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Report on Geotechnical Assessment Longwalls W3 and W4, Picton

Prepared for
Tahmoor Coal Pty Ltd

Project 89541.06
March 2021

Document History

Document details

Project No.	89541.06	Document No.	R.001.Rev1
Document title	Report on Geotechnical Assessment		
Site address	Longwalls W3 and W4, Picton		
Report prepared for	Tahmoor Coal Pty Ltd		
File name	89541.06.R.001.Rev1		

Document status and review

Status	Prepared by	Reviewed by	Date issued
Rev0	Roderick Haselden	John Braybrooke	17 March 2021
Rev1	Roderick Haselden	John Braybrooke	22 March 2021

Distribution of copies

Status	Electronic	Paper	Issued to
Rev0	1	-	Ms April Hudson, Tahmoor Coal Pty Ltd
Rev1	1	-	Ms April Hudson, Tahmoor Coal Pty Ltd

The undersigned, on behalf of Douglas Partners Pty Ltd, confirm that this document and all attached drawings, logs and test results have been checked and reviewed for errors, omissions and inaccuracies.

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FS 604853

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1. Introduction

This report presents the results of a geotechnical assessment for landscape features within the Subsidence Study Area (SSA) of Longwalls (LW) West 3 (W3) and West 4 (W4). The assessment was commissioned in an email dated 22 September 2020 by Ms April Hudson of Tahmoor Coal Pty Ltd (TC) and was undertaken in accordance with Douglas Partners' proposal WOL200362.P.001.Rev1 dated 3 September 2020.

It is understood that TC plans to mine a further two panels, LW W3 and W4, in the Western Domain of Tahmoor Mine using longwall extraction methods. The aim of this geotechnical assessment was to:

- Review the provided information and studies related to subsidence to provide context to the impact on surface features for LW W3 and W4;
- Identify the potential risks to land features, namely cliffs, rock face features, steep slopes and farm dams within the SSA due to mine subsidence;
- Risk assess these features to identify the likely consequence of subsidence-induced instability; and
- Provide a monitoring program and Trigger Action Response Plan (TARP) to manage the risks of mine subsidence-induced impacts.

The assessment comprised a review of the information provided and site inspections by an experienced engineering geologist. The details of the assessment are presented in this report, together with comments and recommendations for the items list above.

This report is based on a high-level assessment and subsequent site inspections conducted for the area. The results of surface subsidence modelling prepared by Mine Subsidence Engineering Consultants (MSEC) were provided by the client for the assessment. Some of the properties within the SSA were unavailable for site inspections. Inspections may be required in the future to evaluate the impact of subsidence on those features.

2. Project Definitions

The Landslide Risk Management Guidelines prepared by the Australian Geomechanics Society (AGS, 2007), provide the following definitions for cliffs and steep slopes:

- Cliff – Slope appears vertical and ranges between 64° and 84°;
- Extreme Slope – need rope access to climb slope and ranges between 45° and 64°;
- Very Steep Slope – Can climb by clutching at vegetation, rocks, etc and ranges between 27° and 45°;
- Steep Slope – Walkable with effort and ranges between 18° and 27°;

Moderate Slope – Walkable and ranges between 10° and 18°; and
Gentle Slope – Easy walking and ranges between 0° and 10°.

In order to incorporate the predicted effects of mine subsidence on the landscape features and to maintain consistency with the impact assessment methodology used on cliffs and slopes, the definitions provided in Table 1 have been adopted in this report. The details given in Table 1 are based on the precedents in other coal fields with similar mining and surface conditions.

Table 1: Definition of Terminology used to describe Surface Features

Feature	Definition by geometry	Impacts due to subsidence
Cliff	A continuous rock face, including overhangs, greater than 20 m in length, a minimum height of 10 m and a minimum slope of 0.5:1 (H:V, ie > 63.4°)	Tilting and cracking resulting in collapse of overhangs, wedge and toppling failures; rock fall roll outs, felling trees and creating public safety hazards. Permanent landscape changes.
Minor Cliff	A continuous rock face, having a minimum length of 20 m, heights between 5 m and 10 m and a slope greater than 0.5:1 (H:V, ie >63.4°) or a rock face having a maximum length of 20 m and a height between 10 m and 20 m.	Tilting and cracking resulting in collapse of overhangs, wedge and toppling failures; rock fall rollouts, felling trees and creating public safety hazards. Temporary to permanent landscape changes.
Cliff Terrace	A combination of two to five minor cliffs in close proximity, which results in a stepped surface profile. The average slopes between upper and lower cliffs range between 50° and 60° with a total cliff height of between 10 m and 25 m.	Tilting and cracking resulting in collapse of overhangs, wedge and toppling failures: rockfall roll outs, felling trees and creating public safety hazards. Temporary to permanent landscape changes.
Rock Outcrop	A discontinuous rock face (<20 m in length) having heights < 5 m and slope > 63.4°	Tilting and cracking resulting in collapse of overhangs, wedge and toppling failures: rock fallouts, felling trees and creating public safety hazards. Temporary landscape changes.
Very Steep Slopes*	An area of land having a gradient of between 1:1 (H:V, ie 45°) and 0.5:1 (H:V, ie 63.4°). This includes precariously located boulders fallen from cliffs.	Tilting and cracking resulting in landslip failures; felling trees and creating public safety hazards, Permanent to temporary landscape changes.
Steep Slopes+	An area of land having a natural gradient ranging between 3:1 to 1:1 (H:V, ie 18.4° to 45°). This includes precariously located boulders fallen from cliffs.	Tilting and cracking resulting in landslip failures; felling trees and creating public safety hazards. Permanent to temporary landscape changes.

* Very steep slopes are generally located within cliff line terraces.
+ Steep slopes generally exist below the cliff terraces, minor cliffs and rock outcrops and can extend for 100 m or more.

3. Site Description and Topography

Tahmoor Mine is an underground coal mine located approximately 80 km southeast of Sydney between the townships of Tahmoor and Bargo, New South Wales (NSW). LW W3 and W4 are located in the 'Western Domain', which is located northwest of the Main Southern Rail (MSR) between the townships of Thirlmere and Picton (refer Figure 1).

Tahmoor Mine is operated by Tahmoor Coal and produces a primary hard coking coal product and a secondary higher ash coking coal product that are used predominantly for steel production. Tahmoor Mine has used longwall mining methods since 1987. Tahmoor Coal has mined 33 longwall panels to the north and west of Tahmoor Mine's current pit top location, and is currently extracting LW W2, which commenced on 7 December 2020. It is anticipated that LW W3 will commence in late 2021.

This study covers the surface area located within the 20 mm predicted subsidence contour and the 35 degree angle of draw from the extents of LW W3 and W4 (refer Figure 1 and Drawing 1 in Appendix B). The proposed extraction of LW W3 and W4 will extend underground coal mining to the west of the Main Southern Railway and to the south east of the Picton Mittagong Loop Line in the Western Domain (refer Figure 1). The surface footprint of these longwall panels is located to the south and east of Stonequarry Creek and Matthews Creek and Cedar Creek, respectively.

Both of the longwalls (LW W3 – W4) are planned to be 283 m and 285 m wide, respectively, with tailgate chain pillar widths in between the longwalls of 39 m and 44 m, respectively (refer Figure 1). The total lengths for LW W3 and W4 are about 1550 m and 1005 m, respectively. The panels will extract the Bulli Seam from north to south. The extraction height is proposed to be constant at 2.15 m. The Bulli Seam dips towards the north east with an average gradient of 5% across the mining area. Based on the information provided by the client, the lowest level of the seam floor is about RL-295 m relative to Australian Height Datum (AHD). The depth of cover directly above the proposed longwall varies between a minimum of 470 m above the commencing end of LW W3 and a maximum of 540 m on the western edge of LW W3.

The surface level contours within the Subsidence Study Area (SSA) indicate that the highest point of topography is about 272 m AHD in the ridge line near the central western part of LW W3. The surface topography is hilly with valleys and ridges with the lowest level being about 160 m AHD in Stonequarry Creek in the north of the SSA. The surface area primarily comprises rural residential and low-density residential developments with properties used for housing, hobby farms, stock grazing and orchards. Water is obtained generally from the town water supply and to a degree from farm dams or groundwater bores.

Based on the definitions provided in Table 1, the SSA for LW W3 and W4 consists of steep slopes and is devoid of any cliffs, terraces, rock outcrops and very steep slopes. Steep slopes are indicated on the flanks of ridges in the SSA and also located along the banks of Stonequarry Creek and an unnamed tributary of Redbank Creek. Steep slopes such as dam walls, embankments and cut batters were also identified by the LiDAR survey. 25 properties have been identified as containing structures close to steep slopes (refer Drawing 1).

A total of 17 dams are located within the SSA for LW W3 and W4, of which, 5 dams are located directly over the longwall (refer Drawing 1).

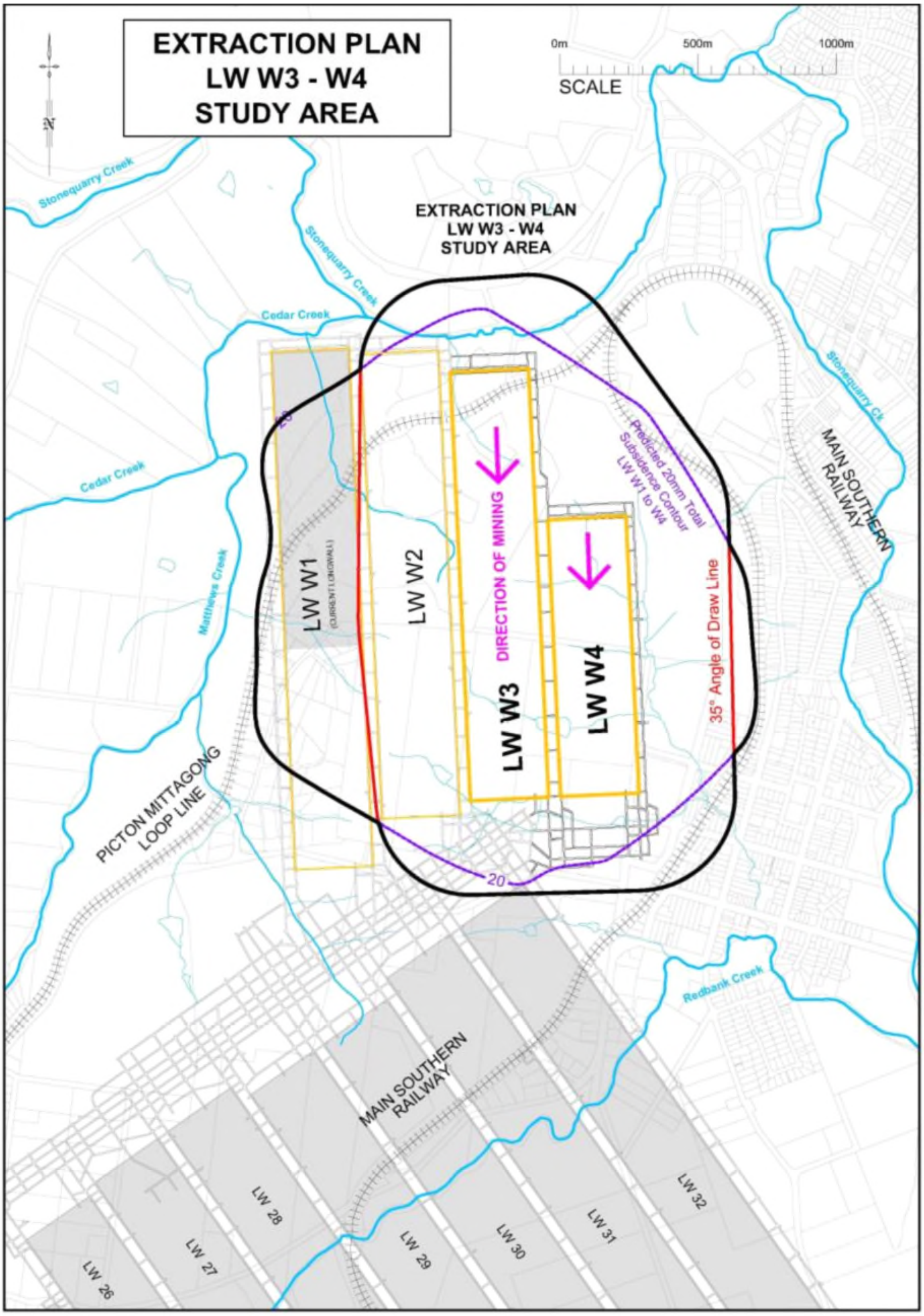

Figure 1: Study Area for Subsidence Effect on Land Features (Courtesy TC)

The SSA also contains sections of the Picton to Mittagong Loop Line heritage railway and the Main Southern Line. It is understood that both of these features, which include cuttings, embankments and tunnels, will be subject of separate geotechnical assessments and are therefore not included in this report.

4. Information Review

4.1 Information Provided by TC

TC previously provided copies of reports and data from a number of investigations conducted as part of the ongoing planning and operation of the longwall panels at Tahmoor Mine. These included:

- GeoTerra report titled "Longwall Panels 31 to 37 – Streams, Dams & Groundwater Assessment";
- GHD report titled "Landslide Risk Assessment of Identified 'Steep Slopes' Principally Affected by Retreat of LW 28";
- GHD report titled "Landslide Risk Assessment of Identified 'Steep Slopes' Specific Properties in Environs of LW 32";
- Glencore report titled "Tahmoor Colliery – Longwall 30 – First 300 m of Extraction, Management Plan for Potential Impacts on Dam at No. 2990 Remembrance Drive";
- GHD report titled "Tahmoor Colliery Subsidence Impact Upon 'Steep Slopes' over LW 24 to LW26";
- SCT report titled "Tahmoor Coal – Investigation into the Potential Impact on the Nepean Fault on Subsidence Adjacent to LW 32;
- MSEC report MSEC1019 titled "Subsidence Predictions and Impact Assessments for Natural and Built Features Due to the Extraction of the Proposed Longwalls W1 and W2 in support for the Extraction Plan Application";
- MSEC report MSEC1045-12 titled "Built Structures Management Plan" Tahmoor North Western Domain Longwalls West 1 and West 2;
- MSEC report MSEC1073 Rev34 titled "Tahmoor LW W1 Subsidence Monitoring Report"; and
- MSEC report MSEC1112 titled "Subsidence Predictions and Impact Assessments for Natural and Built Features Due to the Extraction of the Proposed Longwalls W3 and W4 in support for the Extraction Plan Application".

4.2 Geological Setting

The study area lies within the Southern Coalfield, part of the Sydney Basin. The Permo-Triassic Sydney Basin extends roughly 300 km along the coast of New South Wales and inland for a distance of up to 200 km. The principal coal-bearing sequence in the Southern Coalfield of the Sydney Basin is the Illawarra Coal Measures which consist of four coal seams. The uppermost seam is the Bulli Seam which has been extensively mined in the northern part of the coalfield. The Bulli Seam is immediately overlain by the Narrabeen Group which consists of a series of major sandstone and shale units. The Wombarra Shale and Scarborough Sandstone forms the immediate and main roof. The Wombarra Shale consists of shale and claystone with minor thin interbeds of fine-grained sandstone. The Scarborough Sandstone comprises coarse grained quartz-lithic sandstone. It is noted that while the Coal Cliff Sandstone is typically located between the Wombarra Shale and Bulli Seam in the eastern part of the Southern Coalfield, it decreases in thickness towards the west becoming a band within the Wombarra Shale before disappearing entirely. It has not been identified in drill core in the Tahmoor area. Overlying the Narrabeen Group is the Hawkesbury Sandstone, which comprises a series of bedded sandstone units which date from the Middle Triassic and which has a thickness of up to 185 m, and Ashfield Shale. Much of the surface in the SSA is mapped as being underlain by Ashfield Shale of the Wianamatta Group having a thickness of a few tens of metres. The Mittagong Formation is a transitional unit between the Ashfield Shale and Hawkesbury Sandstone, which consists of interbedded shale, laminite and fine grained sandstone. The Hawkesbury Sandstone and Mittagong Formation crop out along the incised and downstream sections of the local creeks and watercourses. The typical stratigraphic section in the SSA is shown in Figure 2.

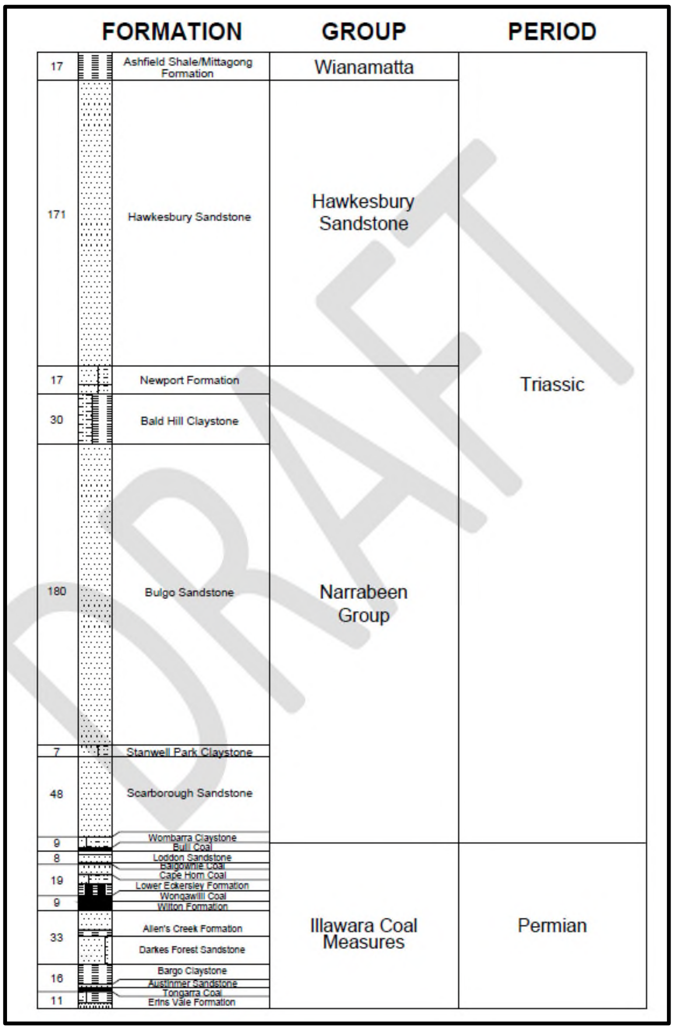

Figure 2: Typical Geological Stratification at Tahmoor (Courtesy MSEC, 2019)

The Ashfield Shale forms the upper surface of the SSA, which is deeply dissected by numerous streams exposing sandstone of Hawkesbury Sandstone formation. Incision tends to follow the dominant joint directions in the rock (ie northwest and northeast) and it is possible that this influences the orientation of the long axis of the valley in which the creeks are formed. The sandstone rocks tend to break up into large blocks due to weathering along the joint planes and near-horizontal bedding planes.

The Nepean Fault Zone is located within the eastern section of the SSA and passes close to the north eastern corner of LW W4. The fault zone is described as a first order fault zone and comprises a number of faults.

4.3 Previous Impacts of Mine Subsidence

No slope instability has been reported in the hillsides in nearby mining areas with similar topography. Soil cracks up to 65 mm wide were reported on both the upper bank and the flank of Myrtle Creek at one location above Longwall 23B. The cracks extended into the soil to depths of between 1.5 m to 2.0 m and over a length of approximately 40 m.

During the extraction of Longwall 24A, Gale and Sheppard (2011) reported that significantly higher displacements, nearly twice the predicted subsidence displacements, were observed. This abnormality was suggested as being due to the weakening of rock material due to weathering, causing reduction in spanning capacity of the weathered section.

Mine subsidence during the extraction of LW W1 has been reported by MSEC as currently being about 50% of mine subsidence predictions (ie a maximum subsidence of 212 mm at the completion of LW W1), which has been similar to mine subsidence behaviour observed during the extraction of LW 901 at Appin Colliery, which was also the first panel in a new series of long walls. Discussions with MSEC have indicated that the subsidence predictions may be closer to predictions following the completion of additional longwalls as the overall span of the across the longwall panels increases.

Monthly geotechnical inspection of cliff lines, steep slopes and farm dams were carried out by DP within the zone of active subsidence during the extraction of LW W1 and at 3-monthly intervals following the completion of active subsidence. In summary, no discernible changes that could be attributed to mine subsidence were observed within the abovementioned features. Trigger Action Response Plan (TARP) levels remained with ‘normal’ range (Level 1) during this period.

4.4 Subsidence Modelling for Longwalls W3 and W4

Based on the MSEC’s 2021 report for LW W3 and W4:

> The maximum predicted incremental subsidence results due to extraction of LW W3 and W4 (studies on calibrated numerical model by MSEC1112) are reported in Table 2.

Table 2: Predicted incremental subsidence details for LW W3 and W4 (MSEC1112, 2021)

Longwall	Maximum predicted incremental subsidence (mm)	Maximum predicted incremental tilt (mm/m)	Maximum predicted incremental hogging curvature (km^{-1})	Maximum predicted incremental sagging curvature (km^{-1})
LW W3	650	4.5	0.05	0.09
LW W4	600	4.5	0.05	0.08

The maximum predicted total subsidence results due to extraction of LW W3 and W4 (studies on calibrated numerical model by MSEC1112) are reported in Table 3.

Table 3: Predicted total subsidence details for LW W3 and W4 (MSEC1112, 2021)

Longwall	Maximum predicted total subsidence (mm)	Maximum predicted total tilt (mm/m)	Maximum predicted total hogging curvature (km^{-1})	Maximum predicted total sagging curvature (km^{-1})
LW W3	950	5.0	0.06	0.10
LW W4	1025	5.0	0.06	0.10

The predicted maximum total strains in the SSA likely to be experienced at any time during mining are given in Table 4.

Table 4: Predicted maximum strains during extraction of LW W1 and W2 (MSEC1112, 2021)

Longwall	Above goaf		Above solid coal	
	Compressive strain (mm/m)	Tensile Strain (mm/m)	Compressive strain (mm/m)	Tensile Strain (mm/m)
95% confidence level	1.7	1.0	0.5	0.6
99% confidence level	3.3	1.5	0.8	1.0

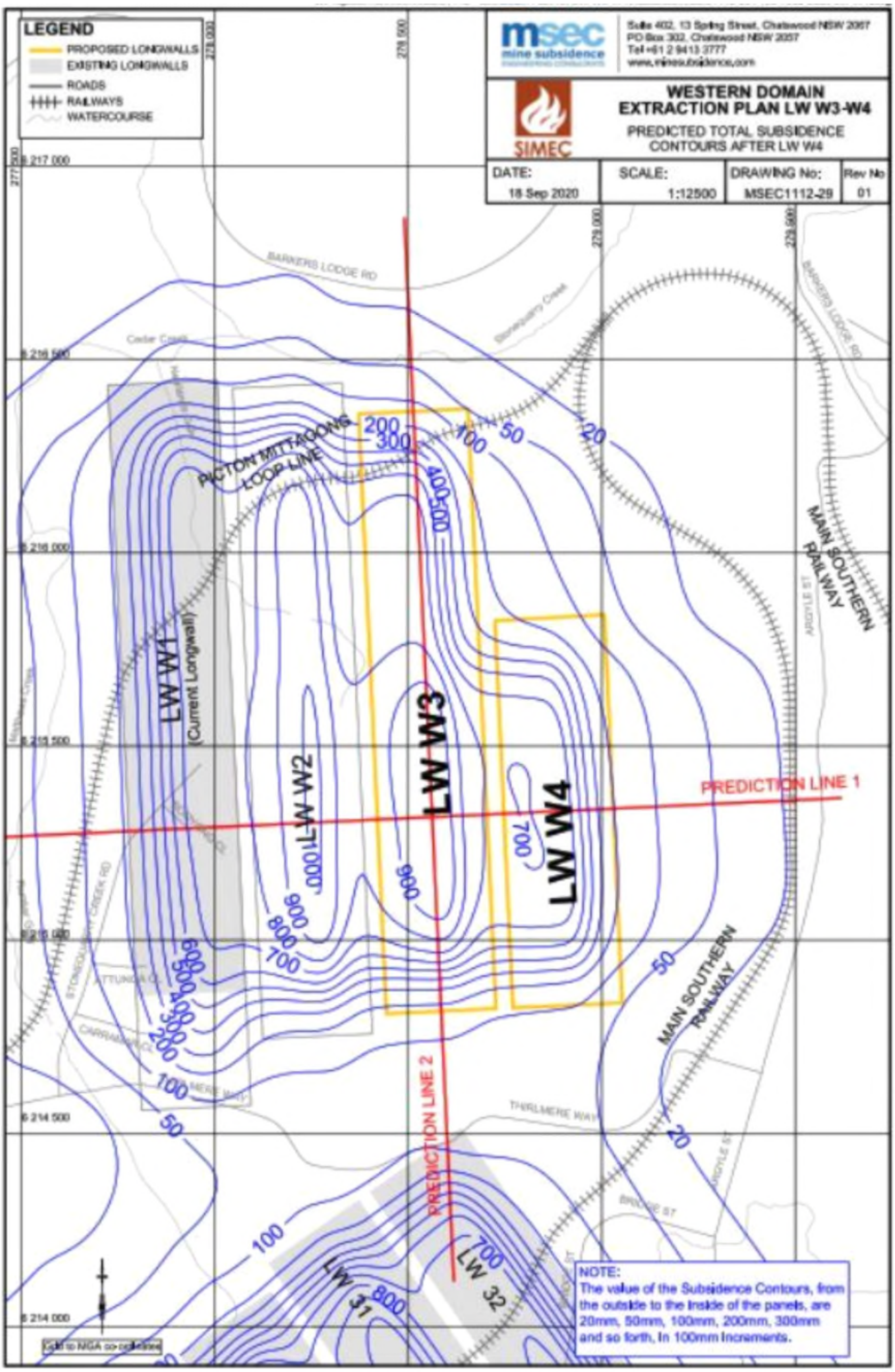

Figure 3: Total mine subsidence following extraction of LW W4 (courtesy MSEC).

5. Field Work

Site inspections of the landscape features within the SSA were undertaken by an experienced engineering geologist on 15, 16 and 26 October 2020, 30 November 2020 and 1 December 2020. In addition to these inspections, DP carries out monthly inspection of surface features within the active subsidence zone for LW W1 and W2, which includes an area of overlap with the SSA discussed in this report. Due to the constraints of accessibility and lack of permissions from land owners, in some areas the inspection of landscape features was undertaken at a distance from the feature.

DP carries out inspections of Stonequarry Creek as part of the monitoring program for LW W1 and W2. Within the SSA the creek comprises a meandering watercourse flowing from west to east along the northern side of the LW W3 and W4 SSA. The creek includes shallow and deep ponds and rock bars and is ephemeral during extended periods of low rainfall.

Areas with steep slopes in the LW W3 and W4 SSA are shown on Drawing 1. The areas of steep slopes with a structure or group of structures located within or adjacent to these areas were identified from LiDAR data and aerial photography, which includes several dwellings that have been constructed at the crest or near the toe of steep slopes. It is understood that as part of the subsidence management for LW W3 and W4, building inspections are carried out for all structures within the SSA. Inspections for steep slopes within the SSA were limited to accessible slopes adjacent to identified structures where permission to enter properties was granted.

The locations of farm dams were identified from surface topography contours and LIDAR data (refer Drawing 1 in Appendix B). The farm dams within the SSA are man-made structures and rely on rainfall for their impoundment. These farm dams are generally up to about 4 m high, although a few dams (FD1, FD3, FD7 and FD12) were up to about 7 m high, and appear to have been constructed by forming shallow embankments across dry valleys. During the previous assessment for LW W1 and W2, which was carried out during an extended period of below average rainfall, some of the farm were observed to be dry.

The following observations were made during inspections of steep slopes and farm dams within the SSA:

- Spillways had been excavated into the steep hillside abutments for both FD1 and FD3.
- Spillways had also been constructed around the edges of FD4, FD5, FD7, FD8, FD12 – FD16 and FD18. FD5 also included a culvert to discharge overflow.
- FD6 has a large slot through the centre of the embankment from a previous failure. The slot is estimated to be up to 2.5 m high and up to 1.5 m wide. While there is still limited water storage capacity in the dam, its capacity has been drastically reduced. Anecdotal information provided by a farmer that runs cattle on the site indicates a wombat hole was previously located in the embankment. There were no signs of a wombat hole during the current inspection. Review of historic aerial photography on Metromap.com.au indicates that the slot in the embankment was present in July 2018 (ie prior to the mining of Longwall W1) and the embankment was intact in December 2016, however, there are signs of erosion of the embankment in the vicinity of the slot, probably from overtopping. In its current state the damage to the existing farm dam is not considered to increase the risk to the Picton Mittagong Loop Line downslope. It is expected that erosion of the embankment will continue, over time, that will result in the total loss of storage capacity.

There has been no access to FD9 for the current assessment or for monthly geotechnical inspections for LW W1 and W2.

Two wombat holes have been observed through the FD11 embankment. The wombat holes could provide a preferential pathway for water through the embankment resulting in piping (ie internal erosion) and possibly failure of the embankment. As FD11 has a relatively small storage capacity (estimated to be approximately 0.4 ML by MSEC) and there are no structures between it and Rumker Gully, if failure of this farm dam were to occur the consequence category remains unchanged (ie at *Very Low*) from DP's November 2019 report.

Loose material has been placed in front of the face of FD13. The grass in the loose material was lush and green, indicating potential seepage through the face. The material may also indicate buttressing of a previous failure in the downstream face.

Recent remedial works had been carried out in the downstream face of FD15 including the clearing of vegetation, re-grading and possibly the construction of a new spillway. The works may be indicative of repairs to recent damage to the downstream face.

Erosion rills up to 0.4 m deep were observed on the downstream face of FD17 and a sheet of sediment had been deposited below the downstream face, which indicates that the dam has previously been overtopped.

The steep slope to the east of 36 Star Street has a dense cover of shrubs and is generally inaccessible.

6. Comments

6.1 General

Incremental and total subsidence due to longwall mining of LW W3 and W4 could result in surface cracking, heaving, buckling and stepping which can influence various landscape features. DOP (2008) provided a comprehensive summary of the range of potential mine subsidence effects and the environmental management techniques. It recommends that a subsidence risk management zone (RMZ) be defined around sensitive features within the mining lease before subsidence occurs. Out of the various features mentioned in DOP (2008), this study focusses on cliff lines, steep slopes and farm dams. The location of these features is the first step in managing prediction uncertainties and potential impacts associated with subsidence. The final step is to identify the methods of monitoring and mitigation which may reduce the subsidence effects to a 'repairable level' or as low as reasonably practicable (ALARP). The features within the SSA are assessed in the following sections of this report.

Due to the nature of assessment, it was decided to adopt a risk management approach to evaluate the impact of subsidence on the features. The features to be assessed are very distinct in nature and hence the approach also varied. The procedure recommended by Australian Geomechanics Society publication *Practice Note Guidelines for Landslide Risk Management 2007* (AGS, 2007) was used to evaluate the steep slopes. The farm dams are evaluated using the Small Dam Consequence Screening tool (VIC DEPI, 2014). As noted earlier in the report, no cliff line features were identified within the SSA.

6.2 Assessment of Steep Slopes

6.2.1 General

As discussed in Section 2, steep slopes are defined as an area of land having a natural slope angle of between 18.4° and 45°. The 1 m surface level contours, generated from the LIDAR survey of the area, provided information regarding the steep slopes in the SSA. The SSA above LW W3 and W4 consists of numerous steep slopes (slope angles typically between 20^0 to 40^0) with shallow residual soil cover underlain by Ashfield Shale. In this section, assessment of steep slopes is discussed with reference to the presence of structures and human life near the slopes. Residential and other structures constructed on or adjacent to steep slopes or within the run-out distance of potential landslides were identified by aerial photography and LiDAR data. The steep slopes are evaluated by considering the likelihood of failure and the impact on structures in the vicinity. Assessment of individual residential structures are beyond the scope of this work. However, field inspection was carried out to ascertain the vulnerability of identified structures. Steep slopes were also located along the banks of Stonequarry Creeks and an unnamed tributary of Redbank Creek. Accessibility to the creeks banks was also limited to properties where access arrangements were in place at the time of the assessment. Some of these steep slopes are directly above LW W3 and W4 and will be affected by the predicted mine subsidence.

The soils in the SSA may be differentiated in terms of the parent material from which they are derived. On the one hand are the residual soils developed on the Wianamatta Shale ridge-tops and on the other, potentially weakly developed soils in the colluvial material of the lower slopes and the alluvial material within the creeks. The ridge-top soils appear to be generally shallow (0.3 – 1.5 m) and undifferentiated into horizons, except for the accumulation of organic matter at the surface.

The landslide risk assessment conducted for this study involved the following steps:

- Identify the landslide processes currently occurring, factors contributing to instability, and likely triggers to future instability;
- Assess the likelihood that these landslide hazards or events will occur in the future;
- Assess the potential consequences in terms of potential damage to property;
- Combine the estimates of likelihood and consequence to derive an assessed risk of slope instability in the pre-mining state;
- Review the estimated subsidence effects on the LW W3 and W4; and
- In light of the above, assess the risk of slope instability post-mining.

The slope risk assessment was undertaken in accordance with the methods and principles presented in the Australian Geomechanics Society publication "Practice Note Guidelines for Landslide Risk Management 2007" (AGS, 2007). The risk assessment takes into account the current site surface conditions and potential effects of the proposed longwall mining. Future changes to the surface profile due to building development and site excavations are not considered in this risk assessment. Each of the sites was assessed on the basis of the estimated likelihood and extent of landsliding in relation to infrastructure that was able to be identified from aerial photographs and from the site walkover assessment. Due to the limited accessibility of the properties, the specifics of impacts like cracking is beyond the scope of the assessment. The structures considered in the assessment includes those identified on MSEC draft plans.

6.2.2 Definitions

The qualitative terminology for use in assessing risk to property in the report is as follows:

Risk – A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability and consequence. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.

Acceptable Risk – A risk which, for the purposes of life or work, society is prepared to accept as is with no regard to its management. Society does not generally consider expenditure justifiable in further reducing such risks.

Annual Exceedance Probability (AEP) – The estimated probability that an event of specified magnitude will be exceeded in any one year.

Consequence – The outcomes or potential outcomes arising from the occurrence of a landslide expressed qualitatively or quantitatively, in terms of loss, disadvantage or gain, damage, injury or loss of life.

Danger – The natural phenomenon that could lead to damage, described in terms of its geometry, mechanical and other characteristics. The danger can be an existing one, such as a creeping slope, or a potential one, such as a rock fall.

Elements at Risk – The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by landslides.

Frequency – A measure of likelihood expressed as the number of occurrences of an event in a given time.

Hazard – A condition with the potential for causing an undesirable consequence. The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material, and the probability of their occurrence within a given period of time.

Individual Risk to Life – The risk of fatality or injury to any identifiable (named) individual who lives within the zone impacted by the landslide or who follows a pattern of life that might subject him or her to the consequences of the landslide.

Landslide Intensity – A set of spatially distributed parameters related to the destructive power of a landslide. The parameters may be described quantitatively or qualitatively and may include maximum movement velocity, total displacement, differential displacement, depth of the moving mass, peak discharge per unit width, kinetic energy per unit area.

Landslide Susceptibility – A quantitative or qualitative assessment of the classification, volume (or area) and spatial distribution of landslides which exist or potentially may occur in an area. Susceptibility may also include a description of the velocity and intensity of the existing or potential landslide.

Probability – A measure of the degree of certainty. This measure has a value between zero (impossibility) and 1.0 (certainty). It is an estimate of the likelihood of the magnitude of the uncertain quantity or the likelihood of the occurrence of the uncertain future event.

Risk Assessment – The process of risk analysis and risk evaluation.

Risk Control or Risk Treatment – The process of decision making for managing risk and the implementation or enforcement of risk mitigation measures and the re-evaluation of its effectiveness from time to time, using the results of risk assessment as one input.

Risk Estimation – The process used to produce a measure of the level of health, property or environmental risks being analysed. Risk estimation contains the following steps: frequency analysis, consequence analysis and their integration.

Risk Evaluation – The stage at which values and judgments enter the decision process, explicitly or implicitly, by including consideration of the importance of the estimated risks and the associated social, environmental and economic consequences, in order to identify a range of alternatives for managing the risks.

Tolerable Risk – A risk within a range that society can live with so as to secure certain net benefits. It is a range of risk regarded as non-negligible and needing to be kept under review and reduced further if possible.

Vulnerability – The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is affected by the landslide.

Zoning – The division of land into homogeneous areas or domains and their ranking according to degrees of actual or potential landslide susceptibility, hazard or risk.

AGS (2007) recommends a series of descriptors to evaluate the landslide hazard perception. The recommended descriptors are outlined in Tables 5 to 7.

Table 5: Landslide Hazard Descriptor

Hazard Descriptor	Rock falls from natural cliffs or rock cut slope	Slides of cuts and fills on roads or railways	Small landslides on natural slopes	Individual landslides on natural slopes
	Number/annum/km of cliff or rock cut slope	Number/annum/km of cut of fill	Number/square km/annum	Annual probability of active sliding
Very High	> 10	> 10	> 10	10^{-1}
High	1 to 10	1 to 10	1 to 10	10^{-2}
Moderate	0.1 to 1	0.1 to 1	0.1 to 1	10^{-2} to 10^{-4}
Low	0.01 to 0.1	0.01 to 0.1	0.01 to 0.1	10^{-5}
Very Low	<0.01	<0.01	<0.01	10^{-8}

Table 6: Descriptor for Risk Zoning using Life Loss Criteria

Annual probability of death of the person most at risk in the zone	Risk zoning descriptors
> 10^{-3}/annum	Very High
10^{-4} to10^{-3}/annum	High
10^{-5} to 10^{-4} /annum	Moderate
10^{-6} to 10^{-5} /annum	Low
< 10^{-6}/annum	Very Low

Table 7: Descriptor for Risk Zoning using Property Loss Criteria

Likelihood		Consequences to property (with indicative approximate cost of damage as a percentage of the replacement cost)				
	Indicative value of approximate annual probability	1 Catastrophic 200%	2 Major 60%	3 Medium 20%	4 Minor 5%	5 Insignificant 0.5%
A. Almost certain	10^{-1}	VH	VH	VH	H	M or L
B. Likely	10^{-2}	VH	VH	H	M	L
C. Possible	10^{-3}	VH	H	M	M	VL
D. Unlikely	10^{-4}	H	M	L	L	VL
E. Rare	10^{-5}	M	L	L	VL	VL
F. Barely credible	10^{-6}	L	VL	VL	VL	VL

AGS (2007b) (Table C1) outlines acceptable and tolerable risk to life criteria for various international and Australian organizations. These risk levels vary from 10^{-3} per annum to 10^{-7} per annum. The AGS guidelines for risk management (2007) suggest a tolerable risk to life for the person most at risk from instability of existing slopes of 10^{-4}. This level has been adopted for the purposes of risk calculations in this study.

6.2.3 Structures at Risk

A review of aerial photography together with the site inspections indicates 24 dwellings and a total of 29 structures or groups of structures are present in the vicinity of steep slopes, although no structures are located on the steep slopes. Many of these structures are located on the eastern side of Stonequarry Creek Road or associated with the ridgelines with the SSA. The structures have been separated into six regions with similar characteristics for the purpose of the slope stability assessment (refer Drawing 2 in Appendix B). The details of the topography in these regions are presented in Table 8. Based on the site inspections, a few structures were identified to be close to steep slopes and may be affected by slope instability. The structures are tabulated in Table 9.

6.2.4 Factors affecting Landslide

Slope instability is governed by the slope geometry, soil/rock strength including consideration of existing defects, and moisture within the soil or rock mass. Instability within the LW W3 and W4 SSA may occur in a variety of forms and incorporate varying proportions of soil, rock, and water. Based on the field observation and understanding of the area, the types of slope instability that the identified steep slopes may undergo is described as follows:

> Type 1 – Extremely slow soil creep in steep slopes and accumulated colluvium, typically within the upper 1.5 m to 2.0 m of the soil profile. While soil creep may not occur on many of the sites above and below the steep slopes, it may be a precursor for landsliding.
>
> Type 2 – Very rapid, shallow soil slumping and rotational failures through colluvial and residual soils on steep slopes with the low potential to run-out into downslope properties.
>
> Type 3 – Slow to rapid, intermediate-depth failures through colluvial and residual soil and potentially into the extremely to highly weathered bedrock on steep slopes with the moderate potential for slope regression into sites on the ridgeline or run-out into downslope properties.
>
> Type 4 – Very slow, deep-seated landslide extending through the soil and upper rock profile with a high potential for slope regression into sites on the ridgeline or run-out into downslope properties.
>
> Type 5 – Moderate to rapid, shallow and intermediate depth soil failures triggered by creek bank erosion with a moderate potential for regression of the creek banks into the site.

Structures in Regions 1 – 5 (refer Drawing 2 in Appendix B) have the potential slope instability Types 1 – 4. Region 6 has the potential for Type 5 slope instability. The trigger for such failures can include major storms, extended periods of rainfall and earthquake events. Poor development practices in adjacent areas can also increase the risk of slope instability.

Table 8: Details of Areas containing Structures at Risk in the SSA

Region	Details of the slope		Slope Height (m)	Horizontal Extent of the Slope (m)
	Maximum Elevation of Slope (m ADH)	Minimum Elevation of Slope (m AHD)		
1	270 – 286	230 – 250	30 – 40	30 – 220
2	270 – 286	220 – 250	30 – 40	30 – 210
3	225 – 240	210 – 220	15 – 20	100 – 150
4	240 – 250	200 – 205	35 – 50	100 – 160
5	225	200	25	50 – 90
6	169	174	5	10 – 20

Table 9: Inspected Structures near the Steep Slopes in the SSA

Region	Remarks	Reference	Constructed on Slope	Distance from Steep Slope (m)	Relative to Steep Slope
Region 1	Inspected	14SCR	GS – MS	50	downslope
		18SCR*	MS	< 5	downslope
		26SCR	MS	< 5	downslope
		3BC	GS	15	downslope
		5BC	MS	< 5	downslope
		7BC	MS	25	downslope
		5AC	GS – MS	40	downslope
		6AC	MS	5	upslope
		7AC	MS	<5	downslope
	Not inspected	16SCR	MS	<5	upslope
		2BC	GS	20	downslope
		4BC	GS – MS	15	downslope
		6BC	GS – MS	30	downslope
		8BC	GS – MS	35	downslope
Region 2	Inspected	664TW/1 – /2	GS	20	upslope
		700TW/1 – d/2	GS – MS	< 5	upslope
	Not inspected	10AC	GS	20	upslope
Region 3	Inspected	34SS	GS – MS	20	upslope
		2-10CCr	GS – MS	15	downslope
	Not inspected	786TW	GS – MS	10	downslope
Region 4	Inspected	36SS/1 – /2	GS	10	upslope
		36SS/3 – /4	GS	<10	upslope
Region 5	Not inspected	WTP	GS – MS	<10	downslope
Region 6	Not inspected	3SC/1 – /2	GS	<10	upslope

where: AC = Attunga Close
BC = Booyong Close
CC = Connellan Crescent
SC = Stargard Crescent
GS = gentle slope (5 – 10°)
SS = Star Street
SCR = Stonequarry Creek Road
TW = Thirlmere Way
WTP = Water Treatment Plant
MS = moderately steep slope (10 – 18°)

6.2.5 Mine Subsidence Effect on the Landslide Risk

The potential increased risk of slope stability associated with the expected mine subsidence impacts can be caused due to following conditions:

Tilting – During mine subsidence, minor tilts may alter the angle of potential slide planes. In situations where sliding could occur on low angle slide planes, sliding can be triggered where tilts increases the angle of the slide planes in the downslope direction. Anticipated tilts are expected to be up to about 5 mm/m at the identified locations within the SSA. These tilt movements are not expected to be sufficient to trigger soil movement or a landslide, although low shear strength on some bedding planes could make them sensitive to some movement in combination with other contributing factors such as saturation during extended rainfall events;

Reduced shear strength – mine subsidence movements can reduce the shear strength of a slope or rock mass by introducing cracking. Tensile cracks can form in areas of bulging and areas periphery to the longwall panels. Also, differential movement along low angle bedding planes, which can occur during relaxation of the ground towards a subsidence bowl, can introduce shearing along the plane. These shear movements reduce the available shear strength of the plane and can contribute to slope failure. The anticipated mean compressive and tensile strains are expected to be up to about 1.5 mm/m within this SSA are minor and are not expected to produce significant cracking or differential lateral movements; and

Water concentration – The cracks developed due to tensile or shear failures can allow ingress of water into a slope. This can potentially trigger instability due to saturation and/or piping (ie internal erosion). The water in these cracks may also increase porewater pressures in the soil and rock. The estimated subsidence movements on the surface within the SSA are unlikely to produce cracking of significant dimension in the identified regions except in Region 1. In the case of non-systematic (downslope) movements, there is potential for increased tension and cracking at the tops of slopes which could potentially lead to landslips. The steep slopes in Regions 1 – 5 are well drained and ponding of water on the crest or slopes is not anticipated.

Maximum incremental and total mine subsidence predictions for LW W3 and W4 SSA are order of 650 mm and 1025 mm, respectively. Subsidence will take place over a broad subsidence bowl, due to the depth of mining (greater than 470 m), such that incrementally the changes in relief across the area will generally be minor. Slope instability incidents may occur in the areas where large subsidence gradients (ie in the areas above the eastern sides of LW W3 and W4). During mining of subsequent longwalls, the subsidence bowl will also result in incremental subsidence above the previous longwall panels. There are other possible mechanisms that may affect landslide risk due to mine subsidence such as curvature, stress and strains, however tilt (or slope change) was considered more likely to influence landslide risk rather than these other mechanisms. The structures directly above the longwall excavation could experience cracking and damage. The assessed risk levels to property due to slope instability are provided in Table 10. The assessment indicates that the risk of slope instability for the assessed hazards prior to mining is in the range of *Very Low to Moderate*, which is within the *Acceptable* to *Tolerable* risk ranges when assessed in accordance with AGS (2007). The assessed level of risk was unchanged during and following longwall mining (ie due to mine subsidence) of LW W3 and W4 provide management and monitoring of the regions is carried out during active mine subsidence through the Trigger Action Response Plan (TARP).

Table 10: Assessment of Slope Instability Hazards Due to Mine Subsidence Affecting Structures

Regions	Geotechnical Landslide Hazard	Consequence to the property	Before Mining		During and Post Mining[1]	
			Likelihood of hazard occurring	Assessed risk to the property	Likelihood	Assessed risk to the property
1 and 5	Periodic soil creep for structures located on moderately steep slopes	Minor for dwellings not designed for soil creep	Possible to Likely	Moderate	Possible to Likely	Moderate
		Insignificant for dwellings designed for soil creep	Possible to Likely	Very Low to Low	Possible to Likely	Very Low to Low
	Very rapid, shallow soil slumping and rotational failures	Insignificant to Minor (little damage, tidy and repair)	Possible to extend to structures located 15 m from steep slopes	Very Low to Low	Possible to extend to structures located 15 m from steep slopes	Low
			Unlikely to extend to structures in excess of 15 m from steep slopes	Very Low	Unlikely to extend to structures in excess of 15 m from steep slopes	Very Low
	Slow to rapid, intermediate-depth failures	Minor to Medium (damage to structure, part of the site requiring stabilisation)	Unlikely	Low	Unlikely	Low
	Very slow, deep-seated landslide	Major to Catastrophic (extensive damage and significant stabilisation works)	Rare	Low to Moderate	Rare	Low to Moderate

Notes: (1) Assessed likelihood and risk levels are based on management and monitoring of the regions during active mine subsidence through the TARP.

Table 10: Assessment of Slope Instability Hazards Due to Mine Subsidence Affecting Structures (cont'd)

Regions	Geotechnical Landslide Hazard	Consequence to the property	Before Mining		During and Post Mining[1]	
			Likelihood of hazard occurring	Assessed risk to the property	Likelihood	Assessed risk to the property
2 and 4	Soil Creep	Minor for dwellings not designed for soil creep	Possible to Likely	Moderate	Possible to Likely	Moderate
		Insignificant for dwellings designed for soil creep	Possible to Likely	Moderate	Possible to Likely	Moderate
	Very rapid, shallow soil slumping and rotational failures	Insignificant (little damage)	Unlikely to regress >5 m into upslope properties	Very Low	Unlikely to regress >5 m into upslope properties	Very Low
	Slow to rapid, intermediate-depth failures	Minor to Medium (damage to structure, part of the site requiring stabilisation)	Unlikely to regress >10 m into upslope properties	Low	Unlikely to regress >10 m into upslope properties	Low
	Very slow, deep-seated landslide	Major to Catastrophic (extensive damage and significant stabilisation works)	Rare	Low to Moderate	Rare	Low to Moderate

Notes: (1) Assessed likelihood and risk levels are based on management and monitoring of the regions during active mine subsidence through the TARP.

Table 10: Assessment of Slope Instability Hazards Due to Mine Subsidence Affecting Structures (cont'd)

Regions	Geotechnical Landslide Hazard	Consequence to the property	Before Mining		During and Post Mining[1]	
			Likelihood of hazard occurring	Assessed risk to the property	Likelihood	Assessed risk to the property
3	Soil Creep	Insignificant for dwellings located on gentle slopes.	Barely Credible	Very Low	Barely Credible	Very Low
	Very rapid, shallow soil slumping and rotational failures	Insignificant (little damage)	Unlikely	Very Low	Unlikely	Very Low
	Slow to rapid, intermediate-depth failures	Minor to Medium (damage to structure, part of the site requiring stabilisation)	Rare	Very Low to Low	Rare	Very Low to Low
	Very slow, deep-seated landslide	Major to Catastrophic (extensive damage and significant stabilisation works)	Barely Credible	Very Low to Low	Barely Credible	Very Low to Low
6	Moderate to rapid, shallow and intermediate depth failure of creek banks	Minor (part of the site requiring stabilisation)	Possible	Moderate	Possible	Moderate

Notes: (1) Assessed likelihood and risk levels are based on management and monitoring of the regions during active mine subsidence through the TARP.

6.3 Assessment of Farm Dams

Site inspection of the farm dams were carried out with the exception of FD19, where permission to access was not granted. It is further noted that FD9 and FD10 are outside the current study area. The following information was obtained by the site inspection, the LiDAR survey, aerial photography, contour and topographic maps.

In total, 17 small farm dams are located within the SSA of LW W3 and W4 (refer Drawing 3 in Appendix B). According to ANCOLD, a small dam refers to a dam that does not meet the ANCOLD definition of a large dam having a volume of greater than 500 ML. The characteristics of these farm dams are given in Table 11. The farm dam capacities vary from about 0.2 ML to 30 ML. The topography around the identified farm dams can be classified as steep, however, most of the dams are situated at the toe of the slope. The predicted subsidence that the farm dams located above the longwall panels will be subjected to is in the order of 650 mm incremental subsidence (ie during extraction of a single longwall) and 1025 mm total subsidence. The dams are of earth fill construction and have been established by localised cut and fill operations within valley floors. The farm dams are generally shallow with the maximum wall heights for 13 of the farm dams estimated to up to about 4 m and up to 7.5 m for the remaining four farm dams.

Table 11: Details of Farm Dams

Farm Dam No.	Northing (MGA)	Easting (MGA)	Estimate Maximum Wall Height (m)	Approximate Surface area (m^2)	Estimated Volume (ML)
FD1	278660	6214760	6.0	15000	30
FD2	278390	6214850	1.0	130	0.15
FD3	278770	6215080	5.0	7250	14.5
FD4	278580	6215130	2.7	3850	7.7
FD5	277850	6215420	3.0	3550	7.1
FD6	278210	6215830	2.5	900*	0.6*
FD7	278490	6216120	7.5	5100	10.2
FD8	278750	6215580	4.0	1480	3.0
FD12	278350	6214890	4.5	3100	6.2
FD13	279050	6215480	3.0	2750	5.5
FD14	279040	6215110	2.0	1200	2.4
FD15	279060	6215750	3.0	1200	2.4
FD16	278880	6215700	3.2	1250	2.5
FD17	279220	6215510	4.0	1300	2.6
FD18	278990	6214740	1.5	1580	3.2
FD19	279010	6216350	1.7	750	1.5
FD20	278800	6216270	2.0	260	0.5

Notes: * Reduced estimated dam capacity (ie considering slot in dam embankment).

Australian National Committee on Large Dams (ANCOLD) Guidelines on the Consequence Categories for Dams (2012) defines the consequences of dam failure as 'the outcome or result of a dam failure in terms of loss of life and damage to property and/or services, as well as environmental damage'. In this study, a consequence screening tool was used to arrive at the impact of subsidence on the farm dams. The tool is broadly consistent with the Initial Consequence Assessment level of ANCOLD (2012). The screening tool identifies the consequence of a dam breakage and provides a preliminary basis for determining dam safety management requirements. It covers the aspects such as surveillance and monitoring; emergency preparedness and response; operational procedures, requirement of additional investigation and dam safety improvement works.

The key inputs for assessment of farm dams are listed as following:

- Dam volume;
- Downstream topography;
- Extent of downstream impact;
- Population at Risk (PAR); and
- Location of PAR.

The PAR includes all people who would be directly exposed to flood waters assuming they took no action to evacuate. The PAR should be assessed using demographic data including dwelling occupancy rates, school populations, work sites and other places where people assemble (eg industrial, hospital, commercial and retail areas). The PAR may vary according to time of day, day of week and season. The framework of screening of ANCOLD Consequence Categories for small dams is made as per following steps:

1. Assess the inundation area by estimating downstream extent of dam break impact and PAR within the downstream extent;
2. Initial screening based on PAR and assessing the proximity of PAR to the dam; and
3. Establishing consequence categories for each dam under very low to low; significant or above.

In the present study, farm dams having capacity of 1 ML or more have been considered for analysis based on the volume that could have a significant impact (Table 9). It is noted that DP carried out detailed assessments for FD5 and FD7 including dam break analyses as part of the assessment for LW W1 and W2 (DP, 2020). There are dwellings located between Rumker Street North and a rail embankment for MSL located to the east of Rumker Street North, which are downstream of a number of the farm dams. Farm Dams FD3 – FD8, and FD12 lie directly above the longwall panels where the predicted total subsidence varies between 650 mm to 1025 mm after the extraction of LW W3 and W4. Farm Dams FD5, 7, 12 and 16 will also be subject to total differential subsidence in excess of 100 mm. Cracking of the top surface may cause loss of water pondage and eventually breaching of the dam. Based on the DEPI Consequence Screening Tool for Small Dams, it is assessed that structures located between Rumker Street North and a rail embankment for MSL are at risk of inundation due to dam break if a dam break were to occur. As per the ANCOLD Consequence Categories for small dams, the consequence of farm dam break have been various categorised as Very Low to High C (refer Table 12). It is noted that higher consequence categories (ie Significant and High C) would be applicable for the farm dams upstream of Rumker Street North when cascading failure (ie if the farm dams failed in series, one after another) is considered.

Table 12: Assessment of Farm Dams

Dam ID	Volume (ML)	Downstream Topography	Population at Risk (PAR)	Consequence
FD1	30	Hilly	> 10	High C
FD2	0.15	Hilly	< 1	Very Low
FD3	14.5	Hilly	> 10	High C
FD4	7.7	Hilly	1 – 10	Significant
FD5	7.1	Hilly	< 1	Low
FD6	2.4	Hilly	< 1	Very Low
FD7	10.2	Hilly	< 1	Low
FD8	3.0	Hilly	< 1	Very Low
FD12	6.2	Hilly	1 – 10	Significant
FD13	5.5	Hilly	1 – 10	Significant
FD14	2.4	Hilly	< 1	Very Low
FD15	2.4	Hilly	< 1	Very Low
FD16	2.5	Hilly	< 1	Very Low
FD17	2.6	Hilly	< 1	Very Low
FD18	3.2	Hilly	< 1	Very Low
FD19	1.5	Hilly	< 1	Very Low
FD20	0.5	Hilly	< 1	Very Low

While the farm dams are constructed with clay material, which can absorb conventional cracking, localised cracking and deformations may occur which may require remediation. Farm dams FD1 – FD8, FD12 and FD16 could potentially experience cracking due to mining induced subsidence, which may cause loss of water storage capacity. To assess the quality of construction of the larger farm dams upstream of Rumker Street and the potential extent of downstream of these dams, it is recommended that a geotechnical investigation including dam break analyses are carried out to assess the likelihood and extent of the assessed risk and to provide recommendations on remedial and precautionary works, if required.

The farm dams may require periodic surveillance with regards to water level and visual inspection for crack development. Remediation may be required to restore any affected dam to its pre-mining condition. It may also be necessary to reduce the volume of stored water in some dams during the mine subsidence period. The farm dams that were not inspected should be inspected by DP when site access is available, preferably prior to mining, to confirm the assumptions in the current assessment or to allow for re-assessment where conditions vary from those anticipated.

7. Monitoring Program

Vertical and horizontal ground movement, bulging, local stress redistribution, ground strains and other subsidence related effects on steep slopes and farm dams may pose the following hazards:

- Slope instability of steep slopes resulting in the regression of steep slopes into properties and/or the run-out of landslide debris downslope; and
- Cracking and piping (ie internal erosion) of dam walls potentially resulting in dam failure.

Management of the identified hazards will require the following:

- Baseline monitoring prior to active subsidence;
- Regular monitoring and reporting on changes which have the potential to develop into instability, before, during and after longwall mining;
- Regular inspections and possibly subsurface investigation; and
- Action plans for response to defined events.

The Monitoring Plan outlined within Table 13 has been developed to assess the subsidence impacts on steep slopes and farm dams that can occur due to subsidence during and following the extraction of LW W3 and W4. The monitoring plan includes the following components:

- Steep slope monitoring; and
- Farm dam monitoring.

8. Trigger Action Response Plan

A contingency plan has been developed in the form of a Trigger Action Response Plan (TARP), as outlined on Tables 14 – 16. The actions developed within the TARP are to address any potential significant subsidence related impacts and include steep slopes, surface cracking and farm dams.

Table 13: Monitoring Program for Geotechnical Features

Feature	Monitoring Component / Location	Monitoring		
		Prior to Mining	During Mining	Post Mining
Steep Slopes	Identified steep slopes within the SSA.	Visual Inspection baseline 1 month before active subsidence period by a geotechnical consultant.	Monthly visual inspection during active subsidence period by a geotechnical consultant .	Quarterly visual inspection for 12 month following active subsidence period by a geotechnical consultant .
Farm Dams	Identified farm dams within the SSA.	Dam embankment integrity and water level observation by a geotechnical consultant every month for at least two months immediately prior to undermining using fixed location photo points.	Dam embankment integrity and water level observation every week during active subsidence period using fixed location photo points by TC and every month during the active subsidence period using fixed photo points by a geotechnical consultant.	Dam embankment integrity and water level observation using fixed location photo points on a 3-monthly basis for 12 months following completion of LW W4. This period may be extended by the Tahmoor Coal Environmental Response Group.

Table 14: Trigger Action Response Plan for Steep Slopes

Feature	Management		
	Trigger	Action	Response
	Level 1		
Steep Slope Damage or Instability	Surface cracking < 10 mm wide on slope	– Continue monitoring in accordance with the monitoring program.	– No response required.
	Level 2		
	Surface cracking 10 – 20 mm wide on slope	– Continue monitoring in accordance with the monitoring program. – Convene Tahmoor Coal Environmental Response Group (TC ERG) to review response. – Erect warning signs and restrict access to areas where necessary.	– As defined by TC ERG. – Repair cracks at the completion of the active subsidence period.
	Level 3		
	Surface cracking > 20 mm wide, tree fall	– Increase frequency of monitoring by geotechnical consultant to weekly during active subsidence period. – Convene TC ERG to review response. – Erect warning signs and restrict access to areas where necessary. – Geotechnical consultant inspection to determine need for further action/investigation.	– Notify relevant Government Agencies and other stakeholders. – Repair cracks at the completion of the active subsidence period.

Table 15: Trigger Action Response Plan for Surface Cracking

Feature	Management		
	Trigger	Action	Response
Surface cracking	Level 1		
	Surface cracking < 10 mm wide	– Continue monitoring in accordance with the monitoring program.	– No response required.
	Level 2		
	Surface cracking 10 – 20 mm wide	– Continue monitoring in accordance with the monitoring program. – Convene Tahmoor Coal Environmental Response Group (TC ERG) to review response. – Erect warning signs and restrict access to areas where necessary.	– As defined by TC ERG. – Repair cracks at the completion of the active subsidence period.
	Level 3	–	
	Surface cracking > 20 mm wide	– Increase frequency of monitoring by geotechnical consultant to weekly during active subsidence period. – Convene TC ERG to review response. – Erect warning signs and restrict access to areas where necessary. – Geotechnical consultant inspection to determine need for further action/investigation.	– Notify relevant Government Agencies and other stakeholders – Repair cracks > 20 mm in width with excavation, grouting and re-compaction where practical.

Table 16: Trigger Action Response Plan for Farm Dams

Feature	Management		
	Trigger	**Action**	**Response**
Farm dams	Level 1		
	No cracks develop within dam embankment (ie other than natural desiccation cracking).	– Continue monitoring in accordance with the monitoring program.	– No response required.
	Level 2		
	Development of isolated cracks (<10 mm wide) within dam wall (ie other than natural desiccation cracking).	– Continue monitoring in accordance with the monitoring program. – Continue monthly review of data	– No response required.
	Level 3		
	Development of isolated cracks (> 10 mm wide) within the dam wall (ie other than natural desiccation cracking); AND/OR Development of isolated seepage from the face or toe of the farm dam embankment.	– Increase frequency of monitoring by geotechnical consultant to weekly during active subsidence period. – Convene Tahmoor Coal Environmental Response Group (TC ERG) to review response.	– As defined by TC ERG.
	Level 4		
	Development of persistent longitudinal or arcuate cracking within dam wall > 10 mm; AND/OR Development of seepage from the face or toe of the farm dam embankment.	– Increase frequency of monitoring by geotechnical consultant to weekly during active subsidence period. – Convene TC ERG to review response. – Erect warning signs where necessary – Reduce dam water level by at least half dam volume. – Geotechnical consultant inspection to determine need for further action/investigation.	– Notify relevant Government Agencies and other stakeholders – Repair cracks and embankment instability at the completion of the active subsidence period by excavation, grouting and re-compaction where practical.

9. Comments

A high-level geotechnical assessment was conducted on the land features within the SSA of LW W3 and W4. The geotechnical assessment included risk based assessments of steep slopes and farm dams. A monitoring program and Triger Action Response Plan (TARP) have been developed. The geotechnical assessment was based on the mine inputs received from Tahmoor Coal and the subsidence prediction report by MSEC. Inspections were conducted adjacent to steep slopes and farm dams within the SSA.

The risk assessment of the steep slopes were evaluated by the procedure recommended by Australian Geomechanics Society publication "Practice Note Guidelines for Landslide Risk Management 2007" (AGS 2007). The Small Dam Consequence Screening Tool (DEPI, 2014) was used to analyse farm dams.

The risk assessment of steep slopes indicated that the risk of slope instability prior to mining was within the range of Very *Low* to *Moderate* and within the *Tolerate* risk range defined by AGS (2007). The risk levels were considered to be unchanged following the propose extraction of LW W3 and W4.

The consequence of farm dam failure to property or human lives was assessed to be in the *Significant* to *High C* ranges for farm dams in excess of 5 ML in the tributaries of Redbank Creek in the SSA (ie typically in the eastern and southern parts of the SSA) due the properties located downstream of Rumker Street North, which are expected to be affected if a dam break occurred. When considering cascading failure for farm dams in the tributaries of Redbank Creek, they are all assessed in the *Significant* to *High C* ranges. The remaining farm dams (ie in the western and northern parts of the SSA) were assessed to be in the *Very Low* to *Low* ranges. It is recommended that a detailed assessment is carried out for farms dams located in the tributaries of Redbank Creek and within the SSA to assess the quality of construction of the larger farm dams and a dam break analyses to assess the extent of the flooding impact downstream.

It is recommended that a monitoring program be undertaken to facilitate the early detection of signs of distress and the implementation of remedial works (if any). A monitoring program has been provided as part of the TARP in the report. . In the event that monitoring indicates the measured parameters are exceeding predicted values, the TARP escalates the monitoring requirements and the need for remedial or precautionary measures to be implemented. It is considered that with periodic inspections and visual observations and timely actions, it will be possible to manage the identified risks and to keep them with tolerable levels.

10. References

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11. Limitations

Douglas Partners Pty Ltd (DP) has prepared this report for this project at Longwalls W3 and W4 at Picton in accordance with DP's proposal WOL200362.P.001.Rev1 dated 3 September 2020 and email acceptance received from Tahmoor Coal dated 22 September 2020. The work was carried out under TC's and DP's Umbrella Agreement for Consultancy Services (Contract TAHC0612 executed on 15 October 2019). This report is provided for the exclusive use of Tahmoor Coal Pty Ltd for this project only and for the purposes as described in the report. It should not be used by or be relied upon for other projects or purposes on the same or another site or by a third party. Any party so relying upon this report beyond its exclusive use and purpose as stated above, and without the express written consent of DP, does so entirely at its own risk and without recourse to DP for any loss or damage. In preparing this report DP has necessarily relied upon information provided by the client and/or their agents.

DP's advice is based upon the conditions encountered during this assessment. The accuracy of the advice provided by DP in this report may be affected by undetected variations in ground conditions across and below the site. The advice may also be limited by site accessibility.

The assessment of atypical safety hazards arising from this advice is restricted to the geotechnical components set out in this report and based on known project conditions and stated design advice and assumptions. While some recommendations for safe controls may be provided, detailed 'safety in design' assessment is outside the current scope of this report and requires additional project data and assessment.

This report must be read in conjunction with all of the attached and should be kept in its entirety without separation of individual pages or sections. DP cannot be held responsible for interpretations or conclusions made by others unless they are supported by an expressed statement, interpretation, outcome or conclusion stated in this report.

This report, or sections from this report, should not be used as part of a specification for a project, without review and agreement by DP. This is because this report has been written as advice and opinion rather than instructions for construction.

Douglas Partners Pty Ltd

Appendix A

About This Report

About this Report

Douglas Partners

Introduction

These notes have been provided to amplify DP's report in regard to classification methods, field procedures and the comments section. Not all are necessarily relevant to all reports.

DP's reports are based on information gained from limited subsurface excavations and sampling, supplemented by knowledge of local geology and experience. For this reason, they must be regarded as interpretive rather than factual documents, limited to some extent by the scope of information on which they rely.

Copyright

Borehole and Test Pit Logs

The borehole and test pit logs presented in this report are an engineering and/or geological interpretation of the subsurface conditions, and their reliability will depend to some extent on frequency of sampling and the method of drilling or excavation. Ideally, continuous undisturbed sampling or core drilling will provide the most reliable assessment, but this is not always practicable or possible to justify on economic grounds. In any case the boreholes and test pits represent only a very small sample of the total subsurface profile.

Interpretation of the information and its application to design and construction should therefore take into account the spacing of boreholes or pits, the frequency of sampling, and the possibility of other than 'straight line' variations between the test locations.

Groundwater

Where groundwater levels are measured in boreholes there are several potential problems, namely:

- In low permeability soils groundwater may enter the hole very slowly or perhaps not at all during the time the hole is left open;
- A localised, perched water table may lead to an erroneous indication of the true water table;
- Water table levels will vary from time to time with seasons or recent weather changes. They may not be the same at the time of construction as are indicated in the report; and
- The use of water or mud as a drilling fluid will mask any groundwater inflow. Water has to be blown out of the hole and drilling mud must first be washed out of the hole if water measurements are to be made.

More reliable measurements can be made by installing standpipes which are read at intervals over several days, or perhaps weeks for low permeability soils. Piezometers, sealed in a particular stratum, may be advisable in low permeability soils or where there may be interference from a perched water table.

Reports

The report has been prepared by qualified personnel, is based on the information obtained from field and laboratory testing, and has been undertaken to current engineering standards of interpretation and analysis. Where the report has been prepared for a specific design proposal, the information and interpretation may not be relevant if the design proposal is changed. If this happens, DP will be pleased to review the report and the sufficiency of the investigation work.

Every care is taken with the report as it relates to interpretation of subsurface conditions, discussion of geotechnical and environmental aspects, and recommendations or suggestions for design and construction. However, DP cannot always anticipate or assume responsibility for:

- Unexpected variations in ground conditions. The potential for this will depend partly on borehole or pit spacing and sampling frequency;
- Changes in policy or interpretations of policy by statutory authorities; or
- The actions of contractors responding to commercial pressures.

If these occur, DP will be pleased to assist with investigations or advice to resolve the matter.

About this Report

Site Anomalies

In the event that conditions encountered on site during construction appear to vary from those which were expected from the information contained in the report, DP requests that it be immediately notified. Most problems are much more readily resolved when conditions are exposed rather than at some later stage, well after the event.

Information for Contractual Purposes

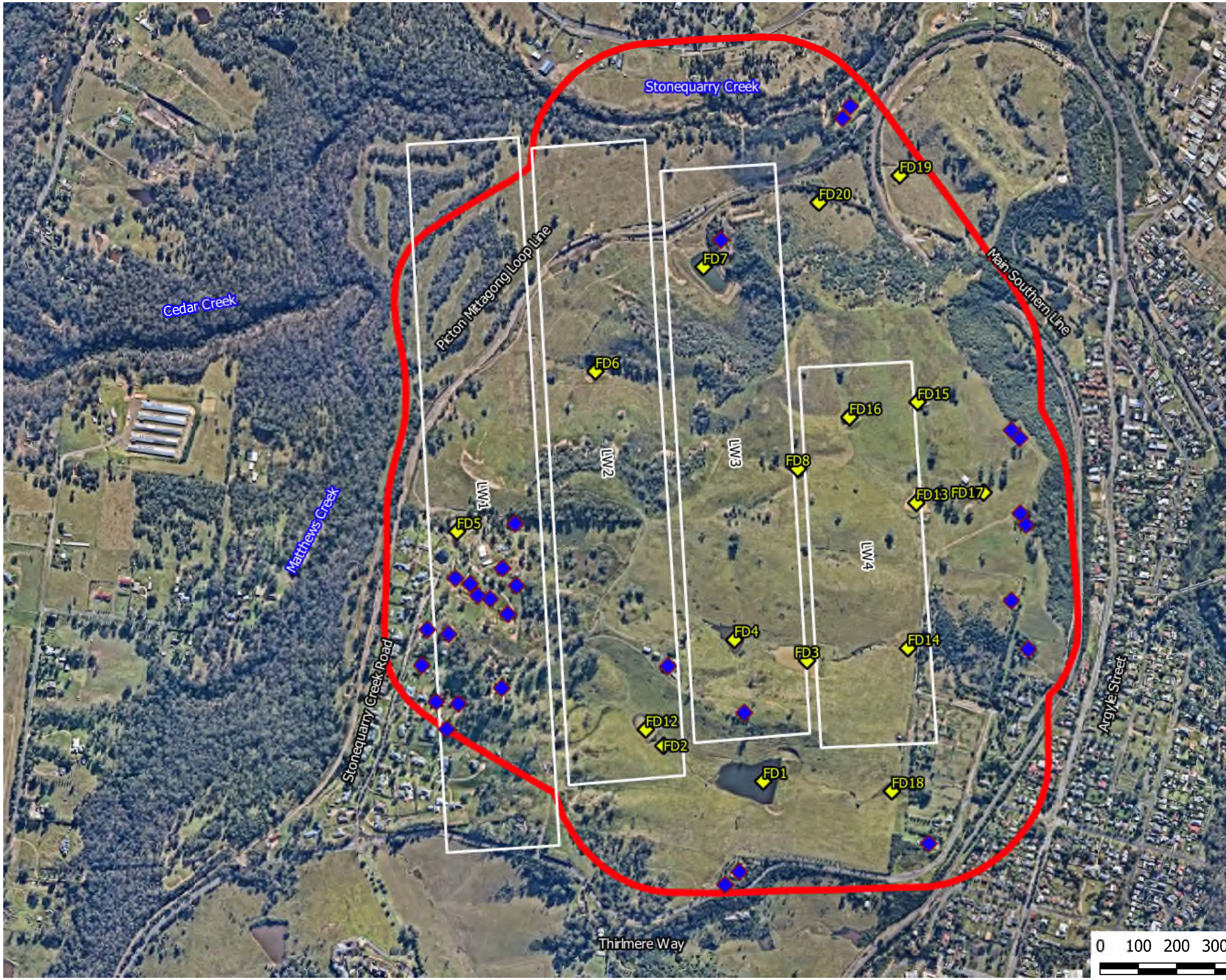
Where information obtained from this report is provided for tendering purposes, it is recommended that all information, including the written report and discussion, be made available. In circumstances where the discussion or comments section is not relevant to the contractual situation, it may be appropriate to prepare a specially edited document. DP would be pleased to assist in this regard and/or to make additional report copies available for contract purposes at a nominal charge.

Site Inspection

The company will always be pleased to provide engineering inspection services for geotechnical and environmental aspects of work to which this report is related. This could range from a site visit to confirm that conditions exposed are as expected, to full time engineering presence on site.

Appendix B

Drawings
Site Photographs



Locality Plan

Notes: Aerial photography from Nearmap.com

Legend

- Structures Near Steep Slopes
- Farm Dams
- Longwalls
- Subsidence Study Area (SSA)

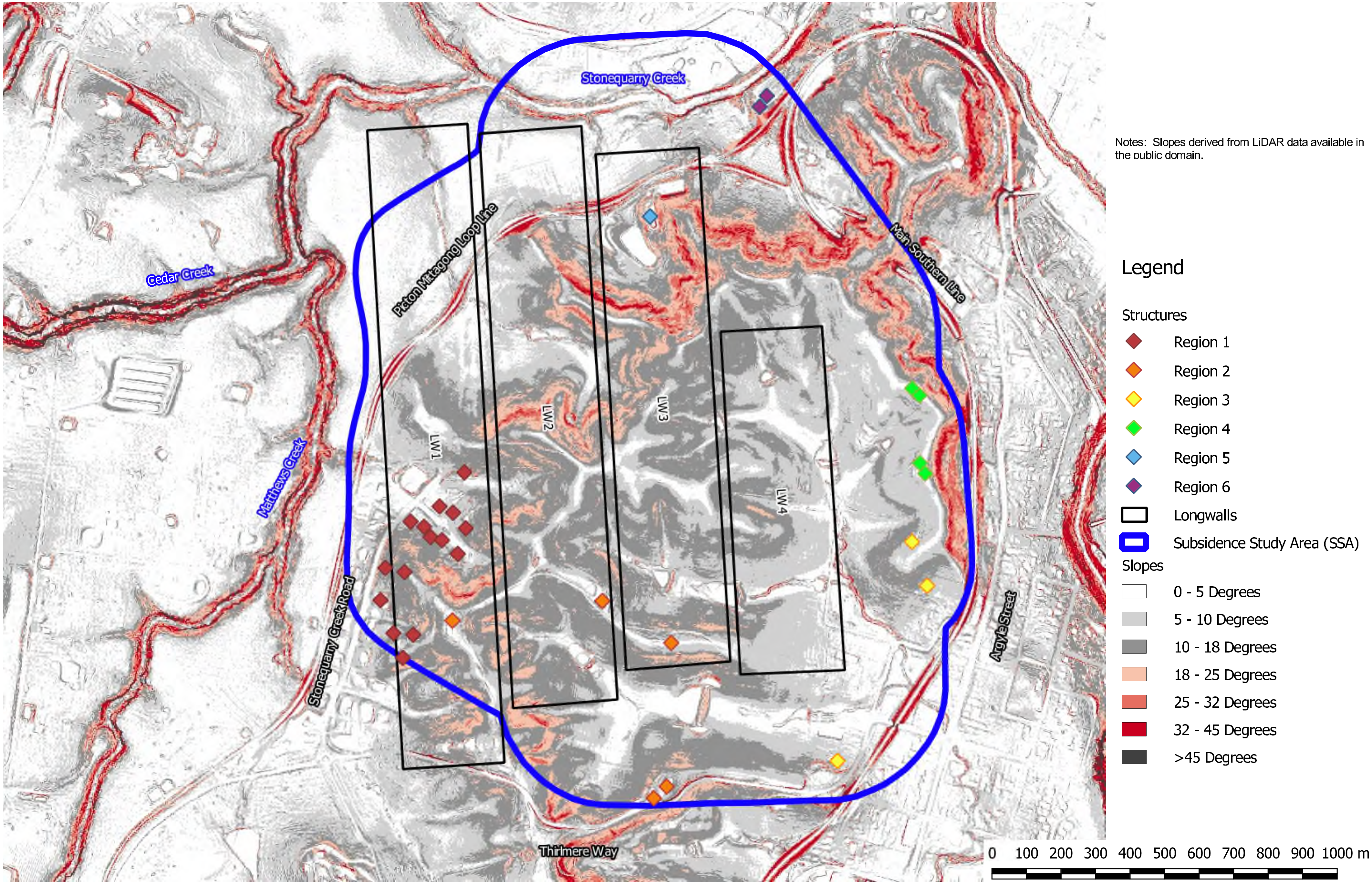
0 100 200 300 400 500 600 700 800 900 1000 m

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Tahmoor Coal Pty Ltd		
OFFICE:	Wollongong	DRAWN BY:	RJH
SCALE:	1:10,000 @ A3	DATE:	20 Nov 2020

TITLE: **Subsidence Study Area and Landscape Features**
Geotechnical Land Management Plan
Longwalls W3 and W4, Picton

PROJECT No:	89541.06
DRAWING No:	1
REVISION:	0



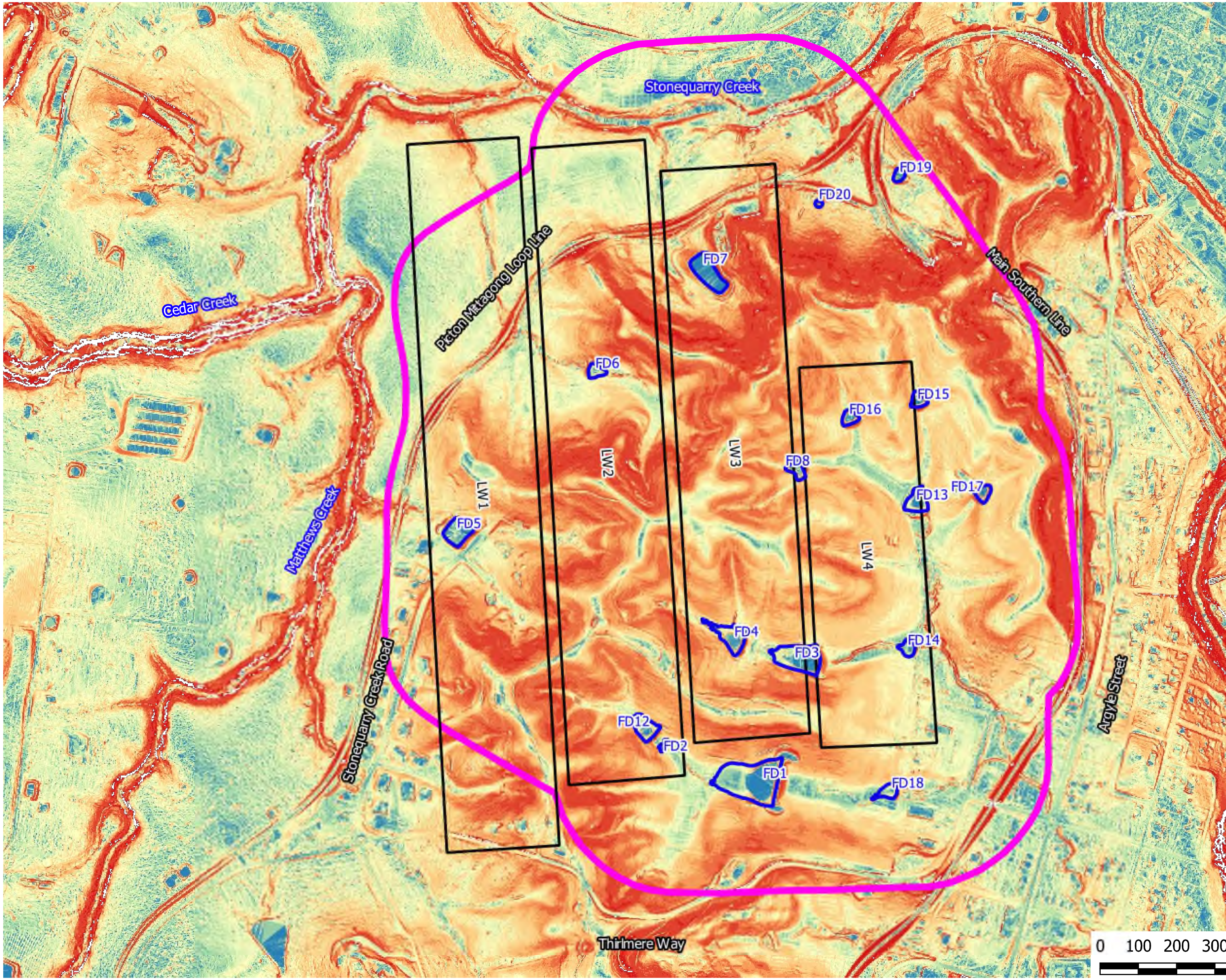
Notes: Slopes derived from LiDAR data available in the public domain.

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Tahmoor Coal Pty Ltd		
OFFICE:	Wollongong	DRAWN BY:	RJH
SCALE:	1:10,000 @ A3	DATE:	20 Nov 2020

TITLE: **Structures Near Steep Slopes**
Geotechnical Land Management Plan
Longwalls W3 and W4, Picton

PROJECT No:	89541.06
DRAWING No:	2
REVISION:	0



Notes: Grades derived from LiDAR data available in the public domain.

Legend

- Farm Dams
- Longwalls
- Subsidence Study Area (SSA)

Surface Grades (H:V)

- 100:1
- 50:1
- 40:1
- 25:1
- 20:1
- 16:1
- 12.5:1
- 10:1
- 8:1
- 6:1
- 5:1
- 4:1
- 3:1
- 2:1
- 1:1

Douglas Partners
Geotechnics / Environment / Groundwater

CLIENT:	Tahmoor Coal Pty Ltd		
OFFICE:	Wollongong	DRAWN BY:	RJH
SCALE:	1:10,000 @ A3	DATE:	20 Nov 2020

TITLE: **Farm Dams Locations and Regional Topography**
Geotechnical Land Management Plan
Longwalls W3 and W4, Picton

PROJECT No:	89541.06
DRAWING No:	3
REVISION:	0

Appendix C

Excerpts of AGS 2007
Excerpts of DEPI 2014

Rate of Movement

Figure B3 shows the velocity scale proposed by Cruden & Varnes (1996) which rationalises previous scales. The term "creep" has been omitted due to the many definitions and interpretations in the literature.

Velocity Class	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid			Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
		5×10^{3}	5 m/sec	
6	Very Rapid			Some lives lost; velocity too great to permit all persons to escape
		5×10^{1}	3 m/min	
5	Rapid			Escape evaluation possible; structures; possessions, and equipment destroyed
		5×10^{-1}	1.8 m/hr	
4	Moderate			Some temporary and insensitive structures can be temporarily maintained
		5×10^{-3}	13 m/month	
3	Slow			Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
		5×10^{-5}	1.6 m/year	
2	Very Slow			Some permanent structures undamaged by movement
		5×10^{-7}	15 mm/year	
	Extremely **SLOW**			Imperceptible without instruments; construction **POSSIBLE WITH PRECAUTIONS**

Figure B3: Proposed Landslide Velocity Scale and Probable Destructive Significance.

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APPENDIX C: LANDSLIDE RISK ASSESSMENT

QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY

QUALITATIVE MEASURES OF LIKELIHOOD

Approximate Annual Probability		Implied Indicative Landslide Recurrence Interval		Description	Descriptor	Level
Indicative Value	**Notional Boundary**					
10^{-1}	$5x10^{-2}$	10 years	20 years	The event is expected to occur over the design life.	ALMOST CERTAIN	A
10^{-2}	$5x10^{-3}$	100 years	200 years	The event will probably occur under adverse conditions over the design life.	LIKELY	B
10^{-3}	$5x10^{-4}$	1000 years	2000 years	The event could occur under adverse conditions over the design life.	POSSIBLE	C
10^{-4}	$5x10^{-5}$	10,000 years	20,000 years	The event might occur under very adverse circumstances over the design life.	UNLIKELY	D
10^{-5}	$5x10^{-6}$	100,000 years	200,000 years	The event is conceivable but only under exceptional circumstances over the design life.	RARE	E
10^{-6}		1,000,000 years		The event is inconceivable or fanciful over the design life.	BARELY CREDIBLE	F

Note: (1) The table should be used from left to right; use Approximate Annual Probability or Description to assign Descriptor, not *vice versa*.

QUALITATIVE MEASURES OF CONSEQUENCES TO PROPERTY

Approximate Cost of Damage		Description	Descriptor	Level
Indicative Value	**Notional Boundary**			
200%	100%	Structure(s) completely destroyed and/or large scale damage requiring major engineering works for stabilisation. Could cause at least one adjacent property major consequence damage.	CATASTROPHIC	1
60%	40%	Extensive damage to most of structure, and/or extending beyond site boundaries requiring significant stabilisation works. Could cause at least one adjacent property medium consequence damage.	MAJOR	2
20%	10%	Moderate damage to some of structure, and/or significant part of site requiring large stabilisation works. Could cause at least one adjacent property minor consequence damage.	MEDIUM	3
5%	1%	Limited damage to part of structure, and/or part of site requiring some reinstatement stabilisation works.	MINOR	4
0.5%		Little damage. (Note for high probability event (Almost Certain), this category may be subdivided at a notional boundary of 0.1%. See Risk Matrix.)	INSIGNIFICANT	5

Notes: (2) The Approximate Cost of Damage is expressed as a percentage of market value, being the cost of the improved value of the unaffected property which includes the land plus the unaffected structures.

(3) The Approximate Cost is to be an estimate of the direct cost of the damage, such as the cost of reinstatement of the damaged portion of the property (land plus structures), stabilisation works required to render the site to tolerable risk level for the landslide which has occurred and professional design fees, and consequential costs such as legal fees, temporary accommodation. It does not include additional stabilisation works to address other landslides which may affect the property.

(4) The table should be used from left to right; use Approximate Cost of Damage or Description to assign Descriptor, not vice versa

APPENDIX C: – QUALITATIVE TERMINOLOGY FOR USE IN ASSESSING RISK TO PROPERTY (CONTINUED)

QUALITATIVE RISK ANALYSIS MATRIX – LEVEL OF RISK TO PROPERTY

LIKELIHOOD		CONSEQUENCES TO PROPERTY (With Indicative Approximate Cost of Damage)				
	Indicative Value of Approximate Annual Probability	**1: CATASTROPHIC 200%**	**2: MAJOR 60%**	**3: MEDIUM 20%**	**4: MINOR 5%**	**5: INSIGNIFICANT 0.5%**
A – ALMOST CERTAIN	10^{-1}	VH	VH	VH	H	M or **L** (5)
B - LIKELY	10^{-2}	VH	VH	H	M	**L**
C - POSSIBLE	10^{-3}	VH	H	M	M	**VL**
D - UNLIKELY	10^{-4}	H	M	**L**	**L**	**VL**
E - RARE	10^{-5}	M	**L**	**L**	**VL**	**VL**
F - BARELY CREDIBLE	10^{-6}	**L**	**VL**	**VL**	**VL**	**VL**

Notes: (5) For Cell A5, may be subdivided such that a consequence of less than 0.1% is Low Risk.

(6) When considering a risk assessment it must be clearly stated whether it is for existing conditions or with risk control measures which may not be implemented at the current time.

RISK LEVEL IMPLICATIONS

Risk Level		**Example Implications** (7)
VH	VERY HIGH RISK	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low; may be too expensive and not practical. Work likely to cost more than value of the property.
H	HIGH RISK	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to Low. Work would cost a substantial sum in relation to the value of the property.
M	MODERATE RISK	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as practicable.
L	LOW RISK	Usually acceptable to regulators. Where treatment has been required to reduce the risk to this level, ongoing maintenance is required.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.

Note: (7) The implications for a particular situation are to be determined by all parties to the risk assessment and may depend on the nature of the property at risk; these are only given as a general guide.