IRBA

GEOLOGICAL ENGINEERING CONSULTANTS

Report on hazards following mine closure, Huntly East

October 2018

for
Waikato District Council

Project 1003

Level 2 • 204 Thorndon Quay • P.O. Box 983 • Wellington 6140 • New Zealand
Phone +64 4 565 1777 • www.irba.co.nz

Contents

1. Introduction

Ian R Brown Associates Ltd (IRBA) were engaged by Waikato District Council to provide advice regarding potential hazards in an area of Huntly that is located over underground mine workings. The extent of the area we have investigated is shown on Figure 1 labelled Huntly AOI – Subsidence Study.

The entrance to Huntly East underground coal mine was established in the highwall of the Kimihia open cast mine by State Coal Mines in 1977. The three main access drives for men and materials, ventilation and conveyor were driven in a westerly direction. Initial extraction of coal was to the south, then to the north of these tunnels. Later, mine development continued to the west and north of the Waikato River (Figure 2).

In 1982 coal extraction commenced in the part of the mine known as the South Headings. Soon afterwards subsidence effects became apparent and damage occurred to overlying structures and infrastructure. Mining ceased in this area in the mid 1980s, with extraction continuing in the area to the north of the mine access drives.

IRBA has been involved in studies of subsidence around the Huntly East area since 2008. Two reports have been prepared and should be referred to for more detailed information on the ground conditions that have led to subsidence (IRBA 2010 and IRBA 2015).

2. Historical subsidence

IRBA's earlier work included supervision of two surveys where bench marks that were established in 1981 were relevelled. For details refer to IRBA (2010) and IRBA (2015). The bench marks generally cover the area of the South Headings, however some of these are no longer available.

The area with greatest measured subsidence is to the south and east of the South Headings (Figure 3). This is where coal was closer to the ground surface, and small pillars were left supporting the workings. Maximum subsidence shown on Figure 3 is about 1 m.

Most of the subsidence occurred soon after mining progressed under the areas that were affected. Our recent survey data gives an indication of subsidence between 2009 and 2014. Although subsidence has continued the rate was low with a maximum of 0.013 m in the 2009 – 2014 period at two bench mark locations.

As part of the present study, we have searched for subsidence data over the extraction area to the north. The only reference we found was a report by Pilbrow (1988) where surface subsidence had been measured over Panel 1, on the eastern side of the workings, to the north of the main mine entry. Mine workings in this area were about 150 m below ground, and maximum subsidence measured was about 1 m. We have not been able to locate the data that were used in Pilbrow's analysis, so have not been able to verify the location of the survey bench marks.

Given the extraction plan and the size of pillars, subsidence of 1 m in this area would not be unusual. However, the mining took place under a rural area, and the only effect that might have been observed would have been disruption to surface drainage.

We have not been able to find any other useful information related to subsidence although we understand that bench marks were located above other parts of the northern mine workings.

3. Mine closure

In late 2015, Solid Energy New Zealand Ltd as operator of the Huntly East mine, announced that the mine would close with the asset being offered for sale as part of the liquidation of the company. Although some Solid Energy assets were purchased by mining companies, the Huntly East mine was not. As they could not sell the mine as a going concern, Solid Energy proceeded to abandon the mine. The last coal was produced in October 2015.

As part of planning for mine abandonment, Solid Energy engaged HMS Consultants Australia Pty Ltd (HMS) to facilitate a series of risk assessments to evaluate the final sealing and inertisation of the mine. Their recommendations for activities associated with mine sealing were reported to Solid Energy in March 2017 (HMS 2017).

The HMS report is mainly concerned with the potential for spontaneous combustion following mine closure, and the need to seal the workings from oxygen that would encourage spontaneous combustion. They did not consider the potential effects of mine flooding affecting pillar stability, or the effect of water infilling and trapping mine gases with subsequent pressure build up leading to migration of gas to the surface.

Subsequently each of the three entry drives were plugged with a concrete surface bulkhead at the portal with a seal 40 m further into the tunnels. A tube was placed through each of the three seals so that mine gases could be bled off and collected at the surface.

The seals are stated to be rated to 365 kPa and were designed to prevent leakage of oxygen into the mine. At the same time, they provide containment of mine gases so that pressure can build up as water flooding of the workings compresses the mine gas.

Following removal of the surface infrastructure at the mine portal area, the land was sold to a neighbour who is currently filling the old open pit mine with water to form a recreational lake. The current owner has undertaken to sample mine gasses on a regular basis. However, there may only be a few months before the lake will submerge the portals, and gas monitoring as presently undertaken will not be possible.

From what we can tell, there was minimal regulatory oversight of the mine closure. The work was outside of usual building consent processes; there were no producer statements provided. We have not been able to confirm whether the HMS recommendations were implemented, and there are no as built drawings showing the state of mine workings at closure.

4. Future subsidence

When mining ceased at the lowest part of Huntly East mine, pumps that had kept the workings drained were turned off. Over the period that the mine operated and expanded down dip to the west and north, groundwater was extracted from the main coal seam and surrounding rocks. Now that pumping has stopped, groundwater is able to progressively fill the voids left by mining.

Solid Energy estimated it would take 5 years to complete filling of mine workings. We have not sighted any documentation to show how this estimate was derived. It is not a simple calculation to estimate time to fill; it would involve some assumptions that are difficult to verify.

At the time of subsidence affecting the area above the Southern Headings, State Coal Mines engineers considered the effect of possible mine flooding. In 1983 P.J. McInally and D. Depledge independently reported on the potential for a reduction in bearing strength of up to 25% when the fireclay floor is flooded. They were concerned that "pillar punching could occur which would cause further surface subsidence". That is where the soft ground under the coal pillar is unable to support the load imposed by the pillar.

In March 2018 Solid Energy informed Waikato District Council that "the area (of the South Headings) was standing well, but access was limited due to the extensive flooding of the areas where bottom coal had been excavated". They also suggested that because many of the pillars are already partly flooded, then that would limit any effects of further flooding. However, they have not documented the timing or extent of partial flooding, expected to be due to water ponding behind roof falls, and in areas of local dip closure. It is not clear whether this might have contributed to the subsidence observed above the South Headings.

The present load carrying capacity of the pillars in the South Headings area is unknown, but given the past subsidence history of the area, we expect to see further subsidence as the mine voids are progressively flooded. This could be either due to pillar punching into the floor as State Coal Mines engineers suggested, or due to widespread pillar collapse as loads are redistributed following pillar punching.

Once the mine workings are filled with water, the hydrostatic pressures in the mine openings will assist pillar stability and limit the amount of future subsidence.

The area of mine workings to the north of the area under study have similar characteristics to the South Headings. However, the area of workings down dip from the main mine access drives has been flooded for some time and are not expected to cause further significant subsidence.

The area up dip and to the north east has been kept drained by pumping. Following from the discussion above, we would also expect there to be further subsidence in that area as the workings progressively flood. As with the South Headings, once all the northern workings are flooded, subsidence would be limited.

5. Gas trapping and migration

As coal is mined and dewatered, gas is expelled from the coal seam. The process of de-gasification is complicated, and the gas constituents and rate of emission can vary depending factors including geological structure, gas pressure gradient, and variations in coal composition.

During operation of the Huntly East mine, mine gases were controlled by the ventilation system which was designed to dilute hazardous gases to acceptable concentrations. At Huntly East, methane was released during mining, along with other gases such as carbon dioxide.

Solid Energy reported to Waikato District Council in a letter dated 14 March 2018 that methane levels in the South Headings were around 0.18%, with the atmosphere primarily nitrogen with small amounts of CO_2. The date of the gas observation is unknown but would appear to reflect the gas composition at a time when the mine ventilation system was still in operation.

As discussed, the mine abandonment planning was focused on limiting ingress of oxygen to the workings. This appears to have succeeded as the mine gas composition is now around 30% methane (Craig Smith pers. comm.) with little or no oxygen hence the objective of suppressing spontaneous combustion appears to have been achieved. However there has been a significant increase in methane since the mine ventilation was stopped and the workings sealed. This atmosphere is assumed to be homogeneous across the open workings in the upper part of the mine.

The effective sealing of the underground workings from oxygen ingress has allowed the gas pressure within the workings to increase and was confirmed when the valve at the portal was opened recently (Craig Smith, pers. comm.). This is due to continued flow of methane from the exposed coal, and the effect of compression of the mine atmosphere as water levels rise.

Gas build up in abandoned workings was discussed in a United Nations report (United Nations, 2016). They state: *When an underground coal mine ceases coal production, methane gas continues to flow into the underground workings through the process of desorption from residual coal within strata disturbed by mining activity. For gassy mines this desorption process may continue for many years after closure but at a rapidly declining rate and, where a mine is flooded, can resume when flooded mine workings are dewatered. The coal mine owner may therefore face potential long-term liabilities including explosion risks on the surface and possible dangers to the public as well as continuing greenhouse gas emissions.*

We have been able to map out areas of the mine workings where gas can be trapped (Figure 4). This is based on the methodology used to predict where natural gas (and oil) can be found due to the configuration of confining strata. In this case we have used the structural contours on the Kupakupa coal seam floor to show where areas of potential closure are located. In the area of the Southern Headings, once water has built up past the intersection with the main mine entries, the gas in those workings is effectively trapped. This is like a stratigraphic trap in conventional oil and gas.

Once gas is trapped, pressure build up will occur until the seal is breached and gas is able to migrate. We know from previous work that methane has very low solubility at the temperature and pressures we are working with (Christenson, 1999), so it will not be absorbed into the water flooding the workings.

There are two possible pathways for gas to move to a low pressure (atmospheric) area. One path is along drill holes that are located around Huntly East. These were mainly drilled before mining as part of resource definition studies. At the end of drilling, they were backfilled without providing an effective seal to the coal seam that they penetrated. HMS recommended that some of the drill holes should be sealed to prevent ingress of oxygen, however we have not been able to verify that this work was completed.

The second pathway for gas to migrate is through the ground overlying the mine workings. In places this will have dilated due to mining disturbance and subsidence, and complex pathways for gas to migrate to the surface will be present.

Generally, methane that reaches the ground surface will dissipate without causing any problems. If there is a trap above the area of discharge, then methane can accumulate. Should this occur, and methane concentrations are in the 5% to 15% explosive limit then combined with an ignition source, there is a potential for explosion. Unfortunately, this has happened in other countries where houses located above coal mines have inadvertently trapped methane.

6. Health and safety

During the period that the Huntly East underground mine was operating, matters of health and safety were under the control of Solid Energy New Zealand Ltd, with oversight from a specialist unit in WorkSafe New Zealand.

We have been informed by WorkSafe that as there is no longer an active mining operation, any health and safety matters that might arise from the abandoned mine workings are for the surface landowners and occupiers to manage.

7. Conclusions and recommendations

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.

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.

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.

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.

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.

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.

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.

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.

8. References

Christenson, B. 1999 Methane solubility in aqueous fluids with special reference to East Coast natural gas reservoirs, New Zealand. Institute of Geological & Nuclear Sciences client report 1999/89.

HMS Consultants Australia Pty Ltd 2017 Solid Energy New Zealand Limited Huntly East mine closure project mine sealing – Area 3 inertisation critical issues risk assessment. Unpublished report for Solid Energy New Zealand Ltd. 20pp and appendices.

Ian R Brown Associates Ltd 2010 Huntly East land subsidence due to coal mining: Review following levelling survey. Unpublished report for Waikato District Council. 14pp.

Ian R Brown Associates Ltd 2015 Huntly East land subsidence due to coal mining – investigation and analysis of potential hazard. Unpublished report for Waikato District Council. 22pp.

Pilbrow, R. 1988 Subsidence and its prediction at Huntly East Mine. Undergraduate project report, Department of Mining Engineering, University of Auckland. 47pp.

Tan, J.K. 1987 Geotechnical monitoring of Wongawilli extraction at Huntly East Colliery, Huntly, New Zealand. Unpublished State Coal Mines Technical Report. 99pp.

United Nations 2016 Best Practice Guidance for Effective Methane Drainage and Use in Coal Mines. United Nations ECE Energy Series No. 47 (second edition).

9. Applicability

This report has been prepared for the benefit of Waikato District Council with respect to the brief given to Ian R Brown Associates Ltd. It may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

Opinions and recommendations contained in this report have been derived from the information and data gathered during our investigations.

No liability is accepted by Ian R Brown Associates Ltd nor by any Director, or any other servant or agent of the company, in respect of the use of this report (or any information contained therein) by any person for any purpose other than that specified in the brief.

Figure 1. Location map

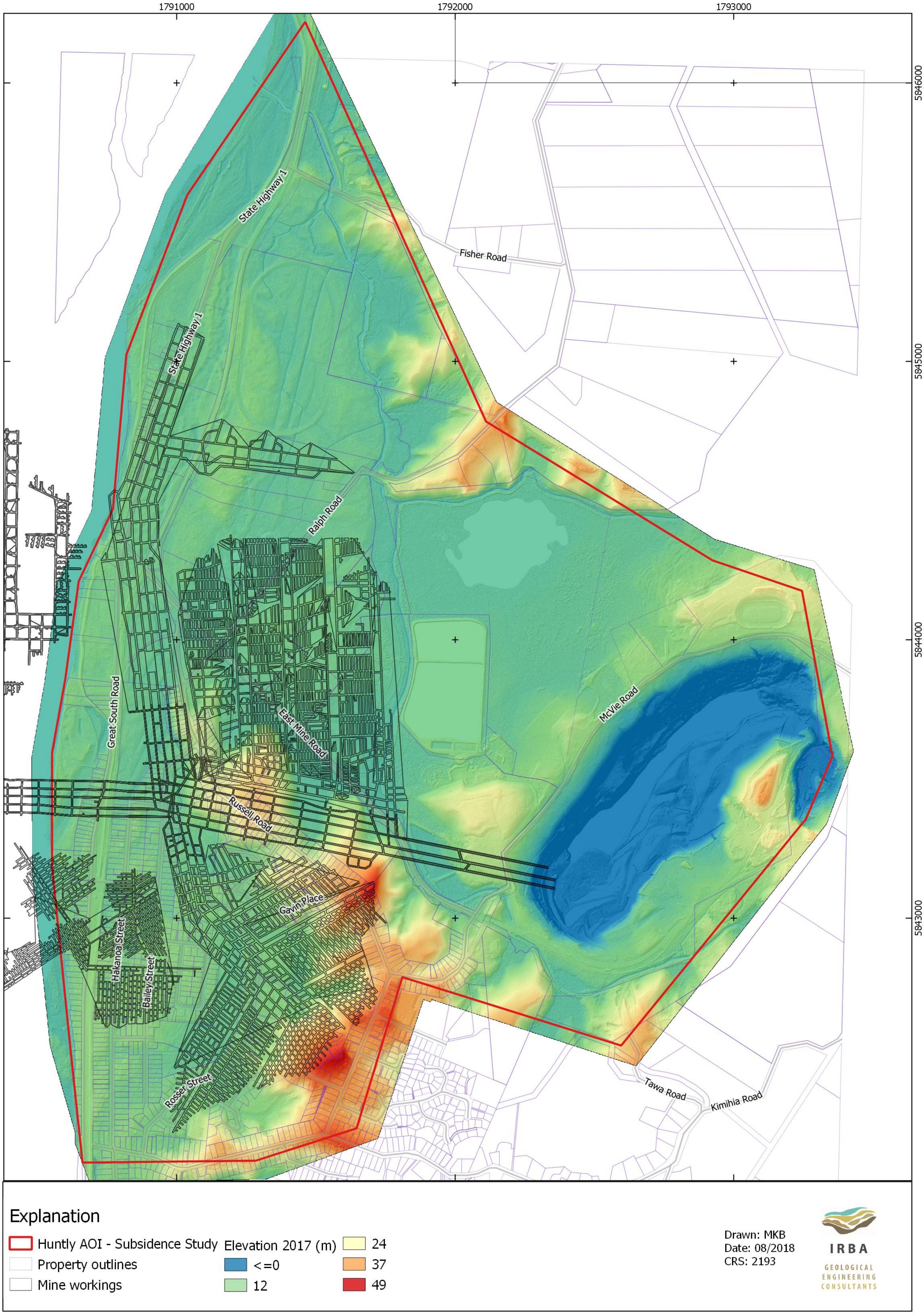

Figure 2 Topography and mine workings

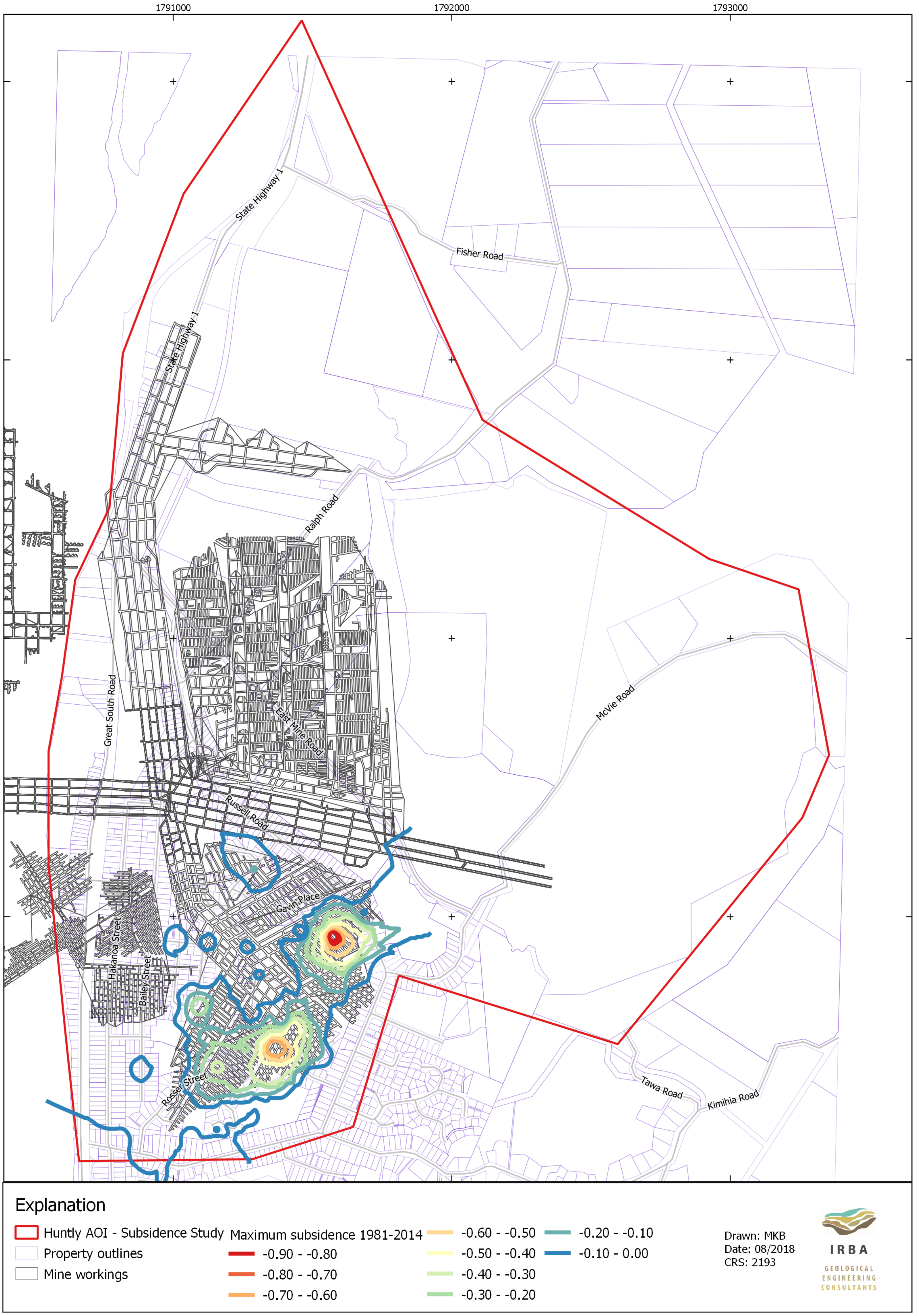

Figure 3 Maximum subsidence 1981 - 2014

Figure 4 Areas of potential gas trap

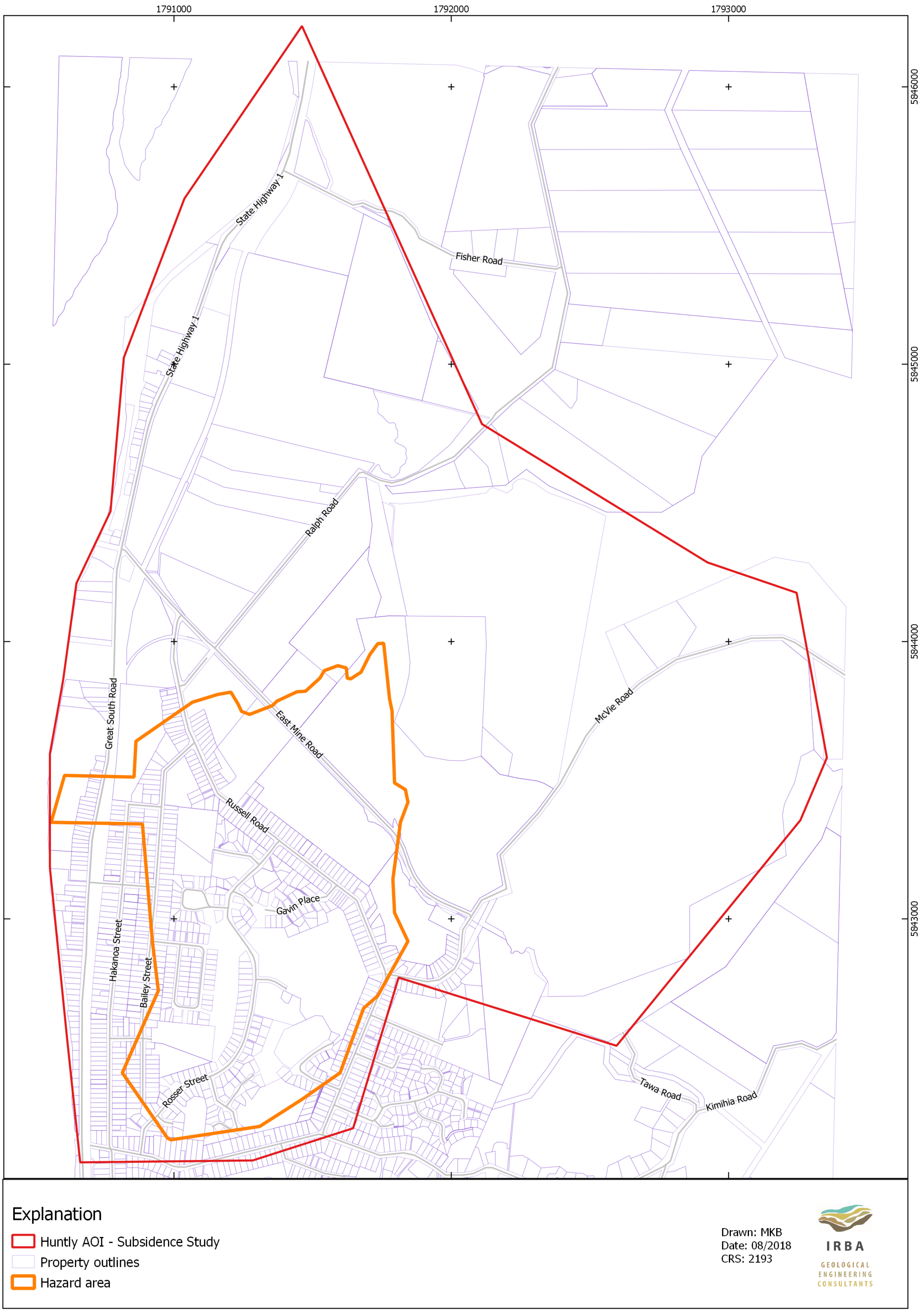

Figure 5 Proposed Hazard Area