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BHP BILLITON ILLAWARRA COAL:

Appin Colliery - Longwall 705

End of Panel Subsidence Monitoring Report for Appin Longwall 705

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MSEC578-01 to MSEC578-39 – Weekly Subsidence Monitoring Review Reports for the HW2 Hume Highway, issued during the extraction of Longwall 705 between the 6th February 2013 and the 26th November 2013.

MSEC579-01 to MSEC579-40 – Weekly Subsidence Monitoring Review Reports for the Main Southern Railway, issued during the extraction of Longwall 705 between the 11th March 2013 and the 24th December 2013.

IC (2014). Appin Area 7 Landscape 705 Monitoring Report. BHP Billiton Illawarra Coal, May 2014.

Ecoengineers (2014). End of Panel Assessment of Water Flow and Quality Effects Appin Colliery Longwall 705, June 2014.

Geoterra (2014). Appin Area 7 End of Longwall 705 Groundwater Monitoring Report. Report No. BHP10-R1, 2014.

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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1.1. Introduction

Illawarra Coal (IC) has completed the extraction of Longwall 705 at Appin Colliery, which is located in the Southern Coalfield of New South Wales. The locations of the longwalls at Appin Colliery are shown in Drawing No. MSEC686-01, in Appendix B. The extraction of Longwall 705 commenced on the 7th September 2012 and was completed on the 27th March 2014.

Mine Subsidence Engineering Consultants (MSEC) was previously commissioned by IC to prepare subsidence predictions and impact assessments for Appin Longwalls 705 to 710. Report No. MSEC342 (Revision C) was issued in June 2008 to support the SMP Application for these longwalls.

The Department of Trade and Investment, Regional Infrastructure and Services (DTIRIS), gave IC approval for the extraction of Longwalls 705 and 706 on the 28th February 2012.

In accordance with Section 18 of the SMP Approval Conditions for Appin Longwalls 705 to 706, this report provides:-

- Comparisons between the observed and predicted subsidence movements at the monitoring lines and points resulting from the extraction of Longwall 705, and
- Comparison between the observed and assessed (i.e. predicted) impacts on the natural and built features within the SMP Area resulting from the extraction of Longwall 705.

Further details on the observed and assessed impacts for some natural features, resulting from the extraction of Longwall 705, are provided in the reports by other consultants. The observations provided in this report should be read in conjunction with those and all other relevant reports.

Chapter 2 of this report describes the locations of the ground monitoring lines and points which were surveyed during the extraction of Longwall 705. This chapter also provides comparisons between the observed and predicted movements resulting from the extraction of Longwall 705.

Chapter 3 of this report describes the natural and built features in the vicinity of Longwall 705. This chapter also provides comparisons between the observed and assessed impacts for the natural and built features resulting from the extraction of Longwall 705. Further details on the observed and assessed impacts for some natural features are provided in reports by other consultants.

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

1.2. Mining Geometry

The total void length (i.e. including the installation heading) of Longwall 705 was 2,836 metres and the overall void width (i.e. including the first workings) was 325 metres. The solid width of the chain pillar between Longwalls 704 and 705 was 45 metres. The extent of mining for Longwall 705 is shown in Drawing No. MSEC686-01 in Appendix B.

The depth of cover to the Bulli Seam, directly above Longwall 705, varies between a minimum of 510 metres, above the commencing (eastern) end of the longwall, and a maximum of 600 metres, towards the finishing (western) end of the longwall.

The thickness of the Bulli Seam, within the extent of Longwall 705, varies between 2.8 metres and 3.2 metres. The longwall extracted the full seam thickness.

2.1. Introduction

The mine subsidence movements resulting from the extraction of Appin Longwall 705 were monitored along a number of survey lines and at a number of survey points including the following:-

- The Nepean River Cross Lines,
- Moreton Park Road Line,
- HW2 East and West Lines,
- FBG monitoring along the HW2 Hume Highway,
- Slot Closure monitoring along the HW2 Hume Highway,
- ARTC monitoring line, strain gauges and tilt sensors,
- ARTC Embankment Points
- Highway and Railway Cutting 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 HW2 Hume Highway, Moreton Park Road, the Douglas Park Twin Bridges and Moreton Park Road Bridge (South), and
- Monitoring lines at Sydney Catchment Authority Infrastructure.

The locations of these survey lines and survey points are shown in Drawing No. MSEC686-01, in Appendix B. Comparisons between the observed and predicted subsidence movements at these monitoring lines and points are provided in the following sections.

2.2. Nepean River Cross Lines

Differential movements across the Nepean River valley were measured by IC along 7 ground monitoring lines, being the NEPX K-Line through to the NEPX Q-Line, during Longwall 705.

The locations of these 2D monitoring lines are shown in Drawing No. MSEC686-01. A summary of the survey dates for these monitoring lines are provided in Table 2.1.

Table 2.1 Summary of Survey Dates for the Nepean River Cross Lines during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
	31st August 2012 (End of Longwall 704)	
Monthly surveys from the commencement of Longwall 705	6th October 2012 16th October 2012 20th November 2012 18th December 2012 21st January 2013 20th February 2013 19th March 2013 17th April 2013 14th May 2013 19th June 2013 16th April 2014	As per approved Longwall 706 monitoring program

The predictions of subsidence, upsidence and closure for the Nepean River, resulting from the extraction of Appin Longwalls 705 to 710, were provided in Report No. MSEC342.

The purpose of the surveys was to measure mining-induced valley closure movements.

The predicted profiles of incremental closure along the centreline of the river, resulting from the extraction of Longwall 705, have been reproduced in Fig. A.01 in Appendix A. The predicted and the observed incremental closure for each cross line, at the centreline of the river, have also been indicated in this figure.

The predicted profiles of total closure along the centreline of the river, resulting from the extraction of Longwalls 701 to 705, have been reproduced in Fig. A.02 in Appendix A. The predicted and observed total closure for each cross line, at the centreline of the river, has also been indicated in this figure.

Comparisons between the observed and predicted profiles of total closure along each of the Nepean River cross lines, resulting from the extraction of Longwalls 702 to 705, are provided in Figs. A.03 to A.09 in Appendix A.

A summary of the maximum observed and maximum predicted incremental closure movements for each of the Nepean River cross lines, resulting from the extraction of Longwall 705, is provided in Table 2.2.

Table 2.2 Summary of the Maximum Observed and Maximum Predicted Incremental Closure at the Nepean River Cross Lines due to the Extraction of Longwall 705

Location	Observed Closure	Predicted Closure
NEPX K-Line	11 mm	25 mm
NEPX L-Line	30 mm	50 mm
NEPX M-Line	59 mm	165 mm
NEPX N-Line	17 mm	130 mm
NEPX O-Line	20 mm	75 mm
NEPX P-Line	10 mm	70 mm
NEPX Q-Line	10 mm	10 mm

A summary of the maximum predicted and maximum observed total closure movements for each of the Nepean River cross lines, resulting from the extraction of Longwalls 701 to 705, is provided in Table 2.3

Table 2.3 Summary of the Maximum Observed and Maximum Predicted Total Closure at the Nepean River Cross Lines after the Extraction of Longwall 705

Location	Observed Closure	Predicted Closure
NEPX K-Line	127 mm	230 mm
NEPX L-Line	151 mm	280 mm
NEPX M-Line	111 mm	245 mm
NEPX N-Line	33 mm	165 mm
NEPX O-Line	10 mm	80 mm
NEPX P-Line	10 mm	70 mm
NEPX Q-Line	10 mm	10 mm

The accuracies of the measured closure movements are in the order of ±3 mm. It is noted that the NEPX M-Line and NEPX N-Lines do not utilise prisms and, in consequence, the accuracies of the measured closure movements for these lines are in the order of ±10 mm to ±15 mm.

It can be seen from Fig. A.01 to Fig. A.09 that the maximum observed incremental and total closures along the cross lines were less than predicted.

2.3. Moreton Park Road 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 Line is shown in Drawing No. MSEC686-02 in Appendix B.

A summary of the survey dates for the Moreton Park Road Line, during the extraction of Longwall 705, is provided in Table 2.4.

Table 2.4 Summary of Survey Dates for the Moreton Park Road Line during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Survey at end of Longwall 705, with one survey after 1000m of extraction	8th August 2012 (End of LW704) 7th December 2012 9th January 2013 12th February 2013 14th March 2013 11th April 2013 16th May 2013 21st June 2013 23rd July 2013 27th August 2013 27th March 2014	As per approved Longwall 706 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the Moreton Park Road Line, resulting from the extraction of Longwall 705, are shown in Fig. A.10 in Appendix A. The observed profiles of total subsidence, tilt and strain along the Moreton Park Road Line, resulting from the extraction of Longwalls 702 to 705, are shown in Fig. A.11 in Appendix A.

The predicted profiles of subsidence and tilt along the monitoring line, at the completion of Longwall 705, are also shown in these figures, which were based on the predicted subsidence contours provided in Report No. MSEC342.

It can be seen from Figs. A.10 and A.11, that there is reasonable correlation between the shapes of the observed and predicted incremental subsidence profiles on the maingate side of the panel (the maingate is the side of the panel on the leading edge of the longwall series adjacent to solid, unmined coal). Observed incremental and total subsidence is, however, less than predicted above the chain pillars. While this is conservative from a vertical subsidence prediction point of view, it leads to differences between predicted and observed incremental and total tilts, curvatures and strains, including:

- Observed incremental and total tilts on either side of the chain pillars exceeding predictions.
- Observed sagging curvature at the base of the subsidence trough exceeding predictions.
- Observed small incremental sagging curvature above the previous longwall panel.

A summary of the maximum observed and maximum predicted incremental subsidence parameters along the Moreton Park Road Line, resulting from the extraction of Longwall 705, is provided in Table 2.5. A summary of the maximum observed and maximum predicted total subsidence parameters along the Moreton Park Road Line, resulting from the extraction of Longwalls 702 to 705, is provided in Table 2.6.

Table 2.5 Maximum Observed and Predicted Incremental Subsidence Parameters along Moreton Park Road Resulting from the Extraction of Longwall 705

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	845	7.2	1.0	3.5
Predicted	1015	4.0	*- Refer to discussions below -*	

Table 2.6 Maximum Observed and Predicted Total Subsidence Parameters along Moreton Park Road Resulting from the Extraction of Longwalls 702 to 705

Type	Maximum Total Subsidence (mm)	Maximum Total Tilt (mm/m)	Maximum Total Tensile Strain (mm/m)	Maximum Total Comp. Strain (mm/m)
Observed	1249	7.7	1.0	4.8
Predicted	1350	5.2	*- Refer to discussions below -*	

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

The maximum observed incremental subsidence along the road, due to the extraction of Longwall 705, of 845 mm was similar to but less than the maximum predicted of 1015 mm. The maximum observed incremental tilt of 7.2 mm/m was greater than the maximum predicted of 4.0 mm/m, however, this occurred in an area of valley closure related non-conventional movement.

The maximum predicted conventional total tensile and compressive strains along the monitoring line, based on applying a factor of 15 to the maximum predicted curvatures, were 1.1 mm/m and 1.8 mm/m, respectively.

The maximum observed incremental and total tensile strain of 1.0 mm/m was, therefore, similar to the maximum predicted based on conventional movements. The maximum observed incremental and total compressive strains of 3.5 mm/m and 4.8 mm/m, respectively, were, however, greater than the maxima predicted based on conventional movements. The compressive strain above Longwall 705 was localised between Marks MPR119 and MPR120 and appears to be the result of valley closure related non-conventional movement.

2.4. HW2 Hume Highway

The HW2 Hume Highway crosses directly above Longwall 705 as shown in Drawings Nos. MSEC686-01 and MSEC686-03, in Appendix B. The monitoring associated with the highway, during the extraction of Longwall 705, included the following:-

- HW2 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 highway (MSEC578-01 to MSEC578-39), which were issued during the extraction of Longwall 705 between the 6th February 2013 and the 26th November 2013.

A summary of the monitoring results for the HW2 Hume Highway are provided in the following sections.

2.4.1. HW2 East and HW2 West Lines

The mine subsidence movements along the HW2 Hume Highway were measured by IC using two 3D monitoring lines, being the HW2 East and HW2 West Lines. The locations of these monitoring lines are shown in Drawing No. MSEC686-01 in Appendix B.

A summary of the survey dates for the HW2 East and HW2 West Lines, during the extraction of Longwall 705, is provided in Table 2.7.

Table 2.7 Summary of Survey Dates for the HW2 East and HW2 West Lines during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Survey full length of monitoring lines at start and end of Longwall 705, plus one 3D survey at 500 metres of extraction, then monthly 3D surveys after 600 metres of extraction, plus weekly focused 2D surveys after 700 metres of extraction	20th August 2012 (End of LW704) 10th September 2012, 16th January 2013, 18th February 2013, then weekly surveys to the 3rd June 2013, then twice weekly surveys to the 1st July 2013, then weekly surveys to the 26th August 2013, then fortnightly surveys to the 24th September 2013, and then monthly surveys to the 20th November 2013	As per approved Longwall 706 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the HW2 East and HW2 West Lines, resulting from the extraction of Longwall 705, are shown in Figs. A.12 and A.13, respectively, in Appendix A. The predicted profiles of incremental subsidence and tilt along these monitoring lines, at the completion of Longwall 705, are also shown in these figures, which were based on the predicted subsidence contours provided in Report No. MSEC342.

It can be seen from Figs. A.12 and A.13, that there is reasonable correlation between the shapes of the observed and predicted incremental subsidence profiles but observed subsidence above the chain pillars is less than predicted, as observed generally in Appin Area 7. Please refer to Section 2.3 for additional commentary, which is also applicable for these monitoring lines.

A summary of the maximum observed and maximum predicted incremental subsidence parameters along the HW2 East and HW2 West Lines, resulting from the extraction of Longwall 705, is provided in Table 2.8.

Table 2.8 Maximum Observed and Predicted Incremental Subsidence Parameters along HW2 East and HW2 West Lines Resulting from the Extraction of Longwall 705

Monitoring Line	Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
HW2 East Line	Observed	1030	7.4	1.3	2.8
	Predicted	1000	4.7	*- Refer to discussions below -*	
HW2 West Line	Observed	941	6.0	1.4	2.5
	Predicted	1000	5.7	*- Refer to discussions below -*	

The accuracies of the measured relative Eastings, Northings and levels along the HW2 East and West Lines are in the order of ±3 mm to ±5 mm. The accuracies of the measured absolute Eastings, Northings and levels along the HW2 East and West Lines are in the order of ±15 mm. The accuracies of the measured strains along the HW2 East and West Lines are in the order of ±0.25 mm/m.

The maximum observed incremental subsidence along the HW2 East and HW2 West Lines of 1030 mm and 941 mm, respectively, were slightly greater than and slightly less than the predicted maximum subsidence of 1000 mm. The maximum observed subsidence along the HW2 East and HW2 West Lines, therefore, represented 103% and 91 %, respectively, of the maximum predicted subsidence. Similarly, the maximum observed incremental tilts along the HW2 East and HW2 West Lines of 7.4 mm/m and 6.0 mm/m, respectively, were greater than the maximum predicted of 4.7 mm/m and 5.7 mm/m, respectively.

The maximum observed incremental tensile strains along the HW2 East Line and HW2 West Line were 1.3 mm/m and 1.4 mm/m, respectively. The maximum predicted incremental and total conventional tensile strain along the monitoring lines, based on applying a factor of 15 to the maximum predicted curvatures, was 0.5 mm/m. Whilst the maximum observed tensile strain along the HW2 East Line exceeded the predicted maxima, based on conventional movements, the observed tensile strains were similar to those typically observed elsewhere in the Southern Coalfield.

The maximum observed incremental compressive strains along the HW2 East Line and HW2 West Line were 2.8 mm/m and 2.5 mm/m, respectively. The maximum predicted total conventional compressive strain along the monitoring lines, based on applying a factor of 15 to the maximum predicted curvatures, was

1.0 mm/m. The observed peak compressive strains were localised between Marks E121R to E122R along the East Line and between Marks W113 to W117 along the West Line with an associated bump in the observed subsidence profile, which indicates that non-conventional movement has developed at this location.

The development of these non-conventional compressive strains, based on their positions relative to the extraction face of Longwall 705, is illustrated in Fig. 2.1. The developments of other non-conventional strains during the previous extraction of Longwalls 703 and 704, and from elsewhere in the Southern Coalfield are also shown in this figure for comparison.

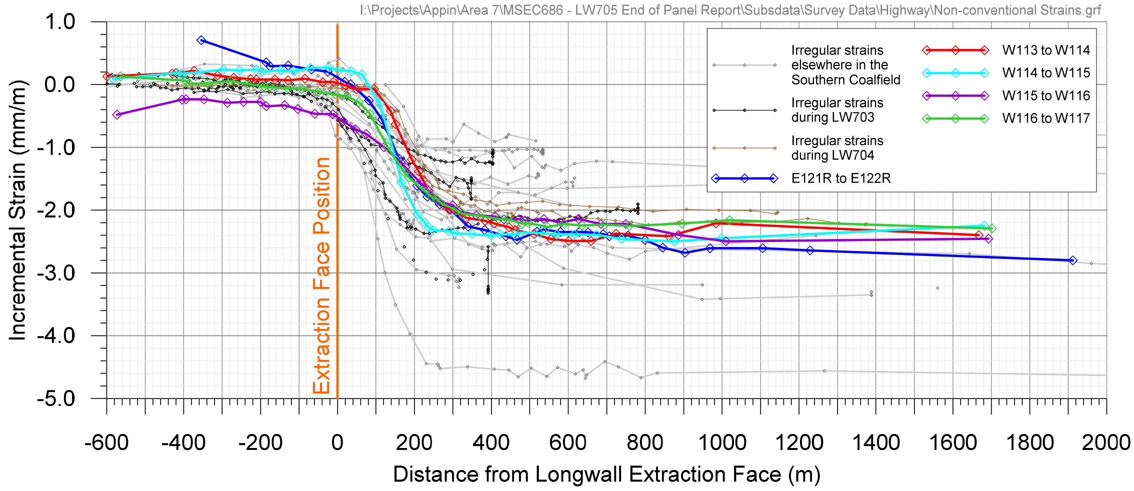


Fig. 2.1 Development of Non-Conventional Strains along the HW2 East and HW2 West Lines Based on the Position relative to the Longwall 705 Extraction Face

It can be seen from the above figure, that the magnitudes of the compressive strains between Marks E121R to E122R and between Marks W113 to W116 were similar to those for the non-conventional movements which developed during the previous extraction of Longwalls 703 and 704. Also, the rates of development of these compressive strains were similar to the maximum rates of development for the non-conventional movements during the previous extraction of Longwalls 703 and 704.

2.4.2. Highway Cutting Points

The Highway Cutting Points are described in Section 2.6.

2.4.3. FBG and Slot Displacement Monitoring

FBG Monitoring

A total of 480 temperature and 480 strain FBG sensors were installed in the top 50 mm of asphalt along each carriageway within the outside shoulder. The sensors are spaced every 10 metres and the temperature and strain were measured every 15 minutes during the mining of Longwall 705.

The temperature compensated FBG strains exceeded the trigger levels in the management plan twice during the mining of Longwall 705. A blue alarm was received on the 29th May 2013 for an exceedance of the average strain at a single FBG 126.2 on the Northbound Carriageway. Upon inspection at the trigger point, a hump, which had been previously detected last week, was found to have grown. A smaller hump was observed on the Southbound Carriageway opposite the site. Observed pavement strains were found to correspond with observed increased compressive ground strains on both the East and West monitoring lines in this area.

A number of additional management measures were undertaken in response to this event between May and August 2013. The measures were undertaken during and after the period of most active changes in differential ground movements and FBG strains, which was between May and late June 2013.

The additional management measures included re-profiling of the pavement and the installation of additional slots. The highway remained safe and serviceable during the event period, though temporary speed restrictions were imposed for short durations during this time. A small number of additional blue alarms were received during this period.

Slot Displacement Monitoring

Displacement sensors were installed in each pavement slot and were measured every 5 minutes during the mining of Longwall 705. The slot displacements did not exceed the management plan trigger levels for closure at any stage during the mining of Longwall 705. The maximum observed closure of the slots located directly above Longwall 705 was 38 mm at SB103 and 58mm at NB126.

2.5. The Main Southern Railway

The Main Southern Railway crosses directly above Longwall 705 as shown in Drawings Nos. MSEC686-01 and MSEC686-03, in Appendix B. The monitoring associated with the railway, during the extraction of Longwall 705, included the following:-

- ARTC 3D ground monitoring line,
- ARTC 3D embankment monitoring points,
- Railway cutting points,
- Strain gauges, and
- Tilt sensors.

The monitoring results and discussions were provided in the weekly subsidence monitoring review reports for the railway (MSEC579-01 to MSEC79-40), which were issued during the extraction of Longwall 705 between the 11^{th} March 2013 and the 24^{th} December 2013.

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

2.5.1. 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. MSEC686-01 in Appendix B.

A summary of the survey dates for the ARTC Line, during the extraction of Longwall 705, is provided in Table 2.9.

Table 2.9 Summary of Survey Dates for the ARTC Line during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 705, with monthly 3D surveys after 700 metres of extraction, plus weekly 2D focused surveys after 950 metres of extraction, then twice weekly focused 2D surveys after 1100 metres of extraction	20^{th} August 2012 (End of LW704) 5^{th} November 2012, 18^{th} February 2013, then monthly to the 18^{th} March 2013, then fortnightly to the 2^{nd} April 2013, then weekly to the 29^{th} April 2013, then twice weekly to the 30^{th} September 2013, then weekly to the 29^{th} October 2013, then monthly to the 20^{th} December 2013, and then 3^{rd} April 2014	As per approved Longwall 706 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the ARTC Line, resulting from the extraction of Longwall 705, are shown in Fig. A.14, in Appendix A. The predicted profiles of incremental subsidence and tilt along the monitoring line, at the completion of Longwall 705, are also shown in this figure, which were based on the predicted subsidence contours provided in Report No. MSEC342.

It can be seen from this figure, that there is reasonable correlation between the shapes of the observed and predicted incremental subsidence profiles but observed subsidence above the chain pillars is less than predicted, as observed generally in Appin Area 7. Please refer to Section 2.3 for additional commentary, which is also applicable for these monitoring lines.

A summary of the maximum observed and maximum predicted subsidence parameters along the ARTC Line, resulting from the extraction of Longwall 705, is provided in Table 2.10.

Table 2.10 Maximum Observed and Predicted Incremental Subsidence Parameters along the ARTC Line Resulting from the Extraction of Longwall 705

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	764	2.9	0.7	2.0
Predicted	950	2.4	*- Refer to discussions below -*	

The accuracies of the measured relative Eastings, Northings and levels along the ARTC Line are in the order of ±3 mm to ±5 mm. The accuracies of the measured absolute Eastings, Northings and levels along the ARTC Line are in the order of ±15 mm. The accuracies of the measured strains along the ARTC Line are in the order of ±0.25 mm/m.

The maximum observed incremental subsidence along the ARTC Line of 764 mm was less than the maxima predicted of 950 mm. The maximum observed subsidence represented around 80 % of the maximum predicted subsidence. The maximum observed incremental tilt of 2.9 mm/m was slightly more than the maximum predicted of 2.4 mm/m.

The maximum observed incremental tensile and compressive strains along the ARTC Line were 0.7 mm/m and 2.0 mm/m, respectively. The maximum predicted incremental conventional tensile and compressive strains along this monitoring line, based on applying a factor of 15 to the maximum predicted curvatures, were both 0.6 mm/m.

The observed peak compressive strains were localised between Marks ARTC1085 to ARTC1086 with an associated bump in the observed subsidence profile, which indicates that non-conventional movement has developed at this location.

The maximum observed incremental compressive strain along the ARTC Line was localised between Marks ARTC1085 to ARTC1086 and, therefore, appears to be the result of an anomalous non-conventional movement. The development of this non-conventional compressive strain, based on its position relative to the extraction face of Longwall 705, is illustrated in Fig. 2.2. The developments of the non-conventional strains along the HW2 East and West Lines, during the extraction of Longwalls 703, 704 and 705, are also shown in this figure for comparison.

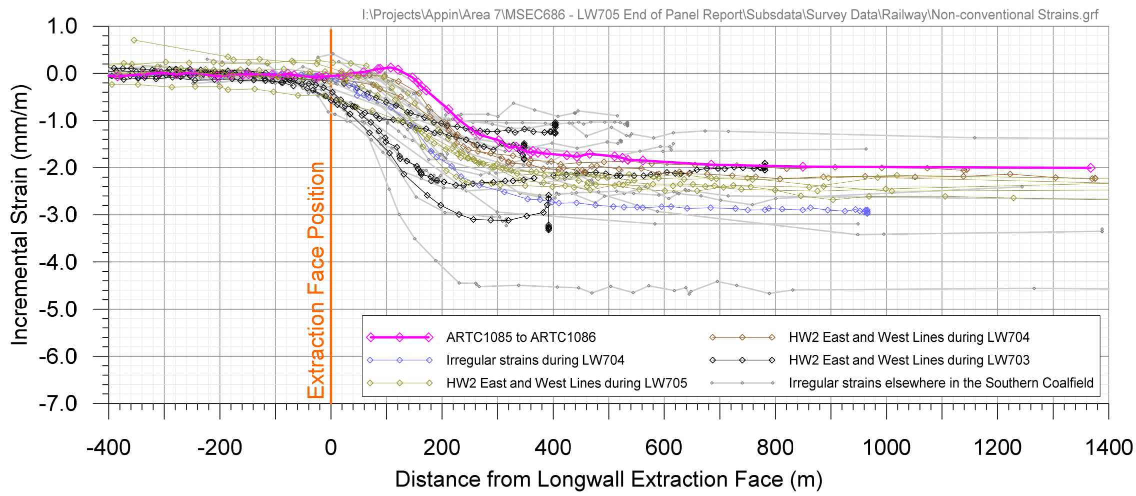


Fig. 2.2 Development of the Non-Conventional Strain along the ARTC Line Based on the Position relative to the Longwall 705 Extraction Face

It can be seen from the above figure, that the magnitude of the compressive strain between Marks ARTC1085 to ARTC1086 was similar to those for the non-conventional movements which developed during the extraction of Longwalls 703 and 704. Also, the rate of development of this compressive strain was similar to the maximum rates of development for the non-conventional movements during the extraction of Longwalls 703 and 704.

2.5.2. Railway Cutting Points

The Railway Cutting Points are described in Section 2.6.

2.5.3. Automated Track Monitoring

Tilt Sensors

Bi-directional tiltmeters are located in the Down (Southbound) track within the railway cutting at 71 km. They measured changes in grade every 15 minutes during the mining of Longwall 705. While the sensors detected changes in tilt as a result of mining, which correlated with ground survey and track geometry measurements, these measurements did not exceed the trigger levels.

Rail Stress Transducers

Rail stress transducers are located along all four rails of the railway track, spaced every 25 metres to 33 metres. They measured changes in rail strain every 5 minutes during the mining of Longwall 705. While some false alarms were triggered during mining due to malfunction or damage to transducers, actual stress readings did not exceed trigger levels.

Expansion Switch Displacement Sensors

Displacement sensors have been installed at each expansion switch. Measurements were recorded every 5 minutes during the mining of Longwall 705. Mining-induced changes were observed, however, larger changes were observed due to thermal movements. While some low level (Blue) alarms were triggered during mining, responses had already been planned in anticipation of the alarms.

2.5.4. Embankment Monitoring

The mine subsidence movements along the Embankment were measured by IC using a 3D ground monitoring line, referred to as the ARTC Embankment. The locations of the monitoring points are shown in Drawing No. MSEC686-01 in Appendix B.

A summary of the survey dates for the ARTC Embankment, during the extraction of Longwall 705, is provided in Table 2.9.

Table 2.11 Summary of Survey Dates for the Embankment lines during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Baseline survey after completion of embankment widening works, and survey at end of Longwall 705, with monthly absolute 3D surveys after 700 metres of extraction, plus weekly local 3D surveys after 950 metres of extraction	7th June 2012 (End of LW704) 5th November 2012, 18th February 2013, 2nd April 2013, then weekly to the 29th October 2013, then monthly to the 20th December 2013, and then 3rd April 2014	As per approved Longwall 706 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the Embankment lines, resulting from the extraction of Longwall 705, are shown in Fig. A.15 to Fig. A.18, in Appendix A. The predicted profiles of incremental subsidence and tilt along the monitoring line, at the completion of Longwall 705, are also shown in this figure, which were based on the predicted subsidence contours provided in Report No. MSEC342.

A summary of the maximum observed and maximum predicted subsidence parameters along the Embankment lines, resulting from the extraction of Longwall 705, is provided in Table 2.10.

Table 2.12 Maximum Observed and Predicted Incremental Subsidence Parameters along the ARTC Embankment Lines Resulting from the Extraction of Longwall 705

Type	Maximum Incremental Subsidence (mm)	Maximum Incremental Tilt (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	751	3.4	1.0	2.0
Predicted	950	2.4	*- Refer to discussions below -*	

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 ARTC Line are in the order of ±10 mm. The accuracies of the measured strains along the ARTC Line are in the order of ±0.15 mm/m.

Please refer to comparisons between predicted and observed subsidence movements in Section 2.5.1, as the findings are the same. The main survey line along the railway corridor is located on the crest of the embankment on the Down side.

2.5.5. Culverts

The mine subsidence movements along a railway culvert were measured by IC using a 3D ground monitoring line, referred to as the ARTC 70.5km Culvert. The locations of the monitoring points are shown in Drawing No. MSEC686-01 in Appendix B, and the measured changes in horizontal distance along the culvert invert are shown in Fig. 2.3.

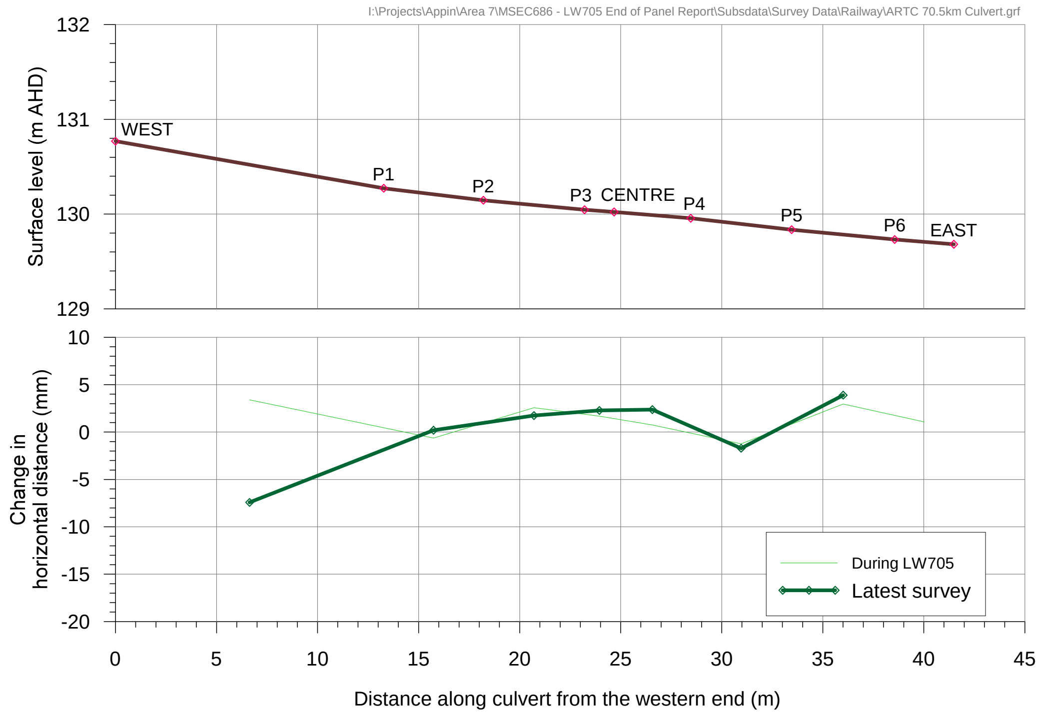


Fig. 2.3 Changes in Horizontal Distance along the ARTC 70.5km Culvert Invert during the Extraction of Longwall 705

2.6. Highway and Railway Cutting Points

The Highway and Railway Cutting Points were measured by IC, during the extraction of Longwall 705, which are 3D monitoring points located on the cuttings along the HW2 Hume Highway and the Main Southern Railway. The locations of these monitoring points are shown in Drawing No. MSEC686-01, in Appendix B.

A summary of the survey dates for these monitoring points is provided in Table 2.13.

Table 2.13 Summary of Survey Dates for the Highway and Railway Cutting Points during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Survey at end of Longwall 705, with monthly surveys during mining after 1500 metres of extraction	20th August 2012 (End of LW704) 23rd April 2013 27th May 2013 1st July 2013 30th July 2013 26th August 2013 24th September 2013 29th October 2013 20th November 2013 20th December 2013 16th April 2014	As per approved Longwall 706 monitoring program

The final observed absolute incremental horizontal movements at the Highway and Railway Cutting Points, due to the extraction of Longwall 705, are shown in Fig. 2.4. It is noted that there are three pegs located on railway sleepers, whose directions of movement are different to those measured at other pegs. This is because the railway track has been re-surfaced and the sleepers have been moved by track machinery.

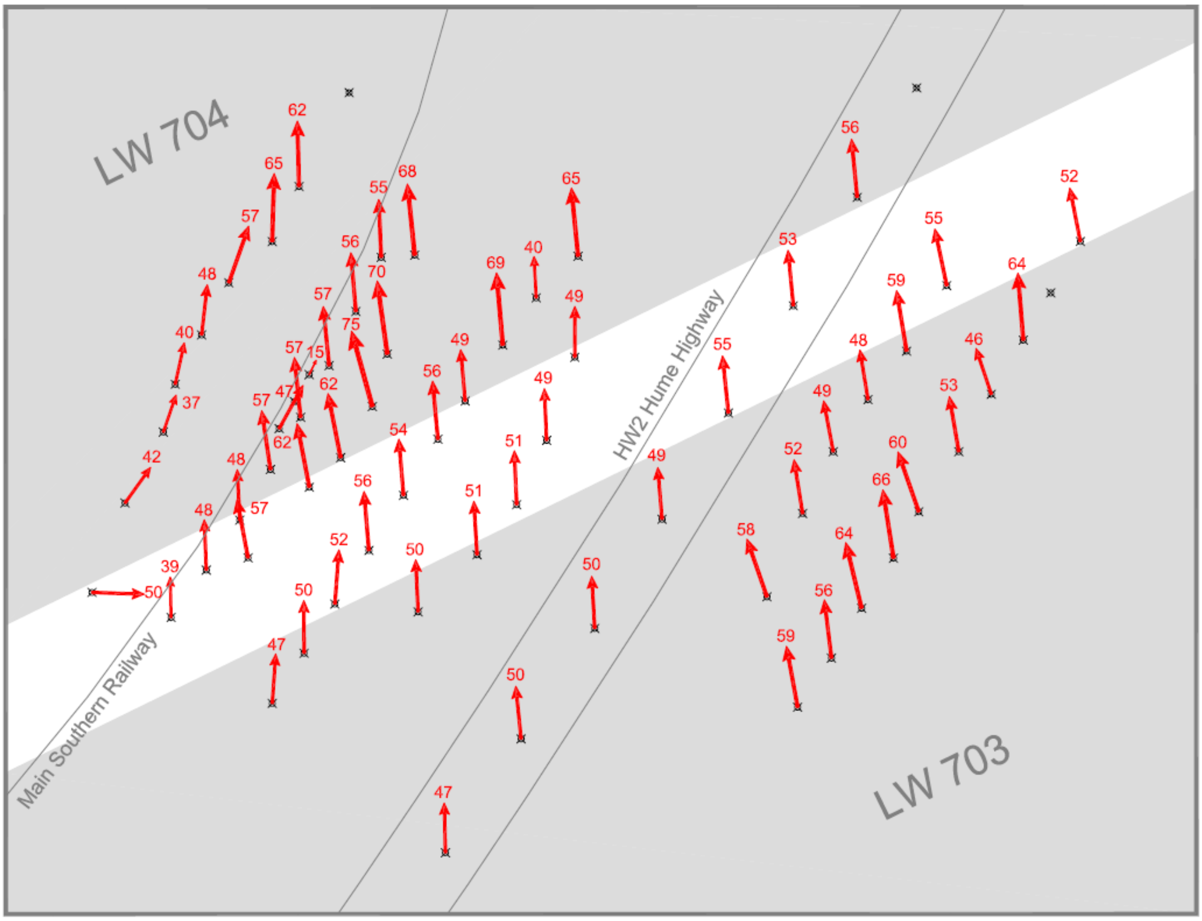


Fig. 2.4 Observed Absolute Incremental Horizontal Movements at the Highway and Railway Cutting Points due to the Extraction of Longwall 705 (16th April 2014)

A summary of the maximum observed absolute incremental horizontal movements at the cutting monitoring points, at any time during or after the extraction of Longwall 705, is provided in Table 2.14.

Table 2.14 Maximum Observed Absolute Incremental Horizontal Movements at the Highway and Railway Cutting Points Resulting from the Extraction of Longwall 705

Longwall	Location	Maximum Observed Incremental Horizontal Movement (mm)
Longwall 705	A01 to A09	93
	B01 to B03	72
	C01 to C08	64
	D01 to D06	75
	E01 to E10	69
	F01 to F05	54
	G01 to G08	58
	H01 to H06	59
	I01 to I10	66

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.

The observed incremental horizontal movements at the highway and railway cutting points versus distance from Longwall 705 are illustrated in Fig. 2.9. It can be seen from this figure that the observed movements were within the range of those observed along the highway and railway monitoring lines, and less than those typically observed elsewhere in the Southern Coalfield.

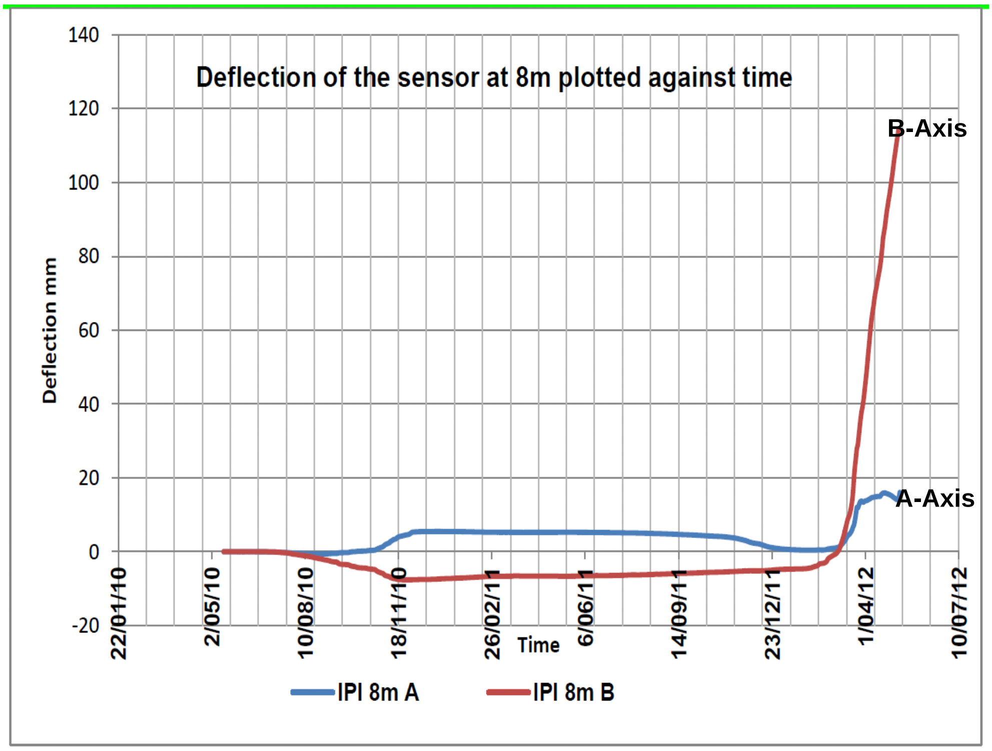
Fixed In-place Inclinometer

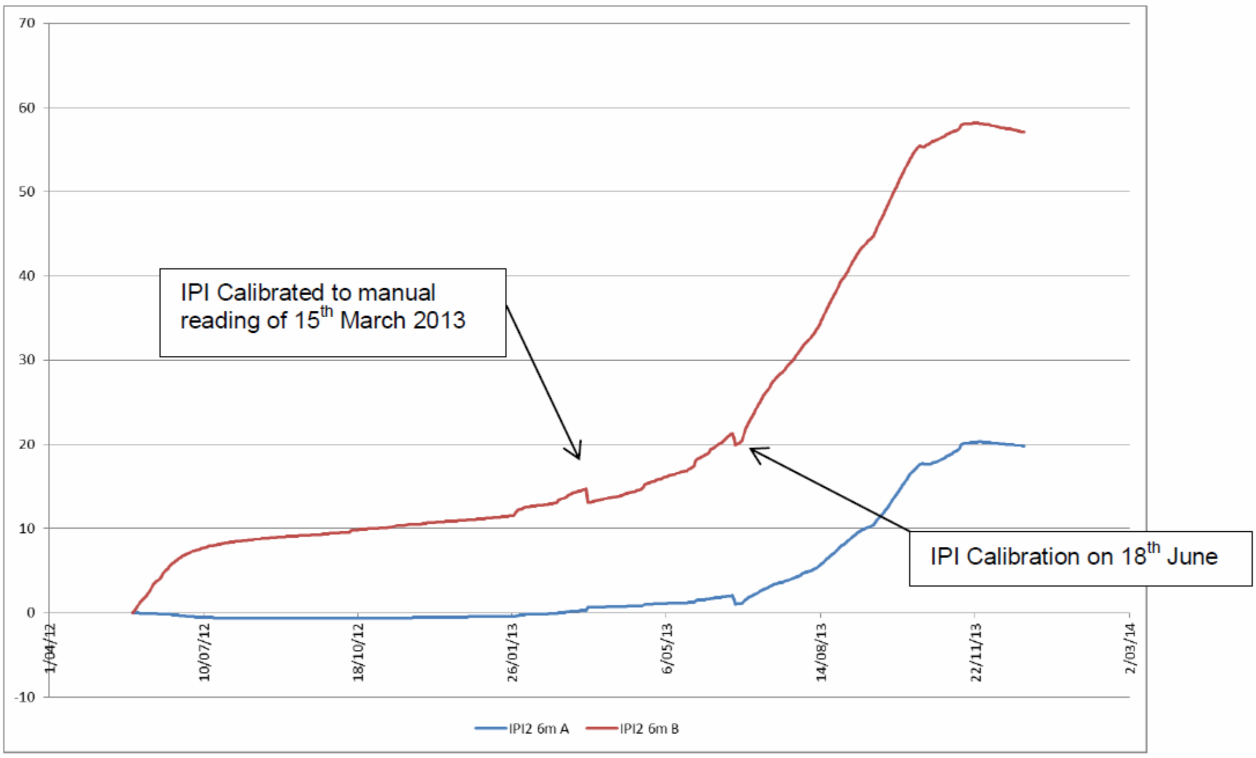
A vertical fixed in-place inclinometer was installed in the floor of the railway cutting near 71 km. The hole intersected a geological fault that was identified in the sides of the railway cutting. Measurements were recorded every hour. The inclinometers comprised tiltmeters generally spaced at 2 metre centres, with a concentration of tiltmeters spaced at 0.5 metre centres in the zone where the hole is projected to intersect the fault line.

During the mining of Longwall 704, the fixed-in-place inclinometer detected very early small deflections at 8 metres depth, where the borehole intersected the fault zone. Deflection of the B-Axis (parallel to the strike of the fault) at 8 metres depth increased as mining progressed, with the rate of change accelerating when the longwall face had passed the inclinometer by approximately 150 metres. The maximum deflection at the 8 metre sensor B-Axis was 147 mm on 4 June, when it reached the limit of its monitoring tolerance and ceased to record.

A new fixed-in-place inclinometer was installed at this time and the readings showed continued deflection where the new borehole intersects the fault at 6 m depth during the mining of Longwall 705 (refer Fig. 2.5). Approximately 50% of the additional differential movements developed during the mining of Longwall 705, as shown in Fig. 2.5.

A plot produced by geotechnical engineer David Christie, showing the development of the deflection at a depth of 8 metres, has been reproduced in Fig. 2.5.





Graph courtesy David Christie

Fig. 2.5 Observed Changes in Fixed In-Place Inclinometer at 8m Depth during Longwalls 704 and 705

2.6.1. Highway Cutting 2

The Highway Cutting 2 Points were measured by IC, during the extraction of Longwall 705, which are 3D monitoring points located on the cuttings along the HW2 Hume Highway. The locations of these monitoring points are shown in Drawing No. MSEC686-01, in Appendix B.

A summary of the survey dates for these monitoring points is provided in Table 2.13.

Table 2.15 Summary of Survey Dates for the Highway Cutting 2 Points during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Survey at end of Longwall 705, with monthly surveys during mining after 1500 metres of extraction	16th January 2013 (Base Survey) 18th February 2013 18th March 2013 23rd April 2013 27th May 2013 1st July 2013 30th July 2013 26th August 2013 24th September 2013 29th October 2013 20th November 2013 15th April 2014	As per approved Longwall 706 monitoring program

The final observed absolute incremental horizontal movements at the Highway Cutting 2 Points, due to the extraction of Longwall 705, are shown in Fig. 2.6.

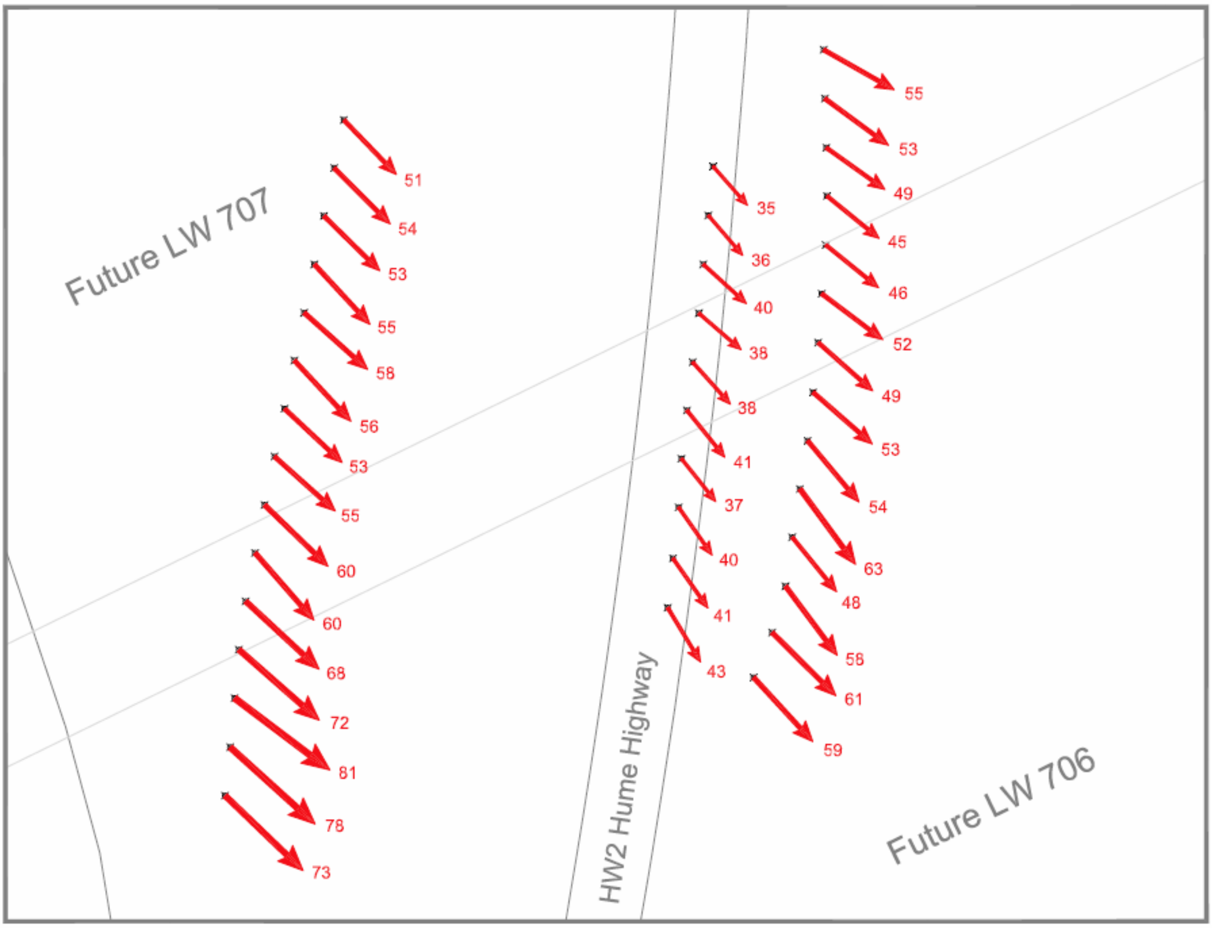


Fig. 2.6 Observed Absolute Incremental Horizontal Movements at the Highway Cutting 2 Points due to the Extraction of Longwall 705 (15th April 2014)

A summary of the maximum observed absolute incremental horizontal movements at the cutting monitoring points, at any time during or after the extraction of Longwall 705, is provided in Table 2.14.

Table 2.16 Maximum Observed Absolute Incremental Horizontal Movements at the Highway Cutting 2 Points Resulting from the Extraction of Longwall 705

Longwall	Location	Maximum Observed Incremental Horizontal Movement (mm)
Longwall 705	W144 to W158	81
	G101 to G110	43
	E146R to E160R	63

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.

2.7. Far-field 3D Marks

The far-field mine subsidence movements were measured by IC using a number of 3D points in the vicinity of Longwall 705. The locations of these monitoring points are shown in Drawing No. MSEC686-01 in Appendix B.

A summary of the survey dates for the far-field 3D monitoring points, during the extraction of Longwall 705, is provided in Table 2.17.

Table 2.17 Summary of Survey Dates for the Far-field 3D Monitoring Points during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 705, with monthly surveys during mining after 300 metres of extraction	21st August 2012 (End of LW704) 19th November 2012 21st December 2012 22nd January 2013 21st February 2013 19th March 2013 22nd April 2013 28th May 2013 24th June 2013 29th July 2012 23rd August 2013 23rd September 2013 30th October 2013 18th November 2013 10th December 2013 20th January 2014 17th February 2014 23rd April 2014	As per approved Longwall 706 monitoring program

The loci of observed absolute incremental horizontal movements at the far-field 3D monitoring points, during the extraction of Longwall 705, are shown in Fig. 2.7.

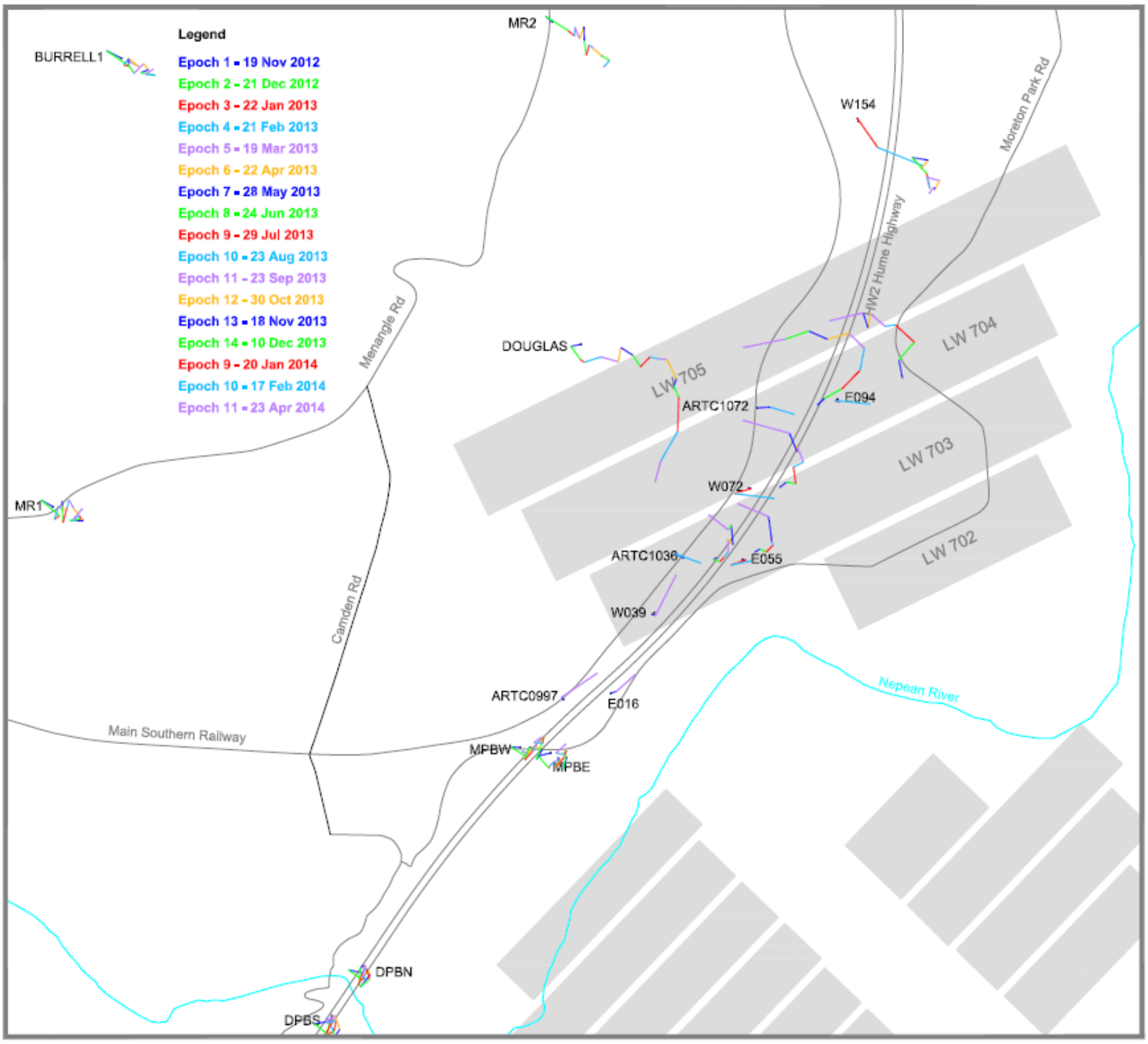


Fig. 2.7 Loci of Observed Absolute Incremental Horizontal Movements at the Far-field 3D Monitoring Points during the Extraction of Longwall 705 (19th November 2012 to 23rd April 2014)

The final observed absolute incremental horizontal movements at the far-field 3D monitoring points, due to the extraction of Longwall 705, are shown in Fig. 2.8.

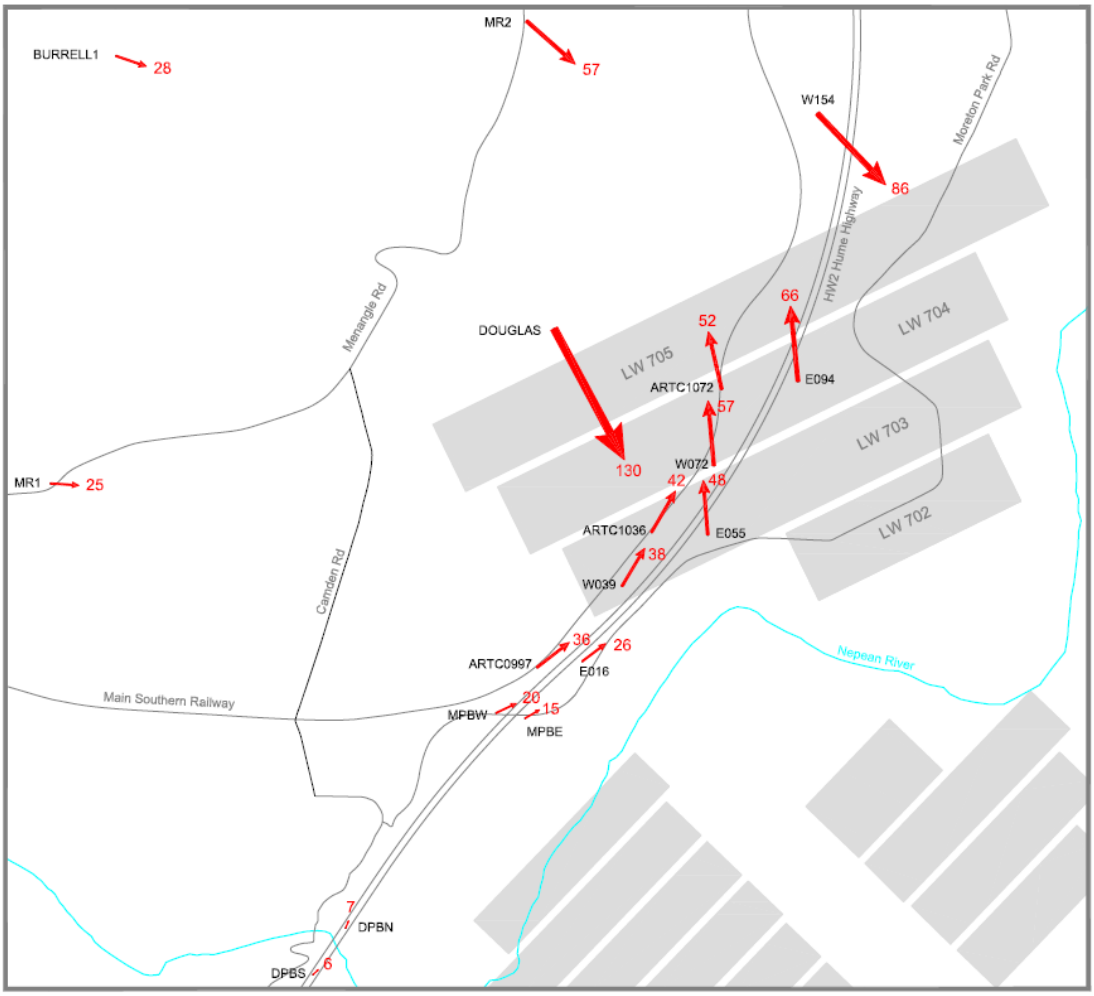


Fig. 2.8 Observed Absolute Incremental Horizontal Movements at the Far-field 3D Monitoring Points due to the Extraction of Longwall 705 (23rd April 2014)

A summary of the maximum observed absolute incremental horizontal movements at the far-field 3D monitoring points, at any time during or after the extraction of Longwall 705, is provided in Table 2.18.

Table 2.18 Maximum Observed Absolute Incremental Horizontal Movements at the Far-field 3D Monitoring Points Resulting from the Extraction of Longwall 705

Longwall	Location	Maximum Observed Incremental Horizontal Movement (mm)
Longwall 705	ARTC0997	36
	ARTC1036	42
	ARTC1072	52
	BURRELL1	28
	DOUGLAS	130
	DPBN	7
	DPBS	6
	E016	26
	E055	48
	E094	66
	MPBE	15
	MPBW	20
	MR1	25
	MR2	57
	W039	38
	W072	57
	W154	86

The accuracies of the measured Eastings and Northings at the far-field 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.

A comparison between the observed incremental horizontal movements for the far-field 3D marks (magenta points), due to the extraction of Longwall 705, with those previously measured elsewhere in the Southern Coalfield (grey points) is provided in Fig. 2.9. The incremental horizontal movements at the HW2 East Line (blue points), HW2 West Line (cyan points), ARTC Line (green points) and the highway and railway cutting marks (orange points), due to the extraction of Longwall 705, are also shown in this figure for comparison.

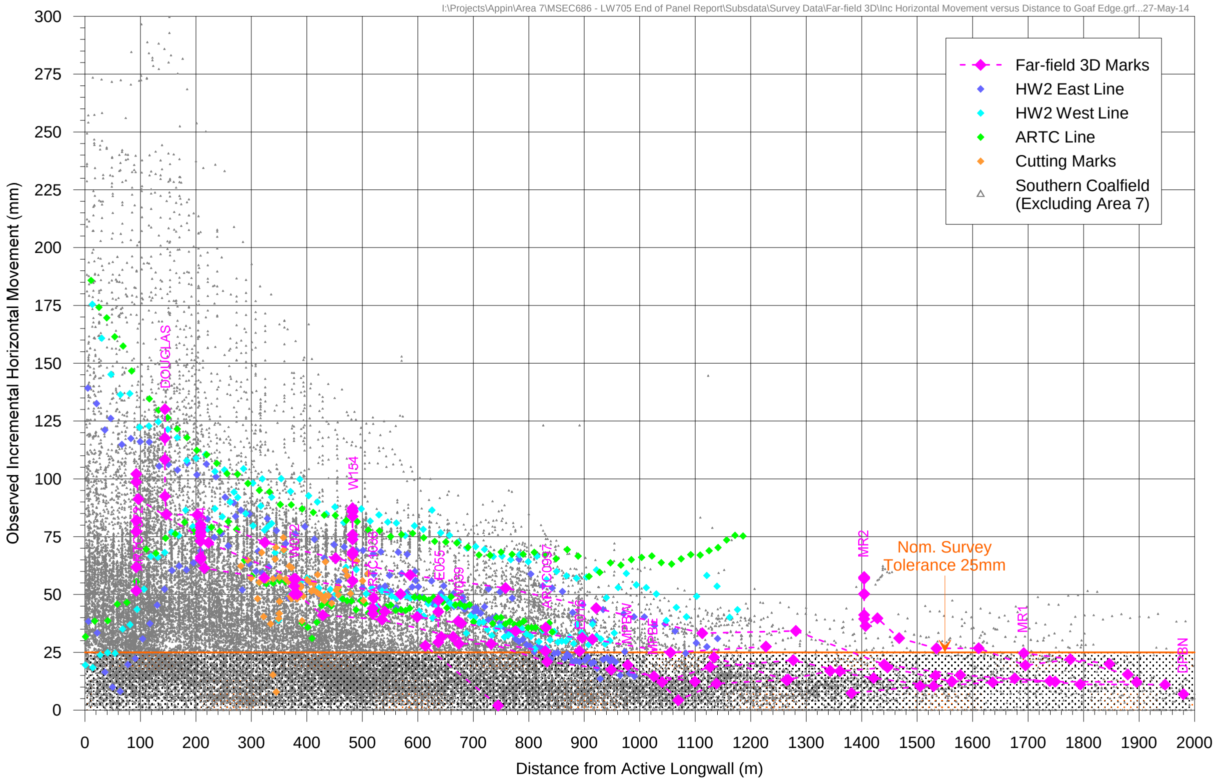


Fig. 2.9 Observed Absolute Incremental Horizontal Movements versus Distance to Nearest Longwall Goaf Edge with Solid Coal between Mark and Extracted Longwall, with Longwall 705 results overlaid

It can be seen from this figure that the observed incremental horizontal movements at the far-field marks, due to the extraction of Longwall 705, were within the range of those previously observed in the Southern Coalfield.

2.8. Douglas Park Twin Bridges over the Nepean River

The Douglas Park Twin Bridges are located approximately 1.9 kilometres south-west of the finishing (western) end of Longwall 705. The locations of these bridges are shown in Drawing No. MSEC686-01, in Appendix B, where the Hume Highway crosses the Nepean River. The monitoring associated with the Douglas Park Twin Bridges, during the extraction of Longwall 705, included the following:-

- 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.

2.8.1. 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 Points DPBN and DPBS, which are located adjacent to the northern and southern ends, respectively, of the bridges. The locations of these monitoring points are shown in Drawing No. MSEC686-01, in Appendix B.

Marks DPBN and DPBS were measured as part of the far-field 3D surveys, which were discussed in Section 2.7. The observed incremental horizontal movements for these marks are illustrated in Fig. 2.7 and Fig. 2.8. It can be seen from these figures that the bridge has moved towards the north-east as the result of the extraction of Longwall 705.

A summary of the maximum observed incremental and total horizontal movements at Marks DPBN and DPBS, after the completion of Longwall 705, is provided in Table 2.19.

Table 2.19 Maximum Observed Absolute Incremental and Total Horizontal Movements at Marks DPBN and DPBS after the Completion of Longwall 705

Mark	Maximum Observed Incremental Horizontal Movement due to Longwall 705 (mm)	Maximum Observed Total Horizontal Movement due to Longwalls 701 to 705 (mm)
DPBN	7	33
DPBS	6	32

The development over time of absolute horizontal movement at Marks DPBN and DPBS is shown in Fig. 2.10.

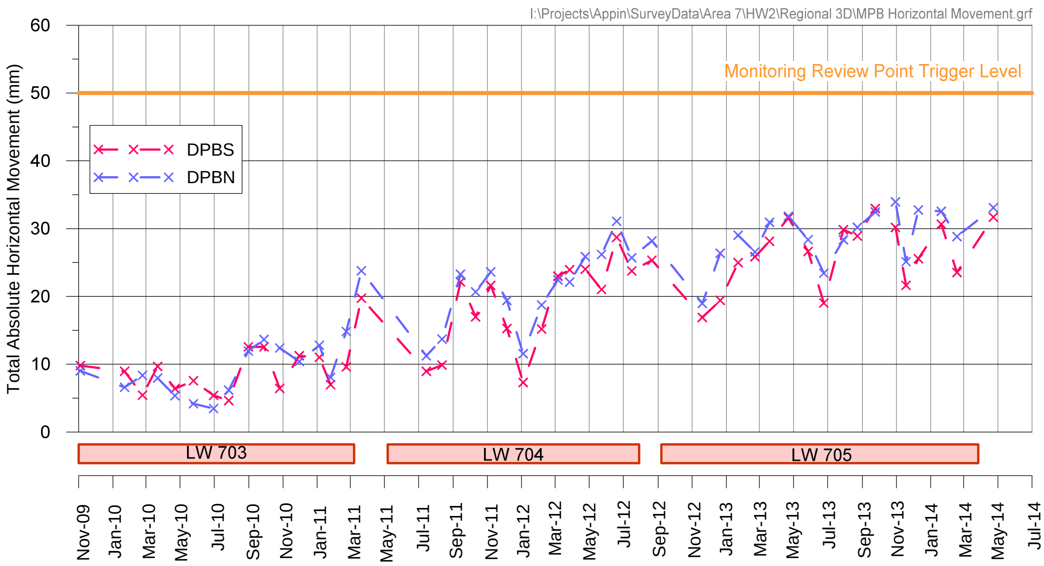


Fig. 2.10 Development of absolute horizontal movement at Marks DPBN and DPBS

The Trigger Action Response Plan (TARP) for the Douglas Park Twin Bridges, which was developed by the RMS chaired Technical Committee, provided triggers for absolute and relative horizontal movements of the far-field 3D Points DPBN and DPBS adjacent to the bridges. A summary of the Level 1 Triggers and the observed horizontal movements at these monitoring points, resulting from the extraction of Longwall 705, are provided in Table 2.20.

Table 2.20 Summary of the Level 1 Triggers and the Observed Horizontal Movements at Marks DPBN and DPBS after the Completion of Longwall 705

Type	Level 1 Triggers (mm)	Maximum Observed Horizontal Movements (mm)
Absolute Horizontal Movement of Points DPBN and DPBS	50	33
Relative Horizontal Movement between Points DPBN and DPBS	5	< 2

It can be seen from the above table, that the maximum observed absolute and relative horizontal movements at the far-field 3D monitoring Points DPBN and DPBS did not exceed the *Level 1 Triggers*.

2.8.2. 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 bridges are shown in Fig. 2.11 and Fig. 2.12 (figures courtesy of IC).

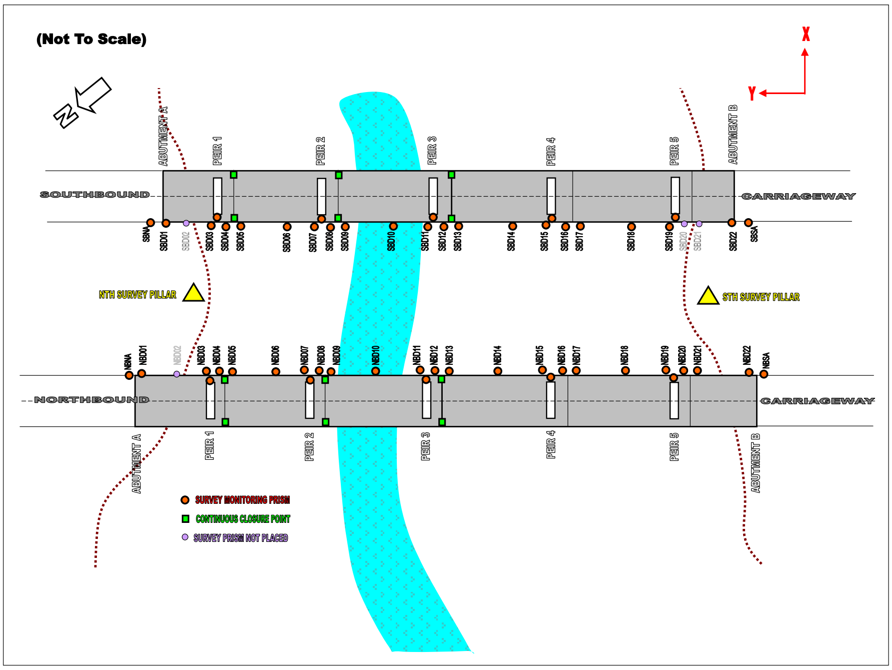


Fig. 2.11 Plan of the Relative 3D Monitoring Points on the Douglas Park Twin Bridges (Courtesy of IC)

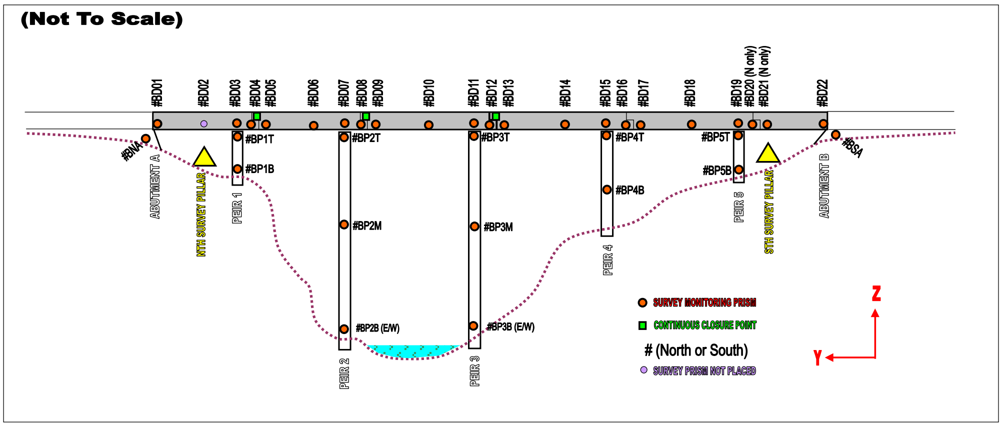


Fig. 2.12 Elevation of the Relative 3D Monitoring Points on the Douglas Park Twin Bridges (Courtesy of IC)

A summary of the survey dates for these monitoring points, during the extraction of Longwall 705, is provided in Table 2.21.

Table 2.21 Summary of Survey Dates for the Relative 3D Monitoring Points on the Douglas Park Twin Bridges during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 705, and by exception where the observed movements exceed the *Level 1 Triggers* at either the far-field 3D monitoring points, at the inclinometers, or at the bridge joint displacement monitors	5th September 2012 (End of LW704) 6th May 2014	As per approved Longwall 706 monitoring program

The survey result on 6 May has found very little differential lateral movement of the bridge, other than changes in the length of the bridge deck due to temperature effects. A small extension was detected along the length of the bridge, though high accuracy horizontal distance check surveys found very little difference in horizontal distances since 2007 (less than 2 mm).

Whilst a small 7 mm relative lateral shift was measured at the base of the central piers 2 and 3, it is noted that the survey of the piers is not linked directly to the deck and no lateral shift is evident in the bases of the piers and abutments on either side of the bridges. The survey result also does not correlate with inclinometer readings. The small measured movement is considered to be a result of very difficult surveying conditions at the base of the bridges. Future surveys will be examined to confirm the accuracy of the results.

2.8.3. Inclinometers near the Douglas Park Twin Bridges

The differential movements at two inclinometers near the Douglas Park Twin Bridges were monitored during the extraction of Longwall 705, being PSM2 and PSM6. There are two other inclinometers, being PSM1 and PSM4, which were not measured during the extraction of this longwall. The inclinometers were installed and maintained by Pells Sullivan and Meynink (PSM), measured by IC and the results interpreted by PSM. The locations of the inclinometers are shown in Drawing No. MSEC686-01.

The inclinometers comprise boreholes with plastic casings which allow probes to measure the differential tilt or inclination over the lengths of the boreholes. Further details on the inclinometers and the results are provided in the monitoring reports by PSM numbers PSM883-219L through PSM883-256L.

A summary of the survey dates for the inclinometers is provided in Table 2.22.

Table 2.22 Summary of Survey Dates for the Inclinometers during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Monthly surveys from the commencement of Longwall 705 until the completion of Longwall 705 and the agreement with the RMS chaired Technical Committee for cessation.	Monthly during LW705	As per approved Longwall 706 monitoring program

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 *Level 1 Trigger* and the maximum observed total differential movements at the inclinometers, at any time during the extraction of Longwall 705, is provided in Table 2.23.

Table 2.23 Summary of the Level 1 Trigger and the Maximum Observed Total Differential Movements at the Inclinometers during the Extraction of Longwall 705

Type	Level 1 Trigger (mm)	Maximum Observed Differential Movement (mm)
Differential Movement	5	3.1 (PSM2) 1.4 (PSM6)

It can be seen from the above table, that the Level 1 Trigger was not exceeded during the extraction of Longwall 705.

2.8.4. 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 Longwall 705. 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), with the locations indicated in Fig. 2.11.

The bridge joint monitor readings commenced on the 29th November 2007 (during the mining of Longwall 701) and measurements have 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 PSM883-219L through PSM883-256L.

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 *Level 1 Trigger* and the maximum observed differential movement across the bridge movement joints, resulting from the extraction of Longwall 705, is provided in Table 2.24.

Table 2.24 Summary of the Level 1 Trigger and the Maximum Observed Differential Movement across the Bridge Movement Joints Resulting from the Extraction of Longwall 705

Location	Level 1 Trigger (mm)	Maximum Observed Differential Movement Across the Bridge Movement Joints (mm)
Joint 1 (Northern Joint)	2	< 0.1 (Northbound Carriageway) +0.2 (Southbound Carriageway)
Joint 2 (Middle Joint)	2	-0.4 (Northbound Carriageway) -0.5 (Southbound Carriageway)
Joint 3 (Main Expansion Joint)	10	-0.8 (Northbound Carriageway) -1.0 (Southbound Carriageway)

It can be seen from the above table, that the Level 1 Triggers were not exceeded as the result of mining Longwall 705.

2.9. Moreton Park Road Bridge (South)

Moreton Park Road Bridge (South) is located approximately 980 metres south of the finishing (western) end of Longwall 705. The location of the bridge is shown in Drawings Nos. MSEC686-01 and MSEC686-03, in Appendix B. The monitoring associated with Moreton Park Road Bridge (South), during the extraction of Longwall 705, included the following:-

- 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.

2.9.1. Absolute 3D Monitoring Points for Moreton Park Road Bridge (South)

The absolute 3D horizontal movements at the Moreton Park Road Bridge (South) were monitored by IC at Points MPBE and MPBW, which are located adjacent to the eastern and western ends, respectively, of the bridge. The locations of these monitoring points are shown in Drawing No. MSEC686-01, in Appendix B.

The surveys for Points MPBE and MPBW were carried out as part of the far-field surveys, which were described in Section 2.7. The maximum observed absolute incremental horizontal movements at Points MPBE and MPBW, at any time during or after the extraction of Longwall 705, were 17 mm and 22 mm, respectively, as shown in Fig. 2.8.

The Trigger Action Response Plan (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 adjacent to the bridge. The Level 1 Trigger for the absolute total horizontal movement was 75 mm, as agreed by the Technical Committee on the 15th November 2011, during the extraction of Longwall 704. During the mining of Longwall 705, the Level 1 Trigger was revised to 100 mm on 29th August 2013, as agreed by the Technical Committee following assessment of monitoring results and approval by the RMS Bridge Maintenance Planner.

The development over time of absolute horizontal movement at Marks MPBE and MPBW is shown in Fig. 2.13.

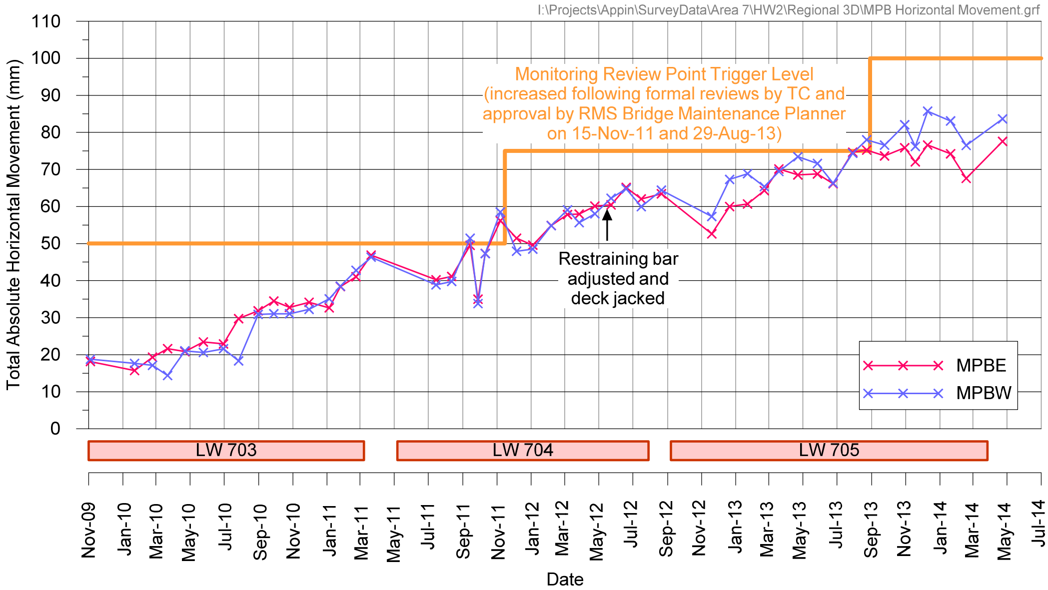


Fig. 2.13 Development of absolute horizontal movement at Marks MPBE and MPBW

A summary of the Level 1 Trigger and the observed absolute total horizontal movements at Points MPBE and MPBW, after the completion of Longwall 705, are provided in Table 2.25.

Table 2.25 Summary of the Level 1 Trigger and the Observed Absolute Total Horizontal Movements at the Marks MPBE and MPBW after the Completion of Longwall 705

Type	Level 1 Triggers (mm)	Maximum Observed Horizontal Movements (mm)
Absolute Horizontal Movement of Points MPBE and MPBW	100	78 (MPBE) 84 (MPBW)

2.9.2. 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. 2.14 and Fig. 2.15 (figures courtesy of IC).

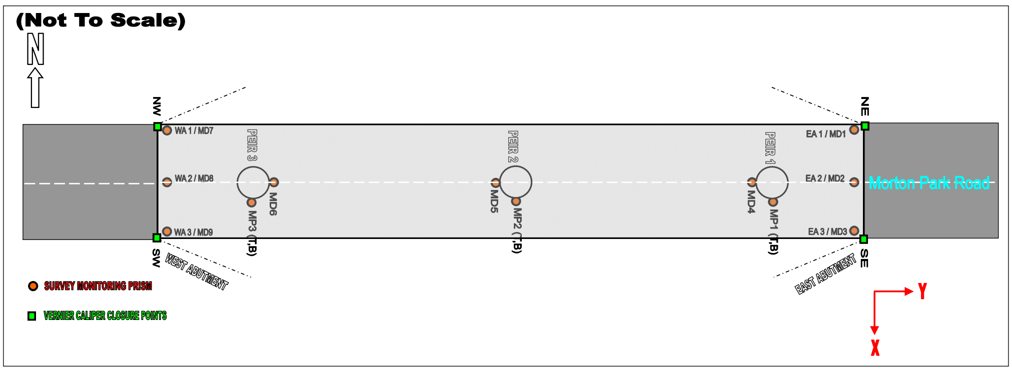


Fig. 2.14 Plan of the Relative 3D Monitoring Points on the Moreton Park Road Bridge (South) (Courtesy of IC)

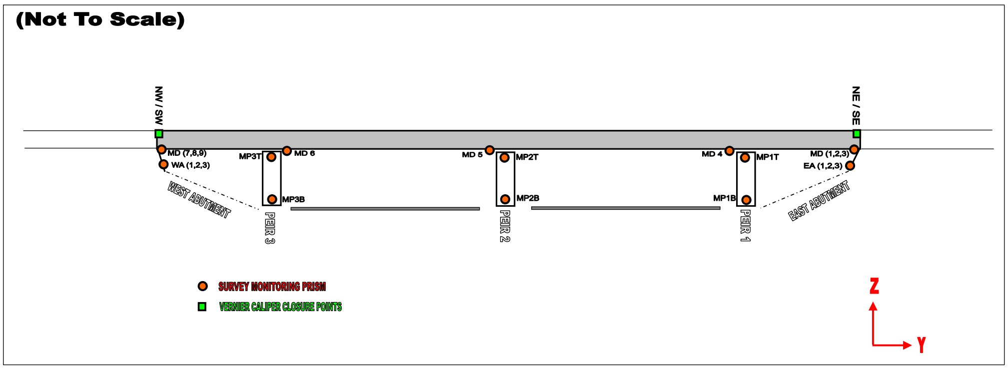


Fig. 2.15 Elevation of the Relative 3D Monitoring Points on the Moreton Park Road Bridge (South) (Courtesy of IC)

A summary of the survey dates for these monitoring points, during the extraction of Longwall 705, is provided in Table 2.26.

Table 2.26 Summary of Survey Dates for the Relative 3D Monitoring Points on the Moreton Park Road Bridge (South) during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 705, plus monthly surveys during mining after 1500 metres of extraction	21st August 2012 (End of LW704) 26th July 2013 22nd August 2013 26th September 2013 4th November 2013 29th November 2013 10th December 2013 20th January 2014 17th February 2014 14th April 2014	As per approved Longwall 706 monitoring program

The observed total changes in the horizontal distance between the abutments, during the extraction of Longwalls 701 to 705, are illustrated in Fig. 2.16. It can be seen from this figure, that there has been a small amount of abutment spreading, in the order of 5 mm, which primarily developed during the extraction of the previous Longwalls 703 and 704. The results vary slightly between surveys and the cause is thought to be related to changes in moisture and/or temperature.

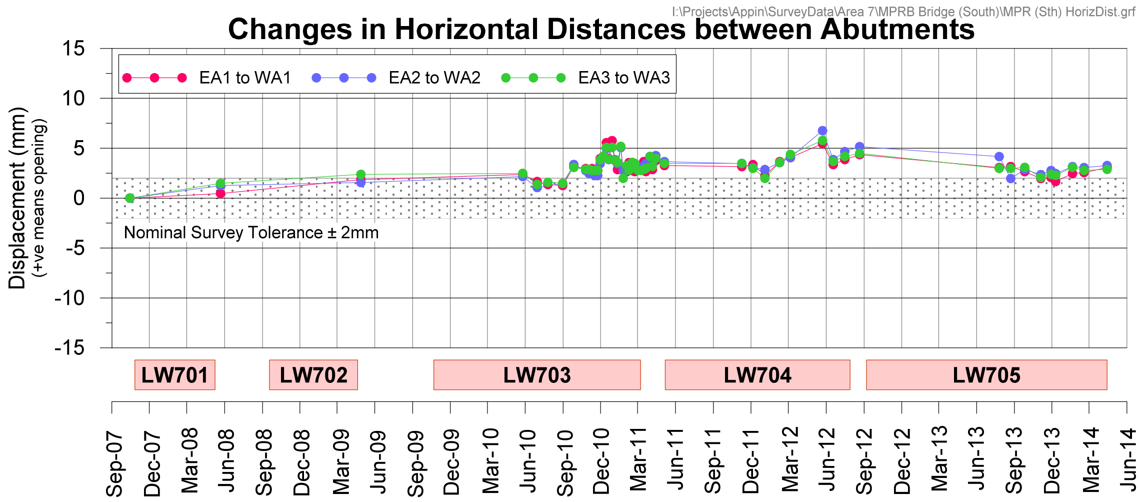


Fig. 2.16 Observed Changes in Horizontal Distances between Abutments

Relative 3D surveys have also detected a horizontal rotation of the deck. The deck movements are not considered to be due to subsidence as the deck is moving independently of the abutment and bases of the column supports.

2.10. SCA Infrastructure

The Sydney Catchment Authority (SCA) infrastructure in the vicinity of Longwall 705 includes the Upper Canal, Devines Tunnels, wrought iron aqueducts, bridges and concrete aqueducts. The locations of the SCA infrastructure are shown in Drawing No. MSEC686-01, in Appendix B.

2.10.1. 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 survey dates for the monitoring points on these aqueducts and bridges is provided in Table 2.27.

Table 2.27 Summary of Survey Dates for the Aqueducts and Bridges during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Start and end of Longwall 705 and monthly surveys during Longwall 705 and West Cliff Longwall 36, for the first 500 metres of extraction, then reducing to three monthly surveys.	26th September 2011 (End of LW704) 25th July 2013 12th September 2013 11th October 2013 12th November 2013 14th February 2014 27th March 2014	As per approved Longwall 706 monitoring program

A summary of the maximum observed 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 Longwall 705, is provided in Table 2.28. 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 survey tolerance for net subsidence, net uplift, closure and opening were around 2 mm.

Table 2.28 Maximum Observed Changes in Net Subsidence, Net Uplift and Closure at the Wrought Iron Aqueducts and Bridges during Longwall 705

Location	Maximum Observed Incremental Net Subsidence (mm)	Maximum Observed Incremental Net Uplift (mm)	Maximum Observed Incremental Closure (mm)
Ousedale Creek Aqueduct	< 2	< 2	-3 (reduction in net closure)
Ousedale Creek Bridge	< 2	< 2	< 2
Mallaty Creek Aqueduct	< 2	- 2	< 2
Mallaty Creek Bridge	< 2	-4	< 2
Leafs Gully Aqueduct	< 2	< 2	< 2
Leafs Gully Bridge	< 2	< 2	< 2
Nepean Creek Aqueduct	< 2	< 2	2.8
Nepean Creek Bridge	< 2	2.1	< 2

It can be seen from the above table that measured changes are similar to or less than survey tolerance.

2.10.2. Concrete Aqueducts C and D

The movements at Concrete Aqueducts C and D were monitored by IC using local 3D surveys. The survey dates for these aqueducts were the same as those for the wrought iron aqueducts and bridges, which are provided in Table 2.27.

The maximum observed incremental net vertical and horizontal movements at the Concrete Aqueducts C and D, during the extraction of Longwall 705, were all less than 3 mm, which are similar to the order of survey tolerance.

2.11. 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 locations of the monitoring points are shown in Drawing No. MSEC686-01 in Appendix B.

A summary of the survey dates for the Telstra Line, during the extraction of Longwall 705, is provided in Table 2.9.

Table 2.29 Summary of Survey Dates for the Telstra Line during Longwall 705

Mining Phase Commitments	Mining Phase Survey Dates	Post Mining Phase Commitments
Survey prior to and after the influence of LW705 on the Tower	22nd March 2013 (Base survey) 1st October 2013, 5th November 2013, 3rd December 2013, 7th January 2014, 12th February 2014, 29th April 2014	As per approved Longwall 706 monitoring program

The observed profiles of incremental subsidence, tilt and strain along the Telstra Line, resulting from the extraction of Longwall 705, are shown in Fig. A.19 in Appendix A. The predicted profiles of incremental subsidence and tilt along the monitoring line, at the completion of Longwall 705, are also shown in this figure, which were based on the predicted subsidence contours provided in Report No. MSEC342.

It can be seen from this figure, that the observed profiles of subsidence and tilt were reasonably similar to the profiles predicted.

A summary of the maximum observed and maximum predicted subsidence parameters along the Telstra Line, resulting from the extraction of Longwall 705, is provided in Table 2.10.

Table 2.30 Maximum Observed and Predicted Incremental Subsidence Parameters along the Telstra Line Resulting from the Extraction of Longwall 705

Type	Maximum Incremental Subsidence at Tower (mm)	Maximum Incremental Tilt at Tower (mm/m)	Maximum Incremental Tensile Strain (mm/m)	Maximum Incremental Comp. Strain (mm/m)
Observed	222	1.6	0.7	0.8
Predicted	275	2.2	*- 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 Telstra Line are in the order of ±10 mm. The accuracies of the measured strains along the Telstra Line are in the order of ±0.25 mm/m. The accuracies of the ground survey measurements of tilt at the tower are in the order of ±1.0 mm/m.

The observed changes in tilt across the base of the Telstra Tower, during the extraction of Longwall 705, are illustrated in Fig. 2.17.

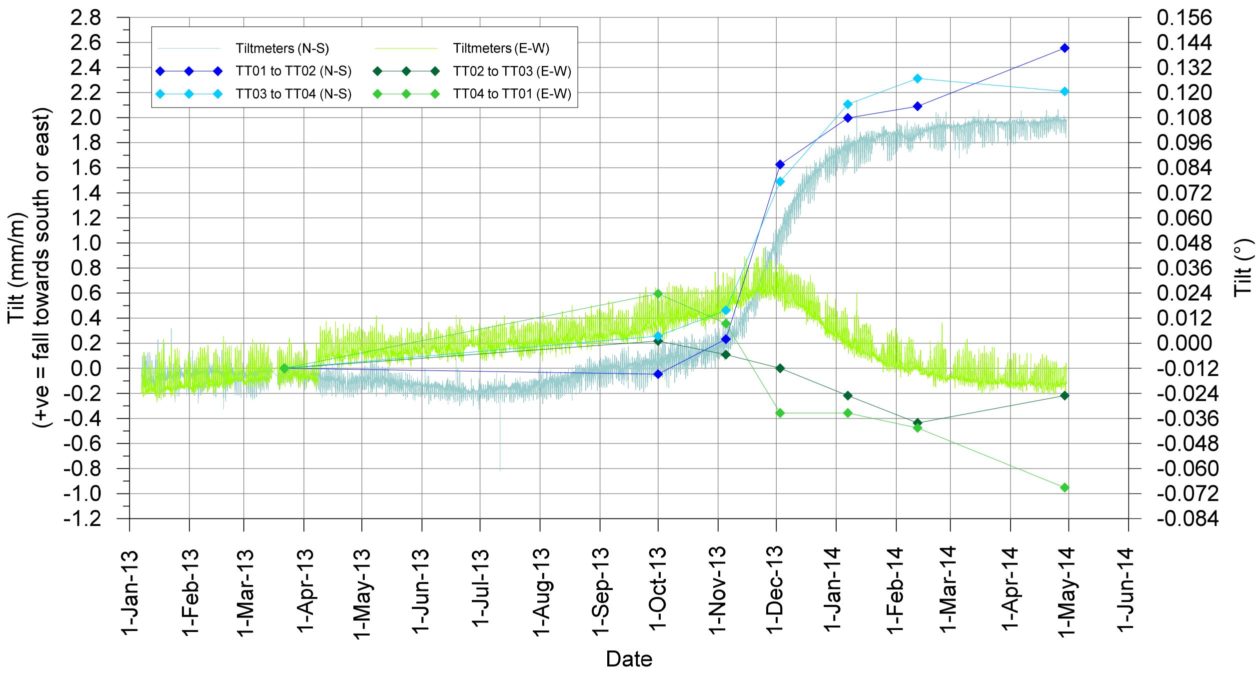


Fig. 2.17 Observed Changes in Tilt at Telstra Tower

It can be seen that there was a reasonable correlation between ground surveys of tilt at the Tower and high accuracy tiltmeter measurements.

The observed tilts are within predictions and substantially less than the operating tolerances of the antennae.

3.0 COMPARISONS BETWEEN THE OBSERVED AND ASSESSED IMPACTS FOR THE NATURAL FEATURES AND SURFACE INFRASTRUCTURE

3.1. Natural Features

The natural features in the vicinity of Longwall 705 are shown in Drawing No. MSEC686-02, in Appendix B, which include:-

- The Nepean River,
- Creeks,
- Cliffs and rock outcrops,
- Steep slopes, and
- Archaeological Sites.

The MSEC assessments for the natural features, resulting from the extraction of Appin Longwalls 705 to 7010 were provided in Report No. MSEC342. More detailed assessments for some natural features were also provided in other consultants reports. Comparisons between the MSEC assessments and the observed impacts for the natural features, listed above, are provided in Table 3.1. The observed impacts are based on those recorded by field investigations undertaken for the *End of Panel* report.

Table 3.1 Summary of the MSEC Assessments and the Observed Impacts for the Natural Features Resulting from the Extraction of Longwall 705

Natural Feature	MSEC Assessed Impacts	Observed Impacts
The Nepean River	**Minor fracturing** could occur in the bed of the river	No visible 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 report by Ecoengineers
	The **surface water level** is expected to remain essentially unchanged. Uplift of the banks could result in some desiccation of the banks	No reported change in water level by IC apart from the normal fluctuations associated with rainfall and SCA discharges
	Possible that mining-induced **springs** could occur	No additional iron staining or iron seeps were observed in the Nepean River
	Possible that isolated **gas emissions** could occur	Gas releases were observed at three sites, which are located closer to Longwalls 702 and 703. Whilst the gas releases were observed during the mining of Longwall 705, their locations are close to where gas releases have been previously observed during the mining of Longwalls 701 to 704 and Tower Longwall 17. Refer to report by *IC* for further details.
	Water quality – Water quality trigger levels not exceeded. Refer to report by Ecoengineers	
	Terrestrial ecology – Refer to report by Niche	
	Aquatic ecology – Refer to report by Cardno Ecology Lab	
Creeks	Potential for some **ponding**, **flooding** and **desiccation** above the longwalls	No impacts observed in the monitored streams
	Fracturing could occur in the beds of the smaller creeks above the longwalls	No impacts observed in the creeks.
Cliffs and Rock Outcrops	Potential for **cliff instabilities** assessed as very low	No reported impacts
Steep Slopes	Potential for **soil slippage**	No reported impacts
Archaeological Sites	Low likelihood of impacts on open sites, scarred tree and shelters.	No reported impacts. Refer to report by *Niche*

It can be seen from Table 3.1, that the recorded impacts on the natural features, resulting from the extraction of Longwall 705, were similar to or less than the MSEC assessments. Further assessments of some natural features have been provided by other consultants, and these are described in the *End of Panel* report.

A comparison between predicted and observed groundwater impacts is provided in a report by *Geoterra*.

3.2. Built Features

The built features in the vicinity of Longwall 705 are shown in Drawings No MSEC686-03, in Appendix B. The features which are located within the predicted 20 mm incremental subsidence contour, due to the extraction of Longwall 705, or which may be sensitive to far-field or valley related movements include:-

- Moreton Park Road and drainage culverts,
- HW2 Hume Highway and associated infrastructure,
- Main Southern Railway and associated infrastructure,
- The 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, resulting from the extraction of Appin Longwalls 701 to 705, were provided in Report No. MSEC342. Comparisons between the assessed and observed impacts for the built features located within either the 35 degree angle of draw line from Longwall 705, or within the predicted incremental 20 mm subsidence contour due to Longwall 705, are provided in Table 3.2. The built features in the vicinity of Longwall 705, which have been considered sensitive to far-field or valley related movements, have also been included in this table.

Table 3.2 Summary of the Assessed and Observed Impacts for Built Features Resulting from the Extraction of Longwall 705

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	Minor localised heaving observed, reported and remediated by the Asset owner.
HW2 Hume Highway	No impacts on the safety or serviceability of the highway after the implementation of the management strategies	No adverse impacts to safety or serviceability. Humps formed on both carriageways and these were remediated by re-shaping of the pavement surface and installation of additional slots 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 established 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

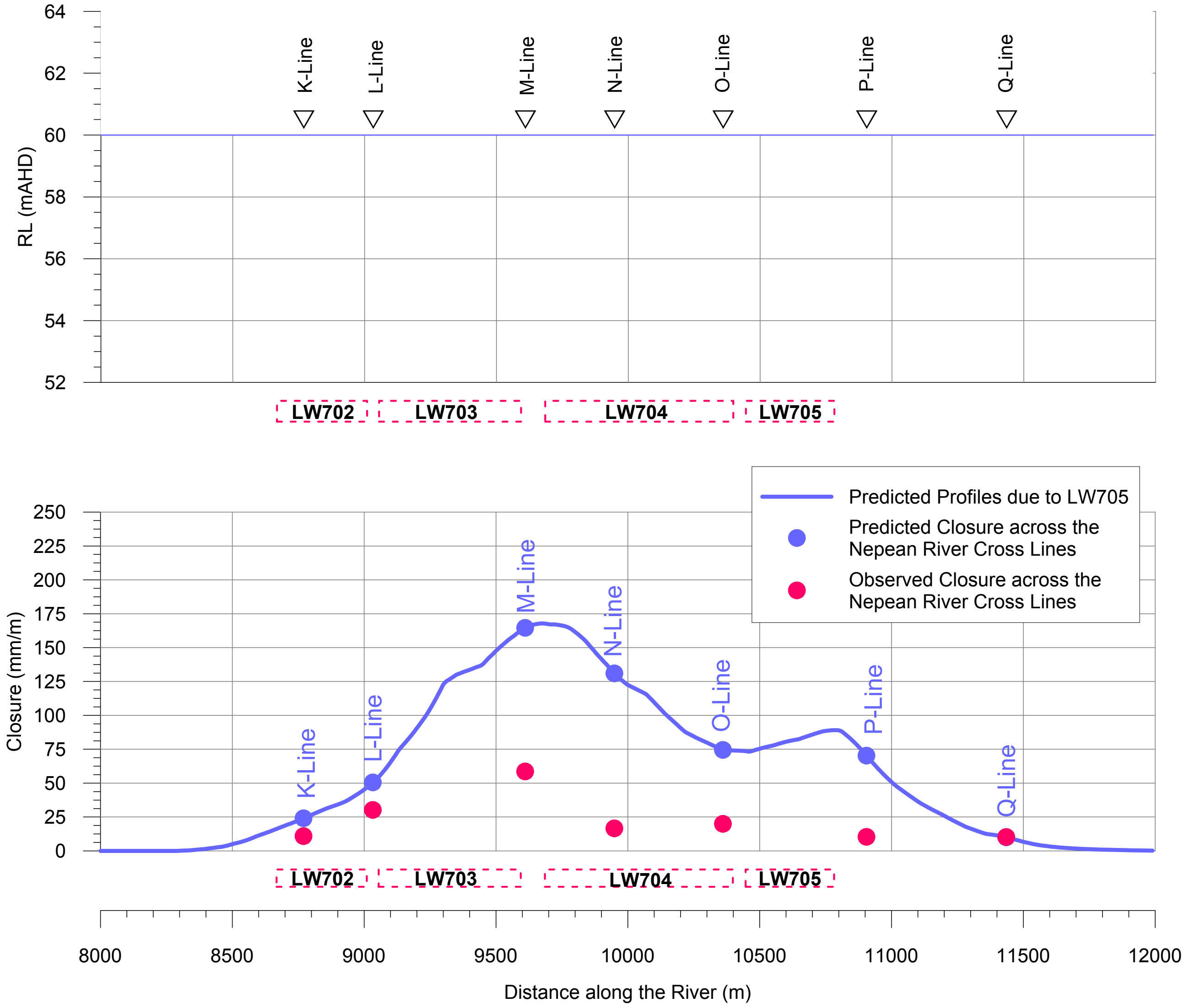
Built Feature	MSEC Assessed Impacts	Observed Impacts
Low voltage powerlines	Impacts unlikely, but minor mitigation measures may be required	No reported impacts
Copper telecommunications cables	Impacts unlikely	No reported impacts
Optical fibre cables	Impacts unlikely with the implementation of the management strategies including OTDR monitoring and mitigation	No reported impacts
Building structures	Typically Category A Tilt Impacts, with 1 x Category B Tilt Impact. Typically Category 0 Strain Impacts, with 6 x Category 1 Strain Impacts, 4 x Category 2 Strain Impacts.	*Houses and Non-Residential Structures* Building structures remained in safe and serviceable condition during mining. To date, no new claims to the MSB for impacts to building structures due to the mining of Longwall 705. *Other Features* One claim to the MSB for impact to pavement and one claim for impact to an irrigation pipe due to the mining of Longwall 705.
Pools	Inground pools could be more susceptible to ground strains	No reported impacts
Water tanks	Impacts unlikely	No reported impacts
Farm dams	Potential for minor cracking or leakage	No reported impacts
Heritage structures	Impacts unlikely	No reported impacts
Groundwater bores	Potential for blockage or reduction in the capacity of the groundwater bores	No blockage of bores reported. No triggers exceeded on groundwater yield or bore serviceability and no ameliorative actions are required. Refer 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

It can be seen from Table 3.2, that the observed impacts on the built features, resulting from the extraction of Longwall 705, were generally similar to or less than the assessed (i.e. predicted) impacts.

APPENDIX A. FIGURES

Appin Colliery - Longwall 705
Predicted and Observed Incremental Closure along the Centreline of the Nepean River

I:\Projects\Appin\Area 7\MSEC686 - LW705 End of Panel Report\Subsdata\Survey Data\Nepean River\Fig. A.01 - Nepean River (Increment).grf

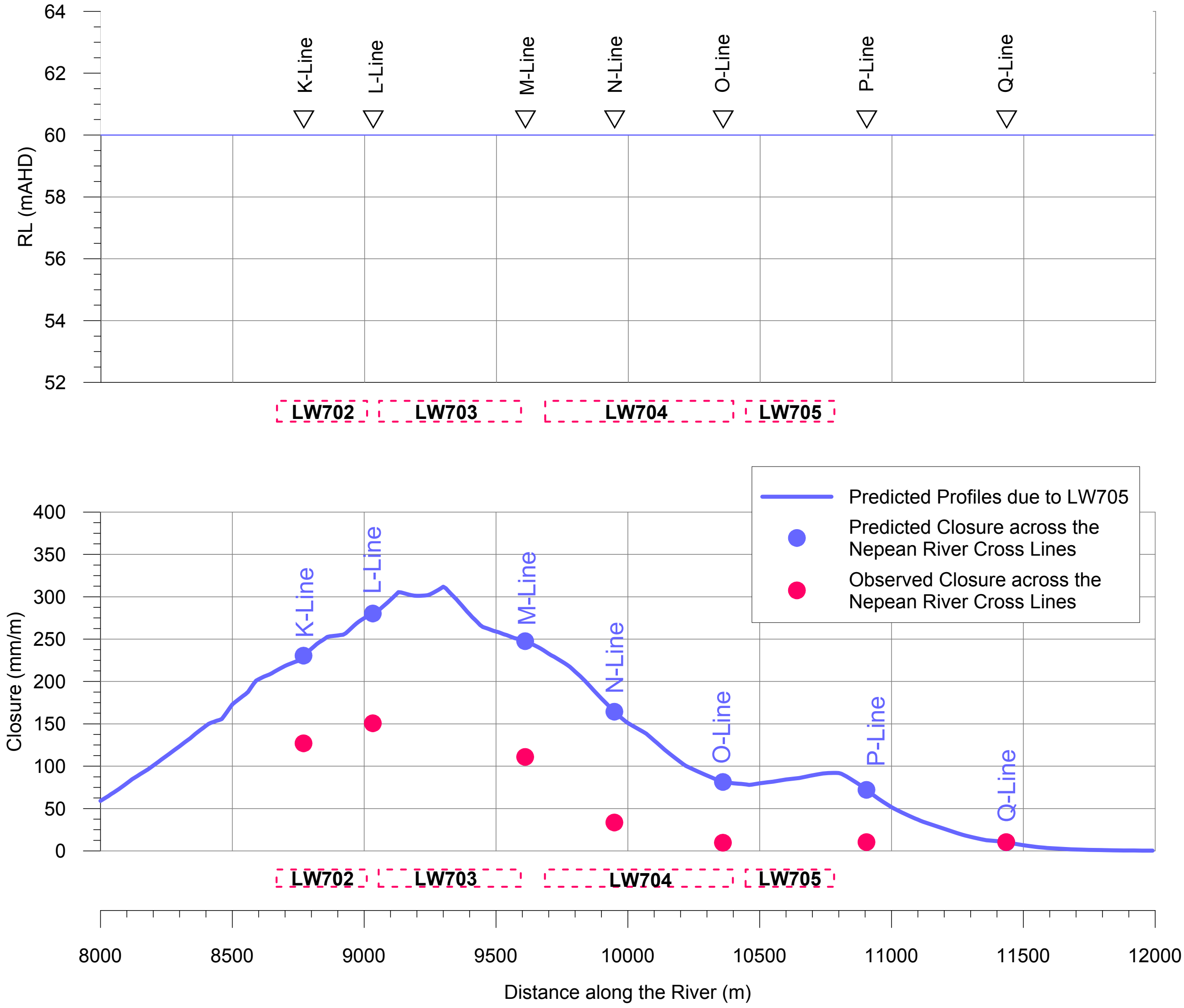


msec

Fig. A.01

Appin Colliery - Longwall 705
Predicted and Observed Total Closure along the Centreline of the Nepean River

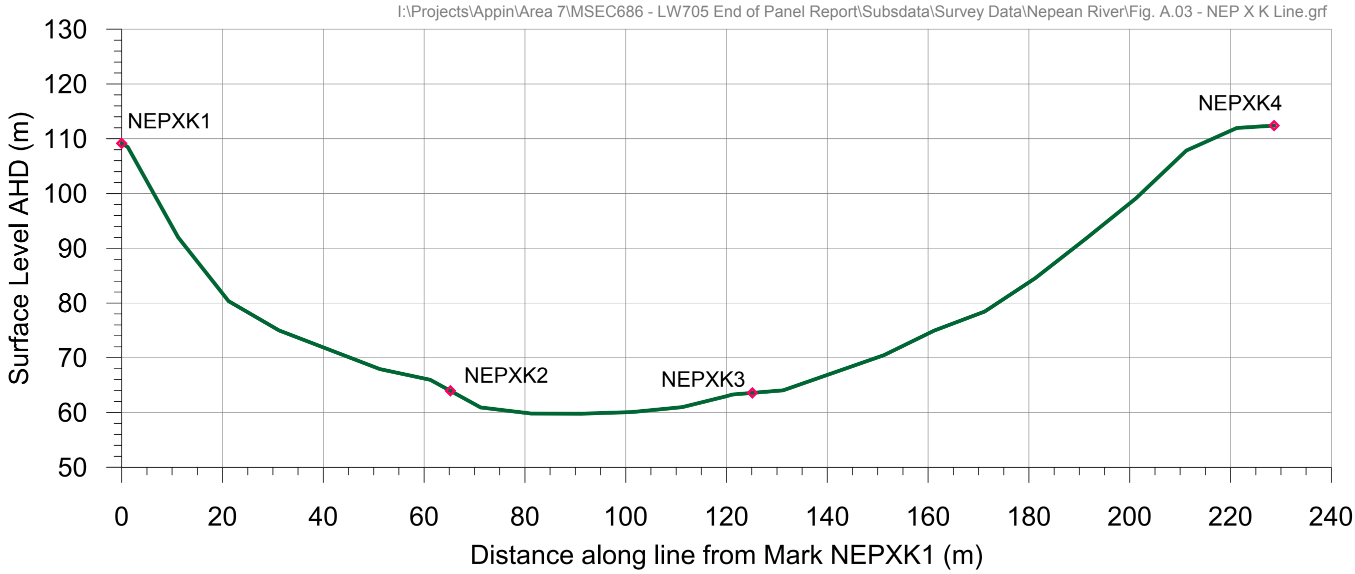
I:\Projects\Appin\Area 7\MSEC686 - LW705 End of Panel Report\Subsdata\Survey Data\Nepean River\Fig. A.02 - Nepean River (Total).grf



msec

Fig. A.02

Appin Colliery - Longwall 705
Nepean River K-Line Total Closure Profiles



LW705 approximately 950 metres north-west of Mark NEPXK4

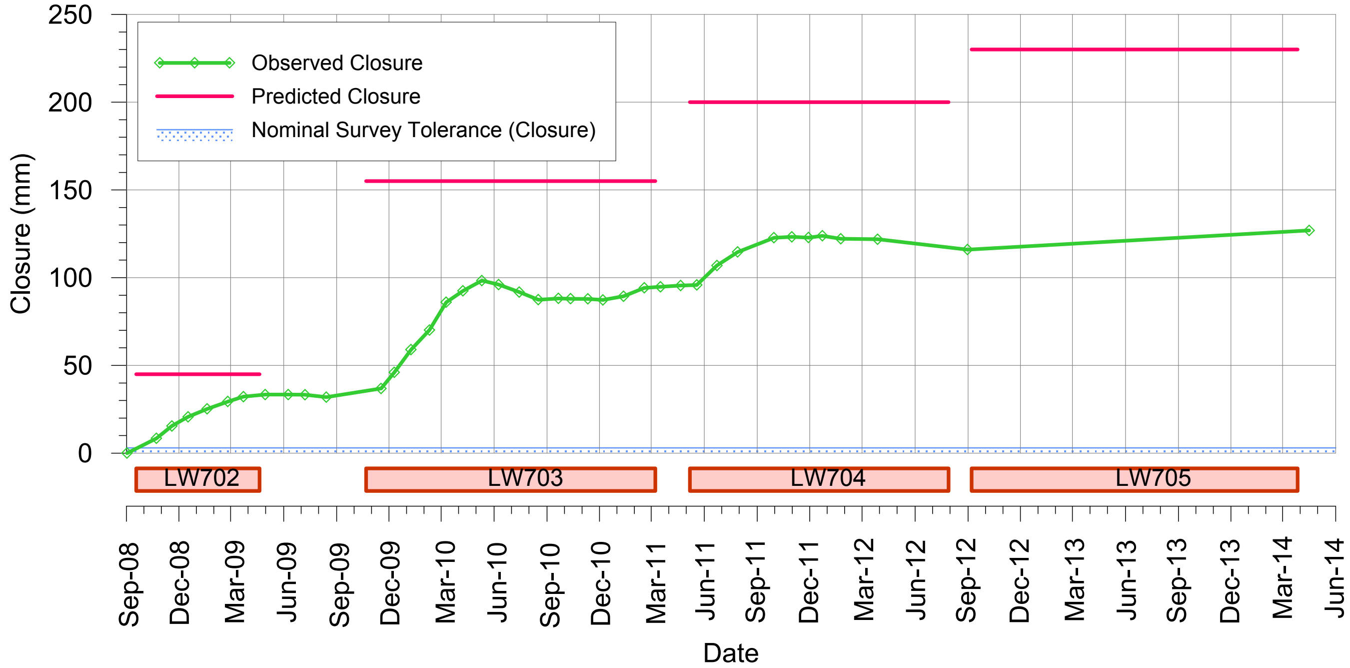


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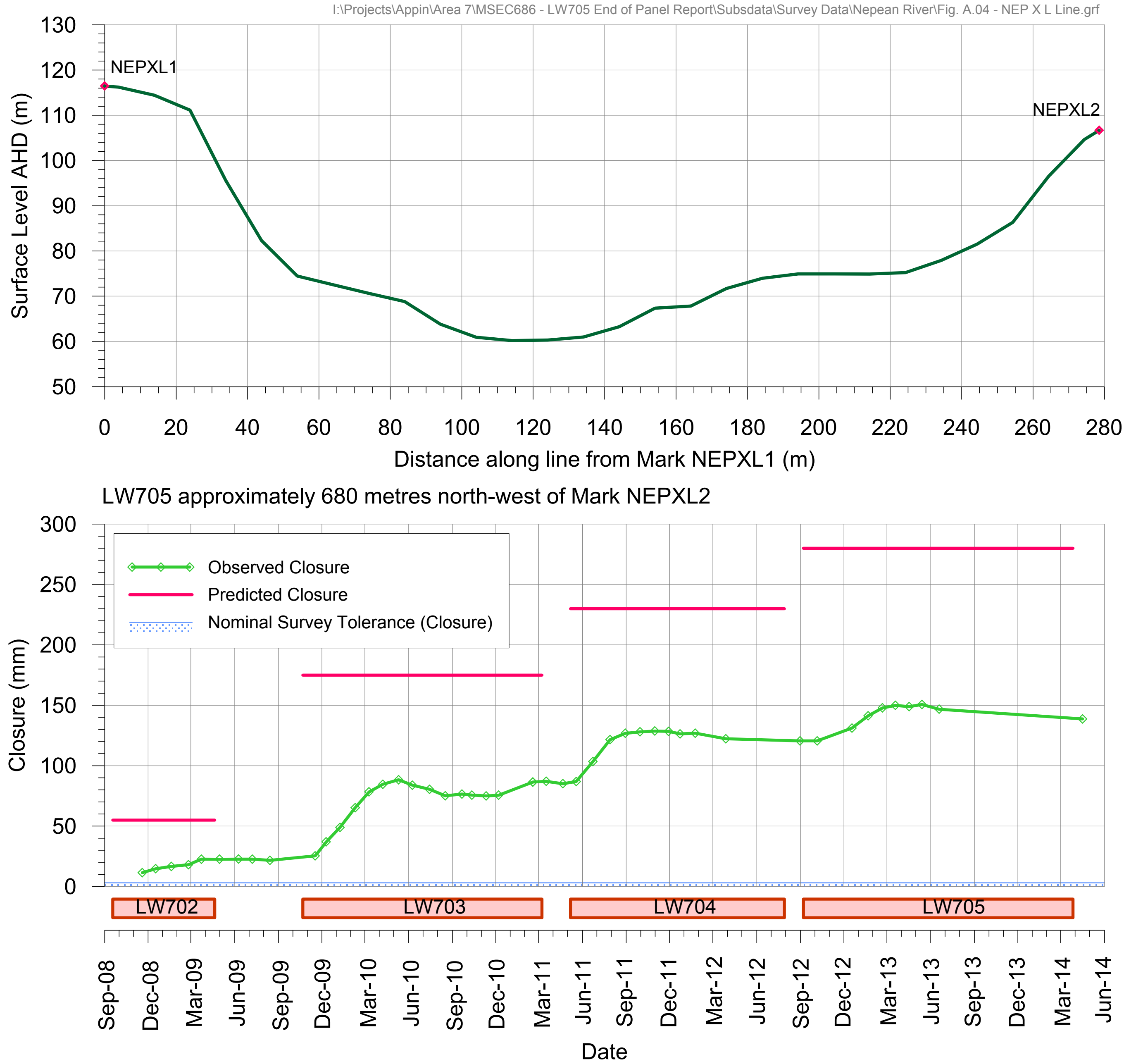
Fig. A.03

Appin Colliery - Longwall 705
Nepean River L-Line Total Closure Profiles



msec

Fig. A.04

Appin Colliery - Longwall 705
Nepean River M-Line Total Closure Profiles

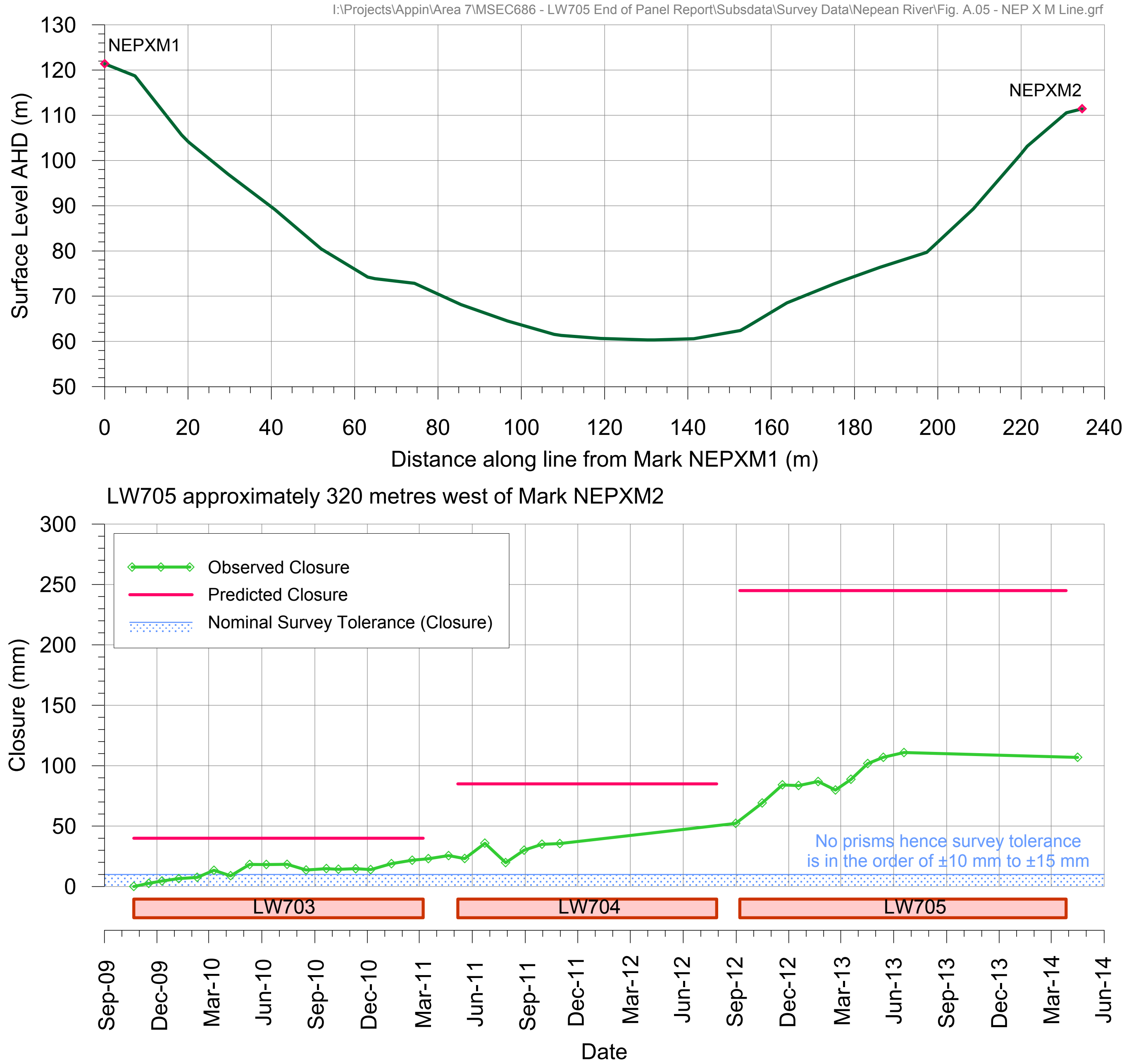


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Fig. A.05

Appin Colliery - Longwall 705
Nepean River N-Line Total Closure Profiles

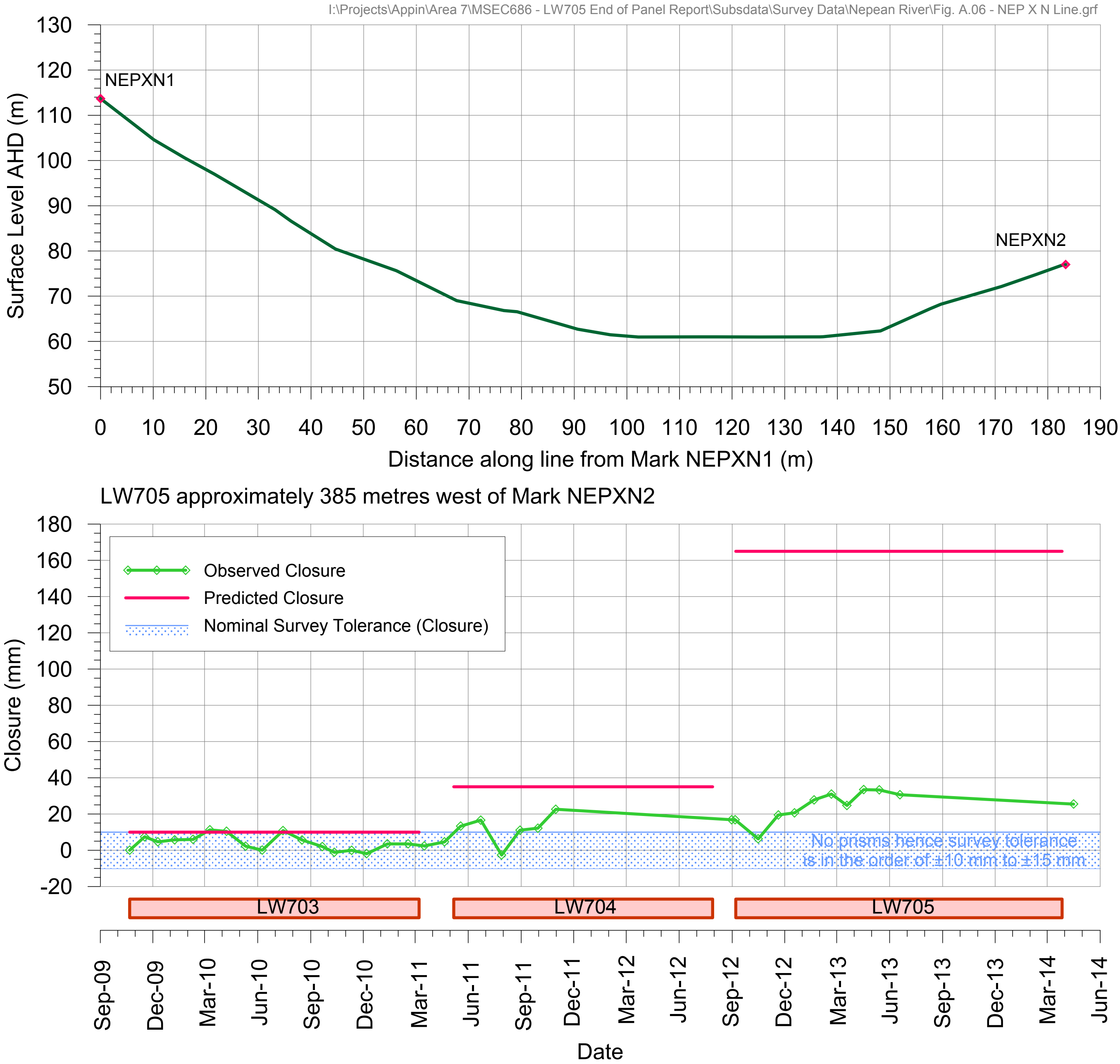
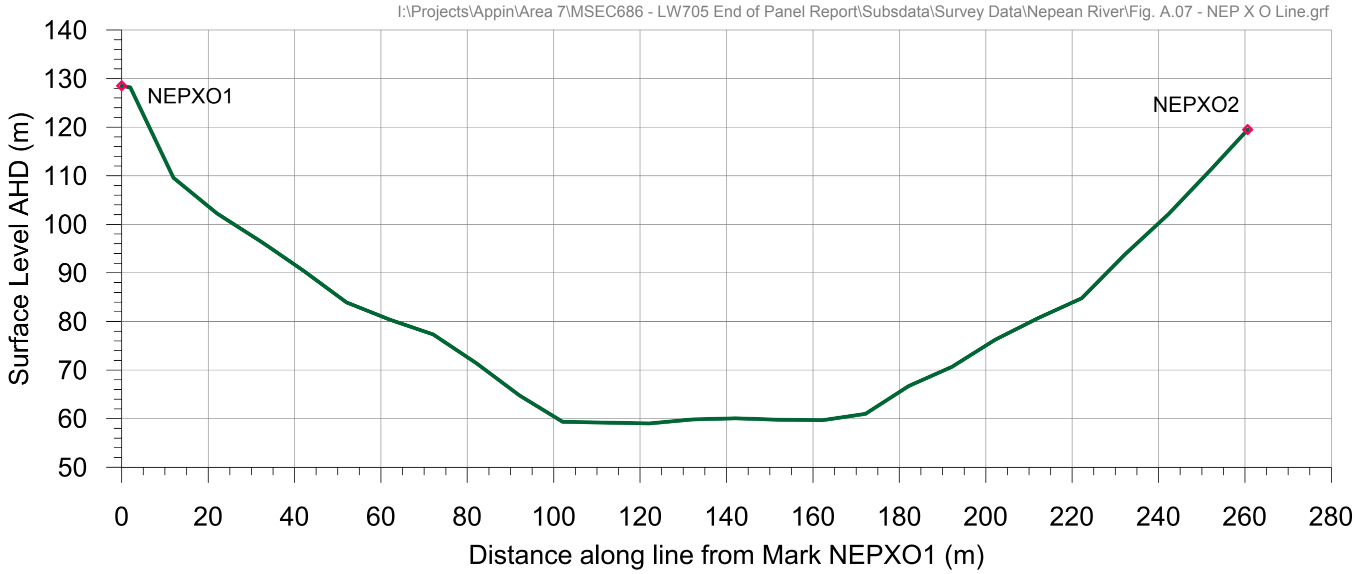


Fig. A.06

Appin Colliery - Longwall 705
Nepean River O-Line Total Closure Profiles



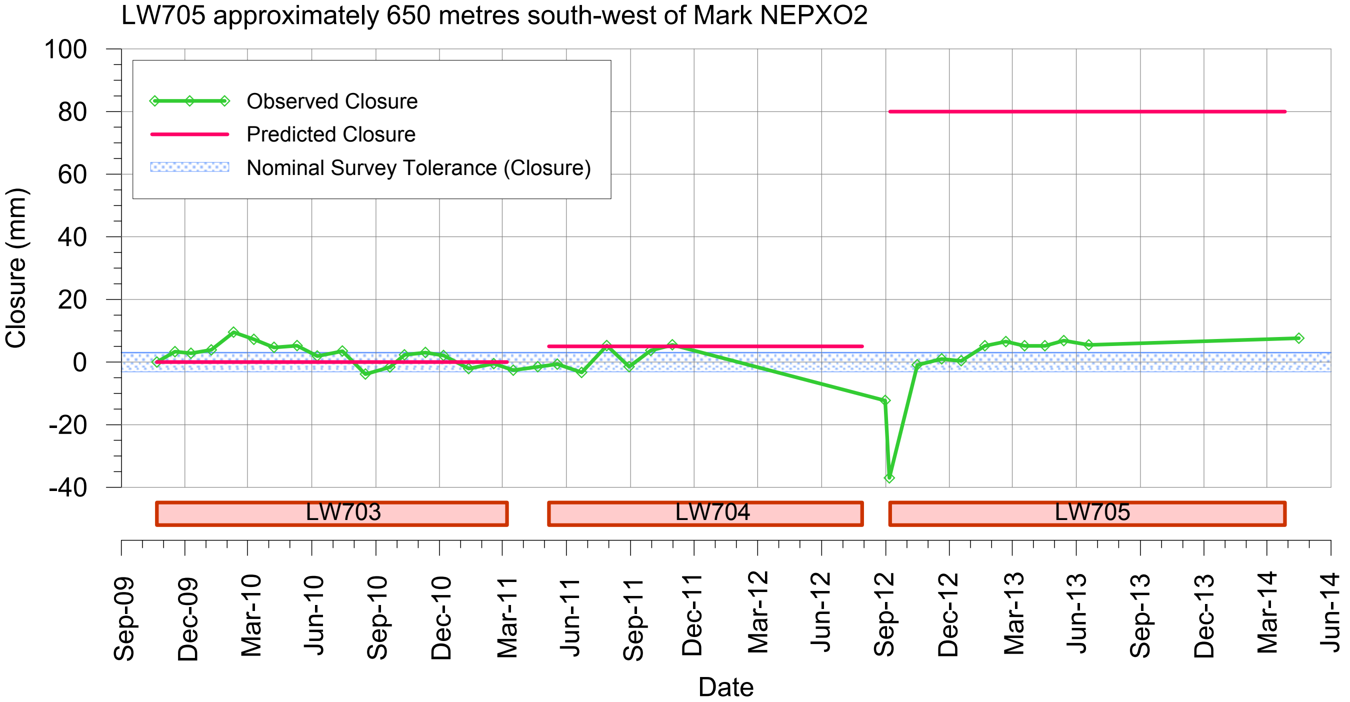


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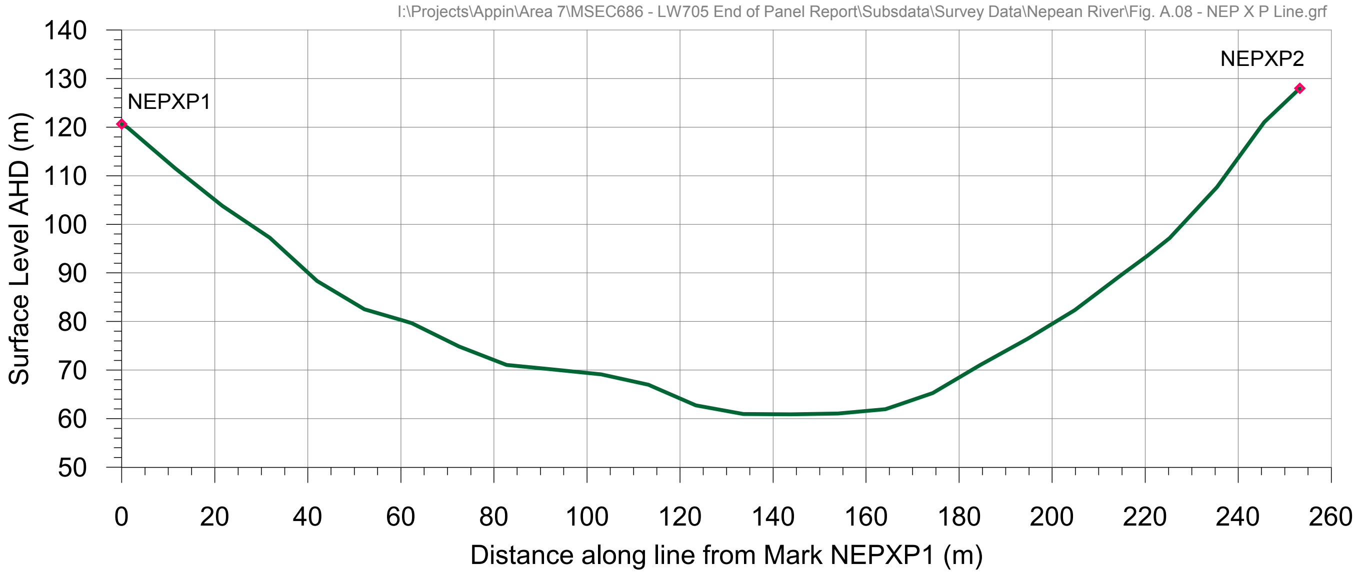
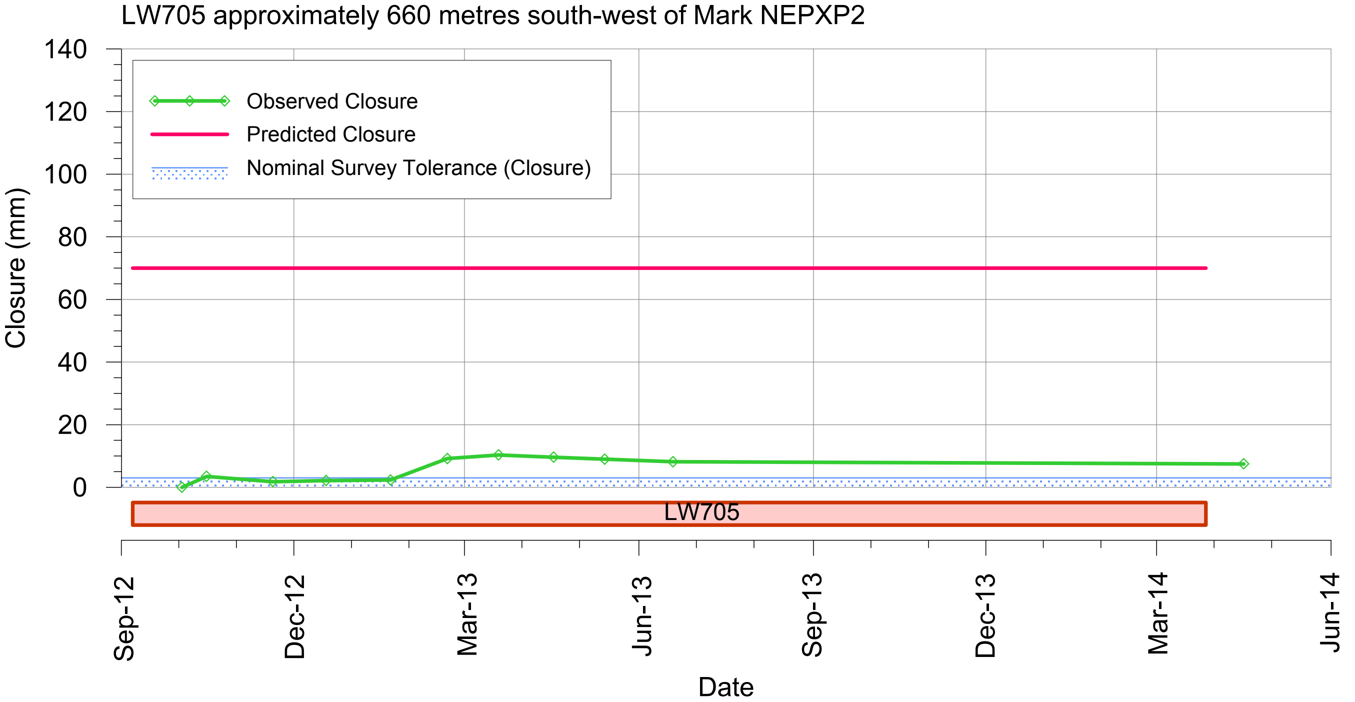
Fig. A.07

Appin Colliery - Longwall 705
Nepean River P-Line Total Closure Profiles



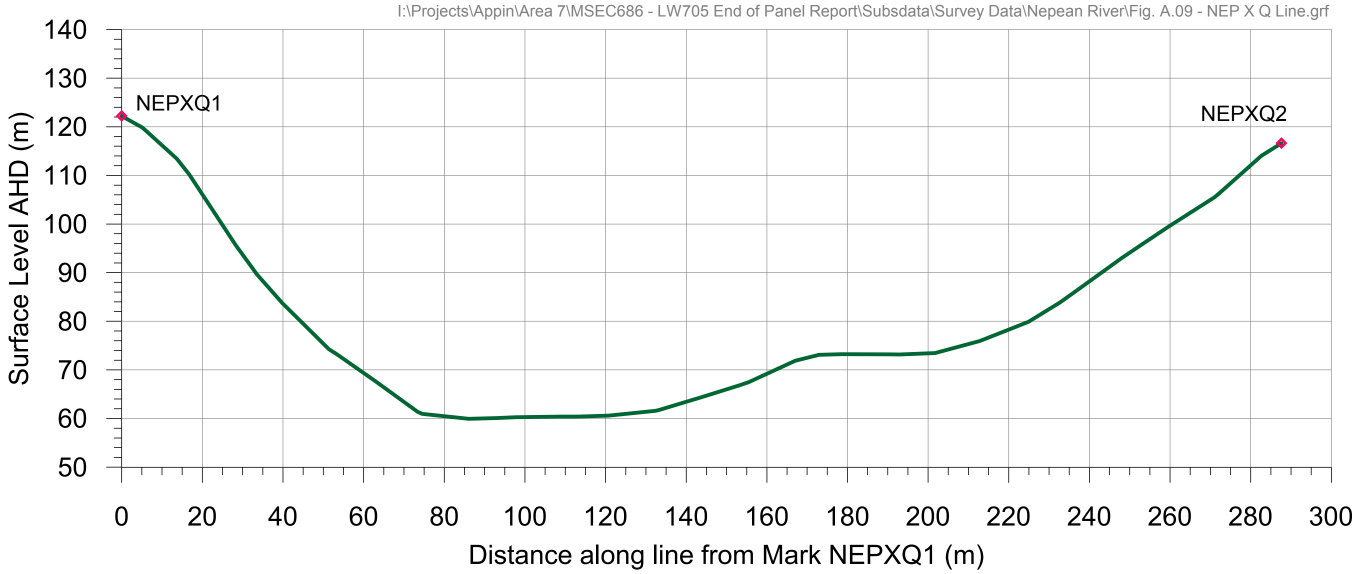


msec

Fig. A.08

Appin Colliery - Longwall 705
Nepean River Q-Line Total Closure Profiles

I:\Projects\Appin\Area 7\MSEC686 - LW705 End of Panel Report\Subsdata\Survey Data\Nepean River\Fig. A.09 - NEP X Q Line.grf



LW705 approximately 860 metres south-west of Mark NEPXQ2

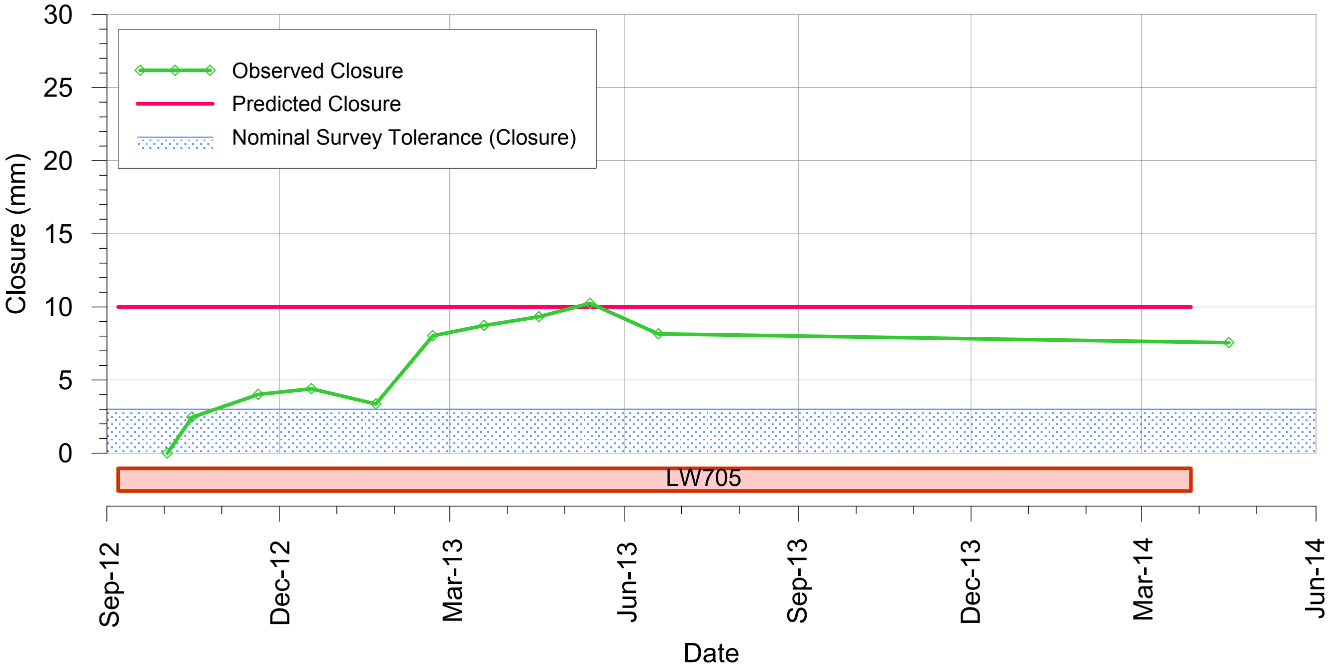


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Fig. A.09

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along Moreton Park Road during Appin Longwall 705

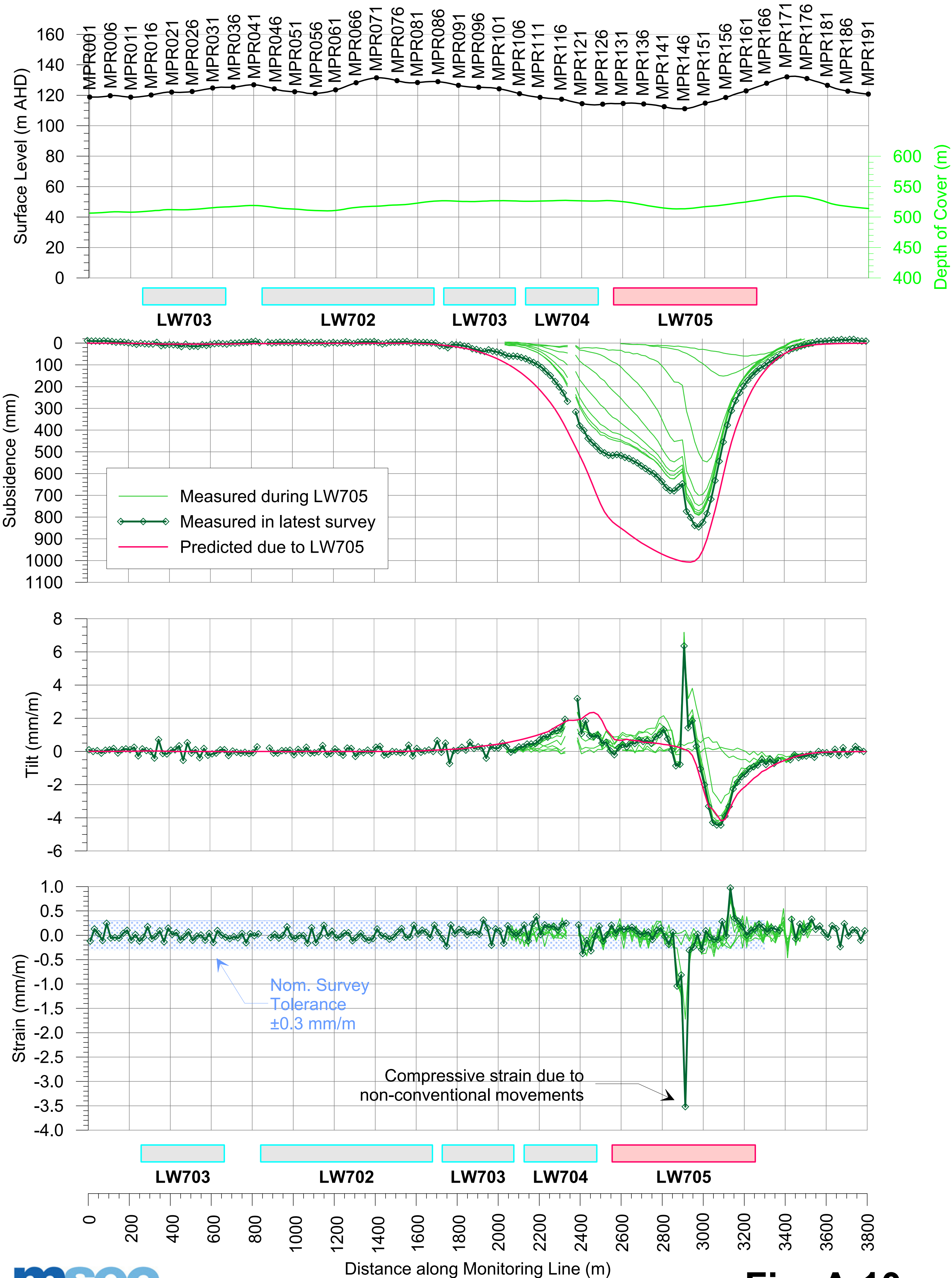

Fig. A.10

Observed and Predicted Profiles of Total Subsidence, Tilt and Strain along Moreton Park Road during Appin Longwall 705

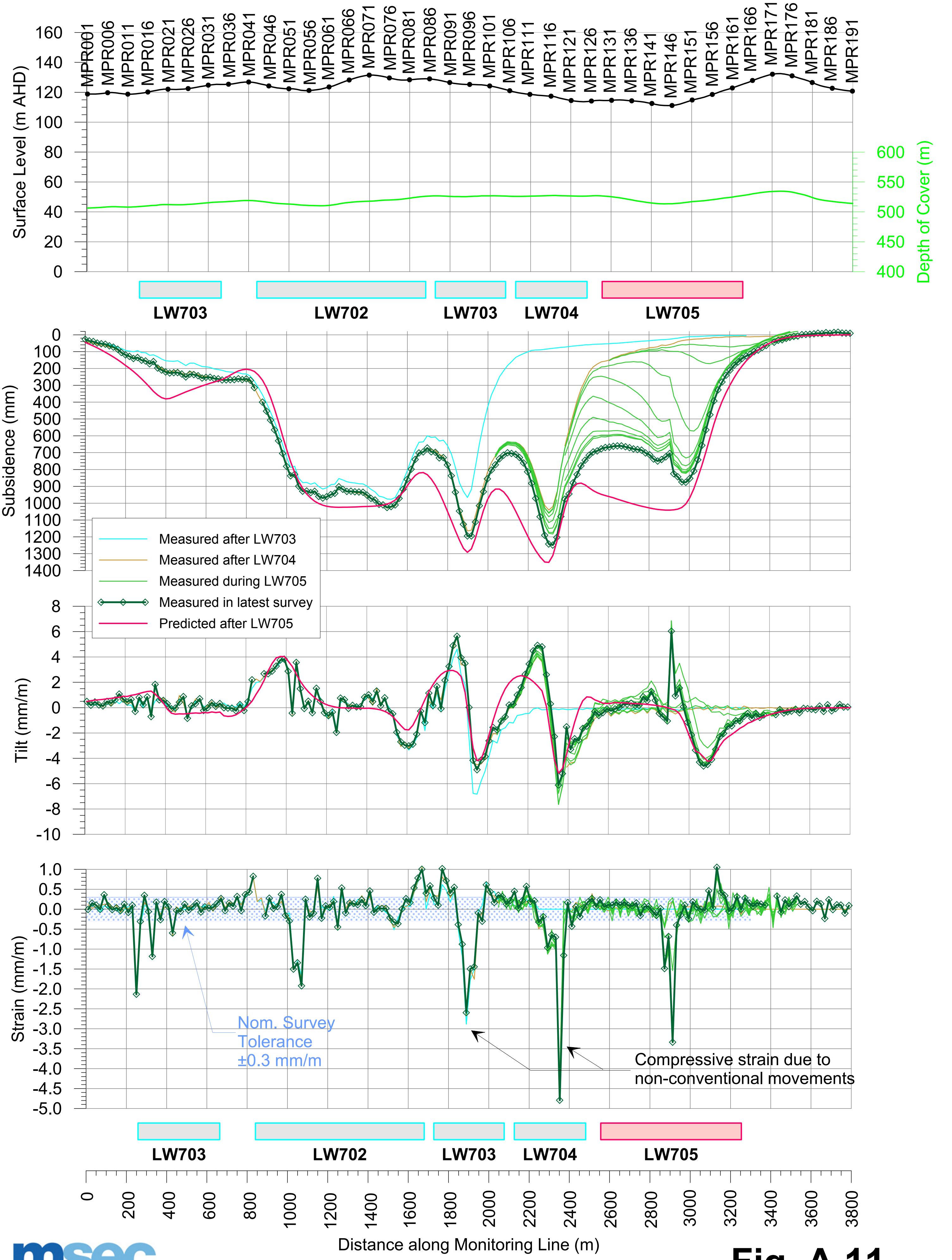

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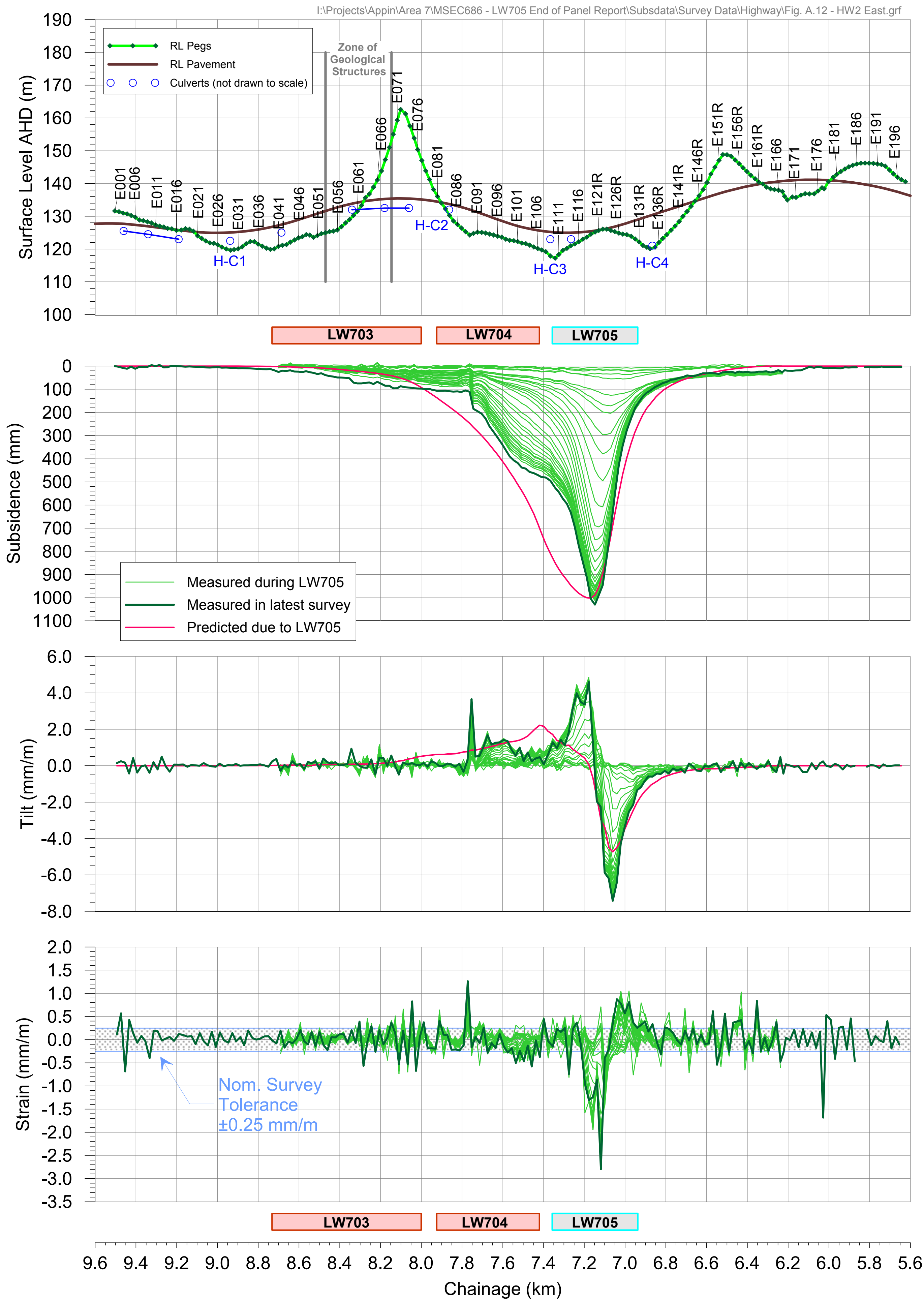
Fig. A.11

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the HW2 East Line during Appin Longwall 705



msec

Fig. A.12

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the HW2 West Line during Appin Longwall 705

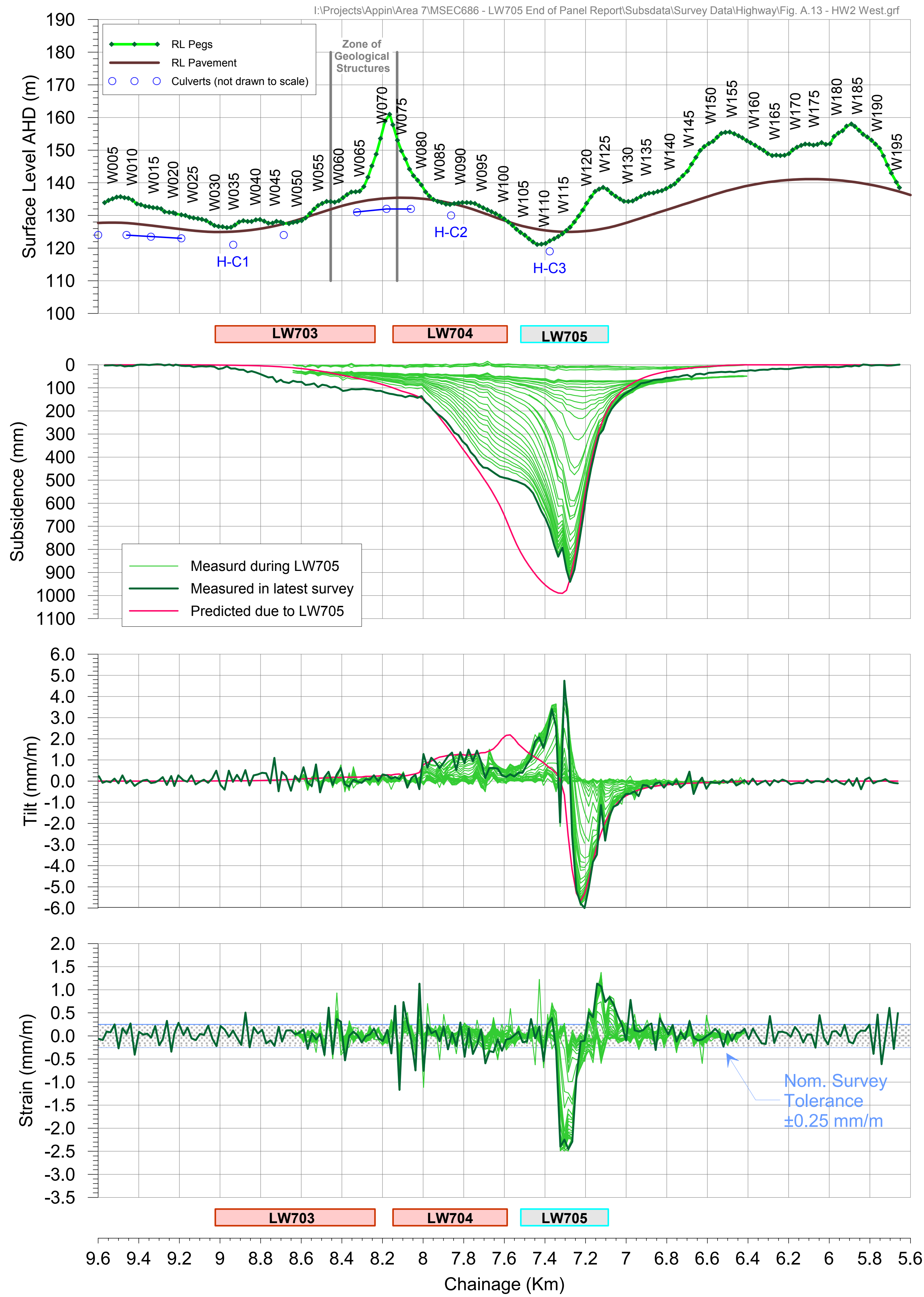


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Fig. A.13

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the ARTC Line during Appin Longwall 705

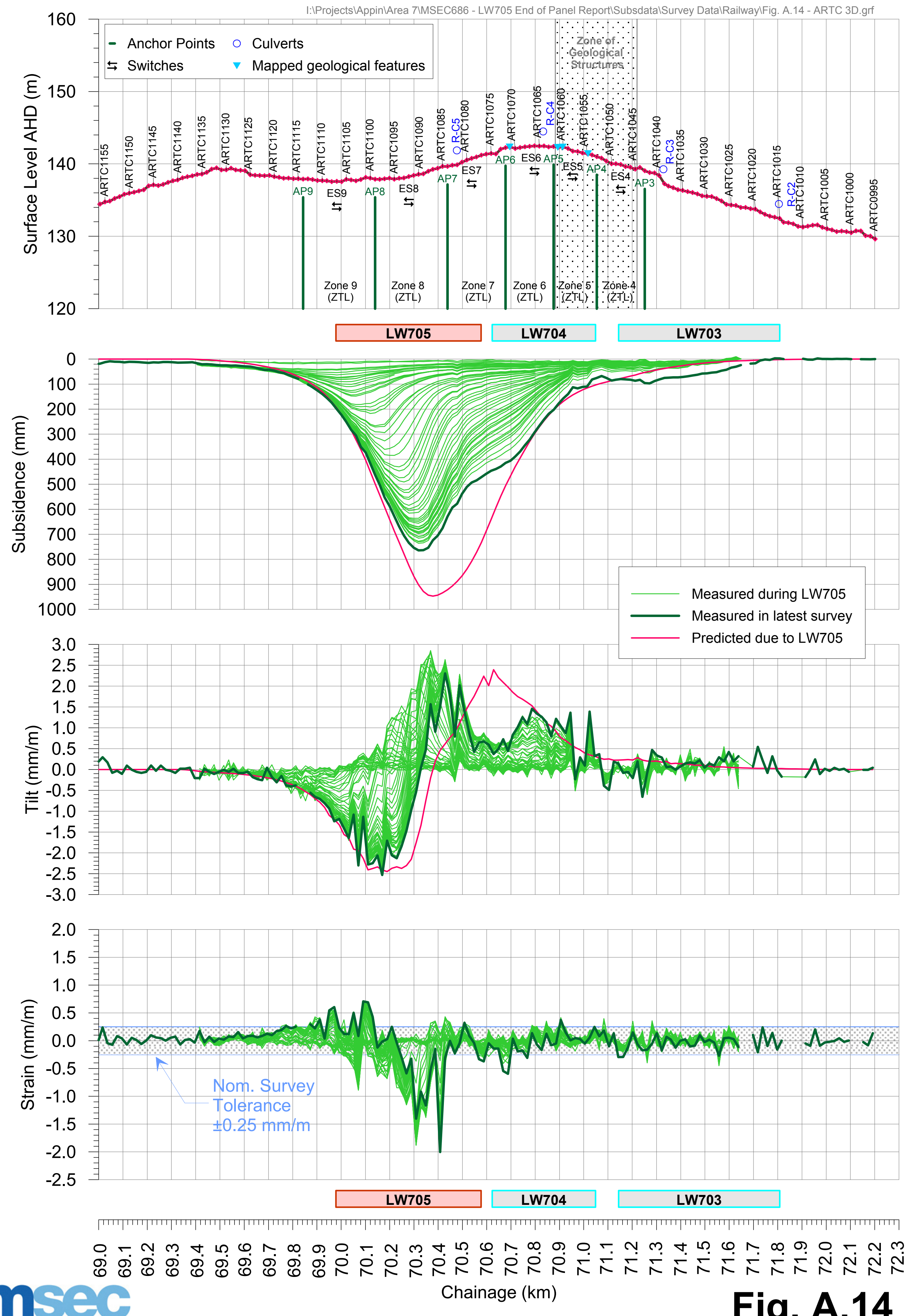

Fig. A.14

Observed Profiles of Incremental Subsidence, Tilt and Strain along Up Base of Embankment during Appin LW705

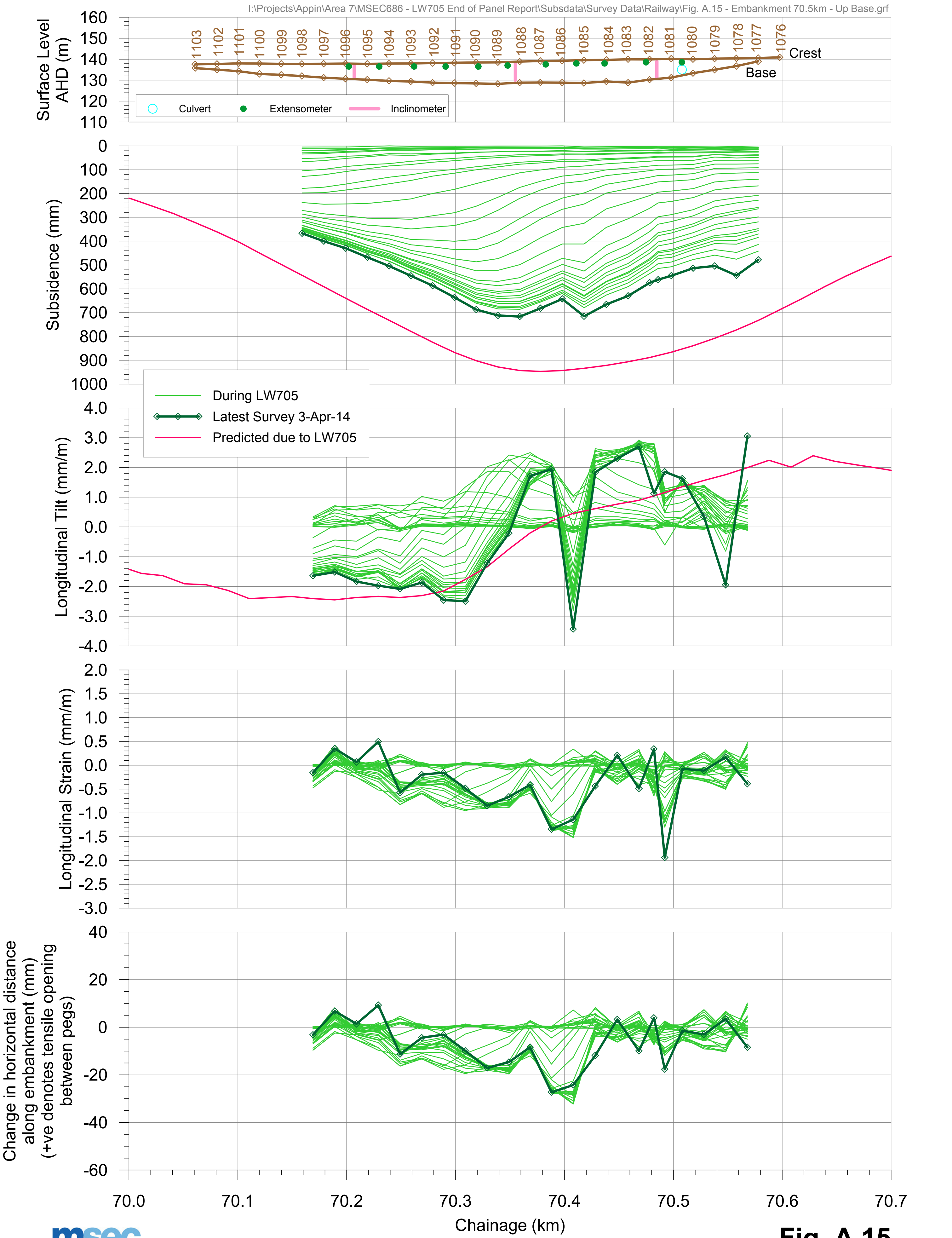

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Fig. A.15

Observed Profiles of Incremental Subsidence, Tilt and Strain along Up Crest of Embankment during Appin LW705

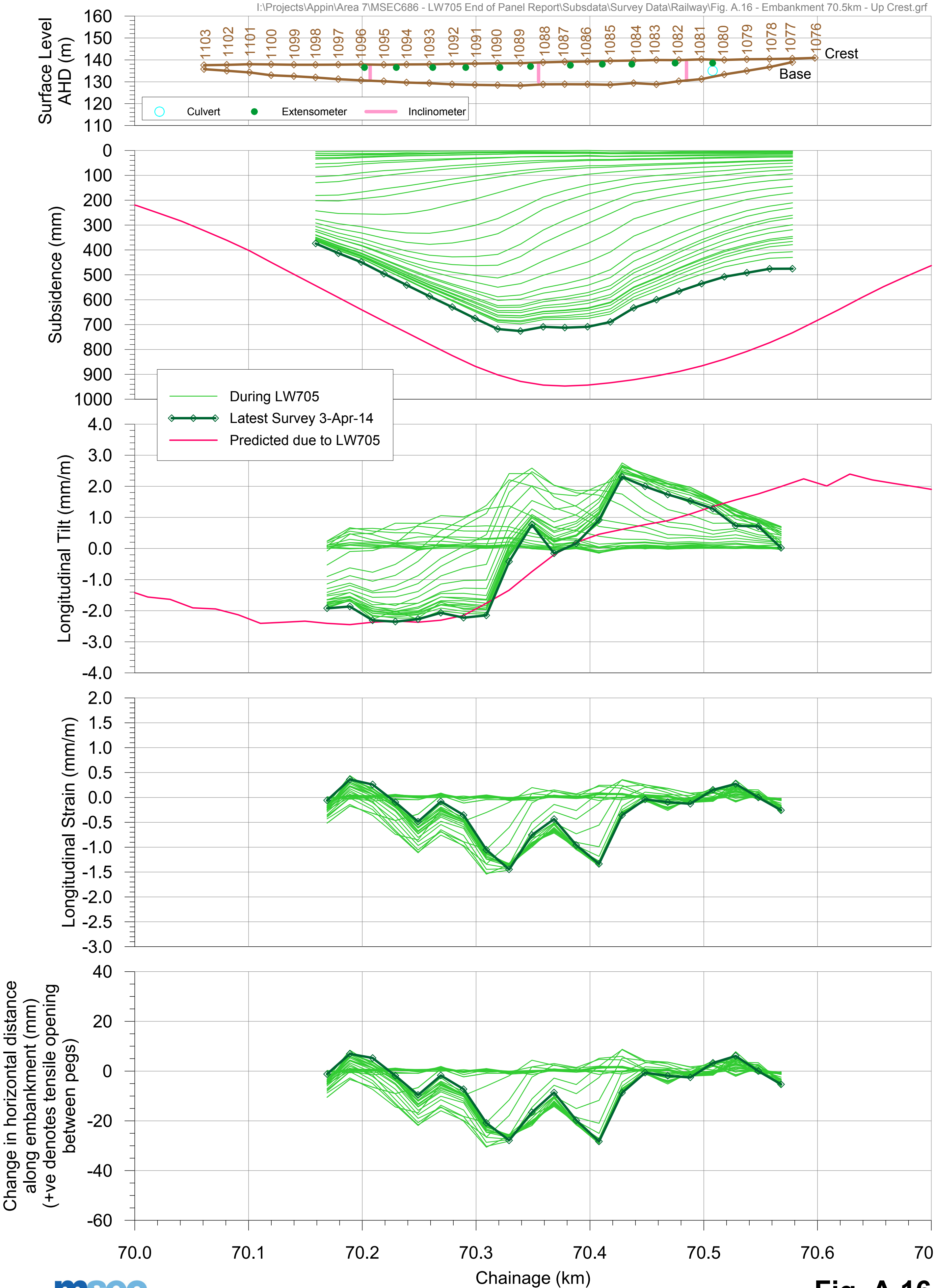

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Fig. A.16

Observed Profiles of Incremental Subsidence, Tilt and Strain along Down Crest of Embankment during Appin LW705

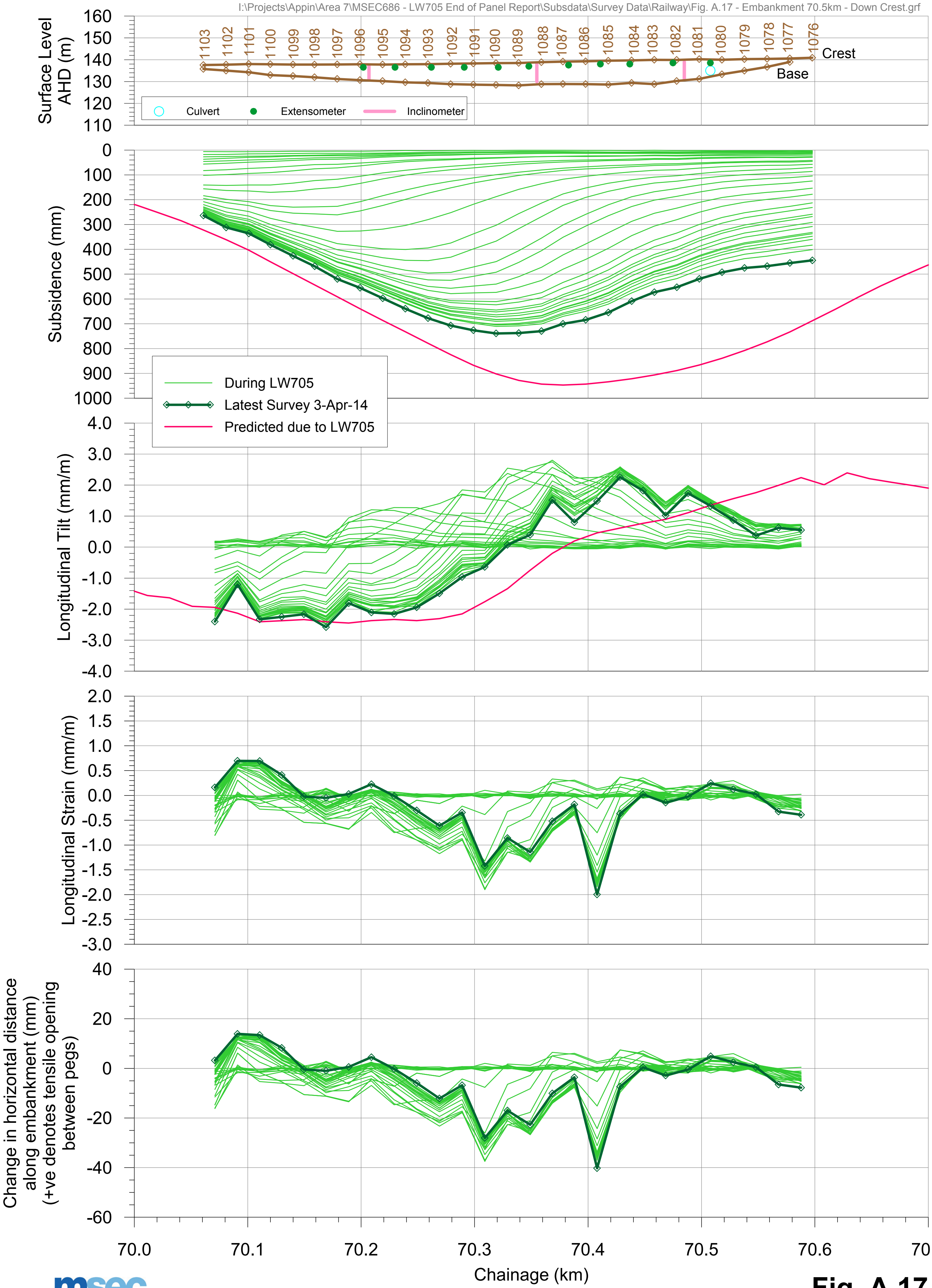
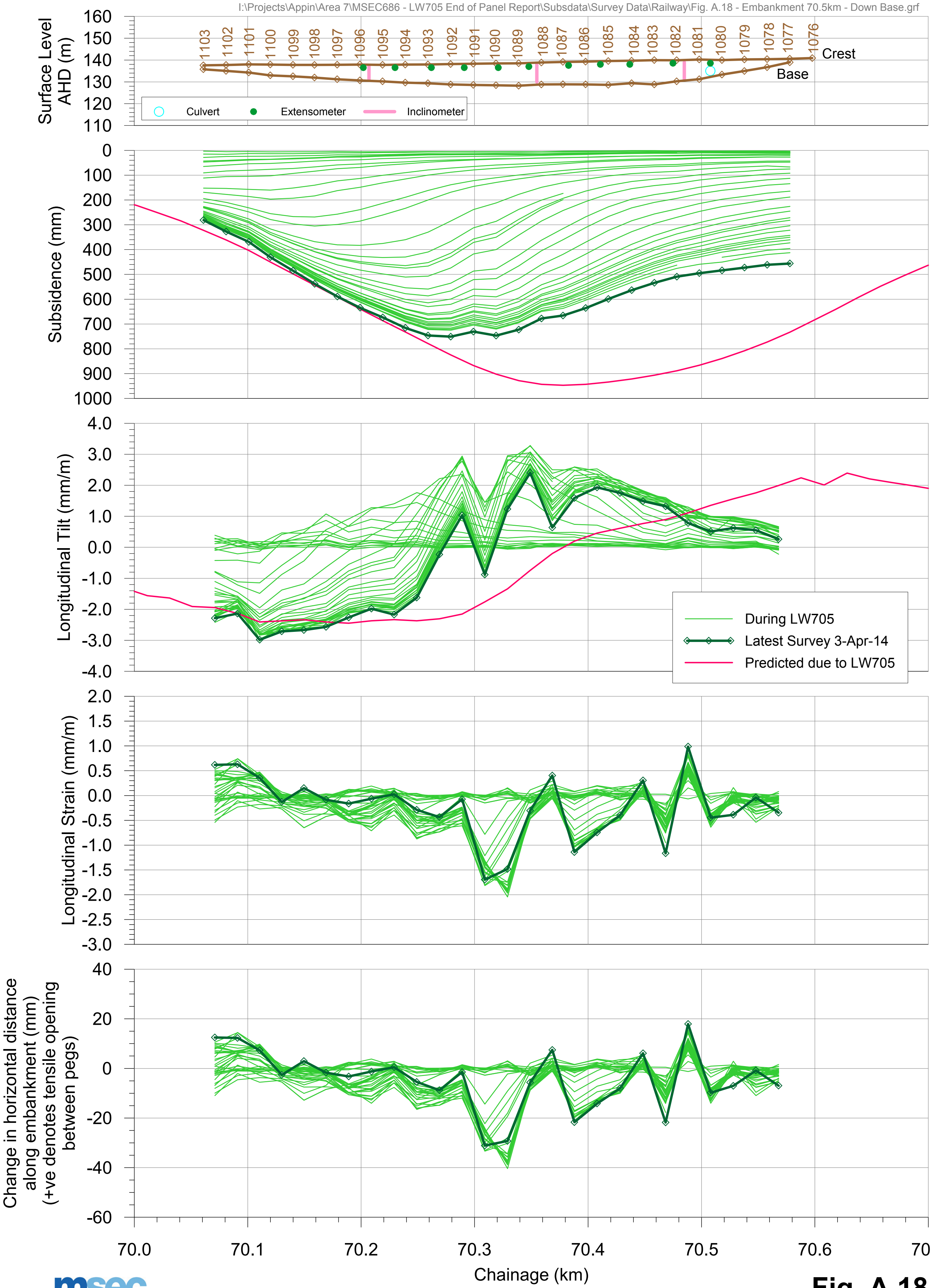


Fig. A.17

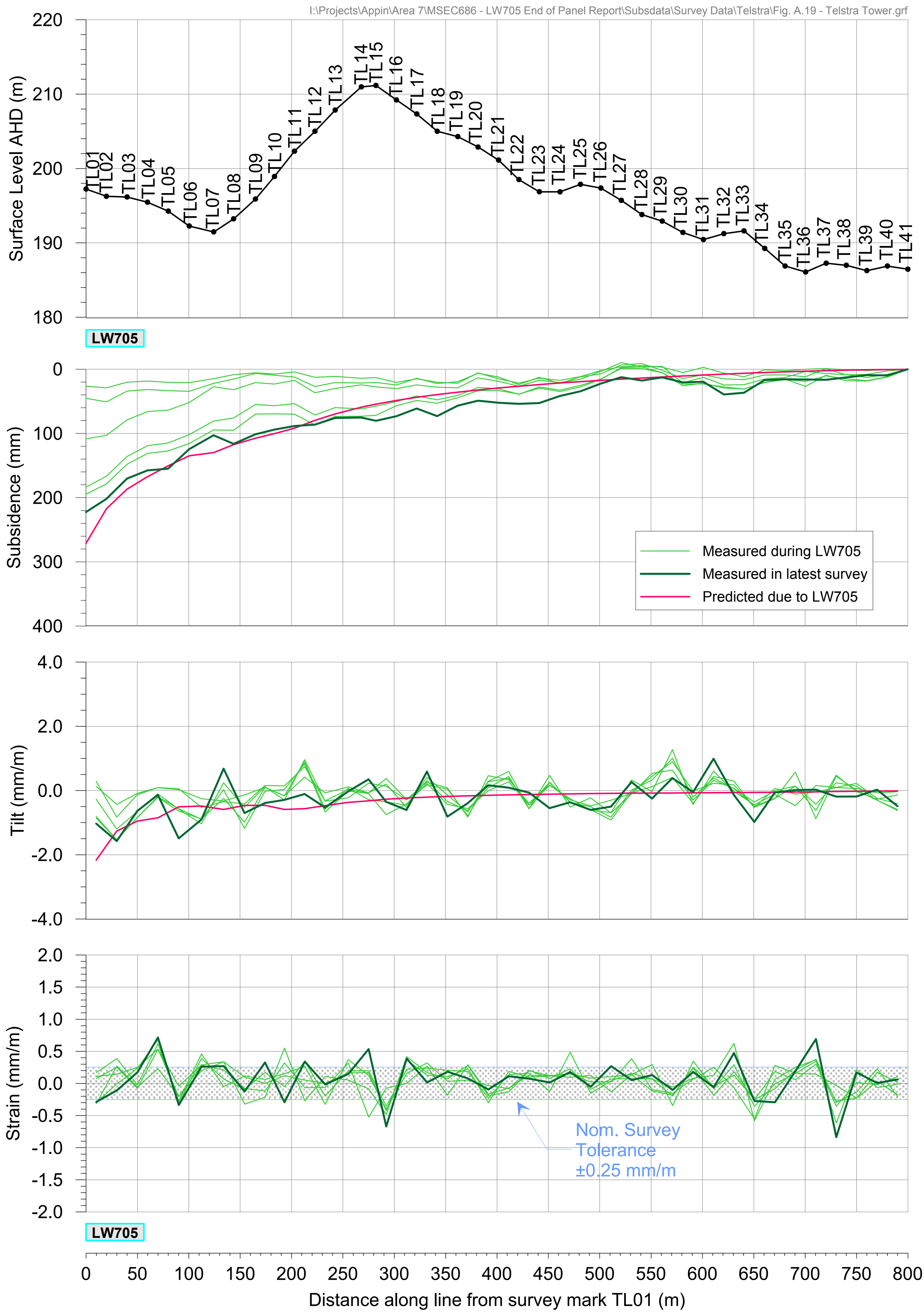
Observed Profiles of Incremental Subsidence, Tilt and Strain along Down Base of Embankment during Appin LW705



msec

Fig. A.18

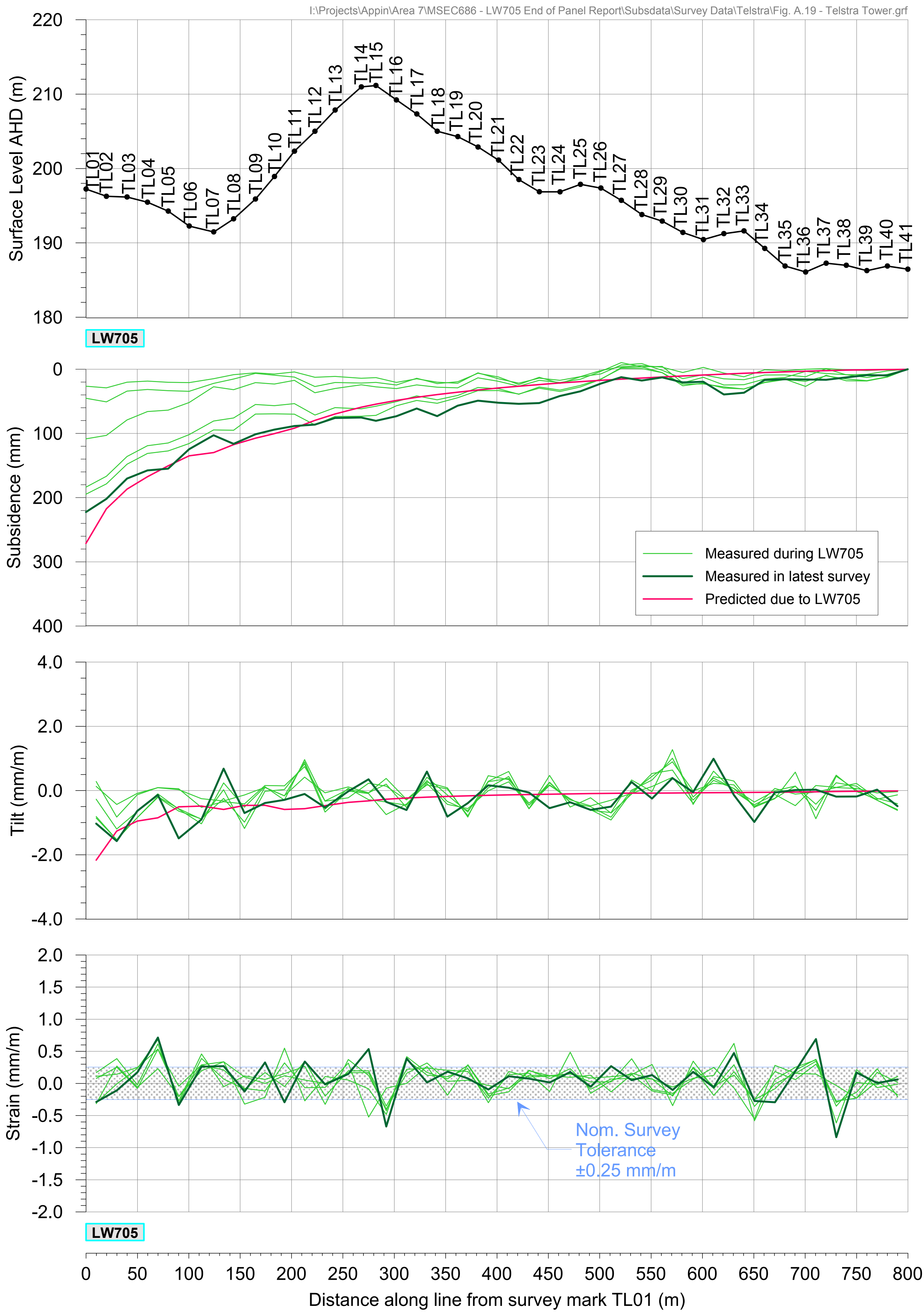
Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the Telstra Line during Appin Longwall 705



msec

Fig. A.19

Observed and Predicted Profiles of Incremental Subsidence, Tilt and Strain along the Telstra Line during Appin Longwall 705



msec

Fig. A.19

APPENDIX B. DRAWINGS

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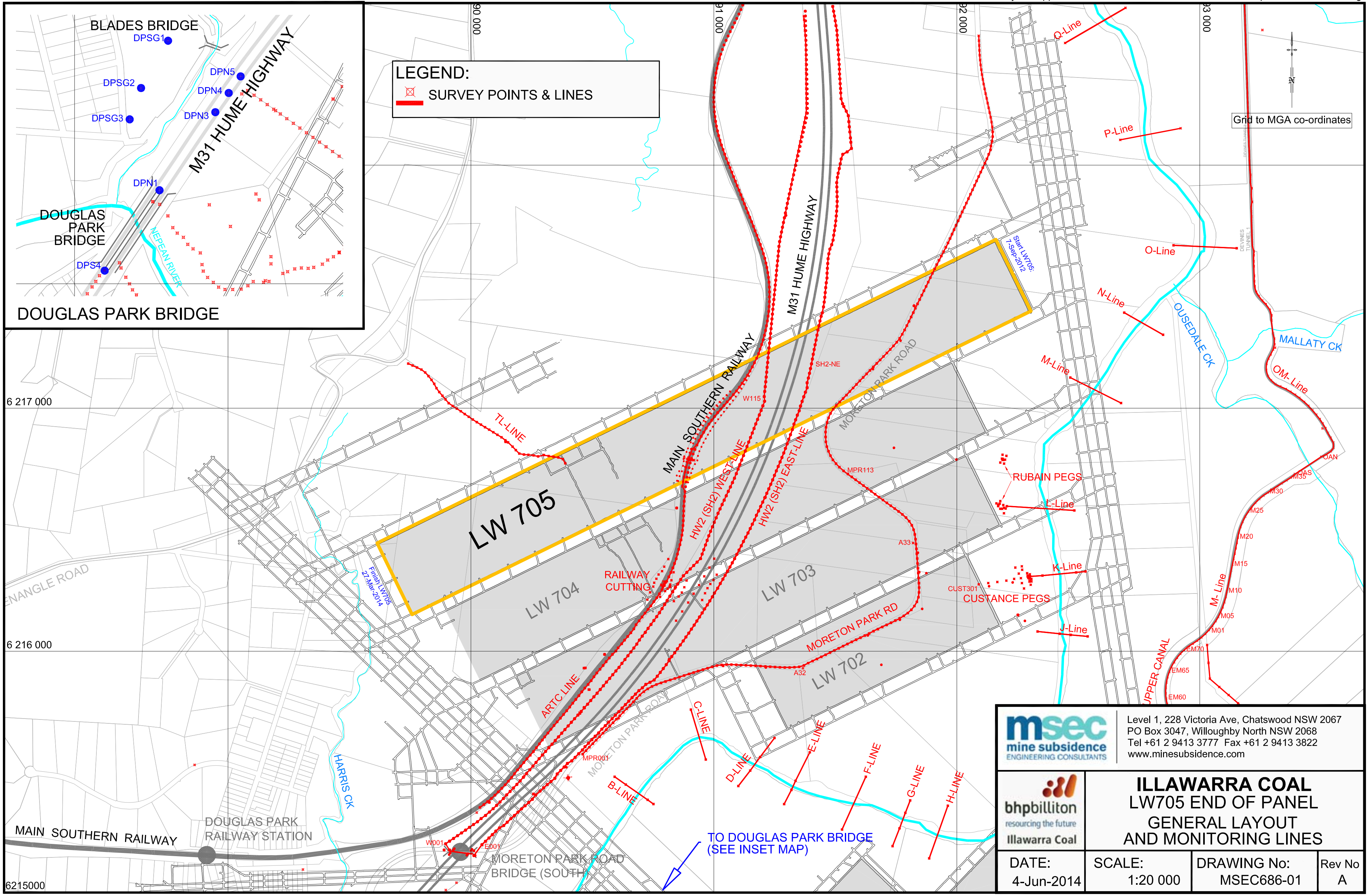

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ILLAWARRA COAL
LW705 END OF PANEL GENERAL LAYOUT AND MONITORING LINES

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ILLAWARRA COAL
LW705 END OF PANEL NATURAL FEATURES

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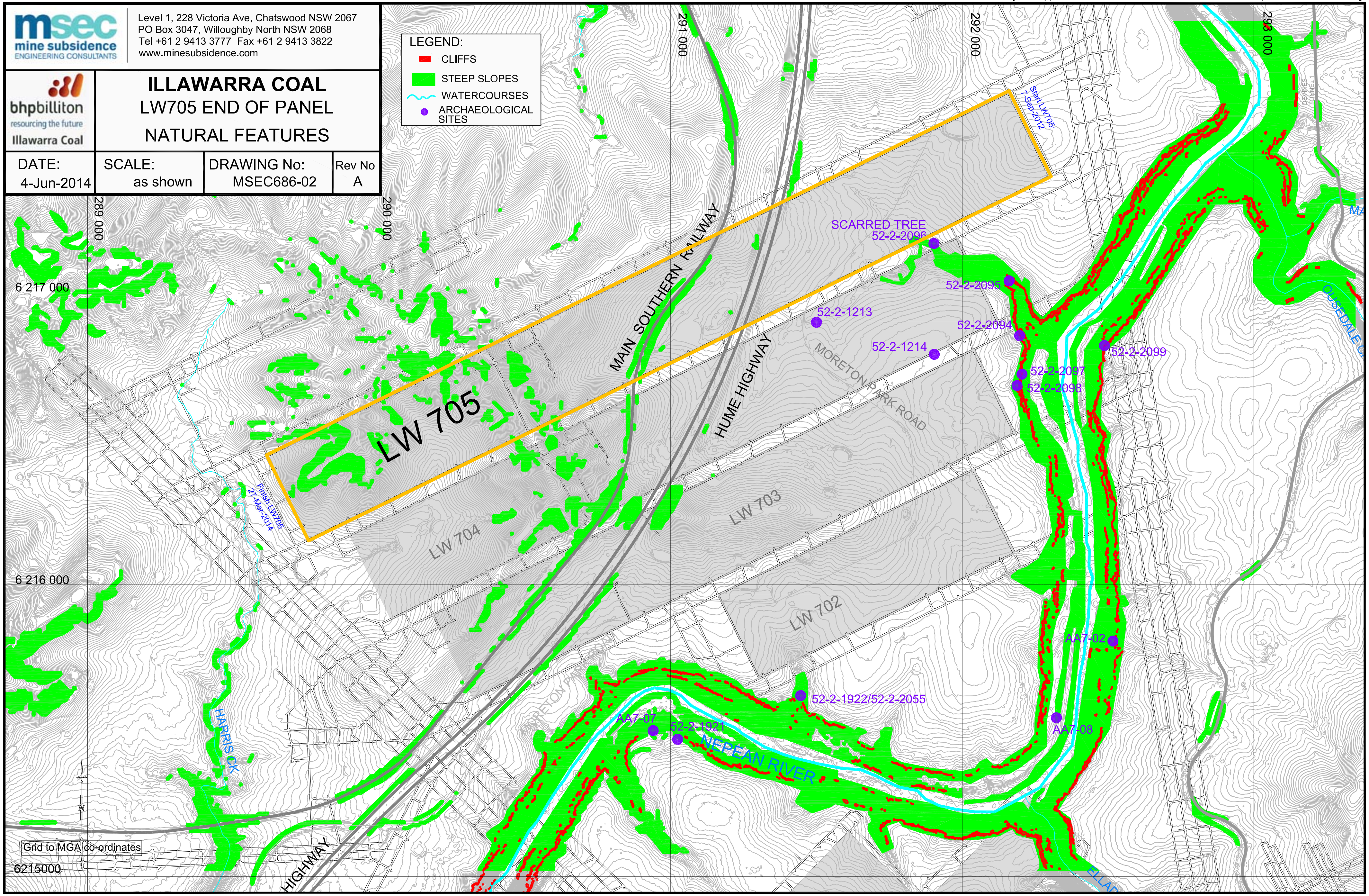

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SURFACE INFRASTRUCTURE

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