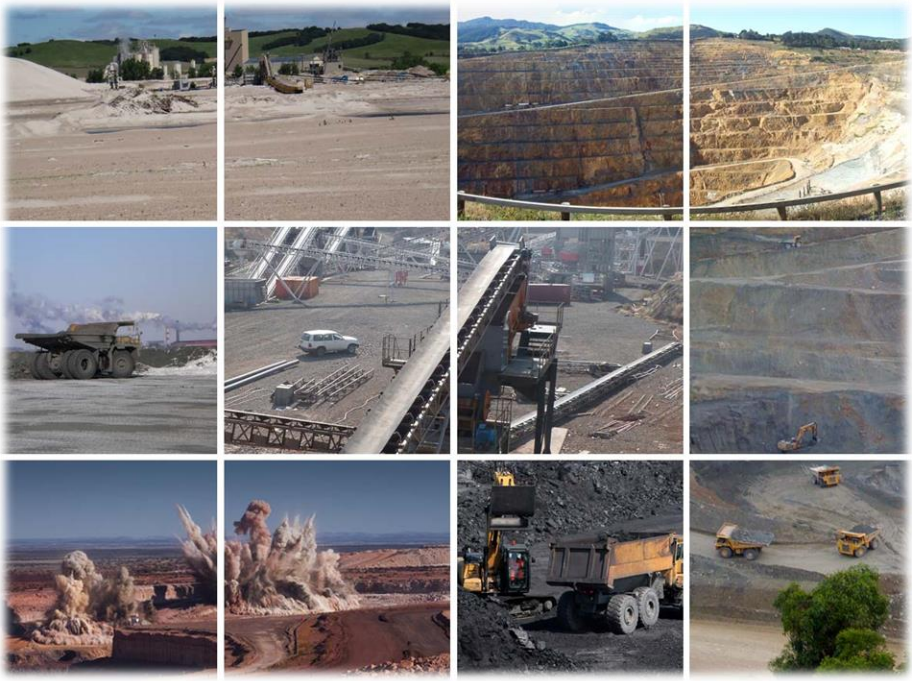
Vandabyte (Pty) LTD

BLASTING IMPACT ASSESSMENT

for the

Proposed Dunbar Coal Project west of Hendrina,

Mpumalanga Province



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EXECUTIVE SUMMARY

INTRODUCTION AND PURPOSE

Enviro-Acoustic Research (EARES) was contracted by Enviro-Insight CC to determine the potential impact due to blasting activities on the surrounding environment due to the proposed development of an opencast mine west of Hendrina, Mpumalanga. This report describes the potential blasting impacts that the operation may have on the surrounding built environment, highlighting the methods used, potential issues identified, findings and recommendations. This study considered local regulations and international guidelines.

PROJECT DESCRIPTION

INSA Coal Holdings (the Applicant) is the owner of a Mineral Right on a farm west of Hendrina, Mpumalanga. They propose to mine coal by means of conventional opencast methods to a depth of between 10 and 40 meters below surface (mbs). The project life of mine (LOM) schedule could be more than 10 years with a ROM production rate of up to 1.8 Mtpa during steady state. The mine will operate on a seven-day week with a 20-hour production shift per day.

BLASTING IMPACT FINDINGS

The potential impacts of ground vibration, air blast levels and fly rock risks were determined using methods provided by the USBM. A site specific blast design was not available and two blast designs were conceptualised based on information reported. This assessment indicated that:

- That ground vibration levels may be disturbing when blasting take place within 850m from residential houses (the unmitigated scenario for a 437 kg charge per delay). The impact may be of high significance and mitigation is available and proposed that will reduce the vibration levels to less than 2.54 mm/s within 1,000 m from the blast;
- That ground vibration levels may pose a risk of damage to building and structures in the direct vicinity of the mining area. The impact may be of high significance and mitigation is available and proposed that will reduce the vibration levels to less than the proposed vibration limit;
- Air blast levels, while clearly audible to surrounding receptors, will be less than 120 dB at the surrounding residential dwellings;
- There are no risks of fly rock to people or residential structures, but blasting close to the mine infrastructure may result in fly rock damage and the rock fragments may pose a risk to road users. Management measures are available to ensure the risks are minimised.

PROPOSED MITIGATION

Mitigation is available that can and will reduce the potential magnitude of vibration and air blast levels and the significance of this impact. While the risks from blasting impacts are manageable, people are always concerned about the potential effects and dangers of blasting and measures are recommended for the applicant to note. The mitigation include technical as well as management measures:

- The Blasting Impact Assessment report must be updated if the blast design is changed where more than 500 kg explosives are detonated per delay.
- Mine to reduce the charge per delay (less than 437 kg) to ensure that maximum ground vibration levels are less than 2.54 mm/s when blasting has to take place within 850m from residential houses.
- Mine should initiate a forum to inform the close residents about the likely vibration and air blast levels, the proposed blasting schedule and warning methodology the mine will employ before a blast. When the residents are inside the house during a blast, vibration of windows and ceilings may appear excessive.
- Mine to erect blasting notice boards in the area with blasting dates and times highlighted.
- Mine to prevent blasting in adverse meteorological conditions where possible (overcast conditions, strong wind blowing in direction of local community, early in the mornings or late in the afternoon).
- People and livestock to be moved further than 500 m from active blast before a blast is detonated;
- Any evidence of fly rock further than 250 m from a blast is noted and the blast be analysed for possible improvements;
- Blaster to keep full records of blast (blast design, timing, explosive mass per blast hole, stemming, subdrill, spacing, burden, etc.).

CONCLUSIONS AND RECOMMENDATIONS

The mine must know that community involvement needs to continue throughout the project. This is especially true for opencast mining projects close to residential dwellings. Blasting related impacts are likely to upset the community and complaints will be one of the tools that the community may use to express their annoyance with the project, rather than a rational reaction to the vibration or air blast level itself.

At all stages surrounding receptors should be informed about the project, providing them with factual information without setting unrealistic expectations. Even with the best measures, blasting related impacts will be perceived and the community members may complain. It is therefore in the best interest of the mine to continually monitor and manage the blast in an effort to improve and minimise potential blasting effects. It is highly recommended that the mine conduct a detailed photographic survey at brick and cement residential houses (that does not belong to the applicant) located within 2,000m from the mine (from the opencast boundary limit) before the construction phase start. This should include a survey of all water boreholes to determine the status of each borehole.

CONCLUSION

It is concluded that, if the mine considers the recommendations in this report (incorporated in the Environmental Management Plan), that blasting risks do not constitute a fatal flaw. It is, therefore, the recommendation that the Dunbar Coal Project be authorized (from a blasting impact perspective) subject to compliance with the conditions of the EMP.

CONTENTS OF THE SPECIALIST REPORT – CHECKLIST

Contents of this report in terms of Regulation GNR 982 of 2014, Appendix 6 (as amended 2017)		Relevant Section of Specialist study
(1)	A specialist report prepared in terms of these Regulations must contain-	
	details of-	
	(i) the specialist who prepared the report; and	Section 1
	(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Section 1
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	Section 2
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 3.1
(cA)	an indication of the quality and age of base data used for the specialist report;	Section 3.3
(cB)	a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 3.3
(d)	the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 3.3
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Section 3.4
(f)	details of an assessment of the specifically identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	Sections 3.2.2
(g)	an identification of any areas to be avoided, including buffers;	Sections 3.2.2 and 8
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Sections 3.2.2 and 8
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 7
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity or activities;	Sections 8 and 9
(k)	any mitigation measures for inclusion in the EMPr;	Sections 10.1
(l)	any conditions for inclusion in the environmental authorisation;	Sections 10.1
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Sections 8 and 10.1
	a reasoned opinion -	Section 11
	whether the proposed activity, activities or portions thereof should be authorised;	Section 11
	regarding the acceptability of the proposed activity or activities; and	Section 11
	if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Sections 10.1
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	No comments received

Contents of this report in terms of Regulation GNR 982 of 2014, Appendix 6 (as amended 2017)		**Relevant Section of Specialist study**
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	No comments received
(q)	any other information requested by the competent authority.	No comments received

This report should be cited as:

De Jager, M. (2019): "*Blasting Impact Assessment for the Proposed Dunbar Coal Project West of Hendrina, Mpumalanga Province*". Enviro-Acoustic Research CC, Pretoria

Client:

Enviro-Insight	862 Wapadrand Road
on behalf of	Wapadrand Security Village
INSA Coal Holdings	Pretoria

Report no:

EI-ICHD/BIA/201909-Rev 0

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Date:

September 2019

TABLE OF CONTENTS

page

LIST OF TABLES

page

LIST OF FIGURES

APPENDICES

Appendix A	Glossary of terms and definitions
Appendix B	Ground vibration and Effects

GLOSSARY OF ABBREVIATIONS

EIA	Environmental Impact Assessment
EHS	Environmental, Health, and Safety
IAP	Interested and Affected Party
LOM	Life of Mine
mbs	Meter below surface
MWP	Mine Works Program
PSS	Potential Sensitive Structure
PPV	Peak particle velocity
USBM	United States Bureau of Mines

GLOSSARY OF UNITS

dB	Decibel (expression of the relative loudness of the un-weighted sound level in air)
dBA	Decibel (expression of the relative loudness of the A-weighted sound level in air)
Bcm	Bank cubic meters (of in-situ rock)
Hz	Hertz (measurement of frequency)
kg/m^2	Surface density (measurement of surface density)
km	kilometre (measurement of distance)
m	Meter (measurement of distance)
m^2	Square meter (measurement of area)
m^3	Cubic meter (measurement of volume)
mamsl	Meters above mean sea level
m/s	Meter per second (measurement for velocity)
Mtpa	Million tons per anum
mm/s	Millimetres per second (representing PPV)
µPa	Micro pascal (measurement of pressure – in air in this document)

1 THE AUTHOR

The Author started his career in the mining industry as a bursar Learner Official (JCI, Randfontein), working in the mining industry, doing various mining-related courses (Mining [stoping and development], Rock Mechanics, Surveying, Sampling, Safety and Health [Ventilation, noise, illumination etc.] and Metallurgy. He did work in both underground (Coal, Gold and Platinum) as well as opencast (Coal) for 4 years, the last two during which he studied Mining Engineering. He used to be a holder of a temporary blasting certificate during the period he mined at JCI: Cook 2 shaft. He changed course from Mining Engineering to Chemical Engineering after the second year of his studies at the University of Pretoria.

After graduation he worked as a Water Pollution Control Officer at the Department of Water Affairs and Forestry for two years (first year seconded from Wates, Meiring and Barnard), where duties included the perusal (evaluation, commenting and recommendation) of various regulatory required documents (such as EMPR's, Water Licence Applications and EIA's), auditing of licence conditions as well as the compilation of Technical Documents.

Since leaving the Department of Water Affairs, Morné has been in private consulting for the last 20 years, managing various projects for the mining and industrial sector, private developers, business, other environmental consulting firms as well as the Department of Water Affairs. During that period he has been involved in various projects, either as specialist, consultant, trainer or project manager, successfully completing these projects within budget and timeframe. During that period he gradually moved towards environmental acoustics, focusing on this field exclusively since 2007.

He has been interested in acoustics as from school days, doing projects mainly related to loudspeaker design. Interest in the matter brought him into the field of Environmental Noise Measurement, Prediction and Control that ultimately resulted in the addition of blasting impact assessments to services supplied.

2 DECLARATION OF INDEPENDENCE

I, Morné de Jager declare that:

- I act as the independent specialist on this project
- I will perform the work relating to this specialist study in an objective manner, even if this results in views and findings that are not favourable to the applicant
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting environmental impact assessments, including knowledge of the National Environmental Management Act (107 of 1998), the Environmental Impact Assessment Regulations of 2014, and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing this project;
- all the particulars furnished by me in this form are true and correct;
- will perform all other obligations as expected from an environmental assessment practitioner in terms of the Regulations; and
- I realise that a false declaration is an offence in terms of regulation 71 and is punishable in terms of section 24F of the Act.

Disclosure of Vested Interest

- I do not have and will not have any vested interest (either business, financial, personal or other) in the proposed activity proceeding other than remuneration for work performed in terms of the Environmental Impact Assessment Regulations, 2014.

____

Signature of the environmental practitioner:

Name of company:

Enviro-Acoustic Research cc

Date:

<u>2019 – 10 - 08</u>

3 INTRODUCTION

3.1 INTRODUCTION AND PURPOSE

Enviro-Acoustic Research (EARES) was contracted by Enviro-Insight CC (Enviro-Insight in this report) to determine the potential impact due to blasting activities on the surrounding environment due to the proposed development of an opencast mine. This operation will be located just west of the town of Hendrina in the Mpumalanga Province.

This report describes the potential blasting impacts that the operation may have on the surrounding built environment, highlighting the methods used, potential issues identified, findings and recommendations. This study considered local regulations and international guidelines.

3.2 BRIEF PROJECT DESCRIPTION

3.2.1 Overview of the Project

Vandabyte (Pty) Ltd (the Applicant) is applying for a Mineral Right on a farm west of Hendrina, Mpumalanga. They propose to mine coal by means of conventional opencast methods to a depth of between 10 and 40 meters below surface (mbs).

The project life of mine (LOM) schedule could be more than 5 years with a ROM production rate of up to 1.8 Mtpa during steady state. The mine will operate on a seven-day week with a 20-hour production shift per day.

This assessment will consider the requirement will have to drill, blast and haul approximately 100 Mbcm of hard overburden in 10 m benches.

3.2.2 Study area and Potential Sensitive Structures

Figure 3-1 illustrates the representative Potential Sensitive Structures (PSS) or Blast Sensitive Receptors (BSR) located within 2,000m that may be affected by blasting activities, with **Figure 3-2** depicting a number of structures (including pylons, buildings and structures, cement dams, roads and railroads, etc.) located within 500m. The following should be noted:

- Area within the 500 m buffer from opencast limits: Area around the mine pit where people and animals will be moved prior to blasting may take place (buffer indicates area during some future stage of mining). Ground vibration and air blast levels likely to be significant with a high risk of fly-rock closer to the blast area (see also **Figure 3-1** where structures located within 500m from future locations where blasting may take place are indicated).
- Area 500 to 2,000 m from opencast limits (see also **Figure 3-1**): Area outside the zone where fly rock may be a concern, but:

  - noise from the airblast will be very high;
  - in the unmanaged situation ground vibration and air blast levels could be of a significant concern.
  - in a managed situation ground vibration and air blast levels may be insufficient to result in structural damage to most structures but vibration and air blast levels will be sufficiently high to create annoyance with the blasting and project.
- Area further than 2000 m from opencast limits:
  - Noise from the airblast could be high and will be clearly audible;
  - In the unmanaged situation ground vibration and air blast levels could result in concerns and potential complaints;
  - In a managed situation ground vibration and air blast levels will be low and unlikely to result in concerns and complaints.

Further than 2,000m there is a low possibility of any structural damage in the managed situation. People however may still be concerned about blasting due to the secondary effects of blasting (such as the resonance from flat surfaces potentially perceived as vibration) as well as the perceived risks and dangers. It should be noted that there is no agreed distance where people may not experience annoyance with the blasting activity, whether audible, detectable or due to a ground vibration.

3.2.2.1 Roads

The paved P622 pass the site approximately 1,300m to the south-east from the opencast area (see also **Figure 3-1**).

3.2.2.2 Railway lines

There is a railway line approximately 600m directly west of the opencast area (see also **Figure 3-1**).

3.2.2.3 Power Pylons and lines

There is a power line running south-east to north-west 280m north of the opencast pit, with two other lines running further than 500m from the mining area. Not indicated (though considered) on **Figure 3-1** are telephone poles and smaller power lines within 2,000m from the mining area, including power pylons servicing the trains.

3.2.2.4 Structures

There are a number of metal and cement structures located close to the proposed opencast pits (see also **Figure 3-1**). The statuses of these structures are unknown and were not investigated. These structures include:

- A number of permanent brick buildings and sensitive structures constructed out of corrugated iron;
- Some cement dams and boreholes;
- A number of ventilation fans.

3.3 CURRENT IMPACTS

The site is located in an area with a significant mining character. There are a number of opencast mines in the area and people may have been exposed to instances of vibration and air blasts due to blasting in the area.

3.4 TERMS OF REFERENCE

Unfortunately there are no guidelines, standards or legislation in South Africa that specifically covers vibration from blasting activities, air blast levels and fly rock control and this report is based on available literature used in other countries, specifically the standards and guidelines developed by the United States Bureau of Mines (USBM).

Ground vibration is associated with various different activities, including amongst others from heavy equipment operating, traffic movement, tunnelling, underground blasting etc. These vibrations however are minor when compared to blasting associated with opencast mining activities. This study therefore specifically would assess the potential blasting impacts from opencast mining activities.

A blasting impact assessment is done to estimate the potential risk that blasting activities may pose to receptors staying in the vicinity of the operation as well as infrastructure located within the potential zone of impact. This assessment investigates the potential magnitude of ground vibration, air blast sound pressure levels as well as the potential zone of influence from fly rock due to blasting activities.

The potential magnitude of blasting related impacts (ground vibration, air overpressure and fly rock dangers) is calculated in a scientific manner, using that information to rate the potential significance of these dangers and provide mitigation and management measures if a potential medium or high significance risk is identified. The mitigation measures should be sufficient to reduce the potential risk to a low significance.

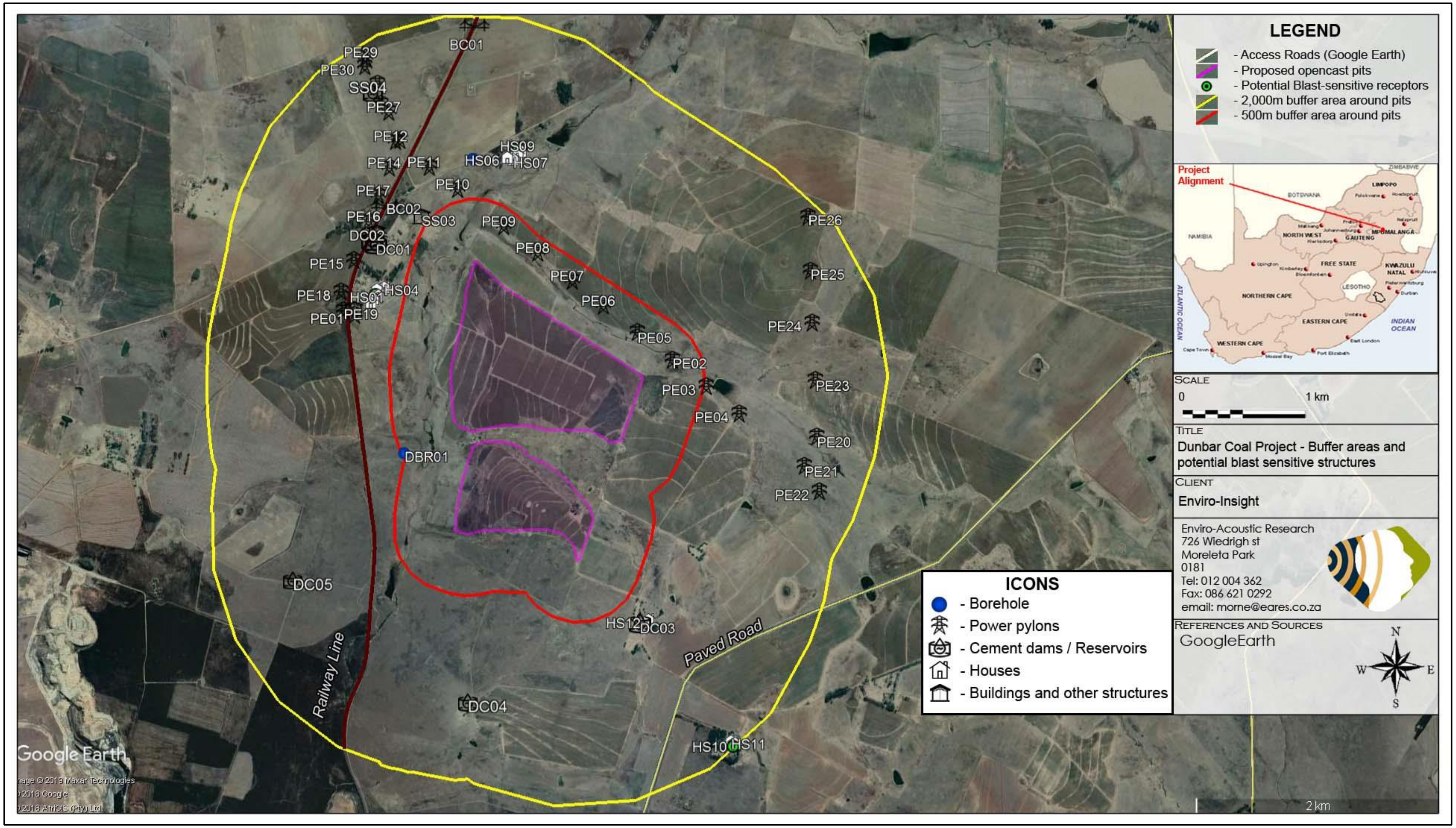


Figure 3-1: Aerial image indicating potential PSS and receptors within 2,000m of potential blasting area

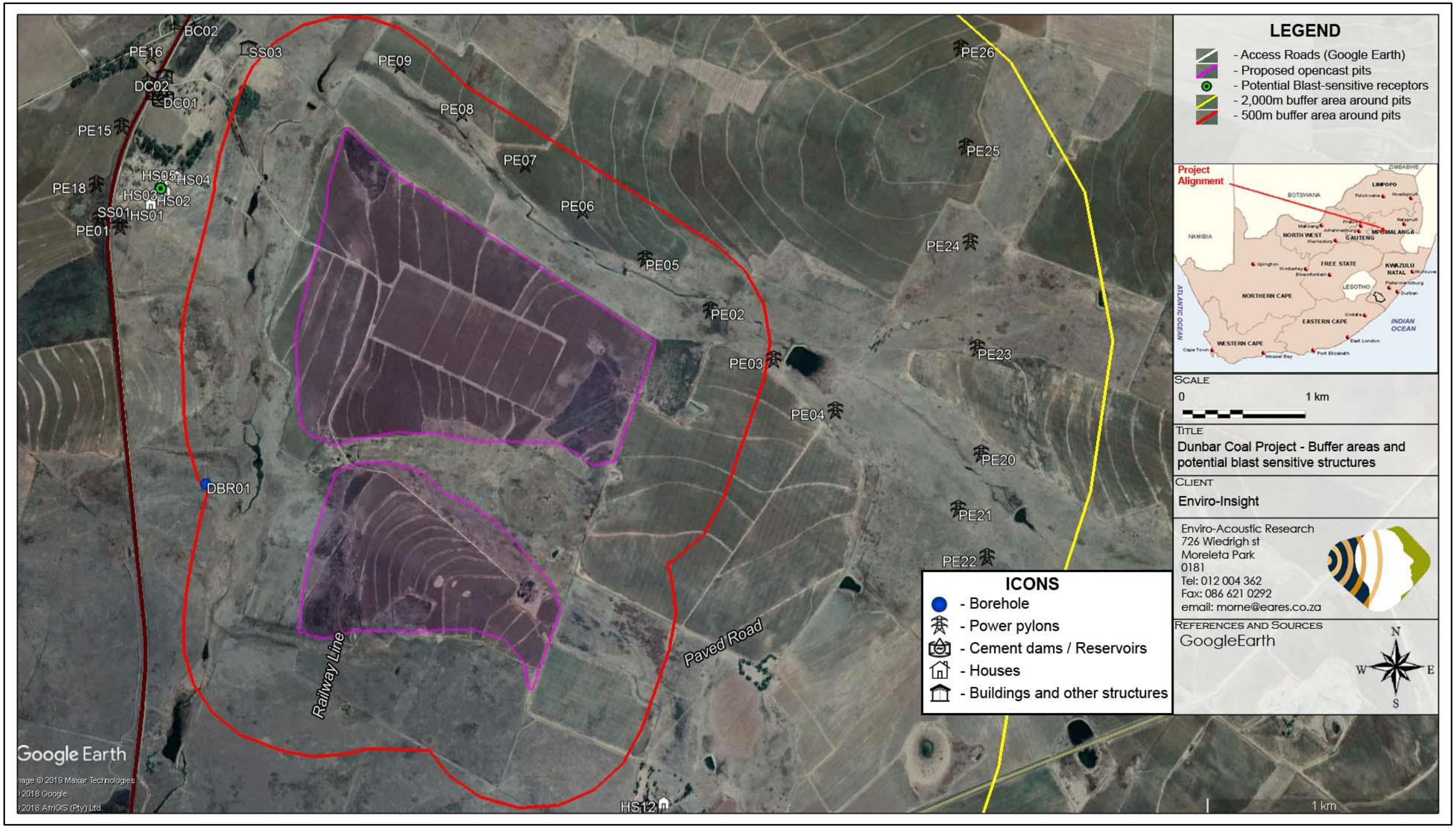


Figure 3-2: Aerial image indicating PSS close to the proposed project area

4 LEGAL CONTEXT, POLICIES AND GUIDELINES

4.1 MINERAL AND PETROLEUM RESOURCES ACT, 2002 (ACT 28 OF 2002)

This Act governs the acquisition, use and disposal of mineral rights. It however does refer the management and control of blasting, vibration and shock to the Mine Health and Safety Act (Act 29 of 1996), as well as other applicable law in section 67. It stipulates that impacts relating to blasting, vibration and shocks be assessed and form part of the environmental management and authorization reports.

4.2 MINE HEALTH AND SAFETY ACT NO. 29 OF 1996 (AS AMENDED, ACT 74 OF 2008)

The Mine Health and Safety Act was established to assist the Department of Mineral Resources to safeguard the health and safety of mine employees and communities affected by mining operations.

Regulations (Government Notice R.584 of 2015) were made in terms of Section 98 of this Act (Act 29 of 1998) covering the safe use of Explosives on a mine.

This Act and associated regulations does not stipulate limits for ground vibration and air blast levels, nor limit the distances that fly rock travel. GNR.584 of 2015 does limit blasting within 500m from certain structures unless various conditions are met.

It does state:

Precautionary measures before initiating explosive charges

Clause 4.7. The employer must take reasonable measures to ensure that when blasting takes place, air and ground vibrations, shock waves and fly material are limited to such an extent and at such a distance from any building, public thoroughfare, railway, power line or any place where persons congregate to ensure that there is no significant risk to the health or safety of persons.

General precautions

Clause 4.16. The employer must take reasonable measures to ensure that:

(1) in any mine other than a coal mine, no explosive charges are initiated during the shift unless –
   (a) such explosive charges are necessary for the purpose of secondary blasting or reinitiating the misfired holes in development faces;
   (b) written permission for such initiation has been granted by a person authorised to do so by the employer; and
   (c) reasonable precautions have been taken to prevent, as far as possible, any person from being exposed to smoke or fumes from such initiation of explosive charges;

(2) no blasting operations are carried out within a horizontal distance of 500 metres of any public building, public thoroughfare, railway line, power line, any place where people congregate or

any other structure, which it may be necessary to protect in order to prevent any significant risk, unless:

(a) a risk assessment has identified a lesser safe distance and any restrictions and conditions to be complied with;

(b) a copy of the risk assessment, restrictions and conditions contemplated, in paragraph (a) have been provided for approval to the Principal Inspector of Mines;

(c) shot holes written permission has been granted by the Principal Inspector of Mines; and

(d) any restrictions and conditions determined by the Principal inspector of Mines are complied with.

4.3 EXPLOSIVES ACT (AS AMENDED, NO. 15 OF 2003)

The Explosive Act manage the manufacture, importation, exportation, transportation, distribution, destruction, storage and any other use of explosives. The regulations define the requirements for the person that manages blasting activities, including the safe use of explosives. This Act and associated regulations does not stipulate limits for ground vibration and air blast levels, nor for limiting the distances that fly rock travel.

4.4 OCCUPATIONAL HEALTH AND SAFETY ACT (ACT 85 OF 1993)

The Occupational Health and Safety Act aims to provide for the health and safety of persons at work and for the health and safety of persons in connection with the activities of persons at work and to establish an advisory council for occupational health and safety.

The Occupational Health and Safety Act are supported by subordinate legislation, Regulations and Codes of Practice, which give practical guidelines on how to manage health and safety issues. The health and safety standards for employers and users of explosives at the workplace are covered in the Explosives Regulation promulgated under this Act. This Act and associated regulations does not stipulate limits for ground vibration and air blast levels, nor can limiting the distances that fly rock travel.

4.5 INTERNATIONAL FINANCE CORPORATION GUIDELINES

4.5.1 IFC: Environmental, Health and Safety Guidelines - Mining

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry specific examples of Good International Industry Practice (GIIP). When one or more members of the World Bank Group are involved in a project, the EHS Guidelines are applied as required by their respective policies and standards.

The guideline provides a summary of EHS issues associated with mining activities (and including ore processing facilities) which may occur during the exploration, development and construction, operation, closure and decommissioning, and post-closure phases, along with recommendations for their management.

It identifies potential environmental issues associated with mining activities, including noise and vibrations that may require management.

4.5.2 IFC: Environmental, Health and Safety Guidelines – General EHS Guidelines: Occupational Health and Safety

The guideline obliges Employers and supervisors to implement all reasonable precautions to protect the health and safety of workers. It provides guidance and examples of reasonable precautions to implement in managing principal risks to occupational health and safety.

5 BLASTING RELATED IMPACTS – THEORY AND CALCULATION

5.1 GROUND VIBRATION: THEORY AND CALCULATION

When an explosive charge is detonated in rock, the charge is converted into hot gases that generate intense pressure over a very short time period. This pressure will melt and crush the rock directly around the blast hole to a certain point. Radial cracks will develop until the rock loses its inelastic properties. The lengths of these cracks are usually determined by the rock properties, explosive properties and the blast design. Broken rock will move upwards and outwards with the level of movement depending on the type and quantity of explosive as well as blast design. The initial shock front causes waves similar to sound waves on the surface and within the body of the earth. Body waves may be reflected or refracted to the surface to become surface waves. These different waves can be further classified but this is beyond the purpose of this assessment.

Compressional and shear body waves propagate spherically from the blast and can be described in three dimensions, namely up-down (“vertical”), back-forth (“longitudinal”) and side-to-side (“transverse”). These differences are also important from the damage standpoint; vibrations in the transverse and longitudinal (sometimes referred as “radial”) directions cause potentially damaging “shear” (differing directions or speeds of movement) within structures. Vertical movement is usually less damaging, though not entirely without consequence, because structures are built to withstand vertical forces.

The vibrational waves can be measured using a seismograph and described in terms of displacement, velocity, acceleration as well as the frequency components of these complex waves.

It is also possible to estimate, with a level of confidence, the peak amplitude level of the ground vibration wave. There is an inverse square relationship from the blast as the vibrational energy spread in a spherical manner from the source. While there are a number of empirical formula (Kumar, 2016) that can be used to calculate the magnitude of the vibration, this report use the square root scaled distance method as developed by the United States Bureau of Mines (Rosenthal, 1987; RI 8507). This formula considers the three most important factors in the magnitude of vibration, namely:

- the distance from the blast – this is the most significant factor to determine the magnitude of the vibration level;
- the magnitude of the blast, defined by the instantaneous explosive mass (also referred as charge per delay) as the source of vibration energy;
- the geology of the site. This is represented by constants that can be experimentally determined for a specific site with vibration measurements.

$$\boldsymbol{v} = \boldsymbol{k}\left(\frac{\boldsymbol{D}}{\sqrt{\boldsymbol{Q}}}\right)^{\boldsymbol{e}}$$ **Equation 1**

Where:

v = peak vibration (PPV) (mm/s)

D = distance from blast (m)

Q = instantaneous charge mass (kg)

k = site constant (initially assumed and can be experimentally determined)

e = site constant (initially assumed and can be experimentally determined)

The site constant ‘k’ has been determined for different locations and are available in literature, although onsite measurements will allow the more accurate determination of this constant. Firing to a free face, in hard or highly structured rock this constant could be:

- Mines or quarries: k = 500,
- For a free face in average conditions: k = 1143 (which this assessment will use),
- For heavily confined blasting, near field: k = 5000.

Typical values of constant ‘e’ for different rock types are:

- Rhyodacite/Rhyolite: e = 2.2 – 2.5,
- Granite: e = 2.1 – 2.4,
- Limestone: e = 2.1,
- Ordovican sediments: e = 2.8,
- **Coal mine overburden: e = 1.5 – 1.8 (this assessment will use 1.65)**,
- Basalt (clay floor): e = 1.5 – 1.6,
- Basalt (massive): e = 1.9 – 3.0.

5.2 AIR BLAST: THEORY AND CALCULATION

The term air blast (also known as air overpressure) is used to describe air vibrations generated by blasting activities. Although not quite impossible, it is quite unusual for blasting activities to create air waves that will reach potential damaging level to buildings. If this occurs the evidence is present and clearly identifiable in the form of shattered or broken windows.

Although this phenomenon might be rare, much interest is attracted to air waves when they generate sound. The sound is what normally causes an alarm to receptors especially if they are unaware of such activities. The air wave carries acoustic energy from less than 1 Hz to the ultrasound range, although most of this energy is concentrated in the lower frequency range. Acoustic energy below 20Hz is referred to as air blast and above 20Hz (the audible range) as noise. When in the audible range it can be extremely annoying to receptors.

As with ground vibration calculations, the calculation of air blast levels are based on empirical formulas, also developed by the USBM.

$$L_{USBM} = 165 - 24.\log\left(\frac{D}{\sqrt[3]{Q}}\right)$$ **Equation 2**

Where:

L_{USBM} = Noise levels due to air blast (dB) as per the USBM method

D = distance from blast (m)

Q = instantaneous charge mass (kg)

An alternative method is employed by the Australian Department of Mines (and Petroleum), defined in Australian Standard AS 2187.2 presented in in **Equation 3** below:

$$P = K\left(\frac{D}{\sqrt[3]{Q}}\right)^{a}$$ **Equation 3**

and

$$L_{AS} = 10\log\left(\frac{P}{P_0}\right)$$ **Equation 4**

Where:

L_{AB} = Noise levels due to air blast (dB) as per the Australian Department of Mines method

D = distance from blast (m)

Q = instantaneous charge mass (kg)

K = a site constant in the region of 1 – 10,000 (using 5,000 initially)

a = a site constant in the region of -1 to -2 (using -1.45 initially)

The Australian Department of Mines method can be employed when data (noise levels) from a number of blasts are available and the site specific constants can be calculated.

5.3 FLY ROCK: THEORY AND CALCULATION

The main purpose of blasting is the fragmentation of the rock mass, with secondary purpose (at times) of moving as much as possible of the rock mass to minimise additional ground movement using trucks, draglines or other heavy equipment from the blast area. Unfortunately, a portion of the explosive energy is lost due to the generation of blast rock that may result in face bursting, cratering and rifling. This is depicted in **Figure 5-1**.

Fly rock is generally perceived as the rock propelled beyond the blast area. IME (1997) has defined fly rock as the rock(s) propelled from the blast area by the force of an explosion. Generally, fly rock is caused by a mismatch of the explosive energy with the geo-mechanical strength of the rock mass surrounding the explosive charge. Factors responsible for this mismatch include:

- Abrupt decrease in rock resistance due to joint systems, bedding layers, fracture planes, geological faults, mud seams, voids, localized weakness of rock mass, etc.
- High explosive concentration leading to localized high energy density,

- Inadequate delay between the holes in the same row or between the rows,
- Inappropriate blast design,
- Deviation of blast holes from its intended directions,
- Improper loading and firing practice, including secondary blasting of boulders and toe holes.

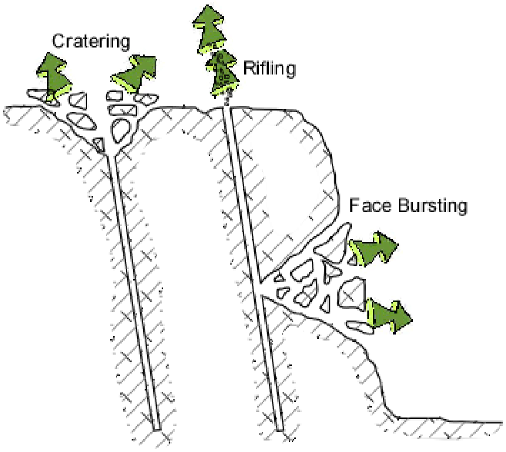


Figure 5-1: Illustration of sources of fly rock

The potential throw distances of fly rock can be estimated using tables or empirical formulas highlighted below:

$$\textbf{\textit{Face bursting}}\quad D_{FB} = \frac{k^2}{g}\left(\frac{\sqrt{m}}{B}\right)^{2.6}$$ **Equation 5**

$$\textbf{\textit{Cratering}}\quad D_C = \frac{k^2}{g}\left(\frac{\sqrt{m}}{SH}\right)^{2.6}$$ **Equation 6**

$$\textbf{\textit{Rifling}}\quad D_R = \frac{k^2}{g}\left(\frac{\sqrt{m}}{SH}\right)^{2.6}\sin\theta$$ **Equation 7**

Where:

Θ = drill hole angle (worse case 80^{o})

D_{FB}, D_C, D_R = maximum throw (m)

m = charge weight/m (kg/m)

B = burden (m)

SH = stemming height (m)

g = gravitational constant (9.81 m/s^2)

k = a constant (can be refined with measurements)

As this study use general constants, it may be required that the mine measure the ground vibration from the start of the mining project. This data can then be analysed to derive site-specific constants that must be used to review and update this blasting impact assessment in the future.

6 IMPACT ASSESSMENT AND SIGNIFICANCE

6.1 HUMAN PERCEPTIONS WITH BLASTING IMPACTS

Beginning in the 1930s, research was conducted with volunteers to determine sensitivities to vibrations. Although people are sensitive to sounds and vibrations, it is difficult to quantify perceptions. Inside a structure, people will feel the building shake and hear the objects around them rattle such as windows and knick-knacks on walls. When an event is perceived, some people will say that they felt very strong vibrations, even if the vibration was too low to be felt outside. The reactions of people are best understood when observed in their own homes during times of real-life events. These reactions may not be the same as those of volunteers under controlled conditions.

Human response to blasting is subjective, as two people will react differently to the same vibration event depending on where they are in a structure, their frame of mind and their personality. Unfavourable reactions to vibrations may often result in complaints. When residents feel a blast, they may become concerned about damage to their home.

The threshold peak particle velocity of ground vibration perception is about 0.51 mm/s for most people. This is 1/100 of the limit of 50 mm/s commonly used for construction blasting.

People in different living environments normally perceive blasting as negative. If a project is not perceived as beneficial to a community, blasting on the project may be unwelcome.

In addition, during a blast event, people inside a building tend to perceive\experience\feel the vibrations differently than people outside a building. People inside a structure are immersed in the vibration event and often cannot tell the source of the vibration. The windows may rattle and there may be other structure responses that enhance their perception of the event. They can also perceive structure vibrations that are well below levels that could possibly cause threshold damage, yet, due to the fear of potential damage, this perception could be result in an increased response (stress, complaints, etc.). On the other hand, a person outside a structure will not notice any of the structure responses. Therefore, their perception of the event will generally be much less, mainly relating to the audible noise or the pressure changes relating to the air blast.

6.2 WHY BLASTING CONCERNS COMMUNITIES

For hard rock mining, blasting is considered as the most efficient and economical method used for fragmenting rocks masses. Nonetheless, only 20-30% of the available energy is used for rocks fragmentation and displacement, while the rest is wasted in the form of ground vibration, air blast, noise and fly-rocks.

Ground vibration and air blast are a matter of great concern as they could result in damage to existing surface structures and generate nuisances to the receptors in the vicinity of mines.

Currently there are no specific legislation pertaining to blasting vibration levels, air blast levels and fly rock control in South Africa. However, most developed countries have ground vibration standards, although most of these standards are based on the following three standards/guidelines, namely:

- Vibration criteria as published by the US Bureau of Mines (USMB) and the US Office of Surface Mining (OSM) – USBM RI 8507 only focus on potential blasting impacts.
- The Swiss standards (SN 640 312a) that are effectively three different standards; one used for blasting, one for pile driving and one used for machines and traffic.
- Vibration limits as developed by the Federal Transit Administration (FTA Noise and Vibration Manual) – used for road construction and traffic.

6.2.1 Ground Vibration

Humans begin to perceive ground vibration at around 0.12 mm/s PPV, a level significantly lower than the vibration level where damage may start to occur. The longer a vibration of a given peak velocity lasts; the more disturbing people will find it. In addition, the longer a vibration lasts, the greater the probability of it causing damage, all other things being equal. It should be noted that there is no correlation between vibration complaints and the ground vibration level, as people may start to complain about vibration even at very low levels.

Chiappetta (2000) and Griffin (1990) defined ground vibration levels for different frequencies as defined in **Table 6-1** and illustrated in **Figure 6-1**.

Table 6-1: Human response to ground vibration

Effects on Humans	Ground vibration Level (mm/s)
Imperceptible	0.025 – 0.076
Barely perceptible	0.076 – 0.254
Distinctly perceptible	0.254 – 0.762
Strongly perceptible	0.762 – 2.540
Disturbing	2.540 – 7.620
Very disturbing	7.620 – 25.400

Vibration damage probability, as with many other quantities in science, roughly follows an S-shaped "sigmoid curve", as a function of vibration intensity. Over a range of low vibration intensities, no houses are damaged. At these low intensities, people may be able to feel the vibration, even though no visible damage is done. At the highest vibration velocities (intensities), virtually all structures experiencing the vibration can visibly be damaged. Essentially all the people feeling such a high intensity vibration will be made distinctly uncomfortable by it.

The USBM RI 8507 standard is generally accepted in South Africa. This standard was developed through research and available data over a number of years and focus on the protection of structures from potential damage. It uses an analysis graph that considers vibration amplitudes and frequency to define the risk of potential structural damage due to ground vibration (See also **Figure 6-1**). To minimise complaints from receptors, vibration levels should ideally be kept beneath the "unpleasant" curve (this is measured from actual blasts).

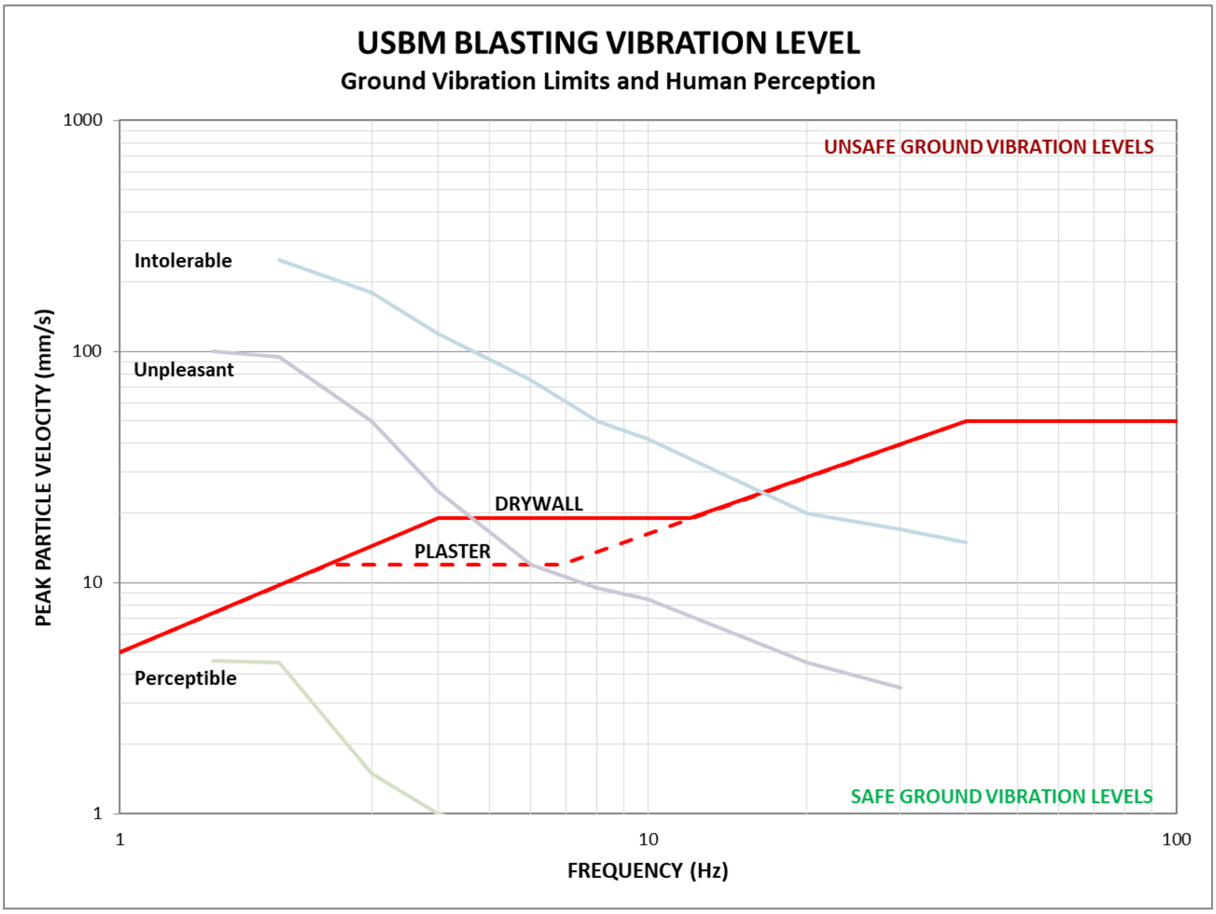


Figure 6-1: Human vibration sensitivities and potential structural damage compared to the RI 8507 limits

To avoid damage to buildings, ground vibration levels should be within the "safe" area as highlighted in **Figure 6-1**. Information from USBM RI 8507 indicates that 50% of homes will experience "threshold damage" at a velocity of about 51 mm/s. For "minor" damage, that 50% point is at about 76 mm/s, while for "major" damage, it is at about 100 mm/s. At the 5% probability level, the PPV for threshold damage from blasting vibrations is about 18 mm/s, based on the same data (drywall construction). The OSM and RI 8507 19 mm/s mid-frequency limits are, thus, set at a level which has approximately a 5% probability of causing damage to a drywall from direct ground vibration. These limits are developed for different types of structures and materials and highlighted in **Table 6-2** (also refer to **Appendix B** for a more complete list and the sources). This report will use the 25 mm/s limit for houses and other sensitive structures (including boreholes). Due to the roads, rail way line, pipeline and the electrical line various other limits will also be considered.

Table 6-2: Ground vibration limits for various structures

Material / Structure	Ground vibration limit (mm/s)
National Roads / Tar Roads / Railways	**150**
Electrical Lines	**75**

Steel pipelines, cement dams	**50**
Sensitive Plant equipment, mortar and brick house, boreholes	**25**
Engineered concrete and masonry (no plaster)	**7.62**
Sensitive structures, adobe and informal houses	**6**
Buildings extremely susceptible to vibration damage	**3**

6.2.2 Air blast concerns

Air blasts can cause discomfort to persons and, at high levels, damage to structures. At very high levels, it may even cause injury to people. Air blasts could also interact with structures and create secondary noises which people detect, raising their concern about the blasting activity. While rare, window breakage may be the result of an air blast. Air blast levels that may result in damage were estimated by Persson (1994) and Oriard (2002) and is defined in **Table 6-3**.

Table 6-3: Air blast levels that may result in damage or complaints

Descriptor	Acoustic Level (dB)
Air pressure from an 11 m/s wind gust.	110
Annoyance threshold in Australia. Mildly unpleasant.	115
Recommended limit in Australia for sensitive sites.	**120**
Resonant response of large surfaces (roofs, ceilings). Complaints start.	130
Limit for human irritability. USBM and OSMRE limit.	134
Some windows break.	150
Most windows break.	170
Structural Damage.	180

6.2.3 Fly-rock concerns

Fly rock is a significant danger to people, equipment and structures with damage due to this being undeniable. Mines therefore go through significant effort to ensure that the risks from fly rock are minimized due to the potential penalties to the mine if fly-rock complaints are registered. These penalties may be institutional consequences (regulatory directives, fines, legal action) and monetary compensation. As such there should be no risk of fly rock at structures or where people or animals may congregate. This is the main reason for the 500m exclusion zone around blasting activities.

6.3 DETERMINING THE SIGNIFICANCE OF THE BLASTING IMPACTS

Regulation 50(c), of the MPRDR (2004) under the MPRDA (2002) requires an assessment of nature (status), extent, duration, probability and significance of the identified potential environmental impacts of the proposed mining operation.

Once a potential impact has been determined it is necessary to identify which project activity will cause the impact, the probability of occurrence of the impact, and its magnitude and extent (spatial and temporal). This information is important for evaluating the significance of the impact, and for defining mitigation and monitoring strategies. Direct and indirect impacts of the impacts identified during the specialist investigations were assessed in terms of five standard rating scales to determine their significance.

The rating system used for assessing impacts (or when specific impacts cannot be identified, the broader term issue should apply) is based on five criteria, namely:

- **Status** of impacts (**Table 6-4**) – determines whether the potential impact is positive (positive gain to the environment), negative (negative impact on the environment), or neutral (i.e. no perceived cost or benefit to the environment). Take note that a positive impact will have a low score value as the impact is considered favourable to the environment;
- **Spatial extent** of impacts (**Table 6-5**) – determines the spatial scale of the impact on a scale of localised to global effect. While ground vibration and air blast effects can be perceived over distances as far as 10 km, potential damages relating to ground vibration and air blast are always limited to a zone within 2,000 m from the blast and the effect of blasting will be limited to Local (medium);
- **Duration** of impacts (**Table 6-6**) – refers to the length of time that the aspect may cause a change either positively or negatively on the environment. Potential impact is expressed numerically on a scale of 1 (project duration) to 5 (permanent), with blasting activities lasting the duration of the project (long);
- **Severity** of impacts (**Table 6-7**) – quantifies the impact in terms of the magnitude of the effect on the baseline environment, and includes consideration of the following factors:
    - The reversibility of the impact;
    - The sensitivity of the receptor to the stressor;
    - The impact duration, its permanency and whether it increases or decreases with time;
    - Whether the aspect is controversial or would set a precedent;
    - The threat to environmental and health standards and objectives;
- **Frequency of the activity** (**Table 6-8**) – The frequency of the activity refers to how regularly the activity takes place. The more frequent an activity, the more potential there is for a related impact to occur.
- **Probability** of impacts (**Table 6-9**) – quantifies the impact in terms of the likelihood of the impact occurring on a percentage scale of <5% (improbable) to >95% (definite).

The Consequence Rating is calculated by summing Spatial Scale (Extent), Duration and Severity, with the Likelihood (of the impact) Rating calculated by summing Frequency and Probability. The significance is estimated by multiplying the Consequence with Likelyhood ratings.

Table 6-4: Status of Impact

Rating	Description	Quantitative Rating
Positive	A benefit to the receiving environment (positive impact)	+
Neutral	No determined cost or benefit to the receiving environment	N
Negative	At cost to the receiving environment (negative impact)	-

Table 6-5: Impact Assessment Criteria – Extent of Impacts

Rating	Description	Quantitative Rating
Very Low	**Site Specific** – impacts confined within the project site boundary	1
Low	**Proximal** – impacts extend to within 1 km of the project site boundary	2
Medium	**Local** – impacts within 5 km of the project site boundary	3
High	**Regional** – impacts extend beyond the site boundary and have a widespread effect - i.e. > 5 km from project site boundary	4
Very High	**Global** – impacts extend beyond the site boundary and have a national or global effect	5

Table 6-6: Impact Assessment Criteria – Duration

Rating	Description	Quantitative Rating
Very Low	**Project duration** – impacts expected only for the duration of the project or not greater than 1 year	1
Low	**Short term** – impacts expected on a duration timescale of 1 to 2 years	2
Medium	**Medium term** – impacts expected on a duration timescale of 2-5 years	3
High	**Long term** – impacts expected on a duration timescale of 5-15 years	4
Very High	**Permanent** – impacts expected on a duration timescale exceeding 15 years	5

Table 6-7: Impact Assessment Criteria – Severity of Impact (Magnitude / Intensity)

Rating	Description	Quantitative Rating
Very Low	Ground vibration levels less than 0.254 mm/s (see Table 6-1). The projected vibration level is less than 5% of the appropriate limit for a specific structure as identified in Table 6-2. Air blast levels less than 115 dB	1
Low	Ground vibration levels more than 0.254 but less than 0.762 mm/s (see Table 6-1). The projected vibration level is more than 5%, but still less than 10% of the appropriate limit for a specific structure as identified in Table 6-2. Air blast levels more than 115 but less than 120 dB	2
Medium	Ground vibration levels more than 0.762 but less than 2.54 mm/s (see Table 6-1). The projected vibration level is more than 10%, but still less than 25% of the appropriate limit for a specific structure as identified in Table 6-2. Air blast levels more than 120 but less than 130 dB	3
High	Ground vibration levels more than 2.54 but less than 7.62 mm/s (see Table 6-1). The projected vibration level is more than 25%, but still less than 50% of the appropriate limit for a specific structure as identified in Table 6-2. Air blast levels more than 120 but less than 134 dB	4
Very High	Ground vibration levels more than 7.62 mm/s (see Table 6-1). The projected vibration level is higher than the appropriate limit for a specific structure as identified in Table 6-2. Air blast levels exceeding 134 dB	5

Table 6-8: Impact Assessment Criteria – Frequency of impact

Rating	Frequency	Quantitative Rating
Very Low	Annually or less	1
Low	6 monthly	2
Medium	Monthly	3
High	Weekly	4
Very High	Daily	5

Table 6-9: Impact Assessment Criteria – Probability of Impact Occuring

Rating	Description	Quantitative Rating
Highly Improbable	Likelihood of the impact arising is estimated to be negligible; <5%.	1
Improbable	Likelihood of the impact arising is estimated to be 5-35%.	2
Possible	Likelihood of the impact arising is estimated to be 35-65%	3
Probable	Likelihood of the impact arising is estimated to be 65-95%.	4
Highly Probable	Likelihood of the impact arising is estimated to be > 95%.	5

Determination of Impact Significance

The information presented above in terms of identifying and describing the aspects and impacts is summarised and the significance is assigned with supporting rational. Significance will be classified according to the following:

- Very Low to Low - it will not have an influence on the decision;
- Medium to Medium-High - it should have an influence on the decision unless it is mitigated;
- High to Very High- it would influence the decision regardless of any possible mitigation. Alternative options including rehabilitation and/or offset should be investigated.

The environmental significance rating is an attempt to evaluate the importance of a particular impact, the consequence and likelihood as assessed.

The sum of the first three criteria (spatial scope, duration and severity) provides a collective score for the consequence of each impact. The sum of the last two criteria (frequency of activity and probability of impact) determines the likelihood of the impact occurring. The product of consequence and likelihood leads to the assessment of the significance of the impact, shown in the significance matrix below in **Table 6-10** and **Table 6-11**.

The model outcome is then assessed in terms of impact certainty and consideration of available information. Where a particular variable rationally requires weighting or an additional variable requires consideration the model outcome is adjusted accordingly.

Table 6-10: Assessment Criteria: Significance Assessment Matrix

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	4	6	8	10	12	14	16	08	20	22	24	26	28	30
3	6	9	12	15	18	21	24	27	30	33	36	39	42	45

4	8	12	16	20	24	28	32	36	40	44	48	52	56	60
5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
6	12	18	24	30	36	42	48	54	60	66	72	78	84	90
7	14	21	28	35	42	49	56	63	70	77	84	91	98	105
8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
9	18	27	36	45	54	63	72	81	90	99	108	117	126	135
10	20	30	40	50	60	70	80	90	100	110	120	130	140	150

Table 6-11: Assessment Criteria: Significance Impact Ratings

Colour Code	Significance Rating	Value	Negative Impact Management Recommendation	Positive Impact Management Recommendation
	Very High	126-150	Improve Current Management	Maintain Current Management
	High	101-125	Improve Current Management	Maintain Current Management
	Medium-High	76-100	Improve Current Management	Maintain Current Management
	Low-Medium	51-75	Maintain Current Management	Improve Current Management
	Low	26-50	Maintain Current Management	Improve Current Management
	Very Low	1-25	Maintain Current Management	Improve Current Management

7 ASSUMPTIONS AND LIMITATIONS

It is not the purpose of this assessment to calculate exact vibration levels, or the precise level of the air overpressure, but to use various tools to identify potential issues of concern. Due to unknowns this assessment leans towards a precautious approach, rather over-estimate the distance that fly-rock may travel, the ground vibration or the level of an air blast. However, the following assumptions and limitations must be noted:

- No blast design report was available for this project and the blast input parameters were communicated to the author from the developer, considering the blast parameters of a similar mine of the developer. Two scenarios were investigated, namely the blast parameters from a previous project and blast parameters considering the "Rules of Thumb" from Dyno, 2010;
- This impact assessment does not make a statement on the acceptability of the blast design as evaluated (viable bench height, fracturing, powder factors, etc.) and only assesses the potential impacts considering the available information;
- None of the structures were visited to confirm the status of each structure. It is highly recommended that the mine complete a survey of all structures and boreholes (location, depth, yield, static water level, ground water quality, usage, etc.) located within 1,000 m from the proposed opencast limits to determine the status and state of the structures before the construction of the mine start (first blasting taking place);
- This report assumed an average borehole depth of 10m. The borehole depths were used as the average bench height;
- A blast hole diameter of 110 mm was used, with the burden and spacing estimated from the blast hole diameter as well as the average bench height of 10 m using the "Rules of Thumb" from Dyno, 2010, for the second scenario;
- Attenuation rates for ground vibration levels, air blast levels and fly rock distances are site-specific. Empirical formula have been developed by a number of researchers, yet all these equations use constants that should be developed considering site specifics. These site constants can initially be assumed but should be refined considering the results of blasting vibration and air pressure measurements. This data must be analysed and with the information used to update this report;
- Calculations are based on an ideal situation, with the bedrock having constant characteristics, whereas in practice the geology is complex with faults, dykes, folds, stratigrapical layers etc. This means that each blast may different;
- This report assumed that blasting will take place during the afternoon when atmospheric conditions are the most unstable with no inversion layer or a potential inversion layer that is high with no overcast conditions.

8 PROJECTED MAGNITUDE OF BLASTING IMPACTS

Blasting activities could take place during both the construction (development of initial boxcut) and operational phase. As this assessment considers the worst-case scenario (large blast) there is no difference between construction and operational phase blasts.

When a blast is detonated, a great deal of energy is liberated although only 20 – 30% of the energy used for rock fragmentation and displacing (Aloui, 2016). The rest of the explosive energy is wasted in the form of ground vibration, air blast and noise as well as fly rocks. Blasting vibration and air blast levels as well as the potential zone of impact for fly rock can be calculated using the blast design parameters defined in **Table 8-1**.

Table 8-1: Blast design – design parameters

Design parameter	Assumed blast parameters – Scenario 1	Optimized blast parameters – Scenario 2
Average depth of borehole, including subdrill (m)	10.33	10.33
Bench height (m)	10.00	10.00
Subdrill (m)	0.33	0.33
Borehole diameter (mm)	110	110
Burden (m)	4.0	3.0
Spacing (m)	5.0	4.0
Stemming Length (m)	2.58	3.44
Burden stiffness ratio	2.2	2.0
Column length (m)	8.13	8.00
Explosive density (g/cm^3)	1.15	1.15
Explosives per borehole (kg)	85.2	87.4
Charge mass per meter (kg/m)	10.5	10.9
Maximum number of blast holes per delay *(assumed)*	5.0	5.0
Maximum explosive per delay (kg)	426.0	437.0
Powder Factor (kg/m^3)	0.41	0.71

8.1 PROJECTED MAGNITUDE OF GROUND VIBRATION

As discussed in **section 5.1**, the accepted method of a scaled distance is used. This equation mainly uses two constants (initially assumed until it can be calculated using data from blasts), the quantity of explosives used (in kg) and the distance from the blast in meters. For any specific blast, distance to the closest PSS is fixed and cannot be changed with the only parameter that can be changed being the mass of explosives detonated per instance (per charge).

The larger the explosive mass (per delay), the higher the amplitude of the ground vibration. As such the amplitude of the ground vibration can be reduced by reducing the mass of the explosives fired at the same time, or with the appropriate use of delays (using timed blasts) to reduce the mass of explosives detonated per instance. This is referred to as the "charge per delay mass".

Therefore, using Equation 1, the potential ground vibration can be calculated for the assumed blast parameters (see **Figure 8-1**) as well as the "Rule of Thumb" blast parameters (optimised for a 0.7 powder factor) (see **Figure 8-2**). **Figure 8-3** illustrates the distance from a potential blast (mass per charge) for various vibration limits.

Potential buffers are illustrated in:

- **Figure 8-6** for the optimized blast parameters, indicating the buffer area where vibration levels of 2.54 mm/s may impact on people;
- **Figure 8-7** for the optimized blast parameters, indicating the buffer area where vibration levels of 6 mm/s may impact on sensitive structures such as corrugated, adobe and mud buildings;
- **Figure 8-8** for the optimized blast parameters, indicating the buffer area where vibration levels of 75 mm/s may impact on electrical power pylons.

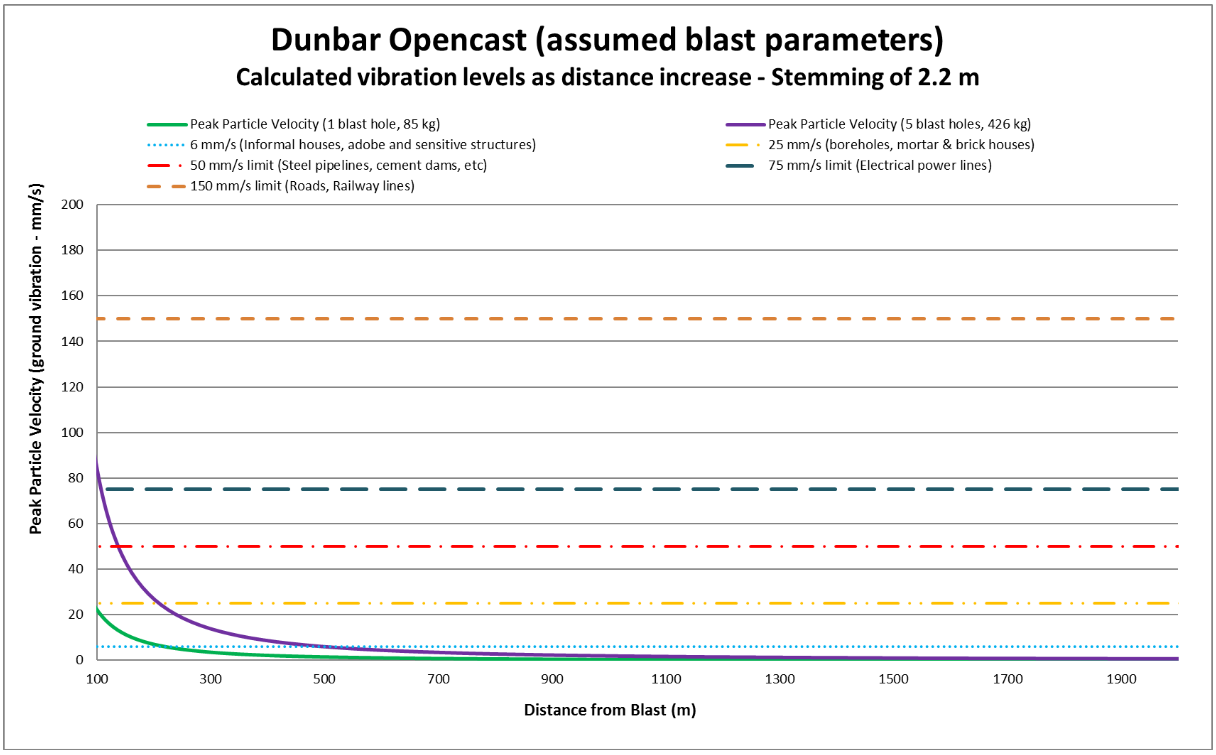


Figure 8-1: Ground vibration levels as the distance increase for assumed blast parameters

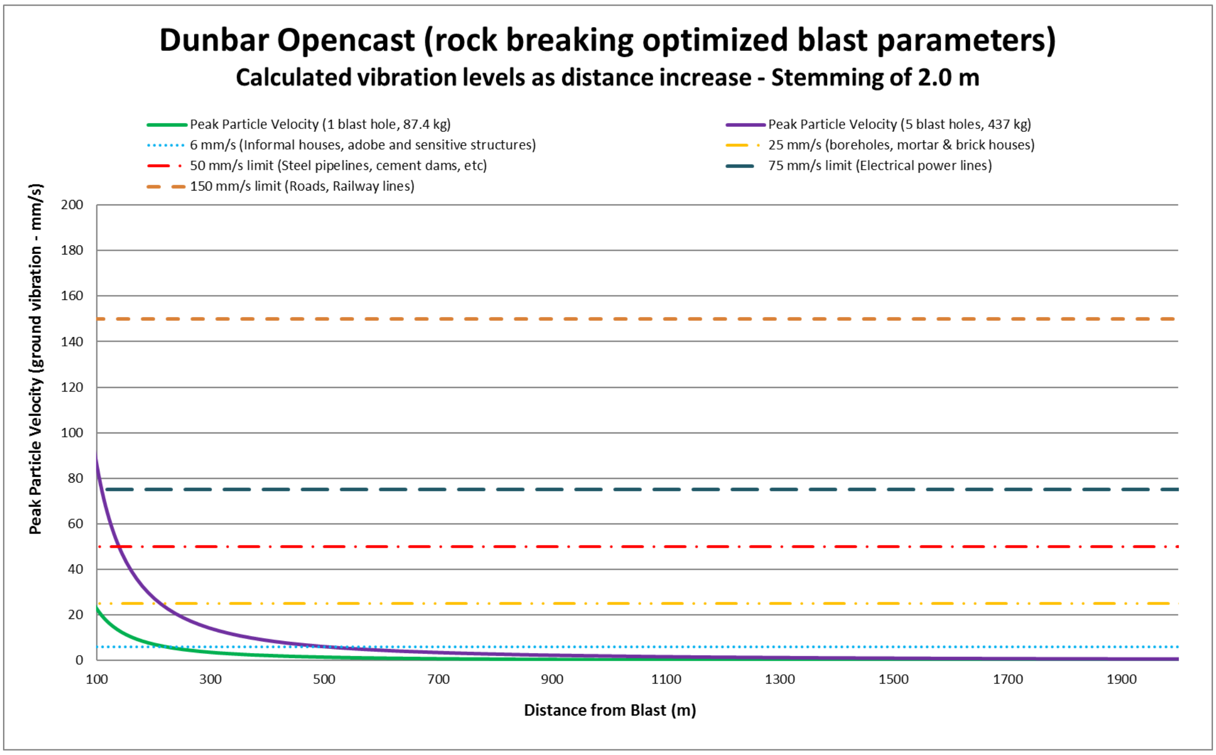


Figure 8-2: Ground vibration levels as the distance increase for optimised blast parameters (ideal rock breakage)

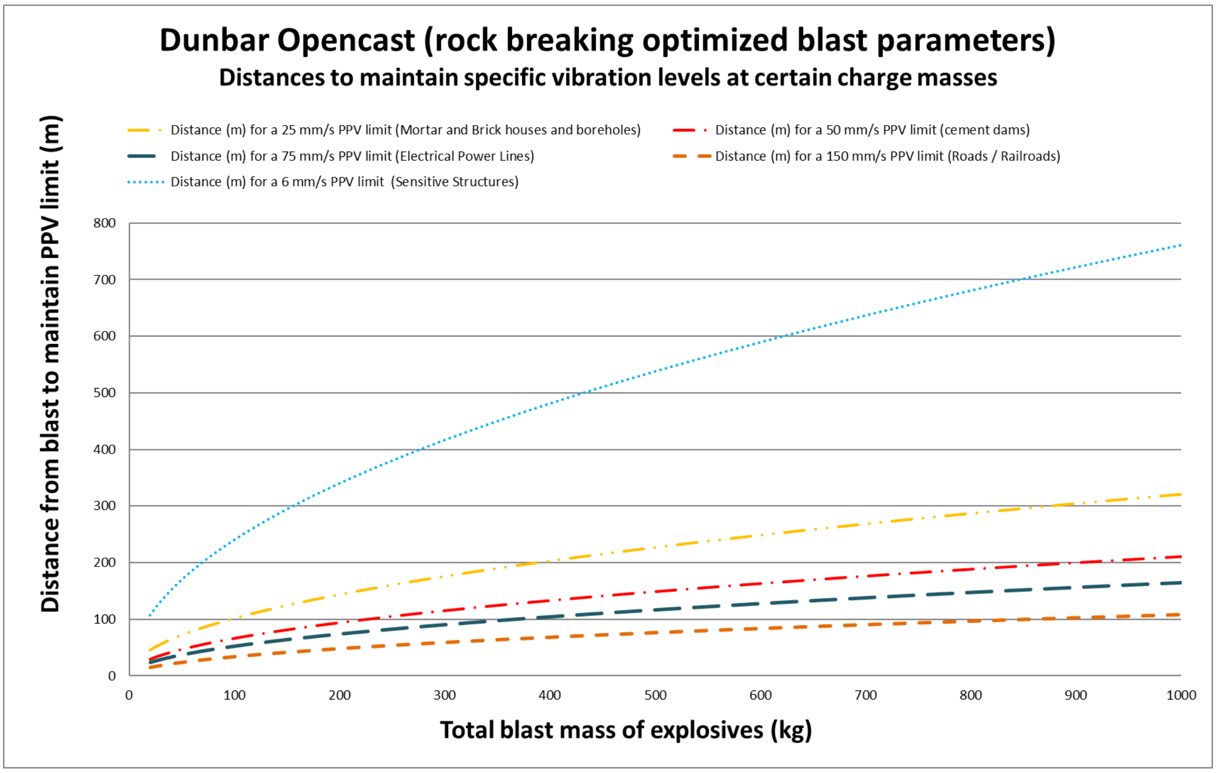


Figure 8-3: Required distances to maintain specific vibration levels at certain charge masses

8.2 Projected Magnitude of Air Blast Level

As discussed in **section 5.2**, as with ground vibration, the method used to calculate the air blast level is also based on a scaled distance formula. The USBM formula only consider the mass of explosives used (in kg) and the distance from the blast in meters where the AS2187.2 method in addition also use two constants that allow the refinement for site specific conditions. Both the methods were considered with the USBM being the more pre-cautious method (higher air pressure level at the same distance than the Australian method).

As can be seen from equation 2, the air blast level can be reduced by reducing the mass of the explosives fired at the same instance (controlled or timed blasting). The two options (assumed and optimized blast parameters) will be considered. Using Equation 2, the potential air blast level can be calculated for the options as indicated in:

- **Figure 8-4** for the assumed blast parameters using the USBM method; and
- **Figure 8-5** for the assumed blast parameters using the AS 2187.2 method.

The potential extent of the impact (120 dBA noise limit) is illustrated on an aerial image in **Figure 8-9** (the USBM method). As can be seen from these figures and similarly to ground vibration, the deeper the blasthole, the more explosives are used which would increase the airblast levels (everything being the same).

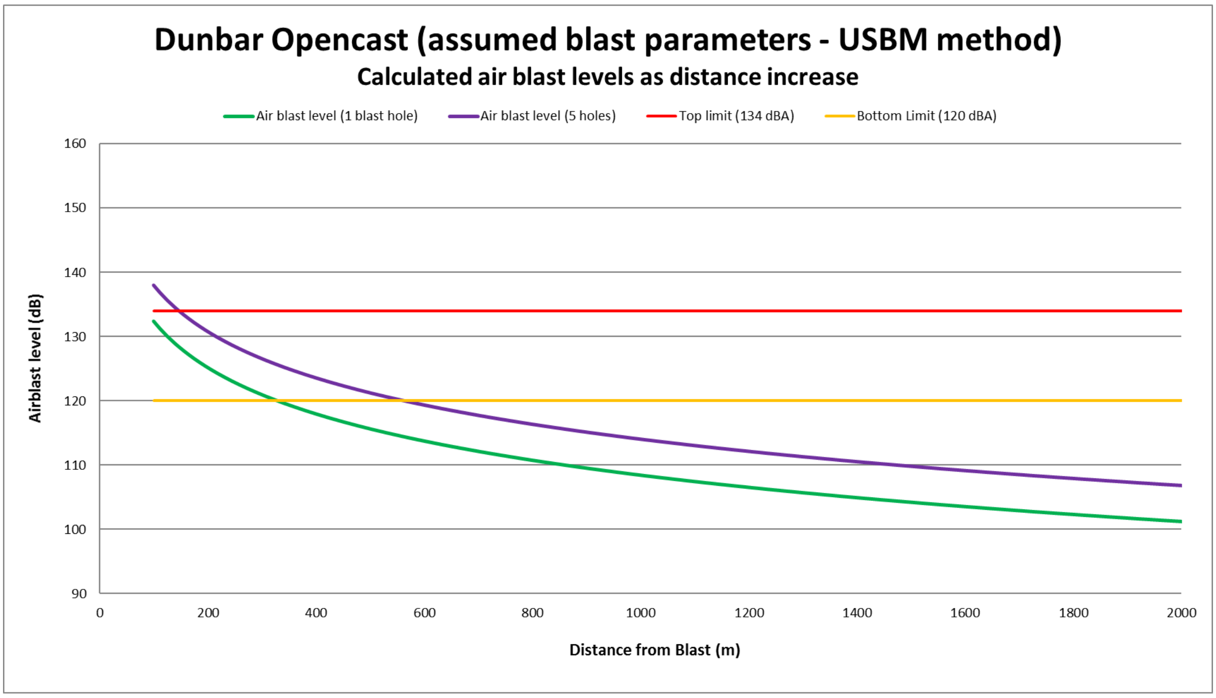


Figure 8-4: Air blast levels as the distance increase for assumed blast parameters using the USBM method

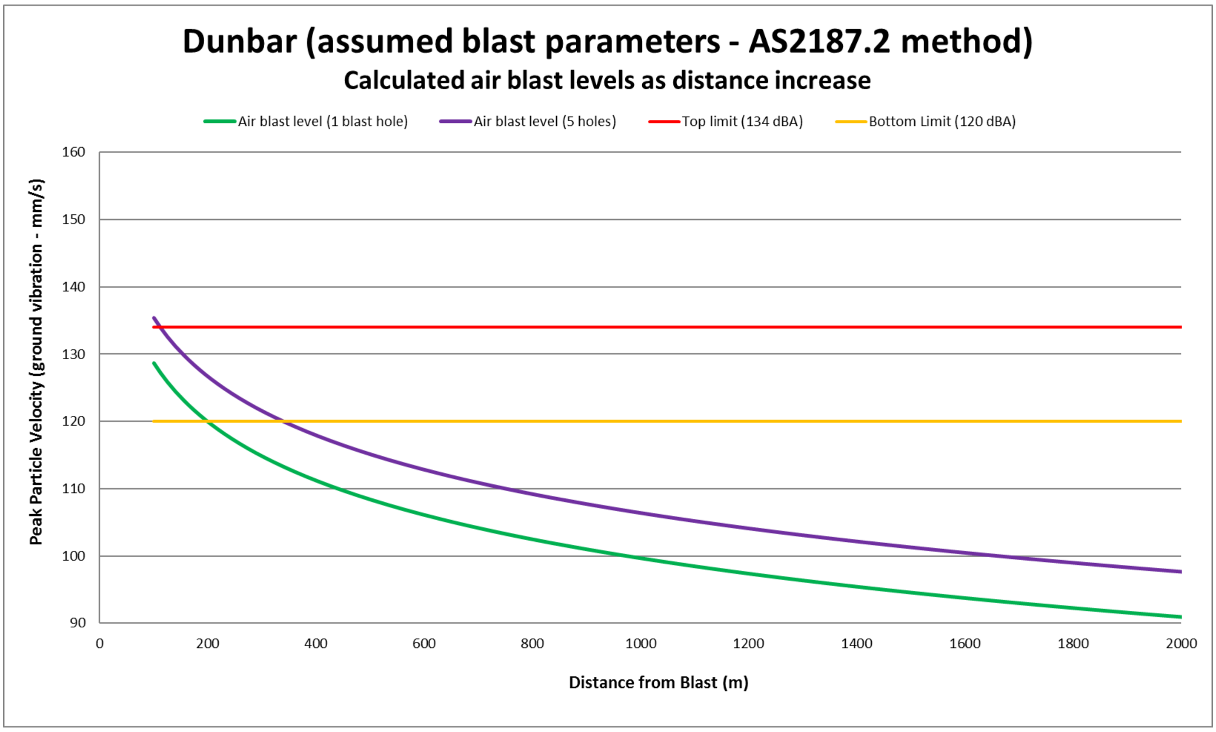


Figure 8-5: Air blast levels as the distance increase for assumed blast parameters using the AS2187.2 method

8.3 Projected Magnitude of Fly rock Risks

Section 5.3 discusses the different ways that fly rock may be created as well as the methods how it can be calculated. The explosive mass (per meter) is used in all three formula, with blast design (the burden and stemming length) playing a very important role. Using these equations, the potential extent of fly rock was calculated and defined in **Table 8-2** with the extent of the risk illustrated on an aerial image on **Figure 8-10**. It should be noted, that, even with the best precautions, fly rock will occur and could travel further than the distances indicated in this report. As such a safety factor is recommended, which in some cases could be as high as 4 times the maximum throw distance. It is recommended that the mine at all times use a minimum exclusion zone of 500 m (equipment, people or livestock).

Table 8-2: Type of Flyrock and potential area of risk

Fly rock type	Value (m) – Assumed blast parameters	Value (m) – Optimized blast parameters
Face bursting	43 m (for a 4 m burden)	96 m (for a 3 m burden)
Cratering	203 m (for a 2.2 m stemming depth)	274 m (for a 2.0 m stemming depth)
Rifling	69 m (for a 2.2 m stemming depth)	94 m (for a 2.0 m stemming depth)

8.4 Potential Decommissioning, Closure and Post-closure Blasting Impacts

There is no, or small blasting impact risks once the operational phase is completed. At worst, a small blast may be required to ensure that the final void highwalls isn't too steep and dangerous, but the impact will be less than a typical overburden blast. This risk is significantly lower than construction and operational blasting and this will not be investigated further.

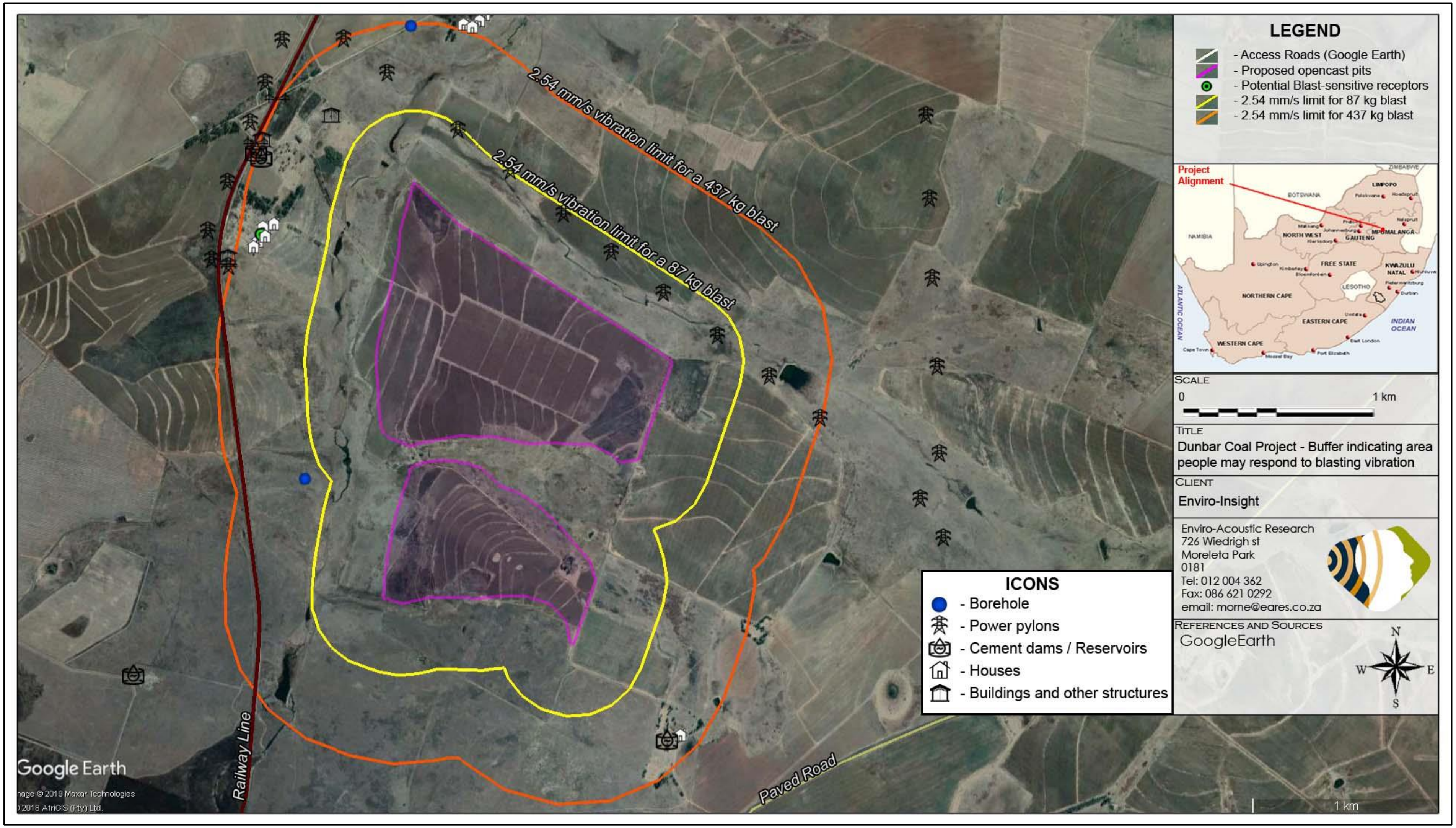


Figure 8-6: Projected Extent of Blasting Impacts – Potential area where people may respond to blasting vibration for the optimized blast parameters

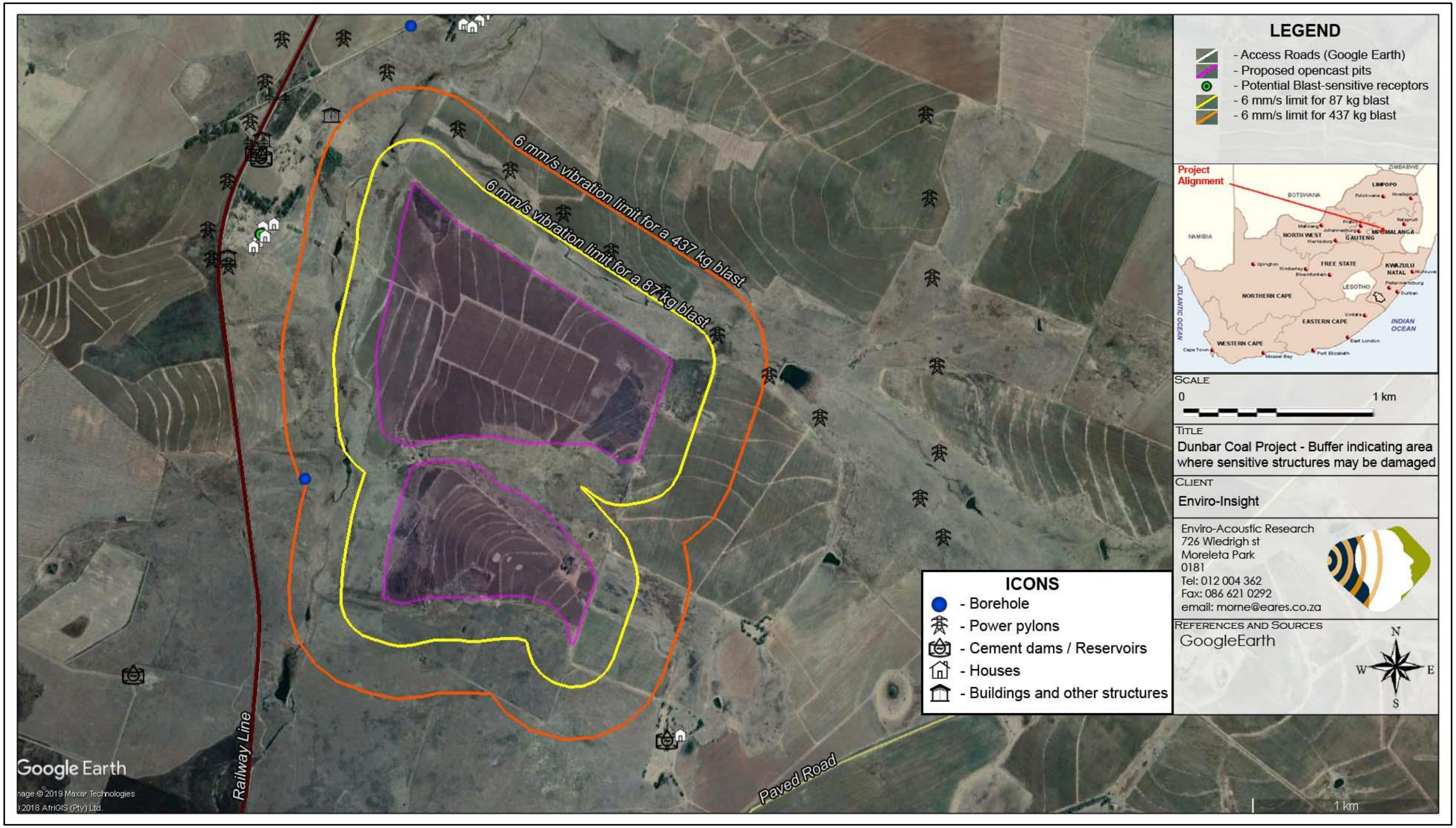


Figure 8-7: Projected Extent of Blasting Impacts – Potential area where sensitive structures may be damaged for the optimized blast parameters

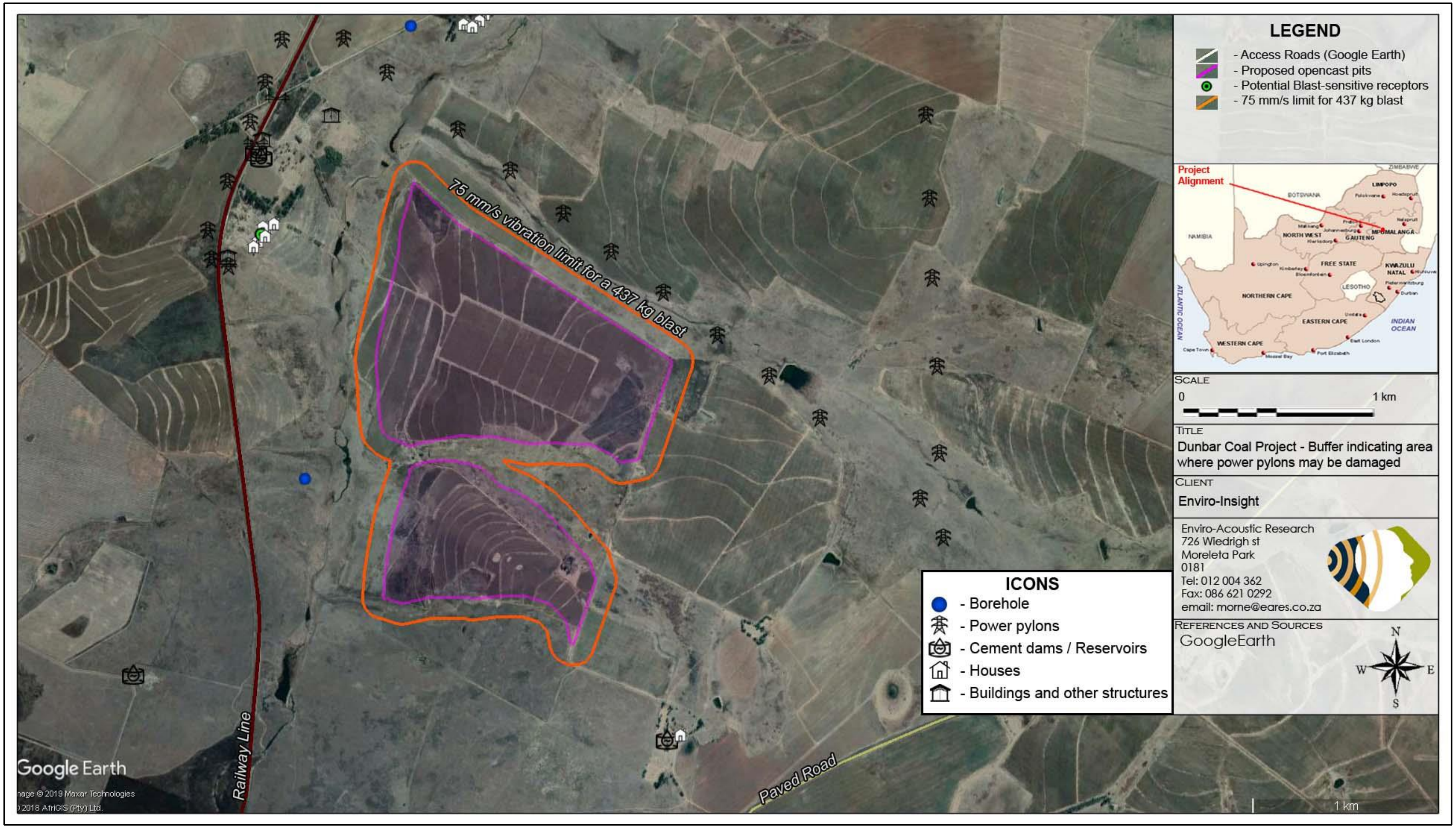


Figure 8-8: Projected Extent of Blasting Impacts – Potential area where pylons may be damaged for the optimized blast parameters

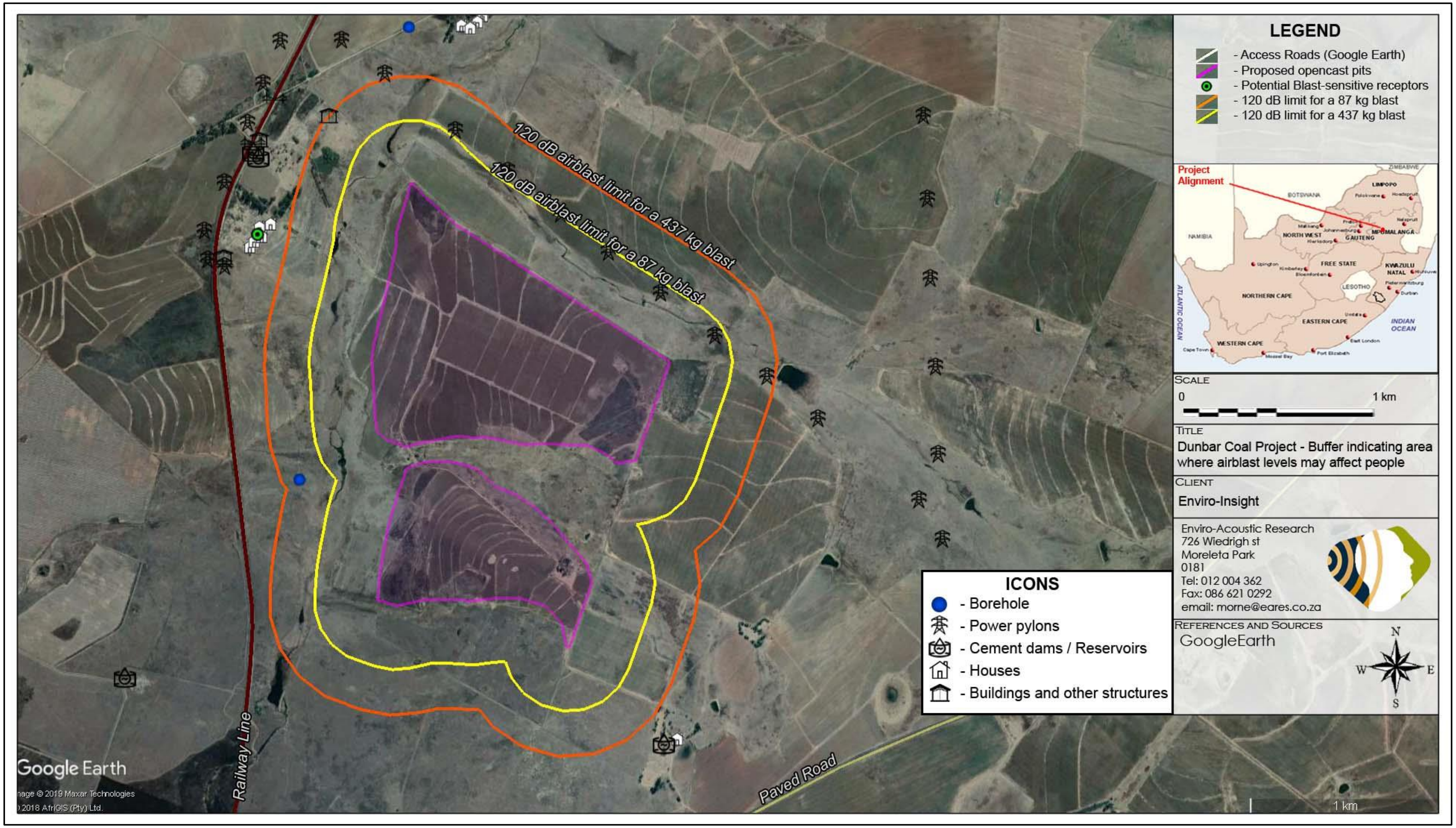


Figure 8-9: Projected Extent of Blasting Impacts – Air blast level for the optimized blast parameters

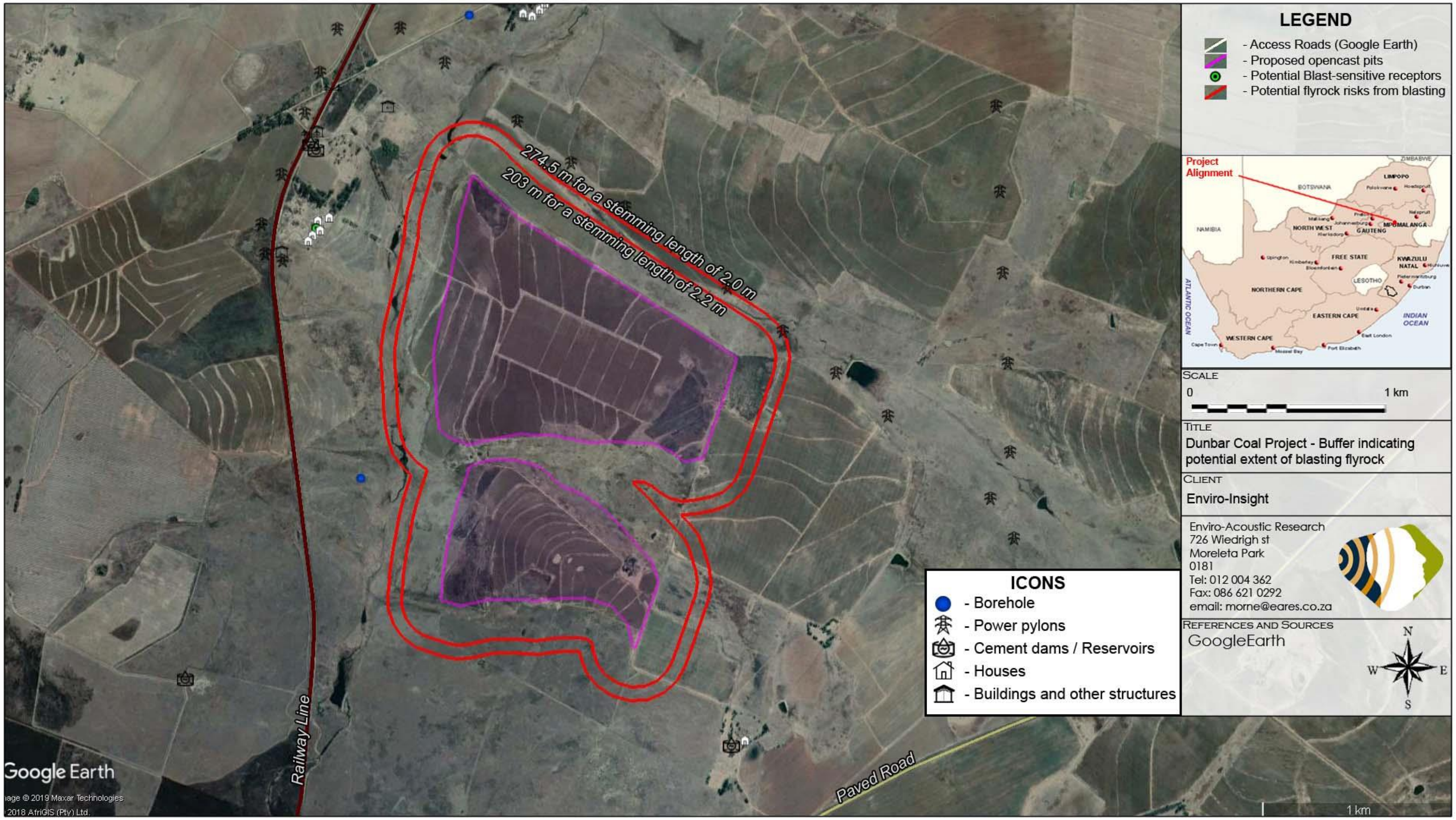


Figure 8-10: Projected Extent of Blasting Impacts – Fly rock risks

9 SIGNIFICANCE OF THE BLASTING IMPACTS

The impact assessment tables are based on the levels and potential response as defined in **Table 9-6**.

9.1 SIGNIFICANCE OF GROUND VIBRATION IMPACTS

The magnitude of the ground vibration levels were calculated in section **8.1**, defined in **Table 9-6** with the significance summarised in **Table 9-1** (human response) and **Table 9-2** (dangers to structures).

Table 9-1: Impact Assessment: Ground vibration impacts (Human Responses)

Acceptable Level (Table 6-1)	Use the level of 2.54 mm/s as the limit for people in the area (see **Figure 6-1**, **Table 6-1** and **Table 9-6**)	
Status (Table 6-4)	Negative	
	Without Mitigation (detonating 5 blastholes simultaneously for a 437 kg charge per delay)	***With Mitigation (detonating only 1 blasthole at a time for a 87.4 kg charge per delay)***
Extent (Table 6-5)	Low (Proximal - 2)	Low (Proximal - 2)
Duration (Table 6-6)	High (Long term – 4)	High (Long term – 4)
Severity (Table 6-7)	High (4 – for a 437 kg charge per delay)	Medium (3 – for a 84.7 kg charge per delay)
Frequency (Table 6-8)	High (Weekly – 4)	High (Weekly – 4)
Probability (Table 6-9)	Probable (4)	Possible (3)
Significance of Impact	**Medium-High (80)**	**Low (42)**
Reversibility	High	High
Degree of Confidence	**Medium-high**	
Mitigation:	Mitigation required, including: - If no complaints are registered the blast monitoring can be ceased. This report must be updated if the blast design is changed where more than 500 kg explosives are detonated per delay. - The Mine must consider the location of closest residents to the planned blast and reduce the charge per delay to less than 437 kg when blasting within 850 m from a dwelling used for residential purposes.	

Table 9-2: Impact Assessment: Ground vibration impacts (Damage to residential structures in area)

Acceptable Level (Table 6-1)	Use the level of 6 mm/s as the limit for informal houses in local community (see **Figure 6-1**, **Table 6-2** and **Table 9-6**)	
Status (Table 6-4)	Negative	
	Without Mitigation (detonating 5 blastholes simultaneously for a 437 kg charge per delay)	***With Mitigation (detonating only 1 blasthole at a time for a 87.4 kg charge per delay)***
Extent (Table 6-5)	Low (Proximal - 2)	Low (Proximal - 2)
Duration	High (Long term – 4)	High (Long term – 4)

(Table 6-6)		
Severity (Table 6-7)	High (4 – for a 437 kg charge per delay)	Medium (3 – for a 84.7 kg charge per delay)
Frequency (Table 6-8)	High (Weekly – 4)	High (Weekly – 4)
Probability (Table 6-9)	Improbable (2)	Highly Improbable (1)
Significance of Impact (Table 6-10 and Table 6-11)	**Low-medium (60)**	**Low (54)**
Reversibility	High	High
Degree of Confidence	**Medium-high**	
Mitigation:	Mitigation not required but highlighted due to the sensitivity of people to blasting vibrations. The Mine must consider the location of closest residents to the planned blast and could reduce the charge per delay. Local community members to be notified of times when blasts will be undertaken. Community to know that the potential impact of vibration was assessed.	

Table 9-3: Impact Assessment: Ground vibration impacts (Damage to Structures in area)

Acceptable Level (Table 6-1)	Use the level of 25 mm/s as the limit for buildings and structures in area. Use the level of 50 mm/s as the limit for pipelines, cement dams and reservoirs in area. Use the level of 75 mm/s as the limit for electrical power lines in area. Use the level of 150 mm/s as the limit for roads and railway line in area. (see Table 6-2 and Table 9-6)	
Status (Table 6-4)	Negative	
	Without Mitigation (detonating 5 blastholes simultaneously for a 437 kg charge per delay)	***With Mitigation (detonating only 1 blasthole at a time for a 87.4 kg charge per delay)***
Extent (Table 6-5)	Low (Proximal - 2)	Low (Proximal - 2)
Duration (Table 6-6)	High (Long term – 4)	High (Long term – 4)
Severity (Table 6-7)	Medium (3 – for a 437 kg charge per delay)	Medium (3 – for a 437 kg charge per delay)
Frequency (Table 6-8)	High (Weekly – 4)	High (Weekly – 4)
Probability (Table 6-9)	Highly Improbable (1)	Highly Improbable (1)
Significance of Impact (Table 6-10 and Table 6-11)	**Low (45)**	**Low (45)**
Reversibility	High	High
Degree of Confidence	**Medium-high**	
Mitigation:	Mitigation not required but highlighted due to the sensitivity of people to blasting vibrations.	

9.2 SIGNIFICANCE OF AIR BLAST IMPACTS

The magnitude of the air blast levels were calculated in **section 8.2**, defined in **Table 9-6** with the significance summarised in **Table 9-4**.

Table 9-4: Impact Assessment: Air blast Impacts for a 2,484 kg blast (worst-case)

Acceptable Level (Table 6-1)	Use the level of 120 dB as the limit for people in the area (see Table 6-3 and Table 9-6).	
Status (Table 6-4)	Negative	
	Without Mitigation (detonating 5 blastholes simultaneously for a 437 kg charge per delay)	***With Mitigation (detonating only 1 blasthole at a time for a 87.4 kg charge per delay)***
Extent (Table 6-5)	Low (Proximal - 2)	Low (Proximal - 2)
Duration (Table 6-6)	High (Long term – 4)	High (Long term – 4)
Severity (Table 6-7)	Low (2 – for a 437 kg charge per delay)	Very Low (1 – for a 87.4 kg charge per delay)
Frequency (Table 6-8)	High (Weekly – 4)	High (Weekly – 4)
Probability (Table 6-9)	Possible (3)	Improbable (2)
Significance of Impact (Table 6-10 and Table 6-11)	**Low-Medium (56)**	**Low (48)**
Reversibility	High	High
Degree of Confidence	**Medium-high**	
Mitigation:	Mitigation not required, although it should be noted that: - Mine should initiate a forum to inform the close residents about the likely vibration and air blast levels, the proposed blasting schedule and warning methodology the mine will employ before a blast. When the residents are inside the house during a blast, vibration of windows and ceilings may appear excessive. - Mine to erect blasting notice boards in the area with blasting dates and times highlighted. - Mine to prevent blasting in adverse meteorological conditions where possible (overcast conditions, strong wind blowing in direction of local community, early in the mornings or late in the afternoon).	

9.3 SIGNIFICANCE OF FLY ROCK IMPACTS

The magnitude of potential fly rock risk levels were calculated in section **8.3** and the significance is summarised in **Table 9-5**.

Table 9-5: Impact Assessment: Flyrock Risks

Acceptable Level (Table 6-1)	There should be no risk of fly rock that can pose a risk to people, structures or equipment.	
Status (Table 6-4)	Negative	
	Without Mitigation (stemming from 2.0 m associated with optimised blast design)	***With Mitigation (stemming from 2.2 m associated with assumed blast design)***
Extent (Table 6-5)	Low (Proximal - 2)	Low (Proximal - 2)
Duration (Table 6-6)	High (Long term – 4)	High (Long term – 4)
Severity	Very High (5)	Very High (5)

(Table 6-7)		
Frequency (Table 6-8)	High (Weekly – 4)	High (Weekly – 4)
Probability (Table 6-9)	Improbable (2)	Highly Improbable (1)
Significance of Impact (Table 6-10 and Table 6-11)	**Low-Medium (66)**	**Low-Medium (55)**
Reversibility	High	High
Degree of Confidence	**Medium-high**	
Mitigation:	Mitigation not required, but the mine should: - Recommended that buildings and structures closer than 260 m from potential blasting area be relocated; - People and livestock to be moved further than 500 m from active blast before a blast is detonated; - Any evidence of fly rock is noted and the blast be analysed for possible improvements; - Consider the blast design to increase the stemming length to more than 2.2m; - Blaster to keep full records of blast (blast design, timing, explosive mass per blast hole, stemming, subdrill, spacing, burden, etc.).	

9.4 CLOSURE AND DECOMMISSIONING PHASE IMPACTS

No drilling and blasting is expected during the closure and decommissioning phase.

9.5 EVALUATION OF ALTERNATIVES

No alternatives were considered for this assessment.

Table 9-6: Potential responses to the blasting activities – optimized blast parameters

Description of Structure	Reference, see Figure 3-2	Distance from potential blast site (m)	PPV, 87.4 kg Blast Charge (mm/s)	PPV, 437 kg Blast Charge (mm/s)	Air blast level, 437 kg Blast Charge (dBA)	Potential structural damage		Potential Human Response		
						87.4 kg Blast Charge	437 kg Blast Charge	Vibration, 87.4 kg Blast Charge	Vibration, 437 kg Blast Charge	Air blast level, 437 kg Blast Charge
House	HS01	761	**0.8**	**3.0**	117	Very Low Risk	Very Low Risk	Detectable	Unpleasant	No Response
House	HS02	744	**0.8**	**3.2**	117	Very Low Risk	Very Low Risk	Detectable	Unpleasant	No Response
House	HS03	709	**0.9**	**3.4**	118	Very Low Risk	Very Low Risk	Detectable	Unpleasant	No Response
House	HS04	672	**1.0**	**3.7**	118	Very Low Risk	Very Low Risk	Detectable	Unpleasant	No Response
House	HS05	730	**0.9**	**3.3**	117	Very Low Risk	Very Low Risk	Detectable	Unpleasant	No Response
House	HS06	884	**0.6**	**2.4**	115	Very Low Risk	Very Low Risk	Detectable	Detectable	No Response
House	HS07	886	**0.6**	**2.4**	115	Very Low Risk	Very Low Risk	Detectable	Detectable	No Response
House	HS08	930	**0.6**	**2.2**	115	Very Low Risk	Very Low Risk	Detectable	Detectable	No Response
House	HS09	971	**0.5**	**2.0**	114	Very Low Risk	Very Low Risk	Detectable	Detectable	No Response
House	HS10	1960	**0.2**	**0.6**	107	Very Low Risk	Very Low Risk	Detectable	Detectable	No Response
House	HS11	1928	**0.2**	**0.7**	107	Very Low Risk	Very Low Risk	Detectable	Detectable	No Response
House	HS12	750	**0.8**	**3.1**	117	Very Low Risk	Very Low Risk	Detectable	Unpleasant	No Response
Boreholes	DBR02	836	**0.7**	**2.6**	116	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Boreholes	DBR01	473	**1.8**	**6.7**	122	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Bridge	BC01	1921	**0.2**	**0.7**	107	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Bridge	BC02	863	**0.7**	**2.5**	116	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Bridge	BC03	875	**0.6**	**2.4**	116	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Cement dam	DC01	820	**0.7**	**2.7**	116	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Cement dam	DC02	856	**0.7**	**2.5**	116	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Cement dam	DC03	714	**0.9**	**3.4**	118	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Cement dam	DC04	1465	**0.3**	**1.0**	110	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Cement dam	DC05	1639	**0.2**	**0.9**	109	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Structure	SS01	886	**0.6**	**2.4**	115	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Structure	SS02	845	**0.7**	**2.6**	116	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Structure	SS03	572	**1.3**	**4.9**	120	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Structure	SS04	1608	**0.2**	**0.9**	109	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant

Pylon	PE01	876	**0.6**	**2.4**	116	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE02	279	**4.2**	**15.9**	127	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE03	522	**1.5**	**5.7**	121	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE04	839	**0.7**	**2.6**	116	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE05	287	**4.0**	**15.2**	127	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE06	316	**3.4**	**12.9**	126	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE07	355	**2.8**	**10.7**	125	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE08	391	**2.4**	**9.1**	124	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE09	368	**2.7**	**10.1**	125	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE10	607	**1.2**	**4.4**	119	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE11	857	**0.7**	**2.5**	116	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE12	1178	**0.4**	**1.5**	112	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE13	1165	**0.4**	**1.5**	113	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE14	1040	**0.5**	**1.8**	114	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE15	957	**0.6**	**2.1**	115	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE16	935	**0.6**	**2.2**	115	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE17	960	**0.5**	**2.1**	115	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE18	1015	**0.5**	**1.9**	114	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE19	969	**0.5**	**2.0**	114	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE20	1500	**0.3**	**1.0**	110	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE21	1502	**0.3**	**1.0**	110	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE22	1714	**0.2**	**0.8**	109	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE23	1409	**0.3**	**1.1**	111	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE24	1452	**0.3**	**1.0**	110	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE25	1619	**0.2**	**0.9**	109	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE26	1877	**0.2**	**0.7**	108	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE27	1409	**0.3**	**1.1**	111	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE28	1653	**0.2**	**0.8**	109	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE29	1890	**0.2**	**0.7**	107	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE30	1828	**0.2**	**0.7**	108	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Pylon	PE31	1498	**0.3**	**1.0**	110	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant
Railway	Railway	774	**0.8**	**3.0**	117	Very Low Risk	Very Low Risk	Not relevant	Not relevant	Not relevant

10 MITIGATION OPTIONS

10.1 MITIGATION OPTIONS THAT SHOULD BE INCLUDED IN THE EMP AND ENVIRONMENTAL AUTHORIZATION

Mitigation is available that can and will reduce the potential magnitude of vibration and air blast levels and the significance of this impact. While the risks from blasting impacts are manageable, people are always concerned about the potential effects and dangers of blasting and measures are recommended for the applicant to note. The mitigation include technical as well as management measures:

- The Blasting Impact Assessment report must be updated if the blast design is changed where more than 500 kg explosives are detonated per delay.
- Mine to reduce the charge per delay (less than 437 kg) to ensure that maximum ground vibration levels are less than 2.54 mm/s when blasting has to take place within 850m from residential houses.
- Mine should initiate a forum to inform the close residents about the likely vibration and air blast levels, the proposed blasting schedule and warning methodology the mine will employ before a blast. When the residents are inside the house during a blast, vibration of windows and ceilings may appear excessive.
- Mine to erect blasting notice boards in the area with blasting dates and times highlighted.
- Mine to prevent blasting in adverse meteorological conditions where possible (overcast conditions, strong wind blowing in direction of local community, early in the mornings or late in the afternoon).
- People and livestock to be moved further than 500 m from active blast before a blast is detonated;
- Any evidence of fly rock further than 250 m from a blast is noted and the blast be analysed for possible improvements;
- Blaster to keep full records of blast (blast design, timing, explosive mass per blast hole, stemming, subdrill, spacing, burden, etc.).

11 CONCLUSION AND RECOMMENDATIONS

This blasting impact assessment covers the proposed development of the Dunbar Coal Project west of Hendrina, Mpumalanga, evaluating the potential impact due to blasting activities of the mine.

The potential impacts of ground vibration, air blast levels and fly rock risks were determined using methods provided by the USBM. A site specific blast design was not available and two blast designs were conceptualised based on information reported. This assessment indicated that:

- That ground vibration levels may be disturbing when blasting take place within 850m from residential houses (the unmitigated scenario for a 437 kg charge per delay). The impact may be of **Medium-High** significance and mitigation is available and proposed that will reduce the vibration levels to less than 2.54 mm/s within 850 m from the blast;
- That ground vibration levels may pose a risk of **Low-Medium** significance to potential sensitive residential building and structures in the vicinity of the mining area. Mitigation is available and proposed that will reduce the vibration levels to less than the recommended vibration limit for such sensitive structures;
- While there are other structures in the area such as power pylons, a railroad and road, risk of any damage to these structures due to the proposed blasting activities will be low;
- Air blast levels, while clearly audible to surrounding receptors, will be less than 120 dB at the surrounding residential dwellings;
- There are no risks of fly rock to people or residential structures, but blasting close to the mine infrastructure may result in fly rock damage and the rock fragments may pose a risk to road users. Management measures are available to ensure the risks are minimised.

The mine must know that community involvement needs to continue throughout the project. This is especially true for opencast mining projects close to residential dwellings. Blasting relates impacts are definite to upset the community and complaints will be one of the tools that the community may use to express their annoyance with the project, rather than a rational reaction to the vibration or air blast level itself.

At all stages surrounding receptors should be informed about the project, providing them with factual information without setting unrealistic expectations. Even with the best measures, blasting related impacts will be perceived and the community members may complain. It is therefore in the best interest of the mine to continually monitor and manage the blast in an effort to improve and minimise potential blasting effects. It is highly recommended that the mine conduct a detailed photographic survey at brick and cement residential houses (that does not belong to the applicant) located within 2,000m from the mine (from the opencast boundary limit) before the construction phase start. This should include a survey of all water boreholes and cement dams to determine the status of these structures.

It is concluded that, if the mine considers the recommendations in this report (incorporated in the Environmental Management Plan), that blasting risks do not constitute a fatal flaw. It is, therefore, the recommendation that the Dunbar Coal Project be authorized (from a blasting impact perspective) subject to compliance with the conditions of the EMP.

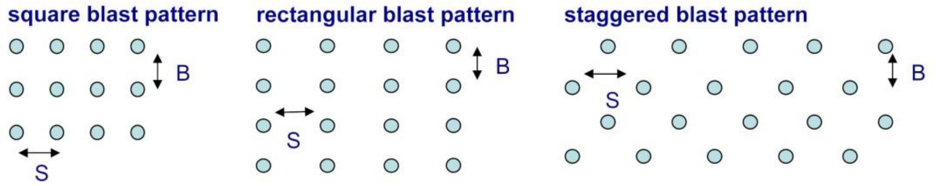
12 REFERENCES

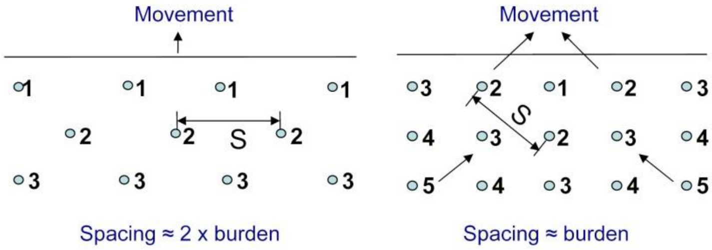
In this report reference was made to the following documentation:

1. Aloui, Monia *et al*. 2016: '*Ground Vibrations and Air Blast Effects Induced by Blasting in Open Pit Mines: Case of Metlaoui Mining Basin, Southwestern Tunisia*'. J Geol Geophys 2016, 5:3
2. Bender, L. Wesley. 2006 '*Understanding Blast Vibration and Air blast, their Causes, and their Damage Potential*'. Presented at the Golden West Chapter of the International Society of Explosives Engineers
3. CFR. '*Code of Federal Regulations'*. Washington, DC: Government Printing Office, Office of the Federal Register.
4. Chiappetta, RF. 2000: '*Vibration/air blast controls, Damage criteria, record keeping and dealing with complaints*'. The Institute of Quarrying, Southern Africa, Symposium, Durban.
5. Dyno Nobel, 2010: '*Blasting and Explosives Quick Reference Guide*'. Dyno Nobel Asia Pacific, Queensland
6. Griffin, MJ. 1996. '*Handbook of Human Vibration'.* Human Factors Research Unit, Institute of Sound and Vibration Research, The University, Southampton, U.K.
7. IME. 1997: '*Glossary of Commercial Explosives Industry Terms. Safety Publication No. 12*'. Institute of Makers of Explosives, Washington, D.C. 20036-3605
8. Kumar, R *et al*. 2016: '*Determination of blast-induced ground vibration equations for rocks using mechanical and geological properties*'. Journal of Rock Mechanics and Geotechnical Engineering 8 (2016)
9. Mansfield, NJ. 2005. *'Human Response to Vibration'*. CRC Press, London
10. Persson, PA, Holmberg, R and Lee, J. 1994: '*Rock Blasting and Explosives Engineering*'. CRC Press, USA.
11. Rosenthal, M. 1987: '*Blasting guidance manual*'. Office of Surface Mining Reclamation and Enforcement, United States Department of the Interior
12. Siskind, D.E., Stagg, M.S., Kopp, J.W. & Dowding, C.H. 1980. *'Structure Response and Damage Produced by Ground Vibration from Surface Mine Blasting'*. U.S. Bureau of Mines, RI 8507.
13. Siskind, D.E., Stachura, V.J., Stagg, M.S. & Kopp, J.W. 1980. *'Structure Response and Damage Produced by Air blast from Surface Mining*'. U.S. Bureau of Mines, RI 8485
14. Workman, J.L., and Calder, P.N. 1994. '*Flyrock prediction and control in surface mine blasting*'. United States.

APPENDIX A

Glossary of Blasting Terms, Definitions and General Information

Air blast	Any blast delivers a shock wave through the air that begins with the actual explosion.
Ammonium Nitrate	NH_4NO_3, which is the ammonium salt of nitric acid.
ANFO	An amalgamation of ammonium nitrate and fuel oil that is highly explosive.
Blast Area	The full area that can experience any flying rock, debris or gas during and after a blast.
Blast Pattern	The array of locations for blast holes and/or the relationship between burden (B) and spacing (S) distance. 
Blasting Vibrations	The post-blast energy that travels through the earth away from the blast area.
Burden	The amount of rock broken and displaced by a blast as measured by the distance between the closest free face and the actual blasting hole.
Charge per Delay	The total charge mass firing during any given span of 8 milliseconds, also known as blast holes per delay
Decibel	A unit typically used to measure the air overpressure of an air blast.
Decking	The use of hole plugs or inert material to create a section without explosives in a blast hole, dividing the charge hole into a "top" and "bottom" deck. It is used to reduce either the charge load per hole, the amount of explosives detonated per delay, to keep explosives out of weak zones or a combination of these.
Delay	A pre-planned and distinct pause between detonations or initiations to allow for explosive to fire separately.
Detonation	The explosive reaction that moves through explosive materials at a speed greater than the speed of sound.
Fly rock	The rocks propelled by an explosion's force in the blast area.
Free Face	Rock surfaces adjacent to water or air that allow for expansion at the time of fragmentation.
Ground Vibration	The shaking of the ground as caused by the shock waves emanating from a blast.
Interested and Affected Party	These are individuals or groups concerned with or affected by the environmental impacts and performance of a project. Interested groups include those exercising statutory environmental control over the project, local residents/communities (people living and/or working close to the project), the project's employees, customers, consumers, investors and insurers, environmental interest groups, the general public, etc. It covers: • Host Communities • Landowners (Traditional and Title Deed owners) • Traditional Authority • Land Claimants • Lawful land occupier • Any other person (including on adjacent and non-adjacent properties) whose socio-economic conditions may be directly affected by the proposed prospecting or mining operation • The Local Municipality • The relevant Government Departments, agencies and institutions responsible for the various aspects of the environment and for infrastructure which may be affected by the proposed project.
Particle Velocity	The rate at which vibrations travel through the ground as measured by the time rate of change of the ground vibration's amplitude.

Peak Particle Velocity	The maximum intensity of ground vibration during a blast.
Pre-blast Condition Survey	The area within 200 meter of the blasting site is commonly surveyed within a month of the blasting, including utilities, buildings, improvements and more.
Presplitting	A technique for controlled blasting that creates a continuous or semi-continuous fracture in the space between blast holes.
Propagation	When explosive charges detonate due to an impulse from another nearby or adjacent detonation of explosives.
Receptor	Target or object on which the impact, stressor or hazard is expected to have an effect.
Scaled Distance	The relative vibration energy as measured by the distance between a charge per delay and a structure.
Seismograph	An instrument used to record ground vibrations.
Shock Wave	The transient pressure pulse that moves at a supersonic velocity.
Spacing	The distance spanning blast holes lined up in a row, measured perpendicular to the burden. 
Specific Gravity	A ratio that expresses the weight of pure water to the weight of an equal volume of another substance.
Stemming	A technique used for limited air-overpressure and rock movement that involves drilling a blast hole beyond or below the desired excavation limit or depth. Stemming contains explosive energy within a blast hole, so that it will break and move the rock without generating flyrock. Sized crushed stone or drill cuttings should be used as stemming.
Sub drilling	The drilling of a blast hole or a portion of a blast hole below or beyond the planned excavation depth or limit. The subdrill portion of a borehole is generally backfilled with drill cuttings or other stemming material and does not contain explosives.
Under-burdened	A hole drilled too close to the face of the blast with not enough rock to effectively contain the explosion and expanding gasses resulting in dangerous fly rock and excessive air blast.
Vibration Limits	Blasting causes vibration in surrounding structures, and this vibration is limited (in inches per second) depending on the types of buildings in the immediate vicinity (residential, commercial, public, historic, etc.)
Warning Signal	Any signal given visually or audibly that warns personnel and bystanders in a blast area's vicinity of the impending explosion.

APPENDIX B

Effect of Blast Vibration on Materials and Structures

PPV (Inch/s)	PPV (mm/s)	Application	Effect	Source
600	15240	Explosive inside concrete	Explosive inside concrete Mass blowout of concrete	Tart, 1980
375	9525	Explosive inside concrete	Explosive inside concrete Radial cracks develop in concrete	Tart, 1980
200	5080	Explosive inside concrete	Explosive inside concrete Spalling of loose/weathered concrete skin	Tart, 1980
> 100	>2540	Rock	Complete breakup of rock masses	Bauer, 1978
100	2540	Explosive inside concrete	Spalling of fresh grout	Tart, 1980
100	2540	Explosive near concrete	No damage	Oriard, 1980
50 - 150	1270 - 3810	Explosive near buried pipe	No damage	Oriard, 1994
25 - 100	635 - 2540	Rock	Tensile and some radial cracking	Bauer, 1978
40	1016	Mechanical equipment	Shafts misaligned	Bauer, 1977
25	635	Explosive near buried pipe	No damage	Siskind, 1993
25	635	Rock	Damage can occur in rock masses	Oriard, 1970
25	635	Rock	Minor tensile slabbing	Bauer, 1978
24	610	Rock	Rock fracturing	Langefors, 1948
15	381	Cased drill holes	Horizontal offset	Bauer, 1977
> 12	>305	Rock	Rockfalls in underground tunnels	Langefors, 1948
12	305	Rock	Rockfalls in unlined tunnels	Blasters' Handbook, 1977
< 10	<254	Rock	No fracturing of intact rock	Bauer, 1978
9.1	231	Residential structures	Serious cracking	Langefors, 1948
8	203	Concrete blocks	Cracking in blocks	Bauer, 1977
8	203	Plaster	Major cracking	Northwood, 1963
7.6	193	Plaster	50% probability of major damage	Blasters' Handbook, 1977
7.0 - 8.0	178 - 203	Cased water wells	No adverse effect on well	Rose, 1991
> 7.0	> 178	Residential structure	Major damage possible	Nicholls, 1971
4.0 - 7.0	101 - 178	Residential structure	Minor damage possible e	Nicholls, 1971
6.3	160	Residential structure	Plaster and masonry walls crack	Langefors, 1948
5.44	138	Water wells	No change in well performance	Robertson, 1980
5.4	137	Plaster	50% probability of minor damage	Blasters' Handbook, 1977
4.5	114	Plaster	Minor cracking	Northwood, 1963
4.3	109	Residential structure	Fine cracks in plaster	Langefors, 1948
> 4.0	> 102	Residential structure	Probable damage	Edwards, 1960
2.0 - 4.0	50 - 100	Residential structure	Residential structure Plaster cracking (cosmetic)	Nicholls, 1971
2.8 - 3.3	71 - 83.8	Plaster	Threshold of damage (from close-in blasts)	Blasters' Handbook, 1977
3	76.2	Plaster	Threshold of cosmetic cracking	Northwood, 1963
1.2 - 3.0	31 - 76	Residential structure	Equals stress from daily environmental changes	Stagg, 1980
2.8	71	Residential structure	No damage	Langefors, 1948
2	50	Residential structure	Plaster can start to crack	Bauer, 1977
2	50	Plaster	Safe level of vibration	Blasters' Handbook, 1977
< 2.0	< 50	Residential structure	No damage	Nicholls, 1971
< 2.0	< 50	Residential structure	No damage	Edwards, 1960
0.9	23	Residential structure	Equivalent to nail driving	Stagg, 1980
0.5	13	Mercury switch	Trip switch	Bauer, 1977
0.5	13	Residential structure	Equivalent to door slam	Stagg, 1980
0.1 - 0.5	2.54 - 12	Residential structure	Equates to normal daily family activity	Stagg, 1980
0.3	7.62	Residential structure	Equivalent to jumping on the floor	Stagg, 1980
0.03	0.762	Residential structure	Equivalent to walking on the floor	Stagg, 1980

End of Report page

End of Report