mine subsidence ENGINEERING CONSULTANTS

TAHMOOR UNDERGROUND

GLENCORE

GLENCORE:

Tahmoor Colliery - Longwalls 28 to 30

Management Plan for Potential Impacts to Wollondilly Shire Council Infrastructure

AUTHORISATION OF MANAGEMENT PLAN

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Aug-06	MSEC286-04	B	Chapter 1 amended and info re Thirlmere Way Overbridge updated, as agreed in Plan Review Meeting, 7 August 2006
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Sep-12	MSEC567-02	A	Updated for Longwall 27
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Oct-12	MSEC567-02	C	Final plan for Longwall 27
Mar-14	MSEC646-02	A	Updated for Longwalls 28 to 30
Apr-14	MSEC646-02	b	Updated following consultation with WSC

REFERENCES

AS/NZS 4360:1999 Risk Management

MSEC (2009). *Tahmoor Colliery Longwalls 27 to 30 - The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Natural Features and Items of Surface Infrastructure due to mining Longwalls 27 to 30 at Tahmoor Colliery in support of the SMP Application.* (Report MSEC355, Revision B, July 2009), prepared by Mine Subsidence Engineering Consultants.

JMA, (2009). *Myrtle Creek Bridges on Remembrance Drive: Condition Report.* John Matheson & Associates, Report No. R0116-Rev 02, May 2009.

JMA, (2009). Bridge Street Rail Overbridge: Condition Report. John Matheson & Associates, Report No. R0118-Rev 01, May 2009.

Gale, W. and Sheppard, I. (2011). *Investigation into Abnormal Increased Subsidence above Longwall Panels at Tahmoor Colliery.* Mine Subsidence Technological Society, Proceedings of the 8th Triennial Conference on Mine Subsidence, May 2011.

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Drawings

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

1.1. Background

Tahmoor Colliery is located approximately 80 kilometres south west of Sydney in the township of Tahmoor NSW. It is managed and operated by Glencore. Tahmoor Colliery has previously mined 26 longwalls to the north and west of the mine's current location. It is currently mining Longwall 27.

Longwalls 28 to 30 are a continuation of a series of longwalls that extend into the Tahmoor North Lease area, which began with Longwall 22. The longwall panels are located between the Bargo River in the south-east, the township of Thirlmere in the west and Picton in the north. A portion of Longwall 28 is located beneath the urban area of Tahmoor. Infrastructure owned by Wollondilly Shire Council is located within these areas.

Tahmoor Colliery's mine plan has changed since the Management Plan for Longwall 27 was prepared, in that Longwalls 29 and 30 have been shortened by approximately 250 metres. This represents a significant change because the potential for impacts on the Remembrance Drive Road Bridge has been substantially reduced.

A summary of the dimensions of these longwalls is provided in Table 1.1.

Table 1.1 Longwall Dimensions

Longwall	Overall Void Length Including Installation Heading (m)	Overall Void Width Including First Workings (m)	Overall Tailgate Chain Pillar Width (m)
Longwall 28	2630	283	39
Longwall 29	2321	283	39
Longwall 30	2321	283	39

This Management Plan provides detailed information about how the risks associated with mining beneath Council infrastructure will be managed by Tahmoor Colliery and Wollondilly Shire Council.

This Management Plan does not include management or monitoring measures for the Bridge Street Overbridge during the mining of Longwalls 28 to 30. These will be addressed in a separate management plan or in an addendum to this Management Plan.

The Management Plan is a live document that can be amended at any stage of mining, to meet the changing needs of Tahmoor Colliery and Wollondilly Shire Council

1.2. Objectives

The objectives of this Management Plan are to establish procedures to measure, control, mitigate and repair potential impacts that might occur to roads, bridges and culverts.

The objectives of the Plan have been developed to:-

- Ensure the safe and serviceable operation of all surface infrastructure. Public and workplace safety is paramount. Disruption and inconvenience should be kept to minimal levels.
- Monitor ground movements and the condition of surface infrastructure during mining.
- Initiate action to mitigate or remedy potential significant impacts that are expected to occur on the surface.
- Provide a plan of action in the event that the impacts of mine subsidence are greater than those that are predicted.
- Provide a forum to report, discuss and record impacts to the surface. This will involve Tahmoor Colliery, Wollondilly Council, Mine Subsidence Board, Department of Trade & Investment, Regional Infrastructure and Services (DTIRIS) and consultants as required.
- Establish lines of communication and emergency contacts.

1.3. Scope

The Management Plan is to be used to protect and monitor the condition of the items of infrastructure identified to be at risk due to mine subsidence. The major items at risk are:-

- Local roads
- Bridges
- Culverts

The Plan only covers infrastructure that is located within the limit of subsidence, which defines the extent of land that may be affected by mine subsidence as a result of mining Longwalls 28 to 30. The management plan does not include other roads, bridges and culverts owned by Wollondilly Shire Council which lie outside the extent of these areas.

This Management Plan does not include management or monitoring measures for the Bridge Street Overbridge during the mining of Longwalls 28 to 30. These will be addressed in a separate management plan or in an addendum to this Management Plan.

1.4. Proposed Mining Schedule

It is planned that each longwall will extract coal working northwest from the southeastern ends. This Plan covers longwall mining until completion of mining in Longwall 30 and for sufficient time thereafter to allow for completion of subsidence effects. The current schedule of mining is shown in Table 1.2.

Table 1.2 Schedule of Mining

Longwall	Start Date	Completion Date
Longwall 28	April 2014	August 2015
Longwall 29	September 2015	October 2016
Longwall 30	November 2016	December 2017

1.5. Definition of Active Subsidence Zone

As a longwall progresses, subsidence begins to develop at a point in front of the longwall face and continues to develop after the longwall passes. The majority of subsidence movement typically occurs within an area 150 metres in front of the longwall face to an area 450 metres behind the longwall face.

This is termed the "active subsidence zone" for the purposes of this Management Plan, where surface monitoring is generally conducted. The active subsidence zone for each longwall is defined by the area bounded by the predicted 20 mm subsidence contour for the active longwall and a distance of 150 metres in front and 450 metres behind the active longwall face, as shown by Fig. 1.1.

Fig. 1.1 Diagrammatic Representation of Active Subsidence Zone

2.1. Maximum Predicted Systematic Parameters

Predicted mining-induced systematic subsidence movements were provided in Report No. MSEC355, which was prepared in support of Tahmoor Colliery's SMP Application for Longwalls 27 to 30. Revised predictions have been provided in Report No. MSEC645, which was prepared in support of Tahmoor Colliery's modification to the commencing ends of Longwalls 29 and 30.

A summary of the maximum predicted incremental systematic subsidence parameters, due to the extraction of each of the proposed longwalls, is provided in Table 2.1. A summary of the maximum predicted total systematic subsidence parameters, after the extraction of each of the proposed longwalls, is provided in Table 2.2.

Table 2.1 Maximum Predicted Incremental Systematic Subsidence Parameters due to the Extraction of Longwalls 28 to 30

Longwall	Maximum Predicted Incremental Subsidence (mm)	Maximum Predicted Incremental Tilt (mm/m)	Maximum Predicted Incremental Hogging Curvature (1/km)	Maximum Predicted Incremental Sagging Curvature (1/km)
Due to LW28	730	5.8	0.06	0.13
Due to LW29	720	5.8	0.06	0.12
Due to LW30	720	5.7	0.06	0.12

Table 2.2 Maximum Predicted Total Systematic Subsidence Parameters after the Extraction of Longwalls 28 to 30

Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (1/km)	Maximum Predicted Total Sagging Curvature (1/km)
After LW28	1250	6.0	0.11	0.14
After LW29	1250	6.0	0.11	0.14
After LW30	1250	6.0	0.11	0.14

The values provided in the above table are the maximum predicted cumulative systematic subsidence parameters which occur within the general longwall mining area, including the predicted movements resulting from the extraction of Longwalls 22 to 30.

2.2. Observed Subsidence during the mining of Longwalls 22 to 27

Extensive ground monitoring within the urban areas of Tahmoor has allowed detailed comparisons to be made between predicted and observed subsidence, tilt, strain and curvature during the mining of Longwalls 22 to 27.

In summary, there is generally a good correlation between observed and predicted subsidence, tilt and curvature. Observed subsidence was generally slightly greater than predicted in areas that were located directly above previously extracted areas and areas of low level subsidence (typically less than 100 mm) was generally observed to extend further than predicted.

While there is generally a good correlation between observed and predicted subsidence, substantially increased subsidence has been observed above most of Longwall 24A and the southern end of Longwall 25. This was a very unusual event for the Southern Coalfield.

Observed Increased Subsidence during the mining of Longwall 24A

Observed subsidence was greatest above the southern half of Longwall 24A, and gradually reducing in magnitude towards the northern half of the longwall, which was directly beneath the urban area of Tahmoor. These observations are shown graphically in Fig. 2.1, which shows observed subsidence at survey pegs located along the centreline of Longwall 24A.

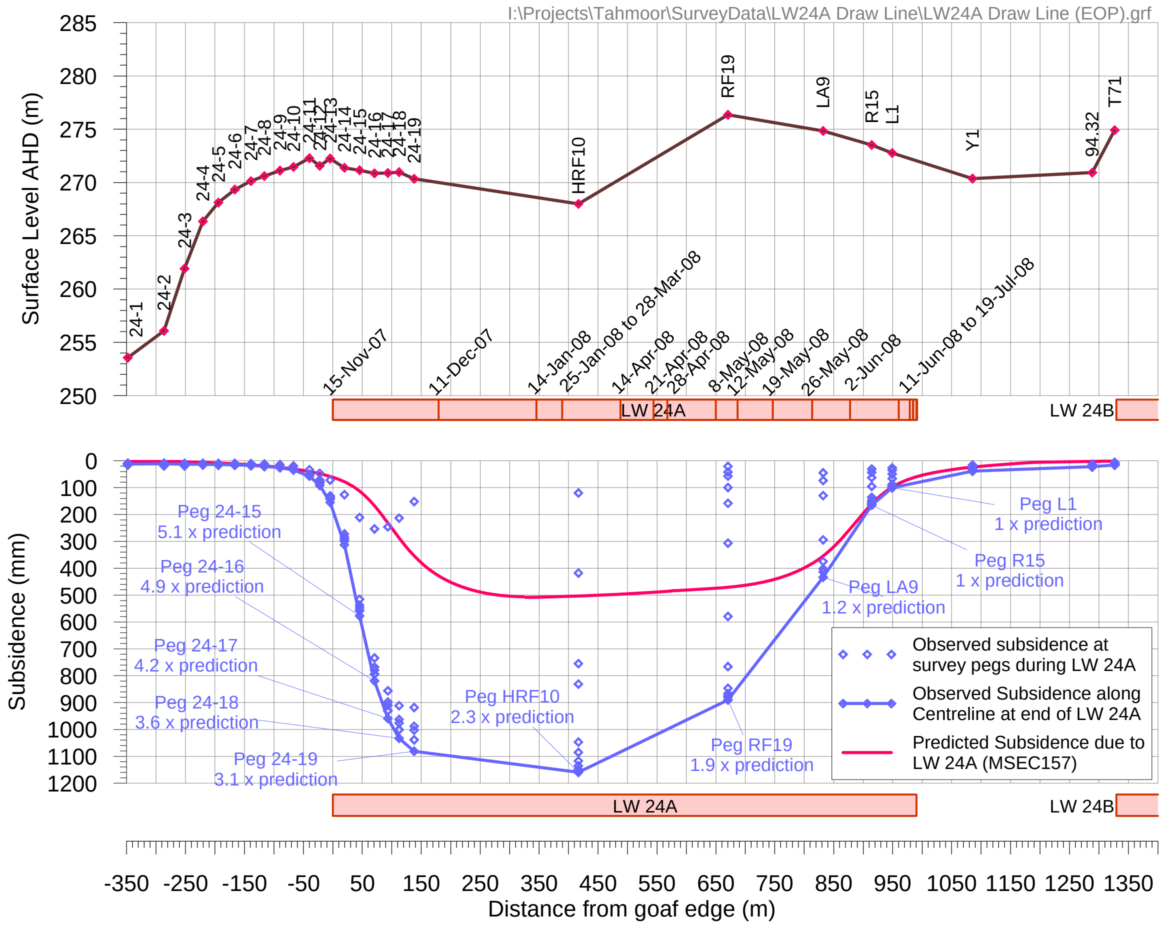


Fig. 2.1 Observed Subsidence along Centreline of Longwall 24A

It can be seen from Fig. 2.1 that observed subsidence was more than twice the predicted maximum value, reaching to a maximum of 1169 mm at Peg HRF10. It is possible that actual maximum subsidence developed somewhere between Pegs HRF10 and RF19, though this was not measured. Observed subsidence was similar to prediction near Peg R15 on Remembrance Drive. Survey pegs RF19 and LA9 are located within a transition zone where subsidence gradually reduced from areas of maximum increased subsidence to areas of normal subsidence.

Observed Increased Subsidence during the mining of Longwall 25

Increased subsidence was observed during the first stages of mining Longwall 25. These observations are shown graphically in Fig. 2.2, which shows observed subsidence at survey pegs located along the centreline of Longwall 25.

It can be seen from Fig. 2.2 that observed subsidence was approximately twice the predicted maximum value, with maximum subsidence of 1216 mm at Peg 25-28.

Observed subsidence is similar to but slightly more than predicted at Peg RE7 and is similar to prediction at Peg Y20 and at all pegs located further along the panel. Survey pegs A6, A7, A8 and A9 are located within a transition zone where subsidence has gradually reduced from areas of maximum increased subsidence to areas of normal subsidence.

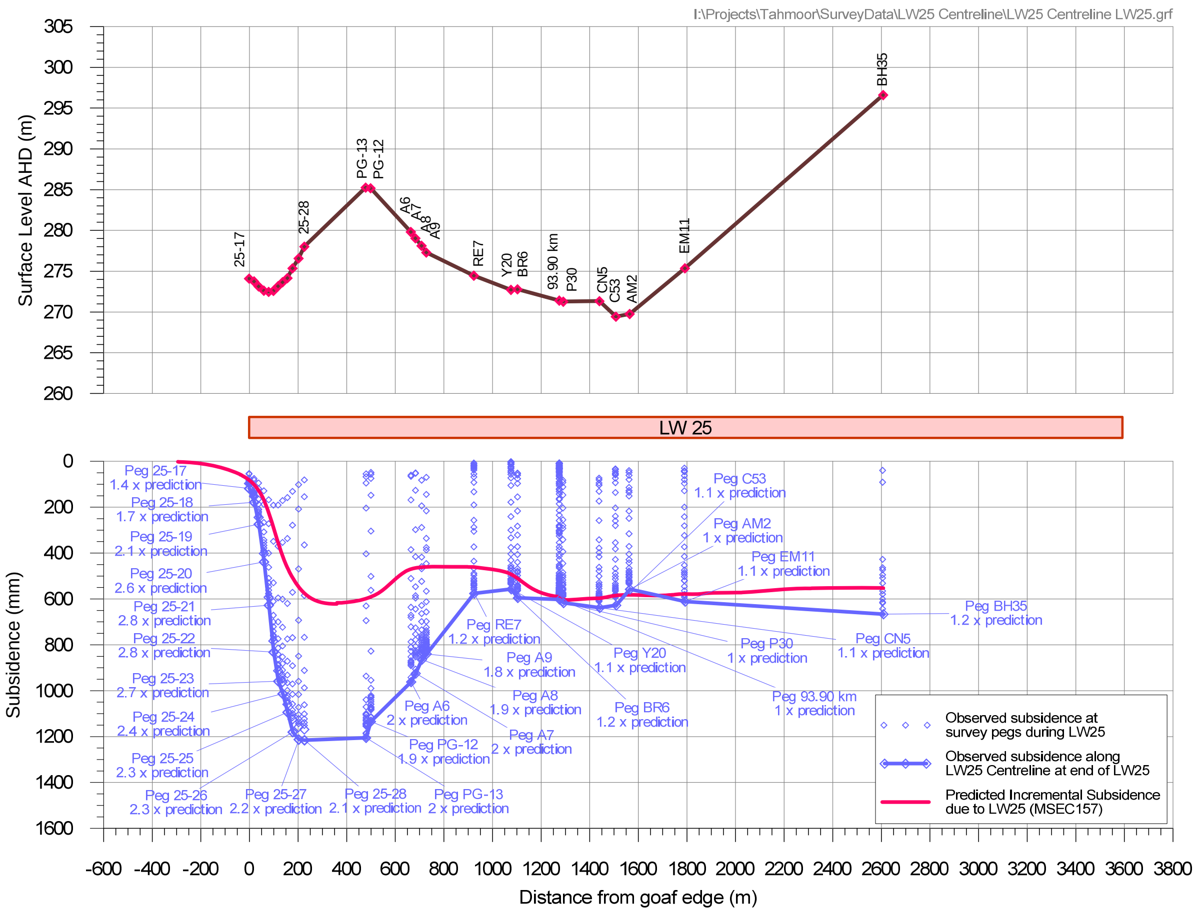


Fig. 2.2 Observed Subsidence along Centreline of Longwall 25

Observed Increased Subsidence during the mining of Longwall 26

Increased subsidence was observed during the first stages of mining Longwall 26, but at a reduced magnitude compared to the subsidence observed above Longwalls 24A and 25. These observations are shown graphically in Fig. 2.3, which shows observed subsidence at survey pegs located along the centreline of Longwall 26.

It can be seen from Fig. 2.3 that observed subsidence was approximately 1.5 times the predicted maximum value, with maximum subsidence of 893 mm at Peg TM26.

Observed subsidence reduced along the panel until Peg Y40 on York Street, where it was less than prediction. Survey pegs S9 and RE27 are located within a transition zone where subsidence has gradually reduced from areas of maximum increased subsidence between Pegs TM26 and MD4 to areas of normal subsidence at Peg Y40 and beyond.

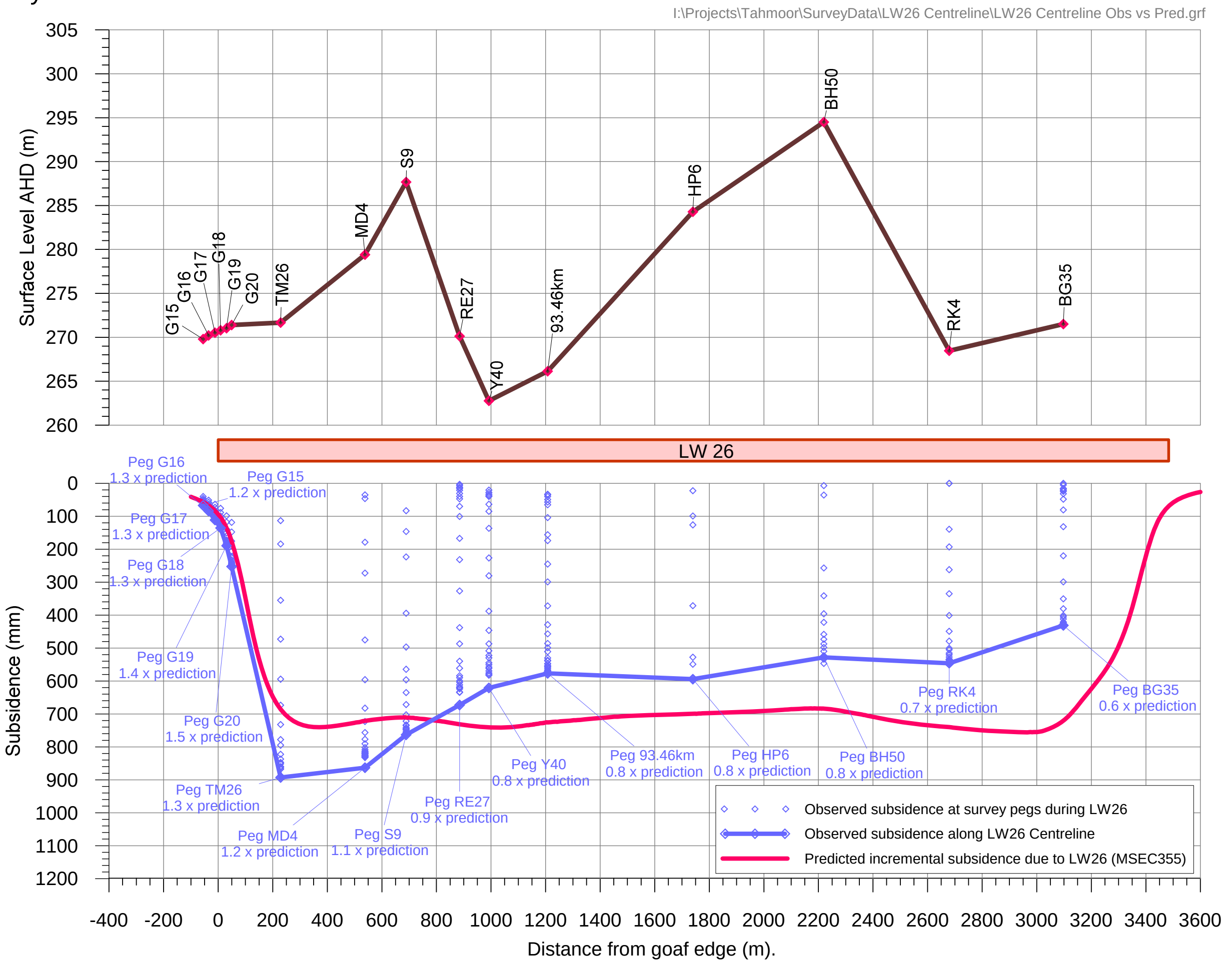


Fig. 2.3 Observed Subsidence along Centreline of Longwall 26

Observed Increased Subsidence during the mining of Longwall 27

The extraction of Longwall 27 is currently underway and is scheduled to finish in early 2014. Monitoring above the commencing end has shown that the magnitude of maximum subsidence is approximately 800 mm, which is slightly less than the measured maximum subsidence of approximately 900 mm above the commencing end of Longwall 26. Observed subsidence at survey pegs located along the centreline of Longwall 27 is shown graphically in Fig. 2.4. The graph shows the latest survey results for each monitoring line as at February 2014. It is likely that further small increases in subsidence will be observed at these pegs when they are surveyed at the completion of Longwall 27.

It can be seen from Fig. 2.4 that observed subsidence is approximately 1.3 times the predicted maximum value, with current maximum subsidence of 793 mm at Peg MC14.

Observed subsidence reduced along the panel from Peg MC14 until Peg TC4, which is located between Remembrance Drive and Myrtle Creek. Observed subsidence along the centreline returned to normal levels as mining progressed beyond Peg TC4.

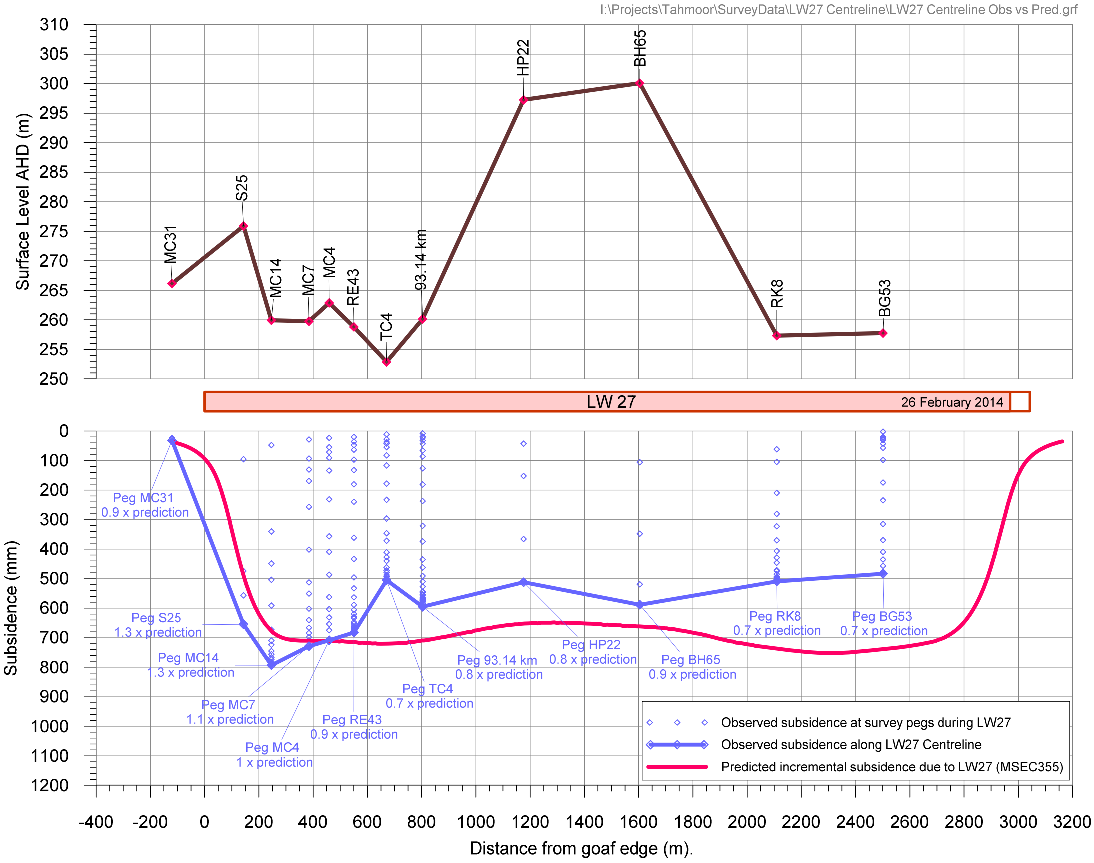


Fig. 2.4 Observed Subsidence along Centreline of Longwall 27

Analysis and commentary

The cause for the increased subsidence has been investigated by Strata Control Technologies on behalf of Tahmoor Colliery (Gale and Sheppard, 2011). The investigations concluded that the increased subsidence is consistent with localised weathering of joint and bedding planes above a depressed water table adjacent to an incised gorge.

In light of the above observations, the region above the extracted longwalls at Tahmoor has been partitioned into three zones:

1. Normal subsidence zone – where the observed vertical subsidence is within the normal range and correlates well with predictions

2. Maximum increased subsidence zone – where the observed vertical subsidence is substantially greater than predictions but has reached it upper limit. Maximum subsidence above the centreline of the longwalls appears to be approximately 1.2 metres above Longwalls 24A and 25, 900 mm above Longwall 26 and 800 mm above Longwall 27.

3. Transition zone – where the subsidence behaviour appears to have transitioned between areas of maximum increased subsidence and normal subsidence.

When the locations of the three zones are plotted on a map, as shown in Drawing No. MSEC646-00-01 (refer Appendix), it can be seen that the transition zone is roughly consistent in width above Longwall 24A, Longwall 25 and Longwall 26. This orientation is roughly parallel to the Nepean Fault. The transition zone then appears to change direction above Longwall 27. This may suggest a relationship to the proximity of Longwall 27 to the Bargo River and a curved transition zone has been drawn to illustrate this. .

The observations above Longwalls 24A to 27 suggest that the location of the zone of increased subsidence is linked to both the alignment of the Nepean Fault and the proximity to the Bargo River. It correlates with the findings of Gale and Sheppard that the increased subsidence is linked to localised weathering of joint and bedding planes above a depressed water table adjacent to the incised gorge of the Bargo River.

The experiences of reduced maximum subsidence above Longwalls 26 and 27 suggest that the magnitude of maximum subsidence above the commencing ends of Longwalls 28 to 30 will be less than previously observed and may return close to normal levels of subsidence elsewhere at Tahmoor.

The zones of increased subsidence and transition to normal subsidence have been conservatively projected above Longwalls 28 to 30 in Drawing No. MSEC646-00-02 (refer Appendix). The projection is conservative as it is based on the orientation of the Nepean Fault rather than its proximity to the Bargo River. A curved dashed line is also shown in in Drawing No. MSEC646-00-02 above Longwall 28, which is an alternative projection based on the observations above Longwall 27 and its proximity to the Bargo River. This alternative projection appears reasonable based on the observations above Longwall 27.Despite the above observations and projections, it is recognised that substantially increased subsidence could develop above the commencing ends of Longwalls 28 to 30 and this Management Plan has been developed to manage potential impacts if substantial additional subsidence were to occur.

With respect to council infrastructure, there are local roads located directly within a potential zone of increased subsidence above Longwall 28 only.

2.3. Predicted Strain

The prediction of strain is more difficult than the predictions of subsidence, tilt and curvature. The reason for this is that strain is affected by many factors, including curvature and horizontal movement, as well as local variations in the near surface geology, the locations of pre-existing natural joints at bedrock, and the depth of bedrock. Survey tolerance can also represent a substantial portion of the measured strain, in cases where the strains are of a low order of magnitude. The profiles of observed strain, therefore, can be irregular even when the profiles of observed subsidence, tilt and curvature are relatively smooth.

In previous MSEC subsidence reports, predictions of conventional strain were provided based on the best estimate of the average relationship between curvature and strain. Similar relationships have been proposed by other authors. The reliability of the strain predictions was highlighted in these reports, where it was stated that measured strains can vary considerably from the predicted conventional values.

Adopting a linear relationship between curvature and strain provides a reasonable prediction for the conventional tensile and compressive strains. The locations that are predicted to experience hogging or convex curvature are expected to be net tensile strain zones and locations that are predicted to experience sagging or concave curvature are expected to be net compressive strain zones. In the Southern Coalfield, it has been found that a factor of 15 provides a reasonable relationship between the maximum predicted curvatures and the maximum predicted conventional strains.

At a point, however, there can be considerable variation from the linear relationship, resulting from non-conventional movements or from the normal scatters which are observed in strain profiles. When expressed as a percentage, observed strains can be many times greater than the predicted conventional strain for low magnitudes of curvature. In this report, therefore, we have provided a statistical approach to account for the variability, instead of just providing a single predicted conventional strain.

The data used in an analysis of observed strains included those resulting from both conventional and non-conventional anomalous movements, but did not include those resulting from valley related movements, which are addressed separately in this report. The strains resulting from damaged or disturbed survey marks have also been excluded.

A number of probability distribution functions were fitted to the empirical data. It was found that a *Generalised Pareto Distribution (GPD)* provided a good fit to the raw strain data. Confidence levels have been determined from the empirical strain data using the fitted GPDs. In the cases where survey bays were measured multiple times during a longwall extraction, the maximum tensile strain and the maximum compressive strain were used in the analysis (i.e. single tensile strain and single compressive strain measurement per survey bay).

2.3.1. Analysis of Strains Measured in Survey Bays

For features that are in discrete locations, such as building structures, farm dams and archaeological sites, it is appropriate to assess the frequency of the observed maximum strains for individual survey bays.

Predictions of Strain Above Goaf

The survey database has been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at Tahmoor, Appin and West Cliff Collieries, for survey bays that were located directly above goaf or the chain pillars that are located between the extracted longwalls, which has been referred to as "*above goaf*".

The histogram of the maximum observed total tensile and compressive strains measured in survey bays above goaf, for monitoring lines at Tahmoor, Appin Area and West Cliff Collieries, is provided in Fig. 2.5. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

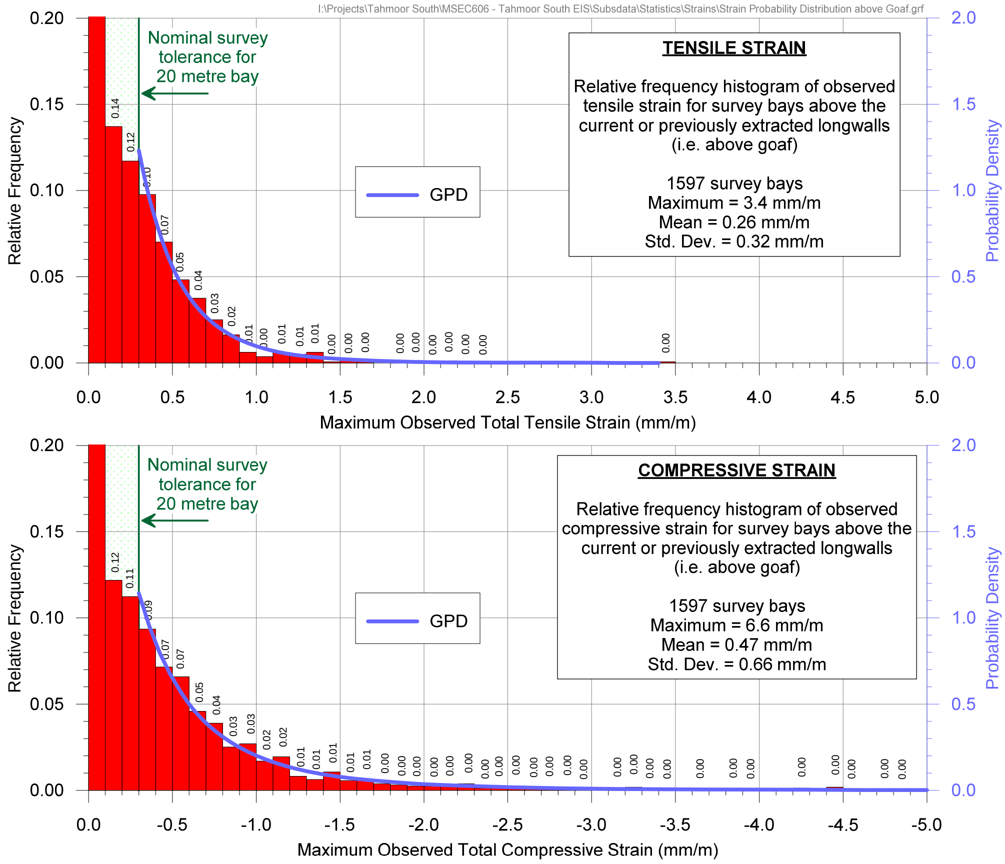


Fig. 2.5 Distributions of the Measured Maximum Tensile and Compressive Strains for Surveys Bays Located Above Goaf at Tahmoor, Appin and West Cliff Collieries

The 95 % confidence levels for the maximum total strains that the individual survey bays *above goaf* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 0.9 mm/m tensile and 1.6 mm/m compressive. The strains for the proposed longwalls are predicted to be 30 % to 50 % greater than those previously observed at these collieries and, therefore, it is expected that 95 % of the strains measured *above goaf* would be less than 1.5 mm/m tensile and 2.5 mm/m compressive.

The 99 % confidence levels for the maximum total strains that the individual survey bays *above goaf* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 1.4 mm/m tensile and 3.1 mm/m compressive. Similarly, it is expected that 99 % of the strains measured *above goaf* for the proposed longwalls would be less than 2.0 mm/m tensile and 4.5 mm/m compressive.

Predictions of Strain Above Solid Coal

The survey database has also been analysed to extract the maximum tensile and compressive strains that have been measured at any time during the extraction of the previous longwalls at Tahmoor, Appin and West Cliff Collieries, for survey bays that were located outside and within 200 metres of the nearest longwall goaf edge, which has been referred to as "*above solid coal*".

The histogram of the maximum observed tensile and compressive strains measured in survey bays above solid coal, for monitoring lines at Tahmoor, Appin and West Cliff Collieries, is provided in Fig. 2.6. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

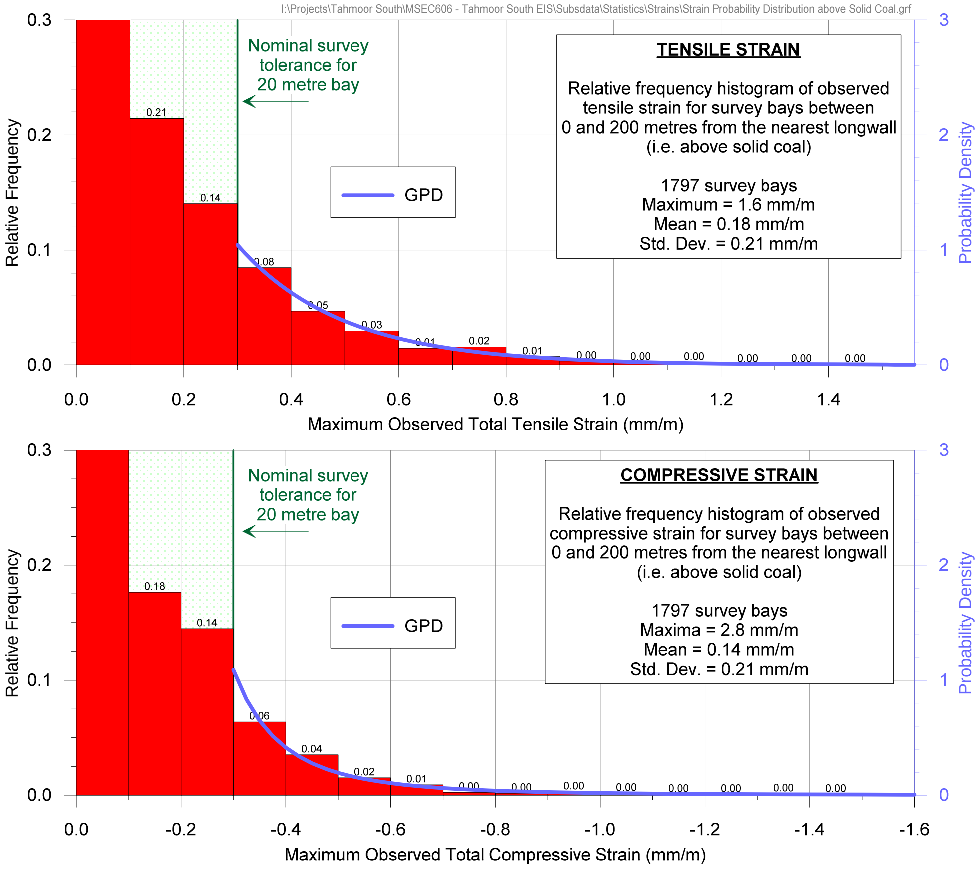


Fig. 2.6 Distributions of the Measured Maximum Tensile and Compressive Strains for Survey Bays Located Above Solid Coal at Tahmoor, Appin and West Cliff Collieries

The 95 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 0.6 mm/m tensile and 0.5 mm/m compressive. The strains for the proposed longwalls are predicted to be 30 % to 50 % greater than those previously observed at these collieries and, therefore, it is expected that 95 % of the strains measured *above solid coal* would be less than 1.0 mm/m tensile and compressive.

The 99 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining at Tahmoor, Appin and West Cliff Collieries were 0.9 mm/m tensile and compressive. Similarly, it is expected that 99 % of the strains measured *above solid coal* adjacent to the proposed longwalls would be less than 1.5 mm/m tensile and compressive.

2.3.2. Analysis of Strains Measured Along Whole Monitoring Lines

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

The histogram of maximum observed total tensile and compressive strains measured anywhere along the monitoring lines, at any time during or after the extraction of the previous longwalls at Tahmoor, Appin and West Cliff Collieries, is provided in Fig. 2.7.

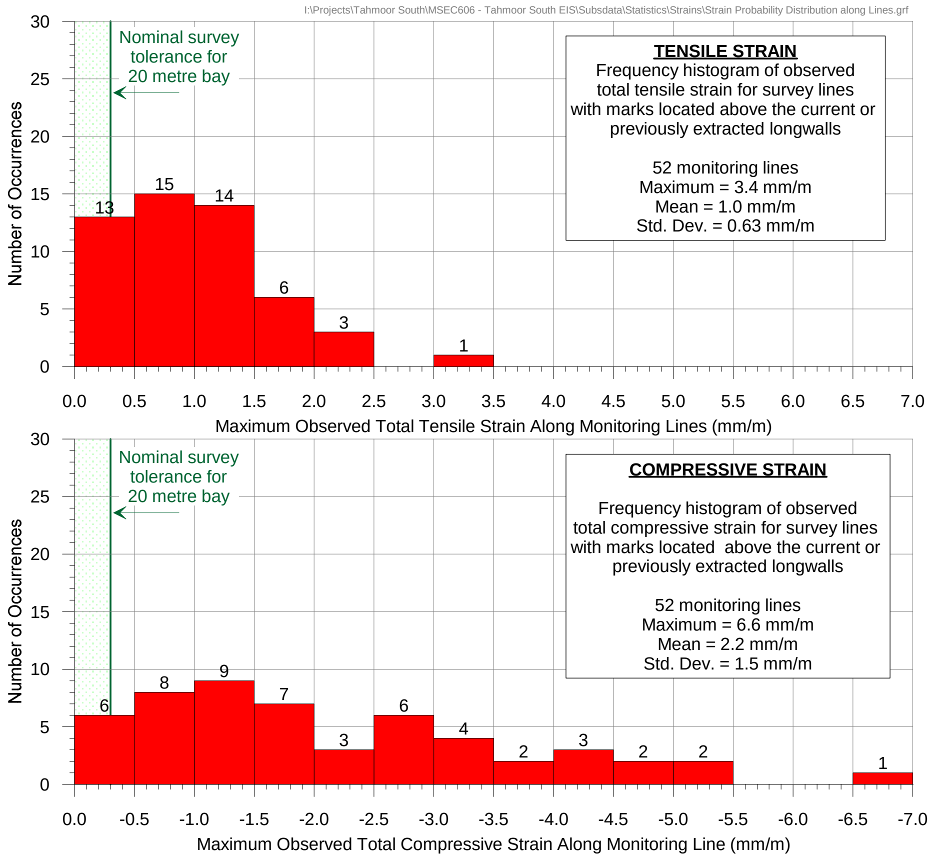


Fig. 2.7 Distributions of Measured Maximum Tensile and Compressive Strains Anywhere along the Monitoring Lines at Tahmoor, Appin and West Cliff Collieries

It can be seen from Fig. 2.7, that 42 of the 52 monitoring lines (i.e. 92 % of the total) at Tahmoor, Appin and West Cliff Collieries had recorded maximum total tensile strains of 2.0 mm/m, or less. The strains for the proposed longwalls are predicted to be 30 % to 50 % greater than those previously observed at these collieries and, therefore, it is expected that 92 % of the monitoring lines above the proposed longwalls would experience maximum tensile strains of 3.0 mm/m, or less.

It can also be seen, that 45 of the 52 monitoring lines (i.e. 87 % of the total) at Tahmoor, Appin and West Cliff Collieries had recorded maximum total compressive strains of 4.0 mm/m, or less. The strains for the proposed longwalls are predicted to be 30 % to 50 % greater than those previously observed at these collieries and, therefore, it is expected that 87 % of the monitoring lines above the proposed longwalls would experience maximum compressive strains of 6.0 mm/m, or less.

2.4. Predicted and Observed Valley Closure across creeks

A number of bridges and culverts above Longwalls 28 to 30 carry road transport over Myrtle Creek, Redbank Creek and other watercourses. Predictions of valley closure and upsidence at each of these features are provided later in this Management Plan.

A comparison between predicted and observed valley closure movements is provided below.

A map of monitoring lines across Myrtle Creek and a small creek that crosses the Main Southern Railway (called the Skew Culvert) is shown in Fig. 2.8.

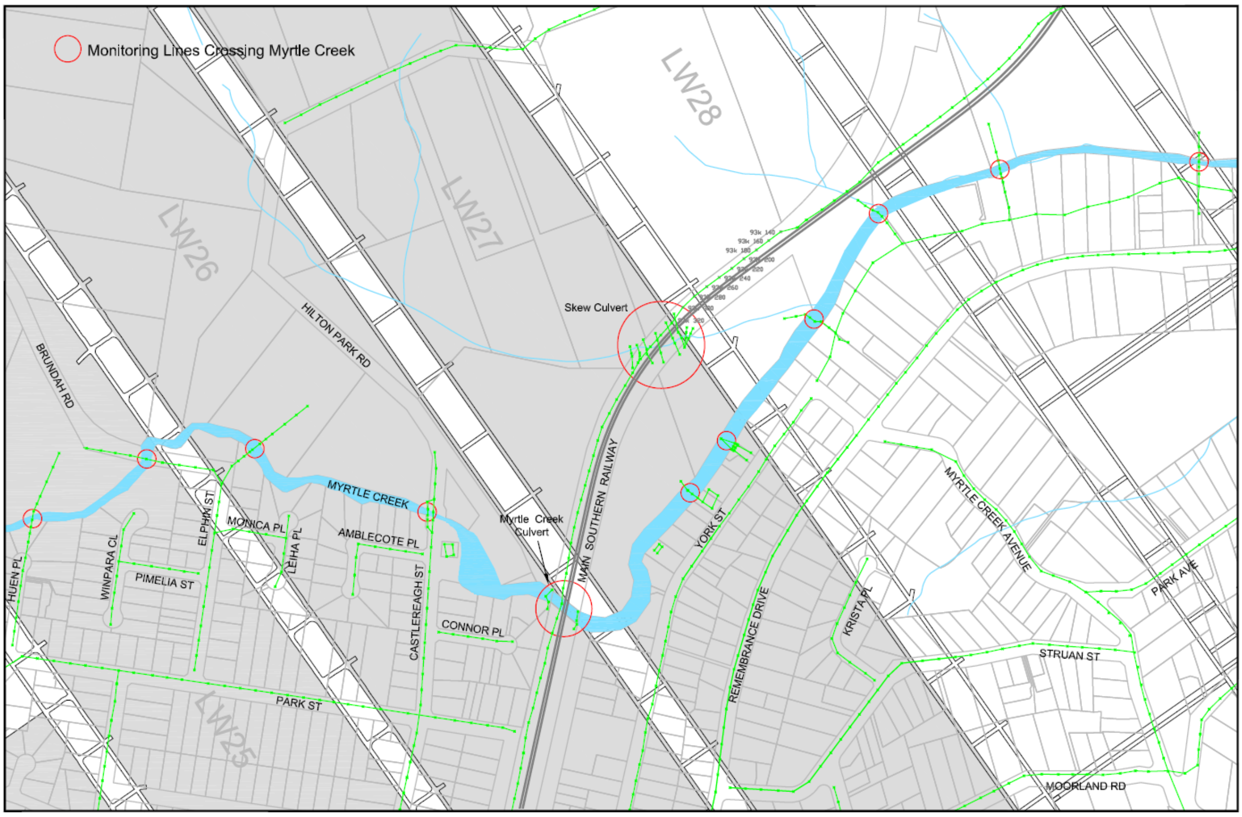


Fig. 2.8 Monitoring lines across Myrtle Creek and Skew Culvert

A summary graph showing the development of valley closure across Myrtle Creek at each monitoring line is shown in Fig. 2.9.

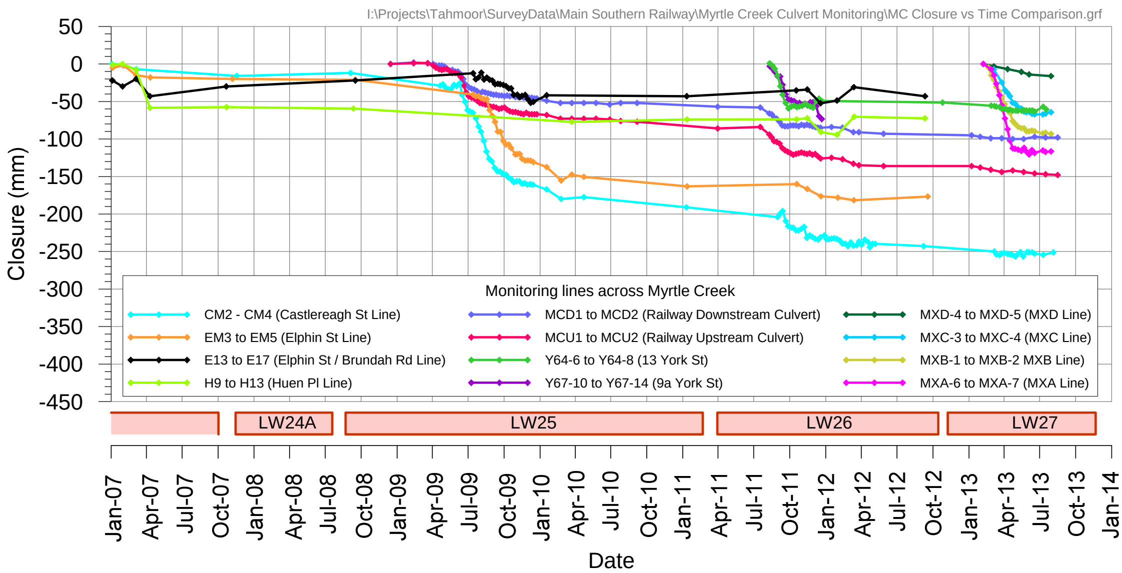


Fig. 2.9 Development of closure across Myrtle Creek during the mining of Longwalls 24B to 27

The development of valley closure across the creek at the Skew Culvert is shown in Fig. 2.10.

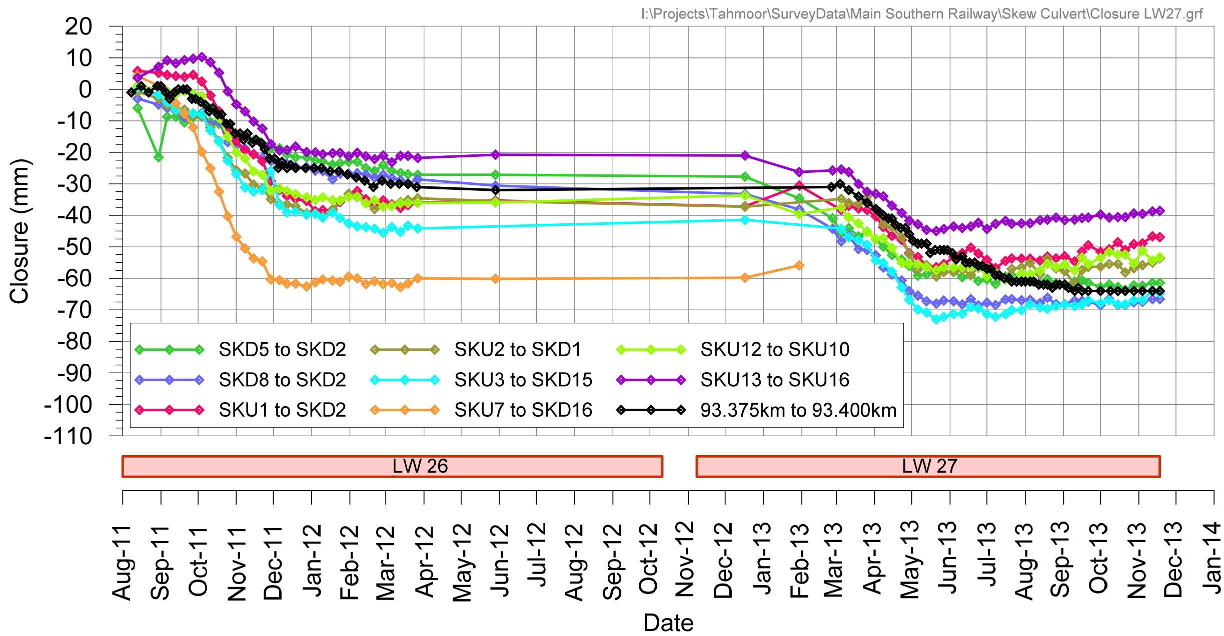


Fig. 2.10 Development of closure across Skew Culvert during the mining of Longwalls 26 and 27

A summary of predicted and observed valley closure across Myrtle Creek is provided in Table 2.3. The predictions are consistent with those provided in Report No. MSEC355, in support of Tahmoor Colliery's SMP application to extract longwalls 27 to 30.

Table 2.3 Predicted and Observed Incremental Valley Closure at Monitoring Lines across Myrtle Creek and Skew Culvert

Location	Category	Predicted and Observed Valley Closure due to Mining of Each Longwall (mm)			
		Due to LW24	Due to LW25	Due to LW26	Due to LW27
Castlereagh St (Pegs CM2 to CM4)	Predicted	Predicted	30	55	45
	Observed	Observed	12	179	52
Elphin-Myrtle (Pegs EM3 to EM5)	Predicted	60	70	40	-
	Observed	21	142	22	-
Elphin St / Brundah Rd (Pegs E13 to E17)	Predicted	75	75	30	-
	Observed	0	21	6	-
Huen Pl (Pegs H9 to H13)	Predicted	60	35	15	-
	Observed	58	15	20	-
Main Southern Railway Upstream (MCU1 to MCU4) Downstream (MCD1 to MCD4)	Predicted	15	30	30	15
	Observed	-	57 (d/s) to 86 (u/s)	36 (d/s) to 50 (u/s)	5 (d/s) to 12 (u/s)
Skew Culvert (8 cross-sections)	Predicted	< 5	10	25	25
	Observed	-	-	21 to 60 (average 36)	8 to 36 (average 21)
13 York St (Pegs Y64-6 to Y64-8)	Predicted	-	-	65	50
	Observed	-	-	51	9
9a York St (Pegs Y67-10 to Y67-14)	Predicted	-	-	85	85
	Observed	-	-	73	No access
MXA Line	Predicted	-	-	-	150

Location	Category	Predicted and Observed Valley Closure due to Mining of Each Longwall (mm)			
(Pegs MXA-6 to MXA-7)	Observed	-	-	-	116
MXB Line (Pegs MXB-1 to MXB-2)	Predicted	-	-	-	170
	Observed	-	-	-	93
MXC Line (Pegs MXC-3 to MXC-4)	Predicted	-	-	-	150
	Observed	-	-	-	64
MXD Line (Pegs MXD-4 to MXD-5)	Predicted	-	-	-	50
	Observed	-	-	-	16

It can be seen that observed valley closure has substantially exceeded predictions at the Castlereagh Street crossing, at the crossing of the Elphin-Myrtle monitoring line and to a lesser extent the crossing of the Main Southern Railway during the mining of Longwall 25. It is considered that the reason for the differences in observations may be linked to the change in orientation of Myrtle Creek as the three above-mentioned monitoring lines are located along the same stretch of Myrtle Creek. It is noted, however, that substantially less closure has developed at Castlereagh Street than predicted during the mining of Longwall 27.

Observed valley closure across the creek at the Skew Culvert has also slightly exceeded predictions, where the differences between predicted and observed closure are relatively small for most cross sections.

Observed valley closure across Myrtle Creek above Longwall 27 has been less than predictions, but greater than previously observed. Predictions for this section of creek were greater than upstream sections because the valley is deeper.

3.1. General

The Australian/New Zealand standard for Risk Management defines the terms used in the risk management process, which includes the identification, analysis, assessment, treatment and monitoring of risk. In this context:-

3.1.1. Consequence

'The outcome of an event expressed qualitatively or quantitatively, being a loss, injury, disadvantage or gain. There may be a range of possible outcomes associated with an event.'[1] The consequences of a hazard are rated from very slight to very severe.

3.1.2. Likelihood

'Used as a qualitative description of probability or frequency.'[2] The likelihood can range from very rare to almost certain.

3.1.3. Hazard

'A source of potential harm or a situation with a potential to cause loss.'[3]

3.1.4. Risk

'The chance of something happening that will have an impact upon objectives. It is measured in terms of consequences and likelihood.'[4] The risk combines the likelihood of an impact occurring with the consequence of the impact occurring. The risk is rated from very low to extreme. In this study, the likelihood and consequence are combined via the qualitative risk analysis matrix shown in Table 3.1, to determine an estimated level of risk for particular events or situations.

The Risk Analysis Matrix is similar to the example provided in AS/NZS 4360:1995, Appendix D, p.25.

Table 3.1 Qualitative Risk Analysis Matrix

Likelihood	CONSEQUENCES				
	Very Slight	Slight	Moderate	Severe	Very Severe
Almost Certain	Low	Moderate	High	Extreme	Extreme
Likely	Low	Moderate	High	Very High	Extreme
Moderate	Low	Low	Moderate	High	Very High
Unlikely	Very Low	Low	Moderate	High	High
Rare	Very Low	Very Low	Low	Moderate	High
Very Rare	Very Low	Very Low	Low	Moderate	Moderate

This Management Plan adopts a common system of nomenclature to summarise each risk analysis, which is **"LIKELIHOOD / CONSEQUENCE → LEVEL OF RISK"**.

For example, if the likelihood of a risk is assessed as "**UNLIKELY**", and the consequence of a risk is assessed as "**SEVERE**", the risk analysis would be summarised as **"UNLIKELY / SEVERE → HIGH"**.

[1] AS/NZS 4360:1999 – Risk Management pp2
[2] AS/NZS 4360:1999 – Risk Management pp2
[3] AS/NZS 4360:1999 – Risk Management pp2
[4] AS/NZS 4360:1999 – Risk Management pp3

4.1. Local Roads

There are a number of local roads directly above Longwalls 28 to 30, as shown in Drawing No. MSEC646-02-01.

The main road is Remembrance Drive (formerly the Hume Highway), which connects Tahmoor with Picton to the north, and Bargo to the south. Some main services infrastructure is located along Remembrance Drive, and includes gas mains, water mains, and optical fibre cables. The main retail and commercial buildings are also located along Remembrance Drive. Remembrance Drive crosses over Longwalls 24A to 28.

The other significant road within the vicinity of Longwalls 28 to 30 is Bridge Street, which connects Thirlmere with Picton to the northeast. Bridge Street crosses directly over Longwalls 28 to 30, and it has been undermined by Longwalls 26 and 27.

The network of local roads is spread across Longwalls 28 to 30, and therefore, they collectively will experience the full range of subsidence impacts, as described in Section 2.1. A discussion on the expected range of tensile and compressive strains during the mining of the proposed longwalls is provided in Section 0.

Predictions of systematic subsidence, tilt and strain were made along two major roads, Remembrance Drive and Bridge Street, which are shown in Fig. 4.2 and Fig. 4.3, respectively. A summary of the maximum predicted systematic subsidence, tilt and strain along these roads, due to the extraction of Longwalls LW26 to LW30, is provided in Table 4.1.

Table 4.1 Maximum Predicted Total Systematic Subsidence, Tilt and Curvature along the Alignments of Remembrance Drive and Bridge Street due to the Extraction of Longwalls 22 to 30

Location	Longwall	Maximum Predicted Total Subsidence (mm)	Maximum Predicted Total Tilt (mm/m)	Maximum Predicted Total Hogging Curvature (1/km)	Maximum Predicted Total Sagging Curvature (1/km)
Remembrance Drive	After LW27	1080	5.6	0.08	0.12
	After LW28	1105	4.4	0.08	0.12
	After LW29	1110	4.3	0.08	0.12
	After LW30	1110	4.3	0.08	0.12
Bridge Street	After LW27	1005	5.8	0.07	0.13
	After LW28	1095	5.9	0.08	0.13
	After LW29	1180	5.8	0.09	0.13
	After LW30	1200	5.7	0.09	0.13

The roads will also be subjected to travelling tilts and curvatures as the extraction faces of the proposed longwalls pass beneath them. A summary of the maximum predicted travelling tilts and curvatures at the roads, during the extraction of each of the proposed longwalls, is provided in Table 4.2.

Table 4.2 Maximum Predicted Travelling Tilts and Curvatures at Remembrance Drive and Bridge Street during the Extraction of Longwalls 28 to 30

Location	Longwall	Maximum Predicted Travelling Tilt (mm/m)	Maximum Predicted Travelling Hogging Curvature (1/km)	Maximum Predicted Travelling Sagging Curvature (1/km)
Remembrance Drive	During LW28	1.9	0.02	0.02
Bridge Street	During LW28	3.0	0.03	0.03
	During LW29	3.0	0.03	0.03
	During LW30	2.9	0.03	0.02

Monitoring of road pavements has been undertaken at Tahmoor during the extraction of Longwalls 22 to 27 at Tahmoor Colliery. The monitoring includes a network of ground monitoring lines and weekly visual inspections in areas that are experiencing active subsidence. Approximately 24.5 kilometres of asphaltic pavement lie directly above the extracted longwalls and a total of 46 impact sites have been reported. The observed rate of impact equates to an average of one impact for every 533 metres of pavement. The impacts were minor and did not present a public safety risk.

One of these impact sites, located on Lintina Street above Longwall 24A, was substantially greater than at other impact sites. A selection of photographs is provided in Fig. 4.1. The impacts on Lintina Street were repaired twice by the Mine Subsidence Board as the longwall progressed.

A hump was observed on Abelia Street during the mining of Longwall 25 and this has been repaired by the Mine Subsidence Board. A hump was also observed on Remembrance Drive at the roundabout intersection with Thirlmere Way, as shown in Fig. 4.1.

While impacts have been observed to local roads at a number of locations during the mining of Longwalls 26 and 27, they have not been as severe as those observed on Lintina Street and Abelia Street, though some have required urgent repairs.

Only very minor impacts have been observed on local roads during the mining of Longwall 27.

More frequent impacts have been observed to concrete kerbs and gutters. The impacts are most commonly focussed around driveway laybacks and involve cracking, spalling or buckling. A typical buckling impact is shown in Fig. 4.1.

A total of 5 drainage pits have been damaged during the mining of Longwalls 24A and 25 in Janice and Abelia Streets. Investigations are currently underway to determine whether impacts have occurred to stormwater pipes in these areas.

Traffic signs and other road infrastructure have not previously experienced any impacts due to mine subsidence.

It is expected that minor impacts will occur to the local roads during mining, similar in frequency and severity to those experienced during the mining of Longwalls 22 to 27.

Lintina Street (most severe to date)

Remembrance Drive (hump at roundabout)

Brundah Road (typical impact to pavement)

Patterson Street (typical impact to kerb)

Struan Street

Moorland Rd

Photographs courtesy of Tahmoor Colliery and Colin Dove

Fig. 4.1 Photographs of impacts to road pavements and kerbs during the mining of LWs 22 to 27

4.1.1. Risk Assessment

The risk to local sealed roads is that deformation (cracking, buckling or wrinkling) of the road surface may occur. Four levels of impact, in increasing order of severity, have been identified for risk analysis.

1. Minor deformations (cracks less than 2 mm), occurring infrequently within the road network
2. Minor deformations (cracks less than 2 mm), occurring extensively within the road network
3. Major deformations (cracks greater than 2 mm), occurring infrequently within the road network
4. Major deformations (cracks greater than 2 mm), occurring extensively within the road network

Table 4.3 summarises the risk analysis for local sealed roads.

Table 4.3 Risk Analysis for Local Sealed Roads

Level of Impact	Likelihood	Consequence	Level of Risk
Infrequent, minor deformations	LIKELY	SLIGHT	MODERATE
Frequent, minor deformations	UNLIKELY	MODERATE	MODERATE
Infrequent, major deformations	UNLIKELY	MODERATE	MODERATE
Frequent, major deformations	VERY RARE	SEVERE	MODERATE

Any damage to local roads will be repaired at the expense of the Mine Subsidence Board.

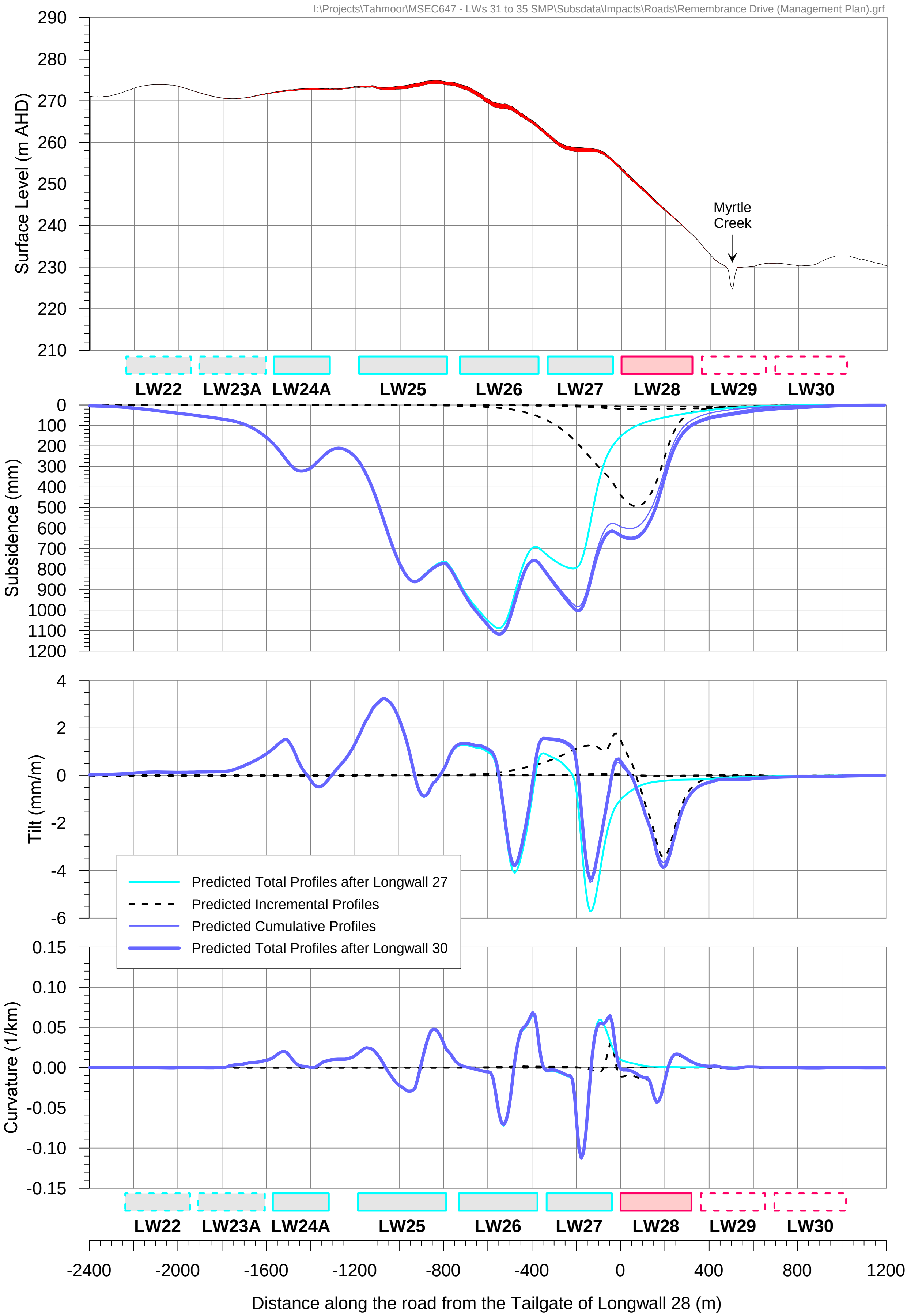


Fig. 4.2 Predicted Subsidence, Tilt and Curvature along Remembrance Drive due to the mining of Longwalls 22 to 30

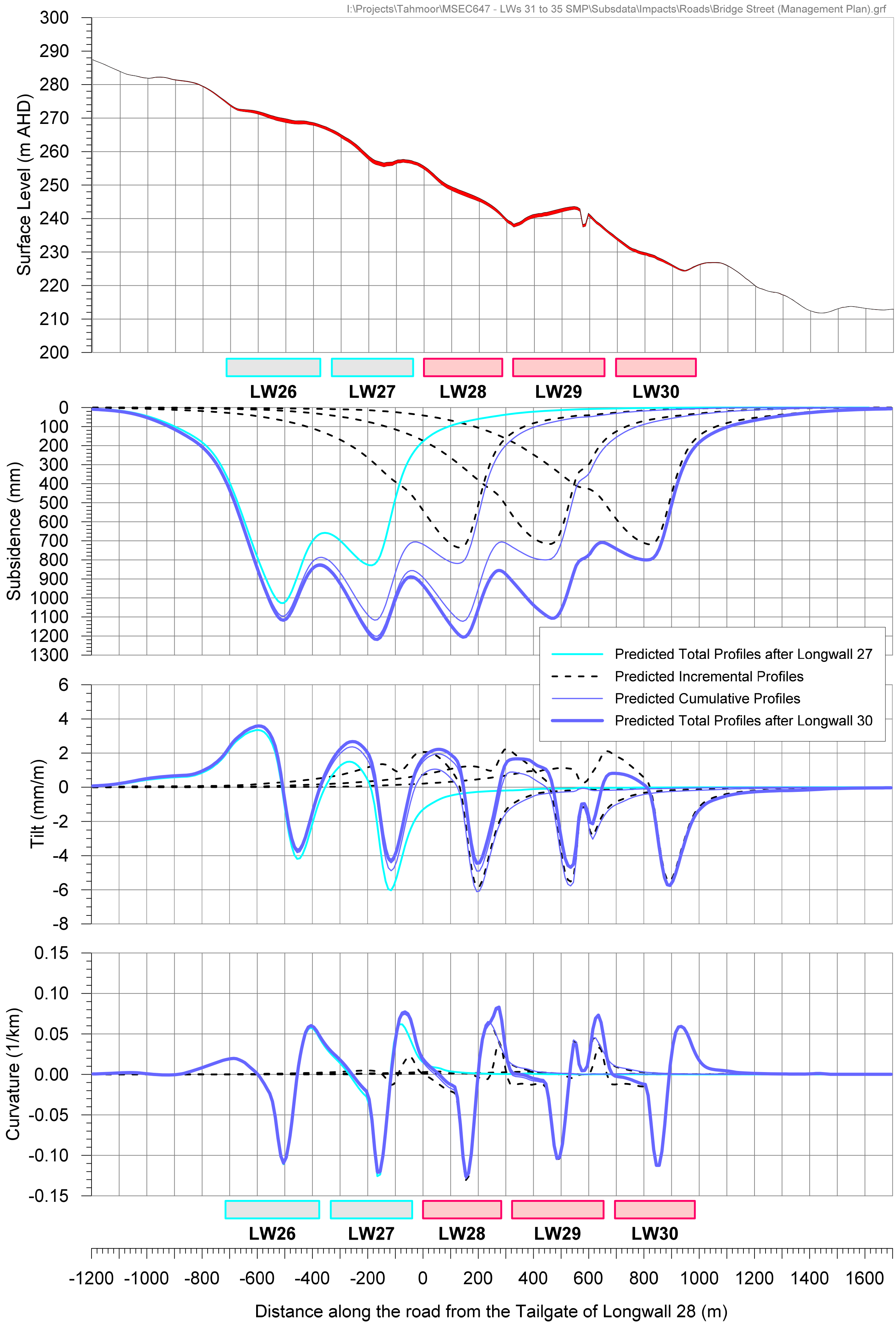


Fig. 4.3 Predicted Subsidence, Tilt and Curvature along Bridge Street due to the mining of Longwalls 22 to 30

4.2. Bridge on Castlereagh Street over Myrtle Creek

The Castlereagh Street Road Bridge over Myrtle Creek is a two-lane bridge that provides access for residents to Hilton Park Road. The single-span bridge is constructed with a concrete deck on concrete abutments, as shown in Fig. 4.4. This bridge is located above the previously extracted Longwall 25.

Fig. 4.4 Castlereagh Street Road Bridge over Myrtle Creek

4.2.1. Predicted Subsidence Movements

The Castlereagh Street Road Bridge over Myrtle Creek is a two-lane bridge that provides access for residents to Hilton Park Road.

Predictions of systematic subsidence, tilt and strain movements have been made at the bridge, and these are shown in Table 4.4.

Table 4.4 Predicted Subsidence Parameters at Castlereagh Street Road Bridge

Stage of Mining	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Tension (mm/m)	Maximum Predicted Compression (mm/m)
Increment due to LWs 28 to 30	20	-0.2	<0.02	<0.02
After Longwall 27	1105	4.7	0.07	0.02
After Longwall 28	1120	4.6	0.07	0.02
After Longwall 29	1120	4.6	0.07	0.02
After Longwall 30	1125	4.5	0.07	0.02

The Bridge will also be subjected to upsidence and closure movements, and these are shown in Table 4.5.

Table 4.5 Prediction of Upsidence and Closure at Castlereagh Street Road Bridge

Stage of Mining	Maximum Cumulative Closure (mm)	Maximum Cumulative Upsidence (mm)
Increment due to LWs 28 to 30	15	10
Total due to LWs 22 to 27	160	195
Total due to LWs 22 to 28	170	200
Total due to LWs 22 to 29	175	205
Total due to LWs 22 to 30	175	205

It can be seen from Table 4.5 that the majority of valley closure movements have already occurred at Castlereagh Street Bridge, with only a very small amount of additional valley closure predicted to occur during the mining of Longwalls 28 to 30.

It is noted that less than 10 mm of valley closure was observed during the mining of Longwall 27, as discussed in Section 2.4.

A comparison between observed and predicted valley closure was provided in Section 2.4. While observed valley closure substantially exceeded predicted closure during the mining of Longwall 25, there was a reasonable correlation between predicted and observed valley closure during the mining of Longwall 26.

4.2.2. Previous experiences at Castlereagh Street Bridge during mining of Longwalls 25 to 27

Very little additional movement was measured at the Bridge and no physical change was observed during the mining of Longwall 27. A brief summary of previous experiences is provided below. A more detailed description of mitigation measures and previous experiences during the mining of Longwalls 24B to 26 can be found in the Management Plan for Longwall 27.

The development of subsidence and valley closure during the mining of Longwalls 25 and 26 is shown in Fig. 4.5.

Longwall 25 experience

During the mining of Longwall 25, the survey results for Castlereagh Street Bridge showed that while the creek sides had closed considerably, the bridge had closed significantly less with the exception of the end of the south-eastern wing wall. The resistance of the bridge structure to closure had resulted in compressive heaving in the road pavement on the southern side of the bridge and damage to the telecommunications conduit at the north-western abutment. Existing cracks on the southern abutment were observed to extend slowly during mining, particularly at the interface between the abutment and south-eastern wing wall.

Differential movements between the bridge deck and the abutments had been observed to gradually increase and they exceeded the BLUE trigger level that had been defined in the Longwall 25 Management Plan. The brackets were cut and set back from the southern abutment on Monday, 7 September 2009. Further small movements were observed after the brackets were removed. At the completion of mining, there was a small air gap between the abutment walls and the bracket supports so that there was no pressure on the brackets, abutments or bridge deck.

Longwall 26 experience

During the mining of Longwall 26, new cracks were identified by Sunrise Building Property Services (SBPS) for the first time on 23 September 2011 when the Longwall 26 face was approximately square with the Bridge. These consisted of vertical cracks on the south-eastern wingwall / abutment junction and a horizontal crack and concrete spalling at roughly 200 mm below the top of the abutment across the width of the abutment, above and behind the support brackets.

SBPS also noted at the time that the underside support brackets were hard against the abutment, when a gap had been observed during previous weekly inspections. SBPS removed the timber blocks between the brackets and abutments to restore a gap. It was found that the gap between the brackets and abutment closed on average 3mm following this work, with no change to the northern abutment.

SMPS also reported a slight bulging of the road pavement at the approach to the southern abutment, as was observed previously during the mining of Longwall 25.

Structural engineer, John Matheson & Associates (JMA) inspected photographs of the cracks on 26 September and a teleconference was held between Tahmoor Colliery and Wollondilly Shire Council on 27 September 2011. At the time of the teleconference it was anticipated that further valley closure movements would develop at the Bridge. It was decided at the meeting to undertake repair works in response to the impacts observed and make adjustments to the Bridge to minimise the potential for further impacts on the Bridge. A summary is provided below.

a) The eastern wing walls had closed significantly more than the abutments. This had resulted in flexural bending at the junction of the wingwall and abutment on the south eastern junction such that compressive spalling of concrete was observed.

   Excavations behind the back of the abutment and wingwall on 10 October 2011 uncovered a single tensile crack between the two walls, rather than a series of small tensile cracks as expected. The contractor reported that he could not find any horizontal steel reinforcement on the back face between the two walls for the first 300 mm in depth, contrary to structural design.

   As a result of this discovery, steel tie bars were installed from one abutment to the other to hold JMA Matheson. Soil nails were also installed behind the south eastern wingwall.

b) The horizontal crack across the width of the abutment indicated that the top of the abutment was suffering distress from the deck pressing hard against the abutment either via the small 200mm high and 200mm wide concrete upstand nib and/or the shearing and rotating of the steel dowels that were located between the deck and the top of the abutment, or both.

   It was found from an examination behind the spalled crack that the vertical steel reinforcement in the abutment did not appear to have been extended to the top of the abutment as per the structural design. The crack in the abutment occurs at the top of the steel bars and it is considered possible that the cracks had developed through a section of concrete that is mildly reinforced. Excavations in the week of 7 October 2011 found that the crack was inclined vertically and did not appear to have continued through to the back of the abutment.

   The concrete upstand nib was removed in accordance with recommendations by JMA. The contractor reported that the steel dowels appeared to be 32mm or 36 mm in diameter and not 28 mm, contrary to the structural drawings. This meant that the dowels had a much greater shear capacity than expected and explained why they did not appear to have sheared. The dowels were also located slightly closer to the front face of the abutment than shown in the structural drawings.

   The cutting of the dowels on 13 and 14 October had resulted in an expected change in trends in measurements of the gap between the support brackets and the abutment wall. The deck was observed to slide further over the southern abutment in response to additional valley closure movements. There was an initial step change in measurements after the dowels were cut, after which the rate of change was gradual and correlated well with changes in valley closure movements.

   The gap between the underside brackets and the abutment reduced as the deck slid over the abutment. This gap has been partially restored by adjusting the brackets.

c) The observed cracking does not appear to be of structural concern at this stage, as the vertical loads continue to be transferred through the abutment. Bars were drilled from the back of the abutment to stitch the cracks, which were also cleaned out and filled with epoxy.

The impacts described above were successfully managed and the Bridge remained safe and serviceable at all times. Some traffic control restrictions were in place while the Bridge was being repaired and strengthened.

Longwall 27 experience

It can be seen from Fig. 4.5 that while a small amount of subsidence developed during the mining of Longwall 27, very little additional valley closure developed (8 mm).

Risk Assessment for Longwalls 28 to 30

Given that little change was observed during the mining of Longwall 27, and that Longwalls 28 to 30 are located further away from the Bridge, the likelihood of additional movement and impacts is assessed as **RARE**. The consequence of additional damage is assessed as **MODERATE**. The risk is therefore assessed as **RARE / MODERATE → LOW**.

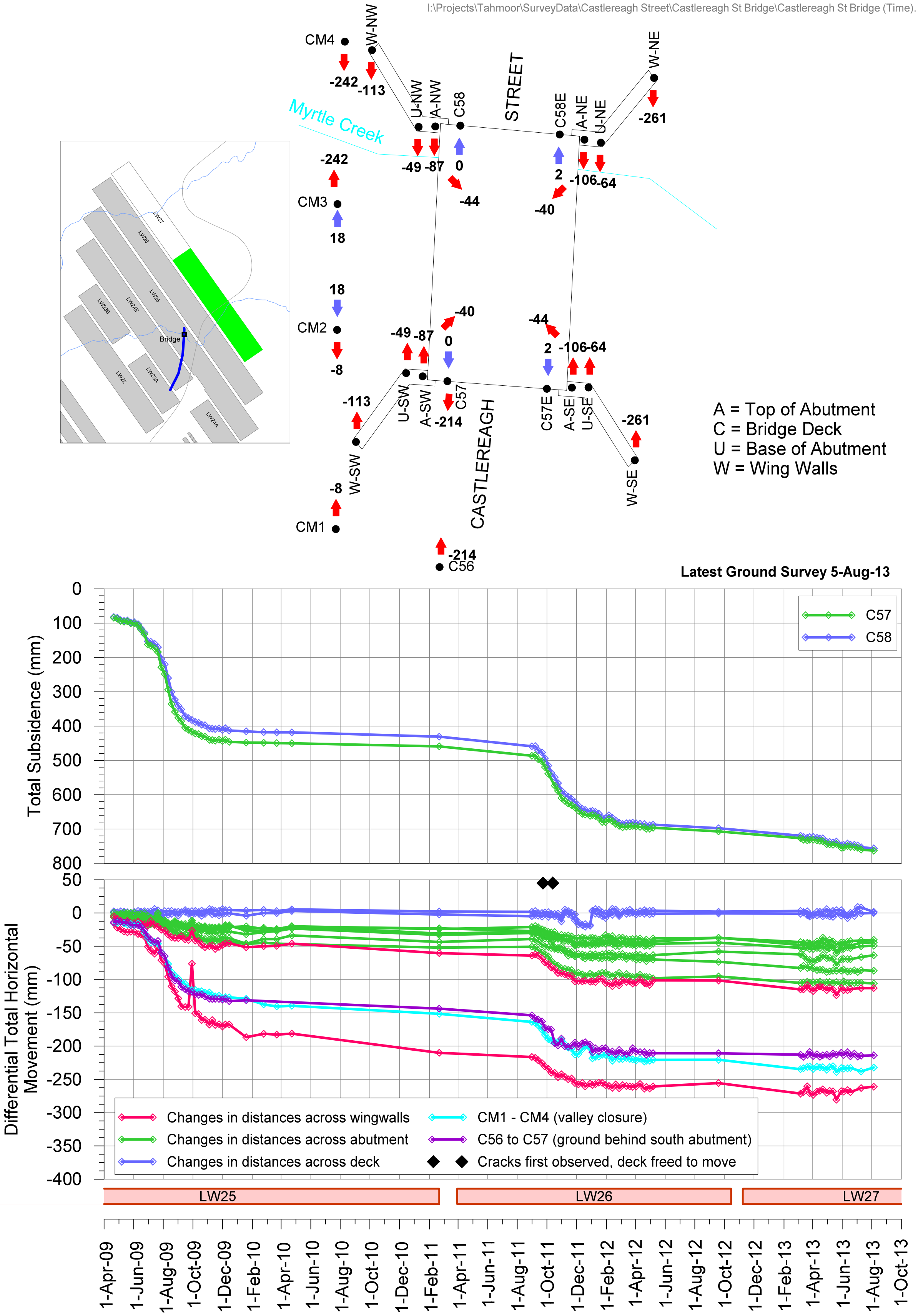
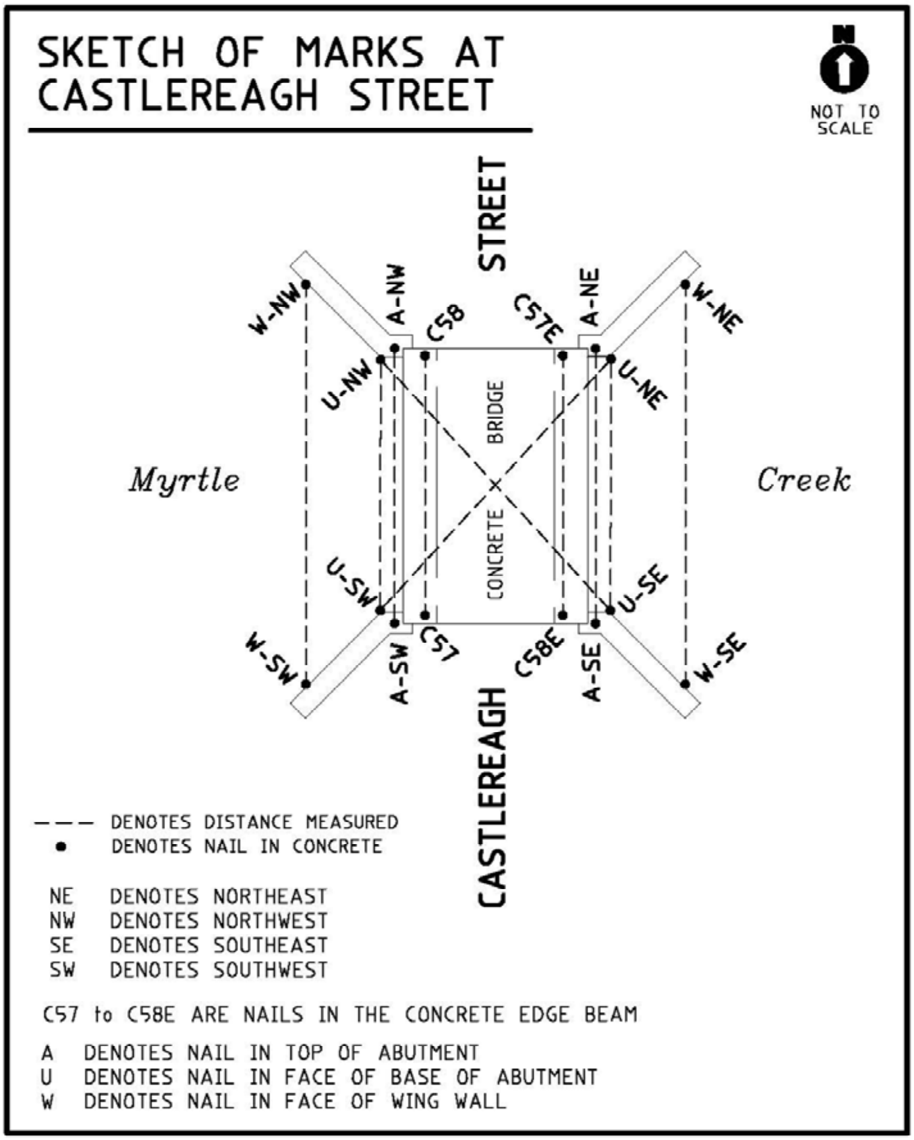


Fig. 4.5 Development of subsidence and valley closure at Castlereagh Street Bridge

4.2.3. Monitoring measures

- Structure survey
  Survey marks have been placed on the top and bottom of the abutment walls, and at the bottom of the wing walls. Marks have also been placed on the bridge deck at each end. The survey marks were installed prior to the influence of Longwall 23A. A sketch of the monitoring mark locations is shown in Fig. 4.6.



Sketch courtesy of Lean & Hayward Surveyors

Fig. 4.6 Location of Survey Marks on Castlereagh Street Bridge

- Bridge Abutment Survey
  Surveys will be conducted to measure differential horizontal movement between the bridge abutment and bridge deck.

- Street survey along Castlereagh Street
  Survey marks have been placed along Castlereagh Street on either side of the Bridge. The street survey will provide general information on subsidence and overall valley closure movements.

- Survey across Myrtle Creek adjacent to Bridge
  Survey marks have been placed on the upstream side of Castlereagh Street Bridge to measure valley ground movements adjacent to the Bridge. Marks have also been placed on the bridge deck at each end. The survey marks were installed prior to the influence of Longwall 24B.

- Visual Inspections
  Visual inspections of the Bridge and approaches will be undertaken during mining and report any signs of impact.

Given the experiences of little change during the mining of Longwall 27, surveys and inspections at the Bridge will be undertaken once a month during the mining of Longwall 28, when the Bridge is within the zone of active subsidence.

Surveys are not planned to be undertaken during the mining of Longwalls 29 and 30 unless adverse changes or impacts are observed.

4.3. Remembrance Drive Road Bridge over Myrtle Creek

The Remembrance Drive Road Bridge over Myrtle Creek is a two-lane bridge, which is located on the northern edge of the Tahmoor urban area. The location of the Remembrance Drive Road Bridge relative to Longwalls 28 to 30 is shown in Drawing No. MSEC646-02-01. The bridge is located approximately 170 metres east of the commencing end of Longwall 28 and approximately 270 metres south of the modified commencing end of Longwall 29.

The effect of shortening the commencing ends of Longwalls 29 and 30 by approximately 250 metres is to substantially reduce the magnitude of subsidence at the bridges.

The Roads and Maritime Services have provided a copy of the structural design drawings, which show that the dual-span bridge is constructed with a concrete deck on concrete abutments and central pier, as shown in Fig. 4.7. The span of the deck is approximately 18 metres and the heights of the abutments are approximately 7 metres.

The bridge units have been integrated with a reinforced concrete slab. The reinforced concrete abutments appear to rest on pad and strip footing foundations. The pre-tensioned bridge deck units are connected to the central pier with dowels. The drawings do not include the abutment connections, but it appears that the bridge units rest on a corbel at each end. It is likely that a concrete upstand has been constructed at the ends of the deck.

Fig. 4.7 Remembrance Drive (Myrtle Creek) Road Bridge

The bridge was inspected in May 2009 by structural engineer John Matheson & Associates (JMA, 2009). The design of the bridge is not conducive to upsidence and closure movements because it is partly supported by a central pier. Upsidence may cause the central pier to move upwards, relative to the abutments. It is likely that the upstand at the ends of the bridge units will prevent the deck from sliding over the abutments as they close towards each other.

Predictions of systematic subsidence, tilt and strain movements have been made at the bridge, and these are shown in Table 4.6.

Table 4.6 Predicted Subsidence Parameters at Remembrance Drive Road Bridge and Pedestrian Bridge

Stage of Mining	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Tension (mm/m)	Maximum Predicted Compression (mm/m)
After Longwall 28	< 20	< 0.2	< 0.01	< 0.01
After Longwall 29	30	0.2	< 0.01	< 0.01
After Longwall 30	50	0.2	< 0.01	< 0.01

The Bridge is located above Myrtle Creek and is predicted to experience upsidence and closure movements. A summary of the maximum predicted upsidence and closure movements at the road bridges is shown in Table 4.7.

Table 4.7 Prediction of Upsidence and Closure at Remembrance Drive Road Bridge and Pedestrian Bridge

Stage of Mining	Maximum Cumulative Closure (mm)	Maximum Cumulative Upsidence (mm)
Increment due to LW28 only	15	20
Total due to LWs 22 to 28	20	25
Total due to LWs 22 to 29	30	45
Total due to LWs 22 to 30	40	50

It can be seen from Table 4.7 that small additional valley closure and upsidence is predicted to occur during the mining of Longwalls 28 to 30. It is noted that the predicted closure refers to closure across the whole valley. It is possible that the predicted closure will not concentrate entirely between the bridge abutments.

Survey marks were installed on the Remembrance Drive Road Bridge prior to the extraction of Longwall 24A. While the Bridge has experienced approximately 40 mm of subsidence, measured changes in horizontal distances between the abutments are small and close to survey tolerance. Minor closure has been detected and a small opening has been measured. Vertical subsidence is relatively consistent across all survey marks, indicating that no measureable upsidence has occurred to date.

The Remembrance Drive survey line crosses Myrtle Creek between the Remembrance Drive Road Bridge and Pedestrian Bridge. Measured changes in horizontal distances between survey pegs within the Myrtle Creek valley are small and close to survey tolerance, as seen in Fig. 4.8.

An irregular spike was once observed across a survey bay that is only 3 metres long. The measured 8 mm change in horizontal distance equated to an apparent ground strain of more than 2 mm/m. Subsequent surveys confirmed that the previous measurement was erroneous. No corresponding spike in compression was observed across the bridge abutments.

Prior to the decision to shorten the commencing ends of Longwall 29 and 30, it had been planned to undertake detailed investigations and potentially undertake mitigation works on the Bridge to reduce the potential for mine subsidence impacts on the Bridge. The shortening of Longwalls 29 and 30, however, substantially reduces the potential for impacts on the Bridge and the steel gas pipe. In light of the shortening, it is planned to manage potential impacts on the Bridge through monitoring and, if necessary, response measures.

By way of comparison, impacts were not observed on the Castlereagh Street Bridge until 23 September 2011 after Longwall 25 had mined directly beneath the Bridge, when the Longwall 26 face was approximately square with it. Approximately 200 mm of valley closure had been observed at this time. In this case, Longwalls 28 to 30 will not mine directly beneath the bridge and are located more than 170 metres away from it. As demonstrated by the predictions, very small changes are predicted during the mining of each longwall and differential movements are expected to develop gradually during these times.

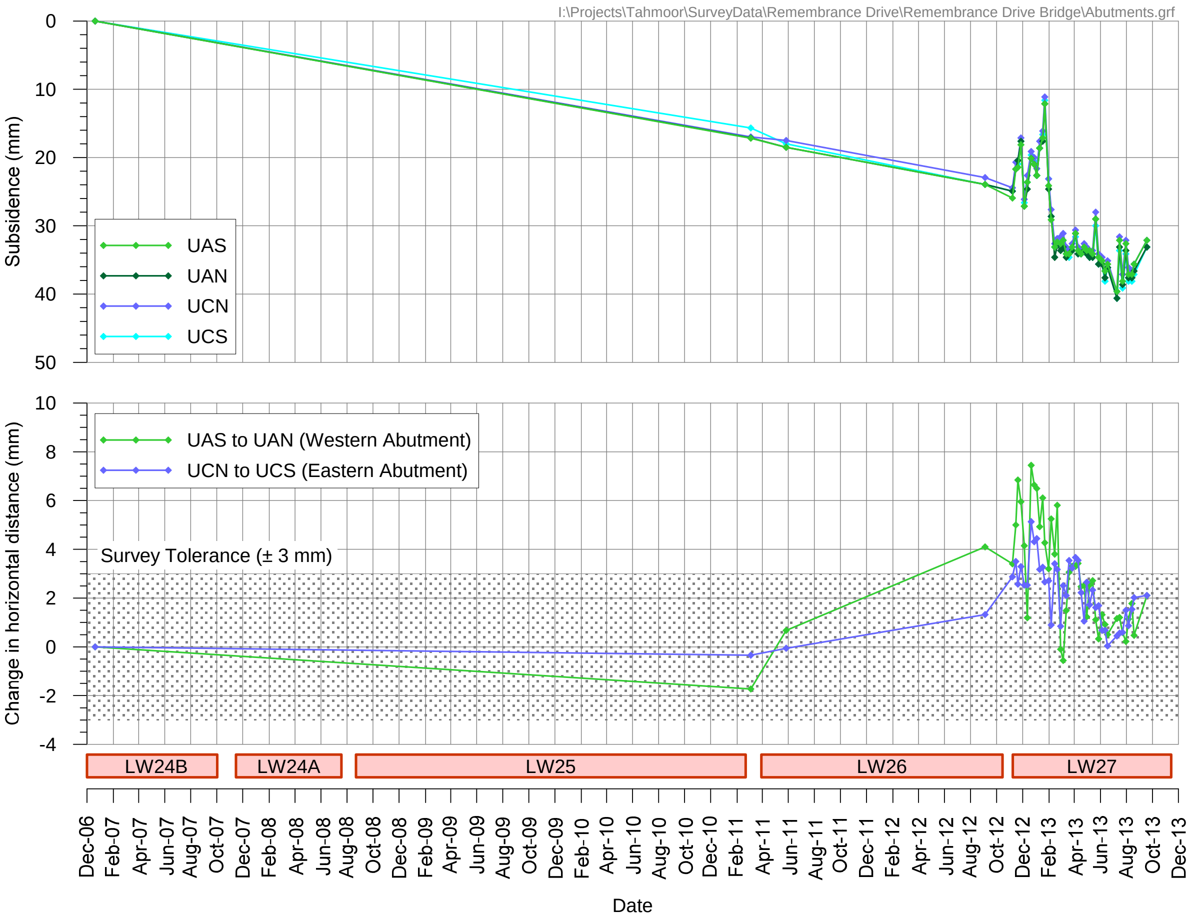
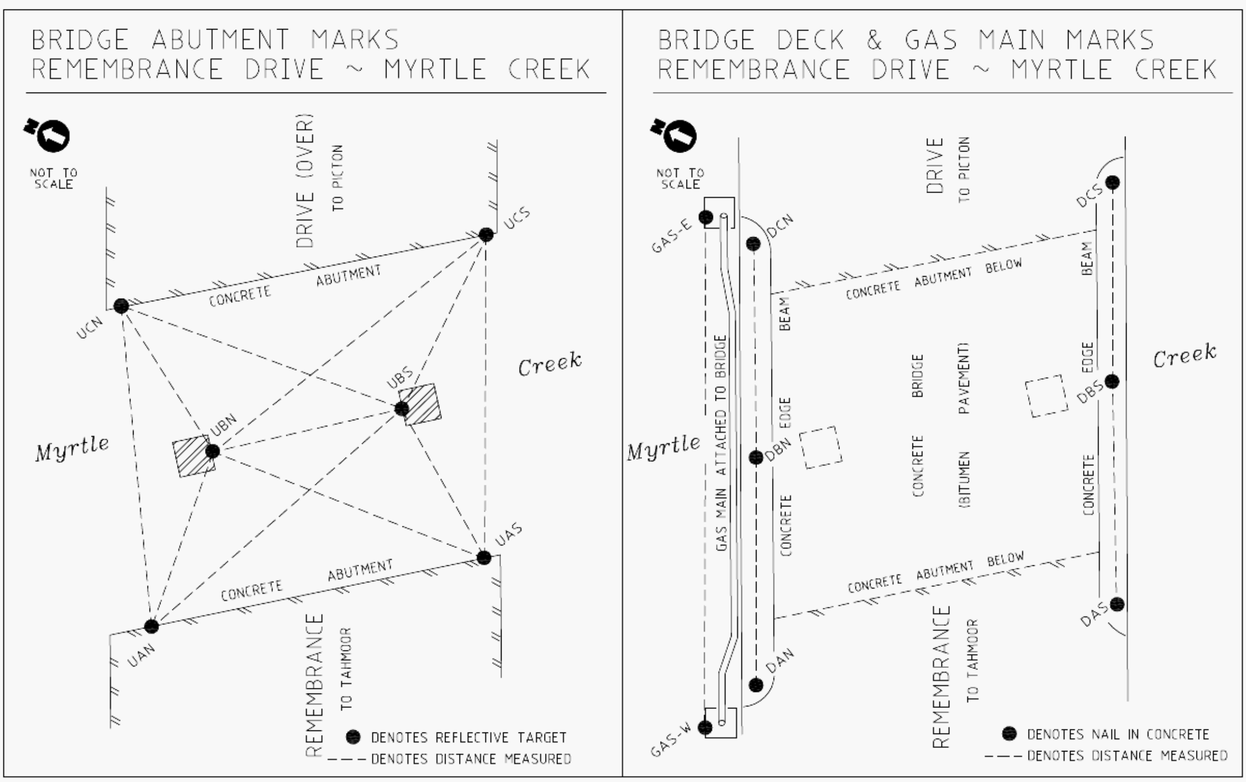


Fig. 4.8 Observed subsidence and changes in horizontal distances across the abutment of Remembrance Drive (Myrtle Creek) Road Bridge

Given the offset distance of the Bridge from Longwalls 28 to 30 and the anticipated very small amount of movement that is expected to occur, the likelihood of the bridge being damaged and requiring repairs during the mining of Longwalls 28 to 30 is assessed as **RARE.** The consequence of this risk is assessed as **MODERATE**. The risk is therefore assessed as **RARE / MODERATE → LOW**.

The Bridge will be surveyed and visually inspected on a weekly basis from the start of extraction of Longwalls 28 and 29. Surveys are not planned to be undertaken during the mining of Longwall 30 unless adverse movements are observed during the mining of Longwalls 28 and 29.

A map of survey points is shown in Fig. 4.9.



Sketch courtesy of SMEC (Urban)

Fig. 4.9 Survey marks on Remembrance Drive (Myrtle Creek) Road Bridge

This information will complement survey data of pegs that are located in the ground and pegs that are located on the Pedestrian Bridge.

4.4. Remembrance Drive Pedestrian Bridge over Myrtle Creek

The Remembrance Drive Pedestrian Bridge over Myrtle Creek is a single-lane bridge, which is located on the northern edge of the Tahmoor urban area, and is shown in Fig. 4.10. The location of the Remembrance Drive Road Bridge relative to Longwalls 28 to 30 is shown in Drawing No. MSEC646-02-01. The bridge is located approximately 170 metres east of the commencing end of Longwall 28 and approximately 250 metres south of the modified commencing end of Longwall 29.

The effect of shortening the commencing ends of Longwalls 29 and 30 by approximately 250 metres is to substantially reduce the magnitude of subsidence at the bridges.

The Bridge is listed as an item of environmental heritage in Wollondilly Shire Council's Local Environmental Plan.

The Roads and Traffic Authority have provided a copy of the structural design drawings for the renewal of the bridge in 1926. The pedestrian bridge was a dual lane bridge, at that point in time. Half of the bridge was demolished when the road bridge was constructed. The structural drawings show that the dual-span bridge was constructed with a concrete deck on sandstone abutments and central pier. The span of the deck is approximately 17 metres and the heights of the abutments are approximately 6 metres. The span of the deck is approximately 18 metres and the heights of the abutments are approximately 7 metres.

The bridge units have been integrated with a reinforced concrete slab. The reinforced concrete abutments appear to rest on pad and strip footing foundations. The pre-tensioned bridge deck units are connected to the central pier with dowels. The drawings do not include the abutment connections, but it appears that the bridge units rest on a corbel at each end. It is likely that a concrete upstand has been constructed at the ends of the deck.

Fig. 4.10 Remembrance Drive (Myrtle Creek) Pedestrian Bridge

The design of the bridge is not conducive to upsidence and closure movements because it is partly supported by a central pier. Upsidence may cause the central pier to move upwards, relative to the abutments. It is likely that the upstand at the ends of the bridge units will prevent the deck from sliding over the abutments as they close towards each other.

The bridge was inspected in May 2009 by structural engineer John Matheson & Associates (JMA, 2009) who advises that the bridge deck is in poor condition and the timber balustrade posts are severely dilapidated due to rot and/or termite damage.

Please refer to previous Section 4.3 for information on predictions and observations of subsidence movements.

Given the offset distance of the Bridge from Longwalls 28 to 30 and the anticipated very small amount of movement that is expected to occur, the likelihood of the bridge being damaged and requiring repairs during the mining of Longwalls 28 to 30 is assessed as **RARE.** The consequence of this risk is assessed as **MODERATE**. The risk is therefore assessed as **RARE / MODERATE → LOW**.

The Bridge will be surveyed and visually inspected on a weekly basis from the start of extraction of Longwalls 28 and 29. Surveys are not planned to be undertaken during the mining of Longwall 30 unless adverse movements are observed during the mining of Longwalls 28 and 29.

A map of survey points is shown in Fig. 4.11.

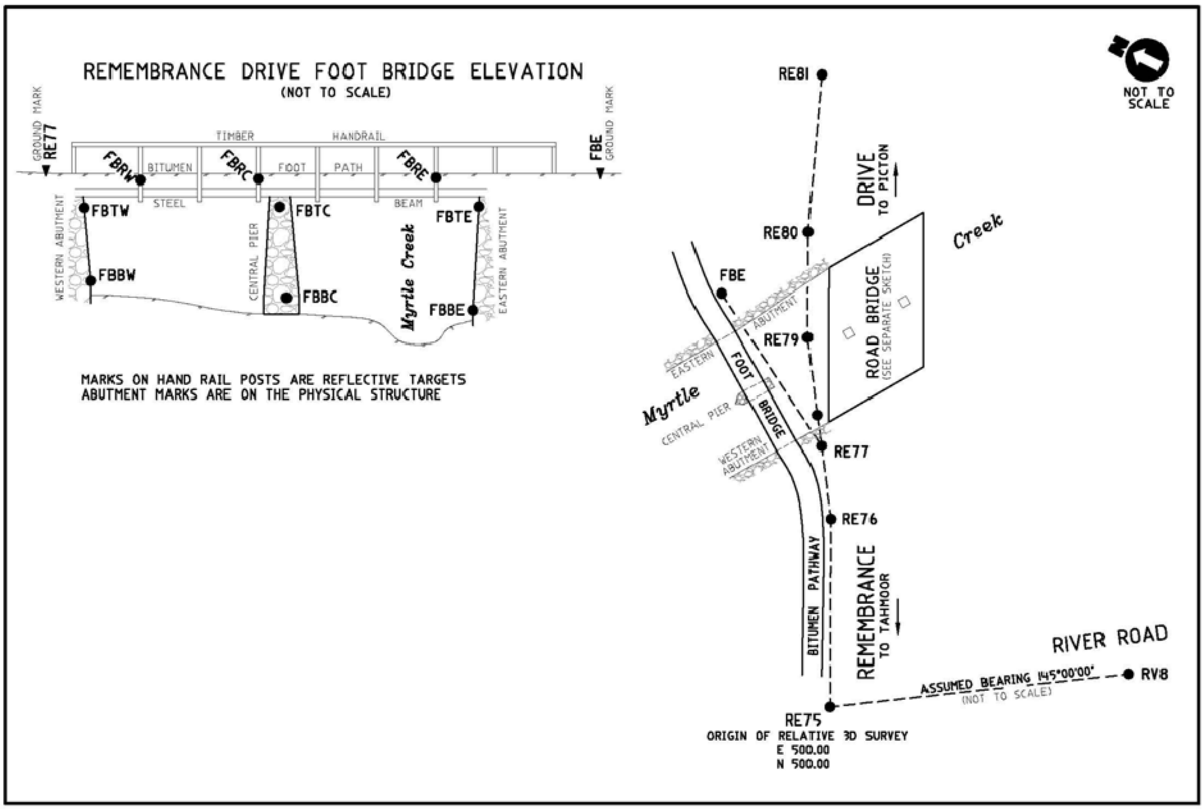


Fig. 4.11 Survey marks on Remembrance Drive (Myrtle Creek) Pedestrian Bridge

4.5. Culverts

There are many culverts in the vicinity of Longwalls 28 to 30. The culverts are generally small in size, and typically range between 450 mm and 900 mm in diameter.

The majority of the culverts are located above or near previously extracted Longwalls 22 to 27, but two 900 mm diameter culverts are located along Bridge Street, as shown in Drawing No. MSEC646-02-02.

The risk of impacts to the culverts is considered low. No impacts to road culverts have been reported during the mining of Longwalls 22 to 27.

The hazard associated with culverts is that they could be damaged and/or rendered unserviceable from mine subsidence impacts.

The likelihood of extensive damage is assessed as **VERY RARE**. The consequence of this risk is assessed as **MODERATE**. The risk is therefore assessed as **VERY RARE / MODERATE → LOW.**

The likelihood of minor damage is assessed as **UNLIKELY**. The consequence of this risk is assessed as **SLIGHT**. The risk is therefore assessed as **UNLIKELY / SLIGHT → LOW.**

5.1. Structures Management Group (SMG)

The SMG is responsible for taking the necessary actions required to manage the risks that are identified from monitoring of structures. The SMG's key members are:

- Tahmoor Colliery
- Wollondilly Shire Council
- John Matheson and Associates
- Mine Subsidence Engineering Consultants
- Mine Subsidence Board

5.2. Mitigation Measures

Mitigation measures have been undertaken for Castlereagh Street Bridge, as described in Section 4.2.

5.3. Monitoring Measures

Monitoring lines have been installed along all streets within the urban area above Longwall 28, as shown in Drawing No. MSEC646-00-03. The monitoring lines have been initially surveyed to provide a baseline reference. Monitoring of street survey lines will be conducted for every 200 metres of longwall travel as a minimum for pegs located within the active subsidence zone.

Additional surveys will be conducted for the Remembrance Drive Road Bridge and Pedestrian Bridge, as described in Table 5.1.

5.4. Risk Control Procedures

Risk control procedures are provided in Table 5.1. The procedures include responses if triggered by monitoring results.

Table 5.1 Risk Control Procedures

Infrastructure	Hazard / Impact	Risk	Trigger	Control Procedure/s	Frequency	By Whom?
Local Roads	Impacts to Roads Impacts to Culverts	**MODERATE / LOW**	None	Conduct visual inspection for surface deformations along local roads.	Detailed inspection once a week Vehicle based inspection once a week within active subsidence area	Tahmoor Colliery
				Conduct surveys along survey lines to provide some early warning for potentially damaging subsidence events	Every 200 metres of longwall face movement	Tahmoor Colliery (SMEC Urban / MSEC)
			Impacts occur	Notify all stakeholders, including Council, Tahmoor Colliery, Mine Subsidence Board and DTIRIS	Within one week	Tahmoor Colliery / WSC
				Repair road	As required	WSC
Bridge on Castlereagh Street over Myrtle Creek	Impacts to Bridge	**LOW**	None	Conduct surveys at Bridge, including: • Structure surveys • Castlereagh Street ground survey (all pegs within 80 metres of Bridge – Pegs C54 to C62) • Myrtle Creek cross line adjacent to Castlereagh Street Bridge)	Monthly within active subsidence zone of LW28 End of LW28	Tahmoor Colliery (SMEC Urban)
				Conduct visual inspections of Bridge	Monthly within active subsidence zone of LW28 End of LW28	Tahmoor Colliery
			Additional impacts occur	Notify all stakeholders, including Council, Tahmoor Colliery, Mine Subsidence Board and DTIRIS and in the case of the Pedestrian Bridge, the Heritage Council	Within one week	Tahmoor Colliery / WSC
				Forecast potential for further movements and impacts and consider whether to undertake additional management and/or monitoring actions	Within one week	SMG
				Repair Bridge	As required	WSC
Remembrance Drive Road Bridge and Pedestrian Bridge	Impacts to Bridge(s)	**LOW**	None	Conduct surveys of Remembrance Drive Road Bridge and Pedestrian Bridge, and survey of ground pegs located in the valley sides between the two bridges	Survey weekly from start of LWs 28 and 29 until 800m of extraction of each LW End of LWs 28, 29 and 30	Tahmoor Colliery (SMEC Urban / MSEC)
				Visual inspections of Remembrance Drive Road Bridge and Pedestrian Bridge	Weekly after start of LWs 28 and 29 until 800m of extraction of each LW	Tahmoor Colliery
			Impacts occur	Notify all stakeholders, including Council, Tahmoor Colliery, Mine Subsidence Board and DTIRIS and in the case of the Pedestrian Bridge, the Heritage Council	Within 48 hours	Tahmoor Colliery / WSC
				Forecast potential for further movements and impacts and consider whether to undertake additional management and/or monitoring actions	Within one week	SMG
				Repair Bridge	As required	WSC

6.0 MANAGEMENT PLAN REVIEW MEETINGS

The monitoring of natural surface features and surface infrastructure which forms an integral part of this Management Plan will be carried out by Tahmoor Colliery. SMG Meetings will be held between Tahmoor Colliery and Wollondilly Shire Council for discussion and resolution of issues raised in the operation of the Management Plan. The frequency of meetings shall be as agreed by the parties.

A secretary will be appointed at the SMG Meeting. All documentation, distribution of meeting minutes and organising of meeting times will be undertaken by the secretary.

SMG Meetings will discuss any incidents reported in relation to the relevant surface feature, the progress of mining, the degree of mine subsidence that has occurred, and comparisons between observed and predicted ground movements.

It will be the responsibility of the meeting representatives to determine whether the incidents reported are due to the impacts of mine subsidence, and what action will be taken in response.

In the event that a significant risk is identified for a particular surface feature, any party may call an emergency SMG Meeting, with one day's notice, to discuss proposed actions and to keep other parties informed of developments in the monitoring of the surface feature.

7.0 AUDIT AND REVIEW

All Management Plans within this document have been agreed between parties. The Management Plan will be reviewed following extraction of each longwall.

Should an audit of the Management Plan be required during that period, an auditor shall be appointed by the Tahmoor Colliery to review the operation of the Management Plan and report at the next scheduled Plan Review Meeting.

Other factors that may require a review of the Management Plan are:-

- Observation of greater impacts on surface features due to mine subsidence than was previously expected.
- Observation of fewer impacts or no impacts on surface features due to mine subsidence than was previously expected.
- Observation of significant variation between observed and predicted subsidence.

8.0 RECORD KEEPING

The secretary will keep and distribute regular minutes of each Plan Review Meeting for each surface feature. The minutes will include reports on the condition of the relevant surface feature, the progress of mining, the degree of mine subsidence that has occurred, comparisons between observed and predicted ground movements, agreements reached between parties, and a log of incidents that have occurred on the surface feature.

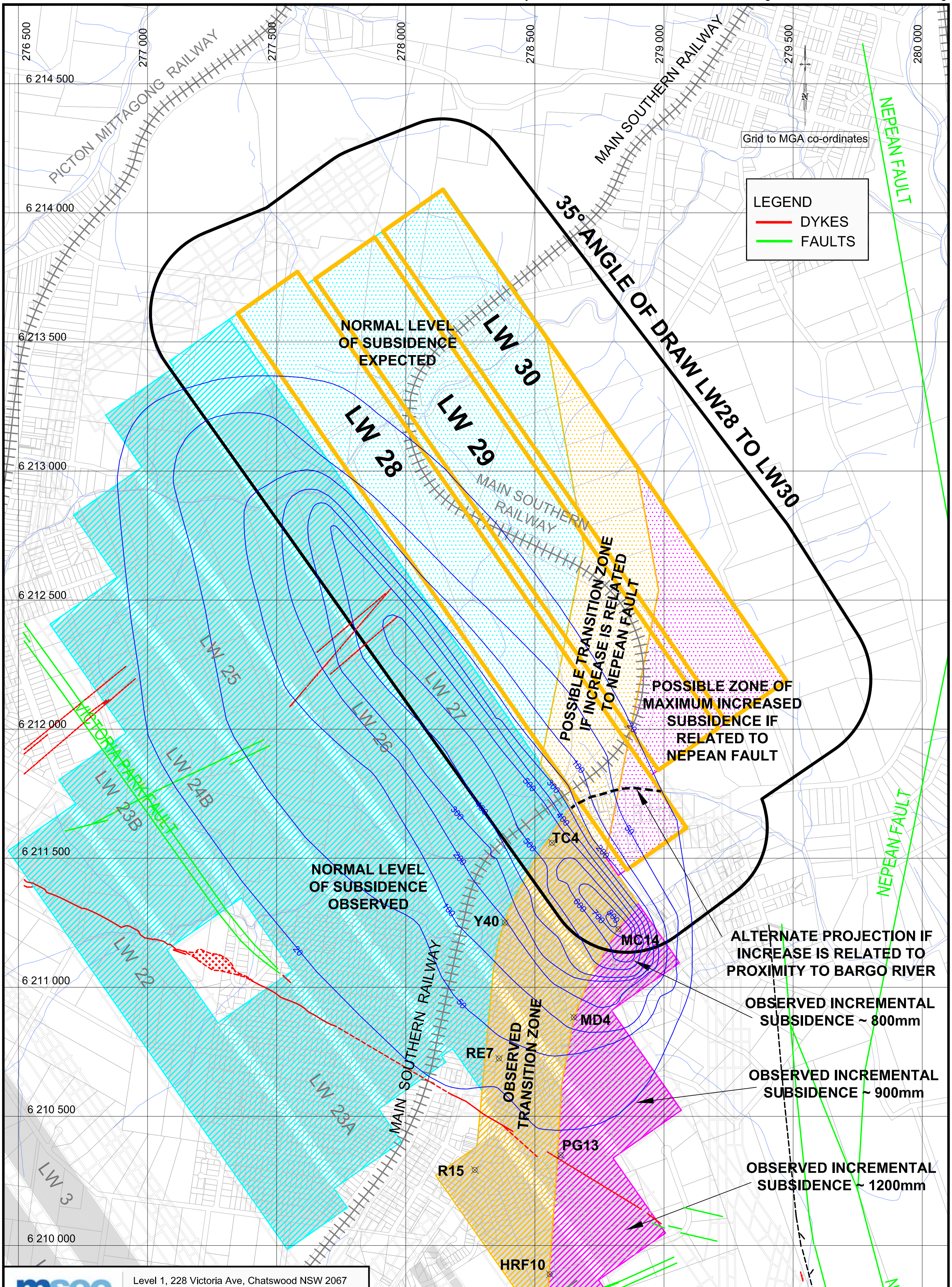
9.0 CONTACT LIST

Organisation	Contact	Phone	Email / Mail	Fax
NSW Department of Trade and Investment, Regional Infrastructure and Services, Division of Resources and Energy (DTIRIS)	Phil Steuart	(02) 4931 6648	phil.steuart@industry.nsw.gov.au	(02) 4931 6790
	Gang Li	(02) 4931 6644 0409 227 986	gang.li@industry.nsw.gov.au	(02) 4931 6790
	Ray Ramage	(02) 4931 6645 0402 477 620	ray.ramage@industry.nsw.gov.au	(02) 4931 6790
John Matheson & Associates (JMA)	John Matheson	(02) 9979 6618	jma.eng@bigpond.net.au	(02) 9999 0121
Mine Subsidence Board	Darren Bullock	(02) 4677 1967	d.bullock@minesub.nsw.gov.au	(02) 4677 2040
Mine Subsidence Engineering Consultants (MSEC)	Daryl Kay	(02) 9413 3777	daryl@minesubsidence.com	(02) 9413 3822
Glencore Tahmoor Coal – Environment and Community Manager	Ian Sheppard	(02) 4640 0156 0408 444 257	Ian.Sheppard@glencore.com.au	(02) 4640 0140
Glencore Tahmoor Coal – Community Coordinator	Belinda Treverrow	(02) 4640 0133	Belinda.Treverrow@glencore.com.au	(02) 4640 0140
Wollondilly Shire Council Manager - Works	Justin Nyholm	(02) 4677 8247	justin.nyholm@wollondilly.nsw.gov.au	(02) 4677 2339
Wollondilly Shire Council Technical Officer - Works	Barry Allen	(02) 4677 8232	barry.allen@wollondilly.nsw.gov.au	(02) 4677 2339

APPENDIX A.

Please refer to the following documents:

- Drawings
- JMA, (2009). *Myrtle Creek Bridges on Remembrance Drive: Condition Report.* John Matheson & Associates, Report No. R0116-Rev 02, May 2009.



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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH - LW28 to LW30
Observed Incremental Subsidence
LW24A to LW27

DATE:	SCALE:	DRAWING No:	Rev No
23-Jan-2014	1:20000	MSEC646-00-01	A

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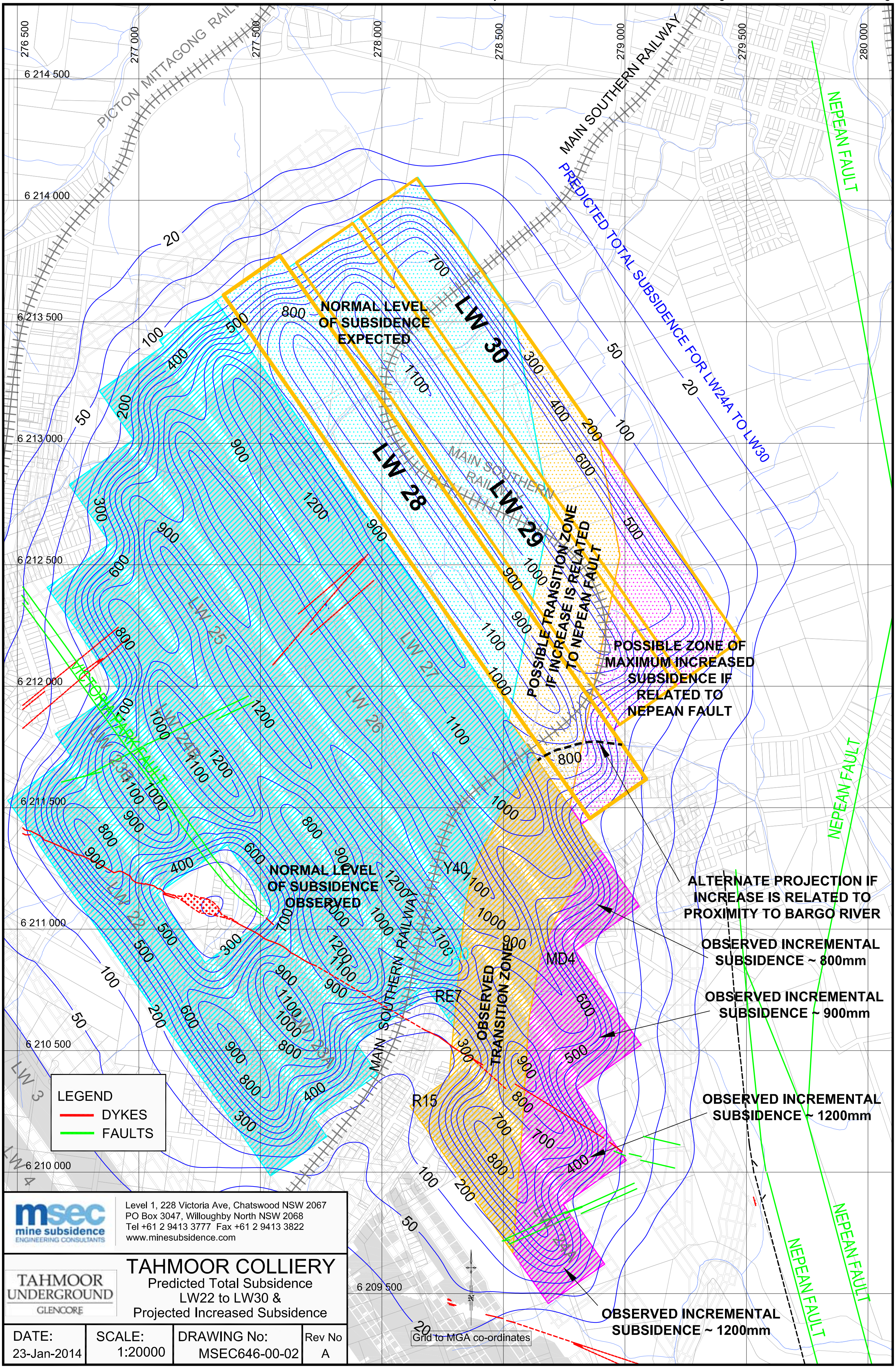

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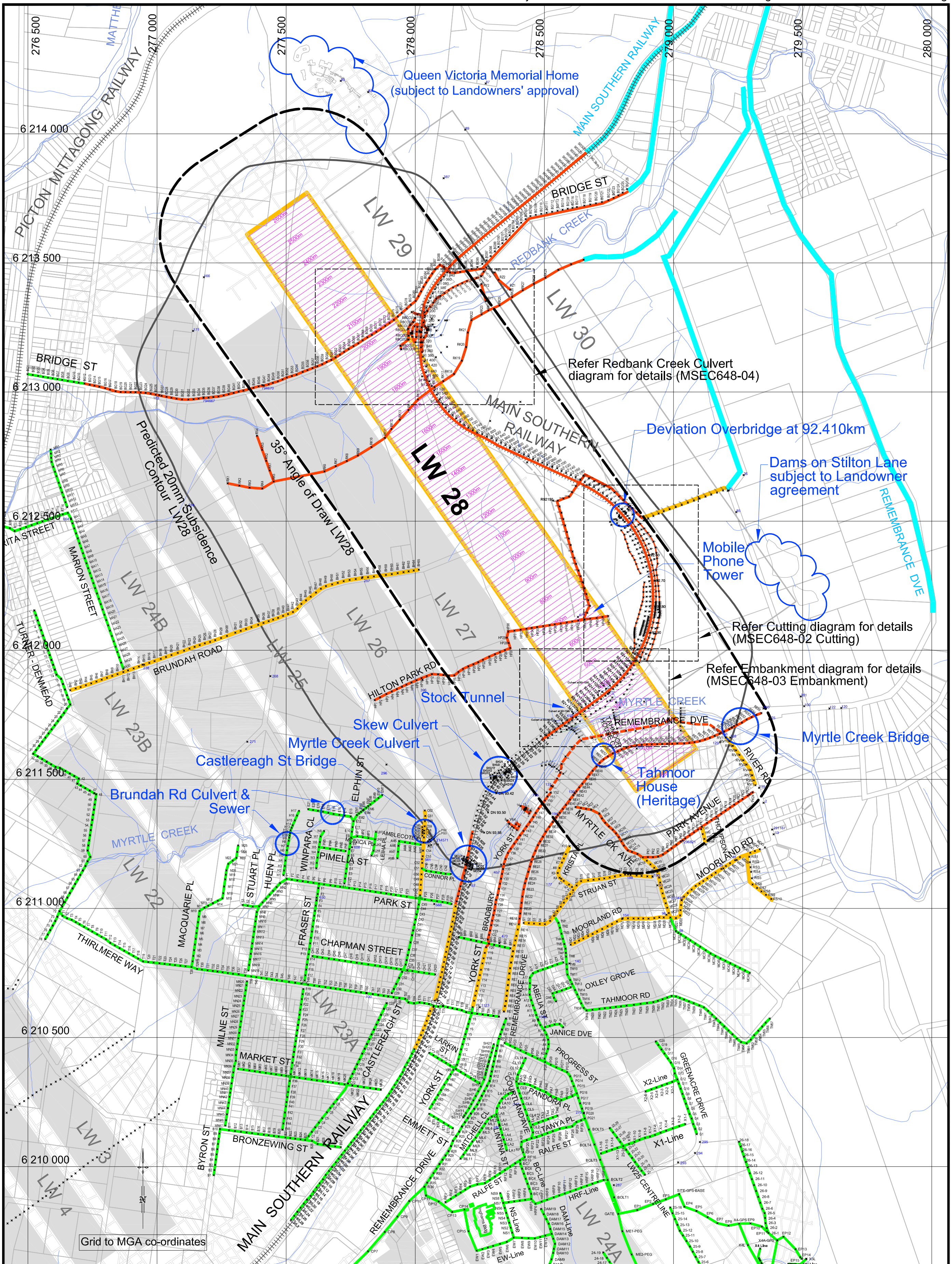
TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

Predicted Total Subsidence
LW22 to LW30 &
Projected Increased Subsidence

DATE:	SCALE:	DRAWING No:	Rev No
23-Jan-2014	1:20000	MSEC646-00-02	A



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TAHMOOR UNDERGROUND
GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH - LW28 to LW30
MONITORING OVER LW28

DATE:	SCALE:	DRAWING No:	Rev No
5-Feb-2014	1:20000	MSEC646-00-03	A

LEGEND
- Existing Monitoring Lines
- Future Monitoring Lines
- Future Monitoring Lines Prior to LW28
- Monitoring Lines Before & End of LW28
- Surveys During LW28
- Critical Power Poles
- Specific Structure Inspections

Refer to Management Plans for Timing & Frequencies

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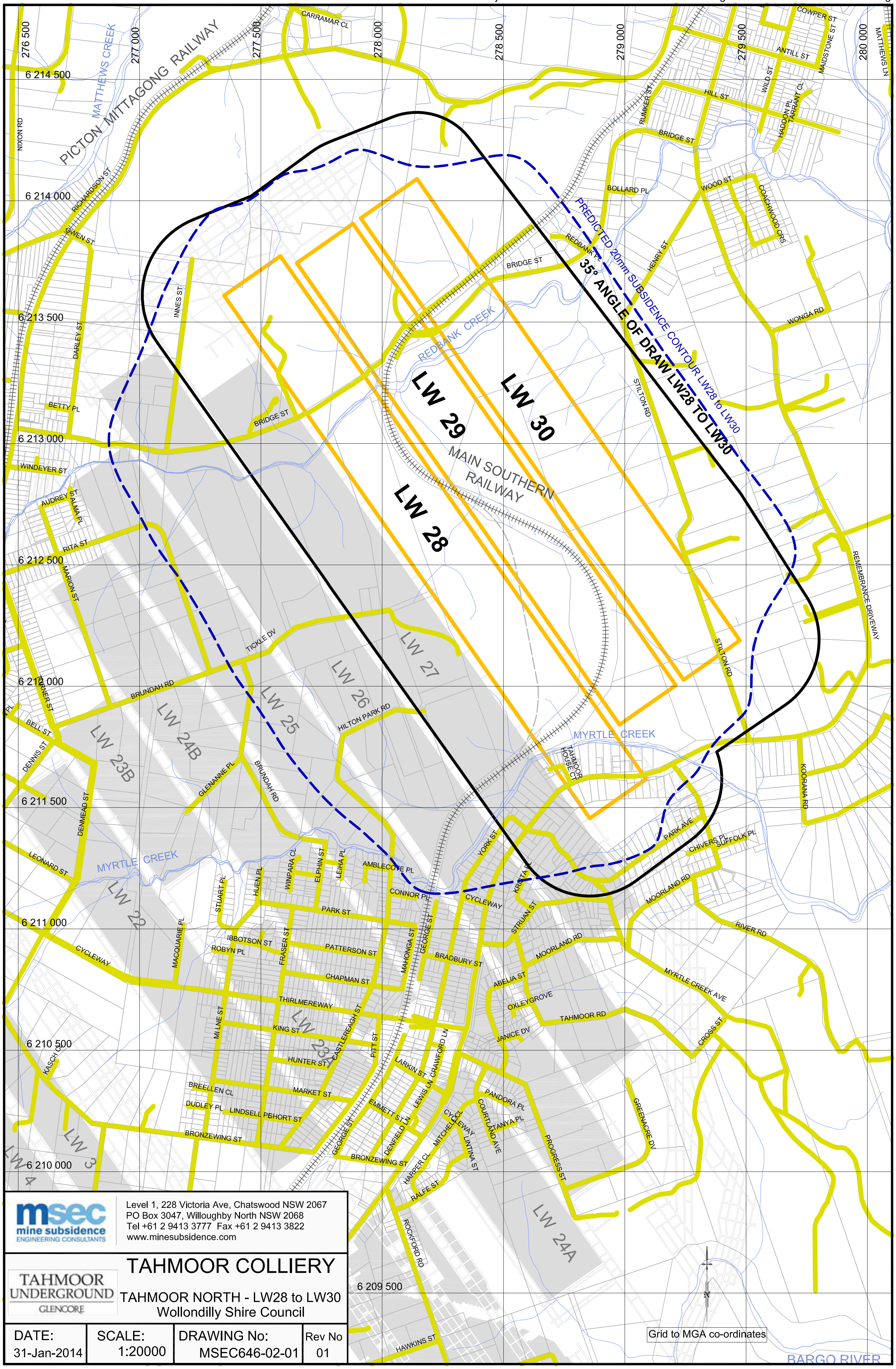

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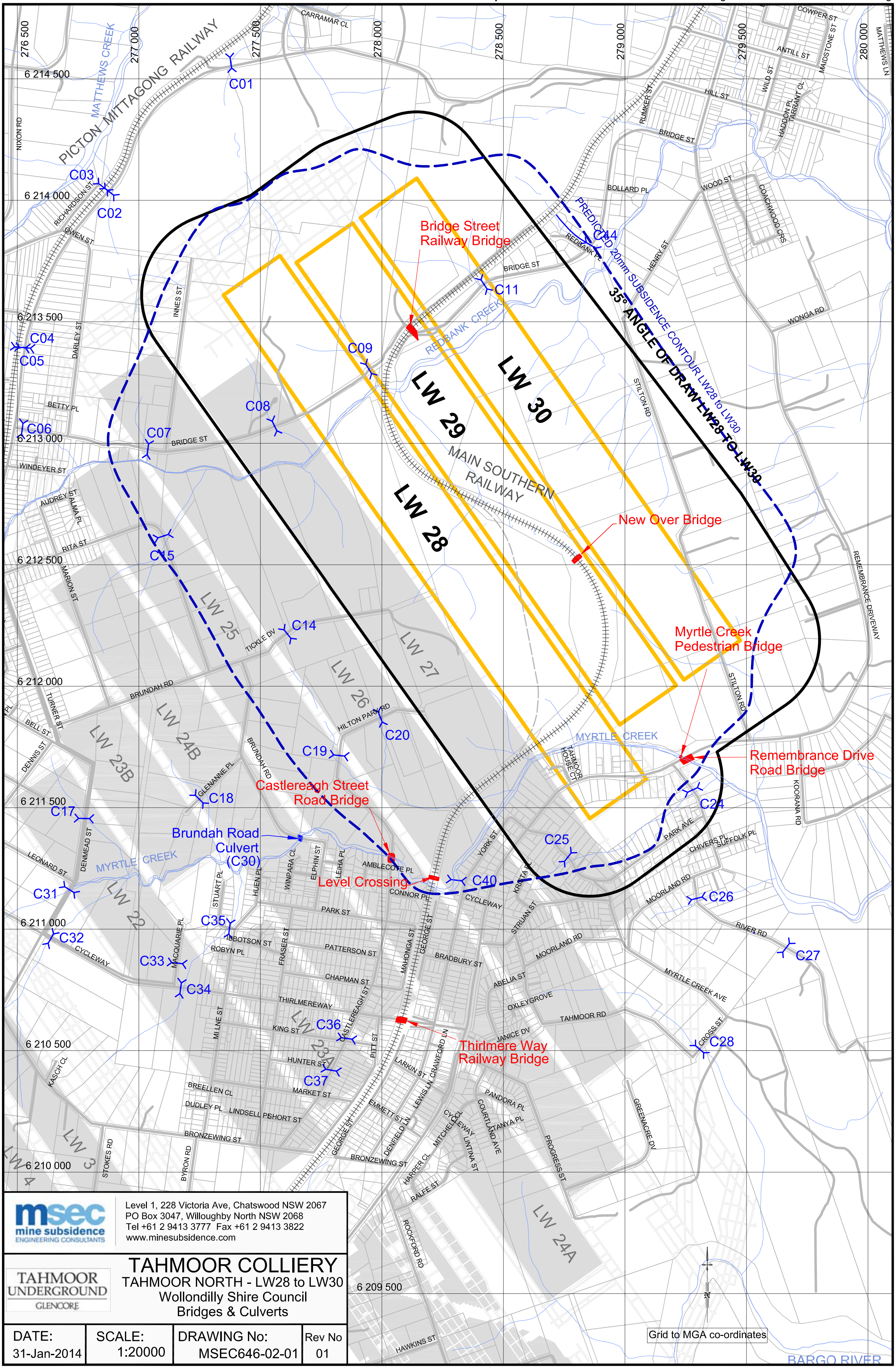
TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH - LW28 to LW30
Wollondilly Shire Council

DATE:	SCALE:	DRAWING No:	Rev No
31-Jan-2014	1:20000	MSEC646-02-01	01



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TAHMOOR UNDERGROUND GLENCORE

TAHMOOR COLLIERY

TAHMOOR NORTH - LW28 to LW30
Wollondilly Shire Council
Bridges & Culverts

DATE:	SCALE:	DRAWING No:	Rev No
31-Jan-2014	1:20000	MSEC646-02-01	01

Myrtle Creek Bridges on Remembrance Drive: Condition Report.

Report: R0116-Rev 02

Prepared by John Matheson

Date: 18th May 2009.

John Matheson & Associates Pty Ltd

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18th May 2009.

Introduction

This structural condition report has been prepared at the request of MSEC concerning the two bridges that cross Myrtle Creek on Remembrance Drive, which are located to the north of Tahmoor. The original bridge crossing served as a vehicular bridge and in more recent times as a pedestrian bridge after a new vehicular bridge was constructed in the early 1970's. The bridges have not been assigned any particular MSEC number to identify them and they are known as the Remembrance Drive Pedestrian Bridge and the Remembrance drive Road Bridge respectively.

1.0 Remembrance Drive Pedestrian Bridge Structure

The abutments and central pier have been constructed using sandstone masonry construction with a sand/cement mortar as can be seen in figures 1 and 5. The masonry abutments walls have been constructed with wingwalls returning back into the embankment and the existing drawings indicate that the foundations have been constructed below the riverbed and are likely to have been founded upon rock. The masonry abutment walls and central pier appeared to be in fair condition at the time of the inspection.

The bridge deck consists of steel rolled steel joists spanning between both abutment walls and the central masonry pier. The beams do not appear to haven joined above the central masonry pier. The bridge deck has been constructed as a tar macadam surface over steel buckle plates spanning between double angle secondary beams and the primary rolled steel joists. The drawings show transverse steel reinforcing rods were placed within the tar macadam to enable the tar macadam to arch between the rolled steel joists in conjunction with the steel buckle plates.

1.1 Remembrance Drive Pedestrian Bridge Structural Assessment

The pedestrian bridge is no longer in use and barrier s have been erected across the both ends of the bridge to prevent pedestrian access as the bridge deck is in poor condition and the timber balustrade posts are severely dilapidated due to rot and/or termite damage and the dilapidated state is clearly visible in figures 2, 3, 6 & 7 in particular. The steel buckle plates show evidence of general corrosion; however, it was not possible to carry out an inspection of the tie rods that were embedded within the tar macadam. The edges of the tar macadam pavement have eroded and fretted due to exposure to wind and rain as can be seen in figures 2, 3 & 6.

Non systematic valley closure and upsidence are likely to occur as a result of subsidence associated with the extraction of coal from longwalls LW 27-LW30. The action of valley closure will cause each abutment wall to move inwards toward the centre of the valley as a rigid body whereas valley upsidence is likely to cause the abutment walls to tilt backwards away from the valley about the base of the wall as a rigid body. The upsidence will also cause the central pier to rise relative to the abutment walls.

Generally speaking, the valley closure will cause compression of the bridge deck unless it is released from the ground in the form of directional sliding bearings. The degree to which upsidence and the associated back slope of the abutment wall will offset valley closure at bridge deck level is uncertain and therefore it is recommended that the bridge deck be allowed to slide relative to the valley sides in order to avoid serious damage to the bridge deck, the abutment walls and the central pier. The ends of the bridge above the abutment walls can be jacked to maintain the planar surface of the bridge deck to reduce the effects of curvature on the bridge deck. It is recommended that the dilapidated timber balustrade posts and rails be removed from the bridge deck to prevent them becoming unstable during the proposed subsidence period and access to the bridge deck be prohibited.

Based upon a methodology of providing directional slip bearings and hydraulic jacks beneath each end of the bridge above both abutment walls the bridge is expected to remain in equilibrium during the proposed subsidence period. The bridge could be rehabilitated after the proposed subsidence where a new deck and balustrade could be constructed upon the existing beams or an entirely new bridge could be erected upon the existing abutment walls and pier after conclusion of the active subsidence period.

It is expected that intervention measures, if required, can be designed to protect the abutment walls, piers and the bridge deck from the most damaging impacts of valley closure and upsidence and that, furthermore, that trigger levels can be established for crack width and structure tilt to maintain the safety and serviceability of the bridge structure and limit the impact of mine subsidence.

1.2 Remembrance Drive Pedestrian Bridge Photographs

Figure 1

Figure 2

Figure 3

Figure 4

Figure 5

Figure 6

Figure 7

2.1 Remembrance Drive Road Bridge Structure

The abutment walls and central piers and headstock have been constructed using reinforced concrete construction based upon a review of the work as executed drawings. The bridge deck has been constructed using simply supported pre-cast pre-tensioned bridge deck units with infill concrete. The drawings show both bridge spans are supported upon elastomeric bearings upon the central headstock and are connected to the central headstock by grouted dowels. A vertical bitumastic strip forms a vertical separation between both bridge spans above the central headstock.

The bridge deck appears to be supported partly upon a reinforced concrete corbel that has been constructed monolithically with the abutment wall and partly upon the abutment wall itself as the barrier post in each corner of the bridge appears to have been constructed upon the bridge deck, refer figure 14. The road surface has cracked behind the abutment wall behind the barrier posts (figure 12), which supports the supposition that the bridge deck continues onto the wall proper. The structural drawings do not show whether or not the deck has been dowelled to both abutment walls. However, experience at the Castlereagh Street Bridge suggests that this is likely.

The drawings call for footings to be founded 450mm into solid rock including the abutment/wing walls and the footings to the concrete piers. The abutment walls do not appear to rely upon cantilever action other than what may be derived from the self-weight of the abutment walls.

2.2 Remembrance Drive Road Bridge Structural Assessment

The vehicular bridge is expected to be impacted by non-systematic valley closure and upsidence as a result of subsidence associated with the extraction of coal from longwalls LW 27-LW30. The action of valley closure will cause the abutment walls to move inwards toward the centre of the valley as a rigid body whereas valley upsidence is likely to cause the abutment walls to tilt backwards away from the valley about the base of the wall as a rigid body. There is some uncertainty as to the extent that closure and upsidence will coexist during subsidence and therefore the bridge structure will require detailed analysis as part of the SSSMP.

Generally speaking, the valley closure will cause compression of the bridge deck since it is unlikely that the bridge deck can be isolated from the abutment walls due to the likelihood that the deck is connected to the abutment wall by grouted dowels. Valley upsidence is expected to relieve the effects of valley closure due to possible back tilt of the abutment walls away from the valley centre as appears to be occurring at the Castlereagh Street Bridge currently being impacted by the subsidence effects of LW25 but the central piers and headstock are expected to rise relative to the abutment walls.

If the bridge deck cannot be isolated from the abutment walls it is possible that earth pressures near the top of the abutment wall may approach passive pressure levels and this may tend to generate significant tensile stresses in the vertical reinforcement near the external face of the wall. This is expected to cause horizontal tensile cracking in the abutment wall unless intervention measures are undertaken to remove the backfill from behind the retaining wall and install a temporary steel back span above the excavated backfill on one or both sides of the bridge to disengage the bridge structure from the effects of compressive ground strain upon the backfill caused by valley closure.

A detailed structural analysis of the abutment walls and the bridge deck should be carried out to assess the structural impacts of valley closure and upsidence upon the structure to determine the extent of any intervention measures that may be required.

It is expected that intervention measures, if required, can be designed to protect the abutment walls, piers and headstocks and the bridge deck from the most damaging impacts of valley closure and upsidence and that, furthermore, that trigger levels can be established for crack width and structure tilt to maintain the safety and serviceability of the bridge structure and limit the impact of mine subsidence.

2.3 Remembrance Drive Road Bridge Photographs

Figure 8

Figure 9

Figure 10 Gas pipeline emerging from the ground next to the southwest corner of bridge

Figure 11 Gas pipe support along bridge.

Figure 12

Figure 13

18th May 2009.

Figure 14

Yours faithfully,

John Matheson & Associates Pty Ltd

John Matheson