Upper Waimangaroa Haul Road & Mount Frederick South Access Road Void Assessment

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1.1	Updates to address Andrew Smith (Pattle Delamore Partners) peer reviewer comments
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TITLE:

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1.0 Introduction

This report presents a high-level assessment of the potential upward migration of voids from historic underground coal mine workings beneath the proposed Upper Waimangaroa Haul Road (UWHR) and Mount Frederick South (MFS) Access Road on the Buller Plateaux (Figure 1). This report also proposes controls for working in areas of insufficient in-situ cover. The UWHR and MFS will be developed as part of the Buller Plateaux Continuation Project, to provide access from the proposed Escarpment Extended and Mount Frederick South sub-areas to the existing Stockton Mine coal handling infrastructure.

Underground coal mining on the Buller Plateaux was extensive from the late nineteenth century onward and the remnants of many underground coal mines are located in the vicinity of the proposed UWHR, largely confined to the southern extent (Figure 1). This underground mining commonly used bord and pillar extraction methods and in some places, retreat pillar extraction was also carried out. The only known underground voids near the MFS Access Road are at the northern end of the proposed road (Figure 1). These voids will be excavated out during opencast mining, prior to the haul road being extended through this area and therefore do not present a void hazard to the MFS Access Road.

As a result of stress redistribution and ground movements above open voids associated with the underground workings, the rock mass above the old workings has most likely relaxed. Loading of the relaxed areas above open voids or excavation of in-situ material during construction of the proposed UWHR has the potential to induce void migration of previously un-collapsed voids presenting the potential for injury to workers or damage to equipment.

[redacted]

2.0 General

The Buller Plateaux near surface geology within close proximity to the UWHR and MFS Access Road consists primarily of Kaiata Formation mudstone and quartz rich Eocene Brunner Coal Measures (BCM). The BCM formation lithologies are comprised of interbedded coarse sandstones, siltstones, mudstones and coal seams. The BCM is separated from basement lithologies by a regional unconformity. These near surface lithologies follow a regional southeast trending dip of approximately 7 degrees, local variations in dip direction and degree of dip are noted near structural boundaries.

Historic underground coal mining targeted the economic coal seams within the lower bounds of the BCM, known as the M1 (deeper / older) and M2 (younger / shallower) coal seams. The location of the historic underground workings are depicted on historic mine plans (Figure 2), these generally define which coal seam(s) were worked and the plans have been digitised and imported into 3 dimensional geological modelling software for this assessment. Deep incised gullies and water courses generally keep the underground workings in a drained state and water is noted to flow from outcropping drives and adits. Water should be expected to pond in areas of synclines and at the bounds of anticlines. It is expected that while some of the voids created by underground mining will have collapsed over time, some may remain open and any changes in the stress strain regime during haul road construction may induce further collapse.

[redacted]

3.0 Site Observations

Onsite inspections of the underground workings are limited to the surface only; it is considered too dangerous to enter these workings as they could be in a state of active collapse, roof support regimes are unknown and there is likely to be inadequate ventilation (i.e. fresh air) available. In most cases, these workings were excavated in excess of 100 years ago, any ground support that was installed during excavation (roof bolting and propping etc) may have degraded and changes in the environmental conditions risk inducing further collapse. Further collapse presents an inundation and inrush hazard as pooled groundwater can be released into previously un-flooded workings. Additionally, the atmosphere within the workings is unknown and could be volatile.

Ground surface investigations along the proposed UWHR and MFS Access Road alignments noted only one area where collapse of historic underground working voids has intersected the ground surface.

This manifested at ground surface as tensile fracturing with an aperture of 100mm and an offset of 1.0 metres (Figure 3) and is observed above the Iron Bridge workings, at the location (1) depicted on Figure 5. Overburden lithologies in this area are Fine to Very Coarse BCM Sandstone with some evidence of historic fires within the underlying coal seam voids noted. Review of the Iron Bridge Mine Plan (Appendix 2) notes there are two levels of underground workings at this location and in-situ cover in this area is approximately 11 metres (distance between void roof and ground surface).

Review of Lidar surfaces did not note any other evidence of underground workings which have collapsed through to the surface within the proposed UWHR and MFS Access Road footprints, nor was any evidence of crown holes observed.

[redacted]

4.0 Mechanisms of Void Migration

Void migration progresses by the collapse of immediate roof strata, the bulking and settlement of collapsed debris and the potential formation or failure of natural arch structures in the overburden.

The bulking limited height is controlled by whether the collapsed roof material can fill the mined void. Published bulking factors for coal measures strata are typically in the range from 1.30 to 1.50 (Bell & de Bruyn, 1999, Ofoegbu et al., 2008). Site field observations would suggest the more conservative lower bound bulking factor is more appropriate to adopt for Brunner Coal Measures overburden due to the joint spacing and grain size observed within the well indurated sandstone and rare mudstone. Lower bulking factors produce taller collapse chimneys because the broken material occupies proportionally less volume.

Roof collapse of the underground workings can lead to the upward propagation of voids breaking through to the surface. Voids breaking through to the surface may form some type of discontinuous subsidence such as crown holes / troughs or chimney caving (Fig 4c, d).

Voids will propagate upward until arrested by:

- The formation of a new stable self-supporting arch;
- A more competent roof layer is intercepted (Fig 4a);

- Bulking of roof debris (Fig 4b); or,
- Migration to the surface forming either a crown hole / trough (Fig 4c) or a chimney (Fig 4d).

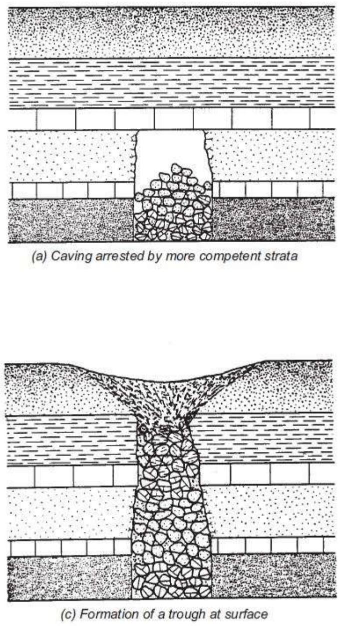

Figure 4. Schematic cross-sections depicting formation of voids above mine workings (Karfakis, 1993).

Simple equations have been developed between the height of collapse, the thickness of the extracted material and the bulking of the roof material. These bulking equations can be used to predict whether caving with a given geometry would reach the ground surface before a void is choked (choked void indicated in Fig 4b). The below calculation can be used to determine the distance of void propagation (D_c) before choking occurs, where h equals extraction height and BF represents the Bulking Factor of the void roof lithology, derived from U.S. NRC (2008):

$$Dc = \frac{h}{BF - 1}$$

Arching limited collapse occurs when overlying rock layers form a natural voussoir or masonry-like arch that arrests upward migration. Research into shallow coal mine void collapse suggests that for a typical near surface coal mine collapse a statistically derived relationship of (collapse height = 2.68 * span of working) has been proposed as the limiting height for arching situations (Garrard, 1981).

5.0 Expected Void Migration

Based on the maximum understood geometries of the underground workings (≤3m height and ≤4.5m span), bulking limited migration heights for underground workings within the Project area typically range from 6 to 10 metres (Table 1). Arching limited heights fall in the range 12.1m, relative to the void width.

Surface breakthrough is most credible where depth of cover is less than 12 m, especially where the overburden rock mass has been structurally weakened due to jointing or faulting and if structural planes align favorably for chimneying. For cover between 12–20 m, breakthrough remains possible if roof materials have very low bulking factors and additional factors as discussed in Section 6.0 are applicable. With cover exceeding 20m, the likelihood of direct breakthrough decreases substantially, although broad subsidence troughs can still form in areas above pillar extraction or areas where multiple levels of coal seams have been mined. These expectations align with observations of near surface void propagation within the same lithologies at the neighboring Stockton opencast mine, approximately 4 kilometres north of the Project area.

The following table presents the expected collapse height ranges for single seam extraction , using site specific parameters.

Table 1: Estimated Void Migration Heights for Typical Denniston Workings

Lithology	Extraction Height (m)	Bulking Factor (BF)	Maximum Bulking Limited Height (m) [A]	Maximum Arching-Limited Height (m)[B]
Sandstone Roof (low BF)	3.0	1.30	10.0	12.1
Sandstone Roof (moderate BF)	3.0	1.40	7.5	12.1
Sandstone Roof (high BF / blocky)	3.0	1.50	6	12.1
[A] Calculated from equation: $Dc = \frac{h}{BF-1}$ [B] Calculated using maximum span of 4.5m				

The highest likelihood of surface breakthrough from historic underground workings occurs where workings lie within 0 to 12 metres of the ground surface. Within this zone, calculated migration heights (bulking limited and arching) overlap substantially with depth of cover making vertical collapse feasible particularly along discontinuities. In areas with 12 to 20 metres cover, although this exceeds the calculated maximum, breakthrough remains possible if there are additional factors affecting the overburden rock mass. Where cover exceeds 20 metres, migration is unlikely to reach the surface but broad subsidence troughs may still form above wider mined areas.

6.0 Additional Factors Increasing Migration Potential

In addition to lithological and geometric controls, these site specific features can increase the risk of roof collapse and in some cases extend the void migration distance:

1. Underground workings within multiple coal seams.
2. Long term fires within the coal seams can alter and weaken the rock mass properties of overburden lithologies.
3. Pillared extraction on retreat in historic workings created larger spans.
4. Structurally, the Buller Plateaux is cut by numerous faults and steep joint sets linked with the Papahaua Range. The Iron Bridge corridor, located on a steeply incised route with known structural complexity, provides natural vertical planes that can assist chimney-style collapse propagation. These features reduce the likelihood that overburden can form stable arch structures.
5. The site sits within an area of moderate to high seismicity relative to the rest of New Zealand, seismic loading adds another mechanism by which partially stabilized collapse chimneys may re-activate or arches collapse.

6.1 Identified void Hazard Areas

Based on the above assessment, review of historic mine workings plans and the UWHR and MFS Access Road designs, the below heat map has been produced. The heatmap depicts void hazard areas near the proposed roads based on in-situ cover between the current ground surface and the roof of the coal seam that was subject to underground extraction. The elevation of the coal seam(s) roof has been modelled using the most up to date / accurate geological data that Bathurst Resources holds.

The colours of the heat map represent:

- Green: ≥ 20 metres of in-situ cover.
- Orange: 12 - 20 metres of in-situ cover.
- Red: ≤ 12m of in-situ cover.

[redacted]

6.2 Proposed Control

Geotechnical drilling must be undertaken before any construction activities, targeting areas of suspected underground workings to confirm the depth of in-situ cover to the underlying coal seam and underground void (if any). This drilling will also provide opportunity to take rock core samples that will be used to confirm rock mass parameters.

Where voids are within close proximity to the surface, it may be feasible to excavate them out entirely to remove the void hazard, then replace them with compacted backfill.

Where voids are identified within 12.1 metres of the ground surface, collapse blasting may be utilized as the key control for mitigating the void hazard. Collapse blasting involves drilling a pattern of drill holes above the void and inserting explosives into the drill hole and firing. This explosion causes significant damage to the overburden rock mass, resulting in collapse of the overburden into the below void. The collapsed area is then bladed smooth by a bulldozer and a suitable subgrade can be prepared for the haul road. Following collapse blasting, surface water must be appropriately managed to ensure it does not run into the collapsed ground, the introduction of surface water can cause internal erosion of the collapse debris into the open voids outside of the collapsed area, resulting in surface subsidence.

Where the haul roads are required to bridge a section of open voids, and above mentioned controls are not suitable, an engineered fill raft roadway foundation must be implemented. This would negate the need for rubblesing the overburden material through drill and blasting.

6.3 Acid Mine Drainage Potential

The Iron Bridge mine currently has several drainage and access adits that intersect the Upper Waimangaroa River valley. The extent to which these openings remain connected to historical mine workings under the UWHR alignment is unknown.

As the technique of rubblising road foundation material via blasting for stability would significantly increase the effective surface area and permeability of BCM sulphides, the potential for increased water ingress and AMD discharge represents a risk to the use of this technique for ground stabilisation above the Iron Bridge mine.

Before adopting rubblisation as a method for ground stabilisation it is necessary to understand the proximity of historical workings to surface, and also to understand the connectivity of these points to discharge locations along the Upper Waimangaroa River valley. During the Pre-Commencement Work, if the potential for acid mine drainage from rubblisation of the road alignment is considered to be too high, alternative controls must be utilized.

7.0 Pre-Commencement Work

- Additional geotechnical drilling along the footprint of the proposed UWHR and MFS Access Road, to confirm the in-situ depth of cover to coal seams and associated underground voids (if any). This drilling will also provide opportunity to take rock core samples that will be used to confirm rock mass parameters.
- Surface geological mapping must be undertaken along the Project alignment to confirm the exposed geology is suitable for supporting the proposed roads.
- Surface geophysical surveys (e.g. electrical resistivity tomography) will be utilized to determine the location and depth of underground voids, from which accurate maps of the void locations will be produced.
- The Proposed Controls must be assessed for their acid mine drainage potential.
- A data review and risk assessment must be completed that considers the risks that the voids and associated controls pose to both safety and the environment. Followed by the development of a Trigger Action Response Plan (TARP) for working around historic underground workings.

8.0 References

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