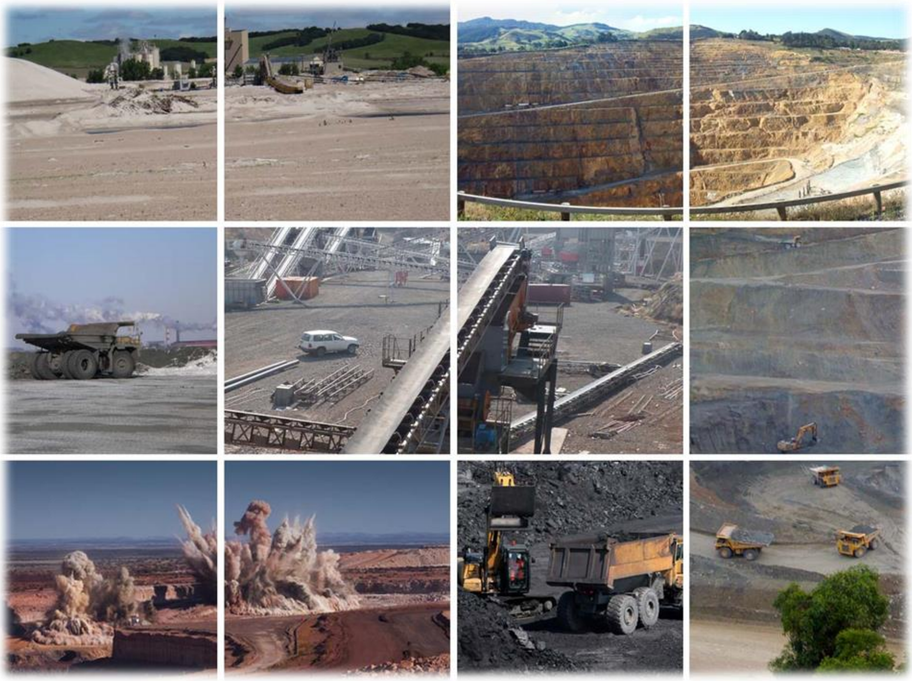
Nozala Coal (Pty) Ltd

BLASTING IMPACT ASSESSMENT

for the

Proposed Gruisfontein Colliery

near Steenbokpan, Limpopo Province



Study done for:

JACANA environmentals cc

Prepared by:

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EXECUTIVE SUMMARY

INTRODUCTION AND PURPOSE

Enviro-Acoustic Research (EARES) was contracted by Jacana Environmentals CC (Jacana in this report) to determine the potential impact due to blasting activities on the surrounding environment due to the proposed development of a coal mine. This operation will be located approximately 60km west of the town of Lephalale in the Limpopo 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.

PROJECT DESCRIPTION

Nozala Coal (Pty) Ltd (the Applicant) proposes to mine coal on the farm Gruisfontein. They propose to mine coal by means of conventional openpit methods to a depth of up to 140 meters below surface (mbs).

The project life of mine (LOM) schedule was determined to be a minimum of 15 years with an annual ROM production rate of ± 6.0 Mtpa during steady state. The mine will operate on a seven-day week with a 24-hour production shift per day.

The Mine Works Program (MWP) calculated that the project will have to drill, blast and haul approximately 47 Mbcm of hard overburden and carbonaceous material in 10 cuts (benches), with each cut optimized to maximize the extraction of the coal resource. This equate to the drilling, blasting and hauling of around 1,9 Mbcm of hard overburden during the first year of operation to almost 4.4 Mbcm of hard overburden during year 13.

POTENTIAL SENSITIVE STRUCTURES AND RECEPTORS

The area is sparsely populated with the closest houses further than 3,000m from the project site. A number of the residential dwellings are only used on a temporary basis; some houses are used by farm labour with other dwellings used for tourism. The closest potential sensitive structures are boreholes and cement dams, of critical importance to the farmers in the area.

BLASTING IMPACT FINDINGS

The potential impacts of ground vibration, airblast 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 available. In total four options were assessed, namely unmitigated options with up to 17 blast holes fired simultaneously for the average and maximum borehole depths, and mitigated options where controlled blasting (times blasts) are used to only fire one blast hole at a time. This assessment indicated that:

- ground vibration levels may be disturbing (unpleasant) when blasting take place within 3,500m from residential houses (the unmitigated scenario). The impact may be of high significance and mitigation (such as controlled blasting) is available and proposed that will reduce the vibration levels to less than 2.54 mm/s within 3,500 m from the blast;
- ground vibration levels may pose a risk of damage to potential sensitive structures when blasting take place within 1,600m from these structures (the unmitigated scenario). 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 at 1,600 m from the blast;
- airblast levels, while clearly audible to surrounding receptors, will be less than 120 dB;
- 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 and controlled blasting methods will be used to ensure blasted material is thrown away from mining infrastructure.

PROPOSED MITIGATION

Mitigation is available that can and will reduce the potential magnitude of vibration and airblast levels and the significance of this impact. The mitigation include technical as well as management measures.

- This report must be updated if the blast design changed in any manner.
- Mine to implement a vibration and airblast measurement programme to allow the monitoring of all blasts during the first year. This data must be analysed and the blast impact assessment be reviewed and updated.
- Mine to initiate a forum to inform the close residents about the likely vibration and airblast levels (provide access to this report), the proposed blasting schedule and warning methodology the mine will employ before a blast. Residents should realise the potential magnitude of the airblast and vibration levels, and when the residents are inside the house during a blast, vibration of windows and ceilings may appear excessive.
- Mine to reduce the charge per delay to ensure that;
    - maximum ground vibration levels are less than 2.54 mm/s when blasting has to take place within 3,500m from dwellings used for residential purposes. This can be accomplished by reducing the charge per delay to less than 13,000 kg;
    - maximum ground vibration levels are less than 25 mm/s when blasting has to take place within 1,600m from identified potential sensitive structures. This can be accomplished by reducing the charge per delay to less than 2,985 kg.
- Mine to erect blasting notice boards in the area (on the main access route from the district road to the mine) with blasting dates and times highlighted.
- Any evidence of fly rock 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.).

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 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 airblast 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 however highly recommended that the mine conduct a detailed photographic survey at all houses and structures located within 3,500m 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 Gruisfontein Colliery is 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

Contents of this report in terms of Regulation GNR 982 of 2014, Appendix 6 (as amended 2017)		**Relevant Section of Specialist study**
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	No comments received
(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 Gruisfontein Colliery near Steenbokpan, Limpopo Province*". Enviro-Acoustic Research CC, Pretoria

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JE-GC/BIA/201904-Rev 0

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April 2019

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GLOSSARY OF ABBREVIATIONS

ANFO	Ammonium Nitrate Fuel Oil
EIA	Environmental Impact Assessment
EHS	Environmental, Health, and Safety
EMP	Environment Management Programme
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:

2019 – 08 - 29

3 INTRODUCTION

3.1 INTRODUCTION AND PURPOSE

Enviro-Acoustic Research (EARES) was contracted by Jacana Environmentals CC (Jacana in this report) to determine the potential impact due to blasting activities on the surrounding environment due to the proposed development of a coal mine. This operation will be located approximately 60km west of the town of Lephalale in Gauteng 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

Nozala Coal (Pty) Ltd (the Applicant) proposes to mine coal on the farm Gruisfontein. They propose to mine coal by means of conventional openpit methods to a depth of up to 140 meters below surface (mbs).

The project life of mine (LOM) schedule was determined to be a minimum of 15 years with an annual ROM production rate of ± 6.0 Mtpa during steady state. The mine will operate on a seven-day week with a 24-hour production shift per day.

The Mine Works Program (MWP) calculated that the project will have to drill, blast and haul approximately 47 Mbcm of hard overburden and carbonaceous material in 10 cuts (benches), with each cut optimized to maximize the extraction of the coal resource. This equates to the drilling, blasting and hauling of around 1,9 Mbcm of hard overburden during the first year of operation to almost 4.4 Mbcm of hard overburden during year 13.

3.2.2 Study area and Potential Sensitive Structures

Figure 3-1 illustrates identified the closest Potential Sensitive Structures (PSS) that may be affected by blasting activities, with **Figure 3-2** depicting a number of structures (including boreholes, sheds, cement dams, windpumps, etc.) and residential dwellings as identified by the Environmental Assessment Practitioner (EAP). Also indicated are buffer areas of 500 m as well as 1,000 m:

- Area within the 500 m buffer from opencast limits: Area around the mine pit where people and animals will be moved prior to blasting during some future stage of mining. Ground vibration and air blast levels likely to be high with a significant risk of fly-rock closer to the blast area.
- Area 500 to 2,000 m from opencast limits: Area outside the zone where fly rock may be a concern.

    - In the unmanaged situation ground vibration and air blast levels will 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:
    - In the unmanaged situation ground vibration and air blast levels could result in concerns and potential complaints.
    - In a managed (controlled blasting) situation ground vibration and air blast levels will be very 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 (such as the resonance from flat surfaces potentially perceived as vibration) of blasting 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

There are an unpaved district road that passes the site on the north (5,000m) and west (4,000 m +). The risk of blasting damage to these roads is insignificant.

3.2.2.2 Power Pylons and lines

There are currently no major power pylons lines close to the project area although there is there is a possibility of Eskom supply to the southern portion of the Gruisfontein property.

3.2.2.3 Structures

Excluding the structures located directly on the farm Gruisfontein, there are no other potential blast-sensitive structures located within 500 m from the proposed opencast limits, with the all potential sensitive structures (PSS) located further than 1,000 m from the closest location where blasting may take place (see also **Figure 3-1**).

3.3 CURRENT IMPACTS

There are no mining close to the area that could create ground vibration or result in any significant air blast levels. No measurements of existing ground vibration or air blast levels were necessary or measured.

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 openpit mining activities. This study therefore specifically would assess the potential blasting impacts from 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. 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.

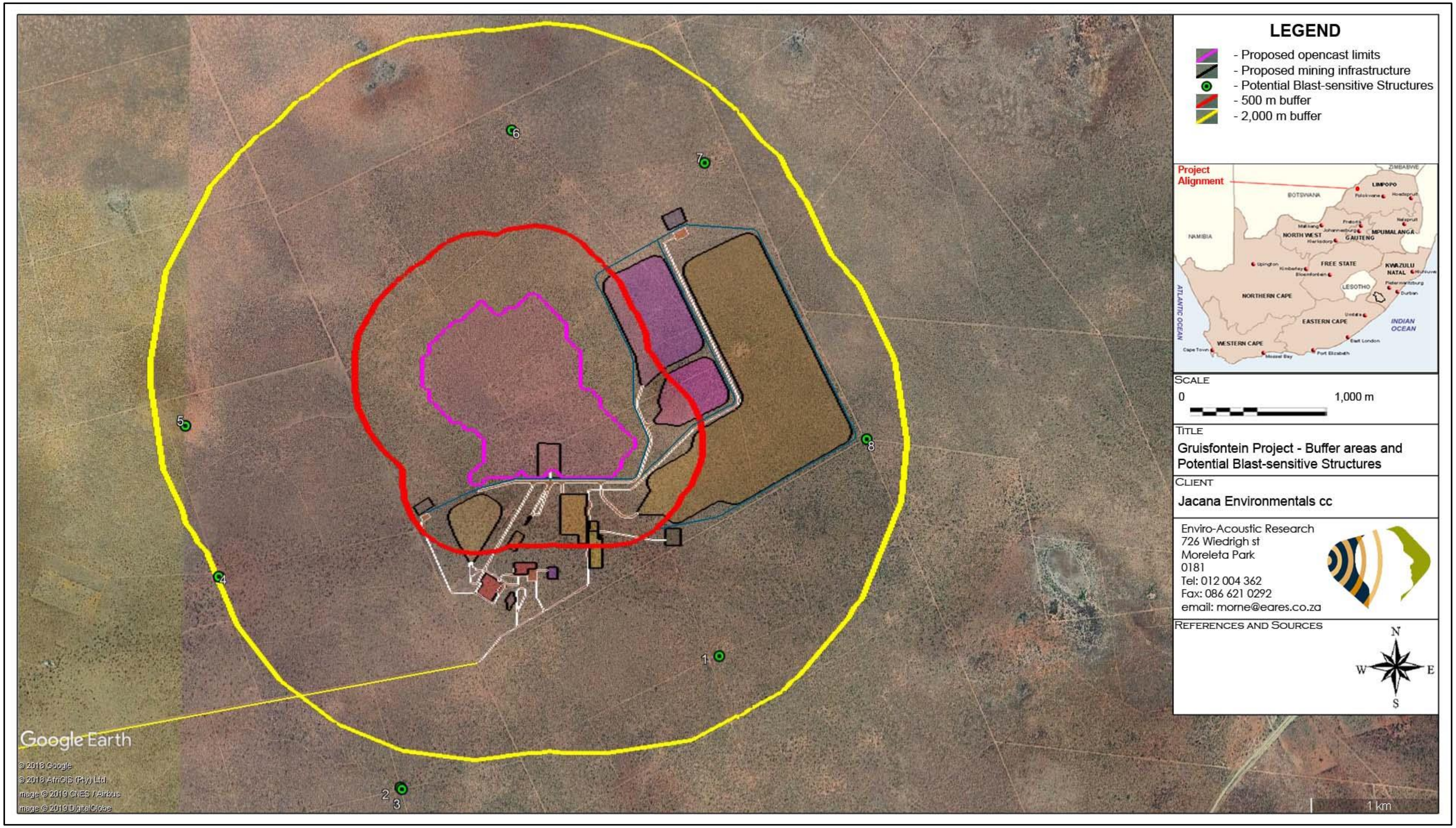

Figure 3-1: Aerial image indicating potentially PSS within 2,000m of potential blasting area

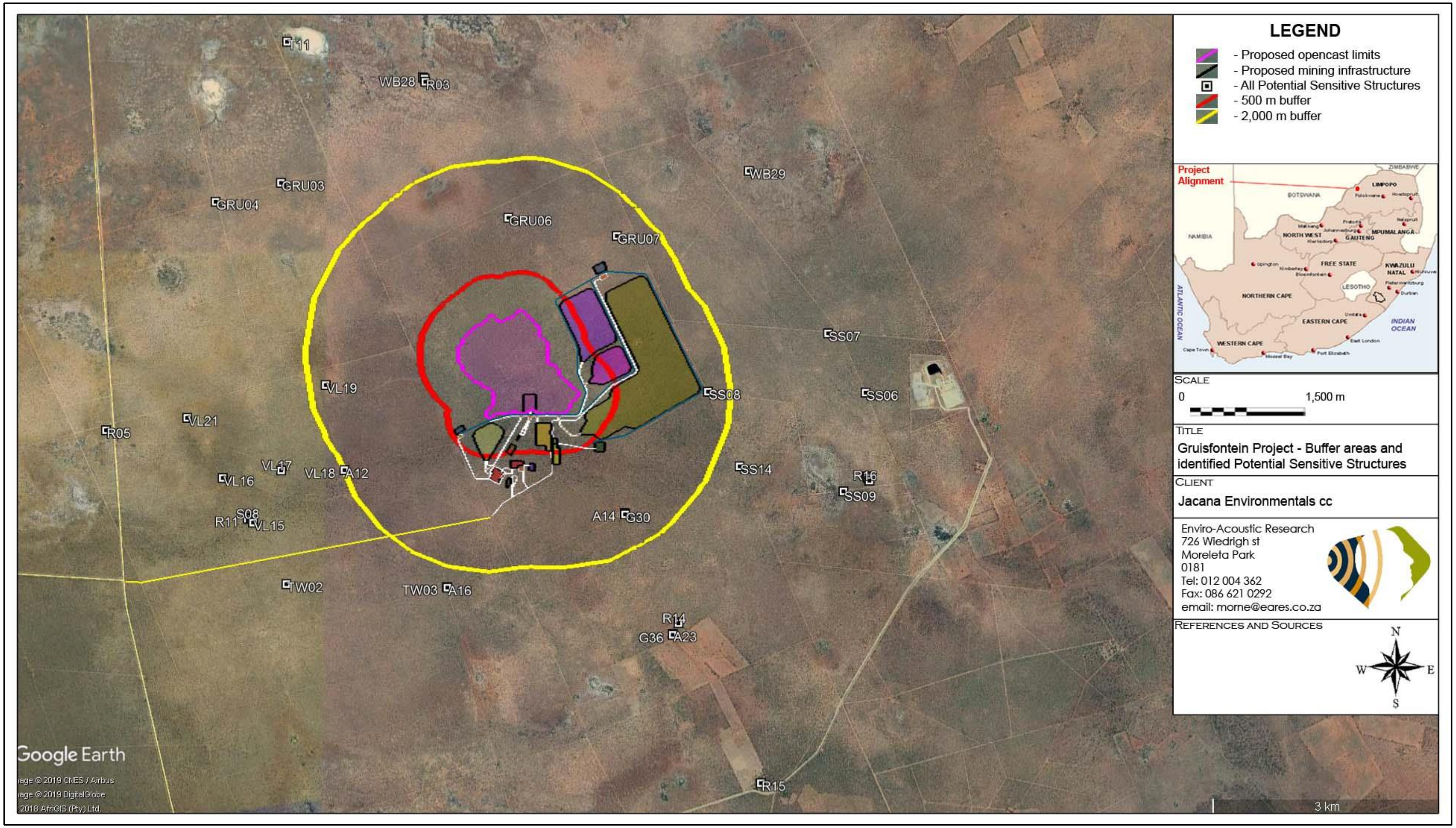

Figure 3-2: Aerial image indicating all PSS identified by the EAP close to the proposed project area

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 can 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 limit the distances that fly rock travels.

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.

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

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

Where:

L_{AB} = Noise levels due to air blast (dB)

D = distance from blast (m)

Q = instantaneous charge mass (kg)

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.

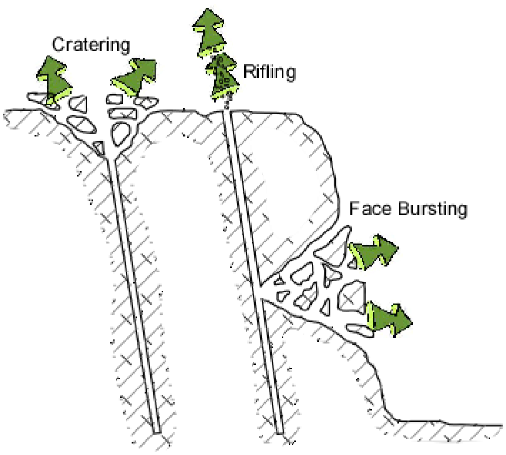

Figure 5-1: Illustration of sources of fly rock

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

$$\textbf{Face bursting} \quad D_{FB} = \frac{k^2}{g}\left(\frac{\sqrt{m}}{B}\right)^{2.6}$$ **Equation 3**

$$\textbf{Cratering} \quad D_C = \frac{k^2}{g}\left(\frac{\sqrt{m}}{SH}\right)^{2.6}$$ **Equation 4**

$$\textbf{Rifling} \quad D_R = \frac{k^2}{g}\left(\frac{\sqrt{m}}{SH}\right)^{2.6} \sin\theta$$ **Equation 5**

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).

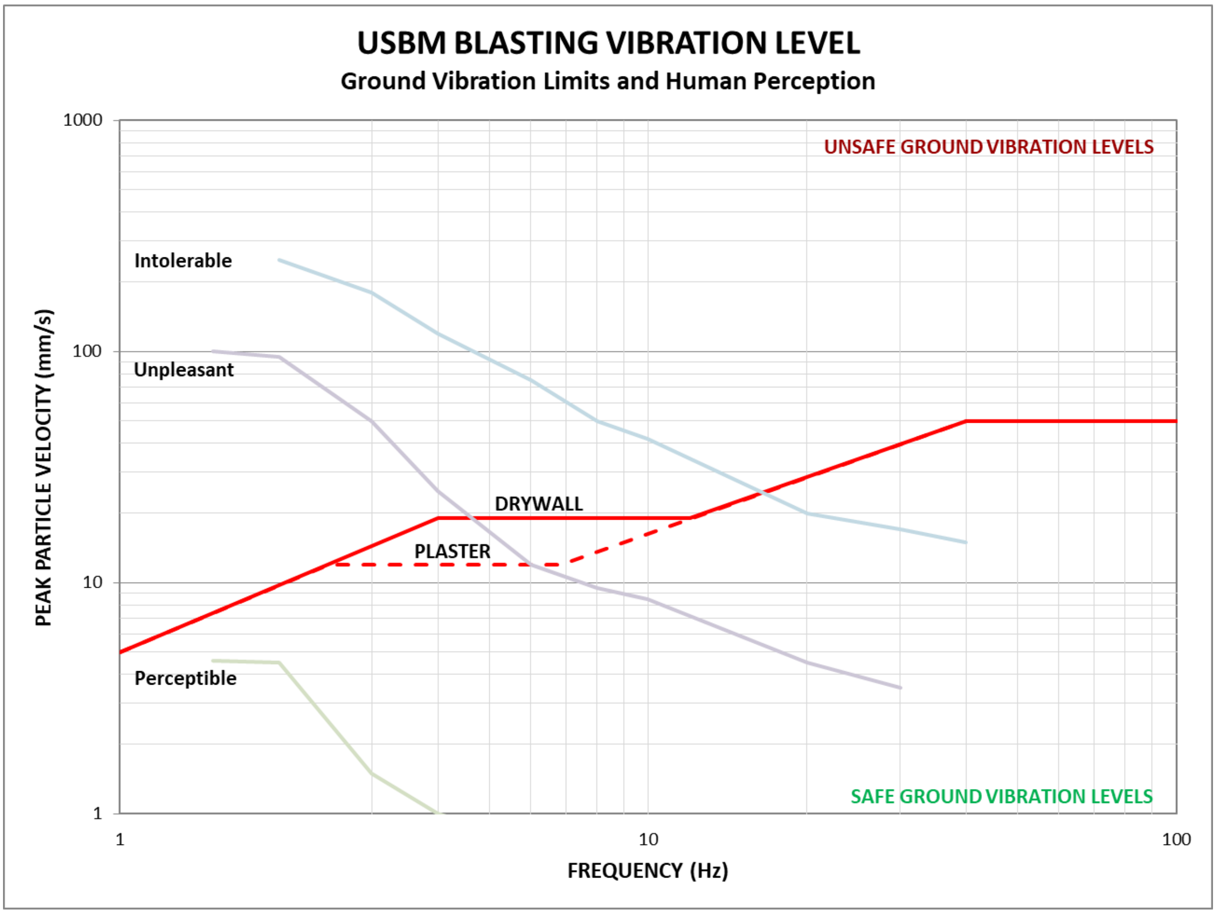

Figure 6-1: Human vibration sensitivities and potential structural damage compared to the RI 8507 limits

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).

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, in 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, windows 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), is defined in **Table 6-3**.

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

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.

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.

The level of detail as depicted in the EIA regulations was fine-tuned by assigning specific values to each impact. In order to establish a coherent framework within which all impacts could be objectively assessed, it was necessary to establish a rating system, which was applied consistently to all the criteria. For such purposes, each aspect was assigned a value as defined in the third column in the tables below.

The impact consequence is determined by summing the scores of Magnitude (**Table 6-4**), Duration and Spatial Extent. The impact significance is determined by multiplying the Consequence result with the Probability score (**Table 6-5**).

Duration and Spatial extent will be:

- Long term: Blasting activities will last for the duration of the project in the area; and
- Local: 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 almost always limited to a zone within 1,000 m from the blast.

In addition, due to the significant risk of blasting, probability will only consider two scales, no risk (improbable) or risk (Definite / Possible / Likely).

Table 6-4: Impact Assessment Criteria – Magnitude

This defines the impact as experienced by any receptor. In this report the receptor is defined as any potential sensitive structure.		
Rating	**Description**	**Score**
Low	Ground vibration levels less than 0.254 mm/s. Air blast levels less than 115 dB	2
Low Medium	Ground vibration levels more than 0.254 but less than 0.762 mm/s. Air blast levels more than 115 but less than 120 dB	4
Medium	Ground vibration levels more than 0.762 but less than 2.54 mm/s. Air blast levels more than 120 but less than 130 dB	6
High	Ground vibration levels more than 2.54 but less than 7.62 mm/s. Potential for damage in adobe structures. Air blast levels more than 120 but less than 134 dB	8
Very High	Ground vibration levels more than 7.62 mm/s. Potential for damage in adobe structures. Air blast levels exceeding 134 dB	10

Table 6-5: Impact Assessment Criteria - Probability

This describes the likelihood of the impacts actually occurring, and whether it will impact on an identified receptor. The impact may occur for any length of time during the life cycle of the activity, and not at any given time. The classes are rated as follows:		
Rating	**Description**	**Score**
Improbable	The possibility of the impact occurring is none, due either to the circumstances, design or experience. The chance of this impact occurring is zero (0%).	1
Definite / Possible / Likely	The impact will take place regardless of any prevention plans, and only mitigation actions or contingency plans to contain the effect can be relied on. The chance of this impact occurring is defined to be between 75% and 100%.	5

In order to assess each of these factors for each impact, the following ranking scales as contained in **Table 6-6** were used.

Table 6-6: Assessment Criteria: Ranking Scales

PROBABILITY		MAGNITUDE	
Description / Meaning	**Score**	**Description / Meaning**	**Score**
Definite/don't know/Possible/ Likely	5	Very high/don't know	10
		High	8
		Medium	6
		Low Medium	4
Improbable	1	Low	2
DURATION		**SPATIAL SCALE**	
Description / Meaning	**Score**	**Description / Meaning**	**Score**
Long Term	4	Local	2

Following the assignment of the necessary weights to the respective aspects, criteria are summed and multiplied by their assigned probabilities, resulting in a Significance Rating (SR) value for each impact (prior to the implementation of mitigation measures). Significance without mitigation is rated on the following scale:

SR<30	Low (L)	Impacts with little real effect and which should not have an influence on or require modification of the project design or alternative mitigation. No mitigation is required.
SR>30	High (H)	The impact is significant, mitigation is critical to reduce impact or risk. Resulting impact could influence the decision depending on the possible mitigation. An impact which could influence the decision about whether or not to proceed with the project.

In order to gain a comprehensive understanding of the overall significance of the impact, after the implementation of the mitigation measures, it was necessary to re-evaluate the impact. Significance with mitigation is rated on the following scale:

SR<30	Low (L)	The impact is mitigated to the point where it is of limited importance.
SR>30	High (H)	The impact is of major importance. Mitigation of the impact is not possible on a cost-effective basis. The impact is regarded of high importance and taken within the overall context of the project, is regarded as a fatal flaw. An impact regarded as high significance after mitigation could render the entire development option or entire project proposal unacceptable.

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, though a blast design was available for a proposed project in the area. Information was identified and used from this blast design report to ensure that a worst-case scenario was assessed.
- This impact assessment does not make a statement on the acceptability of the blast design (viable bench height, fracturing, powder factors, etc.) and only assesses the potential impacts considering the available information.
- A square blast pattern (diamond tie-in for timing the blast) is considered for the mine.
- A delay of 25ms per charge (with a maximum of 17 holes per charge) will be used in the unmanaged situation as reported. The managed situation would be the blasting of 1 hole per charge using delays.
- None of the structures were visited to confirm the status of each house. 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 2,000 m from the proposed opencast limits to determine the status and state of the structures before the construction of the mine start.
- There are a dwelling located within the mining infrastructure area. It will be accepted that the mine will relocate the residents.
- Stemming will be between 20x borehole diameter and 1x the burden to manage blasting impacts. The stemming material will be an 8 – 13 mm aggregate.
- Overburden (hard overburden from surface to first coal seam) range between 20 and 31 m. This assessment will consider the average borehole depth (discussion, Mr. Michael Wright) as well as the potential maximum blast borehole (31 m).
- 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; a potential inversion layer 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. The main difference is that coal will also be drilled and blasted during the operational phase. Being softer than the hard overburden, coal blasts are generally smaller, utilising less explosives resulting in lower vibration and air blast levels.

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	Average borehole design	Maximum borehole depth
Average depth of borehole, including subdrill (m)	24.1	31.2
Bench height (m)	24.1	31.2
Subdrill (m)	0	0
Borehole diameter (mm)	250	250
Burden (m)	7.2	7.5
Spacing (m)	8.3	8.6
Stemming Length (m)	5	5
Column length (m)	19.1	26.2
Explosive density (g/cm^3)	1.15	1.15
Explosives per borehole (kg)	1,078.2	1,479.0
Charge mass per meter (kg/m)	56.45	56.45
Maximum number of blast holes per delay	17	17
Maximum explosive per delay (kg)	18,329.48	25,143.05
Blast area length (m)	150	150
Blast area width (m)	70	70
Powder Factor (kg/m^3)	0.75	0.73

8.1 PROJECTED MAGNITUDE OF GROUND VIBRATION

As discussed in **section 5.1**, the accepted method of a scaled distance in 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 fired per instance.

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 fired per instance. This is referred as the “charge per delay mass”.

Therefore, using Equation 1, the potential ground vibration can be calculated for these average (see **Figure 8-1** for graph of PPV over distance) and maximum (see **Figure 8-2** for graph of PPV over distance) borehole depths with the extent of the impact (6 mm/s limit for the two options) illustrated on an aerial images as follows;

- **Figure 8-5** for an average borehole depth of 24.1 m, with 17 boreholes blasted simultaneously (18,329 kg explosive per delay) as well as a singular blast of 1,078 kg explosive (managed by using delays between each blasthole in a row);
- **Figure 8-6** for the maximum borehole depth of 31.2 m, with 17 boreholes blasted simultaneously (25,143 kg explosive per delay) as well as a singular blast of 1,479 kg explosive (managed by using delays between each blasthole in a row).

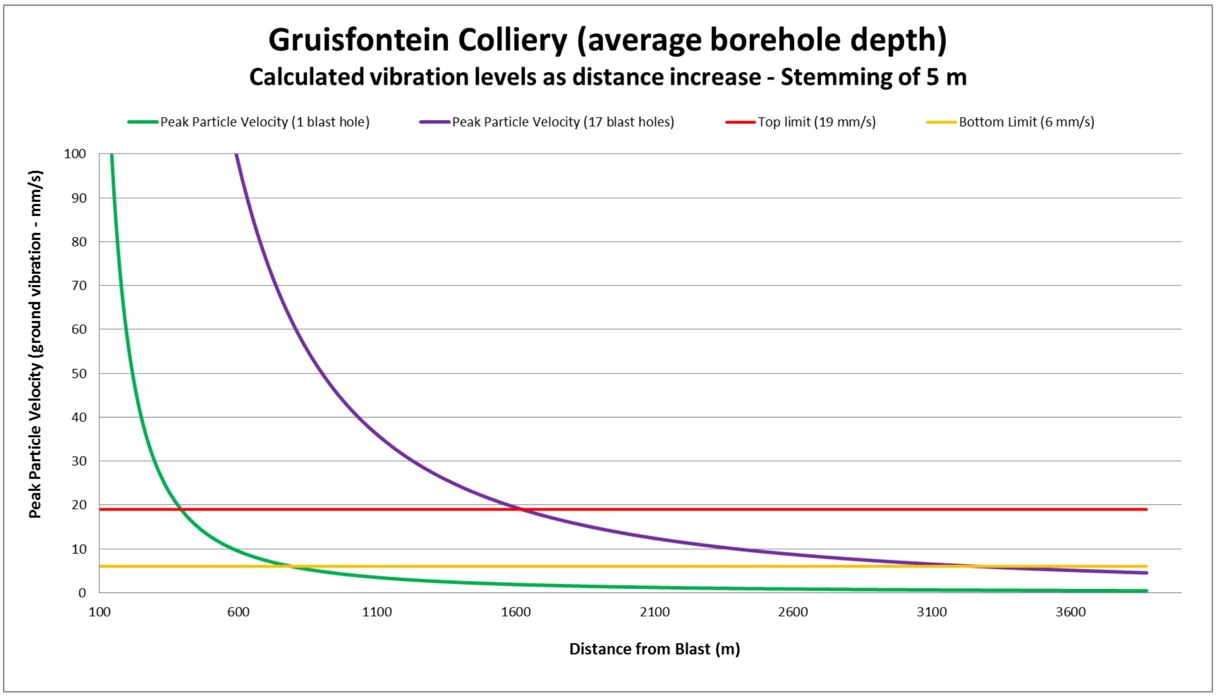

Figure 8-1: Ground vibration levels as the distance increase for average borehole depth (24.1 m)

8.2 PROJECTED MAGNITUDE OF AIR BLAST

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).

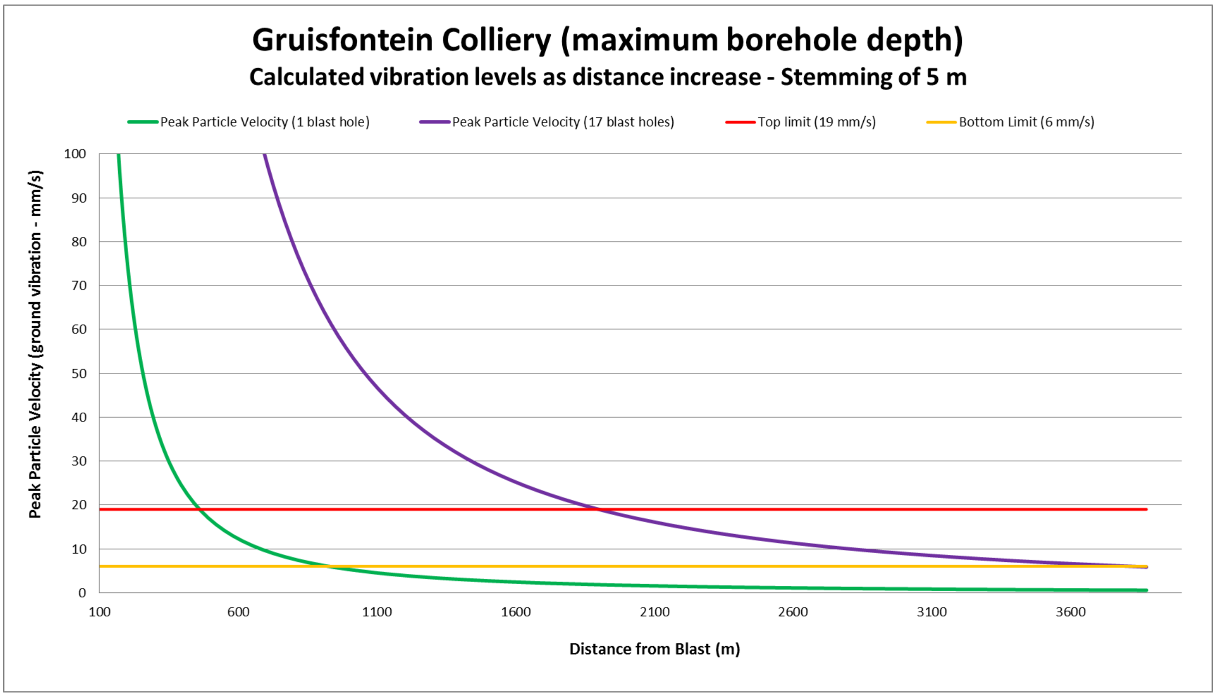

Figure 8-2: Ground vibration levels as the distance increase for average borehole depth (31.2 m)

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 (average and maximum borehole depth) will again be considered. Using Equation 2, the potential air blast level can be calculated for the two options as indicated in **Figure 8-3** and **Figure 8-4** with the extend of the impact (6 mm/s limit for the two options) illustrated on an aerial image on **Figure 8-7** and **Figure 8-8**.

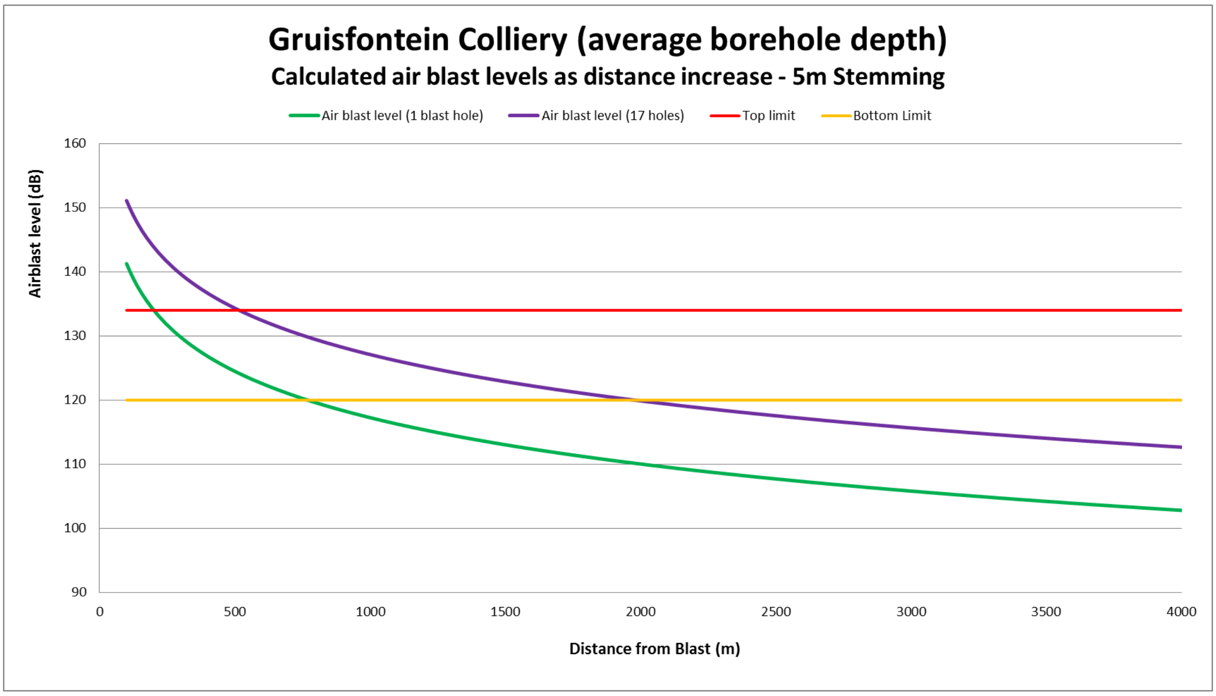

Figure 8-3: Air blast levels as the distance increase for average borehole depth (24.1 m)

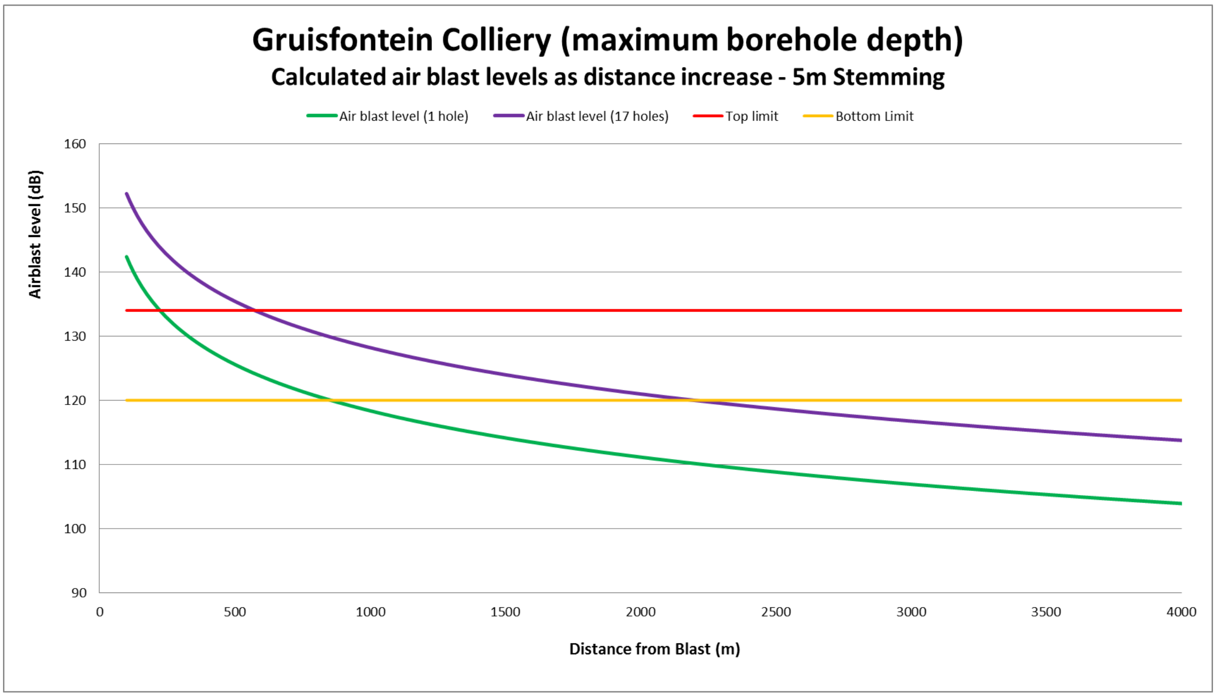

Figure 8-4: Air blast levels as the distance increase for maximum borehole depth (31.2 m)

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 8-9**. 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 (no equipment, people or livestock).

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

Fly rock type	Value (m)
Face bursting	83
Cratering	214
Rifling	73

8.4 Potential Decommissioning, Closure and Post-closure Blasting Impacts

There is no, or small blasting impact risk 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.

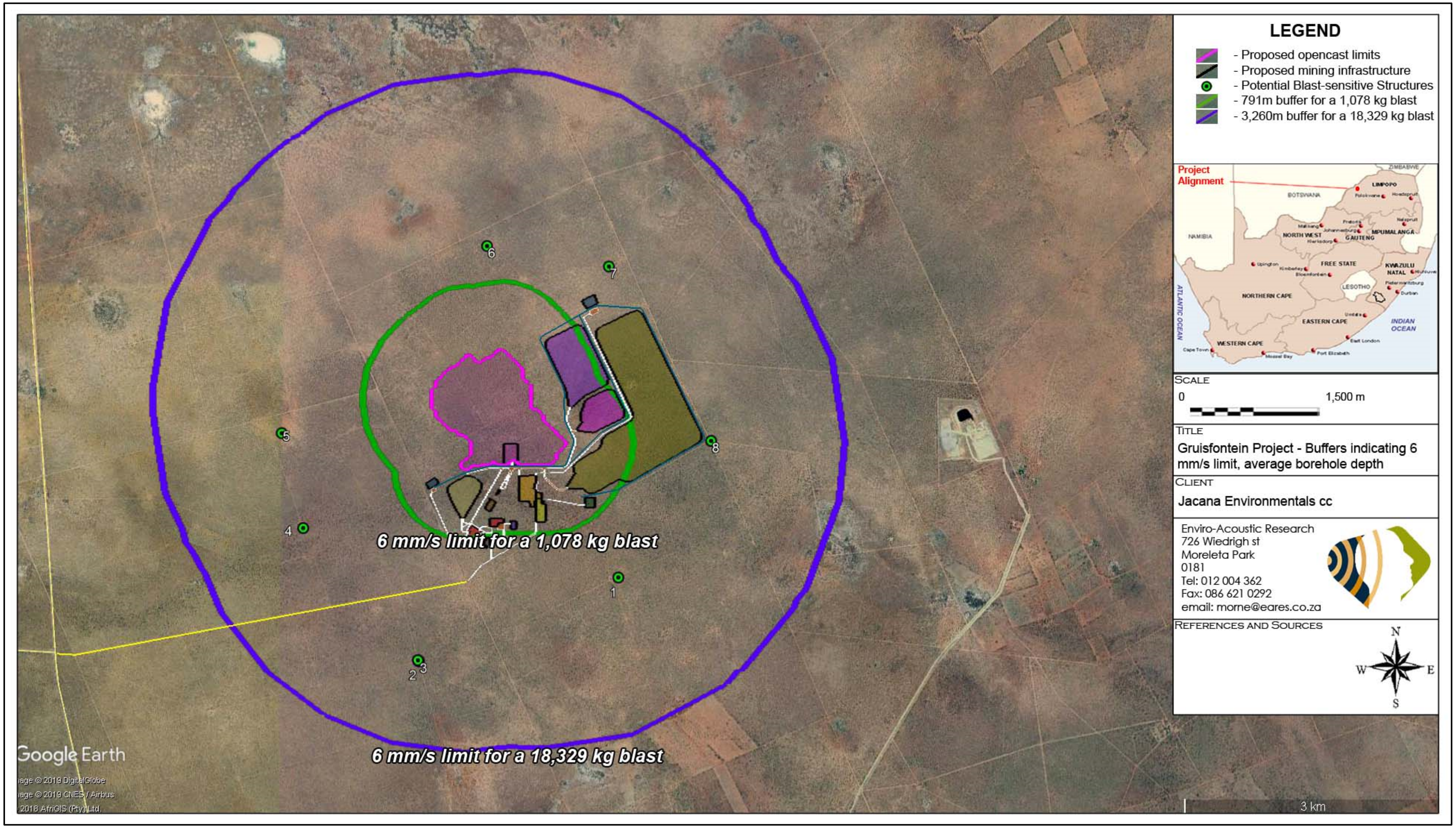

Figure 8-5: Projected Extend of Blasting Impacts – Ground Vibration with a stemming of 5 m for a borehole depth of 24.1 m

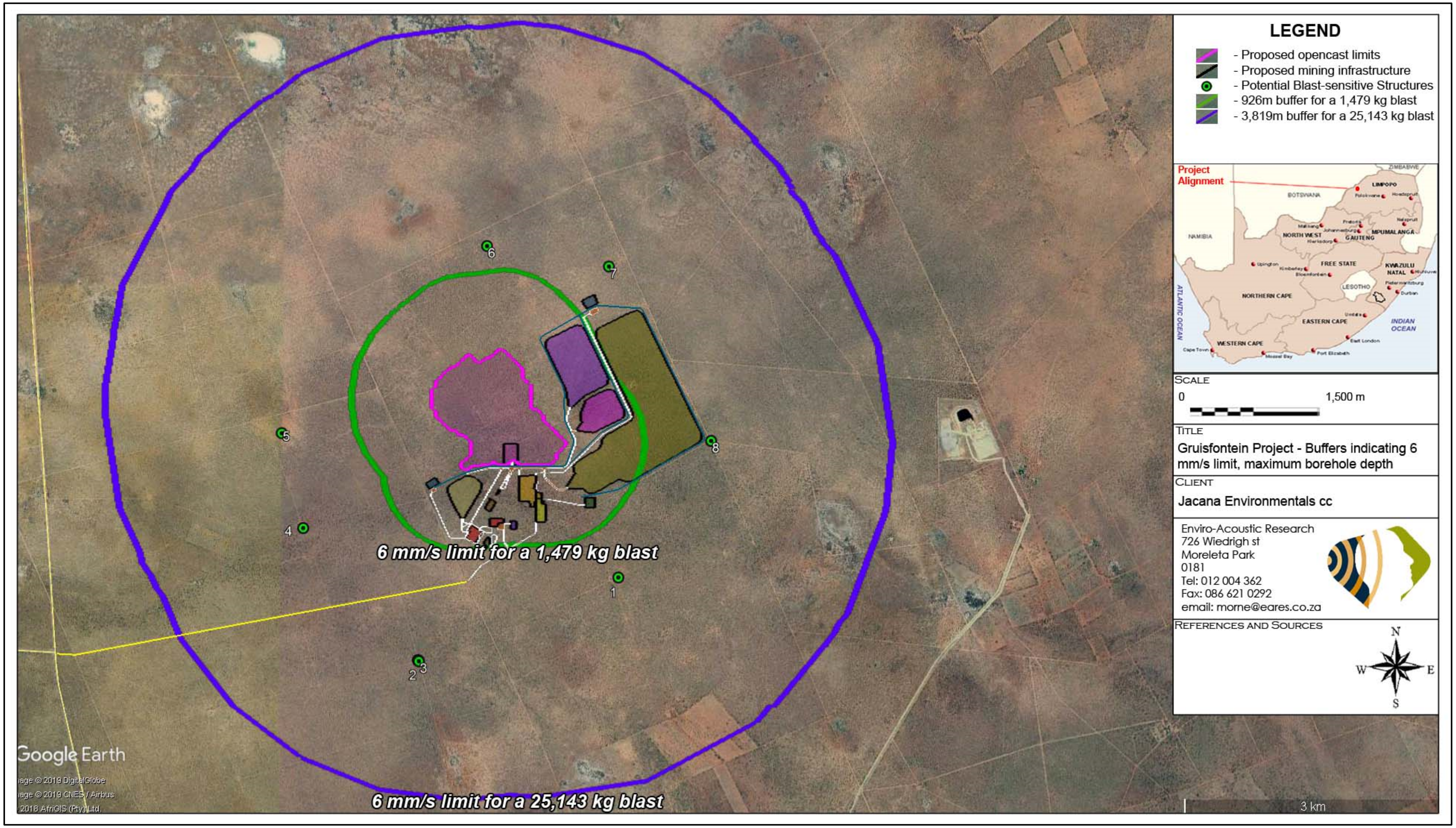

Figure 8-6: Projected Extend of Blasting Impacts – Ground Vibration with a stemming of 5 m for a borehole depth of 31.2 m

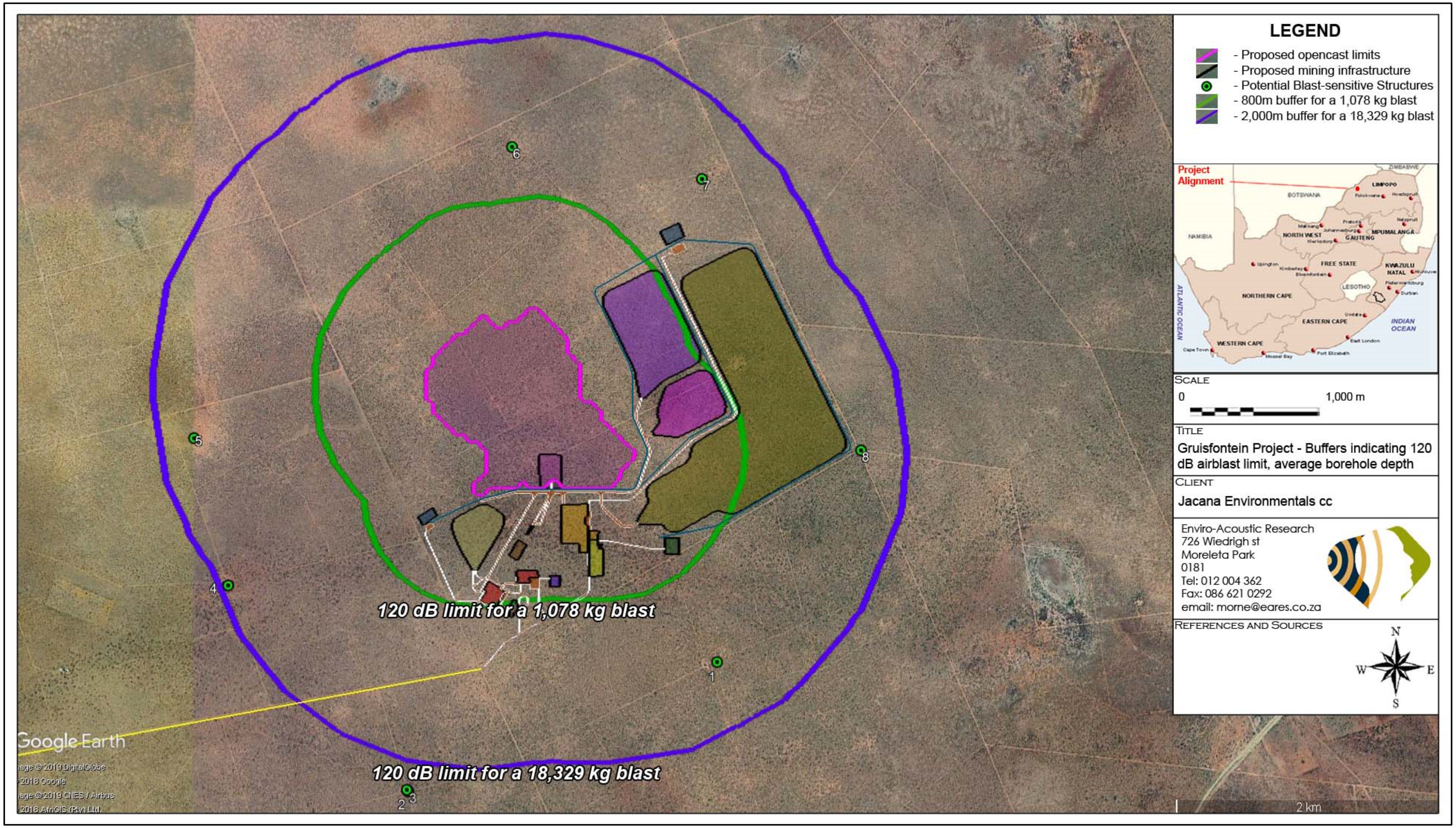

Figure 8-7: Projected Extend of Blasting Impacts – Air blast with a stemming of 5 m for a borehole depth of 24.1 m

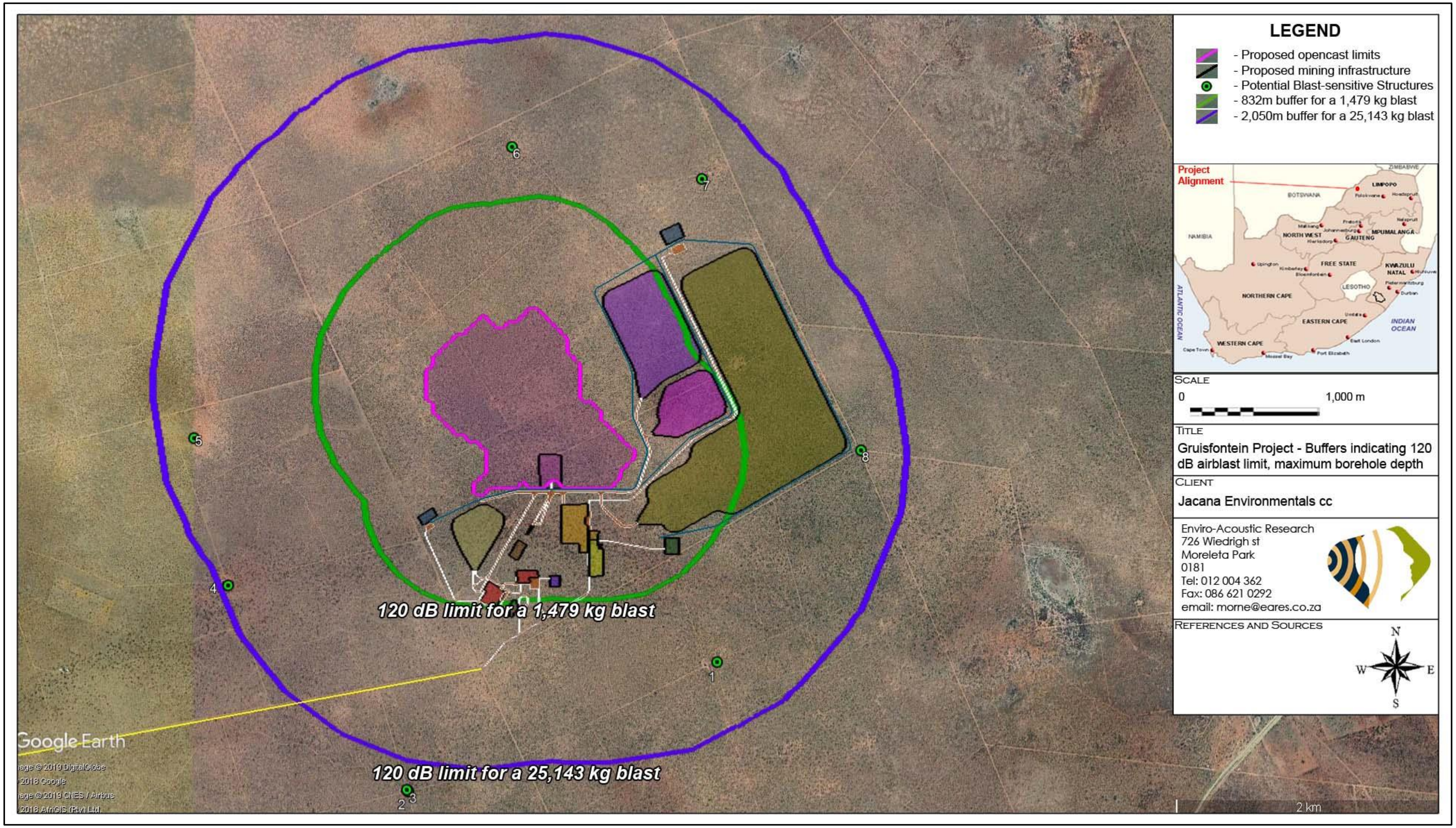

Figure 8-8: Projected Extend of Blasting Impacts – Air blast with a stemming of 5 m for a borehole depth of 31.2 m

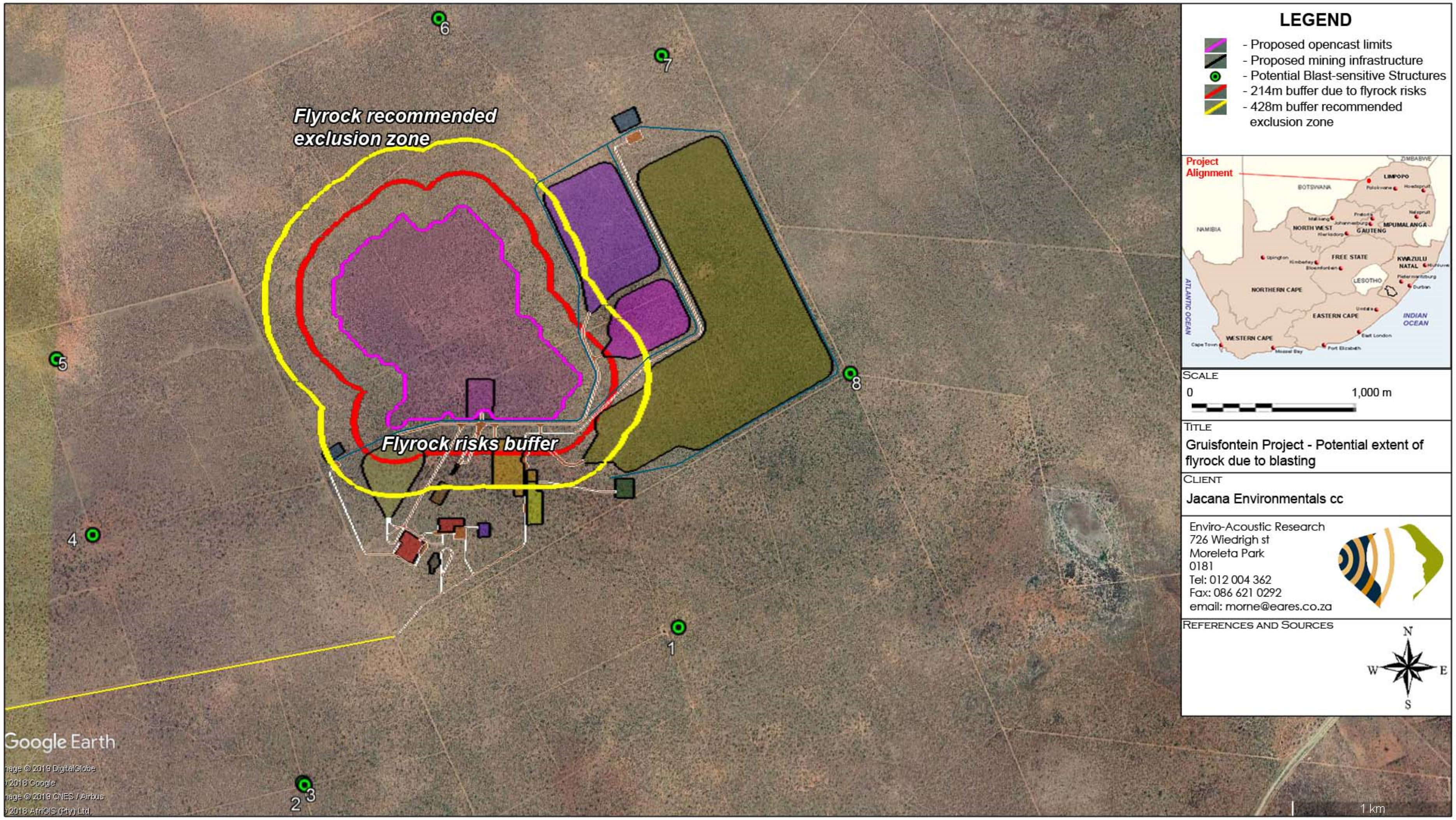

Figure 8-9: Projected Extend of Blasting Impacts – Fly rock risks

9 SIGNIFICANCE OF THE BLASTING IMPACTS

The impact assessment tables are based on the levels and potential response as defined in **Table 9-5**.

9.1 SIGNIFICANCE OF GROUND VIBRATION IMPACTS

The magnitude of the ground vibration levels were calculated in section **8.1**, defined in **Table 9-5** 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.	
	Without Mitigation (18,329 or 25,143 kg charge per delay)	***With Mitigation (2,985 kg charge per delay)***
Magnitude (Table 6-4)	**Medium** for R 3, R 11, R 13 and R 14 (structures located closer than 3,500 m from the mine).	**Low** for everyone
Duration	Long – 4	(Long – 4)
Extent	Local – 2	(Local – 2)
Probability (Table 6-5)	Definite - 5	Improbable - 1
Significance of Impact	**High**	**Low**
Comments	Recommended that annual photographic records to be collected at residential houses within 3 km from the mine.	
Degree of Confidence	**High**	
Mitigation:	Mitigation required, including: - Mine to implement a vibration and air blast measurement programme to allow the monitoring of all blasts during the first year. This data must be analysed and the blast impact assessment be reviewed and updated. - This report must be updated if the blast design changed in any manner. - Mine to reduce the charge per delay (less than 2,985 kg) to ensure that maximum ground vibration levels are less than 2.54 mm/s when blasting has to take place within 3,500m from residential houses.	
Residual Impacts:	This impact will only disappear after the construction and operational phase cease.	

Table 9-2: Impact Assessment: Ground vibration impacts (Damage to Structures)

Acceptable Level (Table 6-2)	Use the level of 25 mm/s as the limit for mortar and brick houses as well as other structures.	
	Without Mitigation (18,329 or 25,143 kg charge per delay)	***With Mitigation (less than 13,000 kg charge per delay)***
Magnitude (Table 6-4)	**High** for GRU06, GRU07, G30 and A14.	Low for other PSS
Duration	Long – 4	(Long – 4)
Extent	Local – 2	(Local – 2)
Probability (Table 6-5)	Definite - 5	Improbable - 1
Significance of Impact	**High**	**Low**

Comments	No houses will be subject to a ground vibration level exceeding 25 mm/s for the blast design as considered in **Table 8-1**. The potential structures include boreholes, cement dams and a wind pump.
Degree of Confidence	**High**
Mitigation:	Mitigation required, including: - Mine to implement a vibration and air blast measurement programme to allow the monitoring of all blasts during the first year. This data must be analysed and the blast impact assessment be reviewed and updated. If no complaints are registered the blast monitoring can be ceased. - Mine to reduce the charge per delay to less than 13,000 kg when closer than 1,600 m from the any identified potential sensitive structure.
Residual Impacts:	This impact will only disappear after the construction and operational phase cease.

9.2 SIGNIFICANCE OF AIR BLAST IMPACTS

The magnitude of the air blast levels were calculated in **section 8.2**, defined in **Table 9-5** with the significance summarised in **Table 9-3**.

Table 9-3: Impact Assessment: Air blast Impacts

Acceptable Level (Table 6-3)	Use the level of 120 dB as the limit for people in the area.	
	Without Mitigation (18,329 or 25,143 kg charge per delay)	***With Mitigation***
Magnitude (Table 6-4)	**Low-medium** for people living in the area (further than 3,000 m from the blasting site.	**Low** for everyone
Duration	Long – 4	(Long – 4)
Extent	Local – 2	(Local – 2)
Probability (Table 6-5)	Improbable (for other people)	Improbable (for other people)
Significance of Impact	**Low**	**Low**
Comments	-	
Degree of Confidence	**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 not to blast in adverse meteorological conditions (overcast, strong wind blowing in direction of houses, early in the mornings, late in the afternoon).	
Residual Impacts:	This impact will only disappear after the construction and operational phase cease.	

9.3 SIGNIFICANCE OF FLY ROCK IMPACTS

The magnitude of potential fly rock risks levels were calculated in section **8.3** and the significance is summarised in **Table 9-4**.

Table 9-4: Impact Assessment: Flyrock Risks

Acceptable Level	There should be no risk of fly rock.	
	Without Mitigation	***With Mitigation***
Magnitude (Table 6-4)	**Low** for people living in the area. Risks to mine equipment and structures within 428 m of the blasts.	**Low** for everyone
Duration	Long – 4	(Long – 4)
Extent	Local – 2	(Local – 2)
Probability (Table 6-5)	Improbable (for other structures)	Improbable (for other structures)
Significance of Impact	**Low**	**Low**
Comments	-	
Degree of Confidence	**High**	
Mitigation:	Mitigation not required, but the mine should: - Any evidence of fly rock 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.).	
Residual Impacts:	This impact will only disappear after the construction and operational phase cease.	

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 9-5: Potential responses to the blasting activities

Description of Structure	Reference, see Figure 3-2	Distance from potential blast site (m)	PPV, 1,479 kg Blast Charge	PPV, 25,143 kg Blast Charge	Air blast level, 25,143 kg Blast Charge	Potential structural damage		Potential Human Response		
						1,479 kg Blast Charge	25,143 kg Blast Charge	Vibration, 1,479 kg Blast Charge	Vibration, 25,143 kg Blast Charge	Air blast level, 25,143 kg Blast Charge
Borehole	TW03	2253	1.4	14.3	120	Very Low Risks (VLR)	VLR	Not relevant (N/R)	N/R	N/R
Borehole	TW02	3384	0.7	7.3	115	VLR	VLR	N/R	N/R	N/R
Borehole	VL15	3338	0.7	7.5	116	VLR	VLR	N/R	N/R	N/R
Borehole	SS09	3697	0.6	6.3	115	VLR	VLR	N/R	N/R	N/R
Borehole	VL16	3455	0.7	7.1	115	VLR	VLR	N/R	N/R	N/R
Borehole	VL17	2737	1.0	10.4	118	VLR	VLR	N/R	N/R	N/R
Borehole	VL18	1972	1.7	17.9	121	VLR	VLR	N/R	N/R	N/R
Borehole	SS14	2311	1.3	13.7	119	VLR	VLR	N/R	N/R	N/R
Borehole	VL21	3642	0.6	6.5	115	VLR	VLR	N/R	N/R	N/R
Borehole	SS06	3778	0.6	6.1	114	VLR	VLR	N/R	N/R	N/R
Borehole	SS08	1712	2.2	22.5	123	VLR	Risks	N/R	N/R	N/R
Borehole	VL19	1780	2.0	21.1	122	VLR	Risks	N/R	N/R	N/R
Borehole	SS07	3382	0.7	7.3	116	VLR	VLR	N/R	N/R	N/R
Borehole	GRU07	1593	2.5	25.4	123	VLR	Risks	N/R	N/R	N/R
Borehole	GRU06	1254	3.6	37.7	126	VLR	Risks	N/R	N/R	N/R
Borehole	GRU04	3732	0.6	6.2	114	VLR	VLR	N/R	N/R	N/R
Borehole	GRU03	3164	0.8	8.2	116	VLR	VLR	N/R	N/R	N/R
Borehole	WB29	3464	0.7	7.0	115	VLR	VLR	N/R	N/R	N/R
Borehole	WB28	3240	0.8	7.9	116	VLR	VLR	N/R	N/R	N/R
Cement dam	A12	1974	1.7	17.8	121	VLR	VLR	N/R	N/R	N/R
Cement dam	A14	1508	2.7	27.8	124	VLR	Risks	N/R	N/R	N/R
Cement dam	A16	2258	1.4	14.3	120	VLR	VLR	N/R	N/R	N/R
Cement dam	A23	3185	0.8	8.1	116	VLR	VLR	N/R	N/R	N/R
Windpump	G30	1523	2.6	27.3	124	VLR	Risks	N/R	N/R	N/R

Description of Structure	Reference, see Figure 3-2	Distance from potential blast site (m)	PPV, 1,479 kg Blast Charge	PPV, 25,143 kg Blast Charge	Air blast level, 25,143 kg Blast Charge	Potential structural damage		Potential Human Response		
						1,479 kg Blast Charge	25,143 kg Blast Charge	Vibration, 1,479 kg Blast Charge	Vibration, 25,143 kg Blast Charge	Air blast level, 25,143 kg Blast Charge
Windpump	G36	3196	0.8	8.0	116	VLR	VLR	N/R	N/R	N/R
Outbuilding	S01	3260	0.8	7.8	116	VLR	VLR	N/R	N/R	N/R
Outbuilding	S06	3330	0.7	7.5	116	VLR	VLR	N/R	N/R	N/R
Outbuilding	S07	3343	0.7	7.5	116	VLR	VLR	N/R	N/R	N/R
Outbuilding	S08	3332	0.7	7.5	116	VLR	VLR	N/R	N/R	N/R
House(s)	T11	4496	0.4	4.6	113	VLR	VLR	Detectable (Detect.)	Unpleasant (Unpl.)	No Response (No Resp.)
House(s)	T03	3929	0.6	5.7	114	VLR	VLR	Detect.	Unpl.	No Resp.
House(s)	R 3	3197	0.8	8.0	116	VLR	VLR	Detect.	Unpl.	No Resp.
House(s)	R 5	4718	0.4	4.2	112	VLR	VLR	Detect.	Unpl.	No Resp.
House(s)	R 9	3952	0.5	5.7	114	VLR	VLR	Detect.	Unpl.	No Resp.
House(s)	R 11	3379	0.7	7.3	116	VLR	VLR	Detect.	Unpl.	No Resp.
House(s)	R 13	3085	0.8	8.5	116	VLR	VLR	Detect.	Unpl.	No Resp.
House(s)	R 14	3097	0.8	8.5	116	VLR	VLR	Detect.	Unpl.	No Resp.
House(s)	R 15	5431	0.3	3.4	111	VLR	VLR	Detect.	Detect.	No Resp.
House(s)	R 16	3980	0.5	5.6	114	VLR	VLR	Detect.	Unpl.	No Resp.

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. The mitigation include technical as well as management measures.

- This report must be updated if the blast design changed in any manner.
- Mine to implement a vibration and air blast measurement programme to allow the monitoring of all blasts during the first year. This data must be analysed and the blast impact assessment be reviewed and updated.
- Mine to initiate a forum to inform the close residents about the likely vibration and air blast levels (provide access to this report), the proposed blasting schedule and warning methodology the mine will employ before a blast. Residents should realise the potential magnitude of the air blast and vibration levels, and when the residents are inside the house during a blast, vibration of windows and ceilings may appear excessive.
- Mine to reduce the charge per delay to ensure that;
    - maximum ground vibration levels are less than 2.54 mm/s when blasting has to take place within 3,500m from dwellings used for residential purposes. This can be accomplished by reducing the charge per delay to less than 13,000 kg;
    - maximum ground vibration levels are less than 25 mm/s when blasting has to take place within 1,600m from identified potential sensitive structures. This can be accomplished by reducing the charge per delay to less than 2,985 kg.
- Mine to erect blasting notice boards in the area (on the main access route from the district road to the mine) with blasting dates and times highlighted.
- Any evidence of fly rock 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 Gruisfontein Colliery west of Lephalale, Limpopo, 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 available information. In total four options were assessed, namely unmitigated options with up to 17 blast holes fired simultaneously for the average and maximum borehole depths, and mitigated options where controlled blasting (times blasts) are used to only fire one blast hole at a time. This assessment indicated that:

- That ground vibration levels may be disturbing when blasting take place within 3,500m from residential houses (the unmitigated scenario). 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 3,500 m from the blast;
- That ground vibration levels may pose a risk of damage to potential sensitive structures when blasting take place within 1,600m from these structures (the unmitigated scenario). 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 at 1,600 m from the blast;
- Air blast levels, while clearly audible to surrounding receptors, will be less than 120 dB;
- 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 however highly recommended that the mine conduct a detailed photographic survey at all houses and structures located within 3,500m 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.

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 Gruisfontein Colliery is 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:

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8. Mansfield, NJ. 2005. *'Human Response to Vibration'*. CRC Press, London
9. Persson, PA, Holmberg, R and Lee, J. 1994: '*Rock Blasting and Explosives Engineering*'. CRC Press, USA.
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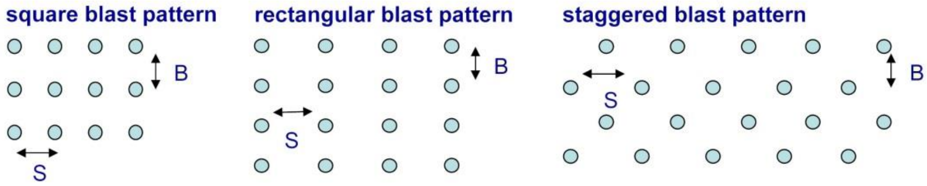
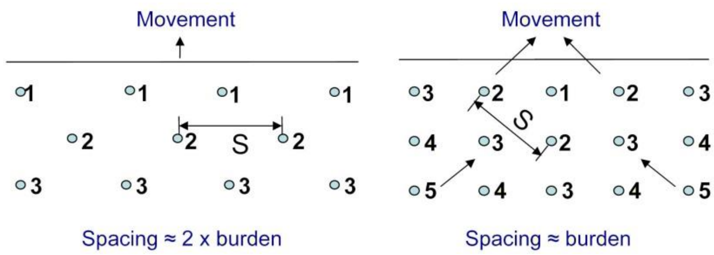
12. Siskind, D.E., Stachura, V.J., Stagg, M.S. & Kopp, J.W. 1980. *'Structure Response and Damage Produced by Air blast from Surface Mining*'. U.S. Bureau of Mines, RI 8485
13. Workman, J.L., and Calder, P.N. 1994. '*Flyrock prediction and control in surface mine blasting*'. United States.

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

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