Peer Review of Ian R Brown Associates report titled

"Report on hazards following mine closure, Huntly East, October 2018, Project 1003"

8 January 2019

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REPORT TO:	Waikato District Council
PROJECT:	Peer Review of Ian R Brown Associates report titled "Report on hazards following mine closure, Huntly East, October 2018, Project 1003"
PROJECT NO:	TFM0096
PEER REVIEWERS:	Craig Smith *(Mining Executive, TFM)* Borys Poborowski *(Ventilation Engineer, TFM)*
DATE:	8 January 2019

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Introduction

Terra Firma Mining Ltd (Terra Firma) has been engaged by the Waikato District Council to peer review the report prepared by Ian R Brown Associates in October 2018.

The peer review will:

1. Review the final report and all referenced material;
2. Engage in dialogue with the author/s if required; and,
3. Prepare a report that includes the following:
    - Discussion on whether or not the assessment of the risk of future subsidence and gas trapping and gas migration follows a robust line of enquiry
    - Discussion on whether or not the information gathered and analysed is sufficient for its purpose and if not detail the gaps in the analysis/ evidence
    - Discussion on whether the assumptions, conclusions and the final recommendations are reasonable and able to be relied on to inform land use planning.
    - Discussion on any limitations of the peer review.

The peer review will not require a new assessment.

Background

As part of the District Plan Review (DPR) project, Council engaged Ian R Brown Associates Ltd to carry out a subsidence risk assessment to ascertain whether the land within the study area was at risk of further ground subsidence as a result of the closure of the East Mine and resulting flooding of the mine workings.

The study area covers the land within the existing Huntly East Mine Subsidence Area identified in the Operative Waikato District Plan as well as an area of land to the north of East Mine Road (study area shown in Figure 1 of the subject report).

This assessment is required to establish the suitability of land for future urban development within the study area. The recommendations will be relied on to inform any changes to provisions for development within the existing Huntly East Mine Subsidence Area and any decision to rezone an area of rural land to the north of Russell Road through the DPR project.

The final report titled *'Report on hazards following mine closure, Huntly East'* dated October 2018 was received by Council on 19 October 2018.

Discussion

1. Regulatory oversight

Under the Health and Safety at Work Act (Mining Operations and Quarrying Operations) Regulations 2016, Solid Energy New Zealand Ltd (SENZ) was required to advise WorkSafe of its decision to close and seal the mine. It would be expected that WorkSafe would require to be advised on the sealing methodology. Whilst WorkSafe would not be expected to approve the SENZ process, WorkSafe was able to issue improvement notices to SENZ if it was not satisfied with the risk treatment. The report does not reference any correspondence between SENZ and WorkSafe.

It appears that the HMS Consultants Australia Pty Ltd (HMS) risk assessment focussed on the risk of fire and explosion due to the expected accumulation of methane and the potential for the coal to spontaneously combust during the sealing process. It is not apparent that the sealing risk assessment considered the potential for gas to be trapped and pressurised in areas of the mine or whether the flooding of the mine could result in increased subsidence in the South and North Sections of the mine. It is understood that SENZ considered this potential hazard but there is no documentation available.

2. Seal design and construction

The installed seals are rated seals, designed to be essentially airtight. Changes in barometric pressure make it practically impossible to eliminate the movement of air between the mine and the outside atmosphere, but the design and construction of the seals minimises this air movement to best ensure the maintenance of an inert atmosphere within the mine. The seals are also designed to contain an explosion should this occur. From our recollection the seals were designed by a chartered engineer based on failure mode analysis. The construction steps were documented and signed off by the mine officials responsible and concrete samples from each seal were tested for compressive strength.

It should be noted, that the quality of the seals does not prevent the likely leakage of gas through the strata to the surface from the shallow roadways. This leakage is undetectable in an operating mine because the flow rate is very low and the gas composition is essentially the same as fresh air. The nature and rate of leakage can be estimated by observing trends in mine pressure and comparing the in-situ gas composition with the sealed-off area composition (e.g. a rising CO_2 level in a sealed-off area that is well above the seam gas level may indicate fresh air leakage into the mine). It is recommended that the gas monitoring data and the pressure trends underground gathered over several months post-sealing be reviewed. It may be possible to extend the outlets of the monitoring tubes and continue to determine the gas composition and pressure from behind the seals.

During sealing the period of greatest risk is during the transition from an oxygen rich and low methane atmosphere to a low oxygen and methane rich air mixture. This is also the period of greatest risk of accelerated spontaneous combustion. It is understood that SENZ minimised the risk of spontaneous combustion by inertising the atmosphere by injecting nitrogen. The most recent sighted sampling and analysis of the atmosphere behind the seals since the mine was sealed shows the atmosphere remains fuel-rich inert. It can become explosive by the introduction of fresh air to raise the oxygen level and reduce the methane concentration to within the explosive range of 5% to 15%.

Installed within the seals are small diameter tubes fitted with shut-off valves outside the seal that allow the atmosphere behind the seals to be sampled. Mine seals are typically also fitted with U-tubes that allows the water level on both sides of the seals to be maintained in an equalised state, to avoid imposing high hydrostatic pressure on the seals. Since the seals were apparently designed to

withstand the maximum potential water head of the future lake, it is assumed that the water traps in the portal seals were forgone to prevent uncontrolled discharge of the mine gas due to lack of maintenance on water traps or accidental pipe damage and workers' exposure to gas inrush during the mechanical filling of the drifts. It is noted that the portal seals do not contain bleeding arrangements to allow high gas pressures or high hydrostatic pressure to be relieved.

The sampling tubes are understood to extend some tens of metres into the mine but nevertheless the gas mixture that is able to be sampled and analysed is only representative of the atmosphere immediately behind the seal. There will undoubtedly be variation in the atmospheric make-up in different parts of the mine especially where there are barriers that limit complete mixing. Should the tubes become blocked due to a build-up of condensation it may be possible for the tubes to be cleared using compressed nitrogen to purge the tubes.

3. Gas content in the sealed-off areas

The coal within East Mine has a low to moderate methane content, however the coal seams are thick providing a comparatively large gas reserve. The gas desorption rate declines over time as the gas content within the coal diminishes.

The sealed-off areas at East Mine have shown a general long-term trend of diminishing methane levels relative to the age of the old workings and the distance to the mine portal. Gas composition prior to the sealing and during the sealing process (November 2016 – July 2017) was well documented.

4. Gas migration to the surface

There is potential for gas to migrate from within the mine through fractures within the overlying strata, particularly in parts of the mine where the strata immediately above the coal seam has collapsed following pillar extraction. Parts of the mine were naturally wet due to connection between the coal seam and the overlying sub-surface aquifers. It is understood that the permeability between the coal seam and the overlying aquifers increased as a result of pillaring. It was observed while the mine was operating that the rate of water in-flow to parts of the mine increased following periods of rainfall indicating a degree of permeability between the coal seam and the surface. There is no reason to suppose that gas will not tend to migrate through these same permeable pathways.

There is no apparent record of gas being measured or detected on the surface above the mine workings.

It was probably outside the scope of the original report, but it is considered important to attempt further hazard mapping - quantification of the hazard of potentially trapped gas (gas pressure, Standard Temperature and Pressure (STP) quantity and trapped area as a function of progressive flooding) plus a revision of the Hazard Area marked in *Figure 5*, for the following reasons:

1. It is likely that gas has been trapped in North64/North 6 roads. These panels are directly adjacent to the western border of the Huntly Area of Interest (AOI).
2. Gas volume reduces with rising pressure (e g 10m of water column will halve the gas volume). It is likely therefore that the risk area will shrink with progressive flooding.
3. Gas does not need to only migrate vertically. It is recommended that delineated surface hazard area should extend beyond the assumed underground area of assumed gas entrapment.

Boreholes have presented a particular hazard allowing connection between the mine and the surface. It is understood that SENZ made some effort to seal these boreholes while the mine was operational to minimise the potential for these boreholes to allow fresh air to enter sealed areas and increase the risk of spontaneous combustion.

Given the likelihood that pathways exist between the mine voids and the surface, there is the potential for gas flows to increase should there be an increase in gas pressure within the mine.

5. Gas composition in the South Section goaf

It is reported that the gas content within the South Section was predominantly nitrogen with a very low methane level. It is not certain that the South Section void will remain separate and sealed off from other pillared areas (goafs) within the mine that contain high levels of methane. There is some likelihood that the gases from different parts of the mine will migrate and mix over the longer term.

Since the quality of the old South seals was not high, it can be expected that some methane migrated to the area directly after mine sealing. This process was expected to stop several weeks after sealing when rising water levels in the natural ponding area in the main roadways directly adjacent to the South roads cut off interconnection to the seals.

6. As-built drawings of the mine workings

It is expected that historic mine plans are available that show to a reasonable level of accuracy the location and dimensions of all roadways and pillars in the primary workings. The accuracy of dimensions of remnant pillars and the dimensions of goafs is less certain, and precautions need to be taken when attempting to calculate the likely subsidence resulting from the mining activity.

7. Water level within the mine

There is no readily available means to monitor the rising water level within the mine. Water will eventually be detected when the water level in the mine entries reaches the gas sampling tubes immediately in-bye the mine seals. It is suggested that the post-sealing reports on gas monitoring from the portal sampling tubes be obtained. These tubes are positioned at different locations and RL levels and they will become submerged at different times, which should allow for an estimation of the water level rise.

8. Effect of flooding on the remaining pillars

Following pillar extraction, a long-term stable condition will be achieved when the surrounding strata has failed and filled the roadway voids to an extent that the remaining pillars are confined and able to resist the imposed stresses. Surface subsidence is expected to decline following the long term stable conditions being achieved in the underground workings. It seems likely that flooding the mine will reduce the strength of some of the surrounding strata and that this will have the potential to cause further strata failure and weaken the coal floor to such an extent that the pillars will punch into the floor. Should this occur, there is the potential for further subsidence on the land surface. It is difficult to predict whether the hydrostatic load when the mine is completely flooded will have a significant positive effect in supporting the remaining standing pillars. It is therefore not apparent or certain that the mine will be more stable when flooded than in an unflooded state.

The latest subsidence monitoring results referred to in the Report are dated 2014. The gap in monitoring between 2014 and when the mine was sealed in 2017 makes it difficult to draw any conclusion on the impact of the sealing and flooding of the mine on surface subsidence. It is recommended that recent subsidence data be obtained and a programme of surface subsidence monitoring be initiated and maintained until the mine is proven to be flooded and stable.

9. Comments on Recommendations in Ian R Brown Associates' Report

i. *We expect that subsidence will continue above mine workings that have yet to be flooded as mine waters rise up dip towards the surface. It is very difficult to predict the amount of subsidence that could occur. In the worst-case scenario where there is widespread pillar collapse, there could be similar surface disruption to that experienced in the early 1980s.*

The flooding of the mine is a changed condition and it is uncertain whether this change will have a destabilising effect on the subsidence in the area concerned. There is the potential for the increased hydrostatic pressure to provide support to the remaining pillars and therefore reduce the potential for further or increased subsidence. There is also the potential for the parts of the strata to be weakened by the ingress of water. It is reasonable to conclude that there is on-going potential for subsidence to occur and that a monitoring programme is implemented to track the subsidence over a period of time to better understand the risk.

ii. *Once the mine workings are filled with water, then we expect there would be only minor continuing subsidence. We do not have a reliable estimate of how long it will take to fill the workings, and without any monitoring in place, it will not be possible to know when water has displaced all the gas.*

It is expected that post-flooding subsidence will decline. It is not possible to predict the time period over which this decline will occur without monitoring. In addition to monitoring the on-going subsidence it would be helpful to identify the means to determine when the mine workings are completely flooded. Drilling boreholes to intersect the goaf in the target area may be possible in addition to monitoring the water pressure behind the main seals.

iii. *The objective of suppressing spontaneous combustion as part of the mine abandonment appears to have been achieved, based on the recent gas analysis from samples taken at the mine portal. This has resulted in the unintended consequence of allowing the build-up of methane in well-defined traps as water level rises in the mine workings.*

It is not known whether there are existing leakage paths from all parts of the mine to the surface allowing for gas release. Each particular strata has a degree of permeability which allows for a flow relative to the differential pressure. With a build-up of water causing a rise in gas pressure the gas will migrate and/or adsorb which in turn will reduce the pressure and be displaced by the rising water level. It may be possible that a borehole(s) drilled from the surface to intersect the target void will allow the mine gases to safely escape as the water level rises. The HMS/SENZ risk assessment does not address the potential hazard of a build-up of methane in gas traps so it is not known whether this is an unintended consequence.

iv. *We have identified a potential hazard caused by migration of methane to the ground surface should it be trapped in a place that is exposed to an ignition source. There does not appear to be a risk of underground explosion given the methane content as has been measured at*

the mine portal is higher than the explosive limit, and the lack of an ignition source due to suppression of spontaneous combustion.

There does not appear to be a significant risk of spontaneous combustion or explosion. All reports are that the mine atmosphere is inert and there is no indication of an incipient heating. There remains the risk of methane escaping from the mine through poorly sealed boreholes and through breaks in the strata above the mine workings. The land above the target area is open to the public and various ignition sources are likely to be present. If methane does enter the outside atmosphere it will be readily diluted but the gas does have to pass through the explosive range. It is reasonable to assume that the gas quantities will be small, however this should be confirmed through the implementation of a monitoring programme. There is also a risk of irrespirable atmosphere, however, the likelihood of this occurring is low. There is the on-going risk of spontaneous combustion however this is also expected to be low. It is understood that there is no recent monitoring data available from inbye areas isolated from the atmosphere behind the seals, therefore it is not possible to determine whether leakages exist that potentially allow for oxygen access into low natural gas make areas. (These are areas in which the rate of gas produced from the coal is low).

v. *Both subsidence and gas hazards are present in all areas where underground workings have yet to fill with water. There are likely to be variations in the subsidence hazard due to changes in depth of mining and pillar geometry, however that is difficult to quantify with the information that is currently available.*

Agreed.

vi. *There are a few mitigation measures that could be carried out to minimise mine subsidence, and control gas build up. These could involve backfilling of mine workings from the surface, and drainage of gas using drill holes. The details of these operations are beyond the scope of this report.*

Partial back-filling of the mine may be technically feasible but would undoubtedly be expensive. There is the possibility that back-filling would lessen the scale and shorten the time of future subsidence but the gain may ultimately not be significant.

Positively draining gas from the mine to minimise the build-up of gas pressure that may present a fire and explosion risk may be an available risk mitigation control that warrants further consideration.

vii. *We have taken both subsidence and gas hazard into account with our definition of a proposed hazard area (Figure 5). This covers the areas of mine workings that have not filled with water, and the areas where we have shown the presence of a gas trap.*

This determination seems reasonable. Further work may be carried out to identify natural gas trapping points and pressure as a function of the flooding progress. If emission monitoring is attempted, it would assist in hazard mapping and potentially reduce the area of concern.

viii. *Should Waikato District Council decide to take a precautionary approach to land use in this area, then it would be appropriate to not allow development in this area until all the mine workings have flooded, or mitigation measures have been put in place. However, without appropriate monitoring, it will not be possible to know when that has been achieved.*

We understand that this report discharges our duty to inform the appropriate parties of hazards that might need to be considered as part of their ongoing health and safety obligations.

The flooding of the mine is a significant change that may compromise subsidence trends based on previous subsidence monitoring carried out by Solid Energy. It is not certain that subsidence will necessarily cease immediately upon the workings being flooded.

Recommendations

The following actions are recommended:

- Establish subsidence monitoring in the area using existing monitoring pegs if possible, to determine subsidence change after sealing/flooding commencement;
- Establish regular seal pressure monitoring;
- Extend (if possible) gas tube monitoring points at the seals (which are under the threat of surface flooding) to allow for inbye areas gas composition and pressure monitoring;
- Obtain records of post-sealing gas monitoring for trending and water level advance estimation;
- Continue gas monitoring the atmosphere behind the seals;
- Consider carrying out hazard mapping to determine the location and volume of gas traps and to estimate the gas pressure resulting from progressive flooding, based on the overburden strength and permeability. Plans of underground workings with roadway roof and floor RLs are necessary for determination;
- Investigate drilling boreholes to intersect gas traps to allow gas to be drawn off while maintaining an inert environment but minimising the hazard of high gas pressures; and,
- Implement a gas detection monitoring programme on the surface, especially during dropping barometric pressure periods.

Summary

- The Ian R Brown Associates' (IRBA) report highlights the potential risk of future subsidence, gas being trapped within the old mine workings and the possibility that gas will migrate.
- The IRBA report properly cautions the Waikato District Council to take a precautionary approach when considering future land use of the land above the mined-out areas of concern.
- The IRBA report highlights the current lack of sufficient knowledge to enable a definitive estimation to be made on when the risks of the identified hazards will fall to acceptable levels.
- The IRBA report raises the suggestion that further monitoring may be an available risk mitigation strategy to measure and track the flooding of the mine and subsidence trend.
- This peer review elaborates on the possible risk mitigation measures available and makes several recommendations.