Appendix F – Nepean Fault and SR17 Report

Strata Control Technology

TAHMOOR COAL PTY LTD

Assessment of Rockbar SR17 and Nepean Fault Complex to Support LW W3 and W4 Extraction Plan

TAH5229

Mining Research and Consulting Group

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TITLE Assessment of Rockbar SR17 and Nepean Fault Complex to Support LW W3 and W4 Extraction Plan

REPORT NO TAH5229

PREPARED BY Ken Mills

DATE 1 February 2021

Report No	Version	Date
TAH5229	Draft	25 January 2021
TAH5229 Rev 1	Draft	29 January 2021
TAH5229 Rev 2	Draft	1 February 2021
TAH5229	Final	1 February 2021

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SUMMARY

Tahmoor Coal Pty Ltd (TC) owns and operates Tahmoor Coal Mine (Tahmoor Mine), an underground coal mine located approximately 80km south west of Sydney. TC is currently preparing an Extraction Plan (EP) for Longwalls West 3 and West 4 (LW W3-W4) that will start near Rockbar SR17 on Stonequarry Creek and mine sub-parallel to the Nepean Fault Complex (NFC) located to the east. TC commissioned SCT Operations Pty Ltd (SCT) to assess potential impacts of the proposed mining on Rockbar SR17 (SR17) and the potential for the NFC to influence subsidence behaviour in the subject area. This report presents our assessment of these two issues.

Valley closure movements at SR17 are expected to be small. SR17 is located at the start of LW W3. In this location, the three processes that are recognised to cause horizontal movements are expected to cancel each other out. The low levels of ground movement observed along Stonequarry Creek to date support this expectation but monitoring from LW W2 will be more informative because of the closer proximity of mining. Predicted valley closure movements are not expected to cause significant impacts at SR17 or cause any loss of water from the pool retained by SR17. Some opening of existing joints and the formation of some small fractures is considered possible as minor readjustments occur in the ground around the rockbar. However, these impacts are expected to be minor in the context of the existing joints and the general character of the site.

Mining LW W3-W4 is expected to cause an increase in maximum subsidence over extracted longwall panels close to the NFC similar to the increased subsidence observed over the starts of LW 24A, 25 and 32. The magnitude of maximum subsidence is expected to be higher than is typically observed in the Southern Coalfield for similar geometries and up to 50% higher over LW W4. The increased subsidence is expected to be manageable under existing TC subsidence management plans and of no particular significance.

Additional mechanisms associated with mining close to the NFC were investigated in the context of potential as principal hazards under *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014*. These included:

1. The potential for greater than predicted subsidence beyond the panel edges.

2. The potential for unconventional subsidence movements occurring over the panels and beyond the footprint of mining.

3. The potential for movements that might occur more quickly than conventional subsidence and increase micro-seismic activity.

None of these mechanisms are considered likely to have potential to contribute to outcomes with potential to be principal subsidence hazards.

TABLE OF CONTENTS

PAGE NO

1. INTRODUCTION

Tahmoor Coal Pty Ltd (TC) owns and operates Tahmoor Coal Mine (Tahmoor Mine), an underground coal mine located approximately 80km south west of Sydney. TC is a wholly owned entity within the SIMEC Mining Division of the GFG Alliance Group. TC is currently preparing an Extraction Plan (EP) for LW W3-W4 that will start near Rockbar SR17 on Stonequarry Creek and mine sub-parallel to the Nepean Fault Complex (NFC) located to the east. SIMEC commissioned SCT Operations Pty Ltd (SCT) to assess potential impacts of the proposed mining on Rockbar SR17 (SR17) and the potential for the NFC to influence subsidence behaviour in the subject area. This report presents our assessment of these two issues.

The report is structured as:

- Section 2 presents the conclusions of our assessment.
- Section 3 presents a description of the site.
- Section 4 presents an assessment of the potential impacts of proposed mining on SR17.
- Section 5 presents an assessment of the potential influence on the NFC on subsidence associated with the project.

SR17 was inspected on 23 September 2020 but our assessment is predominantly a desktop assessment. Further detail and context of these sites and subsidence monitoring more generally can be found in MSEC (2021). It is not intended to reproduce that detail here.

Figure 1 presents an overview of the site and the relationship of previous and proposed longwall panels to SR17 and the NFC.

2. CONCLUSIONS

The main findings of our investigation are presented in this section. More detail is provided in subsequent sections.

2.1 Impacts to Rockbar SR17

Subsidence effects in the form of valley closure movements at SR17 are expected to be small because of the location of SR17 at the start of LW W3. In this location, the three processes recognised to cause horizontal movements are expected to cancel each other out. The low levels of ground movement observed to date along creeks adjacent to LW W1 support this expectation. Valley closure after mining LW W3-W4 is expected to be less than 70mm and, considering the mechanics of horizontal movements about longwall panels, much less. This closure is not expected to be large enough to cause significant impacts at SR17. Monitoring results from mining LW W2 will become available to provide further detail of the magnitude of valley closure along Stonequarry Creek and the valley closure that can be expected at SR17.

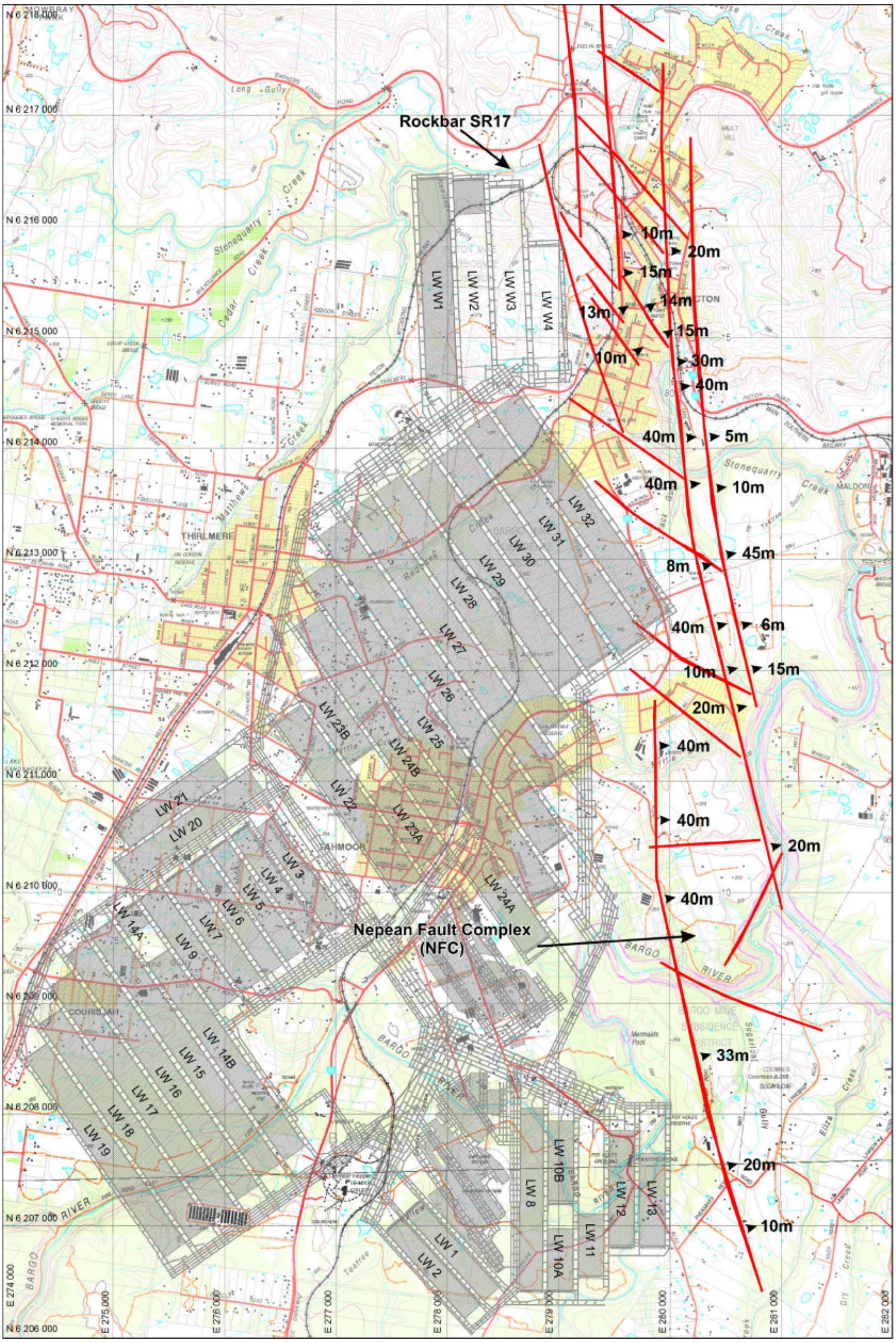

Figure 1: Tahmoor Mine, Rockbar SR17 and Nepean Fault Complex superimposed on 1:25,000 topographic map.

MSEC (2021) estimates valley closure at SR17 of 70mm from mining LW W3-W4 based on a comprehensive empirical dataset of measured valley closure. This dataset is general in nature and is not intended to account for the mechanics of the processes that cause horizontal subsidence movements. For instance, no differentiation is made between valley closure at the start and end of longwall panels. When allowance is made for the processes that cause horizontal movements, valley closure at SR17 at the start of LW W3 is expected to be much less than 70mm.

Some opening of existing joints and the formation of some small fractures is considered possible as minor readjustments occur in the ground around the rockbar. However, these impacts are expected to be minor in the context of the existing joints and the general character of the site.

Barbato et al (2014) report that 70mm of valley closure is unlikely to cause loss of water from the pool retained by SR17.

2.2 Influence of Nepean Fault

The shear stiffness of the overburden strata is expected to be reduced close to the NFC because of previous movements over geological time on the fault structures within this complex. A reduction in the shear stiffness of the overburden strata associated with strata weathering caused by proximity to the Bargo River Gorge was observed to cause an increase in subsidence over LW 24A and LW 25. Mining LW W3-W4 is expected to cause a similar increase in maximum subsidence over extracted longwall panels close to the NFC similar to that observed at the start of LW 32.

The magnitude of maximum subsidence is expected to be higher than is typically observed in the Southern Coalfield for similar panel geometries and overburden depths. Maximum subsidence may be up to 50% higher over LW W4 than is typical for this geometry and overburden depth. The increased subsidence is expected to be manageable under existing TC subsidence management plans and of no particular significance.

Additional mechanisms associated with mining close to the NFC are investigated in this report to provide a thorough and systematic review of all the subsidence outcomes that could reasonably be considered to have potential to be significant. None of these mechanisms is likely to cause outcomes with potential to be principal hazards under *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014*.

The following potential subsidence outcomes were investigated:

1. The potential for greater than predicted subsidence beyond the panel edges.

2. The potential for unconventional subsidence movements occurring over the panels and beyond the footprint of mining including at or across the Nepean Fault because of mining close to the NFC.

3. The potential for movements that might occur more quickly than conventional subsidence because of the presence of the fault and increase normal mining related micro-seismic activity due to the isolating effect of the fault.

Our investigations indicate that none of these mechanisms is likely to be a principal subsidence hazard.

The only subsidence monitoring at Tahmoor Mine that extends across the Nepean Fault is monitoring associated with LW 13; a panel mined in the southeast part of the mine in the early 1990's (see Figure 1). This monitoring extended partly across the projected fault outcrop. No unusual or unconventional subsidence behaviour was observed at the projected fault outcrop.

Abnormal subsidence causing greater than predicted subsidence is observed near the south-eastern ends of the longwall panels from LW 24A, LW 25 and LW 32, but this greater than predicted subsidence over the panel is not associated with significantly greater than predicted subsidence beyond the panel edges. If greater than predicted subsidence occurs over LW W3-W4, subsidence outside the panel footprint is expected to be less than predicted because of the lower overburden shear stiffness.

Unconventional subsidence movements are possible within the subject area unrelated to the presence of the NFC. Step changes at the fault are not expected but would be of small magnitude, less than a few tens of millimetres, if they were to occur. Unconventional subsidence movements observed at Tahmoor previously were identified early and successfully managed with the existing subsidence management plans. This approach is expected to be effective above LW W3-W4 as well.

Mining induced micro-seismicity occurs routinely as the overburden strata fractures and moves downward toward the void created by longwall mining. 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. The micro-seismic activity associated with this ground movement occurs regularly and so has low magnitude. Disturbance of the ground around the NFC is expected to reduce the strength of the ground, increase the frequency of micro-seismic events, and reduce their magnitude.

3. SITE DESCRIPTION

Figure 2 shows a plan of the site, LW W3-W4, SR17 and traces of the NFC based on surface mapping (SCT 2018 and 2020) and in-seam drilling.

TC is planning to mine a 2.1m thick section of Bulli Seam with LW W3-W4 forming voids that are 283m and 285m wide respectively including gateroads. The seam dips to the northeast at approximately 1 in 20. The overburden depth is approximately 470m at the start of LW W3 and approximately 550m at the start of LW W4. The overburden section comprises approximately 310m of Narrabeen Group sandstones and siltstones, up to 185m of Hawkesbury Sandstone, and a cap of Wianamatta Shale at the surface.

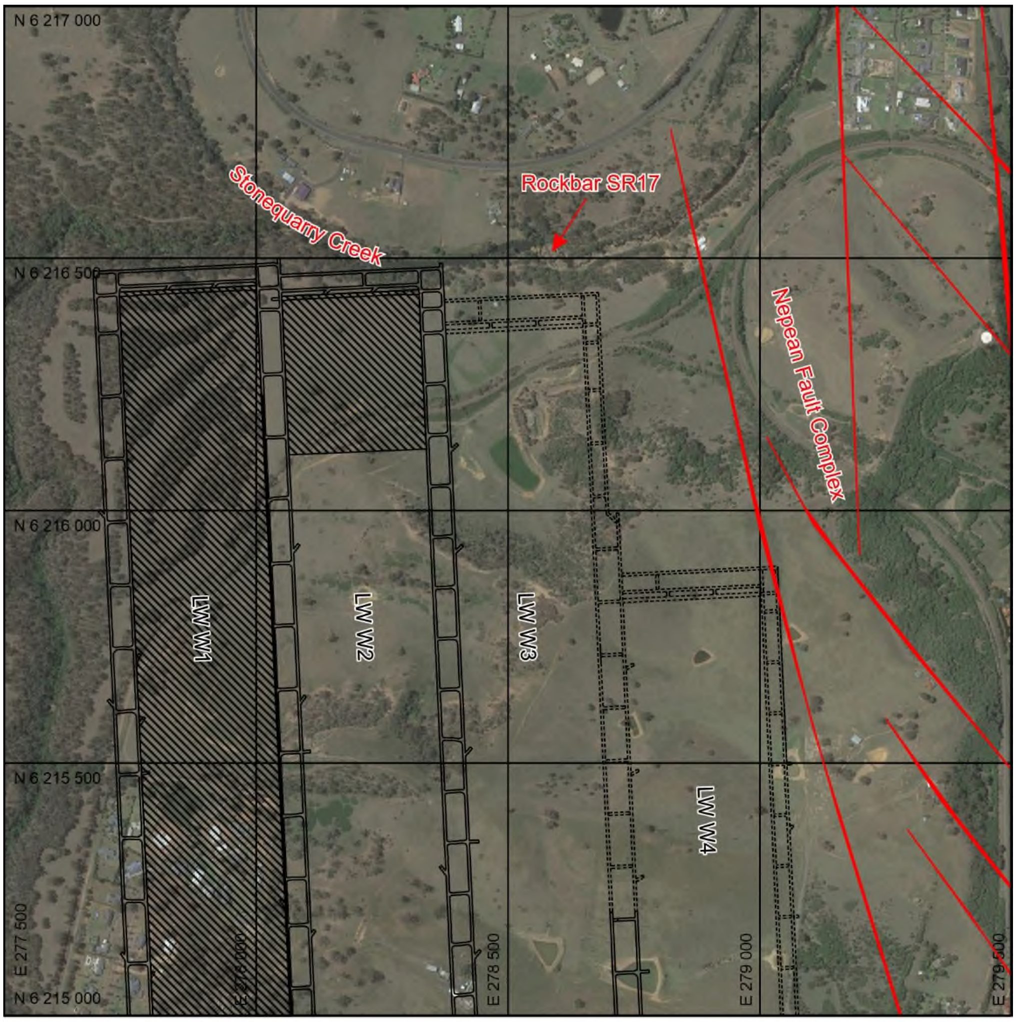

Figure 2: Site plan showing LW W3 - W4 relative to Rockbar SR17, Stonequarry Creek and the Nepean Fault Complex.

SR17 is a broad flat area of exposed rock located on Stonequarry Creek. SR17 is formed within the upper part of the Hawkesbury Sandstone outcrop. The rockbar extends between 100m and 160m north of the start line of LW W3. The rockbar is approximately 40m wide and 70m long. The rockbar is accessible by road and used as a ford; part of which is concreted. Endeavour Energy has installed a power pole on the rockbar to provided 11kV power to private properties on the south side of Stonequarry Creek including Stonequarry Wastewater Treatment Plant. There are up to 120 Aboriginal heritage grinding groove sites located on the rockbar. The site is assessed as having high significance as a heritage site (EMM 2020).

The NFC is located to the east of LW W3-W4 with one branch expected to come close to the northeast corner of LW W4. The NFC is a geological structure that trends for over 85km starting north of Richmond and extending south to south of Bargo. The structure is commonly described as a monocline in the north.

Mapping of surface outcrop indicates a series of en-echelon faults with multiple conjugate fault segments and splays (SCT 2018 and SCT 2020). A complex of ramping strata between fault segments form monoclinal sections.

Fault segments show variable vertical displacement as fault throws reduce towards the terminal ends of each fault segment. This style of faulting strata deformation results in the terrain and the rock type present at the surface reflecting the geometry of the faults.

4. POTENTIAL SUBSIDENCE IMPACTS AT SR17

This section presents the subsidence movements and impacts expected at SR17 from mining LW W3-W4. Valley closure movements at SR17 are expected to be small because of the location of SR17 at the start of LW W3 where the three recognised processes that cause horizontal movements tend to cancel each other out. Valley closure movements of less than a few tens of millimetres are expected when LW W3 is mined. These movements are not expected to be large enough to cause significant impacts at SR17. Monitoring results from mining LW W2 will become available to provide further detail of the magnitude of valley closure along Stonequarry Creek.

4.1 Mechanics of Horizontal Movements

There are three main processes recognised to contribute to horizontal subsidence movements observed on the surface, systematic, stress relief and topographic movements. An overview of these processes is presented in this section to show how they combine to reduce ground movements at the start of each longwall panel. More detail and discussion of these three components is presented in Mills (2014).

Systematic or conventional horizontal movements occur wherever there is active subsidence. The surface moves initially toward the freshly created void and subsequently in the direction of mining. Systematic movements typically have a magnitude of less than about 200-300mm and are largest over the start line of each longwall panel where movement toward the freshly created void and the direction of movement are additive.

Stress relief movements occur when tectonic energy stored as horizontal stress within the overburden strata is released by mining subsidence. When the horizontal stresses are high, the magnitude of this horizontal stress relief movement is typically less than 200mm at the goaf edge but continues gradually away from the panel and may be measurable for some kilometres from active mining. Stress relief movements cause only small differential movements and are generally imperceptible.

Topographic or dilational movements occur in sloping terrain. When the overburden subsides incrementally, fractures are formed within the rock causing the overall volume of the rock to increase by the volume of the fractures. The topographic component occurs in a downslope direction and depending on the terrain may have a magnitude much larger than the other two components, typically in the range 0.3-0.5 times vertical subsidence (300-500mm) and sometimes more than the magnitude of vertical subsidence in steep terrain. This movement typically occurs on bedding planes and is commonly referred to as valley closure because the horizontal movement in a downslope direction causes the sides of valleys to move together.

When mining away from a river valley or other topographic low point, systematic movements and stress relief movements occur in a direction toward the longwall panel and downslope movement associated with topography occurs in the opposite direction toward the river. In this situation, the three components of horizontal movement tend to cancel each other out and valley closure movements are significantly reduced as a result.

4.2 Predicted Movements

MSEC (2021) predicts subsidence movements at Rockbar SR17 from mining LW W3-W4 of 40mm vertical and 70mm horizontal valley closure. Allowing for significantly lower levels of valley closure expected at the start of longwalls mining away from creeks, rock fracturing at SR17 is expected to be slight. No loss of surface water is expected over SR17.

The methodology used by MSEC to estimate valley closure uses a comprehensive empirical data set of valley closure, but one that does not differentiate closure movements based on location relative to a panel. Valley closure movements near the start of a panel are not recognised in the database as being different from valley closure movements along the side of a panel or those near the end of a panel. Using this approach, valley closure movements at the start of a panel are expected to be much less than movements at other locations around an extracted longwall panel because the components contributing to horizontal movement, described in the previous section, act in opposite directions and tend to cancel out. The magnitude of horizontal closure at SR17 is expected to be much less than 70mm given the geometry of SR17 relative to the start of LW W3.

TC measured the closure along Stonequarry Creek during the period of mining LW W1 using survey marks and GNSS units. The only significant movements were apparent during a period of heavy flooding that occurred soon after the LW W1 commenced and may have continued for a period afterwards while the pegs were reinstated. The changes are thought likely to be caused by survey peg disturbance rather than real ground movements. It is possible that some valley closure was missed during the period before monitoring pegs were reinstated. The absence of any further significant closure along Stonequarry Creek during mining of LW W2 would indicate that closure movements at the start of LW W1 and LW W2 remained small and less than the survey tolerance of ±5mm.

Survey measurements of multiple pegs across SR17 indicate horizontal strains measured to date from mining LW W1 are less than survey tolerance of ±0.25mm/m. Strains of this magnitude would be too small to be perceptible as impacts to the rockbar. The corners of LW W1 and W2 are 560m and 260m respectively from SR17.

The start of LW W3 is 100m from SR17 at its closest point. The experience to date of low ground movements at SR17 is encouraging. Further movements are expected to remain small when LW W2 and LW W3 are mined and monitoring will provide the opportunity to confirm this expectation.

4.3 Impact Assessment

Valley closure movements are not expected to be large enough at SR17 to cause significant impacts to the rockbar. Monitoring results from mining LW W2 will become available as further confirmation of the magnitude of valley closure along Stonequarry Creek.

Some opening of existing joints and the formation of some small fractures is considered possible as minor readjustments occur in the ground around the rockbar in response to subsidence from longwall mining. However, these impacts are expected to be minor in the context of the existing joints and the general character of the site.

Barbato et al (2014) report 70mm of valley closure is unlikely to cause Type 3 impacts. Type 3 impacts include fracturing of the rockbar causing a reduction in standing water based on average rainfall and background surface water flow. These observations would indicate that water is unlikely to be lost from the pool retained by SR17.

5. Subsidence Associated with Proximity to NFC

The start of LW W4 is approximately 4km from the Nepean River Gorge and 700m from Stonequarry Creek. The Nepean River Gorge is deeply incised into the surrounding plateau with potential to significantly draw down the groundwater system. Stonequarry Creek is generally less than 10m below the surrounding countryside and much less likely to significantly modify the groundwater system. Changes to the shear stiffness of the overburden strata in the vicinity of LW W4 are, however, likely to be caused by proximity to the NFC.

5.1 Investigation Approach

The approach to investigate the potential impacts of the Nepean Fault on the subsidence associated with mining LW W3-W4 was to examine the potential for subsidence impacts in the context of hazards that would be of significance in the *Work Health and Safety (Mines and Petroleum Sites) Regulation 2014*. This information is intended to assist in:

- Improving co-operation and co-ordination of action, with respect to subsidence between the mine operator and relevant persons conducting any business or undertaking that is, or is likely to be, affected by subsidence.

- Detailing the site characteristics, including relevant mining geometries, geological, hydrogeological or geotechnical conditions and potential impacts on relevant surface and subsurface features.

- Managing the risks to the health and safety of workers and other persons from subsidence.

At the commencement of the investigation, SCT identified the following potential subsidence outcomes in the subject area that might conceivably be a consequence of proximity to the NFC:

1. The potential for greater than predicted subsidence within the footprint of LW W3-W4 to cause greater subsidence beyond the panel edges.

2. The potential for unconventional subsidence movements occurring beyond the edge of LW W4, including at or across the NFC.

3. The potential for mining induced stress changes near the NFC to cause fault structures to be mobilised.

4. The potential for movements that might occur more 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.

Our investigation indicates that none of these potential outcomes is likely to occur and none are considered to have potential to be principal hazards. Nevertheless, they are investigated in the following sections, in the context of providing a thorough and systematic review of all the subsidence outcomes that could reasonably be considered to have potential to be significant.

5.2 Potential for Subsidence Greater than Predicted

Previous subsidence behaviour at Tahmoor is reviewed in this section to provide a basis to assess the potential for greater than predicted subsidence in the subject area. Possible reasons for increased subsidence observed at the south-eastern ends of the longwall panels are explored.

MSEC analysed the extensive subsidence monitoring network developed at Tahmoor above LW 24-32. A review of subsidence monitoring indicates that subsidence above the start of each of these longwall panels is:

- slightly greater over LW 28-31
- significantly greater over for LW 24-27 and 32

than observed more generally across the longwall panels at Tahmoor and elsewhere in the Southern Coalfield of NSW for similar geometries. This increased subsidence is termed "abnormal" because of its unusual character and localised nature.

Gale and Sheppard (2011) reported that numerical modelling showed that this abnormal subsidence is consistent with localised weathering of joint bedding planes above a depressed water table adjacent to an incised gorge. This localised weathering is thought to have contributed to lower shear stiffness of the overburden strata and greater magnitudes of surface subsidence.

As longwall mining moved to the north, the start of each panel moved away from the Bargo Gorge and gradually closer to the NFC. From LW 29 onward, maximum subsidence near the start of each panel once more increased above predictions. Subsidence over the start of LW 32 is approximately 50% higher than predicted and approaches the levels observed over LW 24A and LW 25. Subsidence along most of LW 32 is slightly greater than predicted.

The shear stiffness of the overburden strata is likely to decrease close to the NFC. The increased subsidence associated with proximity to the NFC is considered likely to be a result of this reduction. Over LW 24A and LW 25, proximity to the Bargo Gorge is likely to have been the main cause of the reduced shear stiffness inferred by Gale and Sheppard. Over LW 29-32, proximity to the NFC is likely to be the cause of the reduced shear stiffness. In both cases, the outcome is subsidence greater than predicted based on general experience in the Southern Coalfield.

On this basis, subsidence over LW W3 and LW W4 especially is expected to be greater than the subsidence that would be indicated by general experience elsewhere in the Southern Coalfield. This extra subsidence is of no particular significance and has been managed without incident throughout the period of mining at Tahmoor Mine.

5.3 Potential for Unconventional Subsidence Movements Associated with the NFC

The term "unconventional subsidence movement" is used here to describe ripples and sharp, localised changes in level associated with bedding plane shear. SCT is not aware of any evidence from previous mining at Tahmoor Mine of significant unconventional subsidence movements outside of the mining footprint, but such movements have been observed at other sites.

On this basis, there is some potential for low level unconventional subsidence movements to develop outside the footprint of mining and there may be some greater potential for such low-level movements due to the ground disturbance caused by the NFC.

However, notwithstanding the possibility of unconventional subsidence movements occurring to the east of LW W4 above the NFC, much greater levels of ground movement have been successfully managed previously at Tahmoor Mine using the proposed management strategies. SCT anticipates that these management strategies would again prove suitable to manage any unconventional movements that may develop in the subject area.

5.4 Monitoring Experience

Four subsidence lines at Tahmoor extend partly or fully across the NFC. The first of these, 900 Line, is a cross line located above LW 13 close to and partly over the NFC. The location of LW 13 is shown in the bottom right of Figure 1. Three recent subsidence lines were placed across the NFC adjacent to the starting corner of LW 32. The detailed monitoring results from these lines are presented in MSEC (2021) and are not repeated in this report, but the findings are considered here.

Figure 3 shows the subsidence measured on 900 Line above LW 13. Greater than predicted subsidence was observed near where the NFC is immediately adjacent to LW 13 and coincidentally where the Bargo River crosses the panel. LW 13 void is 235m wide and the depth below surface of the mining horizon is approximately 420m.

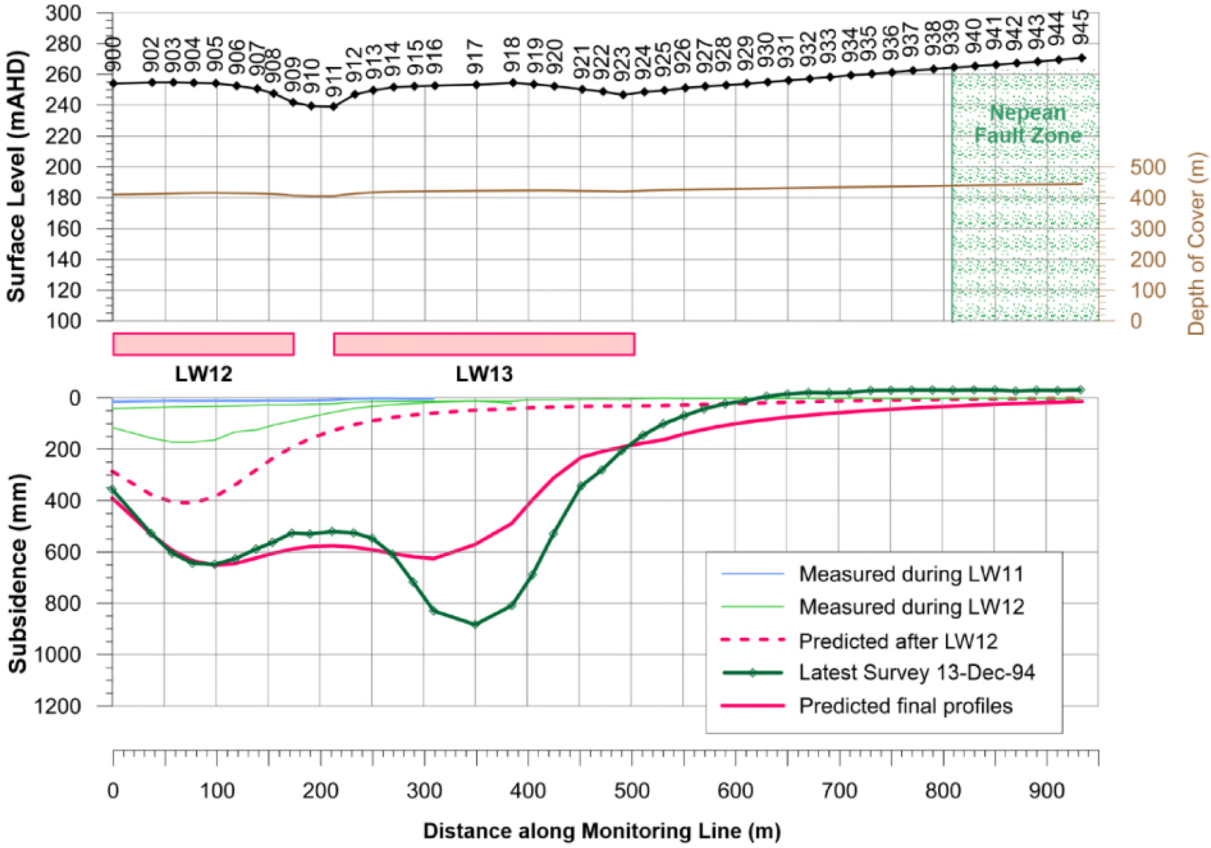

Figure 3: Predicted and observed profile of total subsidence along the 900-Line over Longwall 13 extending above the Nepean Fault Complex (MSEC).

Monitoring across the NFC adjacent to LW 13 and LW 32 indicates no unconventional subsidence occurred in the profile near to the NFC. Subsidence over each panel was greater than predicted, consistent with proximity to the NFC, but the subsidence profiles over the goaf edge are smooth and consistent in character with the subsidence profiles observed elsewhere at the mine where the NFC is not present.

There is no evidence in the subsidence profile over the solid abutment at LW 13 or LW 32 of any differential subsidence movements associated with mining near the NFC.

5.5 Unconventional Subsidence Generally

Although unlikely, it is possible that unconventional subsidence unrelated to the NFC may occur within the subject area during mining of LW W3-W4. Unconventional subsidence movements are observed above TCM from time to time and therefore, may occur above LW W3-W4. The management strategies that have been in place previously are expected to be effective for managing any unconventional subsidence movements that may develop.

The mechanics of the process causing unconventional subsidence movements involve lateral dilation of the subsiding strata that generate relative movement as shear on bedding planes similar in character to valley closure movements. In general, unconventional movements occur within the longwall footprint where subsidence and therefore, lateral dilation forces are greatest. Occasionally, first movements are apparent ahead of mining and then develop further as mining approaches.

5.6 Step Changes at the Fault Outcrops

Individual geological structures within the NFC are mapped as being sub-vertical. Unconventional subsidence movements typically occur on sub-horizontal geological structures such as bedding planes.

The potential for the Nepean Fault itself to cause a step change in the surface is considered small. Expressions of the NFC come closest to longwall panels near the start corner of LW W4. At this location, vertical subsidence is expected to be a few tens of millimetres in magnitude. Any differential vertical movement that may occur at the surface expression of geological structures within the NFC, beyond the panel edge, would be limited to less than this maximum vertical subsidence.

Mills and O'Grady (1998) measured the overburden movements above extracted longwall panels. The three-dimensional geometry of the bridging overburden strata around the start corner of LW W4 limits the potential for differential subsidence movements. Although the overburden strata on the panel side of any geological fault structure may not be able to transfer full load to the other side of the structure, the overburden strata on the panel side of the fault is likely to bridge and limit subsidence to low levels. Along the line of the fault, the effective panel width is small close to the fault because the longwall panel does not mine through the fault. The overburden strata is able to bridge across narrow panels at depth to limit surface subsidence to low levels.

5.7 Potential Increased Micro-Seismic Activity and Rapid Movements

Events that lead to seismic energy being released require the sudden failure of rock strata, most commonly with some component of tensile or shear failure. In the Southern Coalfield, the deformations of the overburden strata directly over the goaf occur as an upward progression of a series of shear and tensile failures involving individual strata units. There are many individual units and the horizontal stresses are large enough, that the failure processes tend to occur incrementally in small steps.

From time to time, failure of some of the thicker units produces enough energy to register as a small seismic event that can sometimes be heard, but even these larger events are seldom large enough to be felt directly. These micro-seismic events can be detected by geophones and their source located by triangulation by comparing arrival times of the seismic energy.

The presence of previously activated shear planes close to the NFC increases the degrees of freedom within the overburden strata for shear movement. The increased flexibility of strata softened by previous shear plane development is expected to reduce the magnitude of any seismic events that might occur from mining.

The gradual progress of longwall mining means that the upward progress of caving tends to develop gradually. Longwall retreat of 10m per day is expected to cause an average upward progression of the zone of large downward movement, using the terminology of Mills and O'Grady (1998), of approximately 10m per day.

It is possible that some stronger, more massive units bridge more effectively. The upward progression of caving may be delayed for a day or two until these units fail. However, the horizontal stresses in the Southern Coalfield are typically so large compared to the strength of the rock subject to the action of gravity in the third dimension that, the upward progress of rock failure inevitably occurs in small steps and is, therefore, gradual at the scale of interest.

In the Southern Coalfield, surface subsidence effects tend to develop gradually because of the gradual nature of the upward progression of caving. By comparison, the presence of massive conglomerate beds and a low horizontal stress environment in the Newcastle Coalfield, particularly near the coast, can lead to the development of sudden tensile failures of large volumes of rock with consequent release of higher levels of seismic energy and sudden movements. Such events are typically not observed on the Southern Coalfield except in a few special circumstances associated with valley closure and initial formation of large goaf areas leading to widespread stress relief. Neither of these special circumstances are relevant to the subject area.

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