SIMEC Mining:

Tahmoor Coking Coal Operations - Longwall 32

Management Plan for Potential Impacts to Jemena Gas Infrastructure

AUTHORISATION OF MANAGEMENT PLAN

Authorised on behalf of Tahmoor Coal Pty Ltd:	
Name:	Ron Bush
Signature:	[signature]
Position:	Environment + Community Manager
Date:	2/10/2018.

Authorised on behalf of Jemena Asset Management:	
Name:	Andrew Walker
Signature:	[signature]
Position:	Networks Engineer
Date:	2/10/18

DOCUMENT REGISTER

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Jul-06	MSEC286-0405	B	Agreed management plan
Aug-06	MSEC286-0405	C	Chapter 1 amended
Mar-08	MSEC286-0405	D	Draft update to mine plan and risk control procedures
May-08	MSEC286-0405	E	Agreed amended plan for Longwalls 24A to 26
Sep-08	MSEC286-0405	F	Updated for Longwalls 25 to 26 and Jemena name change
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Sep-12	MSEC567-05	A	Updated for Longwall 27
Oct-12	MSEC567-05	B	Updated after consultation with Jemena
Mar-14	MSEC646-05	A	Updated for Longwalls 28 to 30
Mar-14	MSEC646-05	B	Updated following Jemena feedback
Apr-14	MSEC646-05	C	Final plan for Longwall 28
Mar-15	MSEC746-05	A	Updated for Longwalls 29 to 30
Apr-15	MSEC746-05	B	Updated following Jemena feedback
Apr-15	MSEC746-05	C	Final plan for Longwall 29 only
Feb-16	MSEC815-05	A	Updated for Longwall 30
Apr-17	MSEC862-05	A	Updated for Longwall 31
Jun-18	MSEC945-05	A	Updated for Longwall 32
Aug-18	MSEC945-05	B	Final update for LW32
Sep-18	MSEC945-05	C	Final following consultation with Jemena

References:-

AS/NZS 4360:1999 Risk Management

AS/NZS ISO 31000:2009 Risk Management – Principles and guidelines

Glencore (2014) Glencore Coal Assets Australia Risk Management Matrix, Glencore, September 2014

Glencore (2018) Environmental Risk Assessment: Tahmoor Underground – Longwall 32 Surface and Subsurface Infrastructure – Jemena Infrastructure, Tahmoor Coking Coal Operations, May 2018.

JMA (2018) Structure Condition Report – Bridges over Redbank Creek, Remembrance Drive, Picton, JMA Solutions, Report No. R0521, May 2018

MSO (2017) Managing risks of subsidence – Guide | WHS (Mines and Petroleum Sites) Legislation, NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations, February 2017.

MSEC (2014) Tahmoor Colliery Longwalls 31 to 37 - Subsidence Predictions and Impact Assessments for Natural and Built Features in support of the SMP Application. (Report MSEC647, Revision A, December 2014), prepared by Mine Subsidence Engineering Consultants.

SCT (2018a) Structure determinations of the Nepean Fault adjacent to Tahmoor Mine, SCT Operations, Report No. TAH4817, May 2018.

SCT (2018b) Investigation into the Potential Impact of the Nepean Fault on Longwall 32 Subsidence, SCT Operations, Report No. TAH4821, May 2018.

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Figures are prefaced by the number of the chapter or the letter of the appendix in which they are presented.

Drawings

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

Drawing No.	***Description***	***Revision***
MSEC945-00-01	Monitoring over Longwall 32	E
MSEC945-05-01	Jemena Gas Pipelines	A

1.1. Background

Tahmoor Coking Coal Operations is located approximately 80 km south-west of Sydney in the township of Tahmoor NSW. It is managed and operated by SIMEC Mining. Tahmoor Coking Coal Operations has previously mined 30 longwalls to the north and west of the mine's current location. It is currently mining Longwall 31.

Longwall 32 is 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. Longwall 32 is located beneath the rural area between Tahmoor, Thirlmere and Picton, including part of the South Picton industrial area. Infrastructure owned by Jemena is located within this area.

A summary of the dimensions of Longwall 32 is provided in Table 1.1.

Table 1.1 Longwall dimensions

Longwall	Overall void length including the installation heading (m)	Overall void width including the first workings (m)	Overall tailgate chain pillar width (m)
Longwall 32	2378	283	39

This Management Plan provides detailed information about how the risks associated with mining beneath the infrastructure will be managed by Tahmoor Coking Coal Operations and Jemena.

The Management Plan is a live document that can be amended at any stage of mining, to meet the changing needs of Tahmoor Coking Coal Operations and Jemena.

1.2. Jemena assets potentially affected by Longwall 32

A map showing the locations of Jemena infrastructure in relation to Longwall 32 is shown in Drawing No. MSEC945-05-01.

There are a number of gas pipelines that are located directly above or adjacent to Longwall 32, which generally follow the alignments of the local roads. The most significant of these are the main 160 mm PE pipelines along Remembrance Drive and Bridge Street.

1.3. Consultation

1.3.1. Consultation with Jemena

Tahmoor Coking Coal Operations regularly consults with Jemena in relation to mine subsidence effects from mining. This includes consultation during the development of Subsidence Management Plans for previous Longwalls 22 to 31, and regular reporting of subsidence movements and impacts.

Details regarding consultation and engagement are outlined below:

- Risk assessment held on 10 May 2018, which was attended by James Wu from Jemena.
- Meeting with Andrew Walker (Jemena), Belinda Clayton (Tahmoor Coking Coal Operations) and Daryl Kay (MSEC) in September 2018 to discuss the draft Subsidence Management Plan for Longwall 32.

Tahmoor Coking Coal Operations will continue to consult regularly with Jemena during the extraction of Longwall 32 in relation to mine subsidence effects from mining.

1.3.2. Consultation with Government Agencies & Key Infrastructure Stakeholders

Government agencies including the NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations, Subsidence Advisory NSW (Mine Subsidence Board) and key infrastructure stakeholders including Wollondilly Shire Council, Endeavour Energy, Sydney Water, and Telstra have also been consulted as part of the Subsidence Management Plan (SMP) approval process.

1.4. Limitations

This Management Plan is based on the predictions of the effects of mining on surface infrastructure as provided in Report No. MSEC647 by Mine Subsidence Engineering Consultants (MSEC, 2014). Predictions are based on the planned configuration of Longwall 32 at Tahmoor Coking Coal Operations (as shown in Drawing No. MSEC945-05-01), along with available geological information and data from numerous subsidence studies for longwalls previously mined in the area.

Infrastructure considered in this Plan has been identified from site visits and aerial photographs and from discussions between Tahmoor Coking Coal Operations representatives and Jemena.

The impacts of mining on surface and sub-surface features have been assessed in detail. However, it is recognised that the prediction and assessment of subsidence can be relied upon only to a certain extent. The limitations of the prediction and assessment of mine subsidence are discussed in report MSEC647 by Mine Subsidence Engineering Consultants.

As discussed in the report, there is a low probability that ground movements and their impacts could exceed the predictions and assessments. However, if these potentially higher impacts are considered prior to mining, they can be managed. This Management Plan will not necessarily prevent impacts from longwall mining, but will limit the impacts by establishing appropriate procedures that can be followed should evidence of increased impacts emerge.

1.5. Objectives

The objectives of this Management Plan are to establish procedures to measure, control, mitigate and repair potential impacts that might occur to Jemena gas infrastructure.

The objectives of the Management Plan have been developed to:-

- Ensure the safe and serviceable operation of all surface infrastructure. Public and workplace safety is paramount. Ensure that the health and safety of people who may be present on public property or Jemena property are not put at risk due to mine subsidence.
- Disruption and inconvenience should be avoided or, if unavoidable, kept to minimal levels.
- Monitor ground movements and the condition of 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.
- Establish a clearly defined decision-making process to ensure timely implementation of risk control measures for high consequence but low likelihood mine subsidence induced hazards that involve potential serious injury or illness to a person or persons that may require emergency evacuation, entry or access restriction or suspension of work activities.
- Provide a forum to report, discuss and record impacts to the surface. This will involve Tahmoor Coking Coal Operations, Jemena, relevant government agencies as required, and consultants as required.
- Establish lines of communication and emergency contacts.

1.6. Scope

The Management Plan is to be used to protect and monitor the condition of the items of Jemena infrastructure identified to be at risk due to mine subsidence and to ensure that the health and safety of people who may be present in the vicinity or on Jemena property are not put at risk due to mine subsidence. The major items at risk are:-

- Main polyethylene (PE) gas pipeline
- Local nylon (NY) gas pipelines; and
- Gas pipelines at creek crossings.

The gas pipelines are shown in Drawing No. MSEC945-05-01 classified by pipe size and by pipe type.

The Management 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 Longwall 32 only. The management plan does not include other gas infrastructure owned by Jemena which lies outside the extent of this area.

1.7. Proposed Mining Schedule

It is planned that Longwall 32 will extract coal working northwest from the south-eastern end. This Management Plan covers longwall mining until completion of mining in Longwall 32 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 32	September 2018	September 2019

Please note the above Schedule is subject to change due to unforeseen impacts on mining progress. Tahmoor Coking Coal Operations will keep Jemena informed of changes.

1.8. 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.

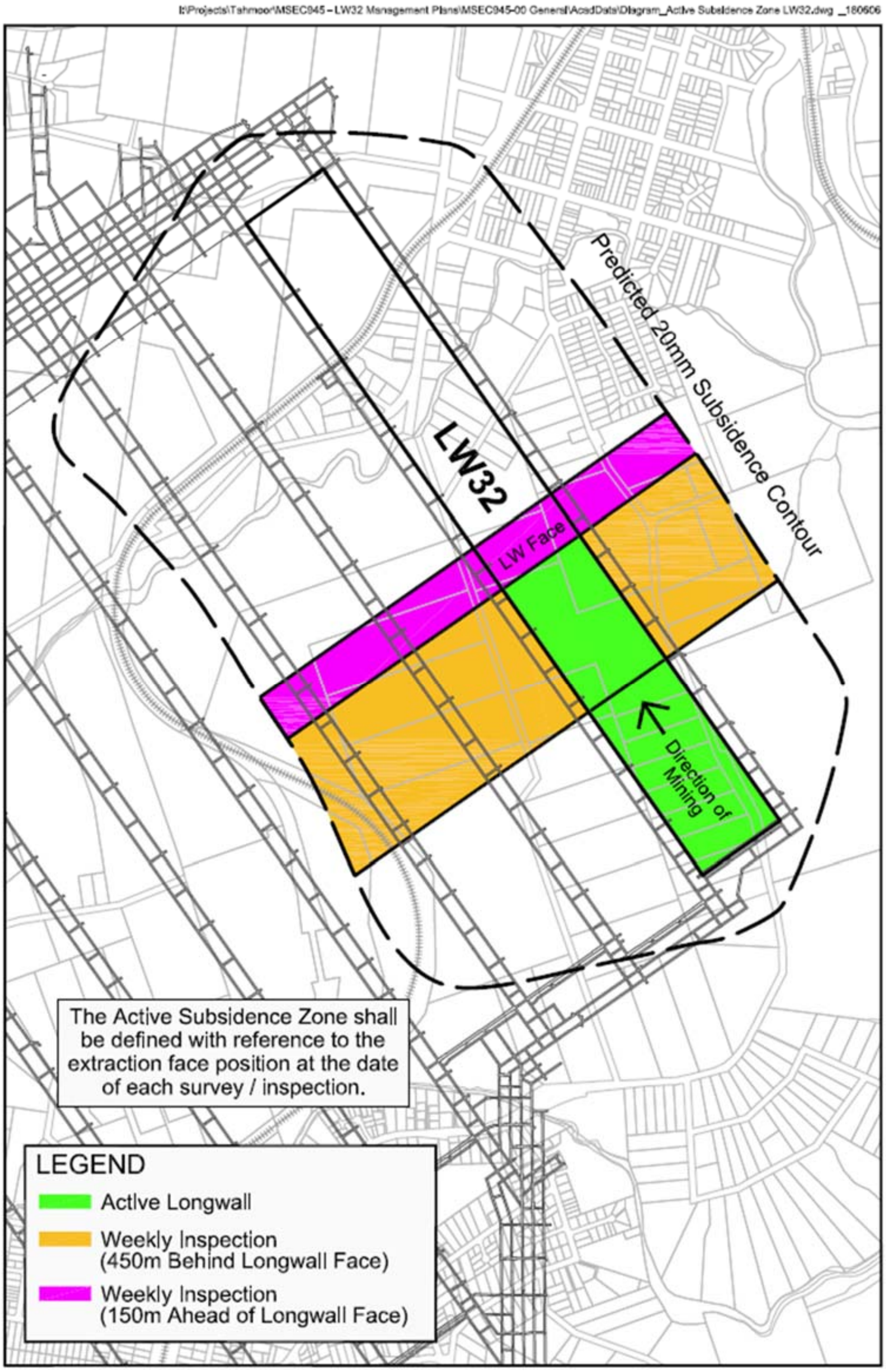

Fig. 1.1 Diagrammatic Representation of Active Subsidence Zone

1.9. Compensation

The Coal Mine Subsidence Compensation Act 2017 (MSC Act) is administered by Subsidence Advisory NSW (Mine Subsidence Board).

Currently, under the Coal Mine Subsidence Compensation Act 2017, any claim for mine subsidence damage needs to be lodged with Subsidence Advisory NSW. Subsidence Advisory NSW staff will arrange for the damage to be assessed by an independent specialist assessor. If the damage is attributable to mine subsidence, a scope will be prepared and compensation will be determined. For further details please refer to *Guidelines – Process for Claiming Mine Subsidence Compensation* at ww.subsideneadvisory.nsw.gov.au.

2.1. NSW Work Health & Safety Legislation

All persons conducting a business or undertaking (PCBUs), including mine operators and contractors, have a primary duty of care to ensure the health and safety of workers they engage, or whose work activities they influence or direct. The responsibilities are legislated in *Work Health and Safety Act 2011* and the *Work Health and Safety (Mines and Petroleum Sites) Act 2013* and associated Regulations (collectively referred to as the 'WHS laws').

The *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014* commenced on 1 February 2015 and contains specific regulations in relation to mine subsidence.

As outlined in the Guide by the NSW Department of Trade & Investment Mine Safety:

"a PCBU must manage risks to health and safety associated with mining operations at the mine by:

- *complying with any specific requirements under the WHS laws*
- *identifying reasonably foreseeable hazards that could give rise to health and safety risks*
- *ensuring that a competent person assesses the risk*
- *eliminating risks to health and safety so far as is reasonably practicable*
- *minimising risks so far as is reasonably practicable by applying the hierarchy of control measures, any risks that it is are not reasonably practical to eliminate*
- *maintaining control measures*
- *reviewing control measures.*

The mine operator's responsibilities include developing and implementing a safety management system that is used as the primary means of ensuring, so far as is reasonably practicable:

- *the health and safety of workers at the mine, and*
- *that the health and safety of other people is not put at risk from the mine or work carried out as part of mining operations."*

Detailed guidelines have also been released by the NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations (MSO, 2017).

The risk management process has been carried out in accordance with guidelines published by the NSW Department of Planning & Environment, Resources Regulator, Mine Safety Operations (MSO, 2017). The following main steps of subsidence risk management have been and will be undertaken, in accordance with the guidelines.

1. identification and understanding of subsidence hazards
2. assessment of risks of subsidence
3. development and selection of risk control measures
4. implementation and maintenance of risk control measures, and
5. continual improvement and change management.

Each of the above steps have been or will be conducted together with the following processes.

1. consultation, co-operation and co-ordination, and
2. monitoring and review.

This Management Plan documents the risk control measures that are planned to manage risks to health and safety associated with the mining of Longwall 32 in accordance with the WHS laws.

2.2. General

The method of assessing potential mine subsidence impacts in the Management Plan is consistent with the Australian/New Zealand Standard for Risk Management. The Standard defines the terms used in the risk management process, which includes the identification, analysis, assessment, treatment and monitoring of potential mine subsidence impacts. In this context:-

2.2.1. 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.

2.2.2. Likelihood

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

2.2.3. Hazard

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

2.2.4. Method of assessment of potential mine subsidence impacts

The method of assessing potential mine subsidence impacts combines the likelihood of an impact occurring with the consequence of the impact occurring. In this Management Plan, the likelihood and consequence are combined via the Glencore Coal Assets Australia Risk Matrix to determine an estimated level of risk for particular events or situations. A copy of the Risk Matrix is included in the Appendix of this Management Plan.

1 AS/NZS 4360:1999 – Risk Management pp2

2 AS/NZS 4360:1999 – Risk Management pp2

3 AS/NZS 4360:1999 – Risk Management pp2

3.1. Maximum Predicted Conventional Subsidence Parameters

Predicted mining-induced conventional subsidence movements were provided in Report No. MSEC647, which was prepared in support of Tahmoor Coking Coal Operations' SMP Application for Longwalls 31 to 37, and includes predictions due to the extraction of Longwall 32. A summary of the maximum predicted incremental subsidence parameters due to the extraction of Longwall 32 only and the maximum predicted total conventional subsidence parameters due to the extraction of Longwalls 22 to 32, are provided in Table 3.1.

Table 3.1 Maximum Predicted Conventional Subsidence Parameters due to the Extraction of Longwall 32

Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Increment due to LW32 only	700	5.5	0.06	0.12
Total after extraction of LWs 22 to 32	1,250	6.0	0.09	0.14

The values provided in the above table are the maximum predicted conventional subsidence parameters which occur within the general longwall mining area, including the predicted movements resulting from the extraction of Longwalls 22 to 32.

The location of the maximum predicted total subsidence is not directly above Longwall 32. Predicted maximum total subsidence directly above Longwall 32 is approximately 800 mm.

3.2. Observed subsidence during the mining of Longwalls 22 to 31

The extraction of longwalls at Tahmoor Coking Coal Operations has generally resulted in mine subsidence movements that were typical of those observed above other collieries in the Southern Coalfield of NSW at comparable depths of cover.

However, observed subsidence was greater than the predicted values over Longwalls 24A and the southern parts of Longwalls 25 to 27. Monitoring during the mining of Longwalls 28 to 31 has found that subsidence behaviour has returned to normal levels.

Survey Peg ST14 on Stilton Lane is located above the centreline of Longwall 31. As at 19 March 2018, subsidence was developing at equivalent rate to pegs located above previously extracted Longwalls 28 to 30. It is unlikely that Peg ST14 will subside at levels observed during the mining of Longwalls 24A to 27.

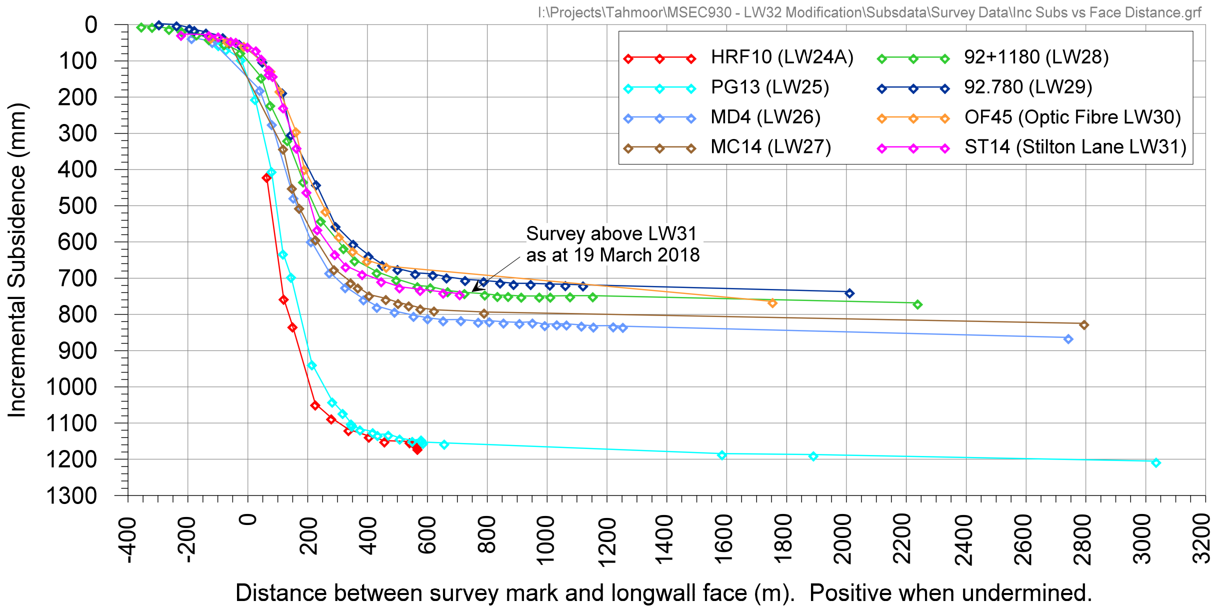

Fig. 3.1 Observed development of subsidence of survey pegs above the centrelines of Longwalls 24A to 31

Ground surveys will continue to be undertaken above Longwall 32. The survey results will be checked against predictions to confirm whether subsidence continues to develop in a normal manner during the mining of Longwall 32.

3.3. 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).

3.3.1. 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 Longwalls 22 to 28 at Tahmoor Coking Coal Operations, 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 at Tahmoor Coking Coal Operations is provided in Fig. 3.2. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

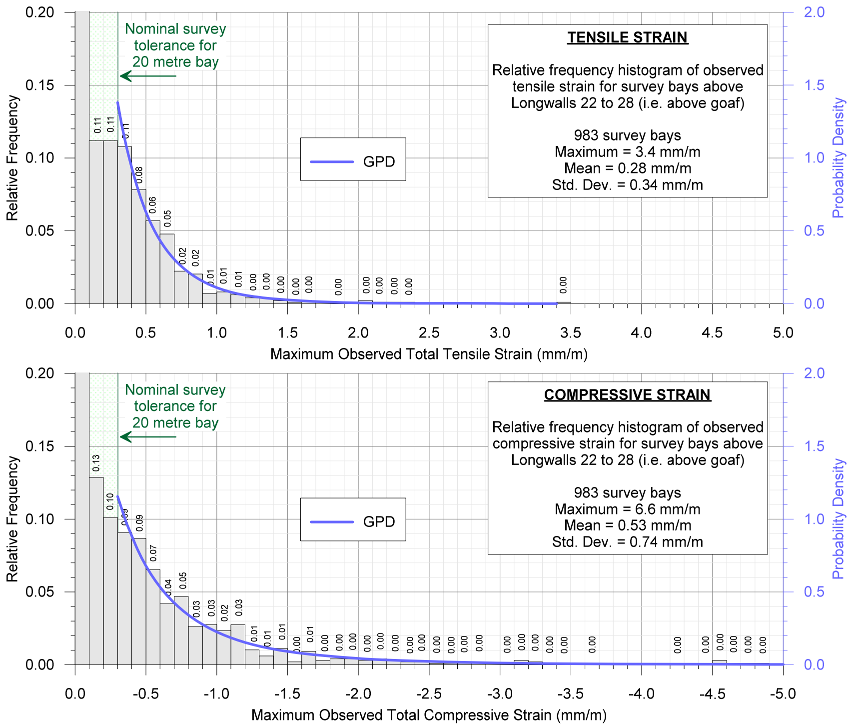

Fig. 3.2 Distributions of the measured maximum tensile and compressive strains for surveys bays located above goaf

The 95 % confidence levels for the maximum total strains that the individual survey bays *above goaf* experienced at any time during mining are 0.9 mm/m tensile and 1.8 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 are 1.5 mm/m tensile and 3.5 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 Longwalls 22 to 28 at Tahmoor Coking Coal Operations, 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 at Tahmoor Coking Coal Operations is provided in Fig. 3.3. The probability distribution functions, based on the fitted GPDs, have also been shown in this figure.

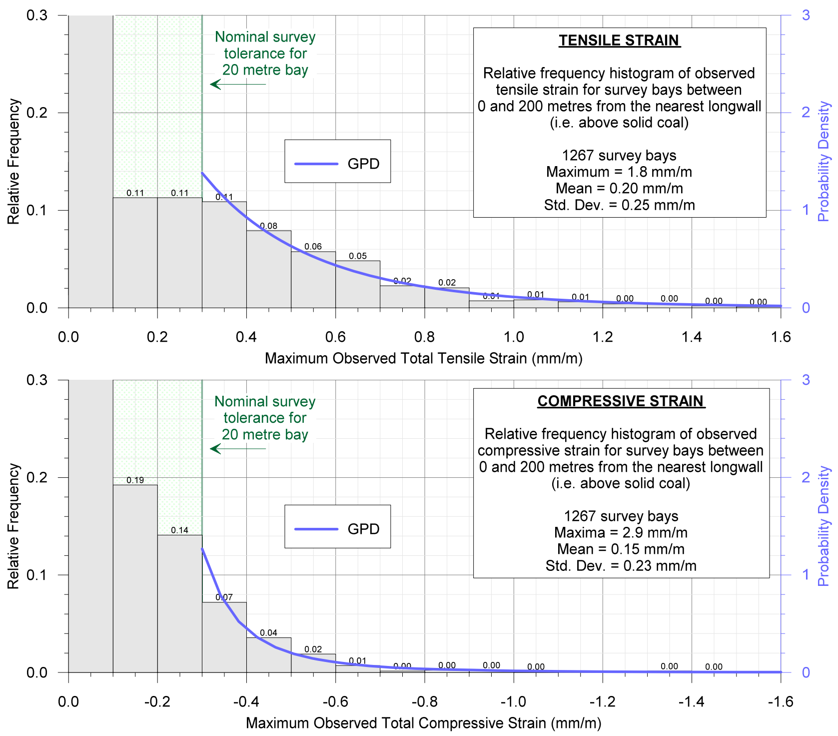

Fig. 3.3 Distributions of the measured maximum tensile and compressive strains for survey bays located above solid coal

The 95 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining are 0.6 mm/m tensile and 0.5 mm/m compressive. The 99 % confidence levels for the maximum total strains that the individual survey bays *above solid coal* experienced at any time during mining are 1.1 mm/m tensile and 0.9 mm/m compressive.

3.3.2. 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 Longwalls 22 to 28 at Tahmoor Coking Coal Operations, is provided in Fig. 3.4.

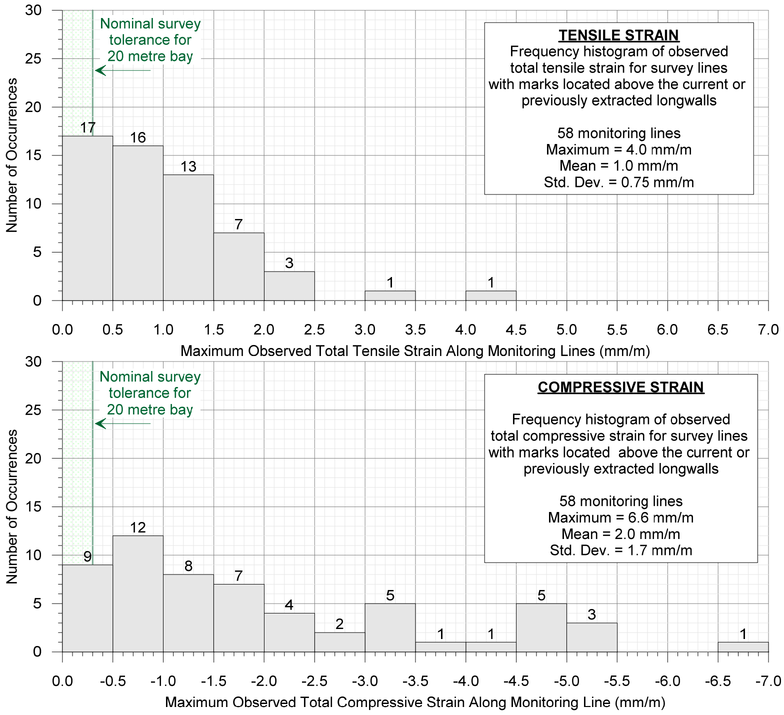

Fig. 3.4 Distributions of measured maximum tensile and compressive strains anywhere along the monitoring lines

It can be seen from Fig. 3.4, that 33 of the 58 monitoring lines (i.e. 57 %) had recorded maximum total tensile strains of 1.0 mm/m, or less, and that 53 monitoring lines (i.e. 91 %) had recorded maximum total tensile strains of 2.0 mm/m, or less. It can also be seen from this figure, that 36 of the 58 monitoring lines (i.e. 62 %) had recorded maximum compressive strains of 2.0 mm/m, or less, and that 48 of the monitoring lines (i.e. 83 %) had recorded maximum compressive strains of 4.0 mm/m, or less.

3.4. Predicted and observed valley closure across creeks

The gas pipelines cross a number of creeks within the area potentially affected by the extraction of Longwall 32. The predictions of valley closure and upsidence for crossings of large creeks are provided later in this Management Plan.

The local gas pipeline along Bridge Street crosses a ‘hidden creek’ directly above Longwall 32. The 160 mm diameter PE pipeline on Remembrance Drive crosses Redbank Creek approximately 350 metres to the side of Longwall 32. The predicted valley related effects on these locations are provided later in this Management Plan.

The main gas pipeline along Remembrance Drive crosses Myrtle Creek at a distance of 880 m from the commencing end of Longwall 32. This creek crossing is located outside the predicted limit of vertical subsidence. The ground movements measured at this creek crossing during the extraction of Longwall 31 were less than 20 mm vertical subsidence and no measurable closure. The main gas pipeline crossing at Myrtle Creek, therefore, has not been included as part of this Management Plan.

3.5. Geological structures

3.5.1. Identification of geological structures

Longwall 32 will be extracted alongside the Nepean Fault, which is a well-known geological feature that is an extension of the Lapstone Monocline.

Tahmoor Coking Coal Operations commissioned an engineering geologist from SCT (2018a) to undertake site inspections and mapping of the Nepean Fault. This work has provided detailed information on the nature and location of Nepean Fault, and second order geological structures associated with the fault.

The Nepean Fault is mapped as “*an en-echelon distribution of first order faults with major offsets. Ramps are developed between these en-echelon fault surfaces. Numerous first order north-south faults, each of limited extent, step across the area investigated.*” (SCT, 2018a). The commencing end of Longwall 32 is located within the fault ramp area between two of the first order faults.

SCT (2018a) further advise that the fault is sub-vertical from surface to seam, based on site investigations and geological information gathered by Tahmoor Coking Coal Operations since 2014. The cross-section provided by SCT (2018a) has been reproduced in Fig. 3.5.

In addition to the mapped first order faults, SCT has mapped second order faults, which are described as "*mainly conjugate sets of strike slip faults and splay faults being observed between the en-echelon first order faults*."

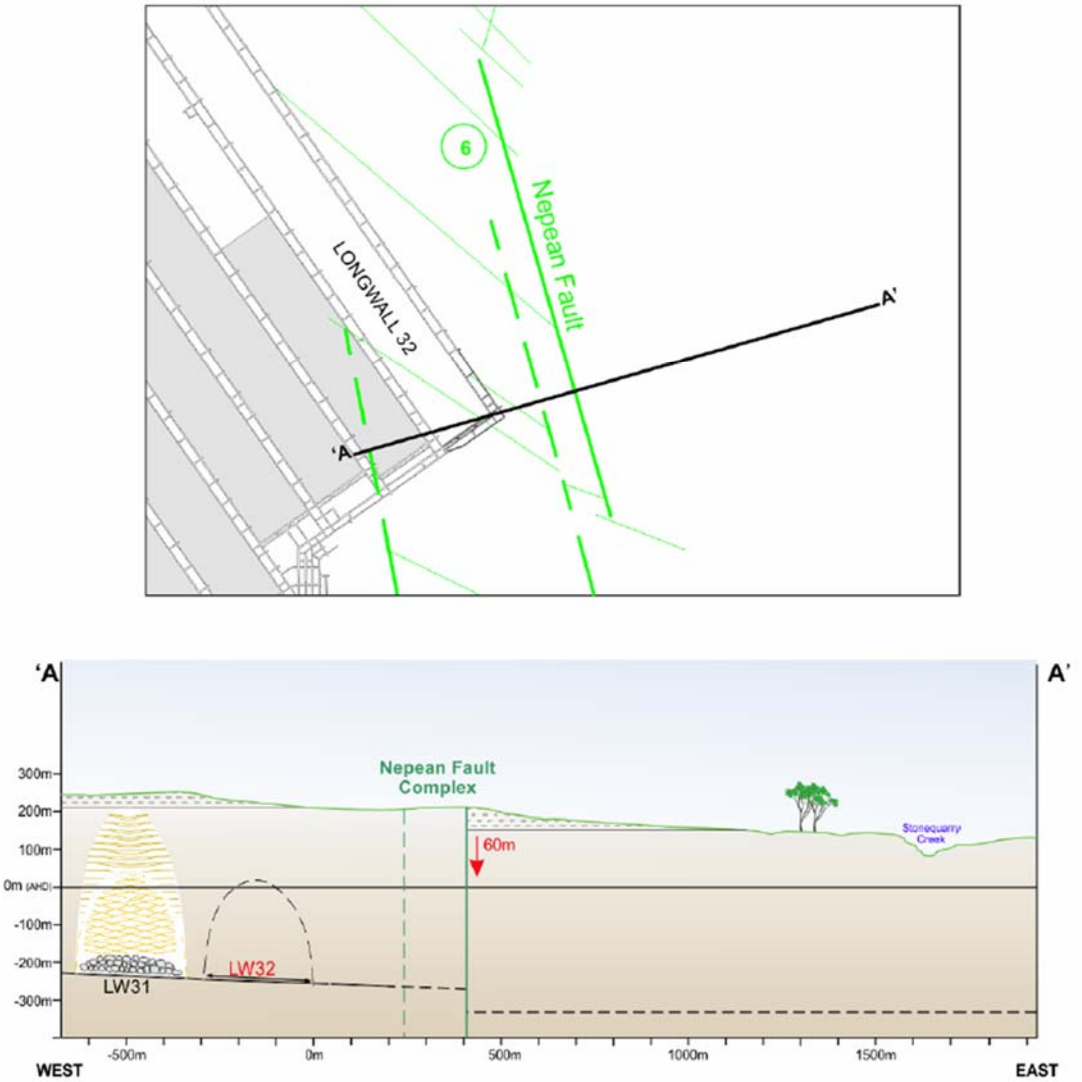

Fig. 3.5 Cross-section of Nepean Fault near Longwall 32 by SCT (2018a)

The geological structures as mapped by SCT (2018a) have been overlaid with surface features within and adjacent to Longwall 32. These are shown in Drawing No. MSEC945-05-01.

It can be seen that the built areas within Tahmoor and Picton are located to the side of a mapped first order Nepean Fault, which follows the escarpment along the western bank of Stonequarry Creek. Drawing No. MSEC945-05-01 shows that no Jemena infrastructure crosses the mapped first order fault.

Jemena infrastructure does, however, cross mapped second order geological structures, of which one intersects Remembrance Drive directly above Longwall 32.

A cross-section has been produced in Fig. 3.6 to show the location of the Nepean Fault and Longwall 32. Predicted subsidence profiles due to the extraction of Longwalls 31 and 32 are also shown in Fig. 3.6. It can be seen from Fig. 3.6 that the first order Nepean Fault structure is located away from Longwall 32.

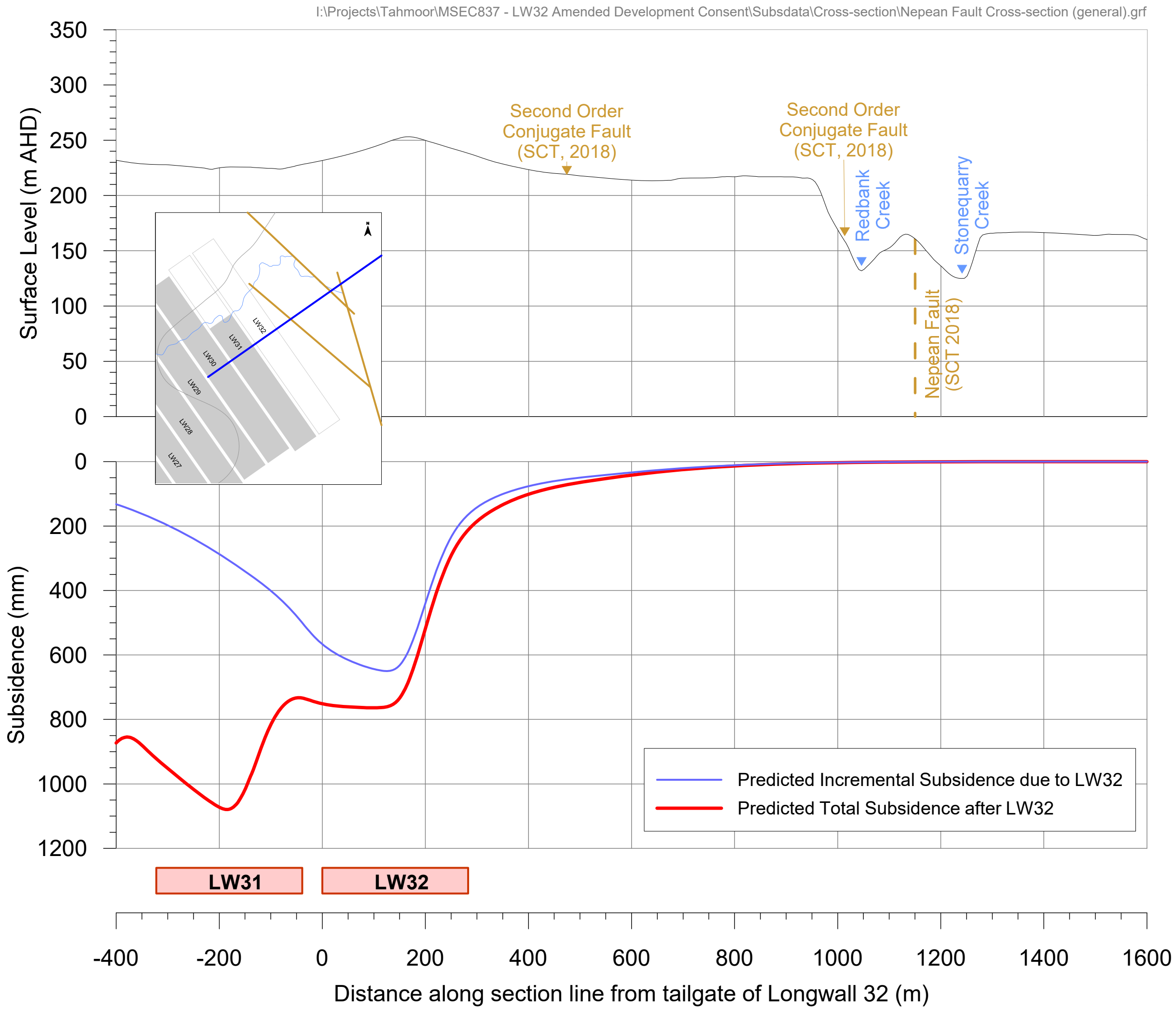

Fig. 3.6 Cross-section showing the mapped geological structures by SCT (2018a), and predicted subsidence profiles

3.5.2. Experience of subsidence movements between previously extracted longwalls and Nepean Fault at Tahmoor Coking Coal Operations

Tahmoor Coking Coal Operations has surveyed subsidence along many streets during the mining of previous Longwalls 24A to 31. Some of these monitoring lines are located over solid, unmined coal, between the extracted longwalls and the Nepean Fault.

None of the survey lines cross first order faults, though two survey lines (Stilton Dam Line and Remembrance Drive East Line) cross mapped second order conjugate faults.

A study has been completed to ascertain whether irregular subsidence have occurred along the survey lines. The information provides an indication of the likelihood of irregular movements during the extraction of Longwall 32.

The locations of the survey lines relative to the Nepean Fault and associated geological structures is shown in Fig. 3.7.

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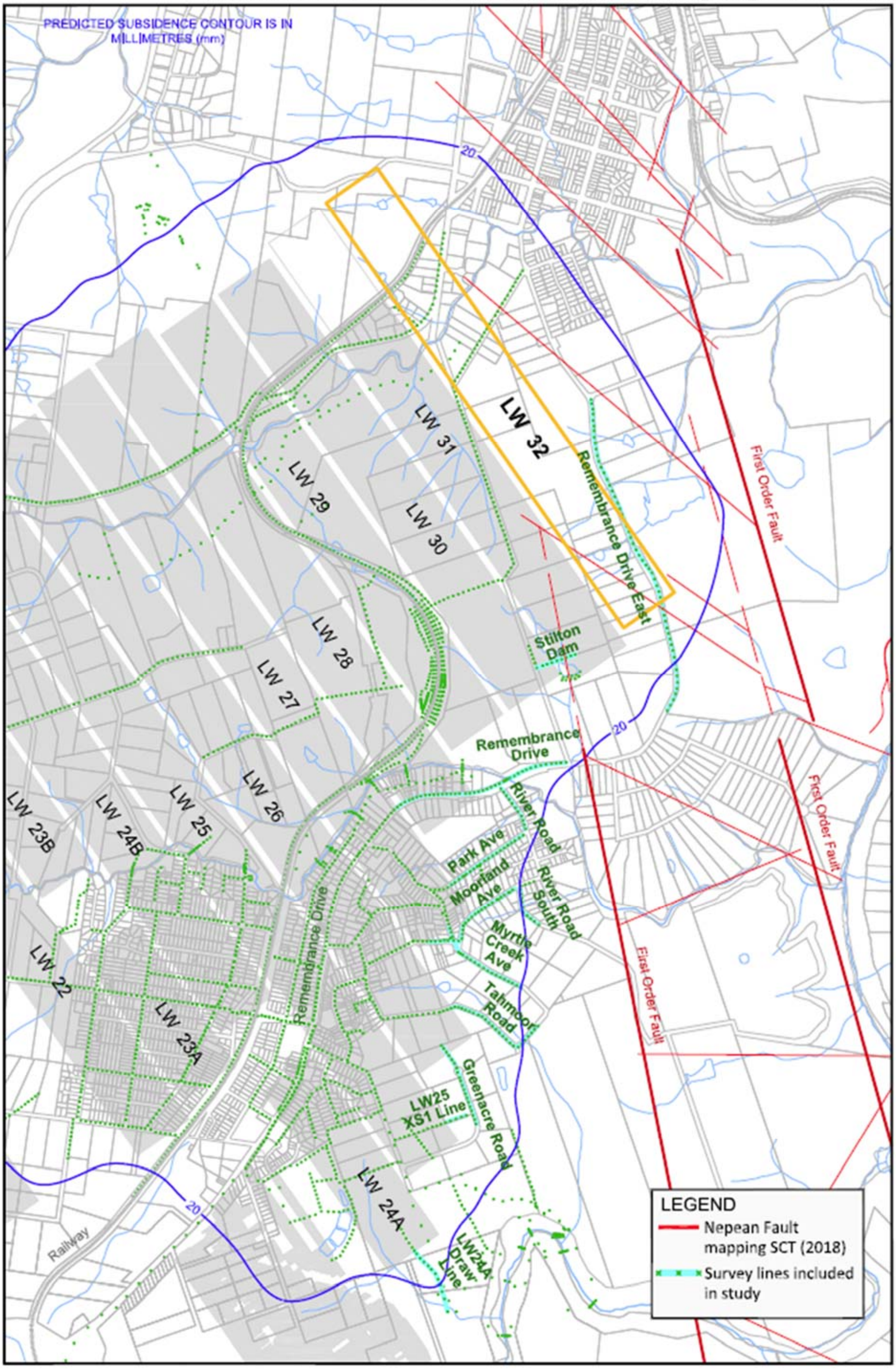

Fig. 3.7 Locations of ground survey lines in relation to the mapped geological structures by SCT (2018a)

The monitoring lines examined included.

- 900-Line, due to the extraction of LWs 12 and 13 (not shown in Fig. 3.7),
- LW24 Draw Line, due to the extraction of LWs 24A and 25
- LW25-XS1 Line, due to the extraction of LWs 25 and 26
- Greenacre Drive, due to the extraction of LWs 25 and 26
- Tahmoor Road Line, due to the extraction of LWs 25 to 27
- Myrtle Creek Avenue, due to the extraction of LWs 25 to 28
- Moorland Road, due to the extraction of LWs 25 to 28
- River Road South, due to the extraction of LWs 27 and 28
- Park Avenue, due to the extraction of LWs 25 to 28
- River Rd, due to the extraction of LWs 26 to 28
- Remembrance Drive, due to the extraction of LWs 24A to 30
- Remembrance Drive, due to the extraction of LWs 24A to 27
- Stilton Dam Northern Line, due to the extraction of LWs 29 to 31 (refer Fig. 3.10)
- Remembrance Drive East, due to the extraction of LW31 (refer Fig. 3.11)

The study found no increased subsidence, tilt or strains were measured along the survey lines that were located over unmined, solid coal areas between the extracted longwalls and the Nepean Fault.

A histogram of the maximum observed tensile and compressive strains measured along the selected survey lines for survey bays located over solid coal between previously extracted longwalls at Tahmoor and the Nepean Fault is provided in Fig. 3.8.

It can be seen from Fig. 3.8 that observed ground strains have been, on average, within survey tolerance. A pair of outlying data points are labelled in Fig. 3.8.

Pegs RE77 and RE78 are located within the base of Myrtle Creek, which is the main watercourse in the area. Whilst Myrtle Creek has experienced a small amount of valley closure at this location due to the mining of Longwalls 29 and 30, it can be seen from Fig. 3.9 that measured strains across the base of the Creek have varied greatly over time. The main reason for the variations is that the pegs are spaced only 3 metres apart, meaning that survey tolerance has a much greater influence on the measured result. Most survey bays in the Southern Coalfield are spaced apart by nominally 20 metres. The second reason is variations have occurred after periods of heavy rainfall, where the pegs have been affected by swelling of the natural soils.

Pegs MD29 to MD30 also appear likely to have disturbed by construction works. The changes occurred after the completion of Longwall 26. The pegs, however, are located approximately 35 metres from the commencing end of Longwall 27, as shown in Fig. 3.9, but they experienced no changes during the mining of this longwall.

Notwithstanding these outliers, the statistics demonstrate that observed ground strains have been very small for survey pegs over solid coal, beyond the edges of the extracted longwalls at Tahmoor Coking Coal Operations.

Two survey lines (Stilton Dam Line and Remembrance Drive East Line) cross mapped second order conjugate faults. As shown in Fig. 3.10 and Fig. 3.11, observed subsidence, tilt and strain have been very low at these intersections. A very small bump was, however, observed along the Remembrance Drive East Line approximately 20 metres from the intersection point. Ground strains remained within survey tolerance at this location.

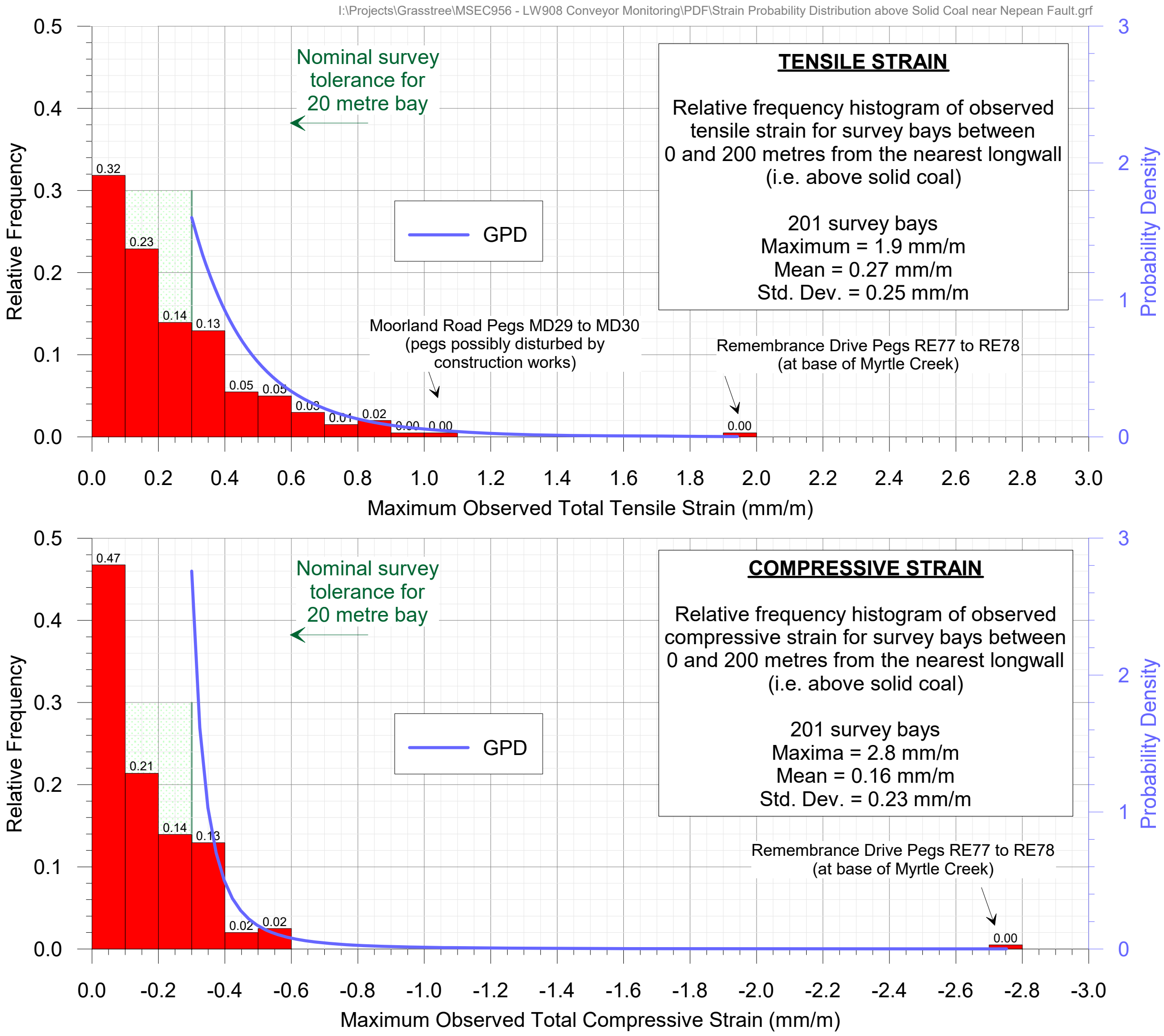

Fig. 3.8 Distributions of the Measured Maximum Tensile and Compressive Strains for Bays Located over Solid Coal between previously extracted longwalls at Tahmoor Coking Coal Operations and the Nepean Fault

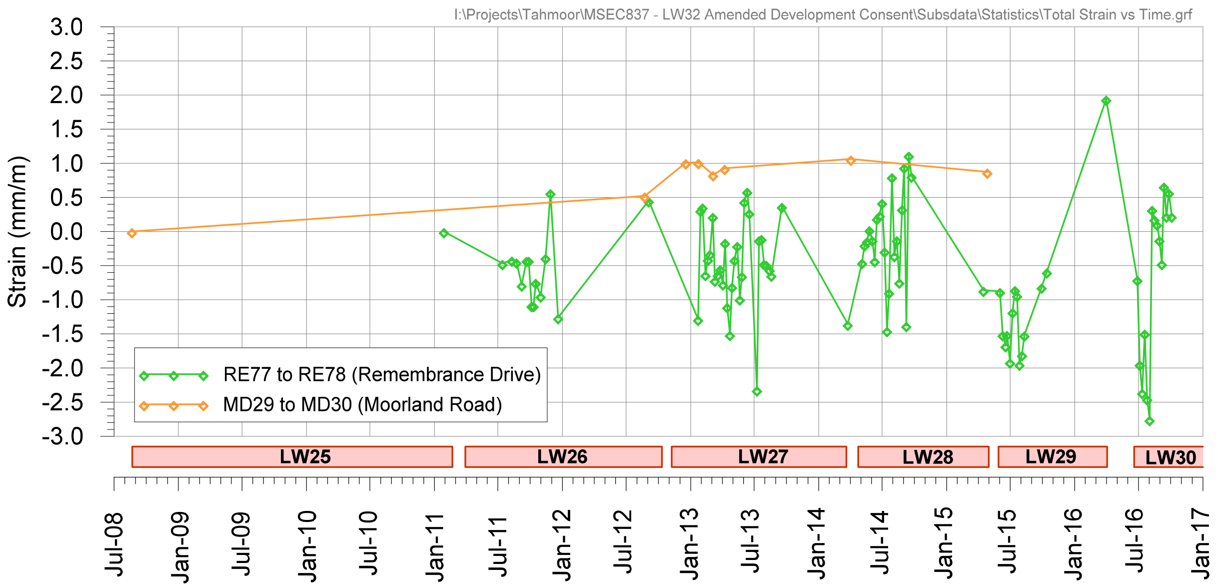

Fig. 3.9 Observed ground strains at selected sites during the mining of Longwalls 25 to 30

Tahmoor Colliery
Relative 3D surveys along Stilton Northern Dam Line
Total profiles during LW31

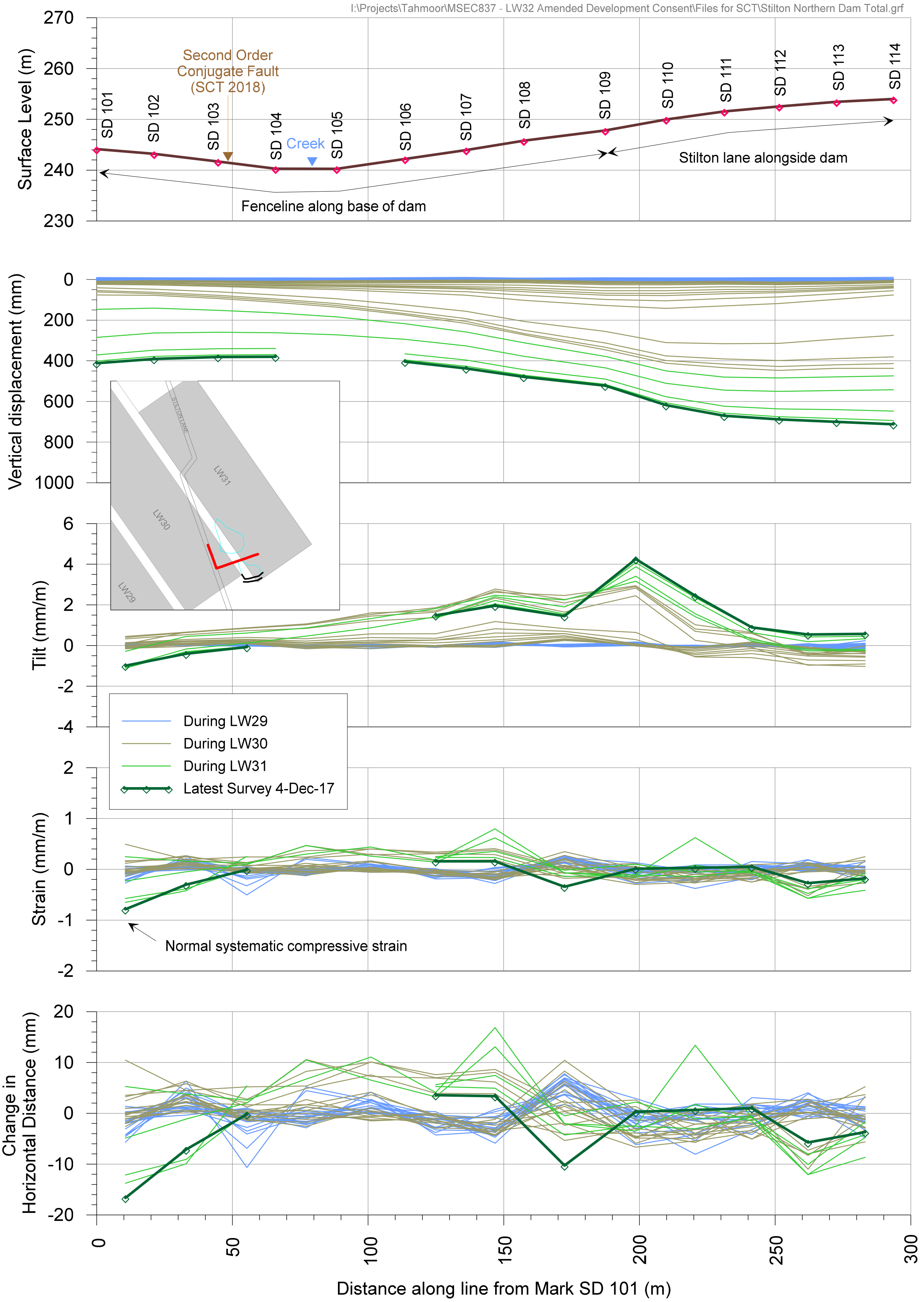

Fig. 3.10 Observed total subsidence profiles along the Stilton Northern Dam Line during the mining of Longwalls 29 to 31

Tahmoor Colliery - Longwall 31
Incremental Subsidence Profiles along Remembrance Drive East

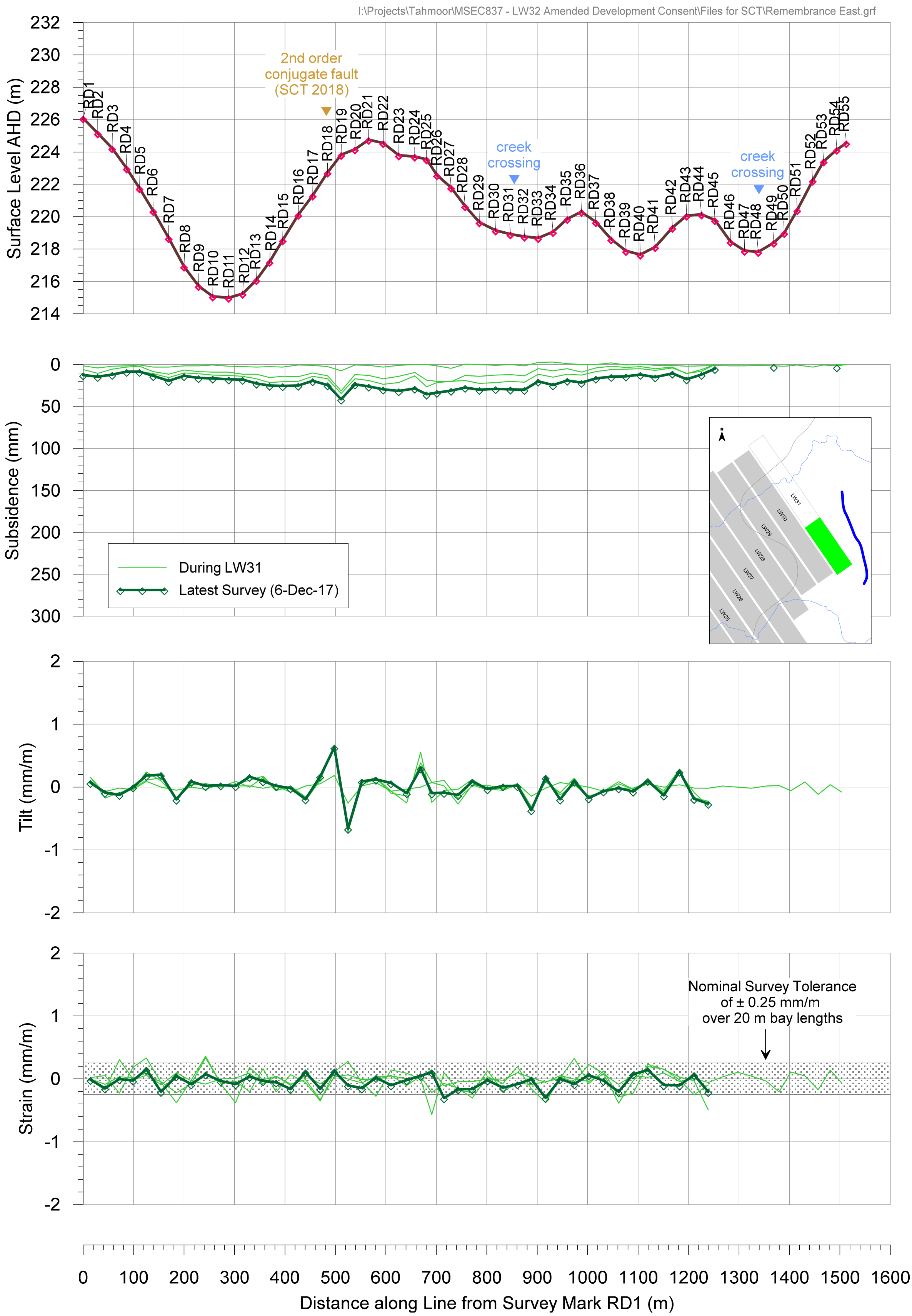

Fig. 3.11 Observed total subsidence profiles along the Remembrance Drive East Line during the mining of Longwalls 31

3.5.3. Potential effects of the Nepean Fault and associated geological structures on the development of subsidence during the extraction of Longwall 32

SCT (2018b) has undertaken a thorough and systematic review of subsidence outcomes that could reasonably be considered to be potentially significant. The following potential outcomes were investigated:

1. *"The potential for greater than predicted (abnormal) subsidence over the LW32 panel to cause greater subsidence beyond the panel edges.*
2. *The potential for unconventional subsidence movements occurring beyond the edge of LW32, including at or across the Nepean Fault.*
3. *The potential for mining-induced stress changes near the Nepean Fault to cause the fault plane to be mobilised.*
4. *The potential for movements that might occur quickly than conventional subsidence because of the presence of the fault and increase normal mining induced micro-seismic activity due to the isolating effect of the fault."*

SCT (2018b) concluded that "*none of the potential outcomes could reasonably be considered to have potential to be significant*". The conclusion is based on the following reasons (SCT, 2018b):

- The mapped planes of the Nepean Fault are remote from Longwall 32. Any differential vertical movement that may occur at the location of the Nepean Fault would be limited to less than a few tens of millimetres.
- Whilst increased subsidence was previously observed above the commencing ends of Longwalls 24A to 28, increased subsidence was not observed beyond the panel edges. Recent observations, including those during the mining of Longwall 31 indicate that subsidence has returned to normal levels.
- The Nepean Fault and associated fault structures are mapped as being sub-vertical. The geological structures that are recognised to be associated with unconventional subsidence are typically sub-horizontal i.e. bedding planes.
- Whilst mining induced stress changes are expected to occur on the fault because of longwall mining, they are not of a nature that would allow the fault plan to be destabilised and slip. This is because the stresses acting on the fault plane are not such that the fault is in limiting equilibrium, i.e. on the verge of instability.
- The high stresses and absence of massive strata in the Southern Coalfield of NSW mean that fracturing and downward movement occurs gradually and incrementally as the longwall retreats. Micro-seismic activity occurs regularly and so has low magnitude.

The conclusions by SCT (2018b) are supported by the results of the subsidence studies at Tahmoor Coking Coal Operations, as described in Section 3.5.2.

SCT (2018b) also advises that "*unconventional subsidence unrelated to the Nepean Fault may occur within the subject area during mining of LW32. Unconventional subsidence movements are observed at Tahmoor from time to time and therefore, may occur within the subject area*." MSEC concurs with this view, noting that the observed frequency of impacts beyond the edges of the longwalls have been infrequent and have been relatively slight in nature.

In addition to the subsidence study, an analysis of reported impacts during the mining of previous longwalls at Tahmoor Coking Coal Operations have recorded very few impacts beyond the panel edges, including in locations between the extracted longwalls and the Nepean Fault.

3.5.4. Potential effects of geological structures on the development of subsidence during the extraction of Longwall 32

Whilst the potential for significant differential movements is considered to be relatively low beyond the edges of Longwall 32, it is possible, however, that significant differential movements could occur at sites located directly above Longwall 32, including where second order geological structures associated with the Nepean Fault have been identified. Whilst no impacts have been observed at the Stilton Lane dam site in Fig. 3.10, differential movements have been observed where other geological structures have intersected the surface.

A recent example occurred at a low angle fault that intersected the Main Southern Railway in a railway cutting at Tahmoor, which was located directly above Longwall 29. The site was monitored extensively during the mining of Longwalls 28 to 31. This included three monitoring lines along the railway cutting, and survey prisms along the railway track.

The results of observed changes in vertical alignment of the pegs along the railway cutting are shown in Fig. 3.12. It can be seen that the most significant changes occurred during the mining of Longwall 29. The changes, however, developed gradually over time, allowing the railway track to be adjusted such that trains could continue to travel through the site.

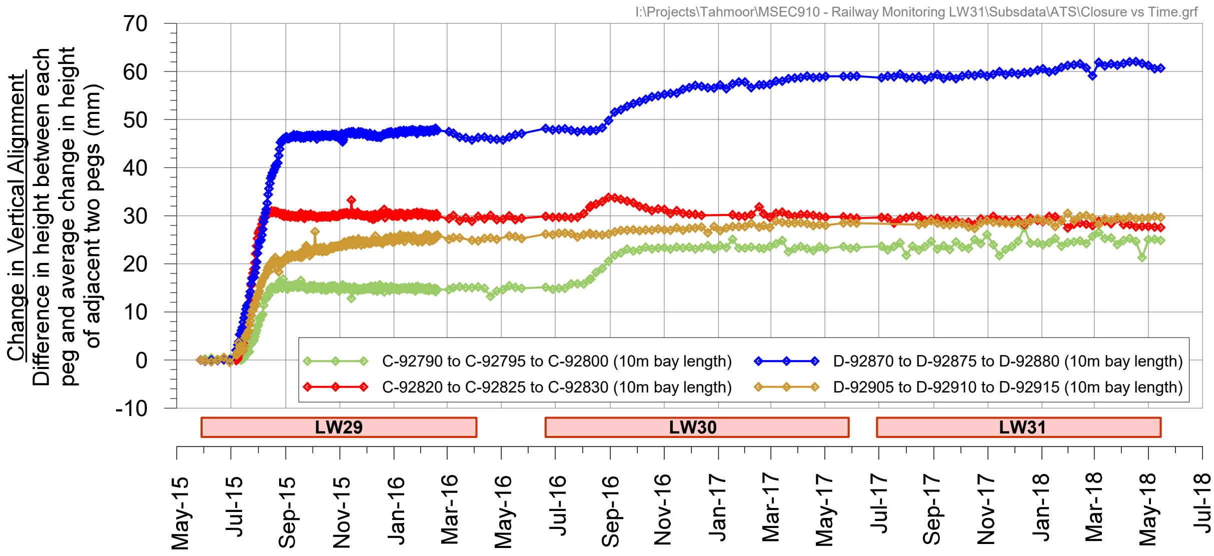

Fig. 3.12 Changes in vertical alignment across a geological fault within a railway cutting during the mining of Longwalls 29 to 31 at Tahmoor Coking Coal Operations

The observations of the gradual development of differential movements have been consistently observed during the mining of previous longwalls at Tahmoor Coking Coal Operations. While some sites have experienced severe impacts, the subsidence movements developed gradually, allowing time to repair before they became unsafe. This is discussed further in the next section.

3.6. Managing Public Safety

The primary risk associated with mining beneath Jemena infrastructure is public safety. Tahmoor Coking Coal Operations has previously directly mined beneath or adjacent to more than 1900 houses and civil structures, commercial and retail properties, the Main Southern Railway and local roads and bridges. It has implemented extensive measures prior to, during and after mining to ensure that the health and safety of people have not been put at risk due to mine subsidence. People have not been exposed to immediate and sudden safety hazards as a result of impacts that have occurred due to mine subsidence movements.

Emphasis is placed on the words “immediate and sudden” as in rare cases, some structures have experienced severe impacts, but the impacts did not present an immediate risk to public safety as they developed gradually with ample time to repair the structure.

In the case of this Subsidence Management Plan, the potential for impacts on public safety has been assessed on a case by case basis. The assessments include an inspection by a structural engineer in relation to bridges, a mine subsidence engineer, a geotechnical engineer for steep slopes, and an engineering geologist for geological structures.

3.6.1. Subsidence Impact Management Process for Infrastructure

Tahmoor Coking Coal Operations has developed and acted in accordance with a subsidence management plan to manage potential impacts during the mining of Longwalls 22 to 31. The management strategy has been reviewed and updated based on experiences gained during the mining of Longwalls 22 to 31 and the strategy for Longwall 32 includes the following process:

1. Regular consultation with Jemena before, during and after mining.
2. Site-specific investigations.
3. Implementation of mitigation measures following inspections by a structural engineer, a mine subsidence engineer, and, if required, a geotechnical engineer or other specialist engineer.
4. Surveys and inspections during mining within the active subsidence area:
   - Detailed visual inspections and vehicle based inspections along the streets
   - Ground surveys along streets
   - Specific ground surveys and visual inspections, where recommended by an engineer based on the inspections and assessments.

A flowchart illustrating the Subsidence Impact Management Process prior to, during and after each Jemena experiences mine subsidence movements is shown in Fig. 3.13.

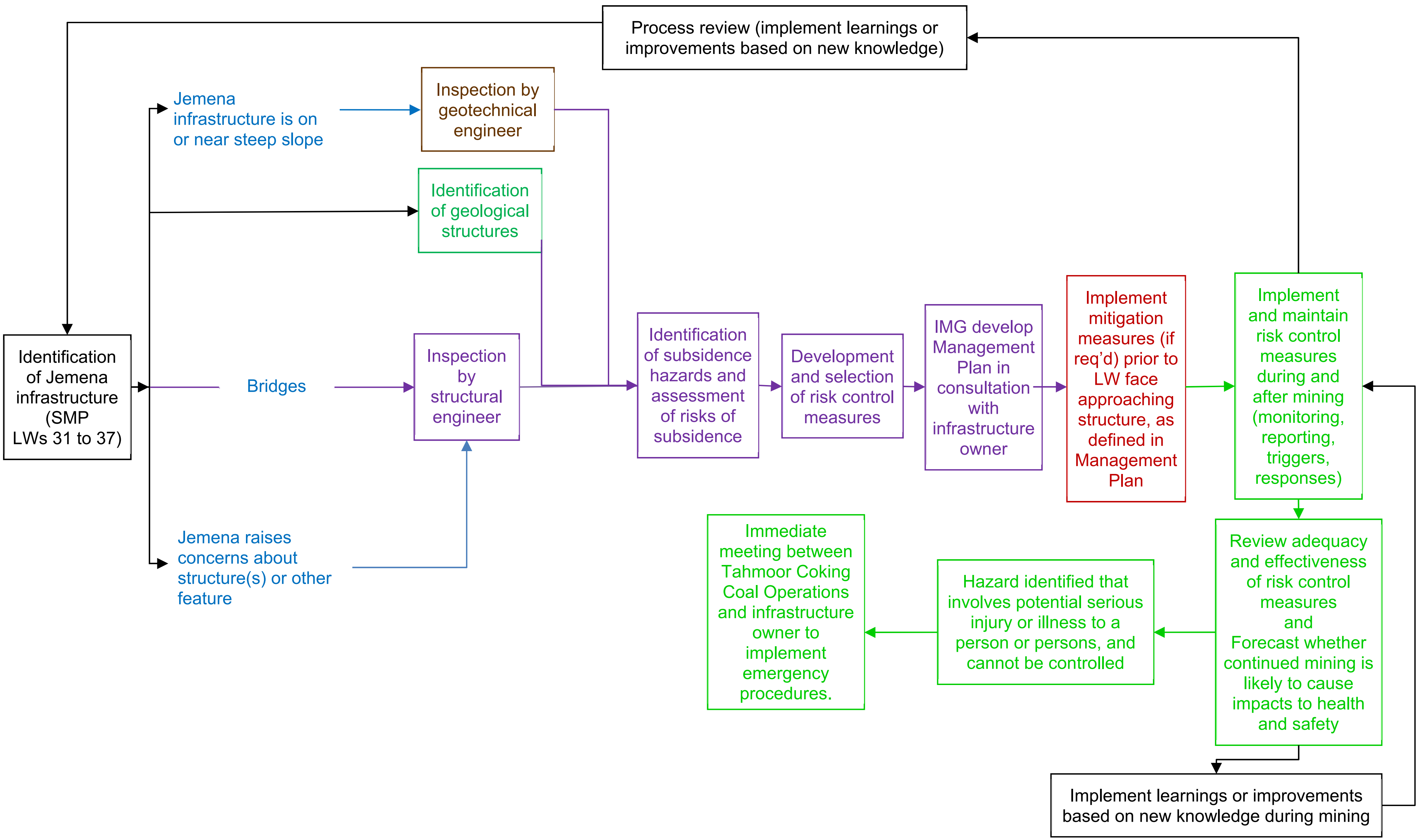

Fig. 3.13 Flowchart for Subsidence Impact Management Process

3.7. Summary of Potential Impacts

A summary of potential impacts on Jemena infrastructure is provided in Table 3.2. The summary is consistent with the risk assessment undertaken by Tahmoor Coking Coal Operations (Glencore, 2018), which is included in the Appendix.

Table 3.2 Summary of Potential Mine Subsidence Impacts

Risk	Likelihood	Consequence	Level of Potential Impact
Jemena gas pipelines affected by LW32			
Damage resulting in gas leak	RARE	MODERATE	LOW
Jemena gas pipelines crossing creeks			
Damage resulting in gas leak	RARE	MINOR	LOW

Additional information on each potential impact is provided below.

3.8. Identification of subsidence hazards that could give rise to risks to health and safety

Clause 34 of the Work Health and Safety Regulation (2017) requires that the duty holder (in this case Tahmoor Coking Coal Operations), in managing risks to health and safety, must identify reasonably foreseeable hazards that could give rise to risks to health and safety.

This section of the Management Plan summarises hazards that have been identified in Chapter 3, which could rise to risks to health and safety of people in the vicinity of Jemena infrastructure.

Using the processes described in Section 3.6 of this Management Plan, mine subsidence hazards have been identified, investigated and analysed in a systematic manner by examining each aspect of infrastructure, as described in Section 3.9 of this Management Plan. Each of the aspects below could potentially experience mine subsidence movements that give rise to risks to the health and safety of people:

- Main polyethylene (PE) gas pipeline
- Local nylon (NY) gas pipelines; and
- Gas pipelines at creek crossings.

The following mine subsidence hazards were identified that could give rise to risks to health and safety on Jemena infrastructure due to the extraction of Longwall 32.

- Potential damage to pipes resulting in a gas leak (refer Section 3.9)

The identification and risk assessment process took into account the location of infrastructure relative to Longwall 32 and the associated timing and duration of the subsidence event, as described in Section 1.8 of this Management Plan.

Whilst mine subsidence predictions and extensive past experiences from previous mining at Tahmoor Coking Coal Operations were taken into account, the identification and risk assessment process recognised that there are uncertainties in relation to predicting subsidence movements, and uncertainties in how mine subsidence movements may adversely impact Jemena infrastructure, as discussed in Section 1.4 and Chapter 3 of this Management Plan. In this case, geological structures have been mapped that intersect gas pipelines.

Tahmoor Coking Coal Operations has considered the outcomes of the hazard identification and risk assessment process when developing measures to manage potential impacts on the health and safety of people, and potential impacts on Jemena infrastructure in general. These are described in Chapter 4 of this Management Plan.

3.9. Gas pipelines

There are a number of gas pipelines that are located directly above or adjacent to Longwall 32, as shown in Drawing No. MSEC945-05-01.

- Main 160 mm diameter polyethylene (PE) gas pipeline along Remembrance Drive / Argyle Street

  This is the main road linking the townships of Tahmoor and Picton. The extraction of Longwall 32 will affect approximately 2.4 km of Remembrance Drive between the southern end of the property owned by Sydney Water's Picton Water Recycling Plant and the intersection of Argyle Street and Hill Street.

  The majority of the affected section of Remembrance Drive is located to the side of Longwall 32, which will extract directly beneath approximately 500 metres of the pipeline.

  Longwalls 24A to 28 have previously mined directly beneath the main polyethylene gas pipeline along the alignment of Remembrance Drive, with no impacts observed.

  The 160 mm PE pipe crosses Redbank Creek on Remembrance Drive via the road bridge. The pipe also traverses three small watercourses within the predicted to be experience subsidence from the extraction of Longwall 32.

  The 160 mm PE pipe along Remembrance Drive also crosses mapped second order geological structures associated with the Nepean Fault at two locations, as shown in Drawing No. MSEC945-05-01.

- 160 mm diameter polyethylene (PE) gas pipeline branch along Bridge Street

  This is one of the main roads that links the townships of Thirlmere and Picton. The 160 mm diameter PE branch line extends approximately 740 metres from the intersection of Remembrance Drive, where it reduces to a 32 mm NY pipe. Longwall 32 will extract directly beneath approximately 200 metres of the pipeline.

  The 160 mm PE pipe crosses a tributary to Redbank Creek on Bridge Street, approximately 270 metres to the side of Longwall 32.

- 160 mm diameter polyethylene (PE) gas pipeline branch along Henry Street

  A short branch line of approximately 100 metres in length is located on Henry Street. The end of the branch line is located approximately 200 metres to the side of Longwall 32.

- 32 mm diameter nylon (NY) gas pipelines

  The extraction of Longwall 32 will affect a network of 32 mm diameter NY pipes, the majority of which are located to the side of Longwall 32.

  The pipes potentially affected by Longwall 32 are located on Bridge Street, Wood Street and Coachwood Crescent. Longwall 32 will extract directly beneath approximately 140 metres of NY pipeline along Bridge Street. This section of pipeline traverses a small watercourse near the intersection of Redbank Place.

3.9.1. Predicted subsidence movements

The gas pipelines located above and adjacent to Longwall 32 generally follow the alignments of the local roads and, therefore, they will collectively experience the full range of predicted subsidence movements, as described in Section 3.1. A discussion on the expected range of tensile and compressive strains during the mining of Longwall 32 is provided in Section 3.3.

The predicted profiles of conventional subsidence, tilt and curvature for the main 160 mm diameter PE gas pipeline along Remembrance Drive is shown in Fig. 3.14. The predicted profiles of conventional subsidence, tilt and curvature for the main 160 mm diameter PE, and the local 32 mm diameter NY gas pipelines along Bridge Street is shown in Fig. 3.15. The predicted total profiles after the completion of Longwall 31 are shown in cyan. The predicted incremental profiles due to the extraction of Longwall 32 only are shown in black. The predicted total profiles after the completion of Longwall 32 are shown in blue.

A summary of the maximum predicted conventional subsidence, tilt and curvature for each of the gas pipelines, after the extraction of Longwall 32, is provided in Table 3.3. The values are the maximum predicted parameters anywhere along the sections of pipelines located within the predicted limit of vertical subsidence for Longwall 32.

Table 3.3 Maximum predicted total conventional subsidence, tilt and curvature for the pipelines

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)
Main 160 mm diameter PE gas pipeline along Remembrance Drive	After LW32	300	1.5	0.02	0.01
Main 160 mm diameter PE gas pipeline along Bridge Street	After LW32	1,200	4.5	0.08	0.11

Bridge Street will also experience transient tilts and curvatures as the extraction face of Longwall 32 mines directly beneath it. The maximum predicted transient movements orientated across the alignment of Bridge Street are 3.5 mm/m tilt, 0.06 km^{-1} hogging curvature and 0.08 km^{-1} hogging curvature.

The sections of pipelines that are crossing creeks are expected to experience upsidence and closure movements, as well as localised and elevated compressive strains due to these valley related movements.

A summary of the maximum predicted upsidence and closure movements at the tributary crossings, resulting from the extraction of the proposed longwalls, is provided in Table 3.4. The maximum predicted compressive strains have also been provided in this table, which are based on a statistical analysis of strains measured across drainage lines within the Southern Coalfield which have effective valley heights less than 20 metres and survey bay lengths between 15 metres and 25 metres.

Table 3.4 Maximum Predicted Total Upsidence, Closure and Compressive Strain for the Creek Crossings

Location	Maximum Predicted Total Upsidence (mm)	Maximum Predicted Total Closure (mm)	Maximum Predicted Compressive Strain (mm/m)		
			60 % Confidence Level	90 % Confidence Level	95 % Confidence Level
Crossings located directly above the proposed longwalls	300	350	2.0	5.5	7.5
Crossing located outside but within 200 metres of the extents of the proposed longwalls	100	100	< 0.5	1.5	2.5
Crossing located more than 200 metres from the extents of the proposed longwalls	< 50	< 50	< 0.5	0.8	1.5

3.9.2. Potential subsidence impacts on gas pipelines

Longwalls 22 to 31 have directly mined beneath approximately 18 km of gas pipelines and no adverse impacts have been reported to date. The main PE gas pipeline and the local NY pipelines are very flexible and have demonstrated that they can withstand the full range of subsidence experienced at Tahmoor Coking Coal Operations. It is unlikely, therefore, that adverse impacts on the gas pipelines would occur due to the extraction of Longwall 32.

The experiences include the extraction of Longwall 25 beneath Abelia Street, where a large compressive strain of 6.5 mm/m (over a 22 m bay length) was measured between Marks A12 and A13, coinciding with a vertical bump in the subsidence profile and a hump in the road pavement. No impacts on the local gas pipelines were reported.

Tahmoor Coking Coal Operations Longwalls 24A to 28 have mined directly beneath the main 160 mm diameter PE pipeline, with no adverse impacts observed. As shown in Fig. 3.16, the pipeline has experienced compressive ground strains over 2 mm/m at four locations, of which three sites experienced ground strains more than 3 mm/m. No gas leaks have been detected at these locations. This includes the glued socket joints along the pipe. The experience of mining beneath Longwalls 24A to 28 provides confidence that the pipeline can accommodate typical mining-induced strains without adverse impacts, and protective works should not be necessary.

The gas pipelines may experience increased ground strains and upsidence related curvature at isolated locations during the mining of Longwall 32. Potential sites include where the pipelines cross creeks, or where the pipelines cross over mapped geological structures associated with the Nepean Fault, as discussed in Section 3.5.

While no adverse impacts to the gas pipelines have been experienced to date, most vulnerable elements of the system are considered to be the rigid copper pipe connections between the gas mains and properties, joints in the nylon pipes at T-intersections. However, there are only a short section of the local gas pipeline located directly above Longwall 32 and, hence, there is a limit number of rigid copper pipe connections. Another potentially vulnerable element is the reducing adapter joint on Bridge Street, where the 160 mm PE pipeline reduces to a 32 mm nylon pipe.

Tahmoor Coking Coal Operations has developed and selected risk control measures in consultation, co-ordination and cooperation with Jemena in accordance with WHS legislation. The controls have been implemented during the mining of Longwalls 22 to 31. In this instance, there are no reasonably practicable controls which could eliminate, substitute or isolate the identified risks, nor engineering controls that could put in place a structure or item that prevents or minimises risks. Tahmoor Coking Coal Operations has identified controls that will manage potential issues associated with damage to pipelines resulting in gas leaks during the extraction of Longwall 32 by implementing the following measures.

- Pre-mining gas detection survey of gas pipelines potentially affected by the extraction of Longwall 32
- Regular ground surveys along streets located within the active subsidence zone
- Regular visual inspections along streets located within the active subsidence zone
- Regular consultation with the community to report potential impacts. As the gas has been odourised, the community are more likely to report gas leaks if they occur.
- Additional inspections and gas patrols by Jemena if triggered by observations of increased ground strains, ground curvature or localised surface deformations
- Exposing pipeline to relieve it of stress if triggered by monitoring results
- In the worst case, repair of damaged pipeline by temporary squeezing off the pipeline, and replacing the damaged section.

Specific potential issues for the gas pipeline along Remembrance Drive are described in the following sections.

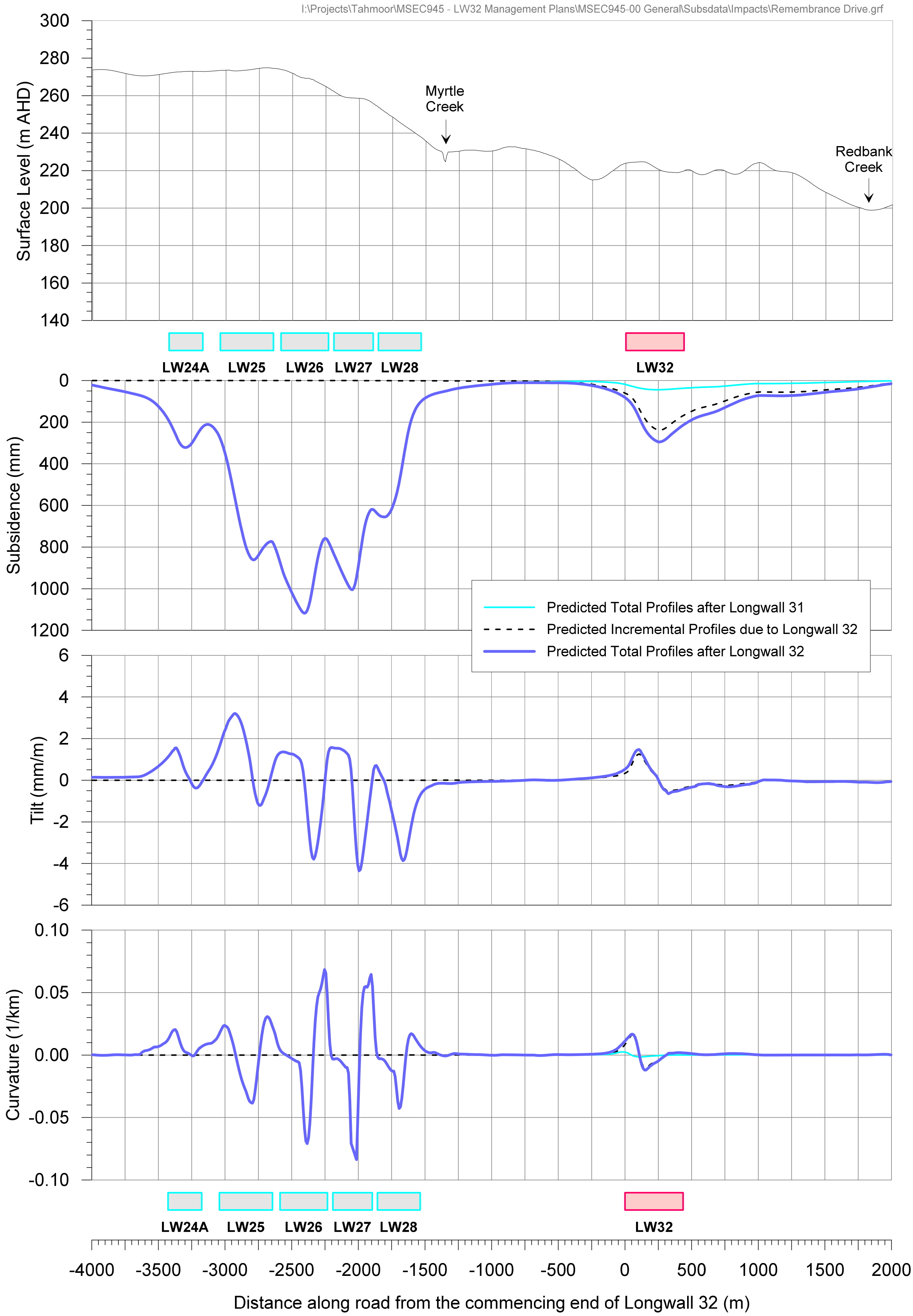

Fig. 3.14 Predicted profiles of total subsidence, tilt and curvature for the main 160 mm diameter PE gas pipeline along Remembrance Drive due to the mining of Longwalls 22 to 32

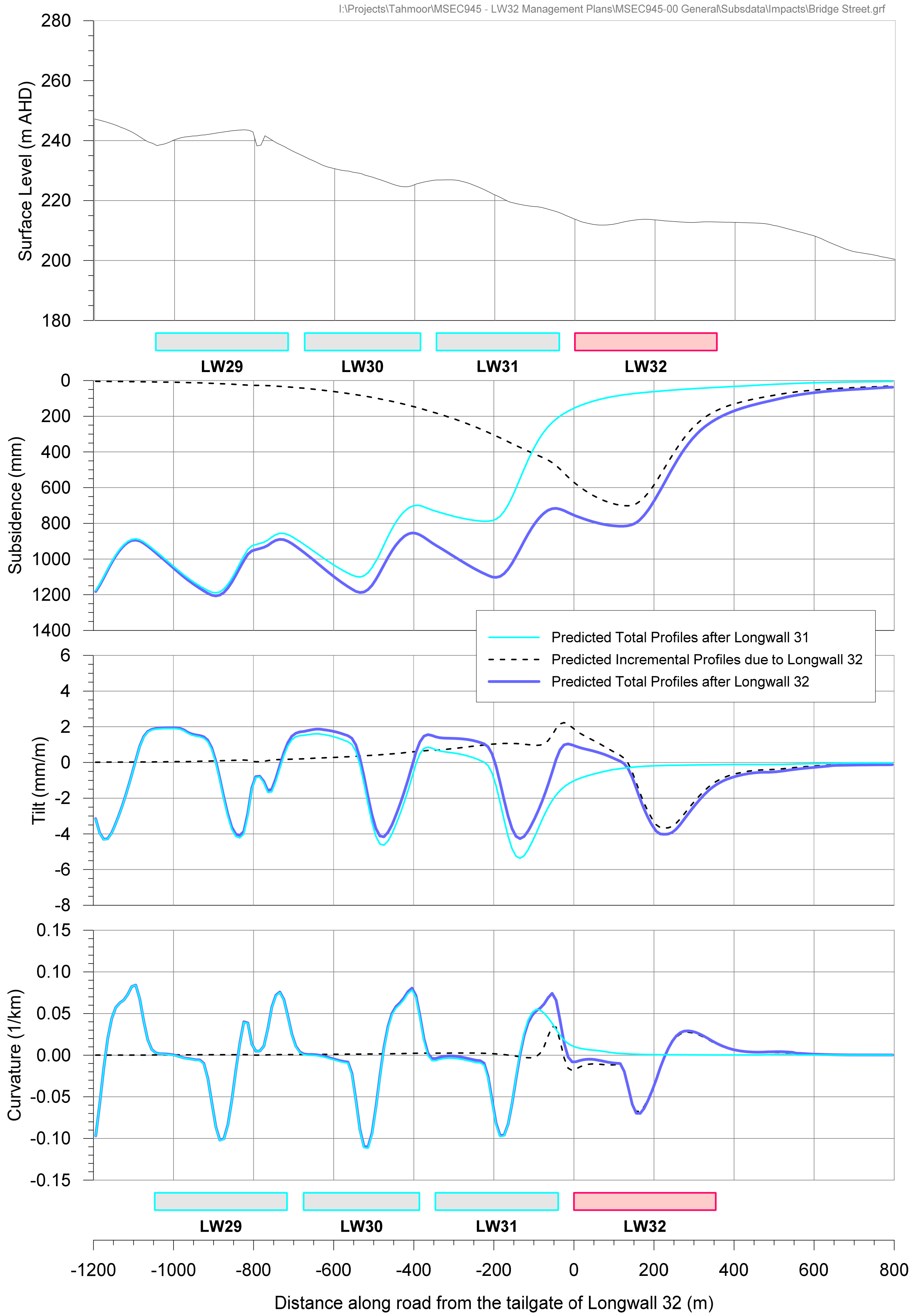

Fig. 3.15 Predicted profiles of total subsidence, tilt and curvature for the main 160 mm diameter PE and local 32 mm diameter NY gas pipelines along Bridge Street due to the mining of Longwalls 22 to 32

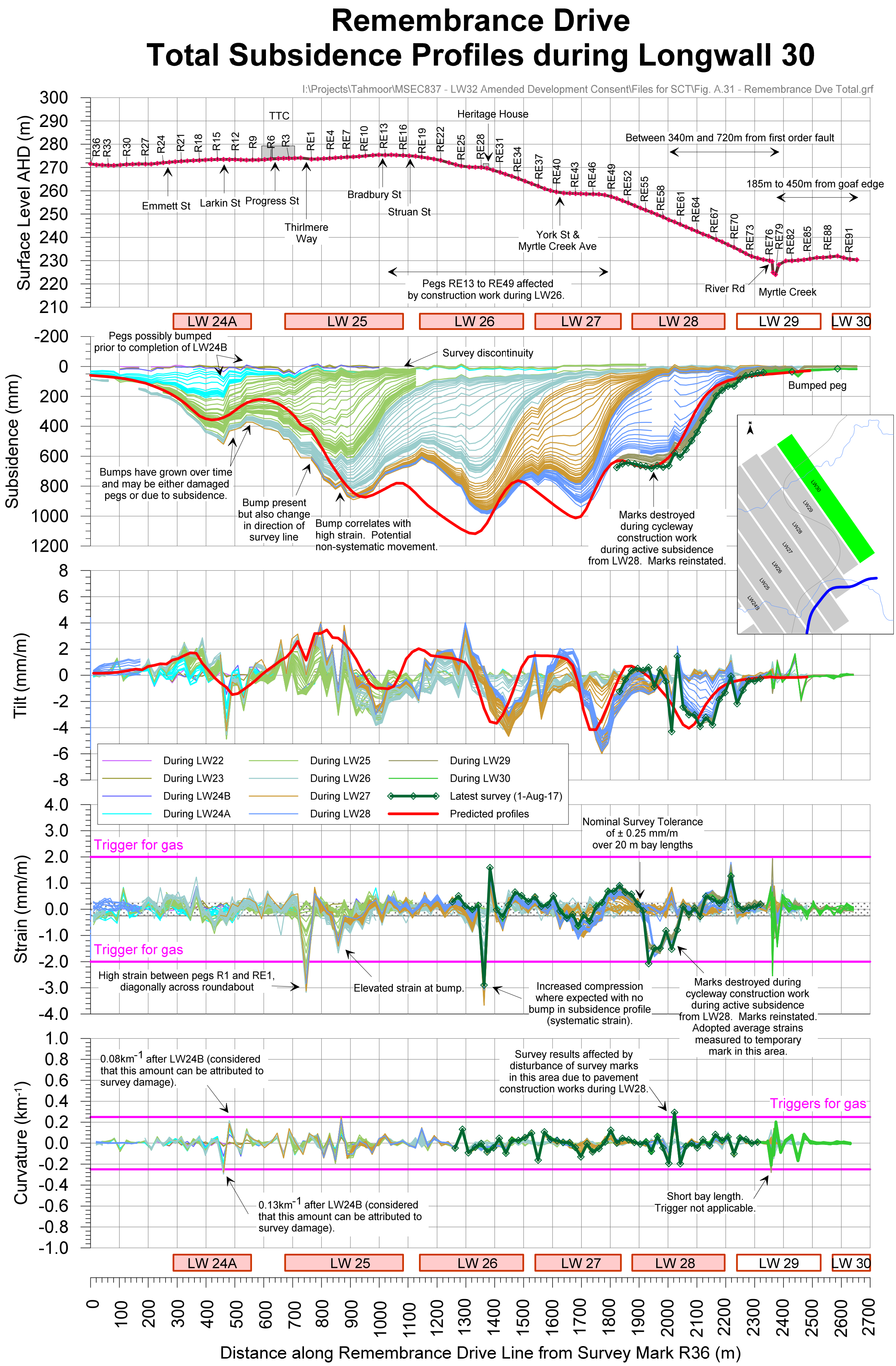

Fig. 3.16 Observed total subsidence profiles along the Remembrance Drive Line during the mining of Longwalls 24A to 30

3.9.3. Remembrance Drive

As shown in Drawing No. MSEC945-05-01, the gas pipeline along Remembrance Drive is located directly beneath the commencing end of Longwall 32. A study of past experiences at the commencement of previously extracted longwalls at Tahmoor Coking Coal Operations and other mines in the Southern Coalfield at similar depths of cover have shown that subsidence develops gradually after approximately 100 metres of extraction. The experiences include extensive and frequent surveys that have been undertaken at the commencements of Longwalls 24B, 26, 29 and 30.

In the case of Longwall 30, a specific survey line was installed to monitor the initial subsidence above the commencing end and the results, showing the gradual development of subsidence, are shown in Fig. 3.17 and Fig. 3.18.

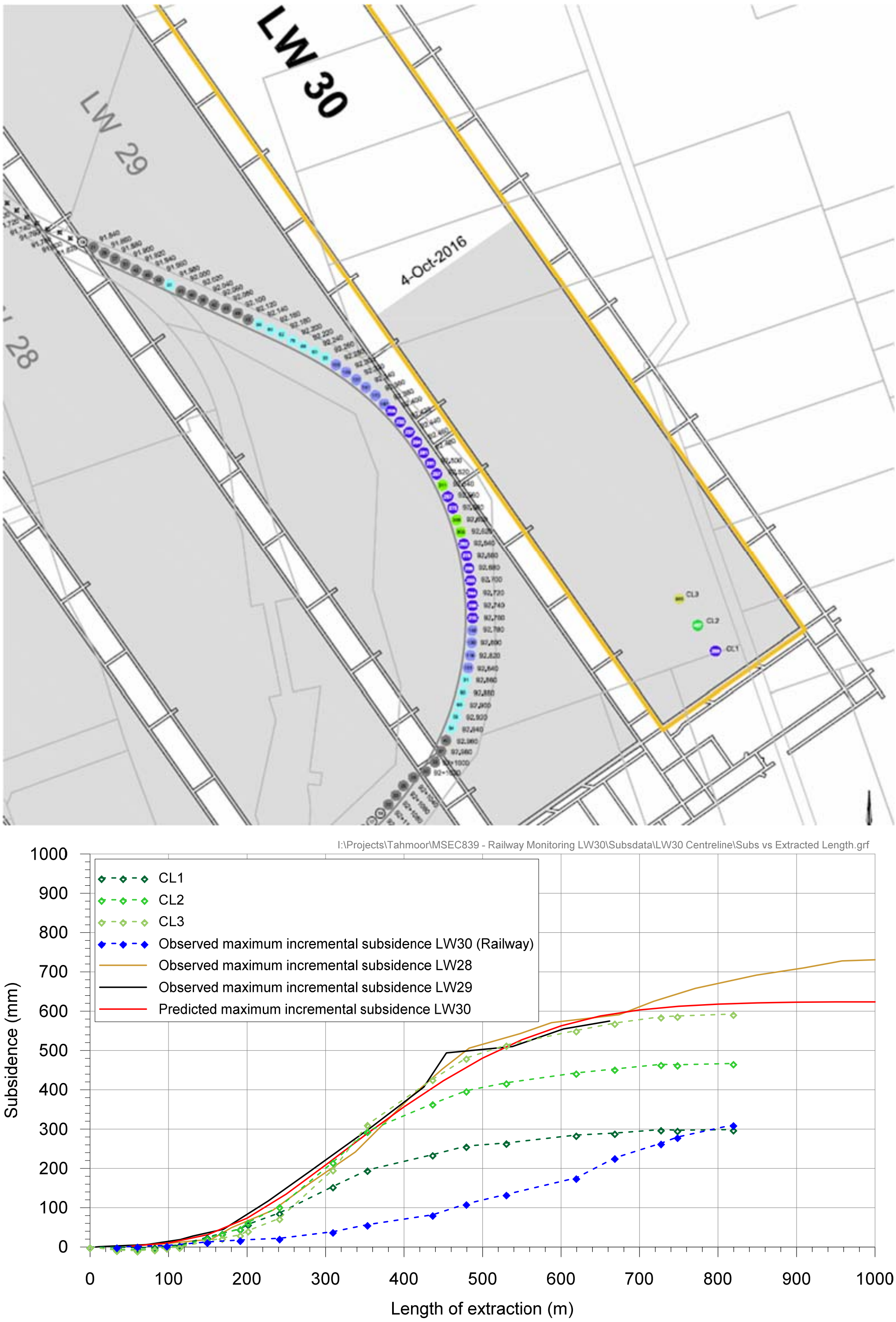

Fig. 3.17 Observed development of initial subsidence above Tahmoor Coking Coal Operations' Longwalls 28 to 30 relative to length of extraction

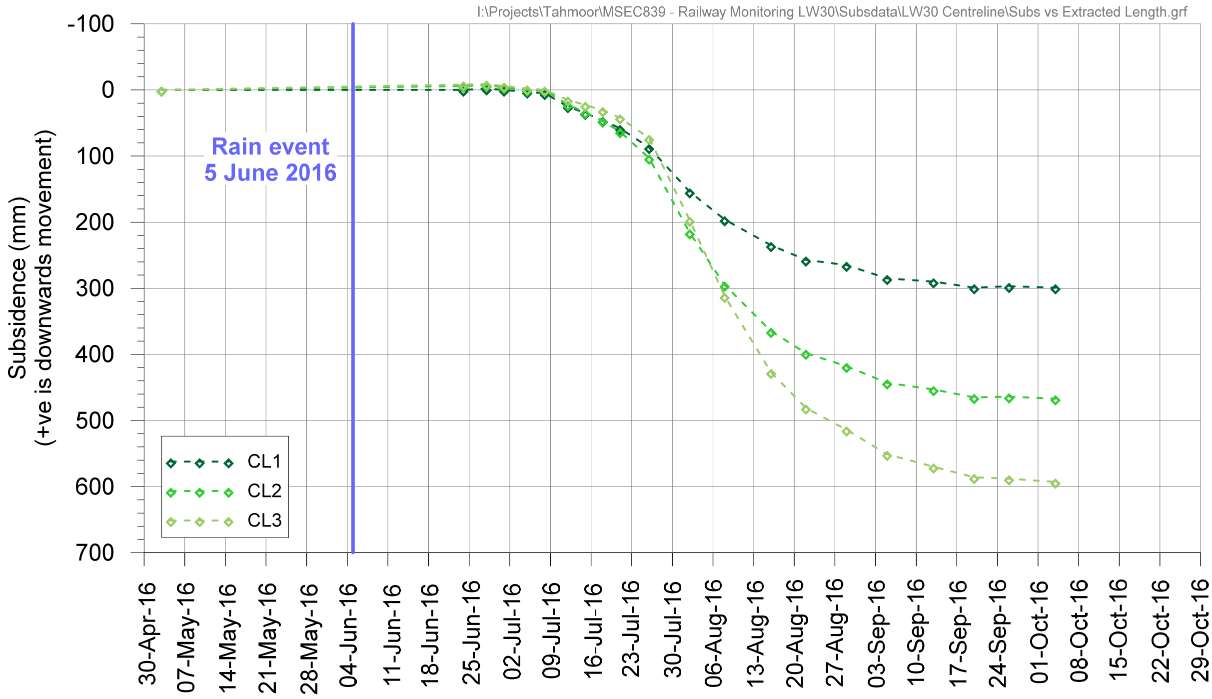

Fig. 3.18 Observed development of subsidence above the commencing end of LW 30 over time

While not supported by observations at Tahmoor Coking Coal Operations to date, it is possible, through very unlikely, that the overburden directly above the commencement end of Longwall 32 could bridge the void that initially forms after mining commences, such that initial subsidence is delayed. A potential issue could arise in this scenario in that once the overburden collapses into the void, subsidence movements could develop at a faster rate than normal and if the differential movements were adverse in nature, impacts could develop rapidly on the pipeline along Remembrance Drive.

Tahmoor Coking Coal Operations has developed and selected risk control measures in consultation, co-ordination and cooperation with Jemena in accordance with WHS legislation. In this instance, there are no reasonably practicable controls which could eliminate, substitute or isolate the identified risks, nor engineering controls that could put in place a structure or item that prevents or minimises risks. Tahmoor Coking Coal Operations has identified controls that will manage potential issues associated with delayed, adverse subsidence movements during the initial stages of extraction of Longwall 32 by implementing the following measures.

- Commencement of weekly ground surveys and visual inspections along Remembrance Drive immediately upon commencement of Longwall 32.
- Report on underground caving conditions
- In the unlikely event that subsidence movements are delayed during the early stages of extraction of Longwall 32, additional management measures may be implemented including an increase in monitoring and reporting, gas detection monitoring, provision of labour, equipment and materials on site to respond if adverse movements develop.

Tahmoor Coking Coal Operations has investigated and confirmed that the measures are feasible and effective for the site-specific conditions during the extraction of Longwall 32.

3.9.4. Pipe crossing over Remembrance Drive Road Bridge over Redbank Creek

Remembrance Drive Road Bridge over Redbank Creek is located approximately 350 metres to the eastern side of Longwall 32. The road bridge is a two lane, reinforced precast concrete arch structure, of BEBO arch design, with precast concrete spandrel walls. The bridge is a clear single span of approximately 9 metres. The bridge surface is sealed with asphalt, and there is a steel guardrail crash barrier on each side. Photographs of the road bridge are provided in Fig. 3.19 and Fig. 3.20.

As shown in Fig. 3.21, which is an extract from Jemena's as-built network map (Ref. Mowbray Park Map 9D), the pipeline runs along the western side of the bridge, buried beneath the road surface in the soil that was backfilled over the brick arch. A marked-up image of the approximate location of the pipeline is shown in Fig. 3.22.

Photograph courtesy JMA Solutions

Fig. 3.19 Remembrance Drive Road Bridge over Redbank Creek (RE-B1)

Photograph courtesy JMA Solutions

Fig. 3.20 Precast concrete arches supporting Remembrance Drive Road Bridge over Redbank Creek (RE-B1)

Plan courtesy Jemena

Fig. 3.21 Extract of Jemena Network Map – Map Mowbray Park 9D in Network Area 887, Wollondilly Municipality Area

Image courtesy Google Streetview

Fig. 3.22 Approximate location of buried gas pipeline on western side of Remembrance Drive Road Bridge over Redbank Creek

The maximum predicted values of total conventional subsidence, tilt and curvature for the Remembrance Drive Bridge over Redbank Creek (RE-B1), after the extraction of each of the proposed longwalls, is provided in Table 3.5. The values provided in this table are the maximum predicted parameters within a 20 metre radius of the bridges.

Table 3.5 Maximum Predicted Total Conventional Subsidence, Tilt and Curvature at the Remembrance Drive Road Bridge over Redbank Creek

Location	Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (1/km)	Maximum Predicted Sagging Curvature (1/km)
Remembrance Drive Road (RE-B1) and Pedestrian Bridges over Redbank Creek	After LW31	< 20	< 0.5	< 0.01	< 0.01
	After LW32	35	< 0.5	< 0.01	< 0.01

The Remembrance Drive road and pedestrian bridges over Redbank Creek could also experience valley related movements. The maximum predicted valley related movements at the bridges, after the completion of Longwall 32, are 20 mm upsidence and 20 mm closure.

JMA (2018) has analysed potential effects due to conventional and non-conventional subsidence movements on the road bridge. The BEBO arch design of the road bridge will allow the road bridge to accommodate valley closure movements in a ductile manner. The bridge may bow upwards by approximately 10 mm in response to 20 mm closure across the arch. Whilst the reinforced concrete arch may experience concrete compression spalling near 1/3 span in response to valley closure, JMA (2018) expects the bridge to remain serviceable. Concrete cracking or spalling can be repaired if they occur.

In light of the above, Tahmoor Coking Coal Operations has developed and selected risk control measures in consultation, co-ordination and cooperation with Wollondilly Shire Council in accordance with WHS legislation. In this instance, there are no reasonably practicable controls which could eliminate, substitute or isolate the identified risks, nor engineering controls that could put in place a structure or item that prevents or minimises risks. The controls are consistent with recommendations provided by the structural engineer.

Prior to the influence of Longwall 32:

- Install and baseline measure survey marks in local 3D at the base of the road bridge arch above the water line on both sides and on top of the bridge deck on both sides at mid-span.
- Install and baseline measure survey marks in local 3D placed along the top of the spandrel walls on both sides of the bridge at abutments and mid-span.
- Baseline measure tilt of the precast concrete wingwalls at mid-length and at the ends of the wingwalls.

Whilst the bridge is within the area of active subsidence due to the extraction of Longwall 32

- Conduct weekly surveys along Remembrance Drive, which cross over the Bridge
- Conduct weekly local 3D surveys of the four survey marks at the base of the arch.
- Undertake visual inspections of the bridge, including the arch, spandrel walls, wingwalls and approaching road pavement.
- Conduct additional surveys and/or inspections, if triggered by monitoring results.
- Repair of bridge in the unlikely event that damage is observed.

Jemena will be kept informed of any impacts on the road bridge and any planned repair works. In the unlikely event that the bridge and pipeline experiences increased compressive ground strains, the pipeline will be inspected by Jemena with gas detection monitors. In the unlikely event that repairs are required to be undertaken on the pipeline, it will be possible to excavate and expose the pipeline within the backfilled material above the bridge and repair the pipeline.

4.1. Infrastructure Management Group (SRG)

The Infrastructure Management Group (IMG) is responsible for taking the necessary actions required to manage the risks that are identified from monitoring the infrastructure and to ensure that the health and safety of people who may be present on public property or Jemena property are not put at risk due to mine subsidence. The IMG develops and reviews this management plan, collects and analyses monitoring results, determines potential impacts and provides advice regarding appropriate actions. The members of the IMG are highlighted in Chapter 8.0

4.2. Development and Selection of Risk Control Measures

Tahmoor Coking Coal Operations has developed and selected risk control measures in consultation, co-ordination and co-operation with the landowner in accordance with WHS legislation. In accordance with Clauses 35 and 36 in Part 3.1 of the Work Health and Safety regulation (2017) and the guidelines (MSO, 2017), a hierarchy of control measures has been considered and selected where reasonably practicable, using the following process:

1. Eliminate risks to health and safety so far as is reasonably practicable, and
2. If it is not reasonably practicable to eliminate risks to health and safety – minimise those risks so far as is reasonably practicable, by doing one or more of the following:
   (a) substituting (wholly or partly) the hazard giving rise to the risk with something that gives rise to a lesser risk
   (b) isolating the hazard from any person exposed to it,
   (c) implementing engineering controls.
3. If a risk then remains, minimise the remaining risk, so far as is reasonably practicable, by implementing administrative controls.
4. If a risk then remains, the duty holder must minimise the remaining risk, so far as is reasonably practicable, by ensuring the provision and use of suitable personal protective equipment.

A combination of the controls set out in this clause may be used to minimise risks, so far as is reasonably practicable, if a single control is not sufficient for the purpose.

There are primarily two different methods to control the risks of subsidence, namely:

Method A – Selection of risk control measures to be implemented prior to the development of subsidence, (Items 1 and 2 above), and

Method B – Selection of risk control measures to be implemented during the development of subsidence (Items 3 and 4 above).

Method A risk control measures are described in Section **Error! Reference source not found.**.

Method B risk control measures are described in Section 4.4 to Section 4.6. Prior to selecting Method B risk control measures, Tahmoor Coking Coal Operations has investigated and confirmed that the measures are feasible and effective for the site-specific conditions during the extraction of Longwall 32.

4.3. Selection of Risk Control Measures for Gas Infrastructure

Based on its own assessments, and the assessments by the structural engineer with respect to the bridge, Tahmoor Coking Coal Operations considered Method A risk control measures, in accordance with the process described in Section 4.2.

Elimination

In this instance, no reasonably practicable controls could be identified that would eliminate the identified risks.

Substitution

In this instance, no reasonably practicable controls could be identified that will change the environment so the hazards could be substituted for hazards with a lesser risk.

Isolation

In this instance, no reasonably practicable controls could be identified to isolate a hazard from any person exposed to it.

Engineering Controls

In this instance, no reasonably practicable engineering controls could be identified to put in place a structure or item that prevents or minimises risks.

Administrative Controls

The following Administrative Controls were identified and selected that will put in place procedures on site to minimise the potential of impacts on the safety of people travelling along Thirlmere Way.

- Implementation of a Monitoring Plan and Trigger Action Response Plan (TARP)
  As described in the Management Plan, Tahmoor Coking Coal Operations and Jemena has developed and implemented a management strategy of detecting early the development of potential adverse subsidence movements in the ground, so that contingency response measures can be implemented before impacts on the safety and serviceability develop. The TARP includes the following:
  - Pre-mining gas detection survey within the area potentially affected by the extraction of Longwall 32.
  - Local 2D surveys along local roads as shown in Drawing No. MSEC945-00-01. These include streets along which gas pipelines are located, including Remembrance Drive, Bridge Street, Henry Street, Wood Street and Coachwood Crescent.
  - Visual inspections along the streets within the active subsidence zone.
  - Surveys and visual inspections of Remembrance Drive Road Bridge over Redbank Creek.
  - Regular consultation with the community to report potential impacts. As the gas has been odourised, the community are more likely to report gas leaks if they occur.
  - Additional surveys and/or inspections, if triggered by monitoring results.
  - Gas detection patrols, if triggered by monitoring results.
  - In the unlikely event that subsidence movements are delayed during the early stages of extraction of Longwall 32, additional management measures may be implemented along Remembrance Drive, including an increase in monitoring and reporting, provision of labour, equipment and materials on site to respond if adverse movements develop.
  - Additional inspections and gas patrols by Jemena if triggered by observations of increased ground strains, ground curvature or localised surface deformations
  - Exposing pipeline to relieve it of stress if triggered by monitoring results
  - In the worst case, repair of damaged pipeline by temporary squeezing off the pipeline, and replacing the damaged section.

4.4. Monitoring Measures

A number of monitoring measures will be undertaken during mining.

4.4.1. Ground Surveys along streets

Survey marks have been placed along streets within the urban area above and adjacent to Longwall 32., as shown in Drawing No. MSEC945-00-01. The survey pegs will be surveyed during the period of active subsidence of these features during the extraction of Longwall 32.

The surveys measure changes in height and changes in horizontal distances between adjacent pegs.

4.4.2. Remembrance Drive Bridge over Redbank Creek

Prior to the influence of Longwall 32:

- Install and baseline measure survey marks in local 3D at the base of the road bridge arch above the water line on both sides and on top of the bridge deck on both sides at mid-span.
- Install and baseline measure survey marks in local 3D placed along the top of the spandrel walls on both sides of the bridge at abutments and mid-span.
- Baseline measure tilt of the precast concrete wingwalls at mid-length and at the ends of the wingwalls.

Whilst the bridge is within the area of active subsidence due to the extraction of Longwall 32

- Conduct weekly surveys along Remembrance Drive, which cross over the Bridge
- Conduct weekly local 3D surveys of the four survey marks at the base of the arch.
- Undertake visual inspections of the bridge, including the arch, spandrel walls, wingwalls and approaching road pavement.

4.4.3. Visual Inspections

Visual inspections will be undertaken during the period of active subsidence by an experienced inspector appointed by Tahmoor Coking Coal Operations who is familiar with mine subsidence impacts. The inspector will undertake the following:

- Visual inspections along streets within the active subsidence zone.
- Visual inspections of roads at creek crossings.

4.4.4. Structural Inspections

Structural inspections will be undertaken of the Remembrance Drive Bridge over Redbank Creek by John Matheson if required by the SRG.

4.4.5. Jemena Gas Patrols

Prior to the commencement of Longwall 32, Tahmoor Coking Coal Operations has completed a pre-mining gas detection survey of gas pipelines potentially affected by the extraction of Longwall 32, including pipelines along Remembrance Drive, Bridge Street, Henry Street, Wood Street and Coachwood Crescent. Macarthur Gas confirmed no gas leakages were detected. Additional gas detection surveys can be undertaken if triggered by monitoring results.

4.4.6. Changes to Monitoring Frequencies

Monitoring frequencies will continue while Jemena infrastructure is experiencing active subsidence due to the extraction of Longwall 32. As a general guide, monitoring is likely to continue until the longwall has moved away from a site by a distance of approximately 450 metres. Monitoring, however, may continue if ongoing adverse impacts are observed.

4.5. Triggers and Responses

Trigger levels have been developed by Tahmoor Coking Coal Operations based on engineering assessments and consultation with Jemena.

Trigger levels for each monitoring parameter are described in the risk control procedures in Table 4.1.

Immediate responses, if triggered by monitoring results, may include:

- Increase in survey and inspection frequencies if required by the IMG.
- Additional surveys and inspections.
- Exposing pipeline to relieve it of stress
- Repair of impacts that create a serious public safety hazard.
- In the worst case, restriction on entry, or access to, Jemena infrastructure.

The risk control measures described in this Management Plan have been developed to ensure that the health and safety of people in the vicinity of Jemena infrastructure are not put at risk due to mine subsidence. It is also an objective to avoid disruption to services, or if unavoidable, keep disruption and inconvenience to minimal levels.

With respect to the extraction of Longwall 32, no potential hazards have been identified that could reasonably give rise to the need for an emergency response. Of the potential hazards identified in Section 3.9, only a gas leak could possibly experience severe impacts that could give rise to the need for an emergency response. The likelihood is considered extremely remote and would require substantial differential subsidence movements to develop before such an event occurs.

As discussed in Section 3.1, mine subsidence movements will develop gradually and there will be ample time to identify the development of potentially adverse differential subsidence movements early, consider whether any additional management measures are required, and repair or adjust affected surface features, in close consultation with Jemena. Regular consultation with the community is important. As the gas has been odourised, the community are more likely to report gas leaks if they occur.

As documented in Section 4.6, Tahmoor Coking Coal Operations and the IMG will review and assess monitoring reports and consider whether any additional management measures are required on a weekly basis. If potentially adverse differential subsidence movements are detected, it is anticipated that a focussed inspection will be undertaken in the affected area, and a decision will likely be made to increase the frequency of surveys and/or inspections. Additional management measures may also be implemented. It is therefore expected that, as a potential adverse situation escalates, Tahmoor Coking Coal Operations will be present on site on a more frequent basis to survey or inspect the affected site, and that Jemena will be consulted on a more frequent basis.

Notwithstanding the above, if a hazard has been identified that involves potential serious injury or illness to a person or persons on public property or in the vicinity of Jemena infrastructure, and cannot be controlled, the immediate response is to remove people from the hazard. If such a situation is observed or is forecast to occur by either Tahmoor Coking Coal Operations or by people on public property, Tahmoor Coking Coal Operations and Jemena will immediately meet and implement emergency procedures.

4.6. Subsidence Impact Management Procedures

The procedures for the management of potential impacts to the property are provided in Table 4.1.

Table 4.1 Risk Control Procedures during the extraction of Tahmoor Coking Coal Operations Longwall 32

Level	Control measures	Frequency	Analysis	Trigger level	Action
1	<u>Ground inspections:</u> - 2D survey - ground inspection	<u>Ground surveys by Tahmoor Coking Coal Operations:</u> Weekly surveys along Remembrance Drive from commencement of LW32. *Initial extent from Survey Peg RD1 to Peg RD32 and then extend to the north to include pegs within the active subsidence zone. After 800 m of extraction, reduce extent to the south beyond active subsidence zone unless ongoing adverse movements are observed* Weekly surveys along Bridge Street, Henry Street, Wood Street, Coachwood Crescent and Remembrance Drive Bridge over Redbank Creek when within active subsidence zone <u>Ground inspections by Tahmoor Coking Coal Operations</u>: Weekly inspection including at the hidden creek crossings and intersections with mapped geological structures within the active subsidence zone	Tahmoor Coking Coal Operations surveys and provides Jemena with - ground surveys - ground movements / features reports	<u>Ground movement survey and measurements</u>: * Radius of ground curvature greater than 4 (km) * Ground strain 0 to 2 (mm/m) * Ground movements rate of change steady <u>Ground conditions monitoring:</u> - ground cracks reported - ground subsidence reported __________ - ground movements showing a <u>step change</u> indicating shear and / or <u>discontinuity</u> in humps near the gas services	Go to LEVEL 2 if LEVEL 1 limit is exceeded: * normal ground patrol by Jemena pipeline officer Jemena actions following receipt of reported incidents: inspects site to confirm operation of gas facilities not affected Assess potential for impacts on pipe crossings due to valley closure, or repairs to Remembrance Drive Road Bridge over Redbank Creek. Consider trigger level for Level 2. __________ * undertake additional inspection e.g. exposing and inspecting gas service as applicable to determine gas facilities integrity *based on above findings, undertake corrective action per Level 3 activities where gas services integrity affected
	<u>Ground subsidence validations:</u> - Observed against predictions	On receipt of data: verify and track results against predictions	MSEC analyses and reports findings to stakeholders		
	<u>Baseline Gas Detection Survey</u>: (Prior to start of LW32 - complete) Undertake a pre-mining gas detection survey of pipes within the area potentially affected by the extraction of Longwall 32 (complete).		Jemena reviews: - 2D ground surveys report - pipe integrity - ground conditions report		
2	<u>Ground inspections:</u> - 2D survey - ground inspection - structural inspection of Remembrance Drive Bridge over Redbank Creek	Submit data within 24 hours duration Twice weekly 2D survey	Tahmoor Coking Coal Operations surveys and provides Jemena with - ground surveys - ground movements / features reports	<u>Ground movement survey and measurements</u>: * Radius of ground curvature 2 to 4 (km) * Ground strain 2 to 5 (mm/m) * Ground movements rate of change increasing with increasing upward trend * Subsidence is delayed (such as subsidence not developing within expectations, and/or reports of no caving underground) <u>Ground conditions monitoring:</u> - ground cracks reported - ground subsidence reported - impacts observed on Remembrance Drive Road Bridge over Redbank Creek __________ - ground movements showing a <u>step change</u> indicating shear and / or <u>discontinuity</u> in humps near the gas services	Go to LEVEL 3 if LEVEL 2 limit is reached: * weekly ground patrol by Jemena pipeline officer Jemena actions following receipt of reported incidents: inspects site to confirm operation of gas facilities not affected Jemena reviews planned minor emergency repair works on Remembrance Drive Road Bridge over Redbank Creek __________ * based on above findings, undertake corrective action per Level 3 activities where gas services integrity affected * if no immediate corrective actions required, Jemena may put field construction on standby
	<u>Ground subsidence validations:</u> - Observed against predictions	Twice weekly: verify and track results against predictions	MSEC analyses and reports findings to stakeholders		
			Jemena reviews: - 2D ground surveys report - pipe integrity - ground conditions report		
3	<u>Ground inspections:</u> - 2D survey - ground inspection - structural inspection of Remembrance Drive Bridge over Redbank Creek	Submit data within 24 hours duration Daily 2D survey	Tahmoor Coking Coal Operations surveys and provides Jemena with - ground surveys - ground movements / features reports	<u>Ground movement survey and measurements</u>: * Radius of ground curvature less than 2 (km) * Ground strain greater than 5 (mm/m) * ground movements showing a <u>step change</u> indicating shear and / or <u>discontinuity</u> in humps near the gas services.	Jemena's field corrective actions: - mobilisation construction in the field - excavate affected area - inspect gas facilities to confirm integrity - repair and / or replace gas services as applicable to maintain supply and safe operation
	<u>Ground subsidence validations:</u> - Observed against predictions	Daily: verify and track results against predictions	MSEC analyses and reports findings to stakeholders		
			Jemena reviews: - 2D ground surveys report - pipe integrity - ground conditions report (as applicable)		

5.1. Consultation, Co-operation and Co-ordination

Substantial consultation, co-operation and co-ordination has taken place between Tahmoor Coking Coal Operations and Jemena prior to the development of this Management Plan, as detailed in Section 1.3.1.

The following procedures will be implemented during and after active subsidence of the property to ensure the continued effective consultation, co-operation and co-ordination of action with respect to subsidence between Tahmoor Coking Coal Operations and Jemena.

- Reporting of observed impacts to Tahmoor Coking Coal Operations either during the weekly visual inspection or at any time directly to Tahmoor Coking Coal Operations.
- Distribution of monitoring reports, which will provide the following information on a weekly basis during active subsidence:
    - Position of longwall
    - Summary of management actions since last report;
    - Summary of consultation with Jemena since last report;
    - Summary of observed or reported impacts, incidents, service difficulties, complaints;
    - Summary of subsidence development;
    - Summary of adequacy, quality and effectiveness of management process;
    - Any additional and/or outstanding management actions; and
    - Forecast whether there will be any subsidence impacts to the health and safety of people due to the continued extraction of Longwall 32.
- Convening of meetings between Tahmoor Coking Coal Operations and Jemena at any time as required, as discussed in Section 5.2.
- Arrangements to facilitate timely repairs, if required.
- Immediate contact between Tahmoor Coking Coal Operations and Jemena if a mine subsidence induced hazard has been identified that involves potential serious injury or illness to a person or persons on public property or Jemena property and may require emergency evacuation, entry restriction or suspension of work activities.

5.2. IMG Meetings

The IMG undertakes reviews and, as necessary, revises and improves the risk control measures to manage risks to health and safety, and potential impacts to structures on the property.

The reviews are undertaken weekly during the period of active subsidence based on the results of the weekly surveys and visual inspections and summarised in the monitoring reports, as described in Section 5.1.

The purpose of the reviews are to:

- Detect changes, including the early detection of potential impacts on health and safety and impacts to Jemena infrastructure;
- Verify the risk assessments previously conducted;
- Ensuring the effectiveness and reliability of risk control measures; and
- Supporting continual improvement and change management.

IMG meetings may be held between Tahmoor Coking Coal Operations and Jemena for discussion and resolution of issues raised in the operation of the Management Plan. The frequency of IMG Meetings will be as agreed between Tahmoor Coking Coal Operations and Jemena.

IMG Meetings will discuss any incidents reported in relation to the relevant infrastructure, 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 mine subsidence impact is observed, any party may call an emergency IMG Meeting, with one day's notice, to discuss proposed actions and to keep other parties informed of developments in the monitoring of the infrastructure.

6.0 AUDIT AND REVIEW

This Management plan has been agreed between parties and can be reviewed and updated to continually improve the risk management systems based on audit, review and learnings from the development of subsidence during mining and manage changes in the nature, likelihood and consequence of subsidence hazards.

The review process will be conducted to achieve the following outcomes;

- Gain an improved understanding of subsidence hazards based on ongoing subsidence monitoring and reviews, additional investigations and assessments as necessary, ongoing verification of risk assessments previously conducted, ongoing verification of assumptions used during the subsidence hazard identification and risk assessment process, ongoing understanding of subsidence movements and identified geological structures at the mine.
- Revise risk control measures in response to an improved understanding of subsidence hazards
- Gain feedback from stakeholders in relation to managing risks, including regular input from business or property owners.
- Ensure on-going detection of early warnings of changes from the results of risk assessments to facilitate corrective or proactive management actions or the commencement of emergency procedures in a timely manner.
- Ensure timely implementation of a contingency plan in the event that the implemented risk control measures are not effective.

Some examples where review may be applied include.

- 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.

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

7.0 RECORD KEEPING

Tahmoor Coking Coal Operations will keep and distribute minutes of any IMG Meeting.

8.0 CONTACT LIST

Organisation	Contact	Phone	Email / Mail
Jemena Control Centre	Emergency Contact	131909	
Jemena Planning and Assessment Manager Networks	Graham Thomas	(02) 9867 7308 0402 060 415	Graham.Thomas@jemena.com.au
Jemena Senior Networks Engineer	Mustafa Karacanta*	(02) 9867 7181 0402 060 227	Mustafa.Karacanta@jemena.com.au
Jemena Networks Engineer	Andrew Walker*	(02) 9867 8346	Andrew.Walker@jemena.com.au
Jemena Pipeline Engineer Asset Strategy Gas	James Wu	-	james.wu@jemena.com.au
NSW Department of Planning and Environment – Resources Regulator	Phil Steuart	(02) 4063 6484	phil.steuart@planning.nsw.gov.au
	Gang Li	(02) 4063 6429 0409 227 986	gang.li@planning.nsw.gov.au
	Ray Ramage	(02) 4063 6485 0442 551 293	ray.ramage@planning.nsw.gov.au
Subsidence Advisory NSW	Matthew Montgomery	(02) 4677 1967 0425 275 564	matthew.montgomery@finance.nsw.gov.au
Mine Subsidence Engineering Consultants (MSEC)	Daryl Kay*	(02) 9413 3777 0416 191 304	daryl@minesubsidence.com
SIMEC Mining Tahmoor Coking Coal Operations Environment and Community Manager	Ron Bush	(02) 4640 0156 0437 266 998	Ron.Bush@glencore.com.au
SIMEC Mining Tahmoor Coking Coal Operations Environment and Community Officer	Belinda Clayton*	(02) 4640 0133 0436 331 630	Belinda.L.Clayton@glencore.com.au

* denotes member of Infrastructure Management Group

APPENDIX A. Drawings and Supporting Documentation

The following supporting documentation is provided in Appendix A.

Drawings

Drawing No.	***Description***	***Revision***
MSEC945-00-01	Monitoring over Longwall 32	E
MSEC945-05-01	Jemena Gas Pipelines	A

Supporting Documentation

Glencore (2014)	Glencore Coal Assets Australia Risk Management Matrix, Glencore, September 2014
Glencore (2018)	Environmental Risk Assessment: Tahmoor Underground – Longwall 32 Surface and Subsurface Infrastructure – Jemena Infrastructure, Tahmoor Coking Coal Operations, May 2018.
JMA (2018)	Structure Condition Report – Bridges over Redbank Creek, Remembrance Drive, Picton, JMA Solutions, Report No. R0521, May 2018
SCT (2018a)	Structure determinations of the Nepean Fault adjacent to Tahmoor Mine, SCT Operations, Report No. TAH4817, May 2018.
SCT (2018b)	Investigation into the Potential Impact of the Nepean Fault on Longwall 32 Subsidence, SCT Operations, Report No. TAH4821, May 2018.

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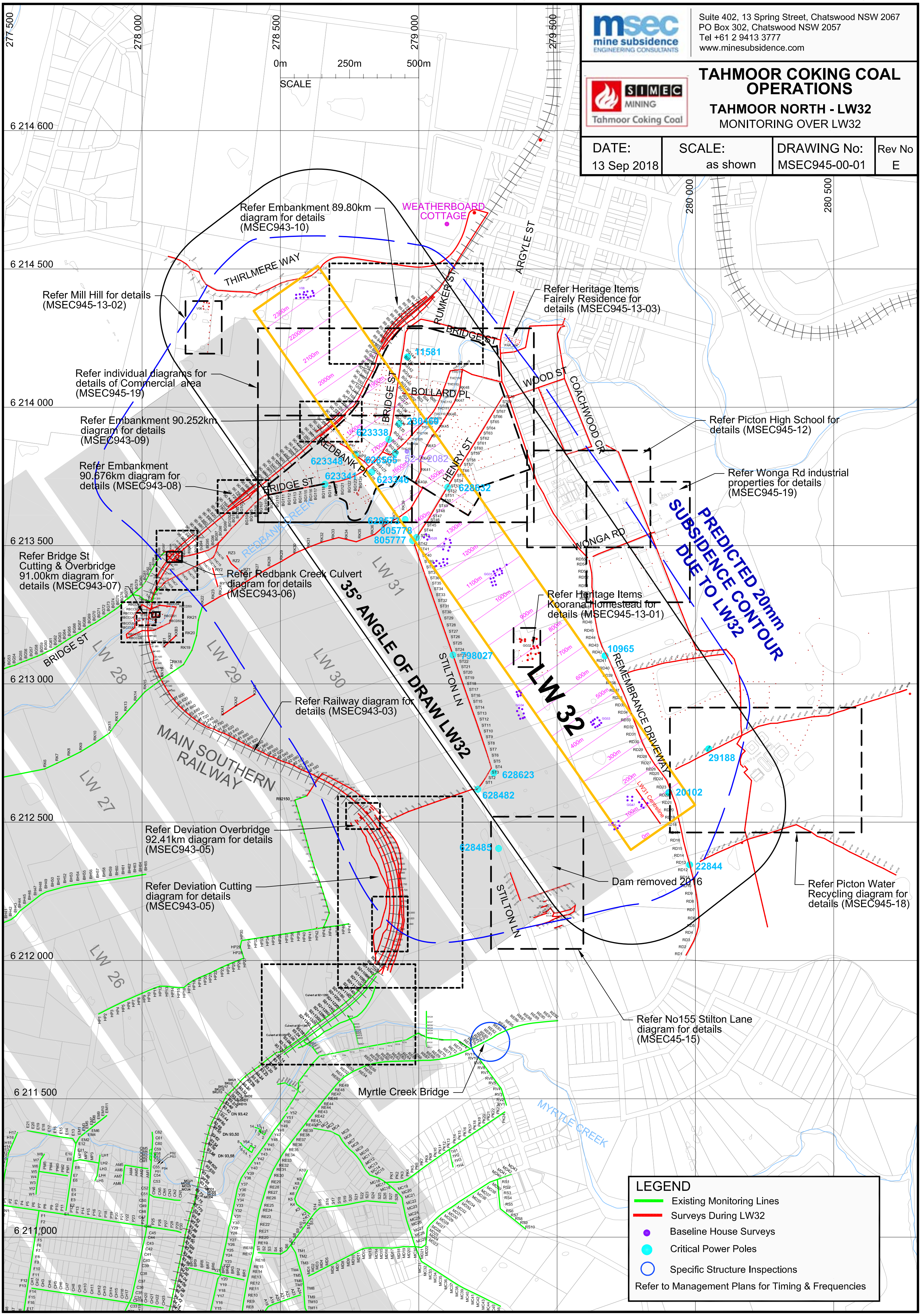

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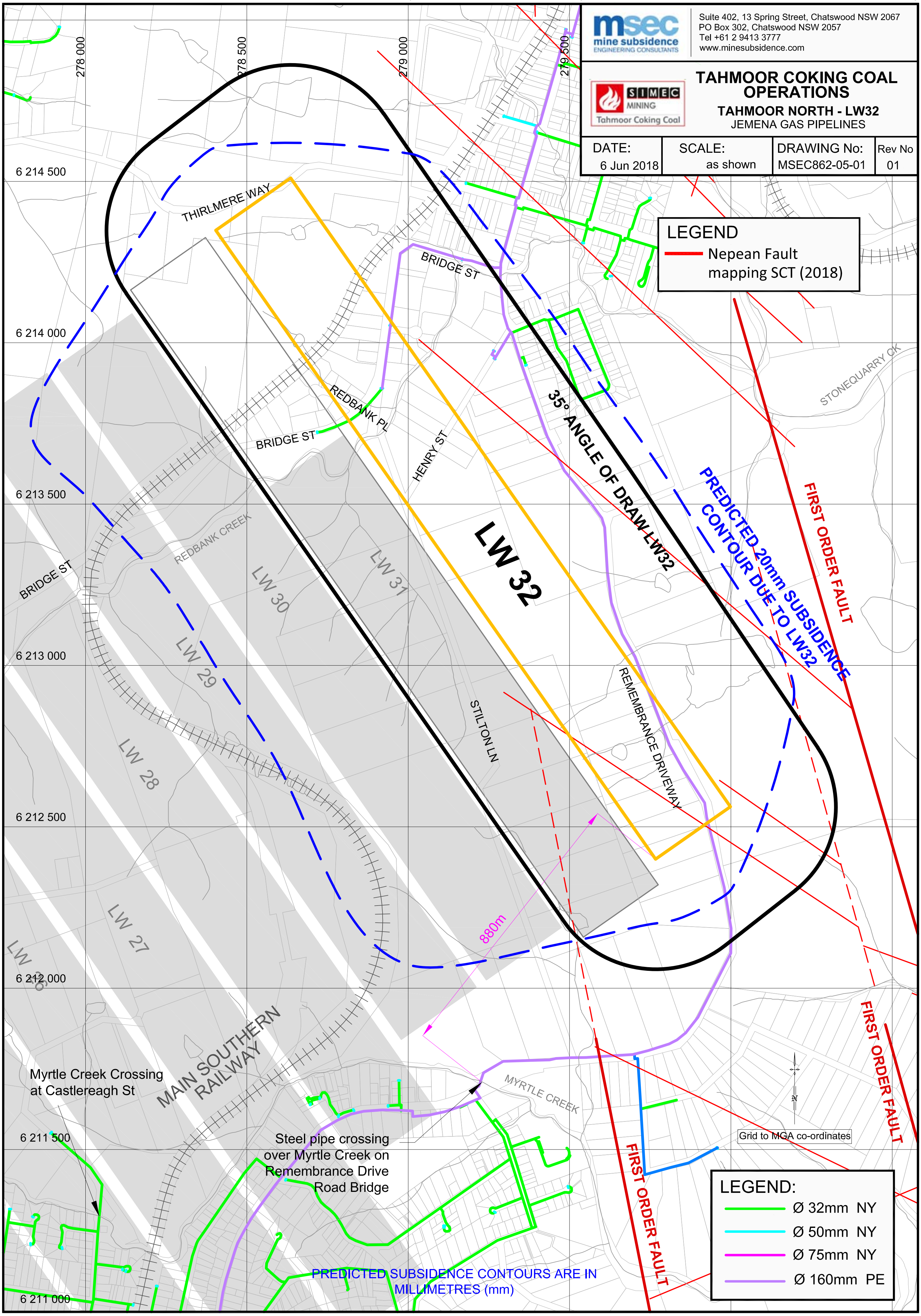

Appendix A - Glencore Coal Assets Australia Risk management Matrix

GLENCORE COAL ASSETS AUSTRALIA RISK MATRIX

CONSEQUENCE [potential foreseeable outcome of the event]

	Health & Safety	Environment	Financial Impact	Image & Reputation / Community	Legal & Compliance
5 Catastrophic	• Multiple fatalities • Multiple cases of permanent total disability / health effects	• Environmental damage or effect (permanent; >10 years) • Requires major remediation	• >$600M investment return • >$100M operating profit • >$20M property damage	• Negative media coverage at international level • Loss of multiple major customers or large proportion of sales contracts • Loss of community support • Significant negative impact on the share price	• Major litigation / prosecution at Glencore corporate level • Nationalisation / loss of licence to operate
4 Major	• Fatality or permanent incapacity / health effects	• Long-term (2 to 10 years) impact • Requires significant remediation	• $60-600M investment return • $20-100M operating profit • $2-20M property damage	• Negative media coverage at national level • Scrutiny from government and NGOs • Complaints from multiple "final" customers • Loss of major customer • Loss of community support • Negative impact on share price	• Major litigation / prosecution at Division level
3 Moderate	• Lost time / disabling injury / occupational health effects / multiple medical treatments	• Medium-term (<2 years) impact • Requires moderate remediation	• $6-60M investment return • $2-20M operating profit • $200K-2M property damage	• Negative media coverage at local / regional level over more than one day • Complaint from a "final" customer • Off-spec product • Community complaint resulting in social issue	• Major litigation / prosecution at Operation level
2 Minor	• Medical Treatment Injury (MTI) / occupational health effects • Restricted Work Injury (RWI)	• Short-term impact • Requires minor remediation	• $600K-6M investment return • $200K-2M operating profit • $10-200K property damage	• Complaint received from stakeholder or community • Negative local media coverage	• Regulation breaches resulting in fine or litigation
1 Negligible	• First Aid Injury (FAI) / illness	• No lasting environmental damage or effect • Requires minor or no remediation	• <$600K investment return • <$200K operating profit • <$10K property damage	• Negligible media coverage	• Regulation breaches without fine or litigation

LIKELIHOOD [of the event occurring with that consequence]

Basis of Rating	E - Rare	D - Unlikely	C - Possible	B - Likely	A – Almost Certain
LIFETIME OR PROJECT OR TRIAL OR FIXED TIME PERIOD OR NEW PROCESS / PLANT / R&D	Unlikely to occur during a lifetime OR Very unlikely to occur OR No known occurrences in broader worldwide industry	Could occur about once during a lifetime OR More likely NOT to occur than to occur OR Has occurred at least once in broader worldwide industry	Could occur more than once during a lifetime OR As likely to occur as not to occur OR Has occurred at least once in the mining / commodities trading industries	May occur about once per year OR More likely to occur than not occur OR Has occurred at least once within Glencore	May occur several times per year OR Expected to occur OR Has occurred several times within Glencore
5 Catastrophic	15 (M)	19 (H)	22 (H)	24 (H)	25 (H)
4 Major	10 (M)	14 (M)	18 (H)	21 (H)	23 (H)
3 Moderate	6 (L)	9 (M)	13 (M)	17 (H)	20 (H)
2 Minor	3 (L)	5 (L)	8 (M)	12 (M)	16 (M)
1 Negligible	1 (L)	2 (L)	4 (L)	7 (M)	11 (M)

Consequence Category	Consequence Type	Ownership	Action
Cat. 5	Catastrophic Hazard	Divisional / Functional / Operational / Asset Leadership	• Quantitative or semi-quantitative risk assessment required. • Capital expenditure will be justified to achieve ALARP ('As Low As Reasonably Practicable'). • Catastrophic Hazard Management Plans (CHMP) must be implemented where practical, Crisis Management Plans (CMP) tested and Catastrophic Event Recovery Plans (CERP) developed.
Cat. 4 (Health & Safety consequence)	Fatal Hazard	Divisional / Functional / Operational / Asset Leadership	• Glencore SafeWork Fatal Hazard Protocols or appropriate management plans must be applied. • Capital expenditure will be justified to achieve ALARP.
Risk Rank	**Risk Rating**	**Ownership**	**Action**
17 to 25	High Risk	Divisional / Functional / Operational / Asset Leadership	• Install additional HARD and SOFT controls to achieve ALARP. • Capital expenditure will be justified to achieve ALARP.
7 to 16	Medium Risk	Operational / Asset Leadership	• install additional HARD and SOFT controls if necessary to achieve ALARP. • Capital expenditure may be justified.
1 to 6	Low Risk	Operational / Asset Leadership	• Install additional controls if necessary to achieve ALARP. • Capital expenditure is not usually justified.

Table 3-3 - Risk Control Effectiveness (RCE)

RCE	Guide
Poor or no existing controls	• Significant control gaps or no credible control; • Either controls do not treat root causes, are non-existent or, if they exist, they are ineffective; • Management has no confidence that any degree of control is being achieved due to poor control design; • Very limited or no operational effectiveness.
Require improvement	• Most controls are designed correctly and are in place and effective; • Controls may only treat some of the root causes of the risk, and/or are not currently effective and/or there may be an over-reliance on “reactive” controls; • Management has doubts about operational effectiveness and reliability; • More work is required to improve operating effectiveness.
Satisfactory	• Controls are well designed and appropriate for the risk; • Controls are largely “preventative” and address the root causes; • Management believes that they are effective and reliable at all times; • Nothing more to be done except review and monitor the existing controls.

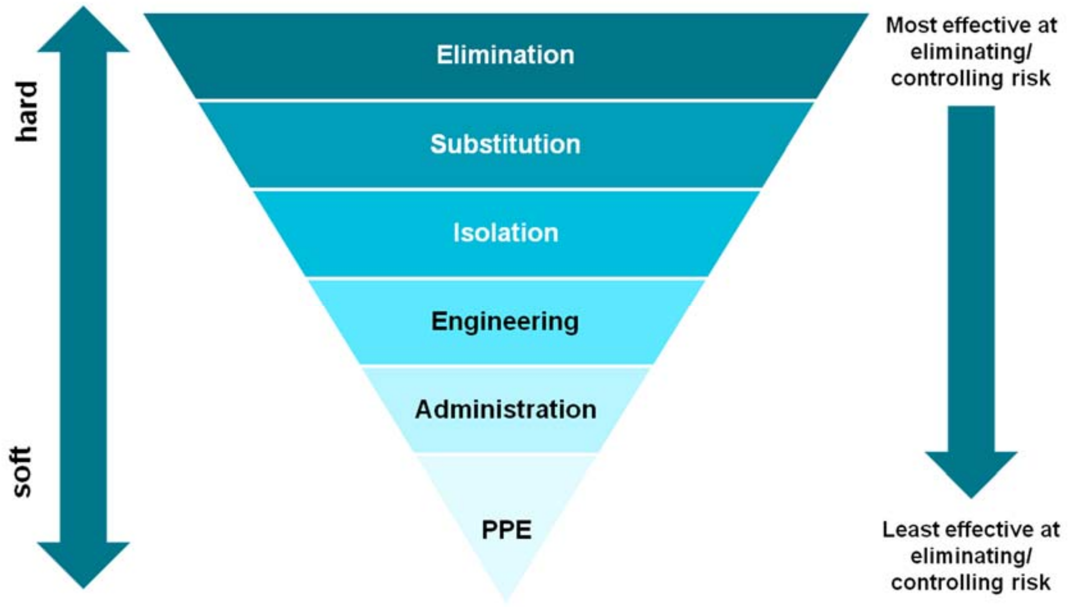

Figure 3-4 – Hierarchy of control

Table 3-4 - Priority for risk treatment authority for continued toleration of risk (applicable for risk assessment level 3 and 4)

Current risk rank	Action	Timing for authority	Authority for continued toleration of current level of risk
23 to 25	The activity must be stopped immediately until action to reduce the level of risk to less than 23 is undertaken or authority to continue is received.	Immediately to within 24 hours.	CE/COO Notification to CE prior to granting of authority to continue
17 to 22	The activity must be stopped immediately until action to reduce the level of risk to less than 17 is under taken or authority to continue is received.	The activity must be stopped immediately until action to reduce the level of risk to less than 17 is under taken or authority to continue is received.	Directors/COO Notification to COO prior to granting of authority to continue
10 to 16	Take action to reduce the level of risk to less than 10 or authority to continue is received.	Within 1 month.	General Managers / Operations Managers / Project Managers
7 to 9	Take action to reduce the level of risk to less than 7 or authority to continue is received.	Within 1 month.	Superintendents/ Managers / Project Team
1 to 6	Tolerable risk unless circumstances change	Ongoing control as part of a management system.	N/A

Environmental Risk Assessment: Tahmoor Underground - Longwall 32 Surface and Subsurface Infrastructure

	Step 2: Assess Type; Key Elements-These change depending on TYPE of Risk Assessment			Step 3: Identify the risks, causes and potential consequences			Step 4: Identify the existing controls to manage the identified risks	Step 5: Determine RCE	Steps 6, 7 & 8: Determine the Expected Consequence / Likelihood applicable to the Expected Consequence / Current level of risk				Step 10: PMC		Step 11: Treat the Risks					
Appendix B	Type of Risk Assessment	Key Element (CURA Context/Category)	Sub Key Element (If applicable)	Risk Description - Something happens……	Consequence - resulting in:	Causes - Caused by	Existing Control Description	Risk Control Effectiveness	Expected Consequence Category	Expected Risk Consequence	Risk Likelihood	Current Risk Rating	Potential Maximum Consequence	Potential Maximum Category	Treatment plans/tasks (Description)	Task Owner	Due Date	Comments	Date Assessment carried out	Action# (CURA/ Xstrasafe)
Tahmoor Underground	Equipment	Jemena gas pipes in general	Gas Infrastructure	Damage resulting in gas leak	Gas leak, emergency repair	Subsidence	Ground survey along Bridge Street - weekly Visual inspections - weekly (AC TARP including repair and gas detection of gas leak if required (AC) Analysis and reporting - as per survey frequency (AC) Consultation, coordination and cooperation with Jemena (AC) Design of gas line flexible pipework (EC) Gas is odourised - community more likely to report gas leaks if they occur (EC)	2	Health & Safety	3	E	3	3	Health & Safety	Infrastructure Management Plan for LW32 (including TARP). Baseline gas detection survey to be conducted along remembrance driveway E & C to confirm Jemena contact and update contact list	Belinda Clayton	31-Jul-18			
Tahmoor Underground	Equipment	Jemena gas pipe crossing hidden creek	Gas Infrastructure	Damage resulting in gas leak	Gas leak, emergency repair	Subsidence	Ground survey along Bridge Street - weekly Visual inspections - weekly (AC TARP including repair and gas detection of gas leak if required (AC) Analysis and reporting - as per survey frequency (AC) Consultation, coordination and cooperation with Jemena (AC) Design of gas line flexible pipework (EC) Gas is odourised - community more likely to report gas leaks if they occur (EC)	2	Health & Safety	2	E	5	2	Health & Safety	Infrastructure Management Plan for LW32 (including TARP). Baseline gas detection survey to be conducted along remembrance driveway E & C to confirm Jemena contact and update contact list	Belinda Clayton	31-Jul-18			

Subtotal CountA (ignoring hidden values)

Structure Condition Report

Reference: R0521
Bridges over Redbank Creek
Remembrance Drive, Picton

John Matheson & Associates Pty Ltd | Consulting Engineers
T/as J M A Solutions
info@jmasolutions.com.au | +61 2 9979 6618 | www.jmasolutions.com.au | ABN 49 061 846 795

DOCUMENT HISTORY			
Revision	Date	Amendments	Author
	21.05.2018	First issue of report	JM

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1 Introduction

A site inspection of the road and pedestrian bridges spanning across Redbank Creek along Rembrance Driveway, Pictons, was conducted on Friday 18 May 2018 by Mr. John Matheson from this office at the request of Tahmoor Colliery. The purpose of the inspection was to take measurements and observe the condition of both structures, observe the creek bed and embankments and infer possible foundation conditions.

Figure 1 Perspective views of the road and pedestrian bridges spanning across Redbank Creek on Remembrance Driveway, Picton.

2 Background

It is proposed by Tahmoor Colliery, to mine coal from the Bulli Seam by longwall panel LW32 noting the following:

i. The Bridges are located to the northeast of LW32 noting that the predicted 20mm subsidence contour passes just to the northeast of the bridge location on Remembrance Driveway.
ii. A ground monitoring survey line will be monitored along Remembrance Driveway during active subsidence, which will record subsidence, tilt and ground strain across Redbank Creek.
iii. Redbank Creek has incised into Hawkesbury Sandstone, following the alignment of rock jointing/lineaments in the area.

3 Subsidence Predictions

The road and pedestrian bridges are located on the creek line of Redbank Creek, which drains beneath Remembrance Driveway in Picton near the limit of the angle of draw up from LW32. The values of subsidence presented in Table 1 and 20mm of valley closure have been considered in this report.

Table 1 Subsidence Predictions for Longwall Panel LW31 & LW32

Location	Longwall	Maximum Predicted Subsidence (mm)	Maximum Predicted Tilt (mm/m)	Maximum Predicted Hogging Curvature (km^{-1})	Maximum Predicted Sagging Curvature (km^{-1})
Remembrance Drive Road (RE-B1) and Pedestrian Bridges over Redbank Creek	LW31	<20	<0.5	<0.01	<0.01
	LW32	35	<0.5	<0.01	<0.01

4 Observations, Appraisal & Recommendations

4.1 The Road Bridge

The internal arch measurements indicate a 9.0metre internal clear span and an estimated rise of around 3metres for the road bridge across Redbank Creek. Whilst there were no identifying plates or manufacturers marks on the precast elements, the bridge appears most likely to have been constructed as a 9300S “BEBO” arch bridge.

The footings were not visible during the inspection but given the creek bed appeared to be class III Hawkesbury Sandstone (SUSMDS), the concrete footings are likely to be have constructed with minimal excavation into the sandstone and may effectively be a levelling strip with a rebated key to receive and restrain the arch segments and spandrel wall panels.

The precast concrete spandrel wall panels have been placed adjacent to the end arches to retain the fill that covers the arch. The eastern abutment wingwalls have been constructed using riprap, and therefore, it is likely that the spandrel walls are horizontally supported by tie rods placed within the fill material. It was normal practice to place the precast concrete wingwalls on an in-situ concrete footing and to prevent horizontal base-sliding by connecting the wingwalls to the concrete footing by galvanised deformed 20mm diameter (C/Y/N grade) dowels grouted into place. The downstream wingwalls have been constructed using riprap armour.

The precast arch, spandrel and wingwall panels were found to be in serviceable condition noting that fine surface shrinkage cracking was evident on most of the elements, which is purely a cosmetic condition. The largest crack that was observed was found on the underside of an arch panel shown in **Figure 12**. The crack in question is classified Category 0 <0.1mm and appears to be related to the background pattern of other very fine shrinkage cracks. The riprap armour that forms the downstream wingwalls is in serviceable condition.

The bridge is a statically indeterminate two-pinned arch structure meaning that a variation in the relative horizontal position of the supporting footings (along the axis of the bridge) will have a corresponding effect on the distribution of bending moment, shear and axial forces in the arch. If subsidence develops as predicted, ground strain in the order of ±0.15mm/m is possible, which corresponds to 1.4mm of possible inwards or outwards movement of one abutment relative to the other.

A preliminary structural analysis of the arch has been carried out assuming a fill density of 20kN/m^3 and a T44 truck live load for which the bridge was most likely designed. Dead, Live and Subsidence load/displacement factors of 1.5, 1.8 (with DLA of 1.3) and 1.5 being applied at the strength limit state. Two live load cases have been evaluated with the T44 axles centred at both midspan and around the haunch or 1/3 span.

The analysis shows a 3-4% increase in bending moment near midspan under 1.4mm of opening across the base of the arch and a 1-2% increase in bending moment near the haunch under 1.4mm of closure, which is not significant.

If 20mm of valley closure developed across Redbank Creek at the location of the arch bridge, the preliminary analysis shows that a 20-30% increase and a 50% reduction in bending moment and a 4-6% and an 8-10% increase in compressive stress could developed at the haunch and midspan locations of the arch, respectively.

The impact of valley closure at midspan appears likely to be low given that axial compression is predicted to increase by around 8-10% and bending moment is predicted to reduce by around 50%. However, the impact of valley closure is predicted to be more significant at the haunches near 1/3 span) under pattern T44 truck loading noting that the analysis has only modelled the arch structure in isolation and not the benefits of arch and fill interaction.

If 20mm of valley closure is applied to the arch in isolation, it is possible that a plastic hinge could develop around the haunch at 1/3 span (under asymmetric T44 truck loading). If this occurs, it is likely that that the external arch reinforcement will yield in tension (ductile behaviour) near the extrados before concrete compression spalling develops on the intrados. Hypothetically, as the plastic hinge develops, the extrados of the arch would tend to push up into the fill material, and interactive behaviour would develop, which it has been noted has not been modelled at this stage.

Soil-structure interaction tends to improve the load/displacement resisting capacity of the structural arch when it is considered in isolation. If the example of Redbank Creek Culvert (RBCC) is considered where horizontal structure closure exceeding 14% of structure diameter occurred without compromising track safety, noting that intervention and additional response measures were installed in the structure, if the RBCC experience is any guide to possible arch-bridge behaviour, it does not seem likely that 20mm of valley closure will cause the Remembrance Drive arch bridge to fail.

Valley closure could impact the spandrel walls causing the midspan to rise upwards as the toe is displaced inwards. At significant levels of displacement, this could cause a hinge mechanism to develop at midspan with compression spalling at the soffit and tension cracking at the top in the middle third of the spandrel wall, depending on the amount of ground strain that can be transmitted through the interface of the spandrel wall and the footings. It is possible if not likely that the interface between the footing and the spandrel wall could shear before the spandrel is severely impacted or vertical separation occurs between the spandrel and the adjoining arch segment. It should be noted that if 20mm of closure develops, a round 10mm of vertical displacement is likely and the vertical overlap between the spandrel wall and the adjoining arc is around 50-100mm as observed on site.

The spandrel wall panels are most-likely to be tied horizontally together through the fill by tie rods to prevent sidewards spreading of the spandrel walls because of the way that the downstream wingwall shave been constructed. Valley closure across Redbank Creek could generate increased outwards pressure against the spandrel walls by way of Poisson effects. The wingwalls are unlikely to be impacted significantly by the predicted ground strain. In the unlikely event that horizontal separation is observed between the spandrel wall and the adjoining arch segments, it is possible that additional tie rods could be bored through the fill material to resist unforeseen outwards spreading displacement of the spandrel walls. However, this is viewed as a more extreme event and is unlikely to occur at 20mm of valley closure.

In addition to weekly survey monitoring along a 20-metre bay length along Remembrance Drive assumed to extend across the road bridge, the following additional monitoring is recommended:

i. Baseline survey marks or tape extensometer eye-bolts should be installed near the invert of the arches, above existing standing water level, on the centreline of both road lanes to monitor for opening or closure of the arch.

ii. Baseline survey marks should also be installed along the top of the spandrel wall on both sides of the bridge at both abutments and midspan to monitor horizontal spreading of the top of the spandrel walls and relative vertical movement of the spandrel walls.
iii. Measure the distance between the internal face of the spandrel walls before impact from LW32.
iv. Baseline measurement of precast concrete wingwall tilt at mid-length and at the ends of the wingwalls.
v. Baseline survey of both abutments at creek level should be carried out before LW32 impacts to evaluate the possible change in shape (distortion from a Rectangular to Rhomboid shape caused by perpendicular abutment movement)
vi. Carry out visual inspections to monitor serviceability of the bridge.
vii. End of panel survey measurements of items i to iv should be carried out at the end of LW32.

The arch bridge that supports Remembrance Driveway across Redbank Creek is a comparatively ductile structure. In the unlikely event that ground movement monitoring indicates that subsidence is becoming likely to exceed predictions and/or weekly bridge inspections indicate that structural impacts are likely to exceed predictions, additional response measures could be considered to maintain the safety and serviceability of the arch bridge structure. Additional response measures such as structural steel props and beams can be installed at short notice in the unlikely event that they were necessary. Whilst the pedestrian bridge is a different form of structure, similar observations and comments apply.

4.2 The Pedestrian Bridge

The pedestrian is comprised of a pre-tension precast concrete Double-T girder spanning 16.38metres to the centre of the bearing, which is supported by a reinforced concrete abutment on both sides of Redbank Creek, which are shown in **Figures 21 & 22**. The foundation beneath the abutment slabs are partly protected by shotcrete revetment walls, however, it is likely that the abutment slabs have been constructed on reinforced concrete bored piers although this could not be verified by non-destructive examination on site during the inspection.

The bearing blocks measure approximately 400mm long and are visible in **Figures 21 & 22** where they extend out beyond the line of the beam stem at the abutments. It was not possible to verify the nature of the bearing material that separates the bridge girder from the abutment and it is likely that whatever the material from which the bearings were manufacture, it has likely hardened and will not tolerate significant movement. It is noted, however, that the bridge currently expands and contracts somewhere in the order of ±4mm at one end. Therefore, an additional 1.4mm is unlikely to cause significant damage to the structure.

If a ground compression anomaly developed across Redbank Creek, it is likely that the bearing interface will act like a fuse and slip-stick displacement is likely to develop between the abutment slab and the underside of the girder since it is the least line of resistance.

In addition to weekly survey monitoring, the following monitoring is recommended:

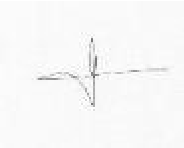
i. Baseline survey marks should be installed on both abutment slabs to establish pre-existing position in 3D and subsequently monitor position and opening and closure displacement across Redbank Creek.
ii. Trace pre-existing position of bridge girder on the western side of the abutment slab and project sideways 50mm to monitor movement of girder relative to the abutment slab.

iii. Carry out visual inspections to monitor serviceability of the bridge, revetment walls and abutment slabs and monitor for trip hazards along the footpath.

iv. End of panel survey measurements of items i to iii should be carried out at the end of LW31 & LW32.

Yours faithfully

John Matheson & Associates Pty Ltd



John Matheson BE (HON II) MIEAust CPEng

Director

5 Appendix A: Photographs

Figure 2 North-western precast concrete wingwall on Sydney abutment noting that the truck shown in the background is stationary on Bridge Street, where it intersects with Remembrance Driveway.

Figure 3 Northern end of western spandrel panel.

Figure 4 Spandrel midspan on western elevation.

Figure 5 South-western precast concrete wingwall on Country abutment.

Figure 6 Sandstone rock bar upstream of the road bridge.

Figure 7 Ponded water below the road bridge during period of dry weather noting the sediment on the creek bed.

Figure 8 View of overlap of spandrel soffit and arch panels

Figure 9 Hairline cracking observed on the intrados of one of the arch panels.

Figure 10 Sandstone creek bed is visible through the ponded water.

Figure 11 North-eastern riprap wingwall on the Sydney abutment.

Figure 12 South-eastern riprap wingwall on the Country abutment.

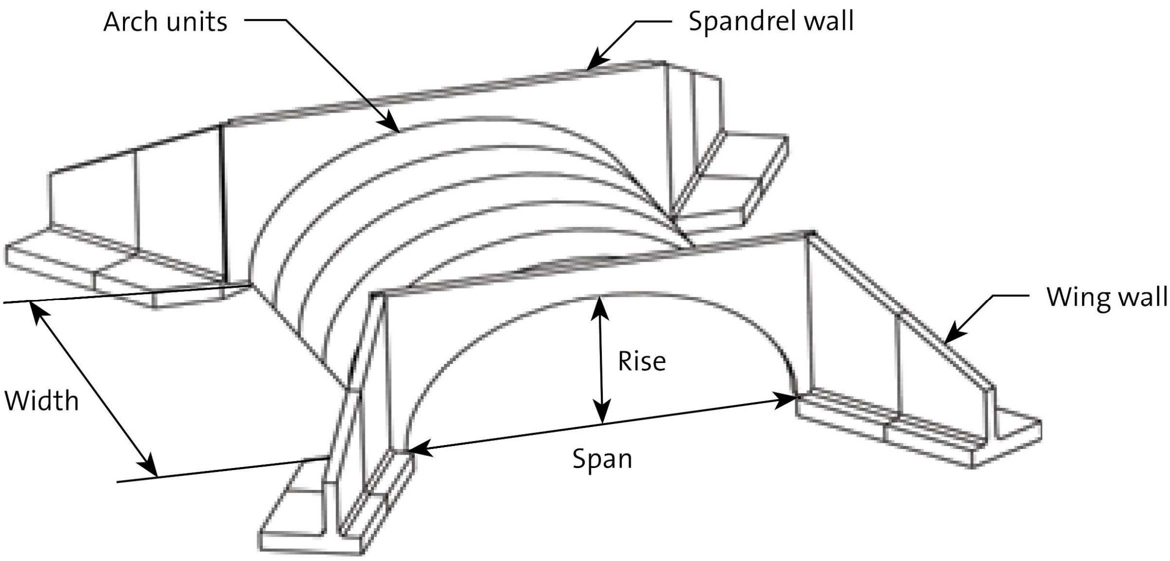


Figure 13 Perspective view of a representative concrete arch bridge reproduced courtesy of Humes

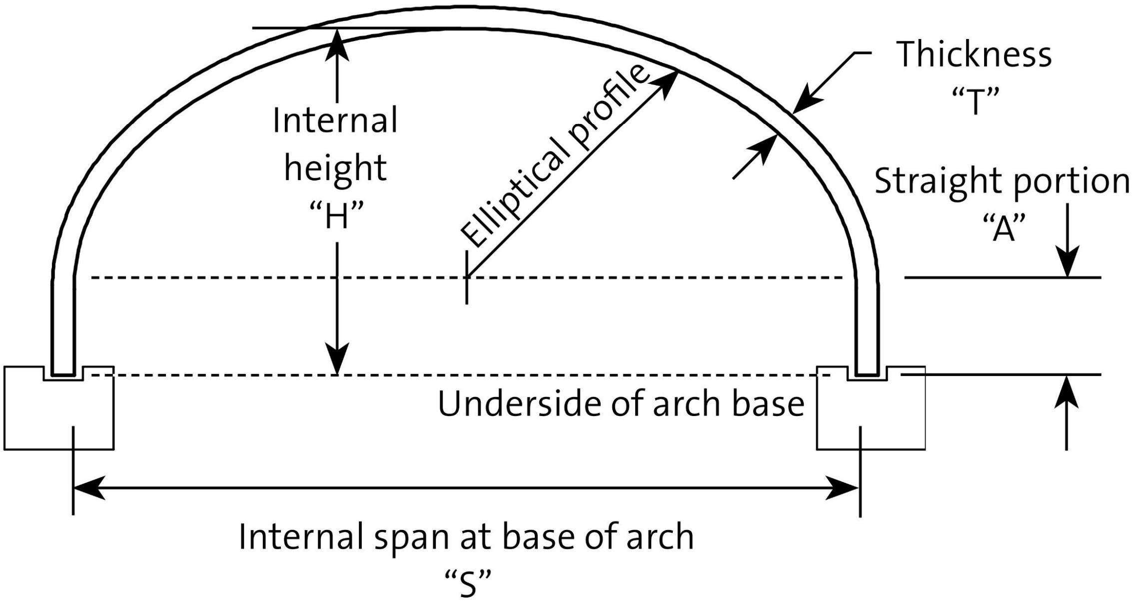


Figure 14 Arch bridge profile reproduced courtesy of Humes.

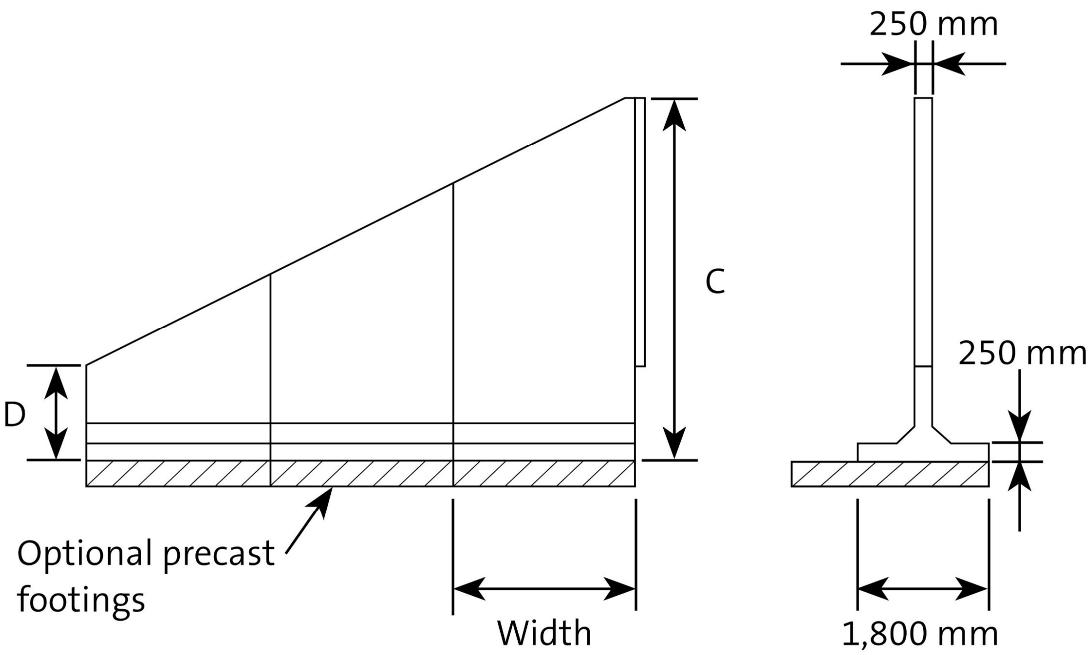


Figure 15 Wingwall elevation and cross-section reproduced courtesy of Humes.

Figure 16 Precast concrete Double-T pedestrian bridge

Figure 17 Southern abutment slab possibly founded on bored concrete piers

Figure 18 Southern abutment showing concrete shotcrete revetment.

Figure 19 Northern abutment