 69.0km
Incremental Subsidence Profiles along Down Crest



msec

Fig. A.08

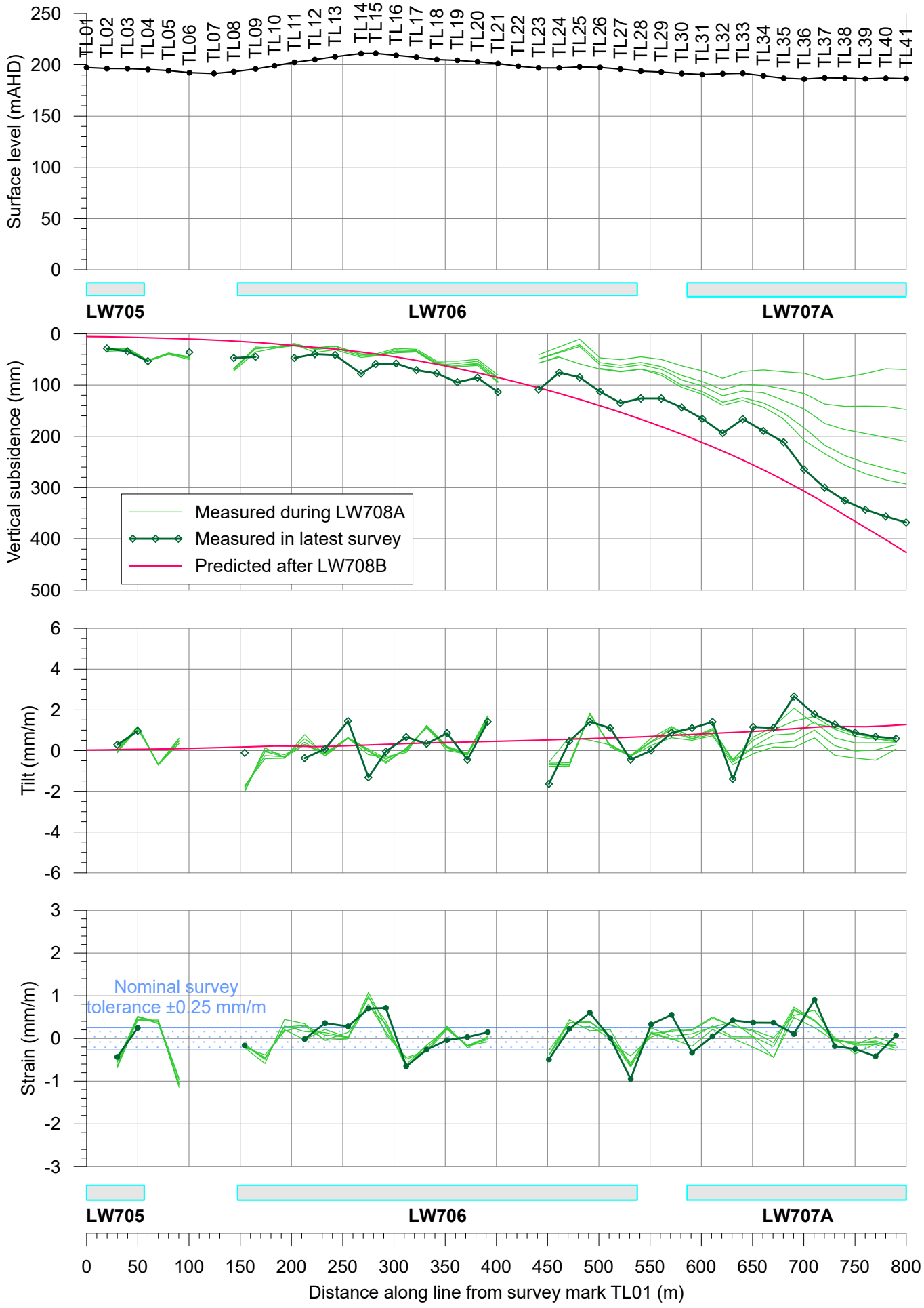
Appin Colliery - LW708B - Embankment at 69.0km
Incremental Subsidence Profiles along Down Base



msec

Fig. A.09

Measured and predicted profiles of incremental vertical subsidence, tilt and strain along the Telstra Line due to LW708A and LW708B



msec

Fig. A.10

APPENDIX B. DRAWINGS

I:\Projects\Appin\Area 7\MSEC1250 - LW708 End of Panel Report\AcadData\MSEC1250-01 General Layout & Monitoring Lines.dwg

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SOUTH32

ILLAWARRA METALLURGICAL COAL
LW708 END OF PANEL
GENERAL LAYOUT AND MONITORING LINES

DATE:	SCALE:	DRAWING No:	Rev No
28 Apr 2022	1:20 000	MSEC1250-01	A

LEGEND:
SURVEY POINTS & LINES

Grid to MGA co-ordinates

LW 708B
LW 708A
LW 707B
LW 707A
LW 706
LW 705
LW 704
LW 703
LW 702

HAWKEY RD
CARROLLS ROAD
MENANGLE ROAD
MAIN SOUTHERN RAILWAY
M31 HUME MOTORWAY
PARTRIDGE VC REST AREA
RW-LINE
ARTC LINE
M31 WEST-LINE
M31 EAST-LINE
MORETON PARK ROAD
TL-LINE
RAILWAY EMBANKMENT
RAILWAY CUTTING
MORETON PARK RD
HARRIS CK
NEPEAN RIVER
UPPER CANAL

R-Line
Q-Line
P-Line
N-Line
M-Line
L-Line
K-Line
J-Line
RUBAIN PEGS
CUSTANCE PEGS
CLST301
C-LINE
D-LINE
E-LINE
F-LINE
G-LINE
H-LINE
I-Line
B-LINE

BURRELL2
PM61513
W001
W115
SH2-NE
MPR113
MPR001
A33
A32
A9FF08
E001

289 000
290 000
291 000
292 000
288 000
6 218 000
6 217 000
6 216 000

TO DOUGLAS PARK BRIDGE (SEE INSET MAP)

DOUGLAS PARK RAILWAY STATION

DOUGLAS PARK BRIDGE

BLADES BRIDGE
DPSG1
DPSG2
DPSG3
DPS4
DPN5
DPN4
DPN3
DPN1
M31 HUME MOTORWAY
DOUGLAS PARK BRIDGE
NEPEAN RIVER
6 216 000

I:\Projects\Appin\Area 7\MSEC1250 - LW708 End of Panel Report\AcadData\MSEC1250-02 Natural Features.dwg

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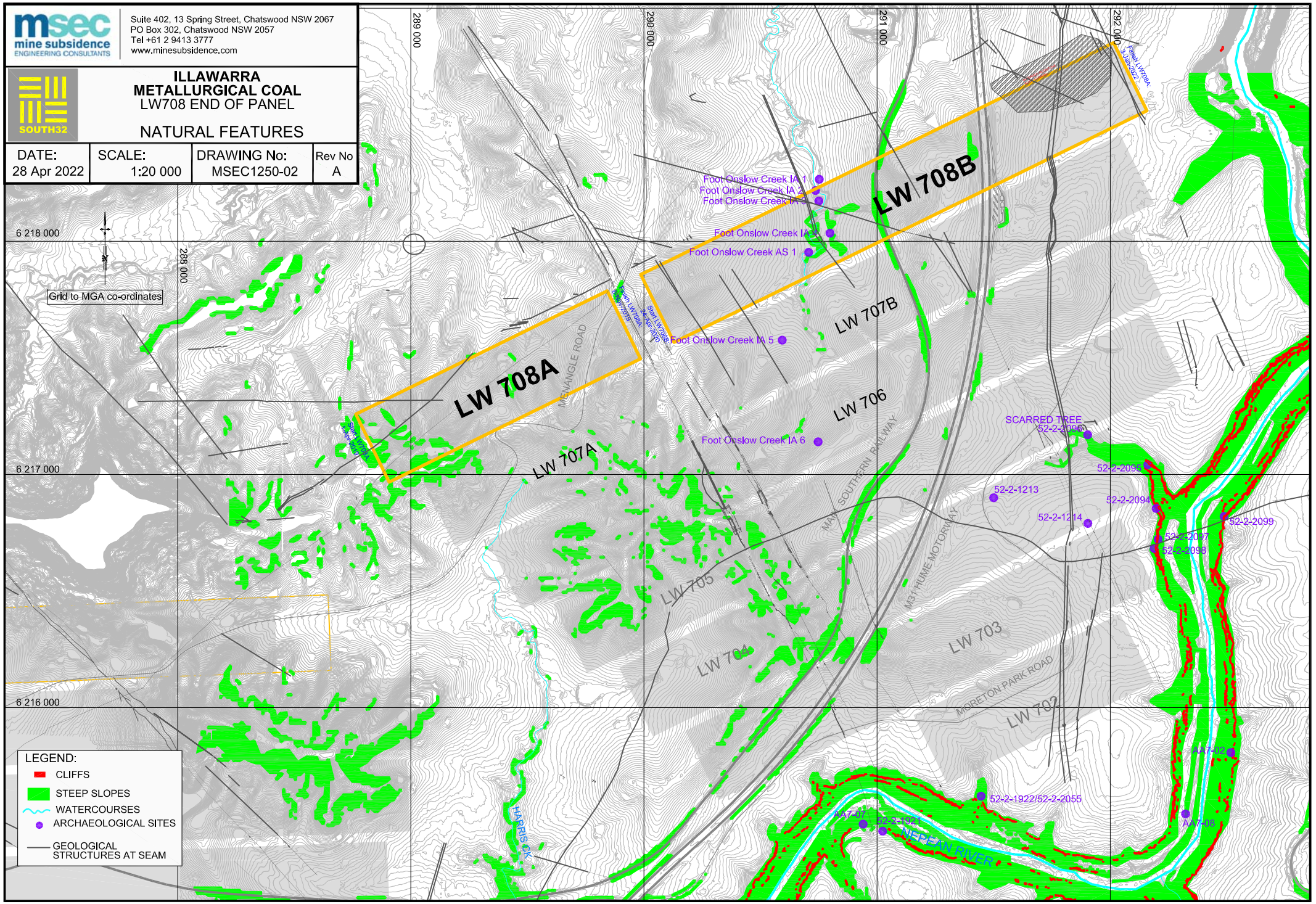
ILLAWARRA METALLURGICAL COAL
LW708 END OF PANEL
NATURAL FEATURES

DATE:	SCALE:	DRAWING No:	Rev No
28 Apr 2022	1:20 000	MSEC1250-02	A



I:\Projects\Appin\Area 7\MSEC1250 - LW708 End of Panel Report\AcadData\MSEC1250-03 Surface Infrastructure.dwg

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ILLAWARRA METALLURGICAL COAL
LW708 END OF PANEL
SURFACE INFRASTRUCTURE

DATE:	SCALE:	DRAWING No:	Rev No
28 Apr 2022	1:20 000	MSEC1250-03	A

289 000 290 000 291 000 292 000
6 218 000 6 217 000 6 216 000

LW 708B LW 708A LW 707B LW 707A LW 706 LW 705 LW 704 LW 703 LW 702

MAIN SOUTHERN RAILWAY
M31 HUME MOTORWAY
PARTRIDGE VC REST AREA
MENANGLE ROAD
MORETON PARK ROAD
DOUGLAS PARK RAILWAY STATION
HARRIS CK
NEPEAN RIVER
Finish LW708A: 3-Jan-2022 NEW FIBRE OPTIC (HIGHWAY) DOUBLE CONDUIT
Start LW708A: 24-Nov-2020
Start LW708B: 24-Nov-2020
Finish LW708A: 8-Nov-2019

Pump 17311
Pump 19430
Pump 19333

Mountbatten 1
Mountbatten 2
Site 2A Mountbatten Group
Harris Creek 1
Harris Creek 2
Harris Creek 3
Morton Park Road 1
Morton Park Road 2
Site 38 Upper Nepean Water Supply System Canal

SS 97734 PM 87186 PM 61513 PM 87183 SS 67659 PM 67986 SS 16320 TS 10421 PM 25150 PM 60540 PM 60539 PM 60538 PM 60537 SS 16325 PM 25153 PM 66381 GW101437 SS 37523 GW104154 SS 16324 SS 16322 SS 97155 PM 60536 PM 67990 SS 98566 PM 50014

LEGEND
- Heritage Sites
- Building Structures & Farm Dams
- Roads & Roads Culverts
- Railway & Rail Culverts
- Groundwater Bores
- Survey Marks
- Telecommunications: Optical Fibre Cables, Copper Cables
- Electrical Infrastructure: Low Voltage Lines, 66kV Line, Power Poles

Grid to MGA co-ordinates