Investigation into Abnormal Increased Subsidence above Longwall Panels at Tahmoor Colliery NSW

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Summary

Tahmoor Colliery, located in the Southern Coalfield of NSW, has been in operation for over 30 years. Longwall extraction of 23 successive longwall panels has occurred with subsidence occurring within predictions and resultant impacts to natural and built environments occurring to expectations.

Subsidence over a recent longwall panel of approximately twice that previously measured occurred at Tahmoor Colliery. An investigation of the potential causes was conducted using computer modelling together with hydrological characterisation and detailed geotechnical characterisation of the strata.

The abnormal subsidence was found to be consistent with localised weathering of joint and bedding planes above a depressed water table adjacent to an incised gorge. The study showed that other factors such as variation in stress field, joint zones, variation in rock strength and topographic factors did not sufficiently induce the abnormal subsidence.

The results have significant implications to subsidence prediction in areas which may be prone to the phenomenon found at Tahmoor. Key indicators of the potential for this form of abnormal subsidence are presented.

1. Background

Tahmoor Colliery has been operating for over 30 years, initially utilising continuous miners in bord and pillar development and ‘Wongawilli’ style pillar extraction. Tahmoor Colliery subsequently introduced longwall coal extraction, extracting nineteen longwalls within the initial Tahmoor Colliery mining lease area. The location of the mine is presented in Figure 1.

Figure 1 Mine Location Plan

A development application was lodged by Tahmoor Colliery in 1992 to extend the mine life by continuing mine operations northwards, not only under rural residential landholdings as had been mined under in the past, but under the more closely settled urban areas comprising the townships of Tahmoor, Picton and Thirlmere.

During public consultation processes conducted for this development application, concerns were raised by the public, infrastructure owners and industry regulators regarding the degree of mine subsidence that could be expected to occur, and the potential impacts on structures and the broader ‘built environment’ which may result from this subsidence.

A key factor in addressing these concerns was the development and use of reliable methods to predict surface subsidence movements, and likely impacts, in advance of mining.

From these predictions, subsidence management plans were developed and agreed with stakeholders and regulators, with the plans including more than adequate arrangements for prediction, mitigation, monitoring and management of potential mine subsidence impacts

Subsequently, development consent for the Tahmoor North mining area was granted by 2000, and Longwalls 20 to 24 were then extracted as mining progressed northwards into the Tahmoor North lease area.

2. Subsidence Management

2.1. Subsidence Prediction

Tahmoor Colliery has engaged consultant subsidence engineers, Mine Subsidence Engineering Consultants (MSEC) formerly known as Waddington Kay and Associates, to develop detailed subsidence predictions for longwall mining at Tahmoor Colliery. Predictions have ranged from broad assessment of expected mine subsidence to support development applications for extension of the mining operations, to detailed subsidence predictions for Subsidence Management Plan approvals required by the mining regulator, Industry and Investment NSW.

MSEC utilise the Incremental Profile Method to predict systematic subsidence parameters, an empirical method based on a large database of observed monitoring data from previous mining within the Southern, Newcastle, Hunter and Western Coalfields of New South Wales.

The database consists of the observed incremental subsidence profiles, which are the additional subsidence profiles resulting from the extraction of each longwall within a series of longwalls. From the normalised incremental subsidence profiles within the database, the observed shapes of the subsidence profiles and magnitudes of the subsidence parameters are reasonably consistent, where the mining geometry and local geology are similar. (MSEC, 2006).

MSEC also state that the subsidence predictions made using the standard Incremental Profile Method use the database of observed incremental subsidence profiles, the proposed longwall geometries, local surface and seam information and geology. The method has a tendency to over-predict the systematic subsidence parameters (ie: is slightly conservative) where the proposed mining geometry and geology are within the range of the empirical database.

In March 2006, Tahmoor Colliery submitted an application for Subsidence Management Plan approval for the extraction of longwalls 24 to 26, supported by a detailed assessment prepared by MSEC, ‘The Prediction of Subsidence Parameters and the Assessment of Mine Subsidence Impacts on Surface and Sub-surface Features.’

The extraction of the first longwall, Longwall 24B, resulted in subsidence occurring consistent with the forecast predictions. However, subsidence parameters measured during the extraction of most of the 985 metres of Longwall 24A, and the initial section of the much longer 3592 metre length of Longwall 25, greatly exceeded those that were predicted for mining geometry that was well within the empirical database.

For Longwall 24A, predicted subsidence was of the order of 500mm in the centre of the longwall while actual subsidence approached 1150mm. Observed and predicted subsidence parameters for Longwall 24A is shown in Figure 2. (MSEC 2008).

It was suspected that there may have been a change in the local geology in the vicinity of these longwalls that may have resulted in the significantly increased subsidence over Longwall 24A and later Longwall 25.

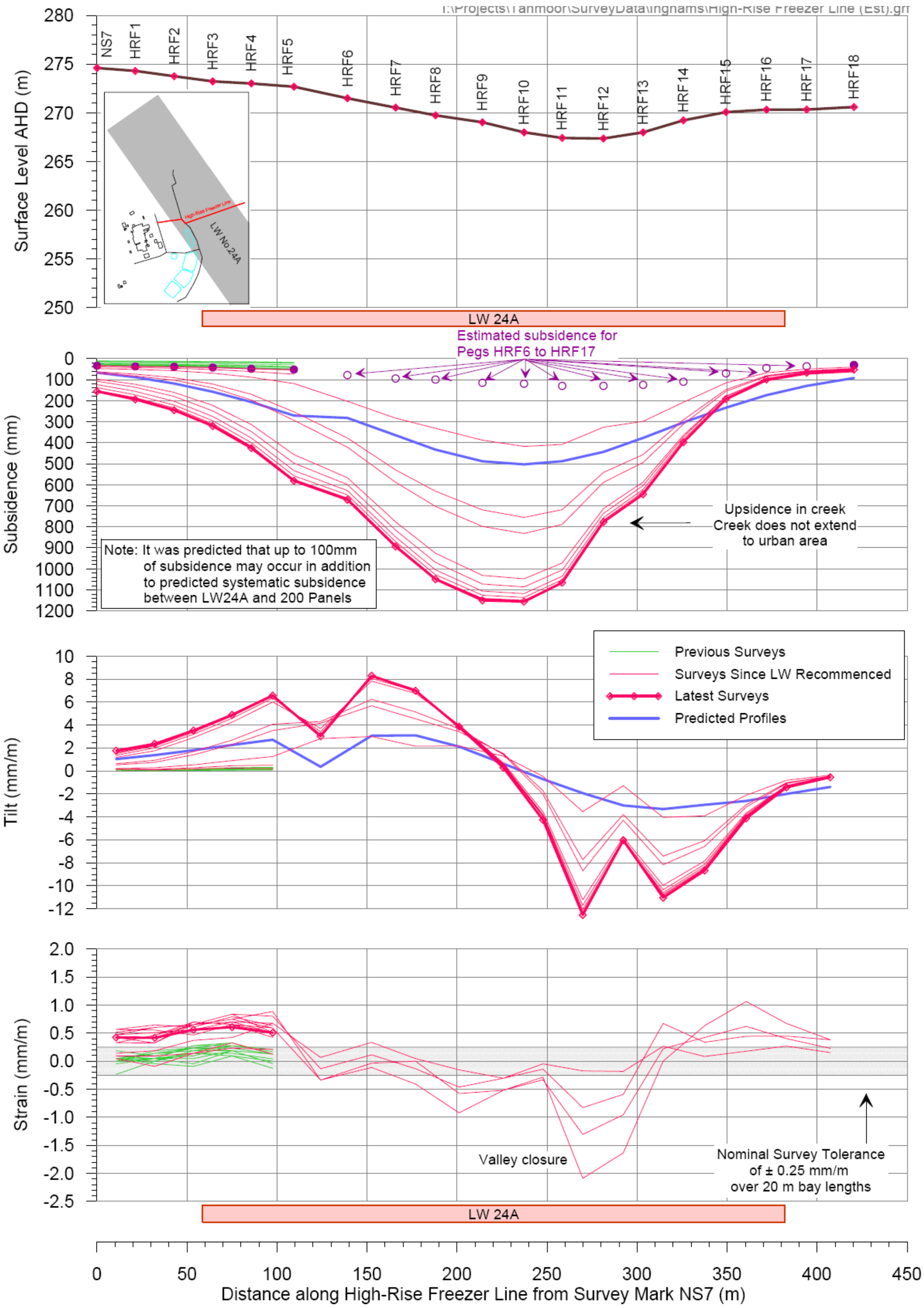


Figure 2 Observed and predicted Subsidence Parameters for Longwall 24A

2.2. Subsidence Mitigation and Monitoring

The reliable prediction and quantification of mine subsidence parameters, such as vertical displacement, tilt, compressive and tensile strain, and hogging and sagging curvature, are key inputs into the assessment of consequent subsidence impacts and the development of measures to be implemented before and during subsidence movements to mitigate any identified unfavourable or unexpected impacts.

In the case of Tahmoor Colliery, such mitigation measures undertaken in advance have been as extensive as the complete replacement of a composite steel and masonry bridge deck of a railway overbridge, and the replacement of an aged ammonia based refrigeration system on a nearby poultry processing facility. In both cases, the structures were subject to subsidence, strain and curvature effects on the perimeter of a longwall extraction.

However in most cases, prediction of mine subsidence parameters, and their potential impacts on surface structures and features require no mitigation measures other than to develop a process of comprehensive and progressive subsidence monitoring to measure and confirm that subsidence movements are consistent with predictions. Should unexpected subsidence movements occur, timely management actions may be undertaken as subsidence occurs, to mitigate any unsatisfactory impacts.

During the extraction of Longwall 24A, the early detection of increased subsidence triggered additional mitigation, monitoring and contingent management actions which included:

- Installation of additional subsidence monitoring lines to measure the developing subsidence movements and potential impacts. In the case of Longwall 24A additional subsidence lines were installed to provide additional data points between those put in place prior to the commencement of mining. The subsidence ground monitoring plan for Longwall 24A is shown in figure 3. (MSEC 2008).

- Increase in the frequency of subsidence monitoring activities to enable prompt response to subsidence events. Again in the case of Longwall 24A subsidence survey monitoring was increased from every 200m of extraction (approximately monthly) to weekly surveys.

- Develop further contingent management actions. An example of this was the assessment of potential impacts to underground sewer line gradients due to greater than anticipated tilts, and the development of mitigation actions to manage any transient and permanent impacts.

A key observation from the ground survey monitoring showed that while significantly increased subsidence, tilt and curvature were measured, ground strains have remained within the normal range.

2.3. Subsidence Impacts

The ground survey monitoring during the extraction of Longwall 24A and the later extraction of Longwall 25, showed significantly increased vertical subsidence, tilt and curvature. However ground strains remained within the normal range (MSEC 2010). Consequently, systematic strain related subsidence impacts did not measurably increase, and the additional subsidence impacts have mainly been related to increased resultant tilts.

The most sensitive infrastructure affected by ground tilt are the gradients on the Sydney Water sewer systems servicing the Tahmoor urban area. Following the observation of increased subsidence above Longwalls 24A and Longwall 25, intensive monitoring for changes in grade were undertaken at key sections of sewer where revised predictions for increased subsidence indicated a potential for reversal of grade.

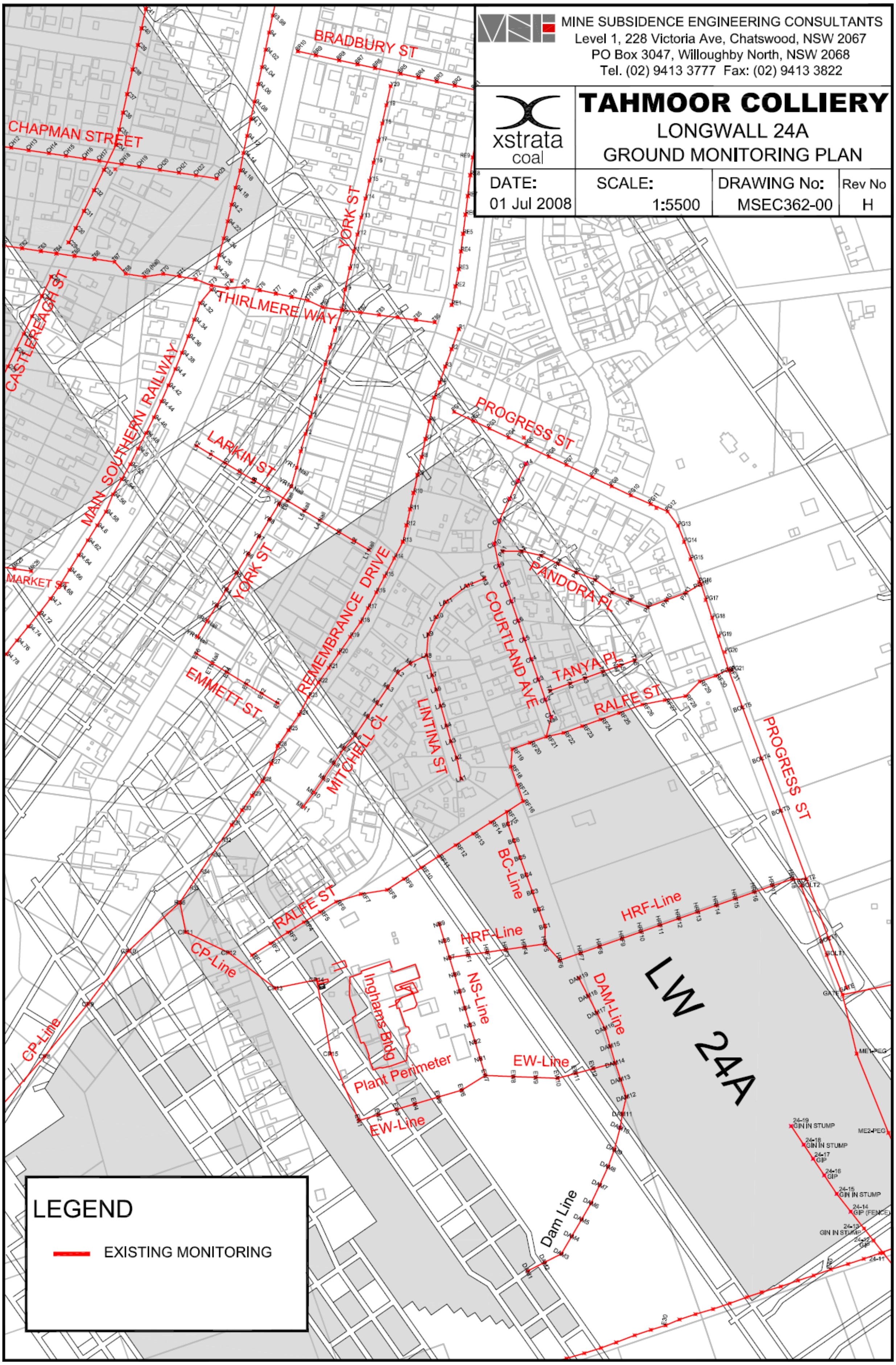


Figure 3 Survey Lines over Longwall 24A at Tahmoor Colliery

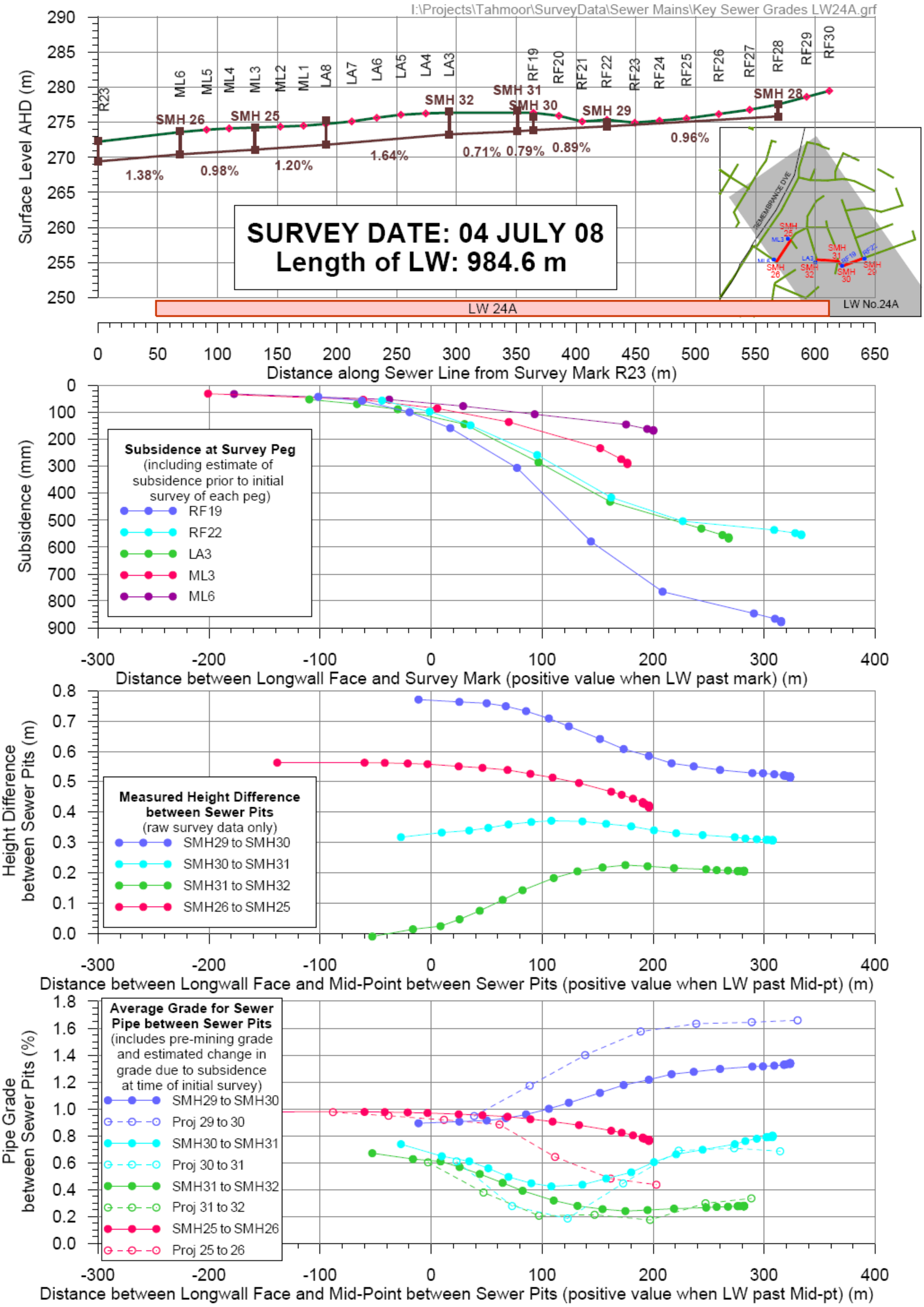


Figure 4 **Changes in Sewer Levels and Sewer Grades over Longwall 24A**

No reversal of grade occurred, but sewer gradients were impacted, being closely monitored prior during and after the period of active subsidence movements. In particular, some shorter sections of sewer lines had gradients that were reduced to a minimum of 2% before recovering slightly after the transient subsidence wave had passed. This is shown in figure 4. (MSEC 2008)

Detailed planning, preparation and trialling of mitigation measures, such as sewer line flushing, were undertaken to ensure that the service could be effectively maintained until permanent repairs were effected.

3. Future Subsidence Prediction

The accurate prediction of mine subsidence parameters and subsequent mine subsidence impacts is an essential component in the development of effective mine subsidence management plans to mitigate, monitor and manage these impacts. Consequently, accurate and reliable mine subsidence predictions are a key component in ensuring impacts on the natural and built environments are within limits acceptable to industry regulators and the broader community.

Subsidence predictions made using the standard Incremental Profile Method use the database of observed incremental subsidence profiles, the proposed longwall geometries, local surface and seam information and geology where the proposed mining geometry and geology are within the range of the empirical database. However, actual subsidence for Longwall 24A and Longwall 25 at Tahmoor Colliery were well outside prediction made using the Incremental Profile Method.

Tahmoor Colliery asked Strata Control Technology (SCT) to undertake a geotechnical investigation to assess the greater than expected subsidence and identify any likely cause for this movement.

4. Geotechnical Investigation

SCT conducted the investigation for Tahmoor Colliery, which mines the Bulli Seam at approximately 420-480m depth. Panel widths have varied over time and the current panel width is approximately 272m and extraction thickness was approximately 2.4m.

Subsidence characteristics of the overburden had been consistent with empirical regional estimates over the history of the mine which included 23 previous longwall panels.

The regional subsidence characteristics are summarised in Figure 5 which presents the subsidence relative to width to depth of the panels. The subsidence is presented as a proportion of extraction height. The width to depth ratio of Longwall 24A is approximately 0.65 and was anticipated to be sub critical in dimension. The predicted range for Longwall 24A and B is presented in Figure 5. The anticipated subsidence was in the range of 500-600mm.

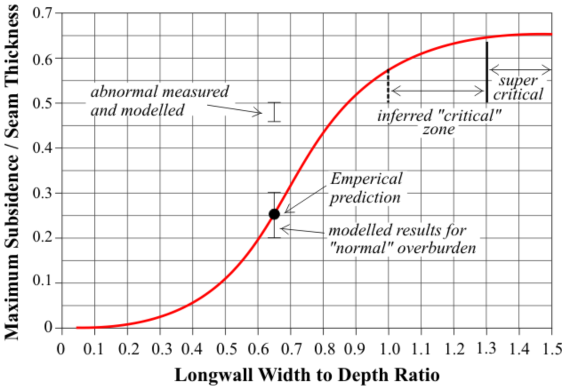


Figure 5 Subsidence Prediction Curve

The subsidence measured during Longwall 24A was in the range of 1-1.2m which was up to double that of the empirical estimates and that of past experience. The abnormal subsidence was located in Longwall 24A, however further north in Longwall 24B, the subsidence returned to be within the regional and previous range for the mine. The abnormal characteristics were also noted in Longwall 25 within the initial 20-30% of the panel.

The subsidence characteristics along the centreline of Longwall 24A and Longwall 25 is presented in Figure 6. In general, the abnormal subsidence is located in the southern area of the panels.

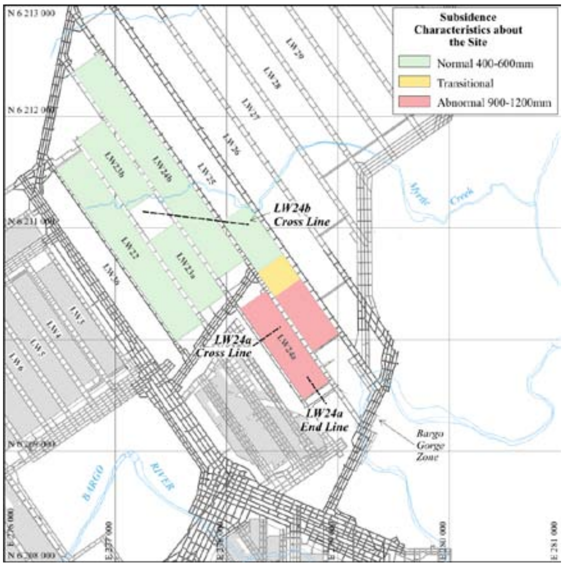


Figure 6 Subsidence Characteristics of Longwalls 22 to 25

The approach to investigate the cause of the abnormal subsidence was to utilise a computer model to simulate extraction of Longwall 24A and the surrounding panels within the strata section over the mining area. Computer modelling of longwall caving has been undertaken by SCT Operations for a number of years and has been found to reliably simulate the rock failure and caving mechanics of the overburden in coal measure strata. It was seen as the best method to assess the potential causes of the abnormal subsidence at this site.

The potential causes investigated were:

- variation in horizontal stress;
- higher joint density associated with faulting;
- weathering effects;
- topographic effects;
- variations in overburden strength.

5. Geotechnical Information

The overall site and major features are presented in Figure 7. The areas of abnormal subsidence are located north of the Bargo Gorge. There are also major fault structures in the area. The Bargo Gorge has incised the surface approximately 100m, and has caused a reduction in the water table in the surrounding area. The water table in the southern area of the blocks is at the level of the base of the gorge, whereas further north it increases to be approximately 30-40m below surface. The fault structures are also known to be water conduits within the overburden.

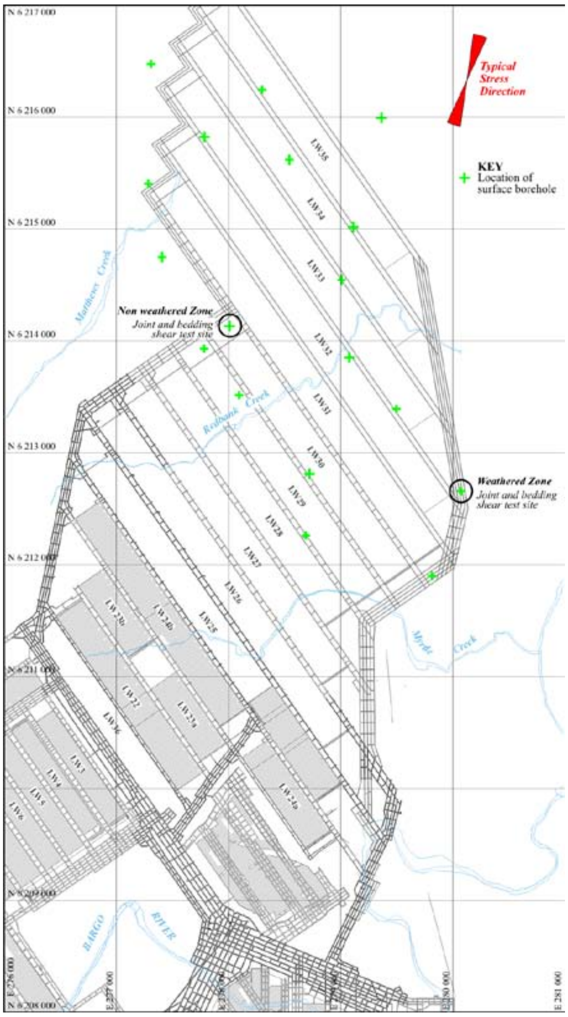


Figure 7 Overall Site Layout and Major Features

The overburden is composed of interbedded siltstone, sandstone and minor claystone units.

The unconfined strength (UCS) of the strata section is presented in Figure 8 for a range of boreholes in the area.

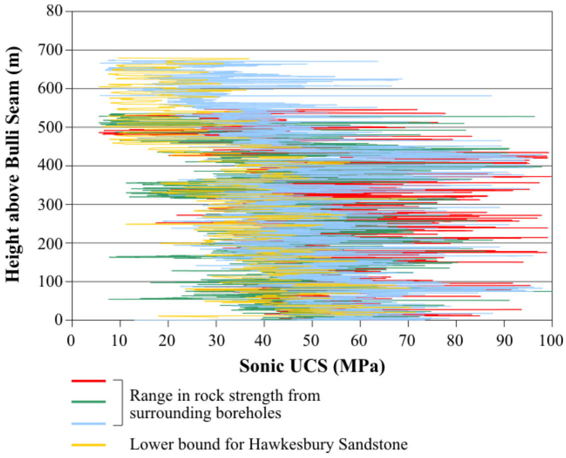


Figure 8 Unconfined Compressive Strength of the Strata

The borehole locations are presented in Figure 7. The UCS was determined on the basis of sonic velocity and core testing. In general, the strata strength varies throughout the section and there is a range within the key units over the area. During this study a number of strength sections were analysed, however the two end members have been used to assess the effect of any strength variation in the overburden on the abnormal subsidence.

6. Modelling Approach

The computer code used is FLAC with fish routines developed by SCT Operations to simulate the rock failure and ground caving characteristics. The background of this has been reported previously (Gale et al, 2004; Gale, 2004; Gale, 2010). The models used for this site ranged up to 1.3km wide and 900m deep. The element size was typically 1m square for simulations of this scale, and the model simulates the elastic and post failure strength properties of the rock units.

Joints and bedding plane partings are included in the overburden on the basis of a normal distribution of the average spacing randomly distributed within the model.

The models are two dimensional to allow for the appropriate level of detail required to map the rock failure modes and stress path.

The generalised strength characteristics of the rock material are presented in Figure 9. Bedding planes have similar intact and post failure characteristics.

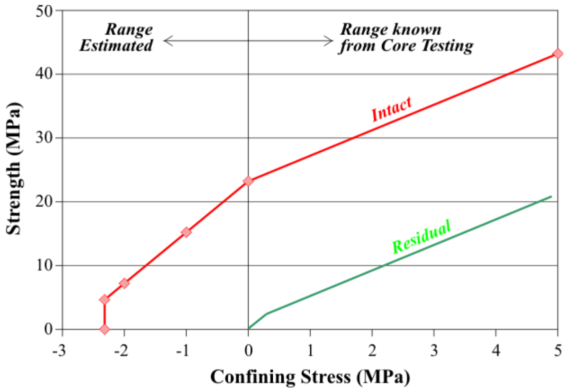


Figure 9 Generalised Strength Characteristics of the Rock Material

The strength of each layer within the model varies about the mean value as a normal distribution. This is an attempt to account for the natural variation of strength within sedimentary strata.

A section of the model with the UCS layers is presented in Figure 10. The mottled appearance of the layers is the variation about the mean for each layer.

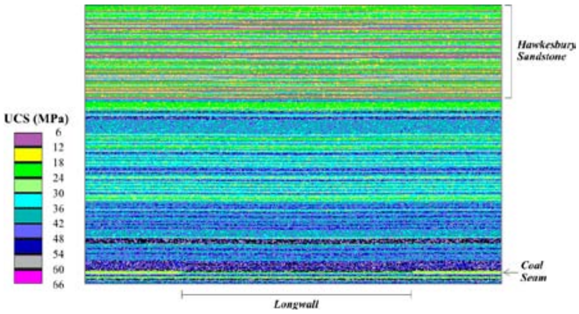
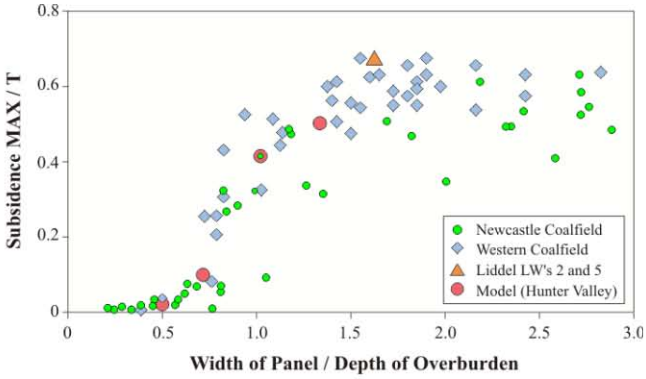
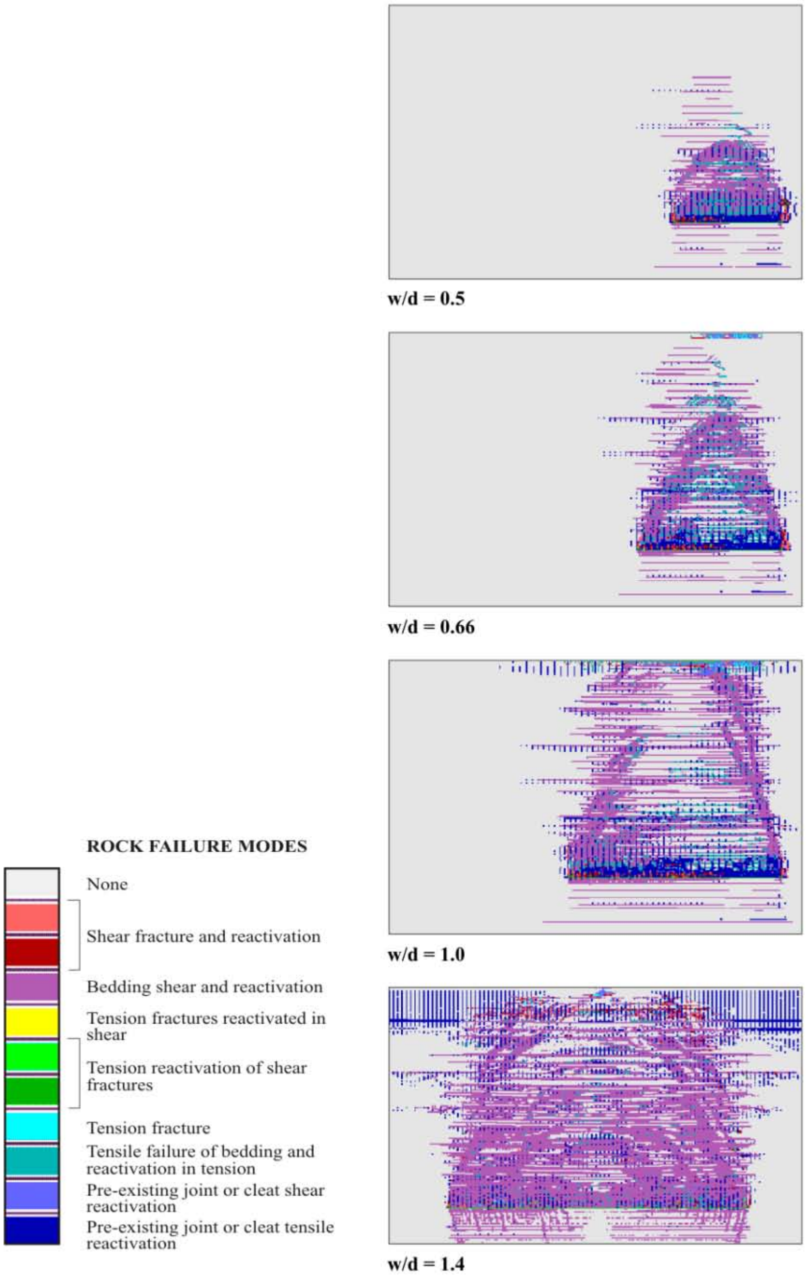


Figure 10 Section of the Model showing UCS Layers

The stress conditions for the region and this site is well known from past stress measurements within the mines.



a) General Relationship.



b) Modelled Strata Fracture.

Figure 11 **Evolution of caving and Development of Subsidence**

The horizontal stress direction for the site is presented in Figure 7. The major stress magnitude is horizontal and relates to a tectonic stress factor of 0.7. This factor is related to the tectonic strain within the rock units. Therefore the horizontal stress in each layer will vary and is related to the tectonic strain, Young's Modulus and the depth. The vertical stress is based on lithostatic load, with an average gradient of 2.5MPa per 100m depth. A discussion of the stress field and the tectonic stress factor is presented in Nemcik et al (2005).

This modelling approach has been used extensively in Australia by SCT Operations to simulate caving and overburden fracture characteristics in coal measure strata. The approach has been found to simulate the key aspects of subsidence in terms of the overall subsidence relative to width to depth ratio, and also the subsidence profile.

An example from the Hunter Valley region, NSW, is presented in Figure 11 which presents the evolution of caving and the amount of subsidence as the width to depth of the panel is increased.

The model results and the regional empirical data are presented. The model shows a very good correlation and depicts the subsidence relative to the spanning mechanics of the overburden. Examples of the subsidence profile match are presented as part of this study.

7. Simulation Of Longwall 24A

Longwall 24A was simulated as a cross section at a depth of 430m. The rock fracture mode for the overburden and stress field anticipated in this area of the mine is presented in Figure 12. This shows the main deformation modes are rock fracture about the panel edges and a significant amount of bedding plane slip higher into the overburden.

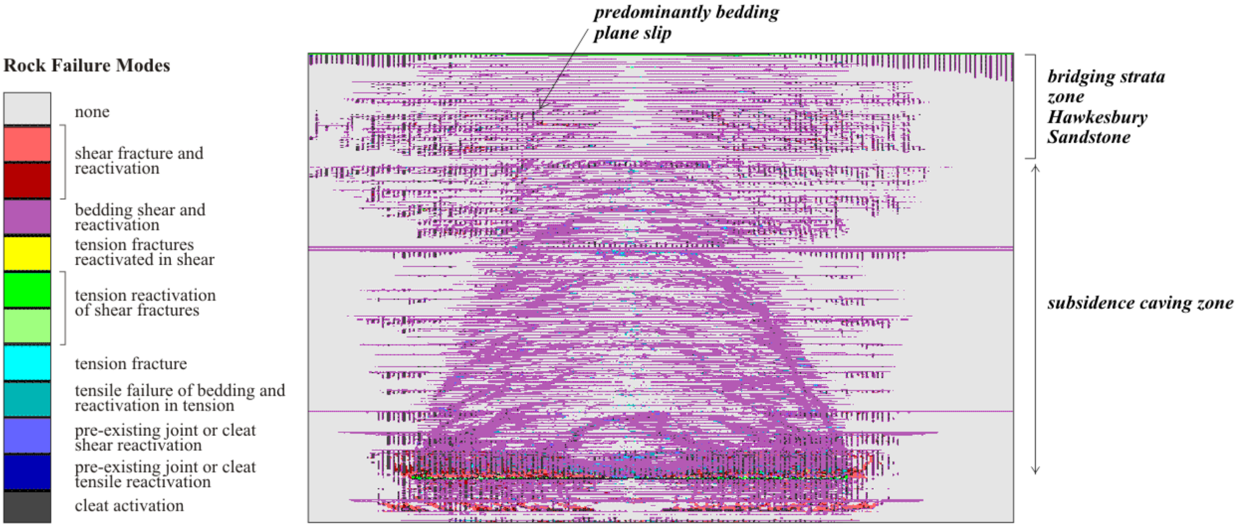


Figure 12 Rock Fracture Modes

The subsidence caving zone is presented in the figure and tends to extend to or slightly into the base of the Hawkesbury sandstone depending on the strength of the sandstone unit.

In general, the height of the subsidence caving zone extends approximately 1-1.2 times the panel width for this case. Above this the strata tend to bridge across the panel. This is termed the bridging zone in the figure. Mobilisation of pre existing bedding partings and joints occurs in this bridging zone.

It is typical for the caving subsidence zone to extend 1-1.5 times panel width (Gale, 2006; Mills and O'Grady, 1998).

The subsidence measurements conducted over the site were controlled by access and were typically along streets and key infrastructure over the mine area. Therefore complete sections were not necessarily available, however a number of lines were appropriate for correlation with the model results.

The measured subsidence along a cross line and a start line during Longwall 24A was available and provides a good example of the abnormal subsidence. A subsidence line oblique across Longwall 24B provides a good example of the normal and regional subsidence characteristics. The subsidence lines are presented in Figure 6.

The subsidence from the model was consistent with that measured in areas not impacted by the abnormal subsidence. A comparison with subsidence across Longwall 24B is presented in Figure 13. This longwall is adjacent to Longwall 23 and in order to compare the data with a single panel (as per Longwall 24A) the subsidence from the measurement line is resolved relative to distance from the eastern panel rib to reduce potential effects from Longwall 23.

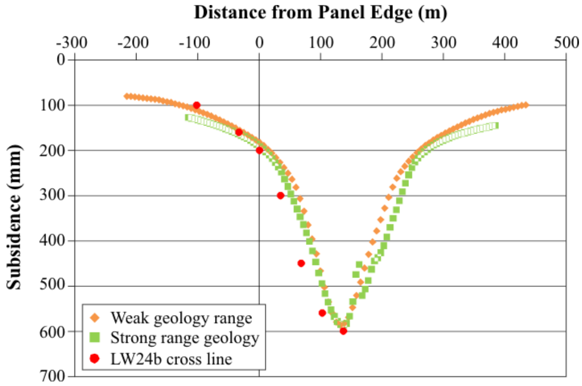


Figure 13 Modelled and Observed Subsidence over Longwall 24B

The results compare very well in terms of magnitude and shape, and provide confidence that the model is simulating the caving and subsidence mechanics of the site under normal geotechnical conditions. The magnitude of subsidence is 0.6m and has a subsidence to seam thickness ratio of 0.25 as per the empirical prediction presented in Figure 5.

These results provide validation of the method used at the site and are a basis to evaluate a range of variations in material properties, stress and topographic features which may impact on the subsidence characteristics.

8. Effect of Variation in Geotechnical Parameters

The variation in strata strength profile (UCS as per Figure 8) was modelled and it was found that the mode of strata failure was similar across the variation. The fracture mode is presented in Figure 12. The subsidence profiles for the end members are presented in Figure 14 and show no significant variation. The modelled subsidence is as per the normal subsidence behaviour presented in Figure 13. The abnormal subsidence is also plotted and indicates the significant change in behaviour from the normal characteristics.

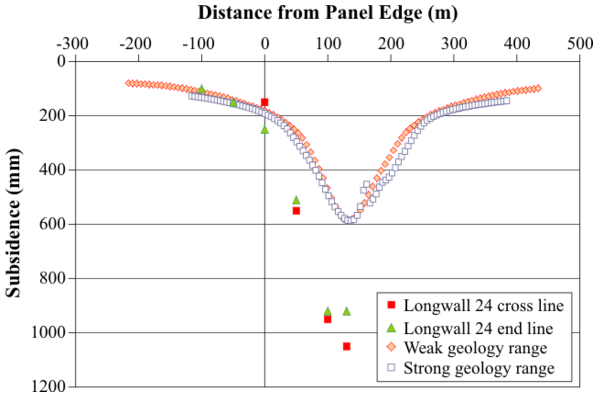


Figure 14 Subsidence Profiles for the End Members

It is clear that there is no correlation with the abnormal subsidence and as such the normal variation in overburden strength is not a major influence on the abnormal subsidence.

The effect of modifying the horizontal stress was also simulated and the resulting subsidence is presented in Figure 15. The horizontal tectonic stress factor was varied from 0.7 to 1.2. The effect of reducing the horizontal stress to lithostatic in the weathered zone was also simulated. Again, these variations had no significant impact and did not induce the abnormal subsidence.

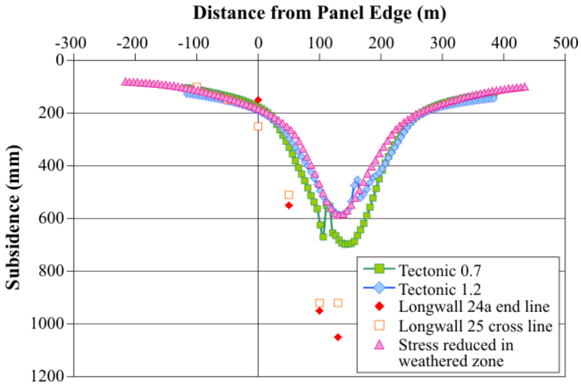


Figure 15 Predicted Subsidence after Modifying the In Situ Stress

The effect of the topographic relief of the gorge was also modelled. It was thought that this may vary the horizontal stress field and the caving mechanics above the initial part of the panel. However, this had no significant impact.

The conclusion reached was that variation in the overburden strength, topographic relief of the gorge and in the stress field could not account for the abnormal subsidence.

The effect of an increased joint and bedding parting density was also simulated. The joints were simulated on the basis of an inclusion within the rock mass with cohesion and friction properties typical of joints within the rock units. The subsidence results are presented in Figure 16 and did not show any significant impact to the subsidence in terms of matching the measured data.

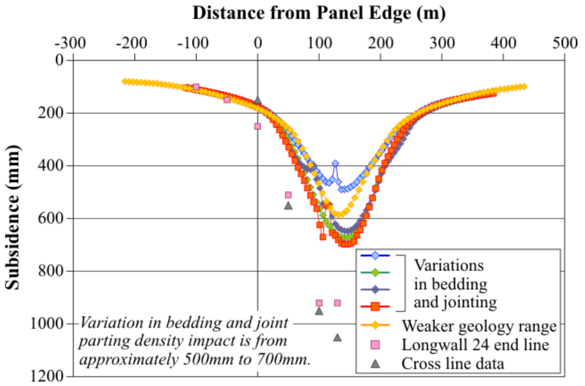


Figure 16 Subsidence profiles with Increased Bedding and Parting Density

The simulation of these factors showed that they were not sufficient to cause to the abnormal subsidence phenomenon.

A review of the subsidence data indicated that the abnormal subsidence was more akin to that related to panels of critical to super critical dimension. Therefore, overburden above the caving subsidence zone was not bridging across the panel at this site as was the case at other sites. It was concluded that the nature of the strata must be different to allow the non bridging behaviour. However, it was known that the material strength of the strata was not significantly different from other sites and as such the rock material had not significantly changed.

It was noted in the exploration work that the water table was significantly lowered toward the gorge.

It was also noted that water loss during drilling occurred in these zones. Hydrological testing of the overburden indicated that the conductivity of the strata above the gorge floor was two to three orders of magnitude above the strata below the gorge and that of holes where the water table was not so depressed. The conductivity is primarily related to fracture flow and indicated that the joints and bedding planes in this area were open relative to elsewhere.

It was noted that the joints and bedding planes were typically weathered and often coated with clay or clayey sand. It was postulated that the weathering of the joints and bedding planes had occurred due to percolation and flow of water through the overburden down to the level of the gorge. This would have occurred over the time frame of the formation of the gorge. Under these conditions the shear stiffness and shear stress along the planes would be significantly lower than those unaffected by weathering. The rock material strength (UCS) was not significantly affected, only the joint and bedding margins.

Models were run to assess this assumption by reducing the friction together with the shear and normal stiffness of the joints and bedding in the weathered zone. The results obtained showed a good match of the measured subsidence in terms of magnitude and shape.

As a means to validate the assumption and provide a better range of material properties, additional drilling and sampling was undertaken. Vertical and angled holes were drilled to intersect joints and bedding planes. The planes were tested to determine the shear and normal stiffness together with friction angle and cohesion.

The results are summarised in Figure 17 and show that the joints and bedding planes above the water table were significantly different to that below.

The friction angle of the joints and bedding was approximately 17-27 degrees in the weathered area whereas it was approximately 38 degrees elsewhere. The average spacing of high angle joints found in the inclined hole was approximately 4-5m.

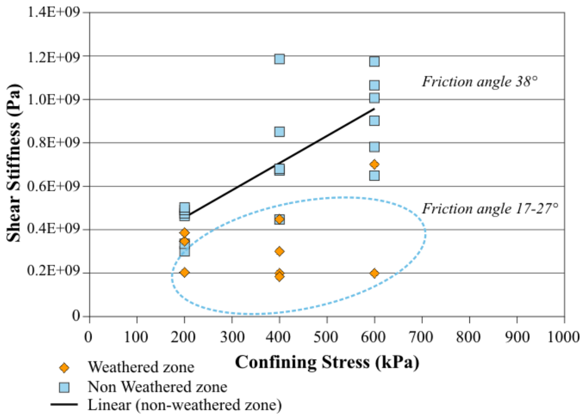


Figure 17 Rock properties in the Weathered and Non-Weathered Zones

The updated properties were included into the model and the resulting subsidence is presented in Figure 18 relative to the measured data. The results are very close in both magnitude and shape and demonstrate the impact of localised weathering of joints and bedding above the water table.

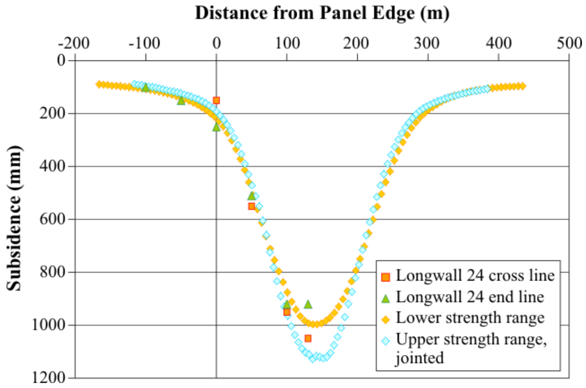


Figure 18 Modelled and Observed Subsidence Profiles in the Weathered Zone

The failure mode of the overburden under these conditions is presented in Figure 19 and shows the dominant role of slip along the bedding and jointing above the water table.

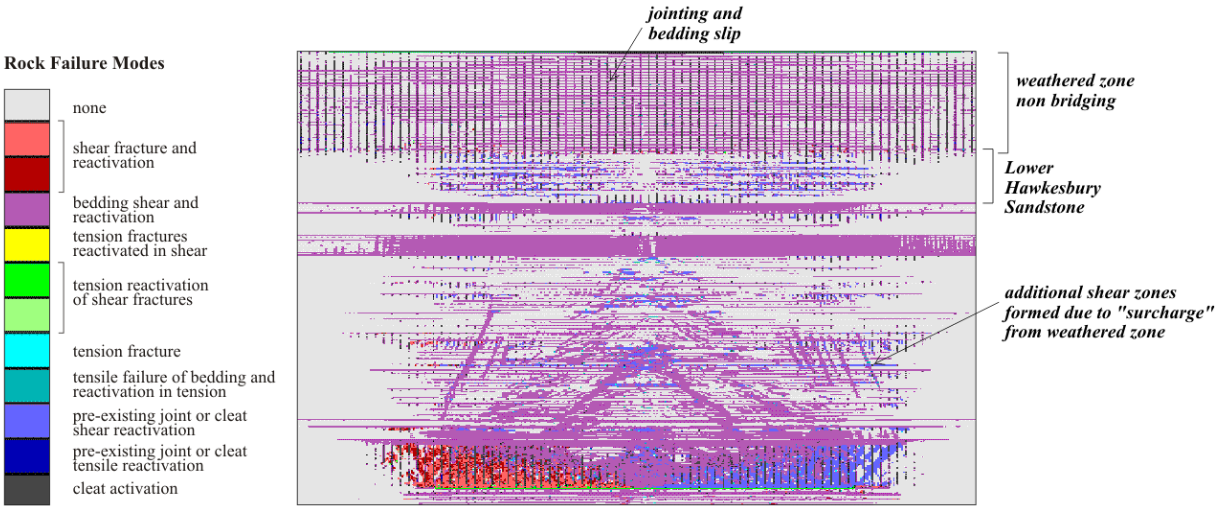


Figure 19 Failure Modes of the Strata in the Weathered Zone

The mechanics of the subsidence process is changed in the weathered zone. In this area, the subsidence caving zone extends up to the base of the weathered zone and the strata above the weathered zone have reduced spaning capability due to the low shear stiffness and friction properties of the joints and bedding. The strata above the water table act essentially as a 'dead weight' on the caved zone below and cause additional subsidence. Additional shear zones are formed in the 'caving subsidence zone' due to the surcharged overburden load. The geometry of the panel and height of the caving fracture zone is such that it is close to the critical dimension, and as such the 'non spaning weight' causes the panel to act more like a critical to super critical panel.

Variation in horizontal stress and rock material strength has no significant impact on the results. The key parameter is the stiffness of the joints and to a lesser extent the reduced friction angle.

The subsidence reduces and style changes along the panels as the thickness of the weathered zone reduces, and as the depth of the coal seam increases. The subsidence in Longwall 24B and Longwall 25 reduces to the north where the water table is restored to its normal value.

The measured subsidence is consistent with the modelling results.

9. Discussion of Results

The key outcome of the study is the recognition of the impact of a weathered zone of joints and bedding planes above the water table. Water loss during drilling is commonly noted in dissected topography and as such this phenomenon may be more widespread than just this site. It is recommended to evaluate the potential of this phenomenon where the joints and bedding planes are "open" due to weathering associated with water flow.

The impact of the weathering will also be dependent on the critical to supercritical dimensions of the panels. In this case, it was apparent that the panel was of critical dimension under the weathered zone. The low shear stiffness characteristics of the overburden in the weathered zone caused the panel to act more akin to a supercritical panel, whereas if the seam was mined at an additional 100m depth, the critical dimensions may not have occurred and the abnormal subsidence may not have developed.

It is possible at other sites, that the rock material may be weakened by the weathering process. This phenomenon would also reduce the spanning capability of the weathered section.

It is clear that each case needs to be assessed on the site conditions and mine geometry, however the phenomenon needs to be considered for subsidence prediction. This is a particular requirement in areas of sensitive infrastructure and residential dwellings where the impact of predictions and remedial measures are a key part of the mine design process.

The key indicators of this phenomenon appear to be a depressed water table and a high hydraulic conductivity of the overburden. Testing of joints, bedding planes and rock strength are key aspects to confirm the likelihood of this phenomenon occurring at a particular site.

Computer modelling has been an excellent tool to assess this phenomenon and is recommended to assess the potential of this phenomenon at sites which have the key indicators.

10. Conclusions

The abnormal subsidence at Tahmoor Mine is consistent with localised weathering of joint and bedding planes above a depressed water table adjacent to an incised gorge. The study has shown that other factors such as variation in stress field, joint zones, variation in rock strength and topographic factors did not sufficiently impact to induce the abnormal subsidence.

The outcome of this work was facilitated by an investigation program which combined normal exploration with hydrological characterisation and detailed geotechnical characterisation of the joints and bedding planes.

It was found that the low shear stiffness and friction angle of the weathered joints and bedding planes significantly reduced the bridging capacity of the strata. Where the weathered strata formed the bridging zone immediately above the caving subsidence zone, the abnormal subsidence occurred.

The subsidence reduced back to normal as the depth of weathering reduced and the resultant geometry of the weathered zone relative to the caving subsidence zone changed. Normal subsidence occurred where the strata above the caving subsidence zone had higher shear stiffness and friction angle to facilitate bridging across the panel.

The key indicators of abnormal subsidence were found to be:

- depressed water table;
- high hydraulic conductivity of the overburden;
- a panel width for which the caving subsidence zone extends close to the depth of weathered jointing and bedding.

Computer modelling has been an excellent tool to assess this phenomenon. Tahmoor Colliery intends to verify and confirm this result as mining progresses northwards from Longwall 26 through to 35 in the Tahmoor North lease area. Tahmoor has undertaken substantial surface to seam drilling in recent years, and has a broad knowledge of the regional water table and the nature of the overburden throughout the planned mining area.

The development and use of this modelling, combined with empirical tools such as the Incremental Profile Method, will improve the prediction of mine subsidence parameters and provide more certainty for all stakeholders in future longwall mining operations.

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