Appendix G – Picton Rail Tunnel Report

Strata Control Technology

TAHMOOR MINE

Structure Determinations of the Nepean Fault Adjacent to the Picton Rail Tunnel

TAH5262

Mining Research and Consulting Group

SCT Operations Pty Ltd PO Box 824 Wollongong NSW 2520 Australia
Phone: +61 2 4222 2777 Email: sctnsw@sct.gs Website: www.sct.gs
ABN 23 078 328 953

Report To	Kevin Golledge Project Manager Rail SIMEC Mining PO Box 100 Tahmoor NSW 2573
Title	Structure Determinations of the Nepean Fault Adjacent to the Picton Rail Tunnel
Report No	TAH5262
Prepared By	Luc Daigle
Date	22 December 2020

Luc Daigle
Senior Engineering Geologist

Report No	Version	Date
TAH5262	DRAFT	14 December 2020
TAH5262	FINAL	22 December 2020

Ken Mills
Principal Geotechnical Engineer

SUMMARY

SIMEC Mining (SIMEC) operates Tahmoor Coal Mine in an area approximately 70km southwest of Sydney. SIMEC requested SCT Operations Pty Ltd (SCT) to comment on potential impact of Nepean Fault Complex projections interpreted to pass through the Picton Rail Tunnel (PRT) area. The tunnel is excavated through the basal Wianamatta Group member the Ashfield Shale, the floor of the tunnel sits very close to the upper contact of the Hawkesbury Sandstone. Subsidence is anticipated to impact the area as far field effects from planned longwall panels located approximately 250 to 500m to the west of the fault projection intersecting the PRT.

The investigation found no direct impact on the PRT from previous subsidence movements on interpreted faulting. Analysis found an additional NFC segment adjacent the tunnel. The faulting in this area is interpreted to represent a zone of small offsets distributed over numerous small faults, splays, and strata ramps. Nearby mining in LW3 is further than 500m from the PRT, and LW4 is 250m from the PRT both are still expected to cause far field subsidence effects that will extend to the PRT. These effects are anticipated to be small, general body movements, distributed and dispersed over the numerous NFC defect planes. Minor strata shears are anticipated. Stress relief associated with mining is expected to increase hydraulic conductivity in the vicinity of the NFC. The changes in hydraulic conductivity are expected to be generally small, with relative position and direction of subsidence and orientation of the NFC segments influencing the magnitude of any change.

SCT has previously completed an investigation of the Nepean Fault Complex (NFC) in 2018, the NFC is a structure that trends for over 85kms starting north of Richmond to south of Bargo. Described often as a monocline in the north, the complex is from this work defined as a series of en-echelon faults with multiple conjugate fault segments and splays, with a complex of ramping strata between fault segments forming sections that form monoclines. Fault segments show highly variable vertical displacement as these offsets rapidly reduce in throw towards the terminal ends of each fault segment, this style of faulting strata deformation resulted in terrain highly influenced by the geometry of the faults and the rock type present at the surface.

In the PRT area and adjoining area over the active mining, the topography is dominated by a plateau surrounded by deep incised gorges and river valleys representing fault boundaries. At the PRT, the NFC is present as the terminating ends of several north-south trending faults segments, no measurable offsets were determined for the sections passing through or adjacent the PRT, faulting further to the east and south east demonstrate fault ramping and large measurable offsets dominate as does a shift in geography from gentle rolling hills and plateaus to steep sided gorges.

This investigation found the following:

- Nepean Fault Complex segments projected through the Picton Rail Tunnel area are mainly terminal ends of north-south trending faults with minimal offsets distributed among the fault planes present.

- No impact from faulting was observed during inspection of the tunnel.

- Review of geotechnical coring investigations recently completed in the tunnel showed no obvious strata change intersected that would indicate any large fault offset or deformation.

- The tunnel is formed on or above the upper contact of the Hawkesbury Sandstone in the overlying Wianamatta Group shales.

- Observation of microstructure has determined listric faulting forms part of the Nepean Fault Complex at this location, taking high angle faulting into curved planes dispersing the displacement into the bedding then re-emerging as multiple faults with smaller displacements.

- Observed microstructure indicates a listric faulting style for the NFC at the PRT consistent with extensional movements transitioning into multiple faults which further disperse and reduce offset displacements. This is a significant determination on fault behaviour at this location and impacts understanding of the faulting distribution.

- Review of the 2018 NFC analysis and analysis of latest imagery found an additional fault projection located immediately west of the PRT.

- The additional fault identified trend north-northwest to south-southeast and abuts the northeast corner of LW4.

- Subsidence movements at the PRT from mining of LW3 are further than 500m away and are anticipated to be slight and of a general body nature affecting the PRT evenly. Mining of LW4 is approximately 250m away but because of the smaller subsidence footprint is also anticipated to be slight impact on the PRT.

- Far field subsidence movements at the PRT are expected to be slight with movement potentially concentrated on strata boundaries and other low strength horizons.

- Subsidence movements on geological fault structures intersecting the PRT area are expected to be distributed over the numerous defect planes found in the terminating fault segments and fault ramps.

- Hydraulic conductivity of the strata around the PRT is expected to increase slightly as stress is relieved on pre-existing joints.

SIMEC has a regular program of inspection and monitoring of the PRT is underway, there is an inclinometer installed adjacent the tunnel, detailed surveys through the tunnel have been completed, distometers are installed throughout the tunnel and regular geotechnical inspections are planned during mining to monitor for any movement and potential damage.

TABLE OF CONTENTS

PAGE NO

1. INTRODUCTION

SIMEC Mining (SIMEC) operates Tahmoor Coal Mine in an area approximately 70km southwest of Sydney. SIMEC requested SCT Operations Pty Ltd (SCT) to comment on potential impact of Nepean Fault projections interpreted to pass through the Picton Rail Tunnel (PRT) area. SCT was commissioned to help define the Nepean Fault Complex (NFC) near LW32 in 2018. That report presented a 12km section of the NFC to characterise the nature of the faulting and best determine the location of the fault planes and their surface expression. The NFC is a structure that trends for over 85kms starting north of Richmond to south of Bargo. Described often as a monocline in the north, the complex is from this work defined as a series of en-echelon faults with multiple conjugate fault segments and splays, with a complex of ramping strata between fault segments forming sections that form monoclines through to steep sided fault bounded gorges.

This report describes an inspection of the PRT, adjacent outcroppings, an updated review of the NFC interpretation and analysis of the fault offsets, and a discussion on the potential impacts on the interpreted faults adjacent the PRT from nearby mining activity.

The findings in this report are based on review of the previously completed mapping, inspection of outcrops at the PRT, further analysis of the mapping completed, and review of recent geotechnical investigations of the tunnel.

In the 2018 investigation, field mapping, data compilation, desktop analysis of aerial imagery and geographic features was completed to define the NFC adjacent the Tahmoor Mine between Picton and Tahmoor. Faulting was found to be dominated by sub-vertical, north-south first order faults typically 2-5 km long, set in an en-echelon distribution. Second order, conjugate, strike slip faults are evident in the space between the first order faults. Additional lesser order splays and low angle faults are anticipated but require direct observation to locate.

The surface geology consists of exposures to the Wianamatta Group and Hawkesbury Sandstone, the contact between these geological formations dominates the terrain. The Wianamatta Group form low rounded hills, slopes, and plateaus while the Hawkesbury Sandstone forms steep sided gorges and cliffs. The contact between the two is very distinct and forms a readily identifiable stratigraphic marker used to determine fault offsets.

Using topographic maps, the relative position of the marker indicated the relative vertical offsets across sections of the NPF. The first order faults were shown to have variable offset that quickly diminished as they terminate and the intervening terrain forms monoclines and fault ramps with vertical offsets ranging up to 60m in the Picton to Tahmoor area.

Mapping and ground truthing was able to delineate and define the nature of the fault complex with first order and second order fault determinations well established. First order faults trend north-south set in an en-echelon pattern dominating the terrain with second order conjugate strike slip faults evident between these. The resultant geography bordered by the faulting is the formation of plateaus, steep sided gorges, and alluvial filled plains.

In 2018, mining at Tahmoor Mine was mining LW32. This panel commenced adjacent a section of the NFC characterised by high-angle, north-south fault sections with large vertical offsets. The majority of LW32 retreated from the faults through a transition zone of fault ramps and into a zone of minimal fault disturbance. The current mine position is a group of four short longwall panels located to the north. These panels run from the north and retreat to the south. The north-south orientation runs sub parallel to where the NFC is located west of Picton and the Picton Rail loop and tunnel.

These four short panels are located beneath an area of plateau characterised by Wianamatta Group shales, numerous dams and low hummocky hills dominate the geography. The interpreted expression of the NFC commences approximately 200m to the east where short terminating portions of the fault complex form a ramp complex. The NPF transitions from high displacement offset areas in the south to more numerous smaller offset faults and ramping adjacent the village of Picton (Figure 1). The area around the PRT shows minimal fault plane offset as most of the first and second order faults are near their terminal ends. Faults trending north from here extend under an alluvial plain and interpretation of offset and location becomes difficult, however the fault offsets are anticipated to increase moving further to the north.

Field observation of the PRT, where a portion of the NFC projects, found no indication of disturbance of the strata immediately surrounding the tunnel. Microstructures observed indicate listric faulting is a mechanism of deformation were mapped within outcrop exposure (Figure 2) of the Ashfield Shale at the tunnel entrance. These mimic the interpreted multi fault plane nature of the NPC structure zone and the dispersed nature of the faults as both smaller offsets and strata ramping. The tunnel appears to be wholly within the Ashfield Shale of the Wianamatta Group and possibly using the upper contact of the Hawkesbury Sandstone as the base. SIMEC has asked what potential impacts their nearby longwall panel mining subsidence may be anticipated on the NFC at the PRT.

Direct mine subsidence event is located approximately 500m west of any faults intersecting the PRT in LW3 and 250m southwest in LW4, the effects on the PRT are considered far field impacts because of the distance from the main predicted event. These impacts will occur as the ambient stress and strain in the rock mass adjusts with the subsidence. The new longwall panels run parallel to the predicted mainly north-south trending NFC, movement from the subsidence will mainly exert a tension de-stressing event or relief of the stress acting on the faults near the surface and at depth. This effect may allow minor settling of these features, small differential movement may occur between the major strata units such as the base of the Wianamatta Shale and top of the Hawkesbury Sandstone, between the Hawkesbury Sandstone and the Bald Hill Claystone, and the underlying Bulga Sandstone. The underlying units and coal seams may also experience minor bedding parallel shear at this location. Structural disturbance may be considered minimal, potential for increased fracture permeability may be locally anticipated but diminish quickly away from the subsidence event.

Distribution of the NFC into several smaller defect planes, fault ramps, splays and conjugate fault planes lessens the potential for subsidence to impact the PRT. Monitoring of the tunnel for displacement is already well established and potential for permeability changes is monitored by existing vibrating wire piezometers.

2. OUTCOMES OF THE INVESTIGATION

Figure 1 shows the latest revised distribution of faults mapped and interpreted from the study. An additional north-south trending segment of the NFC was identified immediately west of the PRT, located approximately 200m east of the new longwall panel LW3 and abuts the north east corner of LW4 outer gateroads, the feature is likely to run mainly towards the north-northwest. Examination of outcrops at the PRT found microstructure in Wianamatta Group shales above the PRT northern portal.

Figure 2 shows a photograph of a vertical defect plane that then curves into the bedding, the movement on the planes then transitions into three curved defect planes that then become vertical. Microstructure are considered to mimic the large scale and are used in mapping to demonstrate the style and geometry of structures present. Here the fault splays from a single fracture into multiple fractures via a listric splaying of the fault surface, the relative larger offset on the singe fracture is dispersed onto the splay and multiple fractures transition from the splay. Listric faulting is indicative of extensional geological conditions which correlates well with fault ramping and stepped fault offsets and normal fault offsets locally observed in the NFC.

Regionally, the NFC is a well-known extension of the Lapstone Monocline; and is usually described as a high angle reverse fault complex with complicated displacement distribution. The NFC exhibits an en-echelon distribution of first order fault segments with major offsets. Ramping between individual fault segments is well developed in the NFC between the numerous en-echelon fault surfaces. First order north-south fault segments, each of limited extent, step across the area investigated. These display a distinct left lateral character. Second order faults are abundant and trend mainly northwest to southeast but can vary significantly. These are mainly conjugate sets of strike slip faults and splay faults located between the en-echelon first order faults, they tend to mimic the dominant joint set present in the Hawkesbury Sandstone. Massive sandstone units are usually characterised by dominant joint sets that will influence the distribution of subsequent occurring structures.

The terrain is heavily influenced by both the position of all these faults and the contact between the erosion resistant, quartz sandstone of the Triassic aged Hawkesbury Sandstone and the overlying Ashfield Shale of the Wianamatta Group. The terrain along the length of the fault forms a disrupted terraced plateau in the north and is deeply incised by gorges towards the south. Outcrops are limited to creek channels and gorges in the drainage system and along road, rail cuttings, and quarry pits.

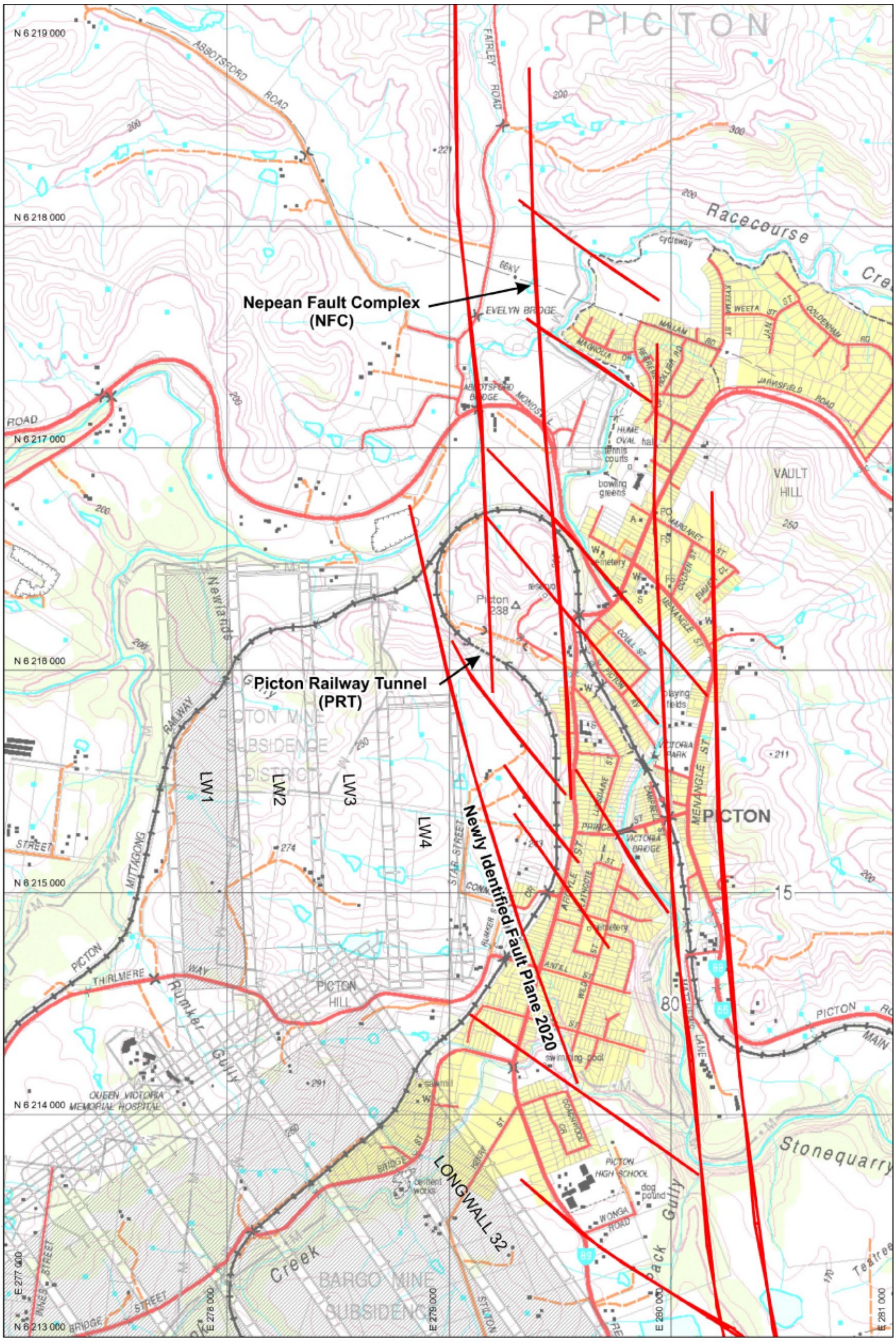

Figure 1: Nepean Fault mapping superimposed on 1:25,000 topographic map.

Figure 2: Picton Rail Tunnel Microstructure detail and listric faulting.

Offset on the faults is dominated by apparent normal throws of several tens of metres. These offsets are easily discerned in the landscape by the relative position of the contact between the Hawkesbury Sandstone and the Wianamatta Group. The offset can be observed where gorges have followed the fault and deeply eroded the surface. Comparison of the elevation of the sedimentary contact on each side of the drainage provides a relative displacement (Figure 3).

The terrain investigation shows the displacement rapidly diminishes laterally, borehole contouring of the Bulli Seam demonstrates the same en-echelon first order faults with ramps. The offset nature of the first order faults indicates the presences of a left lateral shear. Second order strike-slip, conjugate faults are consistent with this observation.

The area of greatest interest in this study is where the PRT is located relative to the NFC and the area of far field subsidence impacts from the nearby longwall mining. At this location, surface mapping shows the fault can be clearly seen expressed as distinct fault segment terminating in the adjoining landscape. The PRT is located adjacent to where the NFC then transitions across fault ramps and then becomes a series of large offset fault segments further to the south east. Subsidence impacts from the new longwall panels may occur from the seam level to the surface.

At the mining horizon, geological conditions adjacent to the first order faulting may include intensified and changed stress condition. Redirection of stress orientation adjacent to faulting is a common occurrence. Stress conditions along the fault ramp should be less intense as offset of the Nepean Fault into conjugate faults helps dissipate the effects of the faulting by redistribution of ground movement into multiple planes rather than focused on a single feature. Fault ramps may be characterised by a greater frequency of jointing and localised low angle faulting which all provide additional features for movement to be dispersed into. The greater the distance from the subsidence event, the less the impact will occur.

Based on the observed distribution of the NPF at the PRT, the impact from the nearby subsidence on the segment of NPF interpreted to pass through the PRT is expected to be minimal. Increased fracture permeability may occur as shifting of the stress orientations may allow NPF defect planes to open especially in strata units which have higher densities of pre-existing fractures.

3. FIELD WORK

The author, a senior engineering geologist, inspected the site on 14 November 2020. Geological structure present in the PRT area was mapped and described. The PRT was inspected for any previous impact on the tunnel from the projected NFC intersection. No direct impacts were observed in the brick and concrete lined tunnel.

Limited outcrop is present at the tunnel, at the northern end portal a steep cutting is present in the railway cutting and also an exposure above the portal. The rock type present is the Ashfield Shale, the basal member of the Wianamatta Group. Approximately 450m to the east, the Hawkesbury Sandstone is exposed in the road cutting at the overpass leading into Picton.

In the exposure above the northern portal of the PRT, minor joint sets are observed, and a small micro-structure was recorded that is interpreted to represent the NFC geometry at this location (Figure 2). A subvertical defect plan, becomes listric and diverges into the bedding planes but then transitions out from the same plane as three spaced subvertical defect planes.

4. FRACTURE ANALYSIS AND TERRAIN OBSERVATION

The fracture analysis and terrain observations previously completed (2018) was reviewed and the latest available imagery was re-analysed with the PRT and new mining area being the focus of this study.

The positioning of the original analysis of NFC segments was adjusted and a new first order north-south trending fault segment, immediately west of the PRT was interpreted. The revised map (Figure 1) plots the interpreted positions of the fault segments of the NFC in the Picton to Tahmoor area. In the current investigation, outcrop investigation was limited to the exposures at the northern portal of the PRT. Micro-structure observed at the tunnel (Figure 2) provided potential detail of the nature of the NFC at this location. A listric transition from a single fault to multiple faults via splayed fault surfaces redistribute below a horizontal plane into several new fault surfaces, this formed a potential décollement horizontal slip which would have dispersed much of the vertical displacement as horizontal bedding parallel shear. Listric faulting is a strong indicator that the NFC formed in an extensional environment, this is also indicated by the presence of fault ramping, stepped faults, splays, and normal fault offsets.

The boundary between the Wianamatta Group and the Hawkesbury Sandstone is distinct and is used in this analysis as a marker to determine the fault displacement along each fault segment where the intersection between this marker and the elevation contour can be determined. Figure 3 shows the interpreted fault throws along the length of the NFC between Picton and Tahmoor. High offset fault segments in the terrain form deep gorges with abutting plateaus, terminal end zones of fault segments tend to transition through a gentler topography of ramping and transition to plateaus, as seen in the area of the PRT.

Fault displacements were not readily observed in the area of the PRT, the interpreted transition of individual fault segments into multiple segments disperse these and result in less disturbed more stable strata. Exposure of Wianamatta Group shales and the Hawkesbury Sandstone dominate the terrain. At the PRT the area at the tunnel and west over the new mining area forms a plateau, this is surrounded by deeply incised gorges and river valleys. The plateau has formed over an area where the NFC is mainly terminal ends of fault segments and fault ramps. These disperse the high offsets observed further to the south east into gentler deformed terrain of the plateau hosting the PRT.

5. FAR FIELD SUBSIDENCE IMPACT ON FRACTURES AND HYDROLOGY

Horizontal subsidence movements at the surface and within the overburden strata can extend laterally for significant distances from longwall mining activity. These far field effects decrease quickly away from the directly subsided strata. Geological features such as faults, strata contrasts such as clay bands, thick sandstone units, coal seams and thick sandstone/conglomerate channels, igneous intrusives such as plugs, dykes and sills can focus far field effects.

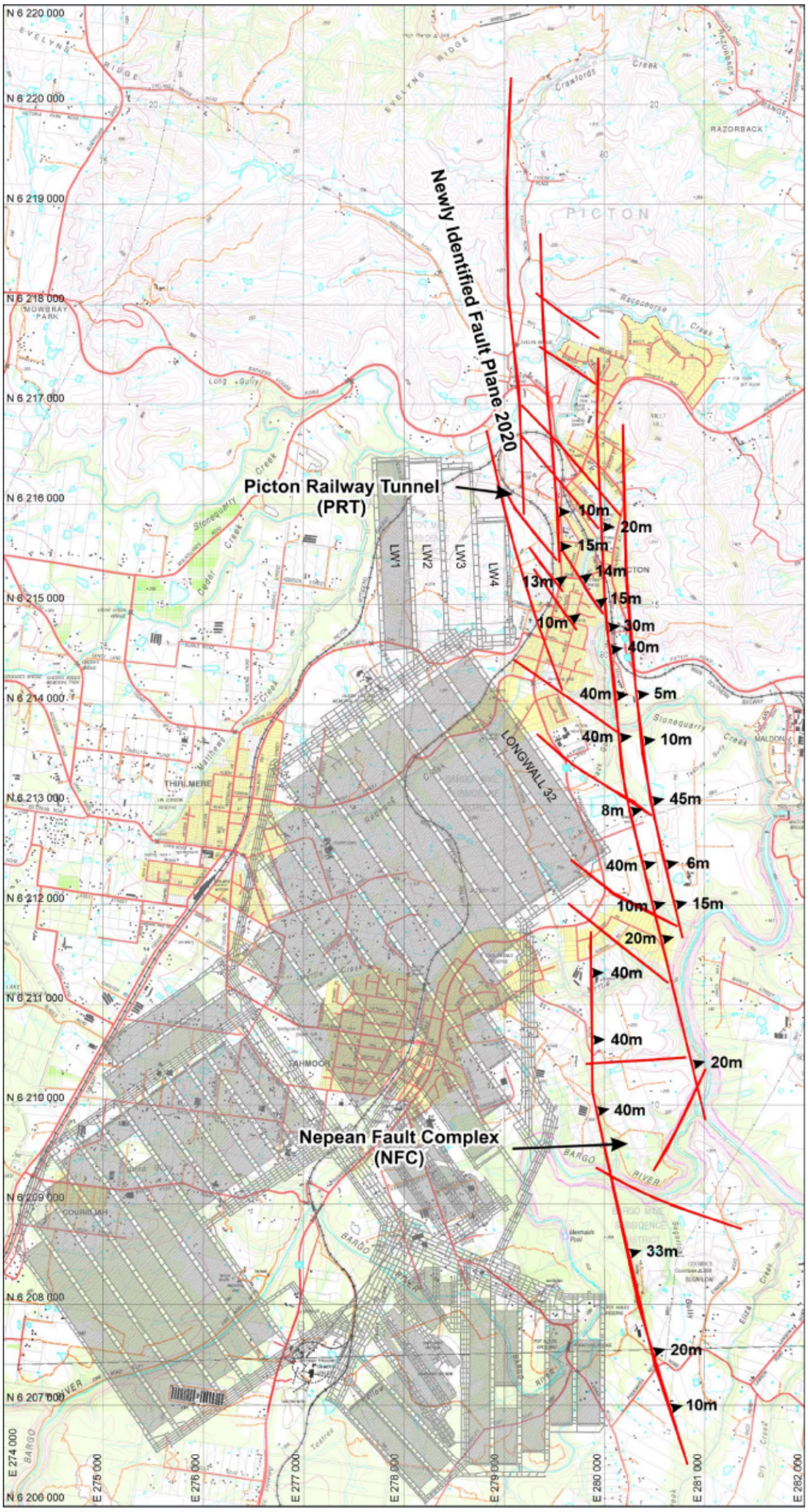

Figure 3: Nepean Fault mapping superimposed on 1:25,000 topographic map.

Concentrated movements may manifest as bedding parallel shear (decollement) where distinct block tilting of the strata results in differential slip especially where the contrast in rock types is greatest. At the PRT the greatest potential for such a surface to occur is the basal contact of the Wianamatta Group and the underlying massive sandstones of the Hawkesbury Sandstone.

The potential for far field subsidence related movement to impact the immediate PRT area must be considered low as the amount of movement predicted at such a distance from the subsidence event will be small. Movement that may occur would likely have its displacement focused along the multiple subvertical NFC fault segments, fault splays and ramps and also any potential tilting would focus potential horizontal shear along the contact between the Wianamatta Group and the Hawkesbury Sandstone.

Far-field subsidence movements affect the entire rock mass from surface to seam level. The distal effects may be described as mainly tensional strains, tilting and horizontal shearing. These effects are expected to impact the hydrology of the surrounding rock mass by causing an increase in hydraulic conductivity of the rock mass and fractures within it. Increase in fracture permeability is influenced by rock type, its geotechnical characteristics, and its ambient distribution of fracturing. The strata surrounding the PRT (Wianamatta Group and Hawkesbury Sandstone) is composed of massive geological units with well-spaced joints, faults, shears, and bedding planes. The far field subsidence impact on the PRT hydrology is expected to be generally small.

At depth, greater fracture density occurs in the coal seams, greater frequency of bedding partings in the surrounding strata and greater potential for horizontal shearing could result in greater rates of pore pressure drawdown through the rock mass closer to mining activity. The presence of the NFC may result in greater fracture permeability, but it may also serve to create offsets of the hydrological strata units and may increase or limit recharge based on structural and strata geometry.

6. CONCLUSION

These results of the investigations are summarised as:

- The Nepean Fault Complex (NFC) projected through the Picton Rail Tunnel (PRT) area mainly comprises the terminal ends of north-south trending fault segments with minimal offsets distributed among the fault planes present.

- No existing impact from the predicted fault intersections was observed during inspection of the tunnel.

- Review of geotechnical coring investigations recently completed in the tunnel showed no obvious strata change intersected that would indicate any large fault offset or deformation.

- The tunnel is formed directly on, or just above the upper contact of the Hawkesbury Sandstone in the overlying Wianamatta Group shales.

- Observation of microstructure has determined listric faulting forms part of the Nepean Fault Complex at this location, taking high angle faulting into a curved plane dispersing the displacement into the bedding then re-emerging as multiple faults with smaller displacements.

- Observed microstructure indicates a listric faulting style for the NFC at the PRT consistent with extensional movements transitioning into multiple faults which further disperse and reduce offset displacements. This is a significant determination on fault behaviour at this location and impacts understanding of the faulting distribution.

- Review of the 2018 NFC analysis found an additional interpreted fault projection located immediately west of the PRT.

- The additional fault identified trend north-northwest to south-southeast and abuts the northeast corner of LW4.

- Subsidence movements at the PRT from mining of LW3 are further than 500m away are anticipated to be slight and of a general body nature affecting the PRT evenly. Mining of LW4 is approximately 250m away but because of the smaller subsidence footprint is also anticipated to be slight impact on the PRT.

- Movements on geological faults intersecting the PRT area are expected to be distributed over numerous defect planes found in the terminating fault segments and fault ramps. Any movements on these structures are expected to be dispersed across multiple structures.

- A slight increase in hydraulic conductivity is expected from stress relief movements associated with nearby longwall mining. The hydraulic conductivity of pre-existing joints and any fresh fractures are expected to slightly increase the hydraulic conductivity of strata around the PRT.

SIMEC has a regular program of inspection and monitoring of the PRT underway, there is an inclinometer installed adjacent the tunnel, detailed surveys through the tunnel have been completed, distometers are installed throughout the tunnel and regular geotechnical inspections are planned during mining to monitor for any movement and potential damage. Regular geotechnical meetings are planned to be held during mining to review the data and determine if any actions are required.