mine subsidence ENGINEERING CONSULTANTS

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Illawarra Coal

SOUTH32 ILLAWARRA COAL:

Appin Colliery – Longwalls 707A and 707B

End of Panel Subsidence Monitoring Report for Appin Longwalls 707A and 707B

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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

MSEC831-01 to MSEC831-60 – Subsidence Monitoring Review Reports for the Main Southern Railway, issued during the extraction of Longwall 707B between February 2017 and August 2018.

MSEC832-01 to MSEC832-60 – Subsidence Monitoring Review Reports for the M31 Hume Motorway, issued during the extraction of Longwall 707B between March 2017 and July 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)

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

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1.1. Introduction

Illawarra Coal (IC) has completed the extraction of Longwalls 707A and 707B (LW707A and LW707B) 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. MSEC975-01, 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 LW707A and LW707B

Longwall	Commencement date	Finishing date
LW707A	7 January 2016	16 August 2016
LW707B	26 September 2016	19 June 2018

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IC 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 SMP Application for LW705 to LW710.

The SMP Application had LW707 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 of the Modification Application for LW707A and LW707B.

The Department of Planning and Environment (Resources Regulator) granted IC approval for the extraction of the modified LW707A and LW707B on the 9 June 2016.

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

- comparisons between the measured and predicted subsidence movements at the monitoring lines and points resulting from the extraction of LW707A and LW707B; and
- comparisons between the observed and predicted effects and impacts on the natural and built features resulting from the extraction of LW707A and LW707B.

Further details on the observed and assessed impacts for some natural features, due to the extraction of LW707A and LW707B, 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 extraction of LW707A and LW707B. This chapter also provides comparisons between the measured and predicted movements due to the extraction of these longwalls.

Chapter 3 of this report describes the natural and built features near LW707A and LW707B. This chapter also provides comparisons between the observed and assessed impacts for these surface features due to the extraction 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. MSEC975-01, in Appendix B. A summary of the as-extracted dimensions for LW702 to LW707B 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

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 1026 m for LW707A and 2061 m for LW707B. The longwall face widths excluding the first workings are approximately 314 m. The length of the coal block between LW707A and LW707B is 230 m.

The longwalls in Area 7 have been extracted from the Bulli Seam, from the west towards the east, i.e. towards the Nepean River. The natural surface and seam levels along the centreline of LW707A and LW707B are illustrated in Fig. 1.1.

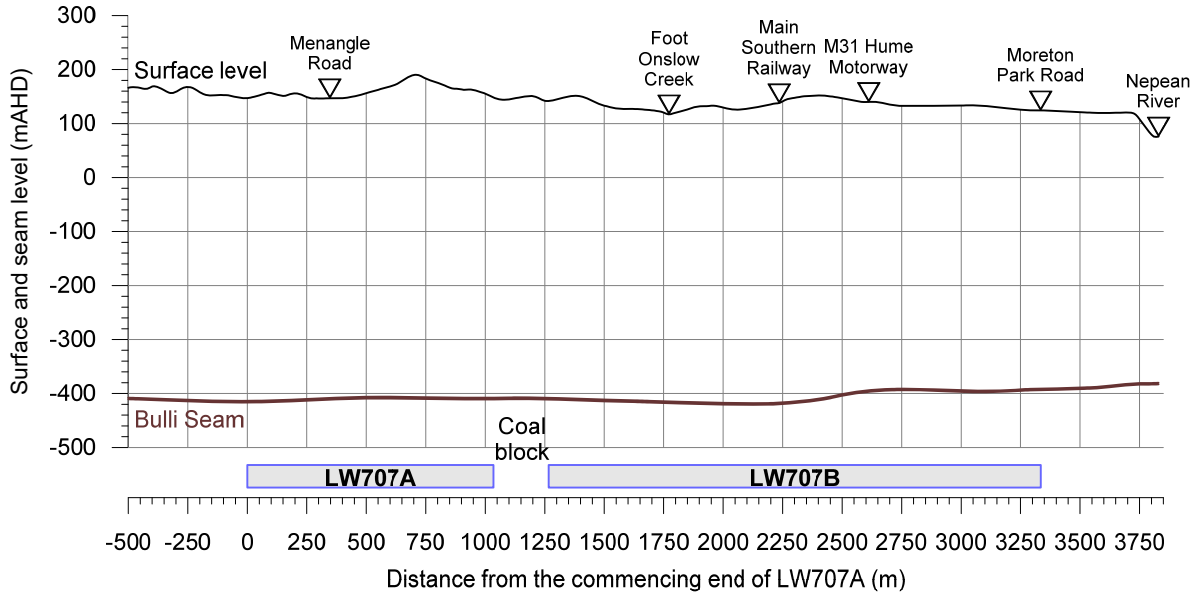


Fig. 1.1 Surface and seam levels along the centrelines of LW707A and LW707B

The depth of cover to the Bulli Seam varies between a minimum of 475 m above the finishing (i.e. eastern) end of LW707B and a maximum of 600 m near the commencing (i.e. western) end of LW707A. The seam thickness varies between 2.8 m and 3.4 m within the extents of these longwalls. IC extracted the full thickness of the Bulli Seam.

2.1. Introduction

The mine subsidence movements due to the extraction of LW707A and LW707B 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. MSEC975-01, in Appendix B. Comparisons between the measured and predicted subsidence movements 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 develop the predicted subsidence contours that were presented in Reports Nos. MSEC342 and MSEC825.

2.2. Nepean River closure lines

The closure movements across the Nepean River valley were measured by IC using 2D survey techniques along six monitoring lines during the extraction of LW707B. The monitoring lines comprise the Nep X N-Line, Nep X O-Line, Nep X P-Line, Nep X Q-Line and Nep X R-Line.

The locations of the Nepean River closure lines are shown in Drawing No. MSEC975-01, in Appendix B. A summary of the survey dates during LW707B is provided in Table 2.1.

Table 2.1 Survey dates for the Nepean River closure lines for LW707B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly surveys from the commencement of LW707B and then at the completion of the longwall	30 November 2015 (end of LW706) 24 January 2018 20 February 2018 27 March 2018 4 May 2018 27 June 2018 (end of LW707B)	As per approved LW708 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 extraction of LW702 to LW707B, is illustrated in Fig. 2.1. The base survey for the Nep X R-Line was carried out during the mining of LW706 and, therefore, it only measured the movements due to LW706, LW707A and LW707B.

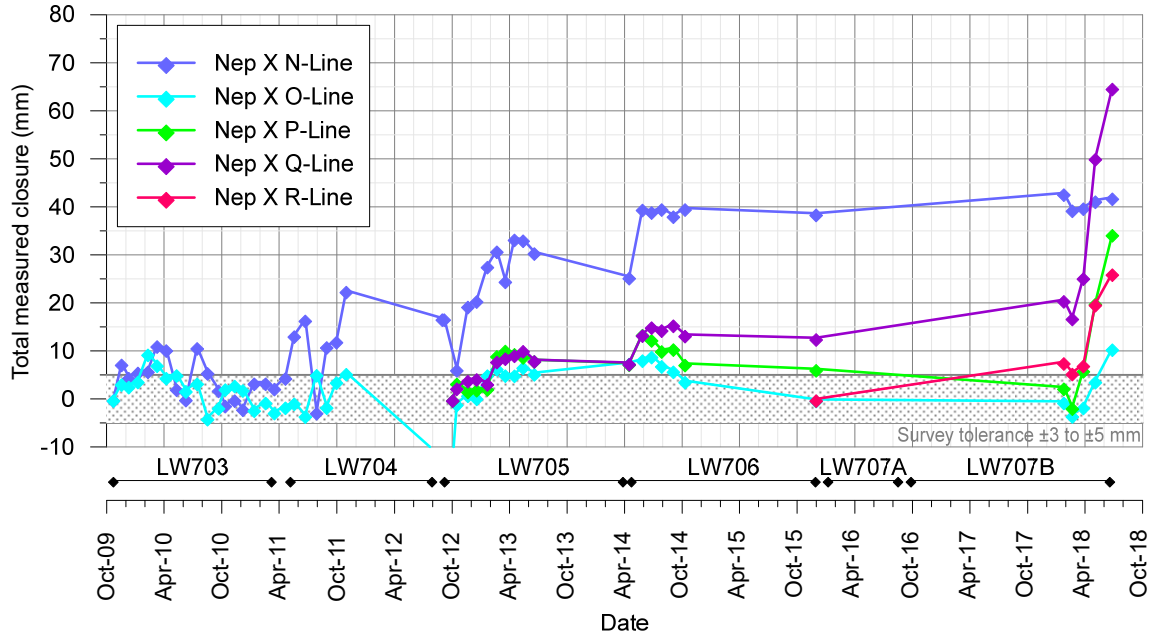


Fig. 2.1 Development of total closure for the Nepean River closure lines

The predictions of vertical subsidence, upsidence and closure for the Nepean River, due to the extraction of LW702 to LW710, were provided in Reports Nos. MSEC342 and MSEC825. The measured and predicted total closures along the Nepean River after the completion of LW707B are illustrated in Fig. 2.2.

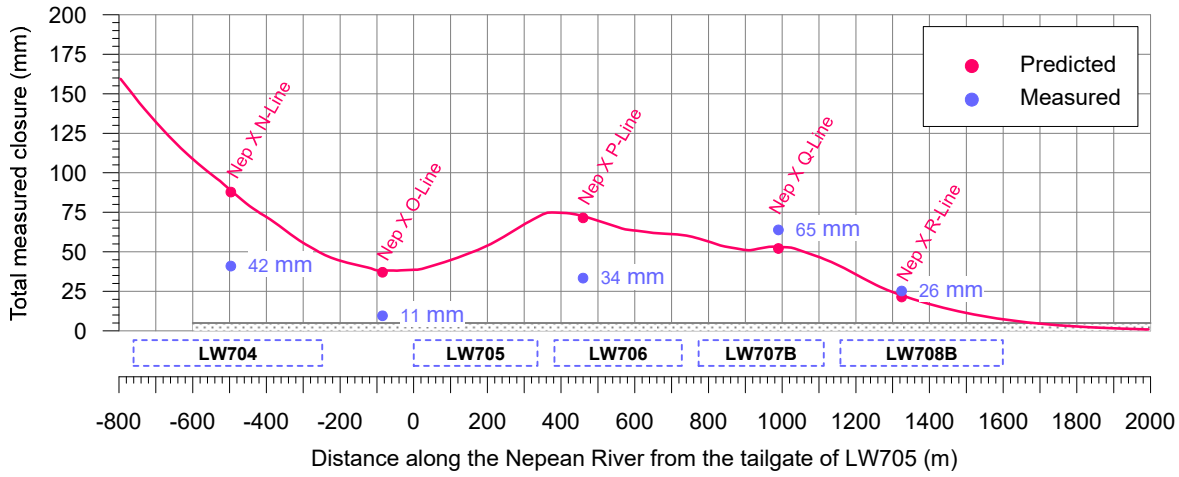


Fig. 2.2 Measured and predicted total closure along the Nepean River after LW707B

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 shortened finishing ends of LW705, LW706 and LW707B.

Table 2.2 Measured and predicted total closure at the Nepean River closure lines after LW707B

Location	Longwalls	Measured total closure (mm)	Predicted total closure (mm)
Nep X N-Line	LW702 to LW707B	42	90
Nep X O-Line	LW702 to LW707B	11	40
Nep X P-Line	LW702 to LW707B	34	70
Nep X Q-Line	LW702 to LW707B	65	50
Nep X R-Line	LW707B only	26	20

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

The measured total closures at the Nep X N-Line, Nep X O-Line and Nep X P-Line were less than the predicted values at the completion of LW707B. The measured total closures at the Nep X Q-Line and Nep X R-Line are greater than the predicted values; however, the exceedances of 15 mm and 6 mm, respectively, are in the order of accuracy of survey tolerance and the prediction method. The closures measured at these two monitoring lines are considerably less than the maximum measured closure anywhere along the Nepean River of 182 mm, at the Nep X C-Line, aft the completion of LW704.

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

2.3. Moreton Park Road monitoring line

The mine subsidence movements along Moreton Park Road were measured by IC using a 3D monitoring line. The location of the Moreton Park Road monitoring line is shown in Drawing No. MSEC975-01, in Appendix B. A summary of the survey dates during the extraction of LW707B is provided in Table 2.3.

Table 2.3 Survey dates for the Moreton Park Road monitoring line during LW707B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Start of LW707B, and then monthly after 300 m extraction and then at the completion of the longwall	3 February 2016 (end of LW706) 13 December 2017 18 January 2018 15 February 2018 15 March 2018 12 April 2018 9 May 2018 28 June 2018 (end of LW707B)	As per approved LW708 monitoring program

The profiles of measured and predicted incremental vertical subsidence, tilt and strain along the Moreton Park Road monitoring line, due to the extraction of LW707B, are shown in Fig. A.01, in Appendix A. The predictions are based on the subsidence contours presented in Reports Nos. MSEC342 and MSEC825.

The location of maximum measured incremental vertical subsidence reasonably coincides with the predicted location. However, the magnitude of the maximum measured vertical subsidence is less than that predicted. The reason is the monitoring line is located directly above the finishing end of LW707B and, therefore, the longwall end effects have reduced the subsidence more than that predicted. The extent of vertical subsidence above the earlier extracted LW704 and LW705 is similar to that 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 extraction of LW707B only.

Table 2.4 Maximum measured and predicted incremental vertical subsidence, tilt and strain along the Moreton Park Road monitoring line due to LW707B 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	120	0.9	0.3	0.4
Predicted	270	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 extraction of LW707B only, are less than the predicted values. Only low-level incremental movements occurred along the monitoring line as it crosses above the finishing end of LW707B.

The maximum measured incremental strains are 0.3 mm/m tensile and 0.4 mm/m compressive. No localised or irregular ground movements occurred due to the extraction of LW707B. 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.

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 and MSEC825.

2.4. Menangle Road monitoring line

The mine subsidence movements along Menangle Road were measured by IC using a 3D monitoring line. The location of the Menangle Road monitoring line is shown in Drawing No. MSEC975-01, in Appendix B. A summary of the survey dates during the extraction of LW707A is provided in Table 2.5.

Table 2.5 Survey dates for the Menangle Road monitoring line during LW707A

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Weekly during the extraction of LW707A and then at the completion of the longwall	4 November 2015 (end of LW706) 24 February 2016, then approximately weekly to 6 October 2016 (end of LW707A)	As per approved LW708 monitoring program

The profiles of measured and predicted incremental vertical subsidence, tilt and strain along the Menangle Road monitoring line, due to the extraction of LW707A, are shown in Fig. A.02, in Appendix A. The predictions are based on the subsidence contours presented in Reports Nos. MSEC342 and MSEC825.

The profile of measured incremental vertical subsidence reasonably matches the predicted profile along the Menangle Road monitoring line. However, the magnitude of the measured vertical subsidence is less than that predicted above LW707A. Localised upsidence has occurred where the monitoring line crosses two tributaries 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 total tilt also reasonably matches the predicted profile. However, there are localised irregularities in the measured tilt profile in the locations of upsidence and the irregular ground movement along the monitoring line. Similarly, localised compressive strains also developed in these locations.

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 extraction of LW707A only.

Table 2.6 Maximum measured and predicted incremental vertical subsidence, tilt and strain along the Menangle Road monitoring line due to LW707A 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	468	6.6*	1.4*	2.0*
Predicted	950	5.5	*- 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 468 mm is approximately half of the maximum predicted incremental vertical subsidence of 950 mm. The monitoring line is located close to the commencing end of the adjacent LW706 and, therefore, the end effects from that longwall could have reduced the subsidence more than that predicted. That is LW707A may have acted more as a first panel in the series, in the location of maximum predicted vertical subsidence, where the monitoring line crosses the longwall tailgate adjacent to the previously extracted LW706.

The maximum measured incremental tilt of 6.6 mm/m occurs in the location of localised uplift near the top of the hill above LW707A. Away from this localised irregular movement, the maximum measured tilt is 4.3 mm/m and it is less than the maximum predicted value of 5.5 mm/m.

The maximum measured incremental tensile and compressive strains occur in the location of localised uplift near the top of the hill above LW707A. Localised compressive strains also occur where the monitoring line crosses the two tributaries to Harris Creek. Elsewhere, away for the irregular ground movements, 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.

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

2.5. M31 Hume Motorway

The M31 Hume Motorway crosses directly above LW707B as shown in Drawings Nos. MSEC975-01 and MSEC975-03, in Appendix B. The monitoring associated with the motorway for LW707B 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 (MSEC832-01 to MSEC832-60), which were issued during the extraction of LW707B between March 2017 and August 2018.

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 movements along the M31 Hume Motorway were measured by IC 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. MSEC975-01, in Appendix B. A summary of the survey dates during the extraction of LW707B is provided in Table 2.7.

Table 2.7 Survey dates for the M31 East Line and M31 West Line during LW707B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Survey full length of monitoring lines at start and end of LW707B, then monthly 3D surveys after 2000 m of extraction until one month after completion of LW707B, plus weekly focused 2D surveys after 2300 m of extraction until one month after completion of LW707B	1 March 2017, then monthly surveys to the 14 November 2017, and then weekly surveys to the 22 May 2018, 3 July 2018 16 August 2018	As per approved LW708 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 extraction of LW707B, are shown in Figs. A.03 and A.04, respectively, in Appendix A. The predictions are based on the subsidence contours presented in Reports Nos. MSEC342 and MSEC825.

The profile of measured incremental vertical subsidence reasonably matches the predicted profile on the maingate side; however, the subsidence measured above the chain pillars 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 M31 East Line and M31 West Line is provided in Table 2.8. The values represent the additional movements due to the extraction of LW707B 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 LW707B 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	824	7.6	1.6	2.2
	Predicted	925	6.0	*- Refer to discussions below -*	
M31 West Line	Measured	904	8.6	1.6	2.1
	Predicted	925	4.9	*- 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 824 mm and 904 mm, respectively, were less than the maximum predicted value of 925 mm. The maximum measured vertical subsidence along these monitoring lines were located slightly closer to the longwall maingate than the predicted locations.

The maximum measured incremental tilt along the M31 East Line of 7.6 mm/m was slightly greater than the maximum predicted value of 6.0 mm/m. The maximum measured tilt along the M31 West Line of 8.6 mm/m was greater than the maximum predicted tilt of 4.9 mm/m. The measured tilts were greater than predicted values due to the lower subsidence measured above the longwall maingate resulting in steeper profiles.

The maximum measured incremental tensile strains along the M31 East Line and M31 West Line were both 1.6 mm/m. The maximum measured incremental compressive strains along the M31 East Line and M31 West Line were 2.2 mm/m and 2.1 mm/m, respectively.

The maximum compressive strains were localised between Marks E165 and E166 along the East Line and between Marks W160 and W161 along the West Line. These strains were also associated with bumps in the measured vertical subsidence profiles and lateral misalignment. This indicates that non-conventional movements have developed at these locations. The maximum tensile and compressive strains are coincident with the location of a small creek and, therefore, could include valley closure effects.

Elsewhere, the maximum measured strains along the M31 East Line and M31 West Line 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 and MSEC825.

2.5.2. FBG and slot displacement monitoring

FBG monitoring

A total of 785 temperature and 785 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 LW707B.

The temperature compensated FBG strains exceeded the trigger levels in the management plan at two locations during the mining of LW707B.

A blue alarm was received on the 27 December 2017 for an exceedance of compressive strain at FBG170.4 on the Northbound Carriageway. A small hump had been previously observed at this location, which had not changed. There were no immediate concerns at that stage. Extraction of LW707B temporarily stopped and very little change in pavement strain was observed. The hump continued to gradually increase in size and the pavement was resurfaced on 2 February 2018.

The compressive strain at FBG170.4 started to increase upon recommencement of extraction of LW707B in March 2018. The Technical Committee agreed to increase the trigger level to -1.1 mm/m on 20 March 2018. A blue alarm was received on 19 April 2018 at FBG170.4 and a visual inspection was carried out. There were no immediate concerns noted from the site inspection, though minor bumps had re-emerged since the pavement had been resurfaced.

The Technical Committee agreed to increase the trigger level to -1.3 mm/m on 26 April 2018. The compressive strain at FBG170.4 continued to increase gradually and the pavement deformation gradually worsened. The pavement was resurfaced again on 24 May 2018, with very minor changes observed since that time.

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 LW707B. The slot displacements did not exceed the management plan trigger levels for closure at any stage during the mining of LW707B. As slots SB159, SB171 and SB173 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 LW707B was 56 mm at SB171 and 51 mm at NB172.

Further investigations found that slot sensors SB171 and NB172 had reached their monitoring limits and SB173 was very close to its monitoring limit. The Technical Committee met on the 2 May 2018 and agreed that an immediate repair was not required as rates of change from the mining of LW707B had reduced to low levels. After considering options, the Technical Committee selected the following actions:

- a check survey of pavement pins was conducted; and
- repair or replace the slot sensors at SB171, SB173 and NB172 prior to the influence of LW708B.

2.6. Main Southern Railway

The Main Southern Railway crosses directly above LW707B as shown in Drawings Nos. MSEC975-01 and MSEC975-03, in Appendix B. The monitoring associated with the railway for LW707B 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 (MSEC831 01 to MSEC831-60), which were issued during the extraction of LW707B between October 2016 and June 2018.

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 movements along the Main Southern Railway were measured by IC using a 3D ground monitoring line, referred to as the ARTC Line. The location of the monitoring line is shown in Drawing No. MSEC975-01, in Appendix B. A summary of the survey dates during the extraction of LW707B is provided in Table 2.9.

Table 2.9 Survey dates for the ARTC Line during LW707B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Start and end of LW707B, with monthly 3D surveys after 1700 m of extraction, plus weekly 2D focused surveys after 2200 m of extraction	3 January 2017, 9 February 2017, 7 March 2017, then weekly to the 3 April 2018, then monthly to the 10 July 2018 and then 14 August 2018	As per approved LW708 monitoring program

The profiles of measured and predicted incremental vertical subsidence, tilt and strain along the ARTC Line, due to the extraction of LW707B, are shown in Fig. A.05 in Appendix A. The predictions are based on the subsidence contours presented in Reports Nos. MSEC342 and MSEC825.

The profile of measured incremental vertical subsidence reasonably matches the predicted profile on the maingate side; however, the subsidence measured above the chain pillars 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 extraction of LW707B only.

Table 2.10 Maximum measured and predicted incremental vertical subsidence, tilt and strain along the ARTC Line due to LW707B 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	1036	7.9	1.0	6.0
Predicted	950	6.3	*- 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 1036 mm was greater than the maximum predicted value of 950 mm. The exceedance of 86 mm represents 9 % 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 7.9 mm/m was slightly greater than the maximum predicted value of 6.3 mm/m. The measured tilt was greater than that predicted adjacent to the maingate of LW707B due to the higher subsidence that developed directly above the longwall.

The maximum measured incremental tensile and compressive strains along the ARTC Line were 1.0 mm/m and 6.0 mm/m, respectively. The maximum measured compressive strain was localised between Marks ARTC1140 and ARTC1141 (i.e. kilometrage 69.31 km) and it was associated with a bump in the measured vertical subsidence profile. This indicates that a non-conventional movement had developed at this location. Elsewhere, the maximum measured strains along the ARTC Line 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 ARTC Line are consistent with the predictions provided in Reports Nos. MSEC342 and MSEC825.

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 LW707B. 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 LW707B. 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 movements along and across the Embankment at 70.5 km and Embankment at 69.0 km were measured by IC during the mining of LW707B. Summaries of the survey dates for the ARTC Embankments at 70.5 km and 69.0 km during the extraction of LW707B are provided in Table 2.11 and Fig. 2.12, respectively.

Table 2.11 Survey dates for the Embankment at 70.5 km during LW707B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly absolute 3D surveys after 1700 m of extraction	3 January 2017 9 February 2017 7 March 2017 4 April 2017 1 May 2017 10 July 2018	As per approved LW708 monitoring program

Table 2.12 Survey dates for the Embankment at 69.0 km during LW707B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly absolute 3D surveys after 1800 m of extraction, plus weekly local 3D surveys after 2000 m of extraction	9 February 2017 29 May 2017, then monthly to the 13 November 2017, then weekly to the 15 January 2018, then monthly to the 14 August 2018	As per approved LW708 monitoring program

The profiles of measured incremental vertical subsidence, tilt and strain along the Embankment at 70.5 km, due to the extraction of LW707B, are shown in Figs. A.06 to A.09, in Appendix A. The profiles of measured incremental vertical subsidence, tilt and strain along the Embankment at 69.0 km, due to the extraction of LW707B, are shown in Figs. A.10 to A.13, 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 both embankments on the Down side.

2.6.4. Culverts

The mine subsidence movements along the railway culverts at 70.5 km and 69.0 km were measured by IC using two 3D ground monitoring lines, referred to as the ARTC 70.5 km Culvert and ARTC 69.0 km Culvert. The locations of these monitoring lines are shown in Drawing No. MSEC975-01, in Appendix B. The measured changes in horizontal distance along the inverts of the ARTC 70.5 km Culvert and ARTC 69.0 km Culvert are shown in Fig. 2.3 and Fig. 2.4, respectively.

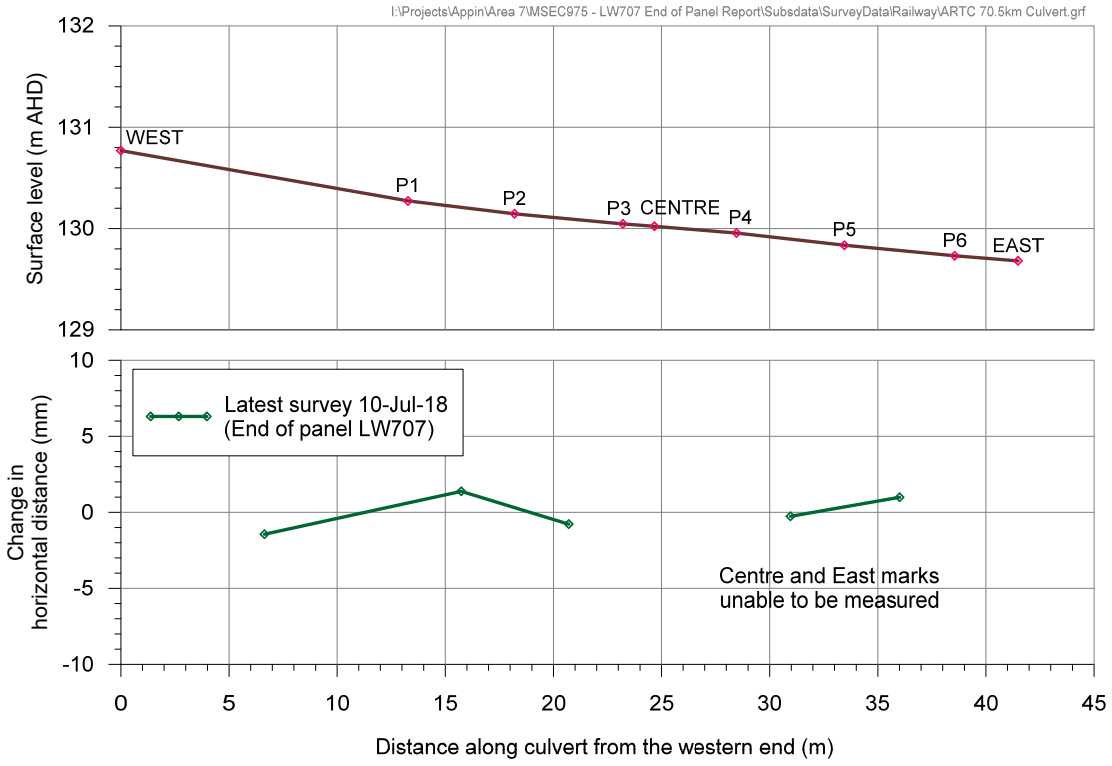


Fig. 2.3 Measured incremental changes in horizontal distance along the invert of the ARTC 70.5 km Culvert during to LW707B

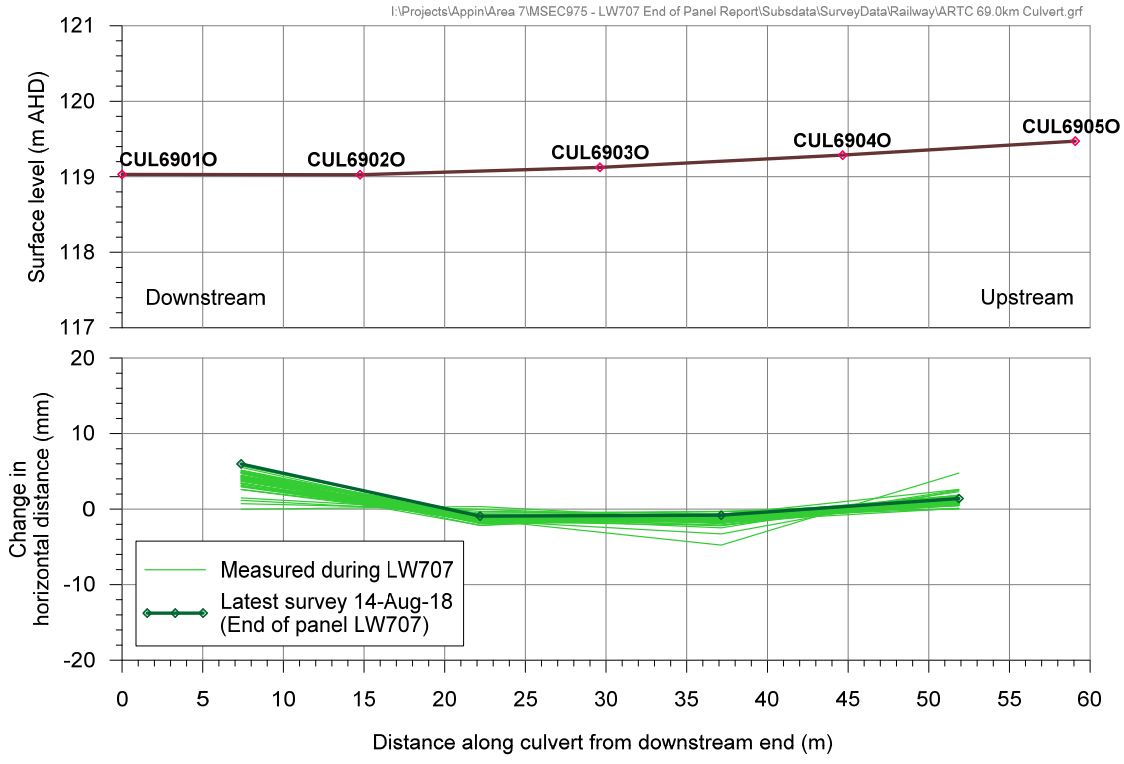


Fig. 2.4 Measured incremental changes in horizontal distance along the invert of the ARTC 69.0 km Culvert during to LW707B

2.7. Highway Cutting 2

The Highway Cutting 2 Points were measured by IC during the extraction of LW707B. 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. MSEC975-01 in Appendix B. A summary of the survey dates during the extraction of LW707B is provided in Table 2.13.

Table 2.13 Survey dates for the Highway Cutting 2 Points during LW707B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Monthly after 2000 m of extraction	1 March 2017 6 April 2017 3 May 2017 31 May 2017 5 July 2017 2 August 2017 29 August 2017 5 October 2017 14 November 2017 12 December 2017 9 January 2018 6 February 2018 6 March 2018 4 April 2018 1 May 2018 3 July 2018 16 August 2018	As per approved LW708 monitoring program

The final measured absolute incremental horizontal movements at the Highway Cutting 2 Points, after the completion of LW707B, are shown in Fig. 2.5.

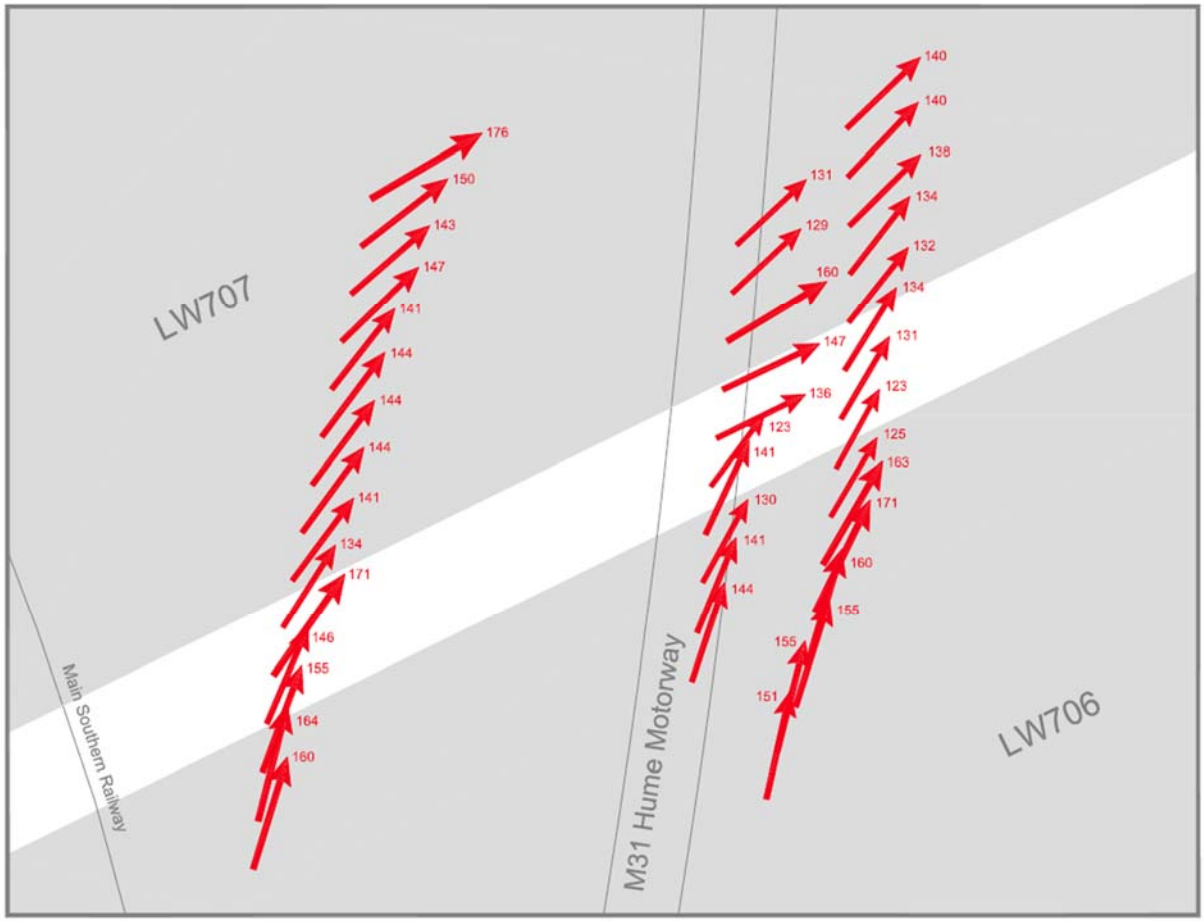


Fig. 2.5 Measured absolute incremental horizontal movements at the Highway Cutting 2 Points due to LW707B

A summary of the maximum measured absolute incremental horizontal movements at the cutting monitoring points is provided in Table 2.14. The values represent the additional movements due to the extraction of LW707B only.

Table 2.14 Maximum measured absolute incremental horizontal movements at the Highway Cutting 2 Points due to LW707B only

Longwall	Location	Maximum measured incremental horizontal movement (mm)
LW707B	W144 to W158	176
	G101 to G110	160
	E146R to E160R	171

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

2.8. Partridge VC Rest Area

The Partridge VC Rest Area points were measured by IC during the extraction of LW707B. The locations of these monitoring points are shown in Drawing No. MSEC975-01, in Appendix B. A summary of the survey dates during the extraction of LW707B is provided in Table 2.15.

Table 2.15 Survey dates for the Partridge VC Rest Area monitoring points during LW707B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Start and end of LW707B, with monthly surveys during mining after 2000 m of extraction of this longwall	1 March 2017 6 April 2017 3 May 2017 1 March 2017, then weekly surveys to the 22 May 2018, then 3 July 2018, and then 16 August 2018	As per approved LW708 monitoring program

The Partridge VC Rest Area experienced up to 859 mm of total vertical subsidence during the mining of LW707B. The ground strains were 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 movements were measured by IC using a number of 3D marks in the vicinity of LW707A and LW707B. The locations of these monitoring points are shown in Drawing No. MSEC975-01, in Appendix B. A summary of the survey dates during the extraction of LW707A and LW707B is provided in Table 2.16.

Table 2.16 Survey dates for the far-field 3D marks during LW707A and LW707B

Mining phase commitments	Mining phase survey dates	Post-mining phase commitments
Start and end of LW707A and LW707B, with monthly surveys during mining after 300 metres of extraction	18 March 2016, then monthly to 27 June 2017, and 7 August 2017, and then monthly to 19 April 2018, and 20 June 2018	As per approved LW708 monitoring program

The measured loci of absolute incremental horizontal movements at the far-field 3D marks, due to the extraction of LW707A and LW707B, are shown in Fig. 2.6.

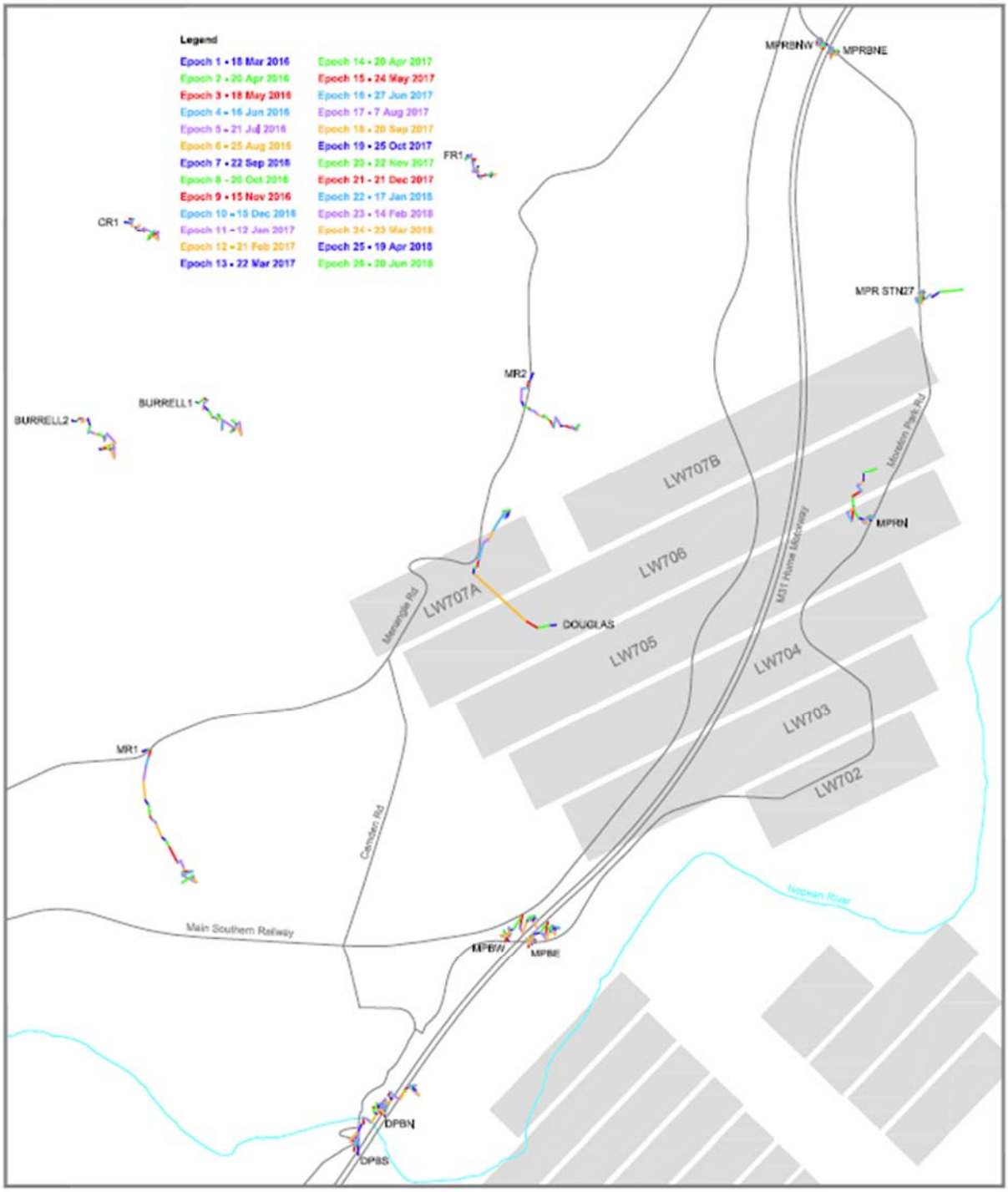


Fig. 2.6 Measured loci of absolute incremental horizontal movements at the far-field 3D marks during the extraction of LW707A and LW707B

The final measured absolute incremental horizontal movements at the far-field 3D marks, after the completion of LW707A and LW707B, are shown in Fig. 2.7.

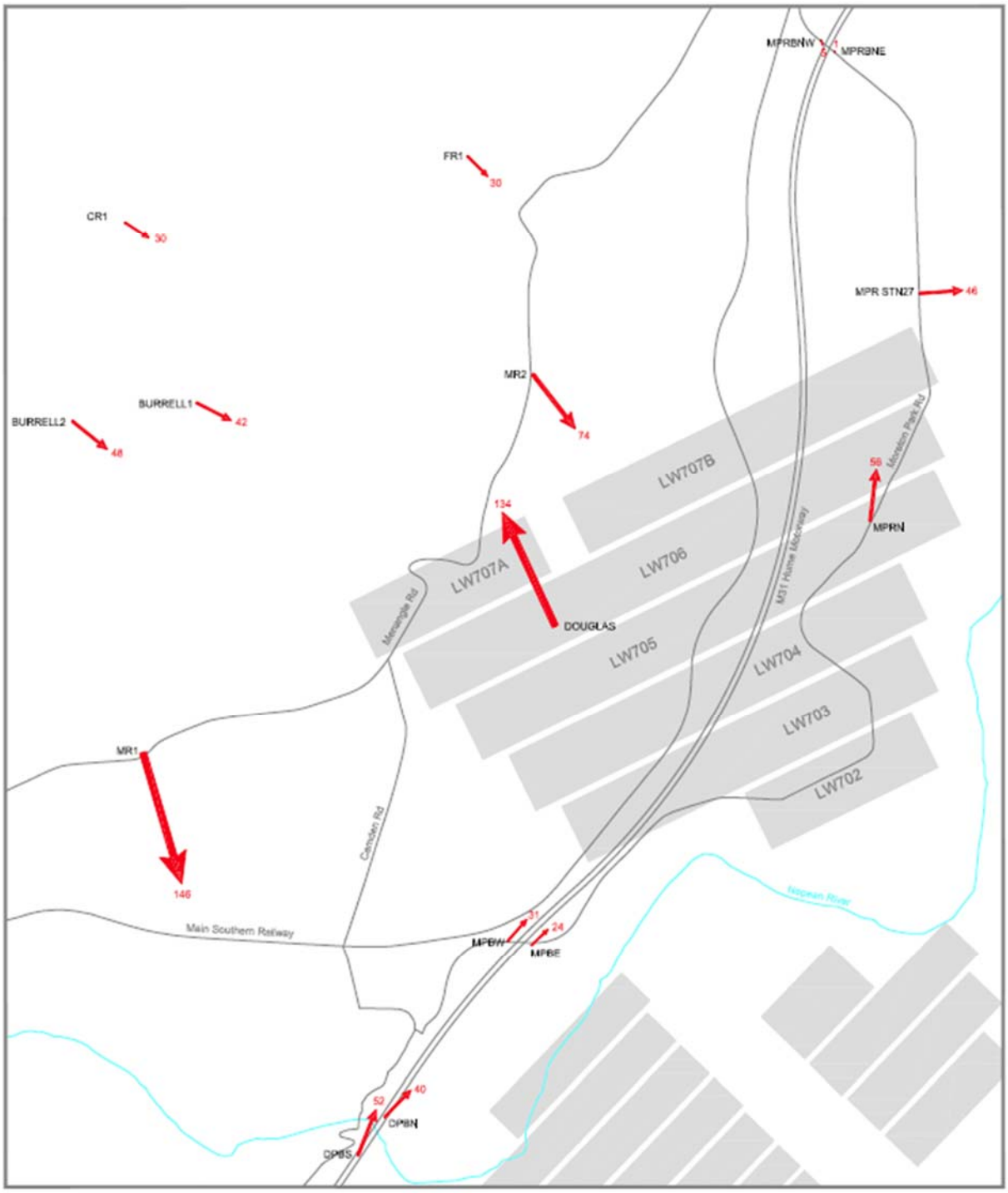


Fig. 2.7 Measured absolute incremental horizontal movements at the far-field 3D marks due to the extraction of LW707A and LW707B

A summary of the maximum measured incremental horizontal movements at the far-field 3D marks is provided in Table 2.17. The values represent the additional movements due to the extraction of LW707A and LW707B only.

Table 2.17 Maximum measured incremental horizontal movements at the far-field 3D marks due to the extraction of LW707A and LW707B

Longwall	Location	Maximum measured incremental horizontal movement (mm)
LW707A and LW707B	BURRELL1	42
	DOUGLAS	134
	DPBN	40
	DPBS	52
	MPBE	24
	MPBW	31
	MR1	146
	MR2	74
	BURRELL2	48
	CR1	30
	FR1	30
	MPRN	56
	MPR STN27	46
	MPRBNE	1
	MPRBNW	5

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.

A comparison between the measured incremental horizontal movements for the far-field 3D marks (i.e. purple diamonds), due to the extraction of LW707A and LW707B, with those previously measured elsewhere in the Southern Coalfield (i.e. grey triangles) is provided in Fig. 2.8. The incremental horizontal movements at the ARTC line (i.e. green diamonds), M31 West Line (i.e. cyan diamonds), M31 East Line (i.e. blue diamonds) and the highway and railway cutting marks (i.e. orange diamonds) are also shown in this figure for comparison.

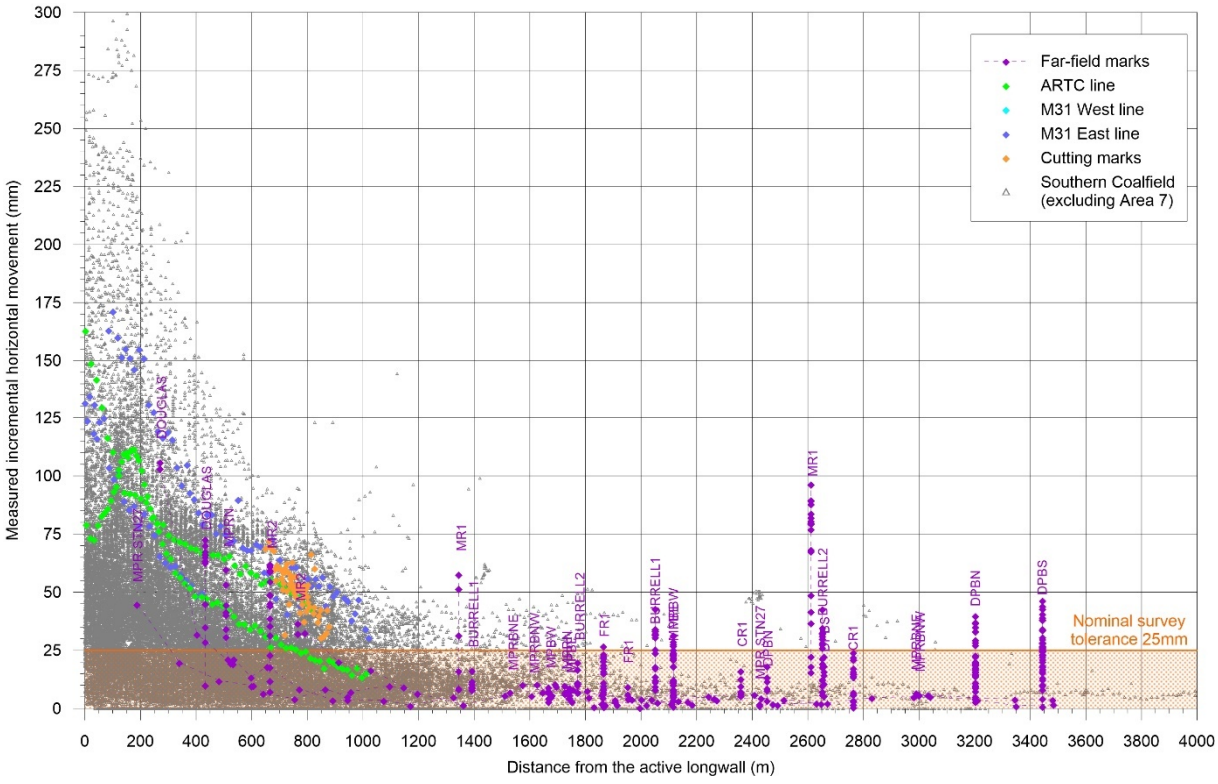


Fig. 2.8 Measured incremental horizontal movements versus distance from the active longwall

The measured incremental horizontal movements at the far-field 3D marks, due to the extraction of LW707A and LW707B, were typically within the range of those measured elsewhere in the Southern Coalfield at distances up to approximately 2000 m.

The measured horizontal movements at Marks MR1, DPBN and DPBS were greater than those typically measured at similar distances elsewhere in the Southern Coalfield. Mark MR1 is located on an embankment along the Main Southern Railway at a distance of 1.3 km west of LW707A. Marks DPBN and DPBS are located near the Douglas Park Twin Bridges and these marks could have been influenced by valley closure effects. Elsewhere, the measured horizontal movements were typically in the order of survey tolerance at distances greater than 2000 m.

2.10. Douglas Park Twin Bridges over the Nepean River

The Douglas Park Twin Bridges are located approximately 2.4 km south of the commencing (i.e. western) end of LW707A. The locations of these bridges are shown in Drawing No. MSEC975-01, in Appendix B, where the M31 Hume Motorway crosses the Nepean River. The monitoring associated with the Douglas Park Twin Bridges for LW707A and LW707B included the:

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

The 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 IC at Marks DPBN and DPBS. These two marks are located at the northern and southern ends of the bridges, as shown in Drawing No. MSEC975-01, 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 horizontal movements for these marks are illustrated in Fig. 2.6 and Fig. 2.7. The bridges moved towards the north-northeast (i.e. towards the active mining in Area 7) due to the extraction of LW707A and LW707B.

A summary of the maximum measured incremental and total horizontal movements at Marks DPBN and DPBS is provided in Table 2.18.

Table 2.18 Maximum measured absolute horizontal movements at Marks DPBN and DPBS

Mark	Maximum measured incremental horizontal movement due to LW707A and LW707B (mm)	Maximum measured total horizontal movement due to LW701 to LW707B (mm)
DPBN	40	87
DPBS	52	87

The development of the absolute horizontal movements at Marks DPBN and DPBS, during the extraction of LW703 to LW707B, is shown in Fig. 2.9. The development of the relative horizontal distance between these two marks is illustrated in Fig. 2.10.

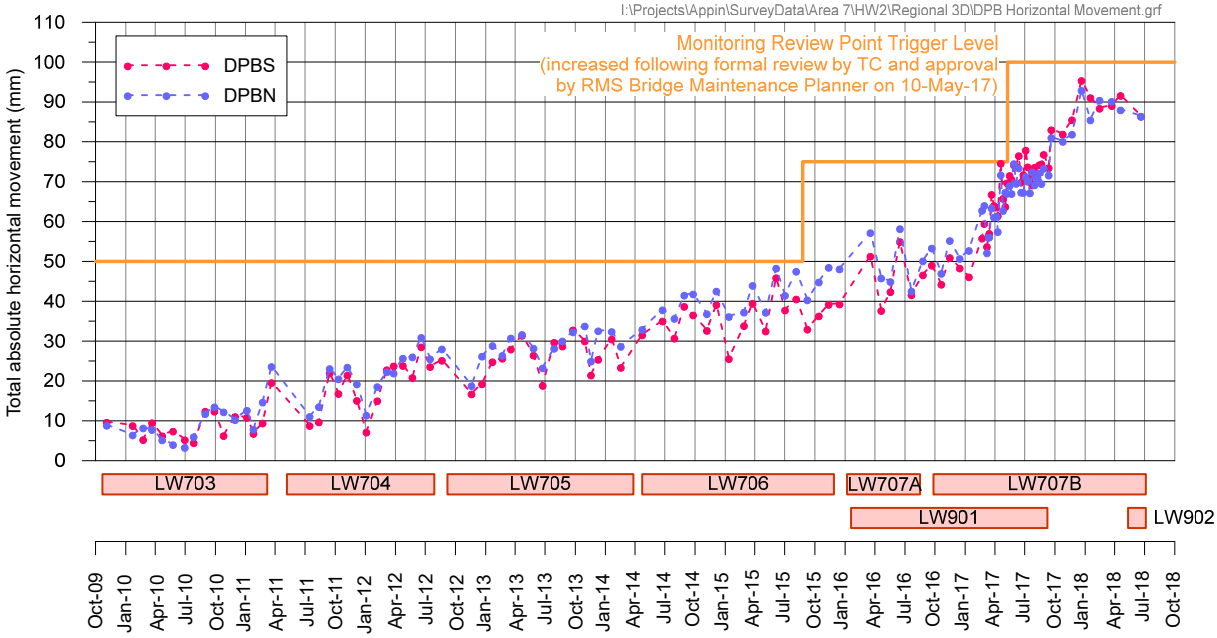


Fig. 2.9 Development of the absolute horizontal movements at Marks DPBN and DPBS

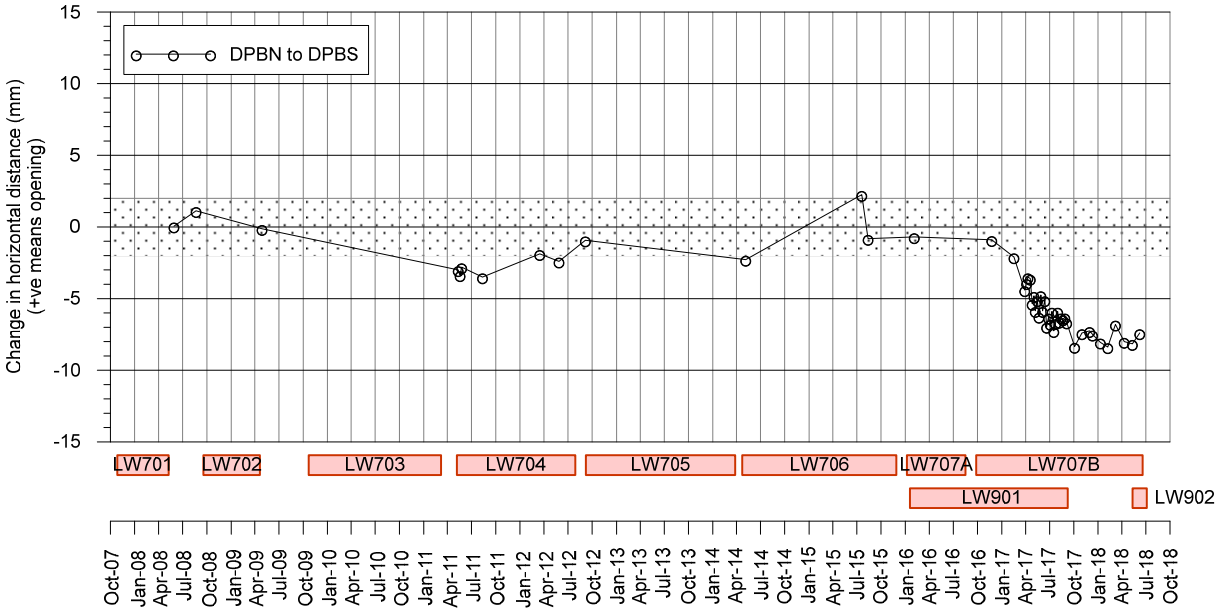


Fig. 2.10 Development of the relative horizontal movement between Marks DPBN and DPBS

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.

A formal review was undertaken by the Technical Committee on 10 May 2017, where it was agreed to increase the Monitoring Review Point trigger level for absolute movement from 75 mm to 100 mm. The decision was based on the surveys of the bridges, monitoring of displacement sensors and FBGs at the bridge joints, which indicated no measurable differential lateral movement.

A summary of the measured horizontal movements at Marks DPBN and DPBS, during the extraction of LW707A and LW707B, and the Level 1 triggers is provided in Table 2.19.

Table 2.19 Maximum measured horizontal movements at Marks DPBN and DPBS during the extraction of LW707A and LW707B and the Level 1 triggers

Type	Maximum measured horizontal movement (mm)	Level 1 trigger (mm)
Absolute horizontal movement of Marks DPBN and DPBS	96	100
Relative horizontal movement between Marks DPBN and DPBS	8	5

The maximum measured absolute horizontal movements of Marks DPBN and DPBS were less than the Level 1 trigger during the extraction of LW707A and LW707B. However, the maximum measured relative horizontal movement between these marks of 8 mm exceeded the Level 1 trigger of 5 mm. In response to this trigger, another relative 3D survey of the bridges was carried out and it was found that the measured lateral alignments of the bridges were within the allowable tolerances.

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

The mine subsidence movements at the Douglas Park Twin Bridges were measured by IC 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. 2.11 and Fig. 2.12 (Source: IC).

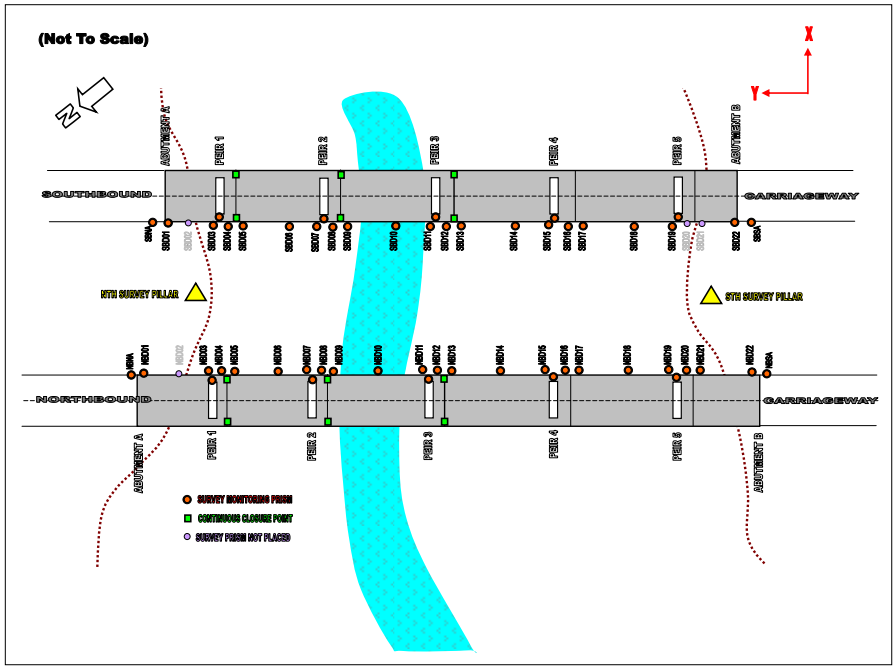


Fig. 2.11 Plan of the relative 3D monitoring points on the Douglas Park Twin Bridges (Source: IC)

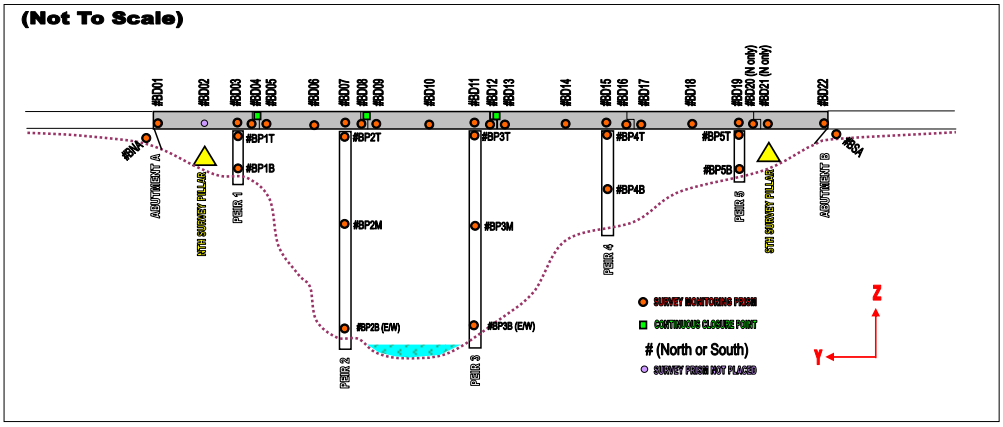


Fig. 2.12 Elevation of the relative 3D monitoring points on the Douglas Park Twin Bridges (Source: IC)

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 start of January 2013, is shown in Fig. 2.13. The nominal survey accuracy is ±2 mm.

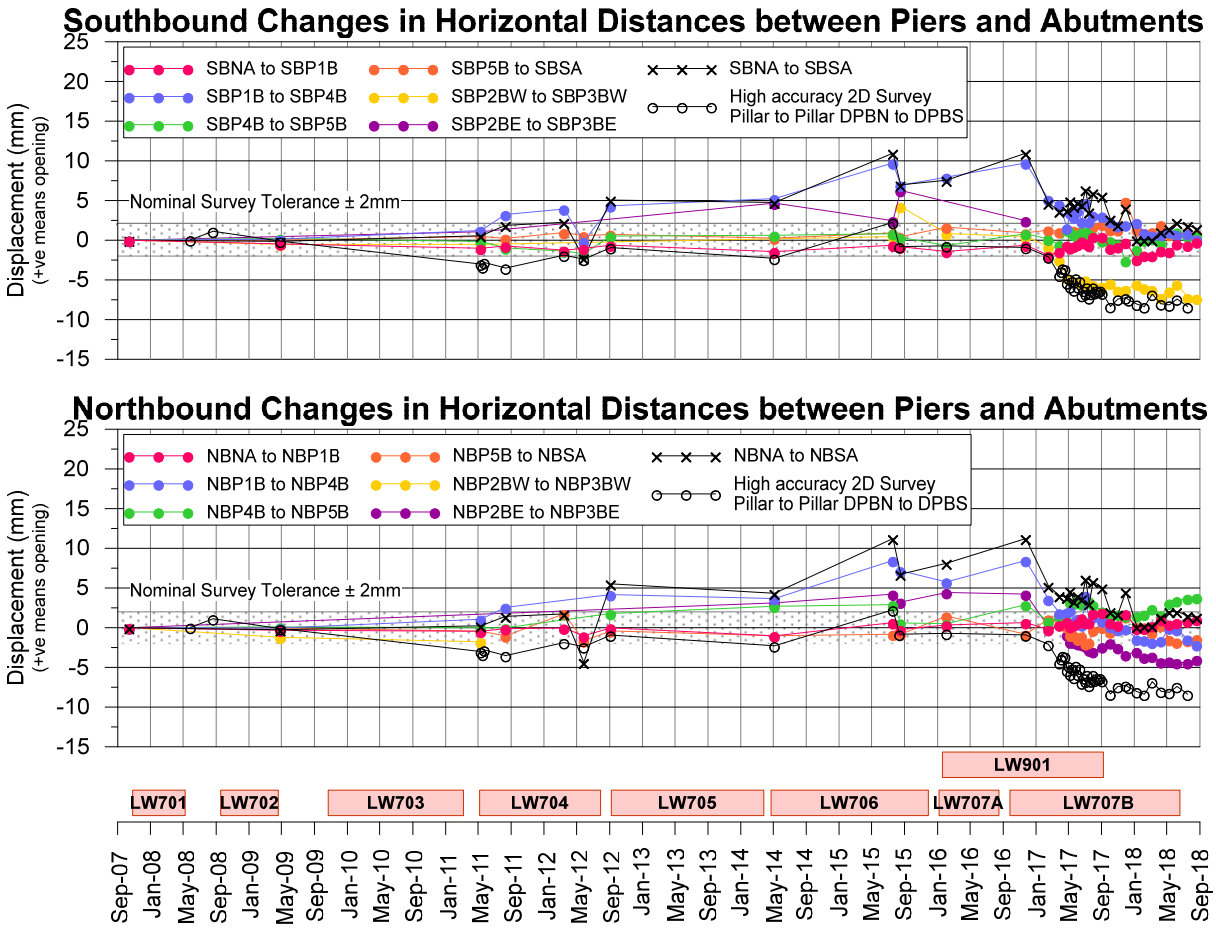


Fig. 2.13 Measured total changes in horizontal distance between the piers and abutments of the Douglas Park Twin Bridges

The total changes in horizontal distance between the abutments and piers at the completion of LW707B 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 RST and SAA inclinometers at Site PSM6, located near the Douglas Park Twin Bridges, were monitored during the extraction of LW707A and LW707B and the concurrent mining in Area 9. The inclinometer was installed and maintained by Pells Sullivan and Meynink (PSM), measured by IC 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 PSM883-309L through PSM883-369L.

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 LW707A and LW707B, and the Level 1 trigger is provided in Table 2.20.

Table 2.20 Maximum measured total differential movements at the inclinometers during the extraction of LW707A and LW707B and the Level 1 trigger

Type	Maximum measured differential movement (mm)	Level 1 trigger (mm)
Differential movement	2.8 (PSM6)	5

The measured differential movements at the inclinometers at Site PSM6 did not exceed the Level 1 trigger during the extraction of LW707A and LW707B.

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 LW707A and LW707B. 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. 2.11.

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 PSM883-309L through PSM883-369L.

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 LW707A and LW707B, and the Level 1 triggers is provided in Table 2.21.

Table 2.21 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)	+0.1 (Northbound Carriageway) +0.5 (Southbound Carriageway)	2
Joint 2 (Middle joint)	-0.8 (Northbound Carriageway) -0.6 (Southbound Carriageway)	2
Joint 3 (Main expansion joint)	-2.7 (Northbound Carriageway) -2.1 (Southbound Carriageway)	10

The measured differential movements at the bridge joints did not exceed the Level 1 triggers during the extraction of LW707A and LW707B.

2.11. Moreton Park Road Bridge (South) monitoring points

Moreton Park Road Bridge (South) is located approximately 1.7 km southwest of the commencing (i.e. western) end of LW707A, as shown in Drawings Nos. MSEC975-01 and MSEC975-03, in Appendix B. The monitoring associated with Moreton Park Road Bridge (South) for LW707A and LW707B 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 IC 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. MSEC975-01, 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, at any time during or after the extraction of LW707A and LW707B, were 24 mm and 31 mm, respectively, as shown in Fig. 2.7.

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 for the absolute total horizontal movement was originally 125 mm, as agreed by the Technical Committee on the 25 August 2015, during the extraction of LW706. During the mining of LW707B, the Level 1 trigger was increased to 150 mm on 30 May 2017, as agreed by the Technical Committee following assessment of monitoring results and approval by the RMS Bridge Maintenance Planner.

The development of absolute horizontal movement at Marks MPBE and MPBW is shown in Fig. 2.14.

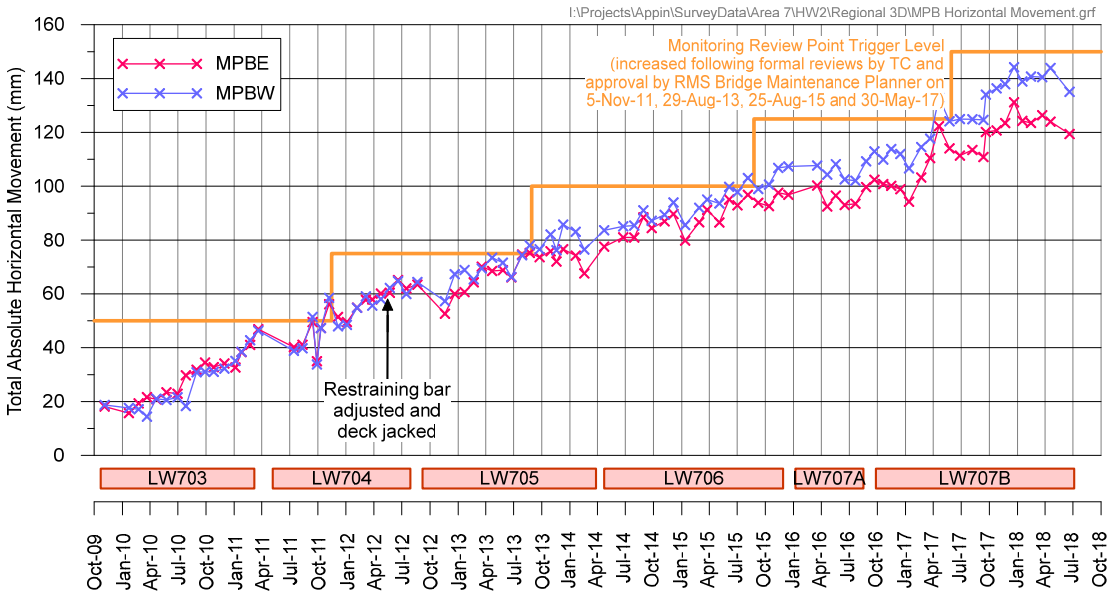


Fig. 2.14 Development of absolute horizontal movement at Marks MPBE and MPBW

A summary of the maximum measured absolute total horizontal movements at Marks MPBE and MPBW, during the extraction of LW707A and LW707B, and the Level 1 trigger is provided in Table 2.22.

Table 2.22 Maximum measured total horizontal movements at Marks MPBE and MPBW during LW707A and L7W707B and the Level 1 trigger

Location	Maximum measured absolute horizontal movement (mm)	Level 1 Trigger (mm)
Marks MPBE and MPBW	119 (MPBE) 135 (MPBW)	150

The maximum measured absolute horizontal movements at Marks MPBE and MPBW were less than the Level 1 trigger at the completion of LW707B.

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

The mine subsidence movements of the Moreton Park Road Bridge (South) were measured by IC using relative 3D marks fixed directly to the bridge structure. The locations of the monitoring points on the bridges are shown in Fig. 2.15 and Fig. 2.16 (Source: IC).

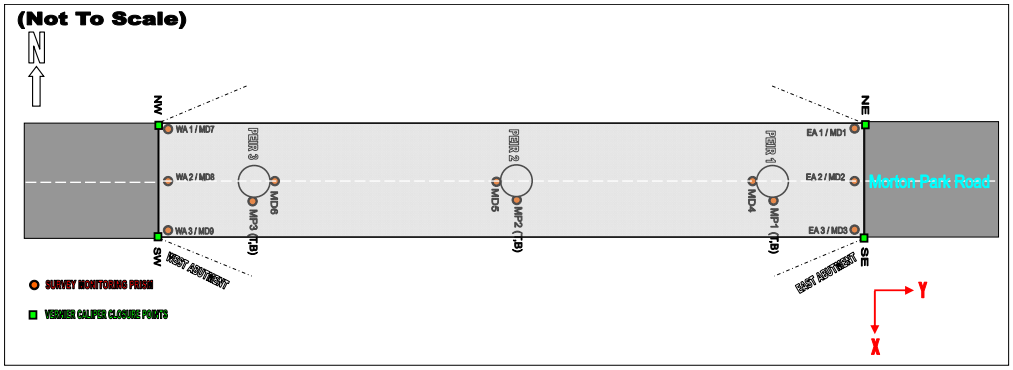


Fig. 2.15 Plan of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IC)

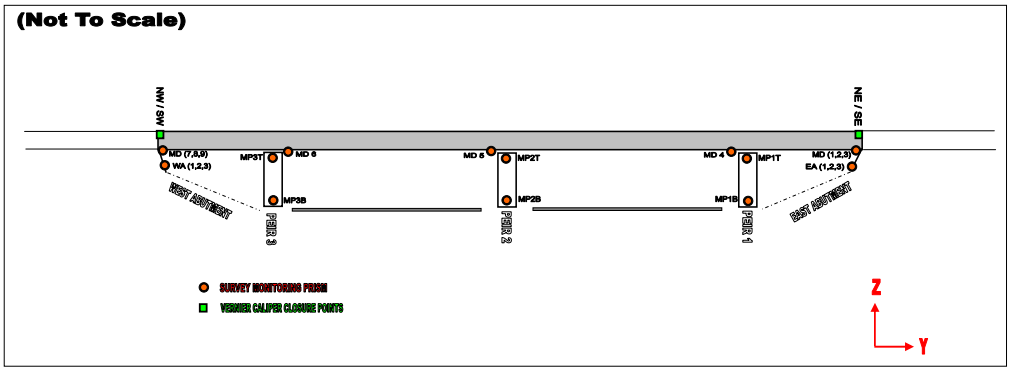


Fig. 2.16 Elevation of the relative 3D monitoring points on Moreton Park Road Bridge (South) (Source: IC)

The changes in horizontal distance between the bridge abutments have been measured during mining in Area 7, since the 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). The development of the total changes in the horizontal distance between the abutments, during the extraction of LW701 to LW707B, are illustrated in Fig. 2.17. The nominal survey accuracy is ±2 mm.

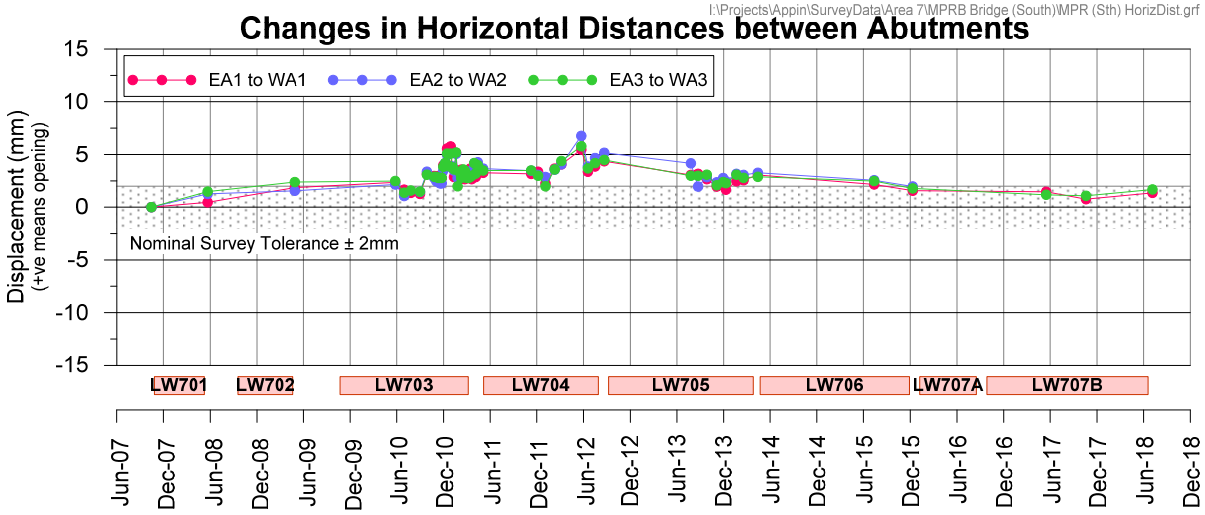


Fig. 2.17 Measured changes in the total horizontal distances between the abutments

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.

The measured total changes in horizontal distance between the bridge abutments were less than ±2 mm at the completion of LW707B. The total measured movements, therefore, were within 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. MSEC975-01, 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 and Bridges were monitored by IC 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 and Bridges, during the extraction of LW707A and LW707B, is provided in Table 2.23.

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 2.23 Maximum measured incremental net subsidence, net uplift and closure at the wrought iron aqueducts and bridges during LW707A and LW707B

Location	Maximum measured incremental net subsidence (mm)	Maximum measured incremental net uplift (mm)	Maximum measured incremental closure (mm)
Ousedale Creek Aqueduct	< 2	< 2	< 2
Ousedale Creek Bridge	< 2	< 2	< 2
Mallaty Creek Aqueduct	< 2	< 2	-4 (closure)
Mallaty Creek Bridge	< 2	< 2	< 2
Leafs Gully Aqueduct	< 2	< 2	+2 (opening)
Leafs Gully Bridge	< 2	< 2	< 2
Nepean Creek Aqueduct	< 2	< 2	+4 (opening)
Nepean Creek Bridge	< 2	< 2	< 2

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 extraction of LW707A and LW707B, were in the order of survey tolerance, i.e. not measurable.

The incremental changes in the distances between the aqueduct headwalls, during the extraction of LW707A and LW707B, were -4 mm (closure) at the Mallaty Creek Aqueduct, +2 mm (opening) at the Nepean Creek Aqueduct and +4 mm (opening) at the Nepean Creek Aqueduct. The movements at the Ousedale Creek Aqueduct were similar to the order of survey tolerance. The observed incremental movements at each of the bridges were in 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 IC using local 3D surveys. The maximum measured incremental net vertical and horizontal movements at the Concrete Aqueducts C and D, during the extraction of LW707A and LW707B, 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 movements along the Telstra optical fibre line were measured by IC using a 3D ground monitoring line, referred to as the Telstra Line. The location of this monitoring line is shown in Drawing No. MSEC975-01, in Appendix B.

The profiles of measured and predicted incremental vertical subsidence, tilt and strain along the Telstra Line, due to the extraction of LW707A, are shown in Fig. A.14, in Appendix A. The predictions are based on the subsidence contours presented in Reports Nos. MSEC342 and MSEC825.

The measured profile of vertical subsidence reasonably matches the predicted profile; however, the magnitude is less than that predicted above LW706 and LW707. The measured extent of vertical subsidence above LW705 is similar to the predicted extent.

A summary of the maximum measured and predicted incremental vertical subsidence, tilt and strains for the Telstra Line is provided in Table 2.24. The values represent the additional movements due to the extraction of LW707A only.

Table 2.24 Maximum measured and predicted incremental vertical subsidence, tilt and strain along the Telstra Line due to LW707A 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	478	3.2	0.9	1.3
Predicted	875	4.3	*- 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 and tilt along the Telstra Line, due to the extraction of LW707A only, are less than the predicted values. The maximum measured incremental strains are 0.9 mm/m tensile and 1.3 mm/m compressive. No localised or irregular ground movements occurred due to the extraction of LW707A. 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.

The measured changes in tilt across the base of the Telstra Tower, during the extraction of LW707A and LW707B, are illustrated in Fig. 2.18. The accuracies of the ground survey measurements of tilt at the tower are in the order of ±1.0 mm/m.

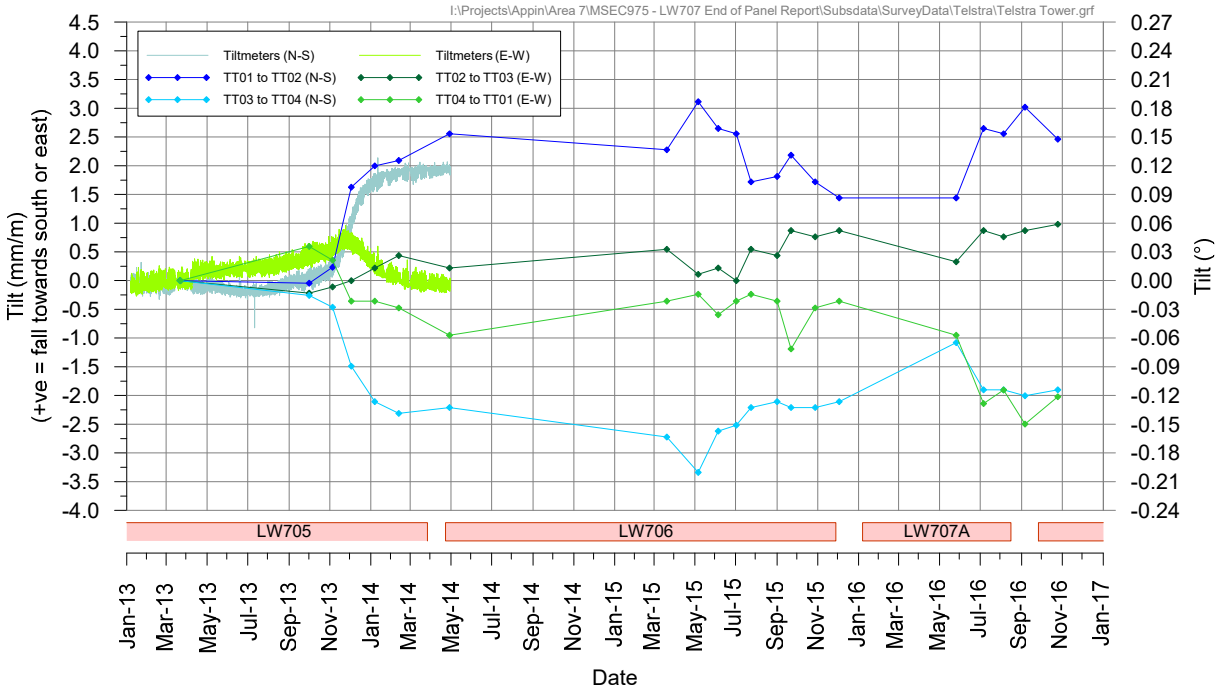


Fig. 2.18 Measured changes in tilt at the Telstra Tower

There was a reasonable correlation between the high accuracy tiltmeter measurements and the ground surveys at the Telstra Tower. The maximum measured tilts were 3.4 mm/m (i.e. 0.20°) in the north-south direction and 2.5 mm/m (i.e. 0.15°) in the east-west direction. The maximum measured tilts were less than the operating tolerances of the antennae.

3.1. Natural Features

The natural features located near LW707A and LW707B are shown in Drawing No. MSEC975-02, 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 extraction of LW705 to LW710 were provided in Reports Nos. MSEC342 and MSEC825. More detailed assessments for some natural features were 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 IC Environmental Field Team and are described in the report entitled *Appin Area Longwall 707 End of Panel Landscape Report*, dated August 2018.

Table 3.1 Summary of the MSEC assessments and the observed impacts for the natural features due to the extraction of LW707A and LW707B

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 GeoTerra
	The **surface water level** is expected to remain essentially unchanged. Uplift of the banks could result in some desiccation of the banks	No observed change in water level apart from the normal fluctuations associated with rainfall and WaterNSW discharges
	Possible that mining-induced **springs** could occur	No additional iron staining or iron seeps were observed in the Nepean River during LW707A and LW707B
	Possible that isolated **gas emissions** could occur	No new gas release zones were identified during the extraction of LW707A and LW707B. Existing gas release zones 14, 15, 17 and 18 were active during this period. However, these gas release zones have since ceased as of January 2018. For further details, refer to the accompanying Landscape Report by IC
	Water quality – Refer to the accompanying Surface Water Report by GeoTerra **Terrestrial ecology** – Refer to the accompanying Landscape Report by IC	
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
Archaeological sites	Low likelihood of impacts on open sites, scarred tree and shelters.	No observed adverse. Refer to the accompanying Cultural Heritage Report by Niche

There were no observed adverse impacts on the natural features due to the extraction of LW707A and LW707B. The existing gas release zones continued during the mining period; however, these have now all ceased. 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 LW707A and LW707B are shown in Drawings Nos. MSEC975-03, in Appendix B. The features considered in this *End of Panel* report include those located within either the 35° angle of draw line from LW707A and LW707B and/or the predicted 20 mm incremental subsidence contour due to the extraction of these longwalls. The built features expected to experience far-field or valley related movements that 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;
- heritage structures (including the Mountbatten Group);
- groundwater bores (including GW101437 and GW104154);
- 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 extraction of LW705 to LW710, were provided in Reports Nos. MSEC342 and MSEC825. Comparisons between the assessed and observed impacts for the built features located near LW707A and LW707B, as listed above, are provided in Table 3.2. The observed impacts are based on those recorded by IC Environmental Field Team.

Table 3.2 Summary of the assessed and observed impacts for built features due to the extraction of LW707A and LW707B

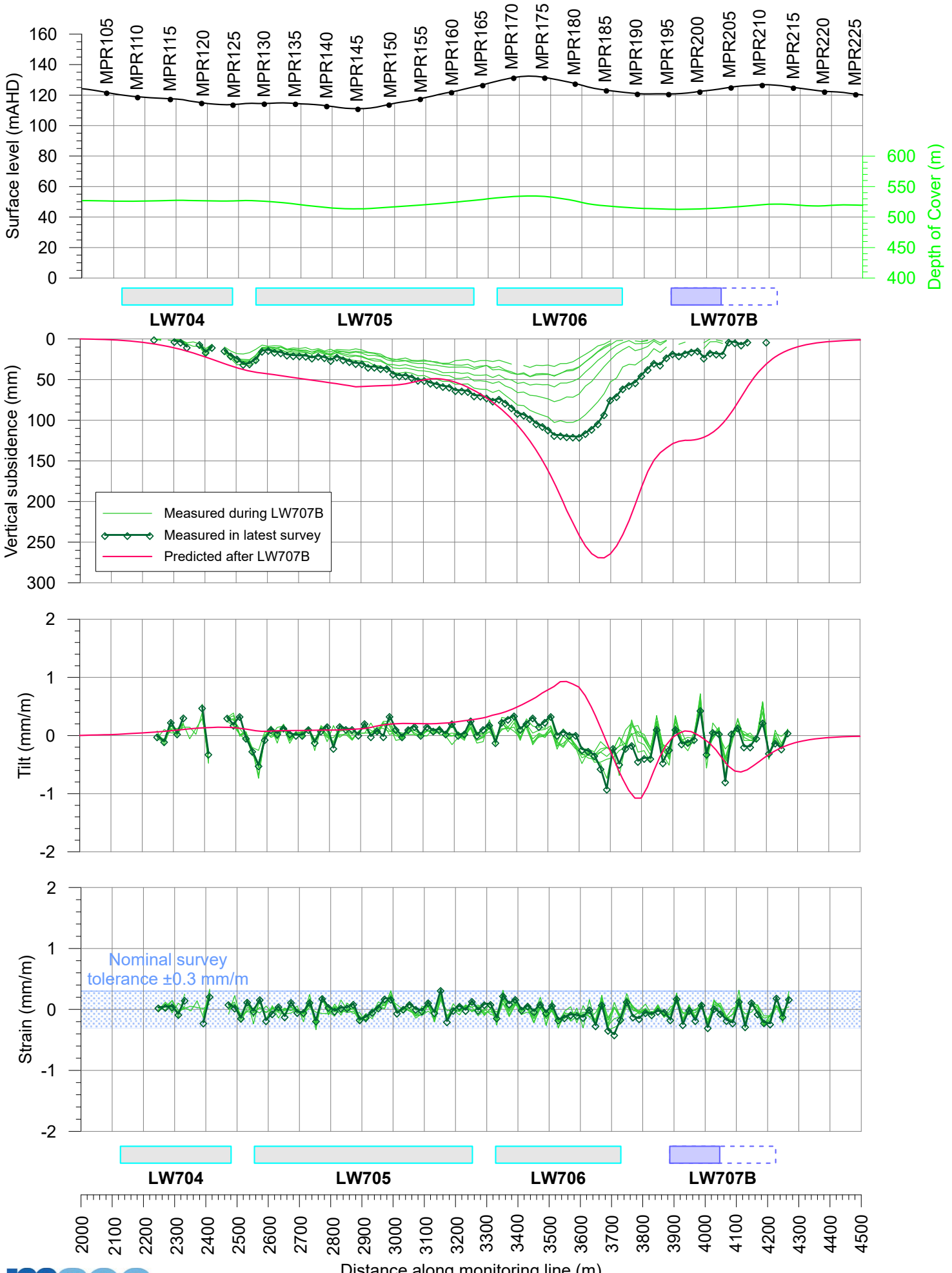
Built feature	MSEC assessed impacts	Observed impacts
Moreton Park Road	Minor cracking and localised heaving of the road surface may occur in some locations above the longwalls	No adverse impacts observed due to the extraction of LW707B
Menangle Road	Minor cracking and localised heaving of the road surface may occur in some locations above the longwalls	Minor cracking observed in the road in the location of a culvert near the commencing end of LW707A and cracking and deterioration of pavement near top of hill above the longwall
M31 Hume Motorway	No impacts on the safety or serviceability of the motorway after the implementation of the management strategies	No adverse impacts on safety or serviceability. Humps formed on both carriageways 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	Changes in track geometry recorded and remediated in accordance with the Management Plan. No adverse impacts to safety and serviceability.
Douglas Park Twin Bridges	Impacts unlikely after the implementation of the TARP	No adverse impacts observed
Moreton Park Road Bridge (South)	Impacts unlikely after the detailed investigation, analysis and implementation of the TARP	No adverse impacts observed
Low voltage powerlines	Impacts unlikely, but minor mitigation measures may be required	No adverse impacts observed

Built feature	MSEC assessed impacts	Observed impacts
Copper telecommunications cables	Impacts unlikely	Small levels of signal loss measured
Optical fibre cables	Impacts unlikely with the implementation of the management strategies including OTDR monitoring and mitigation	Loss of signal along the Telstra optical fibre cable adjacent to the Main Southern Railway at 69.3 km. The cable was excavated and replaced with a new 100 m section of cable in conduit
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 during the extraction of LW707A and LW707B. Claims that have been lodged are being managed by Subsidence Advisory NSW (SA NSW) through the relevant legislation
Pools	Inground pools could be more susceptible to ground strains	Claims that have been lodged are being managed by SA NSW through the relevant legislation
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	Gas release observed in one private dam (Site AA7_LW707_001) and soil cracking observed around another private dam (no adverse impacts)
Heritage structures	No heritage sites located near LW706	No reported impacts
Groundwater bores	Potential for blockage or reduction in the capacity of the groundwater bores	Gas release and iron staining to water expelled from borehole GW102584. Refer to the accompanying Groundwater Report by GeoTerra
Pumps in the Nepean River	Impacts unlikely	No reported impacts
The Upper Canal, Cataract Tunnel and associated infrastructure	Impacts unlikely	No reported impacts
Survey control marks	Small fair-field horizontal movements which could require re-establishment	Small far-field horizontal movements

Minor cracking and deterioration of the pavement occurred along Menangle Road. Replacement of a 100 m section of the Telstra optical fibre cable was also required during LW707B. There are no long-term adverse impacts on this road or cable. Elsewhere, the observed impacts on the built features, due to the extraction of LW707A and LW707B, 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 LW707B



msec

Fig. A.01

Measured and predicted profiles of incremental vertical subsidence, tilt and strain along the Menangle Road monitoring line due to LW707A

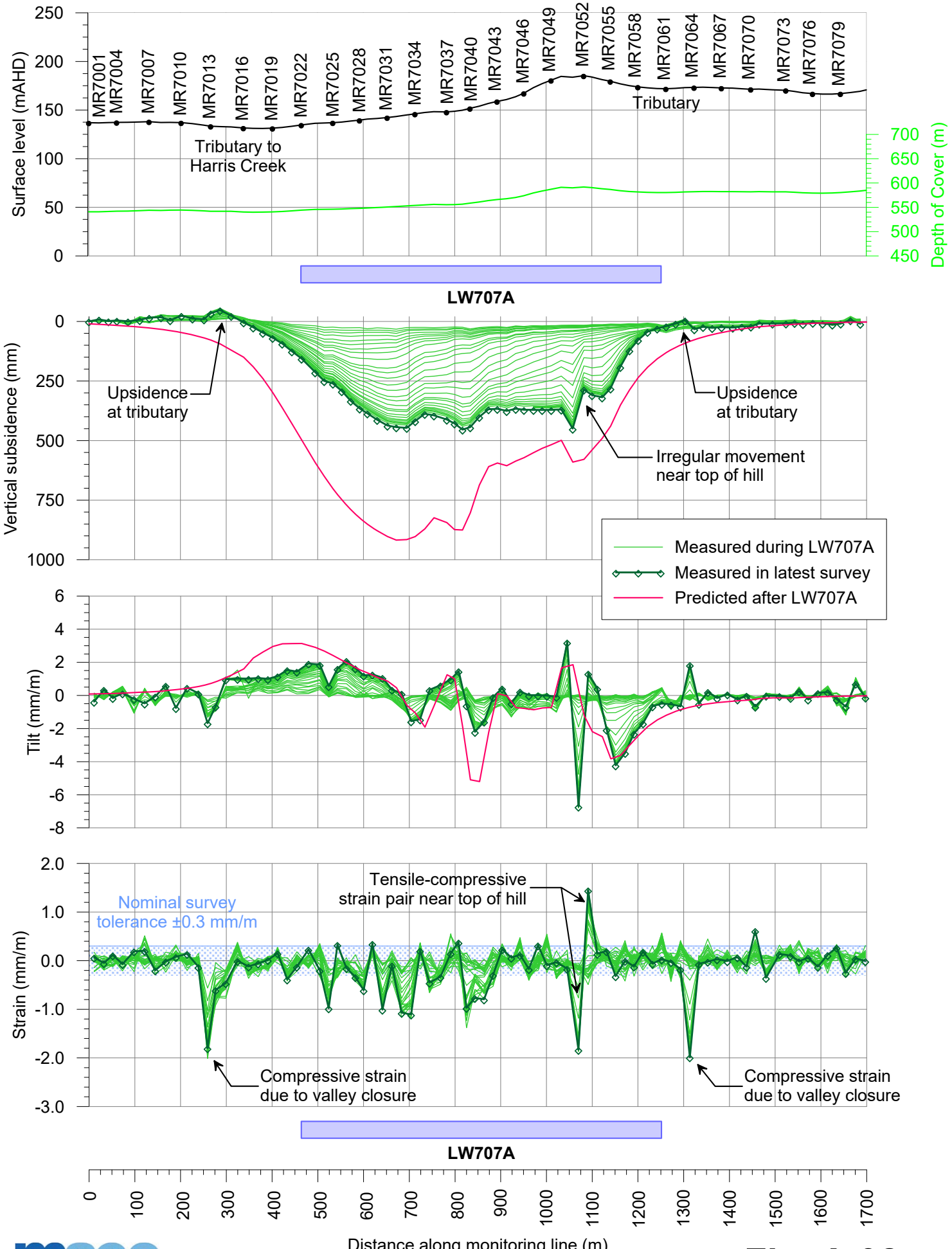


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Fig. A.02

Measured and predicted profiles of incremental vertical subsidence, tilt and strain along M31 East Line due to LW707B

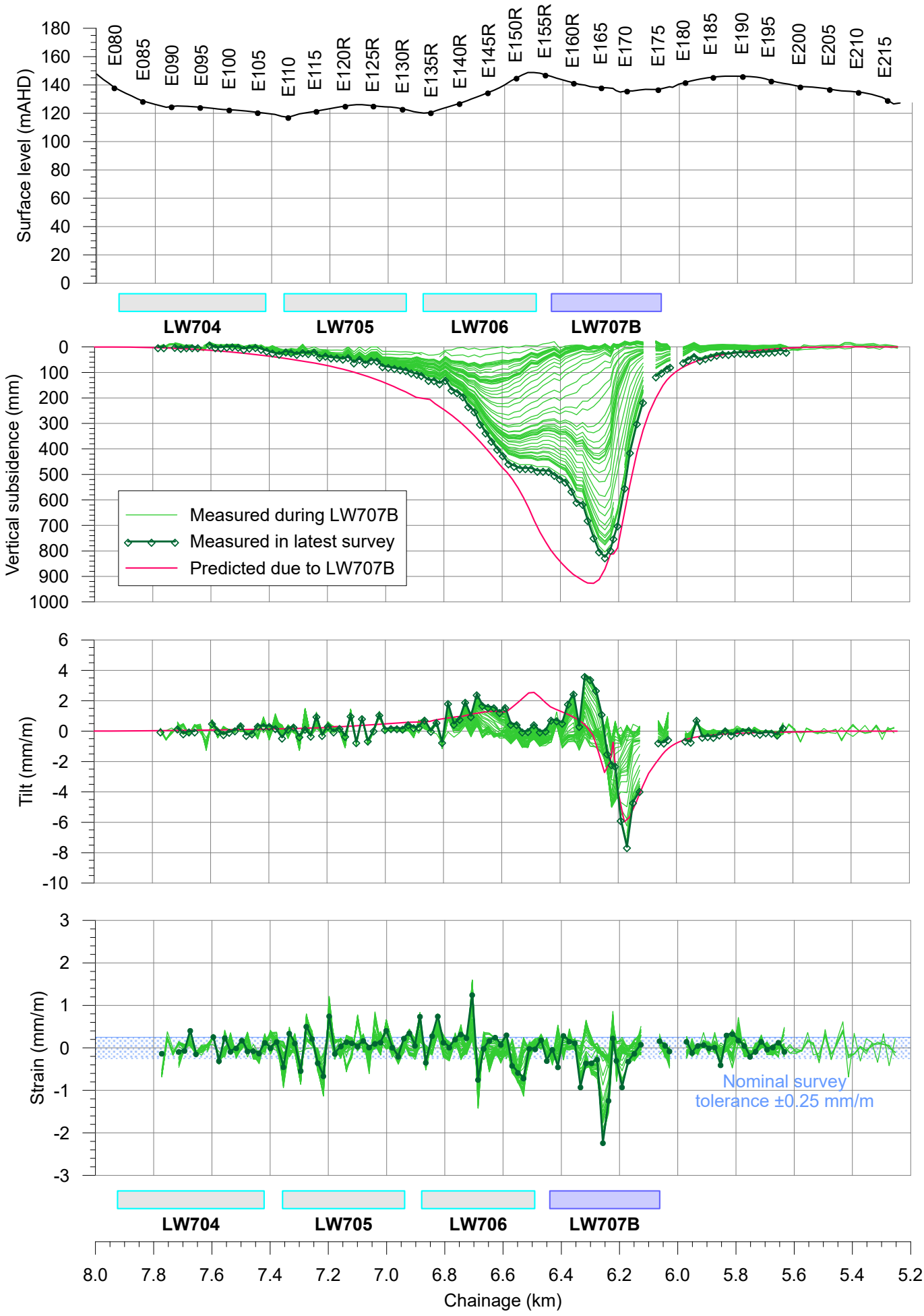

Fig. A.03

Measured and predicted profiles of incremental vertical subsidence, tilt and strain along M31 West Line due to LW707B

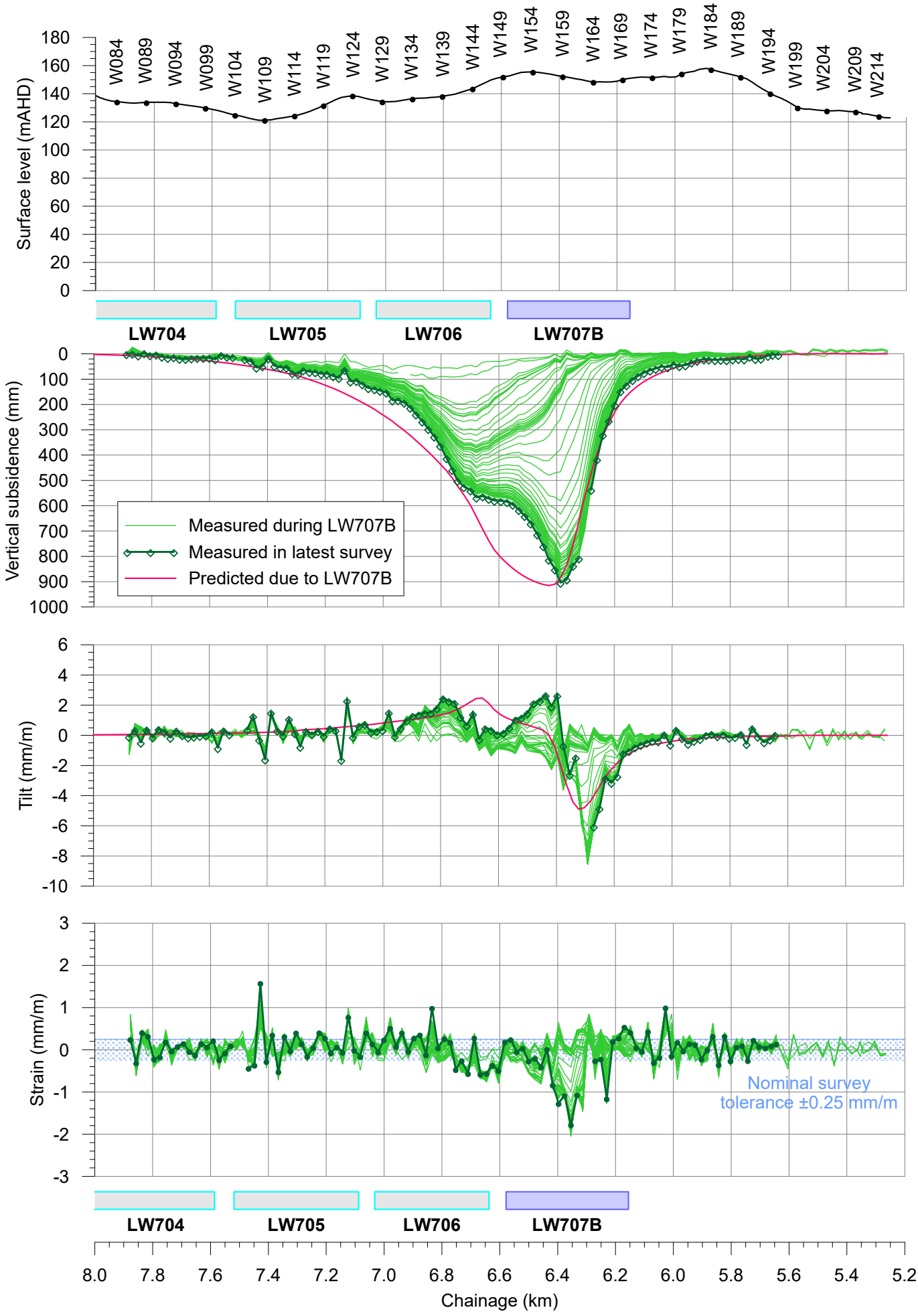

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Fig. A.04

Measured and predicted profiles of incremental vertical subsidence, tilt and strain along the ARTC Line due to LW707B

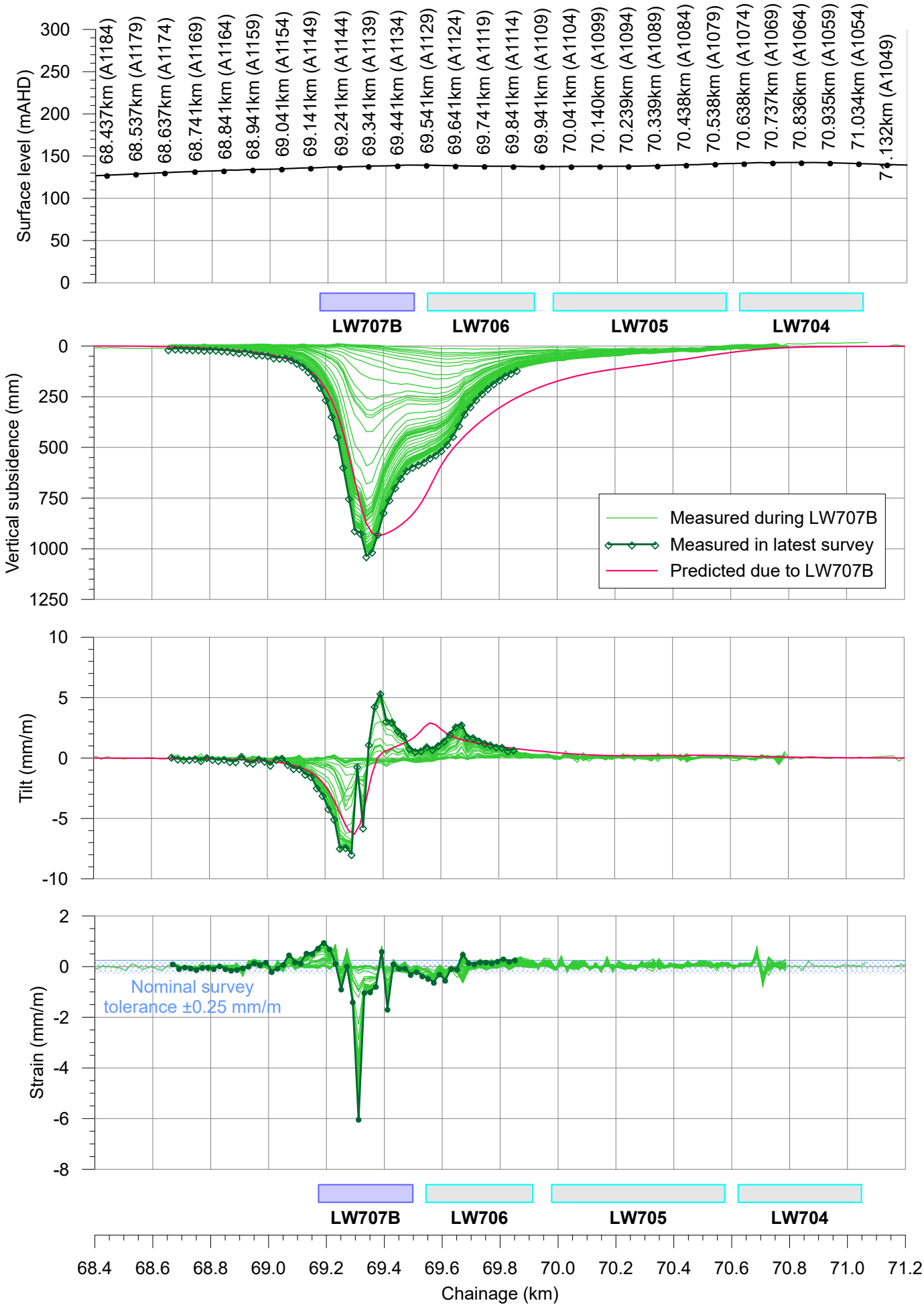

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Fig. A.05

Observed Profiles of Incremental Subsidence, Tilt and Strain along Up Base of Embankment at 70.5km during Appin LW707

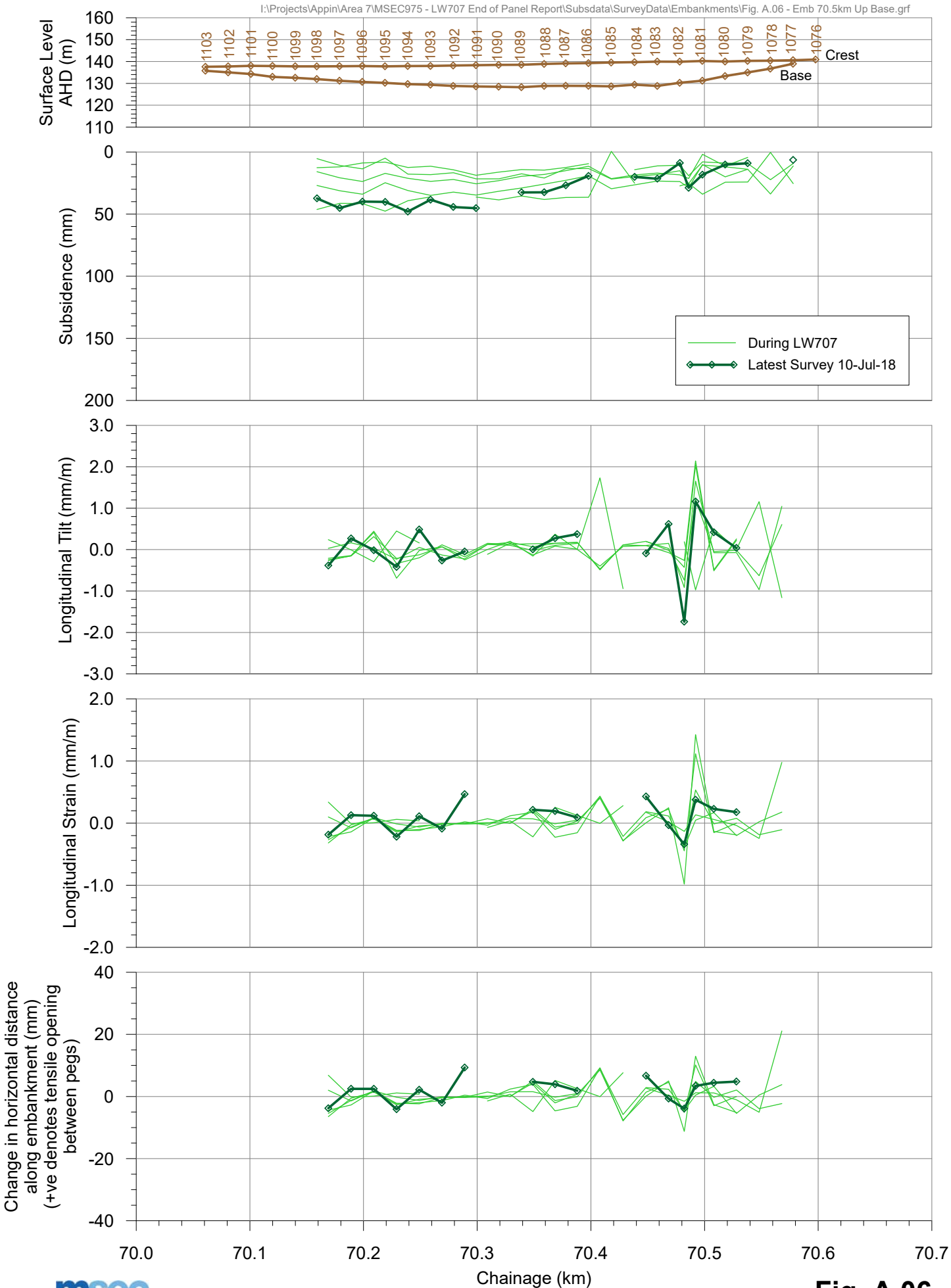

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Fig. A.06

Observed Profiles of Incremental Subsidence, Tilt and Strain along Up Crest of Embankment at 70.5km during Appin LW707

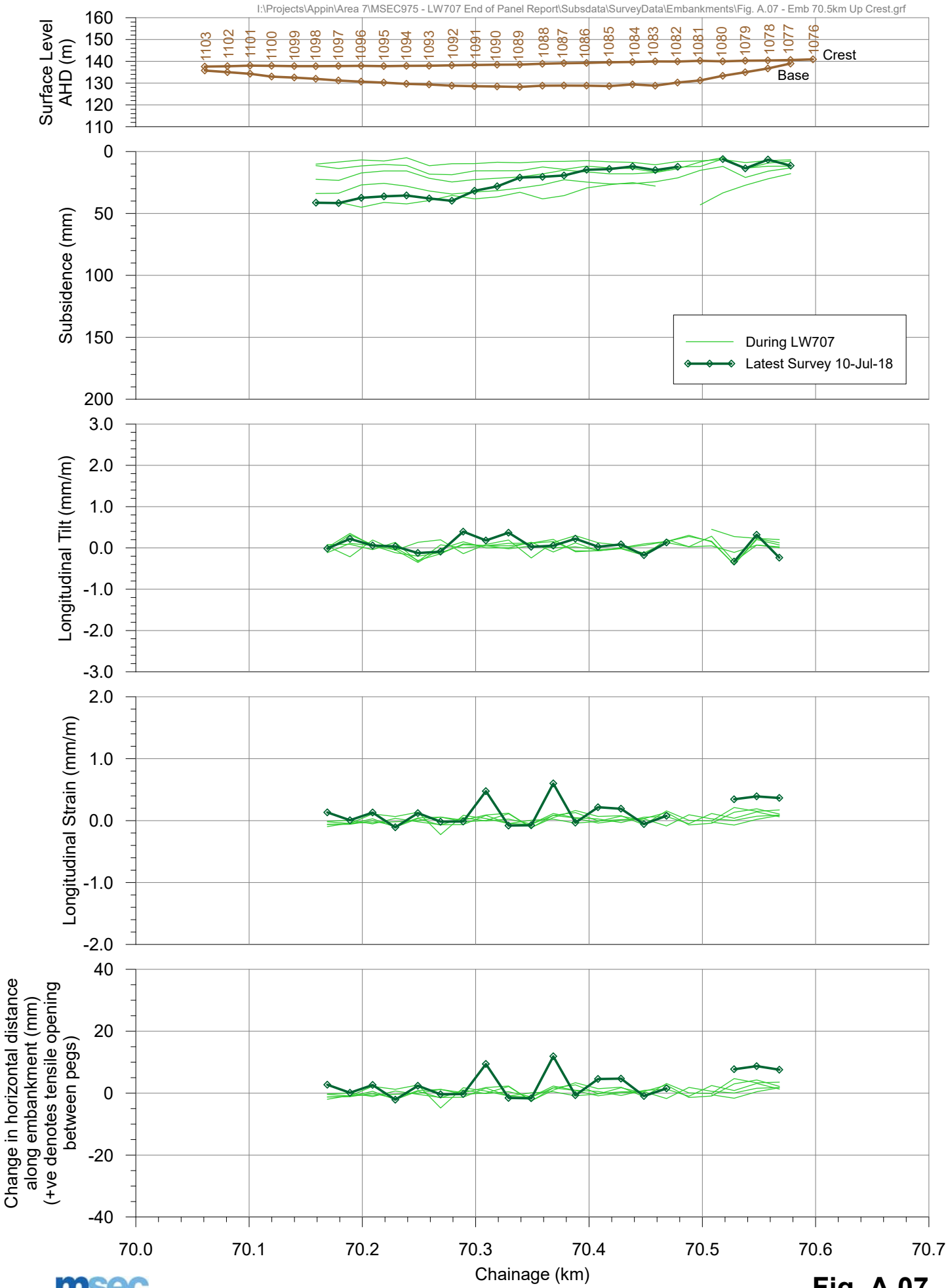

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Fig. A.07

Observed Profiles of Incremental Subsidence, Tilt and Strain along Down Crest of Embankment at 70.5km during Appin LW707

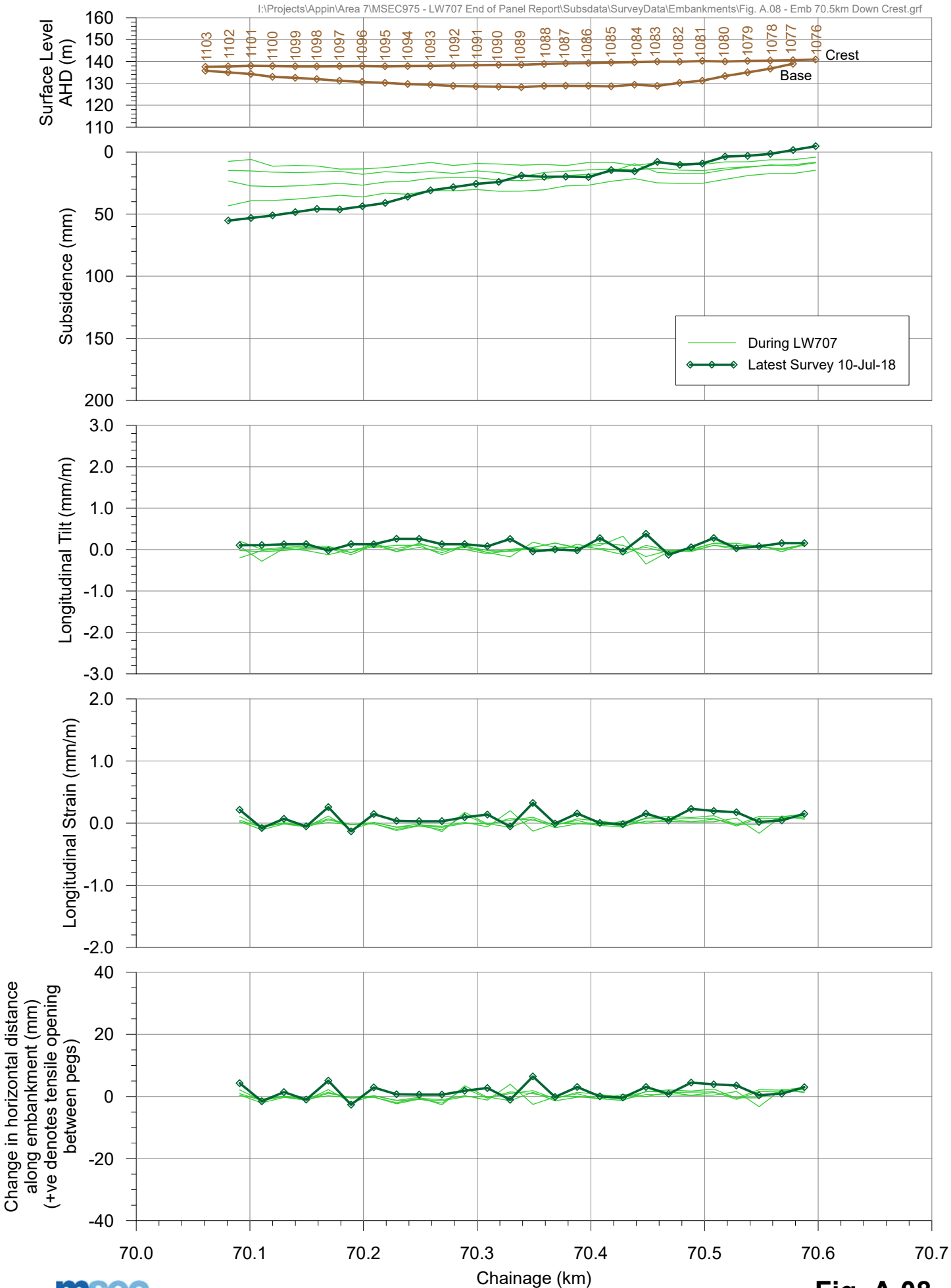

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Fig. A.08

Observed Profiles of Incremental Subsidence, Tilt and Strain along Down Base of Embankment at 70.5km during Appin LW707

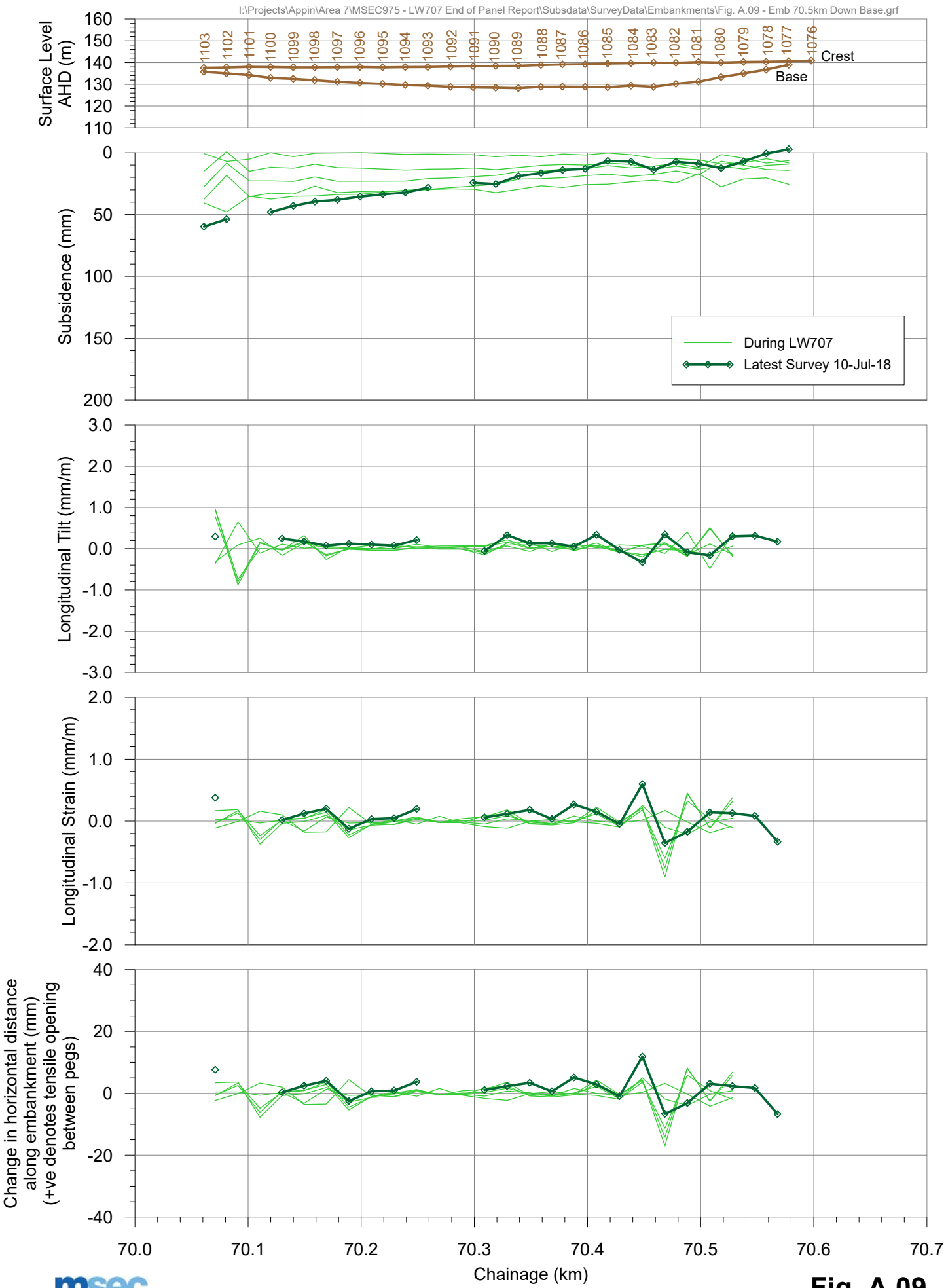

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Fig. A.09

Appin Colliery - LW707B - Embankment at 69.0km
Incremental Subsidence Profiles along Up Base

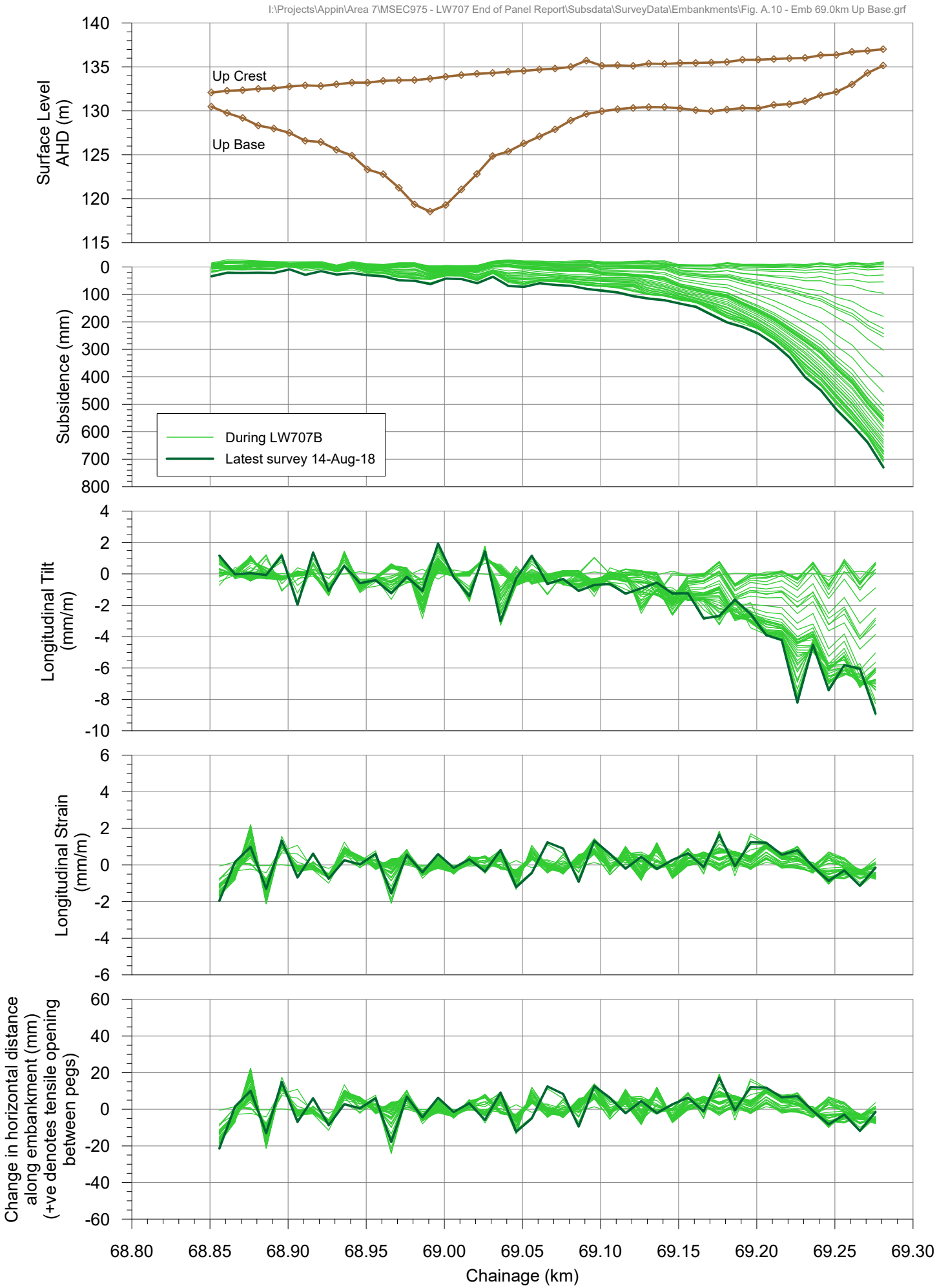

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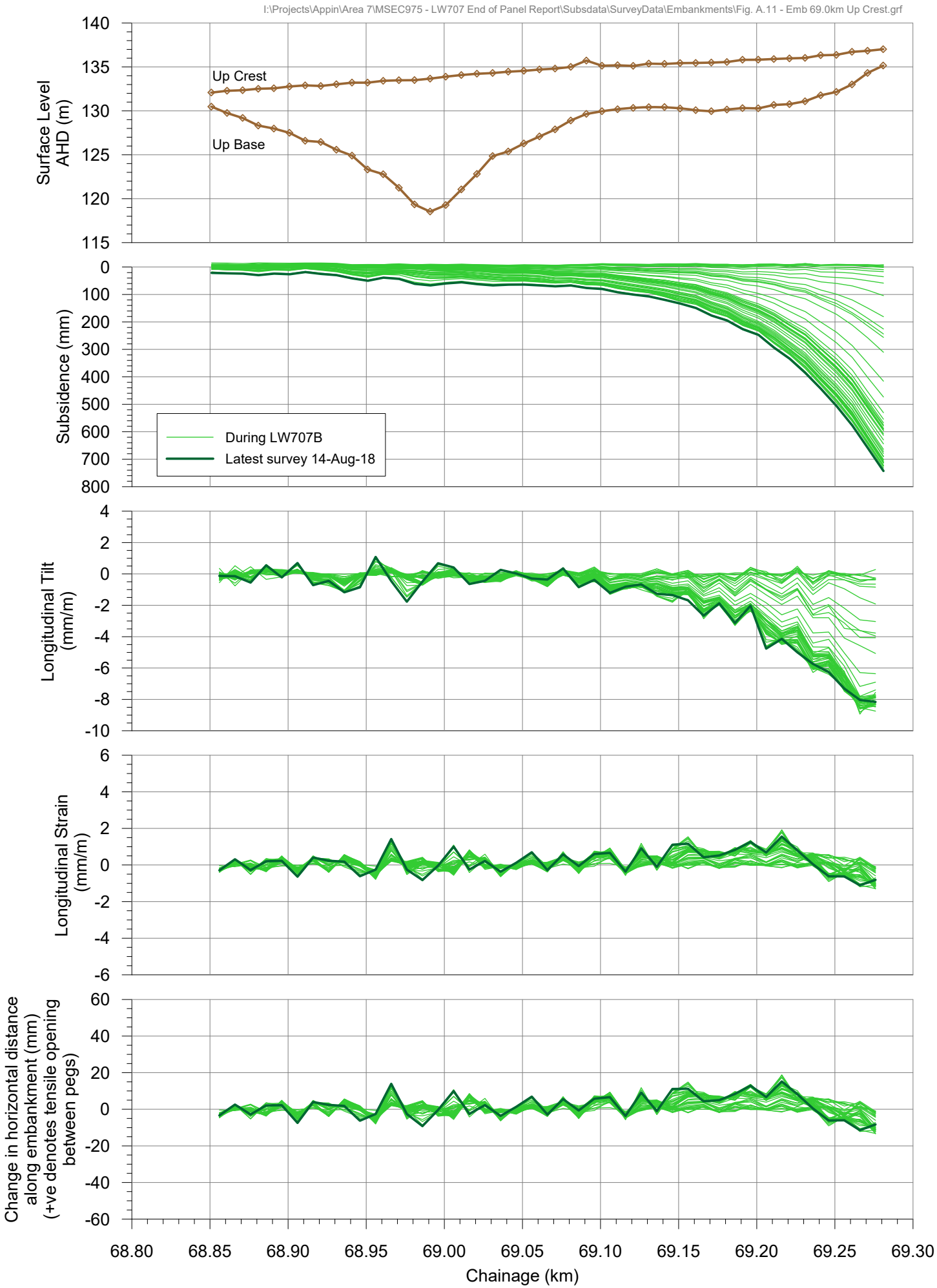
Fig. A.10

Appin Colliery - LW707B - Embankment at 69.0km
Incremental Subsidence Profiles along Up Crest



msec

Fig. A.11

Appin Colliery - LW707B - Embankment at 69.0km
Incremental Subsidence Profiles along Down Crest

I:\Projects\Appin\Area 7\MSEC975 - LW707 End of Panel Report\Subsdata\SurveyData\Embankments\Fig. A.12 - Emb 69.0km Down Crest.grf

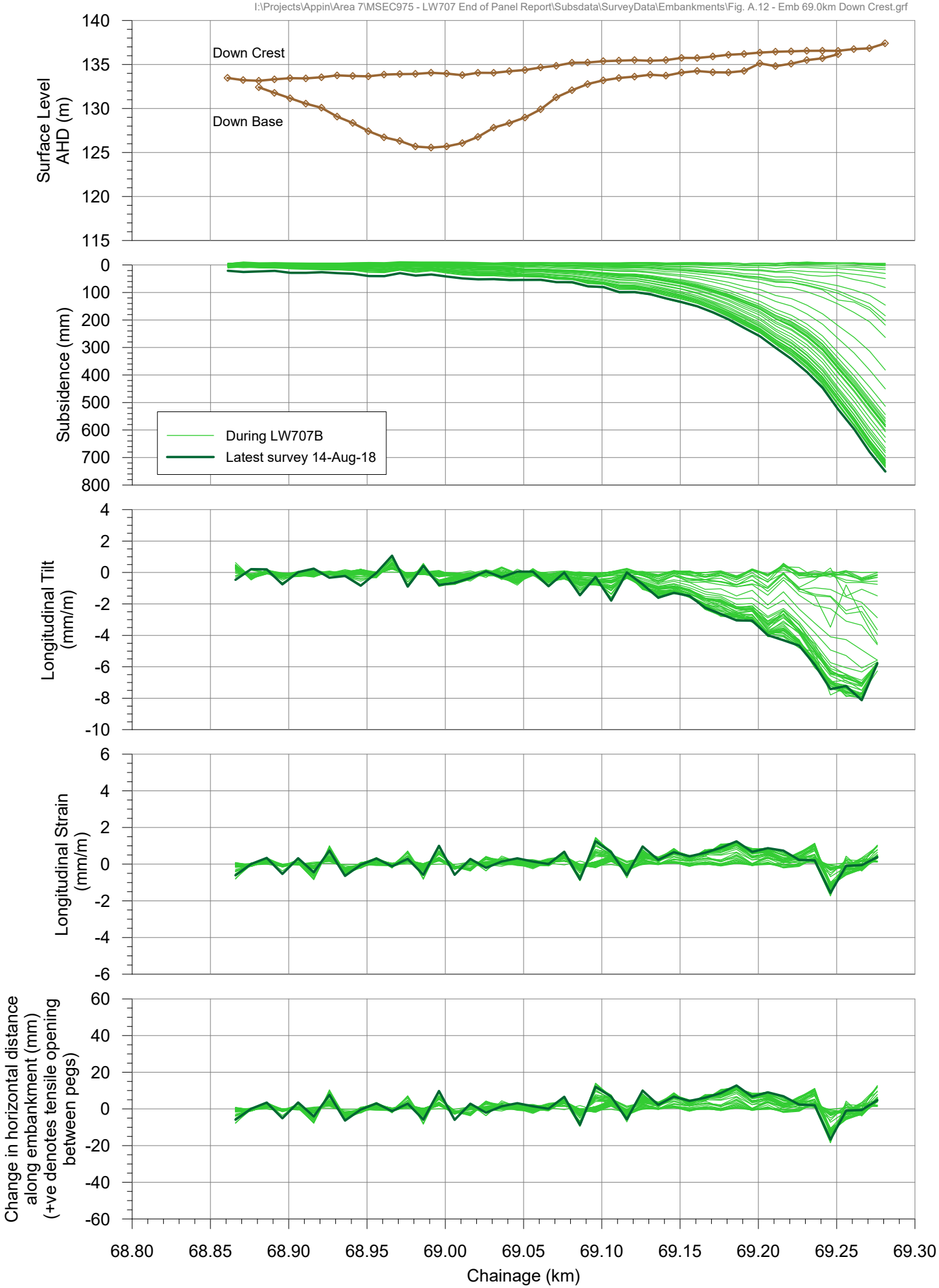


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Fig. A.12

Appin Colliery - LW707B - Embankment at 69.0km
Incremental Subsidence Profiles along Down Base

I:\Projects\Appin\Area 7\MSEC975 - LW707 End of Panel Report\Subsdata\SurveyData\Embankments\Fig. A.13 - Emb 69.0km Down Base.grf

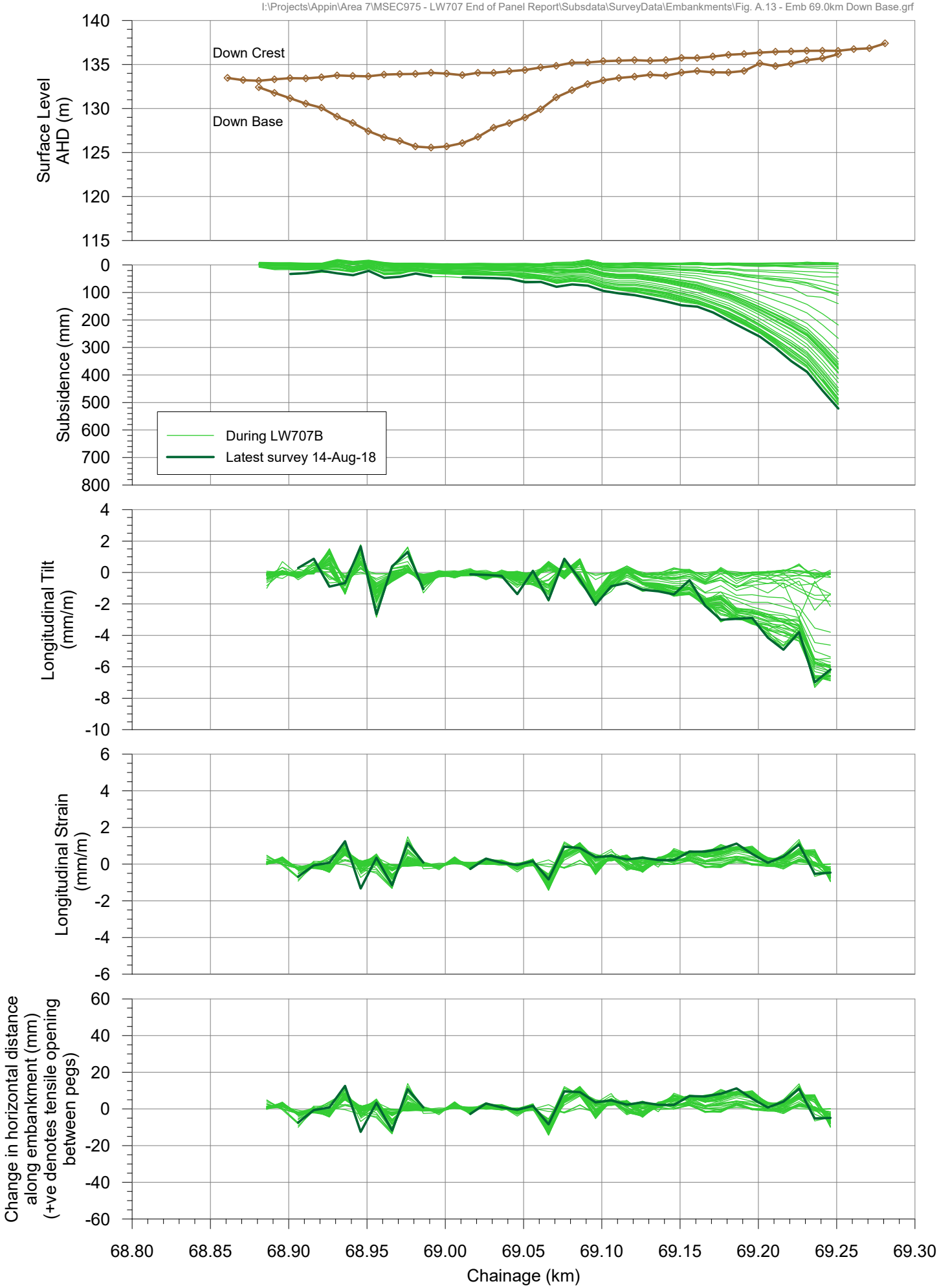

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Fig. A.13

Measured and predicted profiles of incremental vertical subsidence, tilt and strain along the Telstra Line due to LW707A and LW707B

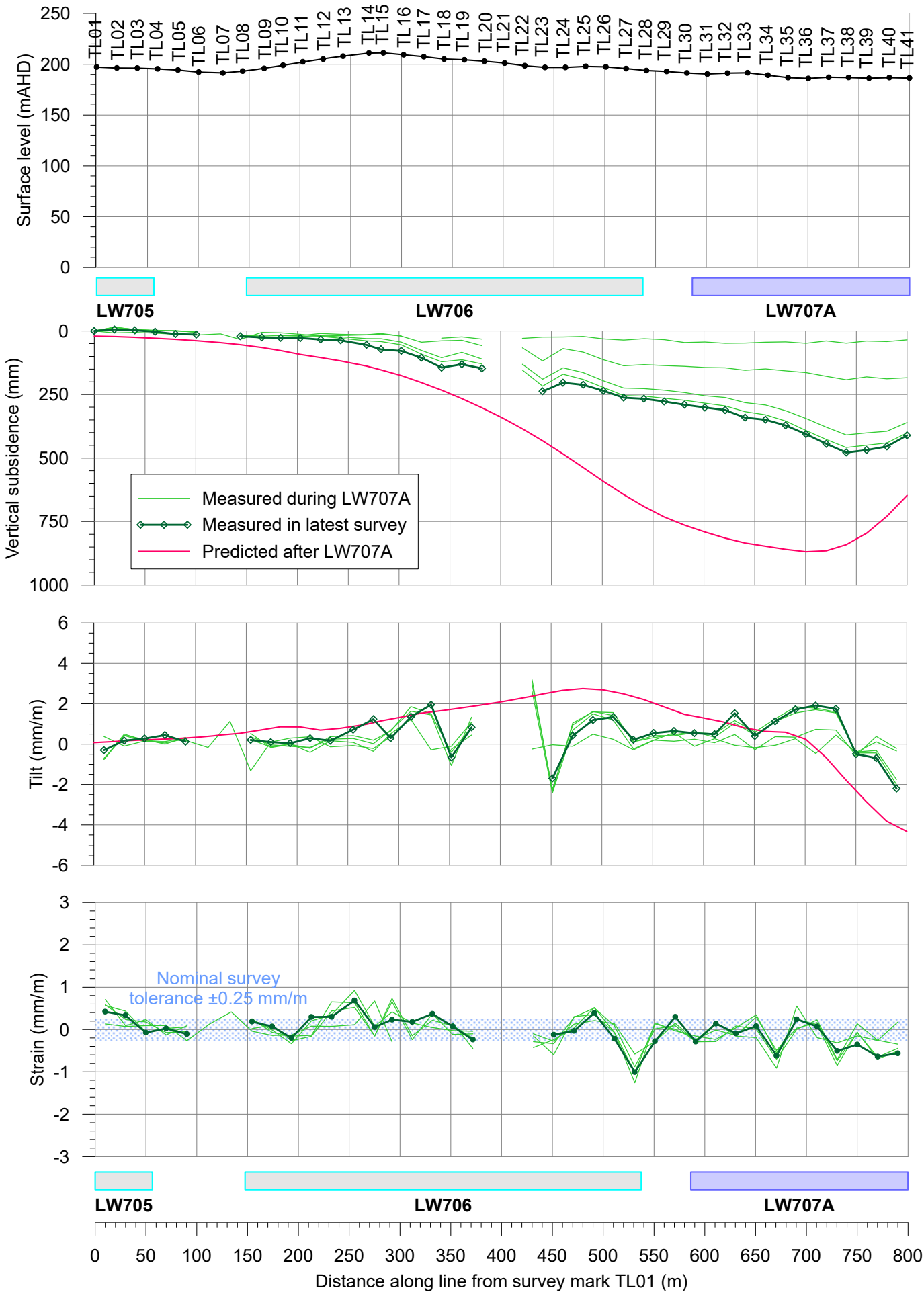

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Fig. A.14

APPENDIX B. DRAWINGS

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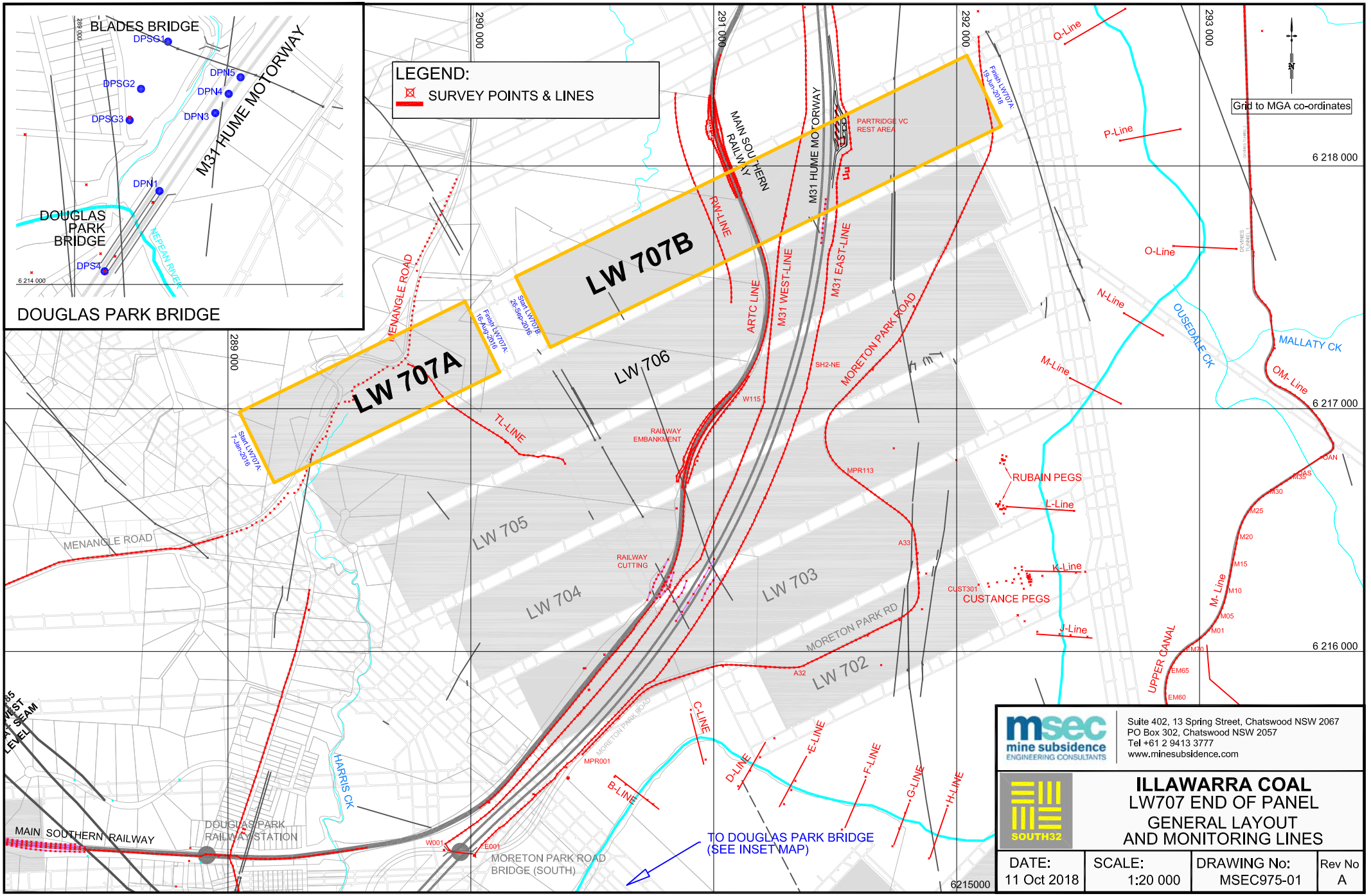

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www.minesubsidence.com

SOUTH32

ILLAWARRA COAL
LW707 END OF PANEL
GENERAL LAYOUT AND MONITORING LINES

DATE:	SCALE:	DRAWING No:	Rev No
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SOUTH32

ILLAWARRA COAL
LW707 END OF PANEL
NATURAL FEATURES

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11 Oct 2018	1:20 000	MSEC975-02	A

LEGEND:
- CLIFFS
- STEEP SLOPES
- WATERCOURSES
- ARCHAEOLOGICAL SITES
- GEOLOGICAL STRUCTURES AT SEAM

Grid to MGA co-ordinates

6 218 000
6 217 000
6 216 000
289 000
290 000
291 000
292 000
293 000

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

Foot Onslow Creek IA 1
Foot Onslow Creek IA 2
Foot Onslow Creek IA 3
Foot Onslow Creek IA 4
Foot Onslow Creek AS 1
Foot Onslow Creek IA 5
Foot Onslow Creek IA 6
SCARRED TREE
52-2-2096
52-2-2095
52-2-1213
52-2-2094
52-2-1214
52-2-2099
52-2-2097
52-2-2098
52-2-1922/52-2-2055
52-2-1924
A47-02
A47-03
A47-04

MEVANGLE ROAD
MAIN SOUTHERN RAILWAY
M31 HUME MOTORWAY
MORETON PARK ROAD
MALLATY CK
QUEENDALE CK
HARRIS CK
NEPEAN RIVER

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SOUTH32

ILLAWARRA COAL
LW707 END OF PANEL
SURFACE INFRASTRUCTURE

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