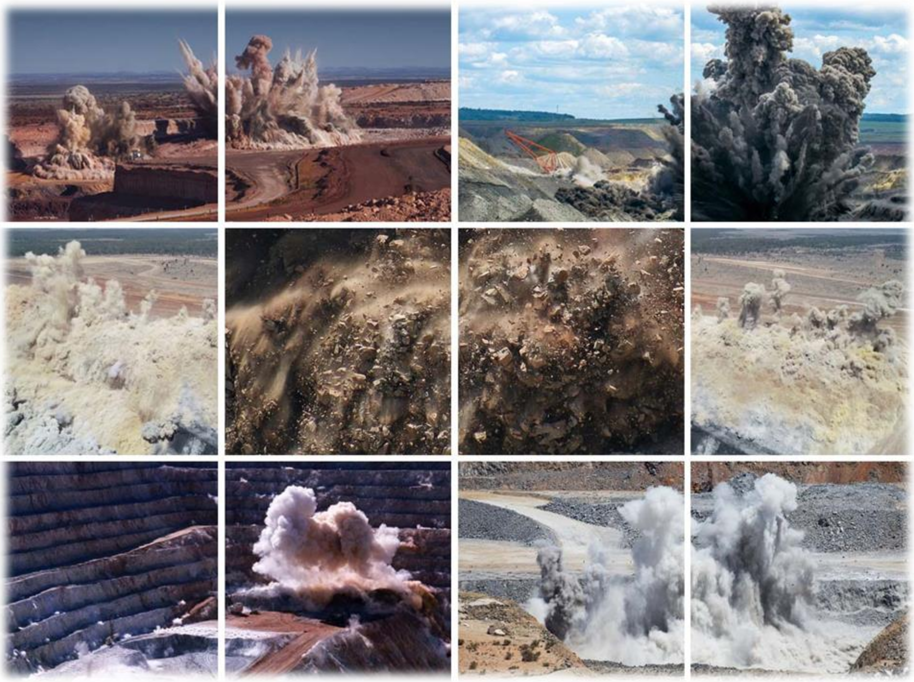
Glencore Coal Operations South Africa (Pty) Ltd

BLASTING IMPACT ASSESSMENT

for the

Proposed Goedgevonden Complex Amendment Project

just South of Ogies, Mpumalanga Province



Study done for:

JACANA environmentals cc

Prepared by:

EARES
Enviro Acoustic Research

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EXECUTIVE SUMMARY

INTRODUCTION AND PURPOSE

Enviro-Acoustic Research (EARES) was contracted by Jacana Environmentals CC (Jacana) to determine the potential impact due to blasting activities on the surrounding environment due to the proposed development amendments at the existing Goedgevonden Complex. This operation is located south of the town of Ogies 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.

PROJECT DESCRIPTION

Glencore Coal Operations South Africa (Pty) Ltd (Glencore) proposed to amend their Environmental Management Program report (EMPr). The amendment proposes to change:

- the layout for the future opencast mining area;
- the inclusion of a number of incline portals to access their coal resource via underground workings;
- a change in the mining method from opencast to underground at a number of locations.

The incline shafts and opencast areas will be developed by means of drilling of blast holes, the charging of the blastholes, blasting and the loading of the broken material until the desired depth is reached. This will take place concurrently with existing mining activities.

BLASTING PARAMETERS

This assessment used actual blasting information recorded at the Goedgevonden complex, including blast hole diameter, borehole depths, burden and spacing as well as stemming information. The potential vibration levels were calculated at 500 m considering the various options in the table below, with this assessment considering the potential blasting impact from:

- an average blast, with 10 m deep blastholes, using a 6 x 6 m pattern for burden and spacing with a 5 m stemming; and
- a worst-case blast, with blastholes up to 24 m deep, using a 7 x 8 m pattern for burden and spacing with a 5 m stemming.

Design parameter	Sandstone, average borehole depth	Sandstone, maximum depth	Shale, minimum depth	Shale, maximum depth	Interburden, minimum depth	Interburden, average depth	Interburden, worst case, maximum depth
Average depth of borehole (m)	10.0	14.0	5.0	9.0	15.0	19.0	24.0
Bench height (m)	10.0	14.0	5.0	9.0	15.0	19.0	24.0
Subdrill (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Borehole diameter (mm)	250.0	250.0	250.0	250.0	250.0	250.0	250.0
Burden (m)	6.0	6.0	6.0	6.0	7.0	7.0	7.0
Spacing (m)	6.0	6.0	6.0	6.0	8.0	8.0	8.0
Burden stiffness ratio	1.7	2.3	0.8	1.5	2.1	2.7	3.4
Stemming Length (m)	5.0	5.0	3.0	5.0	5.0	5.0	5.0
Column length (m)	5.0	9.0	2.0	4.0	10.0	14.0	19.0
Explosive density (g/cm^3)	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Explosives per borehole (kg)	282.3	508.1	112.9	225.8	564.5	790.3	1 072.6
Charge mass per meter (kg/m)	56.5	56.5	56.5	56.5	56.5	56.5	56.5
Powder Factor (kg/m^3)	0.78	1.01	0.63	0.70	0.67	0.74	0.80
Distance from Blast	500	500	500	500	500	500	500
Explosives per delay (kg)	282.3	508.1	112.9	225.8	564.5	790.3	1 072.6
Peak Particle Velocity (mm/s)	**6.84**	**10.66**	**3.43**	**5.78**	**11.54**	**14.88**	**18.74**

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 blast design was provided by the mine and evaluated in this assessment. This assessment indicated that:

- That ground vibration levels may be unpleasant to Blast Sensitive Receptors (BSRs) when blasting take place within approximately 1,000 m from structures used for residential, worship or business activities. The impact is of a potential **Medium** significance and mitigation required and proposed that could reduce the vibration levels. However, due to the sensitivity to blast effects, it is possible that people may still complain about the perceived blast effects;
- That ground vibration levels could be of **Medium** significance to potential Blast Sensitive Structures (BSSs) in the vicinity of the mining area. General measures are highlighted to ensure that risks due to vibration damage are minimized;
- Air blast levels will be clearly audible to all surrounding receptors and the significance may be **Medium** for the closest BSRs. Mitigation is required and measures are proposed that could reduce the airblast levels. Due to the sensitivity of people to the significant loud noise as well as secondary vibration of large surfaces (due to the change in air pressure), BSRs must be informed about the potential impacts;
- There are no risks of fly rock to BSRs or BSSs, but blasting close to the mine infrastructure may result in fly rock damage. Management measures are available to ensure the risks are minimised.

The significance of blasting risks is **Medium** (excluding the **High** significance of the impact on the R53 road transected by future mining areas [Incline Portal 2 and Opencast Area]).

PROPOSED MITIGATION

The project is proposed in an area with a significant number of BSRs and BSSs such as residential houses, a cement bridge, a railway line and a few tar roads. As such blasting must be carefully planned and executed to ensure that people, livestock, structures and equipment are protected. The following should be noted and considered by the mine:

- A number of tar roads transects the project site, with the project plan indicating future mining activities over a portion of road R53 (RAMS naming system). The mine must remember that GNR.584 of 2015 does limit blasting within 500 m from certain structures unless certain conditions are met. The mine will have to discuss the project with the relevant authorities to authorize the closure and implement the agreed upon mitigation measures (which may include the rerouting of road R53 around the future opencast areas);
- It is critical that the mine provide feedback to the surrounding community and identified BSR, highlighting that the blast impacts were calculated and potential mitigation measures proposed;
- The 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 as well as a warning to residents that, when they are indoors during a blast, vibration of windows and ceilings may appear excessive;
- The mine should erect clear signs indicating blast dates and times along the R545 road as well as agreed locations within Ogies. A blast schedule should be available to interested BSRs;
- The mine should discuss the blasting schedule when blasting is to take place within 1,000 m from the Mosque with the Muslim Iman of the Mosque. The mine should agree on the most appropriate time to blast;
- The mine should schedule blasting at the same time in the early afternoons, to minimise airblast levels. No blasting should take place early in the mornings, late in the afternoons, during overcast conditions, in the fog or when the wind is blowing towards the Ogies community;
- Any evidence of fly rock must be noted and the blast be analysed for possible improvements;
- As the onsite conditions are not known, it is recommended that the mine carefully monitor blasting as recommended by Rorke (2005);
- Considering the recommendations set in Dyno (2017), the optimal blasthole diameter is 150 mm for the proposed 10 m bench height. A 250 mm blasthole diameter is large considering a 10 m bench height, resulting in the significant charge per blasthole. Due to the numerous BSRs and BSSs located within the potential area of influence the mine may consider a more optimal blast design.
- There are a number of roads (including the R53 (R545) and R52) located within the project site, and these roads must be closed once blasting is to take place closer than 500 m from these roads. The closure of these roads must be arranged and negotiated with local land owners and the relevant road authority;
- The mine must survey the proposed blasting area before the marking and drilling of blastholes. It is critical that:
    - The burden should be considered to prevent the confinement of blasts. If necessary, the blast design should be adjusted;
    - Blastholes should be accurately drilled and correctly charged with the selected explosives. The over- or undercharging of blastholes must be minimized;

  - Blastholes should always be correctly stemmed, ideally with gravel and not the cuttings from drillings. Too short stemming will result in "blowout" before blast pressure is developed, with too long stemming resulting in insufficient charge and excessive confinement. Both these will result in poor fragmentation, possibly increasing airblast levels and flyrock "unsafe zone".
- The use of detonating cord should be minimised to control airblast levels. When used within 1 000 m from identified BSRs, the cord should be covered with cuttings or aggregate to minimise airblast levels from this source.
- The mine must conduct a photographic (crack) survey at all houses, cement dams as well as define the status of water boreholes located within 1,000 m from areas where future blasting is to take place. Cracks will develop with time, which may be due to construction of the structures, standards of building, the age of the structure, the underlying geology and soils, maintenance etc., and not necessarily due to blasting.

RECOMMENDATIONS AND CONCLUSIONS

The significance of blasting risks is **Medium** (excluding the **High** significance of the impact on the R53 road transected by opencast activities) and blasting monitoring is recommended (as per Rorke, 2005).

In addition, community involvement throughout the project is of utmost importance. This is especially true for any 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 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 conducts a detailed photographic survey at selected structures (that does not belong to the applicant) located within 1,000 m from the mine (from the opencast boundary limit) before any mining activities start (before the construction phase start where blasting is to take place). This should include a survey (condition assessment with photographic records) of residential structures, water boreholes and cement dams to determine the status of these structures.

Opencast mining is proposed over a portion of road R53. The mine must remember that GNR.584 of 2015 does limit blasting within 500 m from certain structures unless certain conditions are met. The mine will have to discuss the project with the relevant authorities to authorize the closure and implement the agreed upon mitigation measures (which may include the rerouting of the road R53 around the future opencast mining area).

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

Goedgevonden EMP Amendment 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-	
(a)	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;	Section 10.3
(l)	any conditions for inclusion in the environmental authorisation;	Section 10.3
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 10.3
(n)	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;	Section 11

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. (2021): "*Blasting Impact Assessment for the Goedgevonden Complex Amendment Project South of Ogies, Mpumalanga Province*". Enviro-Acoustic Research CC, Pretoria

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Report no:

JE-GGCAP/BIA/202110-Rev 0

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Date:

October 2021

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APPENDICES

GLOSSARY OF ABBREVIATIONS

BSS	Blast Sensitive Structure
BSR	Blast Sensitive Receptors
DMRE	Department of Mineral Resources and Energy
EIA	Environmental Impact Assessment
EMPr	Environmental Management Programme report
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 annum
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 and vibration, 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. Blasting vibration was investigated for the following projects in the past two years:

- Tumela Mine - Bierspruit Opencast - Anglo American Platinum Limited
- Vygenhoek Platinum Project - Nomamix (Pty) Ltd
- Gruisfontein Colliery - Nozala Coal (Pty) Ltd
- Bloemendal Coal Project – INSA Coal Holdings
- Dunbar Coal Project – INSA Coal Holdings
- Salene Manganese Project – Thari Resources (Pty) Ltd
- Ericure Coal Project – Ericure (Pty) Ltd
- VTM Mining Project – Ikwezi Vanadium (Pty) Ltd

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:

2021 – 10 – 25

3 INTRODUCTION

3.1 INTRODUCTION AND PURPOSE

Enviro-Acoustic Research (EARES) was contracted by Jacana Environmentals CC (Jacana) to determine the potential impact due to blasting activities on the surrounding environment due to the proposed development amendments at the existing Goedgevonden Complex. This operation is located south of the town of Ogies 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

Glencore Coal Operations South Africa (Pty) Ltd (Glencore) proposed to amend their Environmental Management Program report (EMPr). The amendment proposes to change:

- the layout for the future opencast mining area;
- the inclusion of a number of incline portals to access their coal resource via underground workings;
- a change in the mining method from opencast to underground at a number of locations.

The incline shafts and opencast areas will be developed by means of drilling of blast holes, the charging of the blastholes, blasting and the loading of the broken material until the desired depth is reached. This will take place concurrently with existing mining activities.

3.2.2 Study area and Potential Sensitive Structures

Figure 3-1 illustrates the representative potential Blast Sensitive Receptors (BSR) or Blast Sensitive Structures (BSS – see **Figure 3-2**) located within 2,000 m of the proposed mining areas that may be affected by blasting activities. It is critical to note that each icon may represent a number of different structures. The following should be noted:

- Area within the 500 m buffer from future opencast mining areas: Area around the future opencast mining area (where blasting may take place) where people and animals must be moved prior to blasting taking place. Ground vibration and air blast levels likely to be significant with a high risk of fly-rock much closer to the blast area. Any structures within this area may be damaged or destroyed.
- Area 500 to 2,000 m from future opencast mining areas: Area outside the zone where fly rock may be a concern, but:
  - noise from the airblast could 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 future opencast mining areas:
    - 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 2,000 m 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 or detectable due to a ground vibration.

It should be noted that structures, associated with the proposed mine, located on or within the proposed mining boundary area was not included in this assessment. It is the responsibility of the mine to assess the potential risk of blasting close their equipment and structures, especially the potential impact from fly rock.

3.2.2.1 Roads and Railway Lines

The R52 (the R545 national road) and R53 transects the project study area, with a future opencast area transecting road R53. There is a railway line passing the opencast area to the north-east (see also **Figure 3-2**), with a cement bridge crossing this railway line to the north-east.

3.2.2.2 Power Pylons and lines

No major power lines were identified within the areas where blasting may occur.

3.2.2.3 Pipelines and Water Reservoirs

It is unknown whether there are any pipelines or reservoirs within 500 m from the areas where blasting is to take place.

3.3 CURRENT BLASTING IMPACTS

This project is part of the existing Goedgevonden Mining Complex with a number of active opencast mining areas. There are also a number of other opencast mines in the area, with active mining activities of the Klipspruit operation just west of Ogies.

However, unless blasting activities take place at exactly the same instant, blasting impacts does not cumulatively add the vibration or airblast noise levels.

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. Therefore, 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[1]. 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.

[1] The upper range of vibration levels from pile driving activities are ± 3 mm/s at 40 m, although typical levels are far less. Vibration levels from a large bulldozer or a loaded truck working or operating at 10 m from a location are around ±1.5 mm/s.

Figure 3-1: Aerial image indicating potential BSR within 2,000 m of potential blasting area (complete potential mining opencast area)

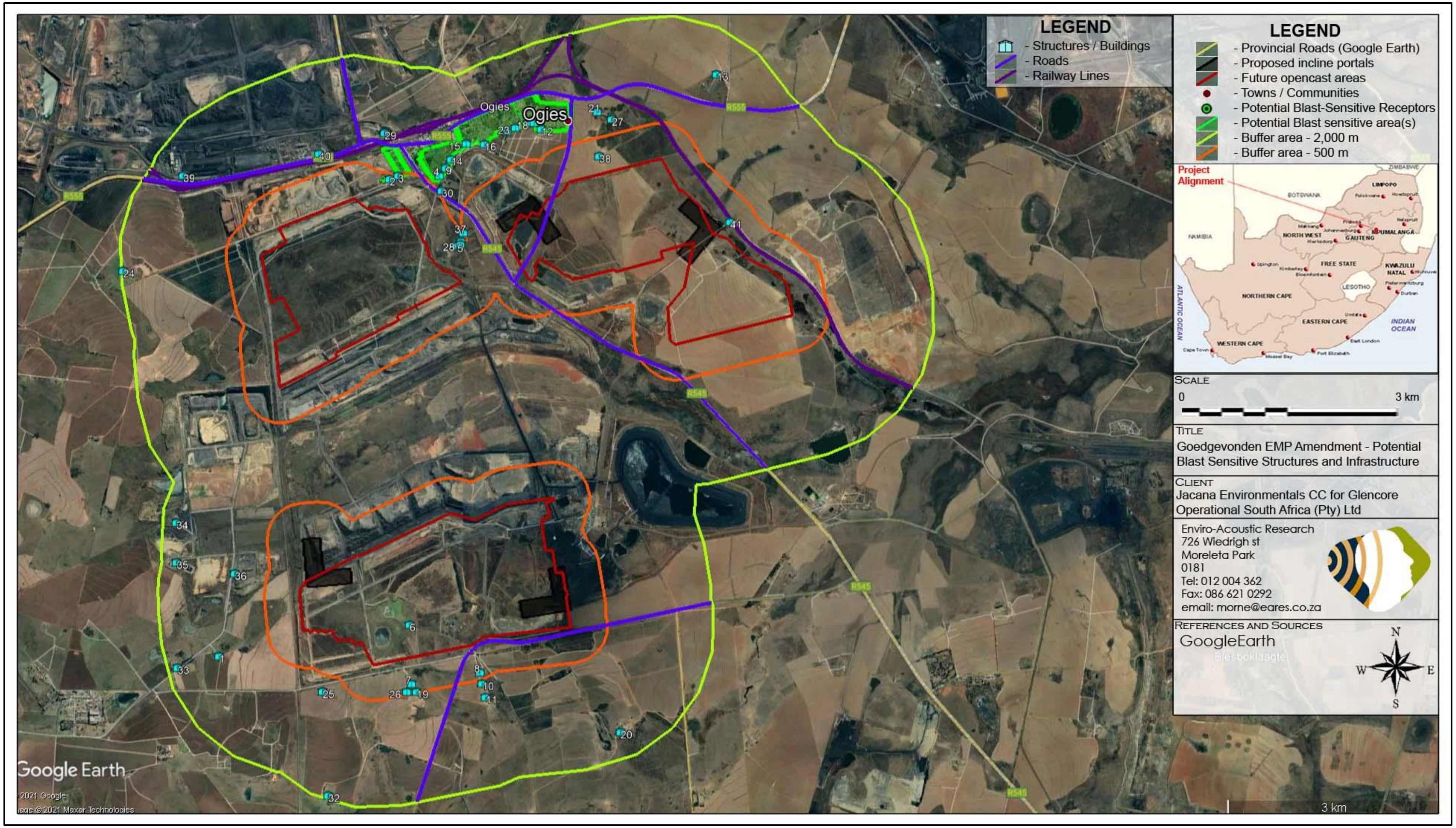

Figure 3-2: Aerial image indicating potential BSS and Infrastructure within 2,000 m of potential blasting areas

4 LEGAL CONTEXT, POLICIES AND GUIDELINES

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

The Mineral and Petroleum Resources Development Act (MPRDA) 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 do 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 500 m 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 do 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 do 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 CRITICAL BLAST DESIGN TERMINOLOGY

The following terms are highlighted as illustrated in **Figure 5-1** as it is referred in this report, with additional terms defined in Appendix A (Glossary of Terms).

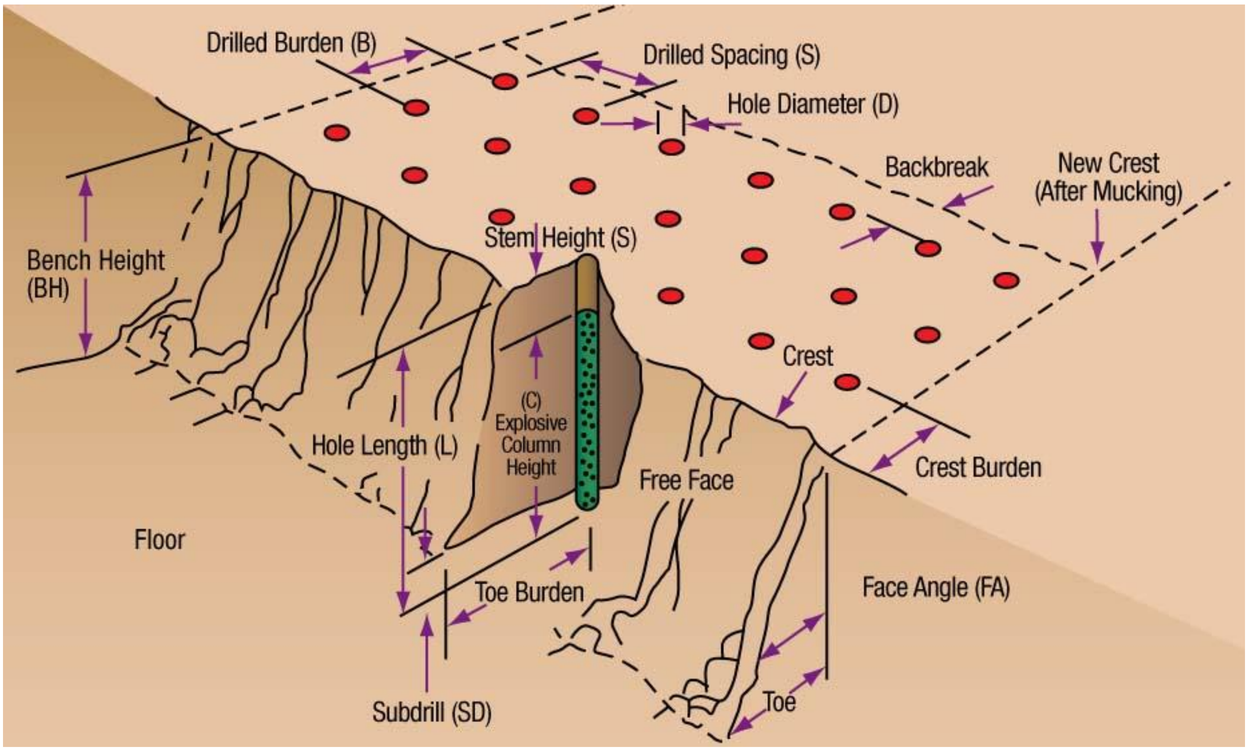

Figure 5-1: Blast Design Terms (from Explosives Engineers' Guide)

5.2 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 uses 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.

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

5.3 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 is based on empirical formulas, also developed by the USBM.

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

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

and

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

5.4 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 5-2**.

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.

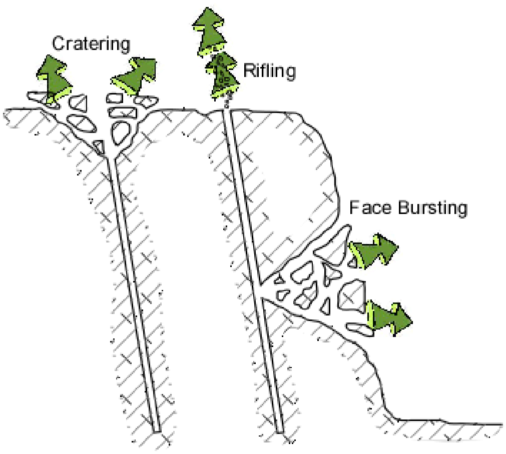

Figure 5-2: Illustration of sources of fly rock

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

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

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

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

Ghasemi *et al* (2012) developed an empirical formula, based on the analysed data from various blasts, with this formula considering various input parameters (see equation 8 below).

$$\boldsymbol{Flyrock}\ D_{FR} = 6946.547\left[B^{-0.796}S^{0.783}SH^{1.994}H^{1.649}D^{1.766}\left(\frac{PF}{Q}\right)^{1.465}\right]$$ **Equation 8**

Where (if not defined above):

S = Spacing (m)

H = Depth of borehole (m)

d = Borehole diameter (m)

PF = Powder Factor (kg/m^3)

Q = mean charge per blast-hole (m)

This assessment will consider the various equations and report the potential worst-case fly rock throw distances.

As this study use general constants, it may be required that the mine measure the ground vibration as mining continue. 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.

This report will use the vibration criteria as published by the US Bureau of Mines (USMB) to define the potential impact of blasting vibration on the surrounding environment.

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. This report uses a limit of 2.54 mm/s as a potentially disturbing and 7.6 mm/s very disturbing.

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).

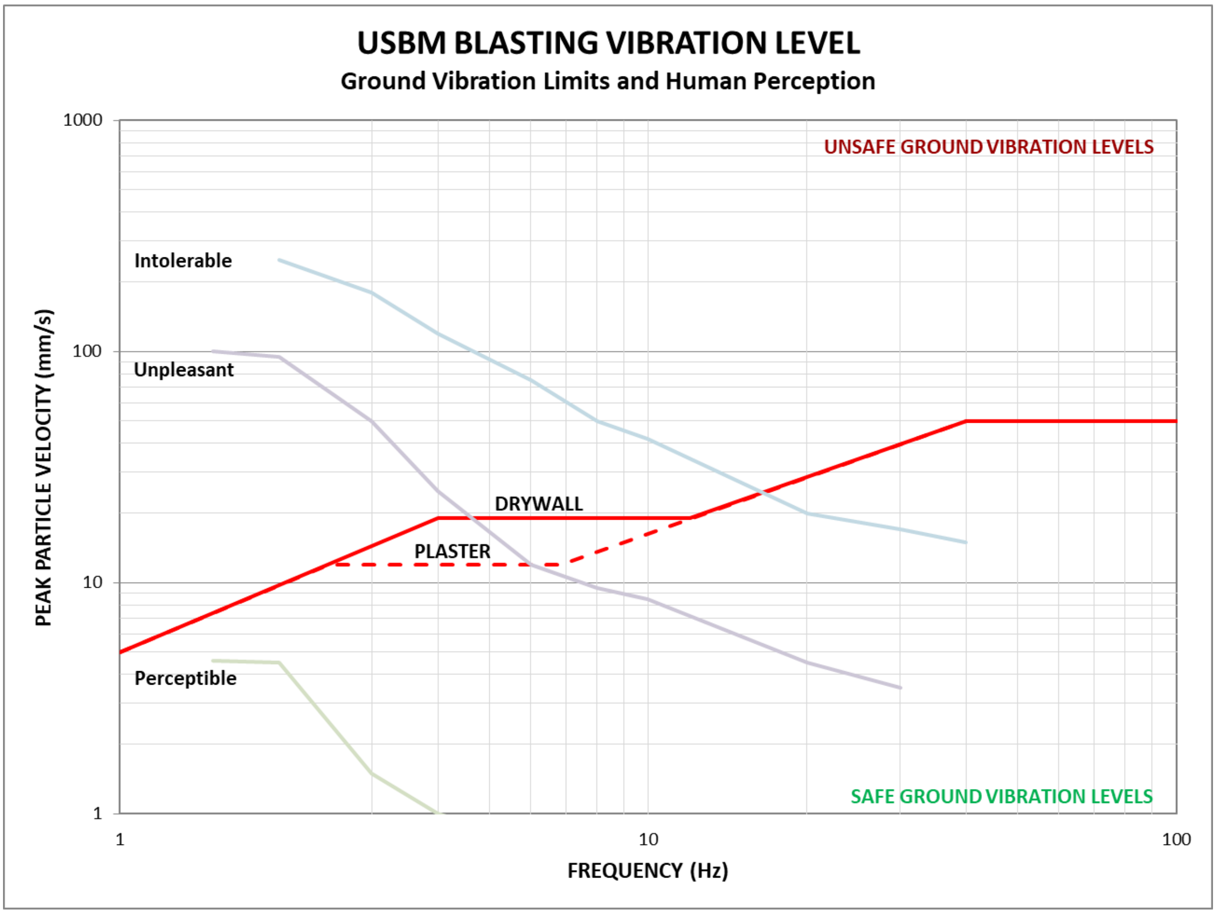

Figure 6-1: Human vibration sensitivities and potential structural damage compared to the RI 8507 limits

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 a 6 mm/s limit for potential sensitive structures, and a limit of 150 mm/s for roads and railroads. This assessment will also use a limit of 50 mm/s for concrete structures, even though Bauer (1977) reports cracking of concrete blocks at a PPV of 203 mm/s. This may be a very precautious approach, as the structure in question is a reinforced concrete bridge (BSS 41) which would be more resilient to vibration impacts.

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 houses, boreholes	**25**
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 absolutely 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

In order to define the significance of the potential blasting impacts, it is required to do assess the potential consequence (the foreseeable outcome of an event) of an incident or impact, as well as the probability (the likelihood) of the event or impact occurring.

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 is based on the two criteria used by Glencore, namely:

- **Consequence** of impacts (**Table 6-4**) – 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;
- **Significance** of impacts (**Table 6-5**) – Significance is determined through a synthesis of the **Consequence** as well as the **Probability** as described in the tables below. It provides an indication of the importance of the impact in terms of both tangible and intangible characteristics.

Table 6-4: Impact Assessment Criteria – Consequence of the Event

	Health & Safety	Environment	Image & Reputation / Community	Legal & Compliance
5 Catastrophic	Multiple fatalities (5 or more fatalities in a single incident) Multiple cases (5 or more) of Permanent Damage Injuries or Diseases that result in permanent disabilities in a single incident	Unconfined and widespread Environmental damage or effect (permanent; >10 years) Requires major remediation	Loss of multiple major customers or large proportion of sales contracts Sustained campaign by one or more international NGOs resulting in physical impact on the assets or loss of ability to operate Security incident resulting in multiple fatalities or major equipment damage Formal expression of significant dissatisfaction by government Grievance from internal or external stakeholder alleging human rights violation resulting in multiple fatalities Loss of multiple major customers or large proportion of sales contracts	Major litigation / prosecution at Glencore corporate level Nationalisation / loss of licence to operate
4 Major	Single incident resulting in: Less than 5 Fatalities	Long-term (2 to 10 years) impact	Security/ stakeholder incident resulting in single loss of life or equipment damage	Major litigation / prosecution at Department level

	Permanent Damage Injury or Disease that results in a permanent disability- less than 5 cases in a single incident	Requires significant remediation	Grievance from internal or external stakeholder alleging human rights violation resulting in single fatality or serious injuries Topic of broad societal concern and criticism Negative media coverage at international level resulting in a Corporate statement within 24 hours Investigation from government and/ or international (or high-profile) NGOs Complaints from multiple "final" customers Loss of major customer Negative impact on share price	
3 **Moderate**	Lost Time Injury (LTI) Lost Time Disease (LTD) Permanent Disabling Injury (PDI) Permanent Disabling Disease (PDD) Single incident that results in multiple medical treatments	Medium-term (<2 years) impact (typically within a year) Requires moderate remediation	Negative media coverage at national level over more than one day Complaint from a "final" customer Off-spec product Local Stakeholder action resulting in national societal scrutiny	Major litigation / prosecution at Operation level
2 **Minor**	Medical Treatment Injury (MTI) Medical Treatment Disease (MTD) Restricted Work Injury (RWI) Restricted Work Disease (RWD)	Near source Short-term impact (typically <week) Requires minor remediation	Negative local/ regional media coverage Complaint received from an internal or external stakeholder	Regulation breaches resulting in fine or litigation
1 **Negligible**	First Aid Injury (FAI) or illness (not considered disease or disorder)	Near source and confined No lasting environmental damage or effect (typically <day) Requires minor or no remediation	Negligible media interest	Regulation breaches without fine or litigation

Table 6-5: Impact Assessment Criteria – Impact Significance based on Consequence and Probability

Basis of Rating	E - Rare	D - Unlikely	C - Possible	B - Likely	A – Almost Certain
LIFETIME OR PROJECT OR TRIAL OR FIXED TIME PERIOD OR NEW PROCESS / PLANT / R&D	Unlikely to occur during a lifetime OR Very unlikely to occur OR No known occurrences in broader worldwide industry	Could occur about once during a lifetime OR More likely NOT to occur than to occur OR Has occurred at least once in broader worldwide industry	Could occur more than once during a lifetime OR As likely to occur as not to occur OR Has occurred at least once in the mining / commodities trading industries	May occur about once per year OR More likely to occur than not occur OR Has occurred at least once within Glencore	May occur several times per year OR Expected to occur OR Has occurred several times within Glencore
5 Catastrophic	15 (M)	19 (H)	22 (H)	24 (H)	25 (H)
4 Major	10 (M)	14 (M)	18 (H)	21 (H)	23 (H)
3 Moderate	6 (L)	9 (M)	13 (M)	17 (H)	20 (H)
2 Minor	3 (L)	5 (L)	8 (M)	12 (M)	16 (M)
1 Negligible	1 (L)	2 (L)	4 (L)	7 (M)	11 (M)

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 air blast levels. However, the following assumptions and limitations must be noted:

- Rorke (2005) did an impact analysis from blasting at Goedgevonden. This study:
    - Provide a desk-top professional opinion regarding the emissions from blasting based on knowledge of blasting of similar excavations in comparative rock. This work involves estimates of likely vibration and air blast amplitudes as well as gas emissions. The estimates are based on computer models and empirical equations derived from measurements at other sites.
    - Include a description of impacts (and their significance) related to:
        - Blast induced ground vibration;
        - Air blast and fly-rock;
        - Dust;
        - Blasting fumes;
    - Examine the impact of blasting on structures that will be constructed in the plant area.
    - Provide measures to manage negative impacts.
    - The study used blasting vibration data as monitored at a neighbouring mine to calculate the site-specific constants from vibration measurements recorded at a neighbouring mine;
- This assessment used actual blasting information recorded at the Goedgevonden complex, including blast hole diameter, borehole depths, burden and spacing as well as stemming information. The potential vibration levels were calculated at 500 m considering the various options, with the assessment considering the typical (best case scenario) as well as the worst-case scenarios;
- This impact assessment does not make a statement on the acceptability of the blast design as evaluated (viable bench height, fracturing, throw, powder factors, drilling cost, blasting cost, etc.) and only assesses the potential impacts considering the available information;
- While the site was visited, structures and the associated uses were not assessed and the status of each structure was not confirmed. It is highly recommended that the mine completes 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 incline portal limits to determine the status and state of the structures (before first blasting taking place). Rorke (2005) did highlight a similar survey though it is not clear whether this survey was undertaken and the results recorded;
- Attenuation rates for ground vibration levels, air blast levels and fly rock distances are site-specific. Empirical formula has 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. Vibration levels should be measured, with the data analysed to calculate site-specific onsite constants. The initial

constants for ground vibration (**section 5.2**) were calculated from monitoring done at a neighbouring mine, determined at 1149 and -1.51;

- 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 be 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 would take place during the construction of the incline portals, taking place concurrently with existing opencast activities (with the blasting analysis done in 2005 by Rorke). This assessment does not replace the Rorke (2005) study for the larger mine, but are mainly to inform the EMP amendment process, considering locations where blasting may take place (both for operational activities and the construction of the incline shafts).

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 overpressure, noise as well as fly rocks (all undesired from a blasting perspective as energy is lost). 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**. It should be noted that the number of blastholes that may be detonated simultaneously may vary from blast to blast. The depth of the blastholes is similarly not constant, but may vary on a day-to-day basis, depending on the mine planning (such as the planned bench height) or geology.

Table 8-1: Blast design – various design parameters

Design parameter	Sandstone, average borehole depth	Sandstone, maximum depth	Shale, minimum depth	Shale, maximum depth	Interburden, minimum depth	Interburden, average depth	Interburden, worst case, maximum depth
Average depth of borehole (m)	10.0	14.0	5.0	9.0	15.0	19.0	24.0
Bench height (m)	10.0	14.0	5.0	9.0	15.0	19.0	24.0
Subdrill (m)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Borehole diameter (mm)	250.0	250.0	250.0	250.0	250.0	250.0	250.0
Burden (m)	6.0	6.0	6.0	6.0	7.0	7.0	7.0
Spacing (m)	6.0	6.0	6.0	6.0	8.0	8.0	8.0
Burden stiffness ratio	1.7	2.3	0.8	1.5	2.1	2.7	3.4
Stemming Length (m)	5.0	5.0	3.0	5.0	5.0	5.0	5.0
Column length (m)	5.0	9.0	2.0	4.0	10.0	14.0	19.0
Explosive density (g/cm^3)	1.15	1.15	1.15	1.15	1.15	1.15	1.15
Explosives per borehole (kg)	282.3	508.1	112.9	225.8	564.5	790.3	1 072.6
Charge mass per meter (kg/m)	56.5	56.5	56.5	56.5	56.5	56.5	56.5
Powder Factor (kg/m^3)	0.78	1.01	0.63	0.70	0.67	0.74	0.80
Distance from Blast	500	500	500	500	500	500	500
Explosives per delay (kg)	282.3	508.1	112.9	225.8	564.5	790.3	1 072.6
Peak Particle Velocity (mm/s)	**6.84**	**10.66**	**3.43**	**5.78**	**11.54**	**14.88**	**18.74**

This assessment will consider the potential blasting impact from:

- an average blast, with 10 m deep blastholes, using a 6 x 6 m pattern for burden and spacing with a 5 m stemming; and

- a worst-case blast, with blastholes up to 24 m deep, using a 7 x 8 m pattern for burden and spacing with a 5 m stemming.

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 BSR and/or 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 (**section 5.2**), the potential ground vibration can be calculated for the estimated blast parameters (see **Figure 8-1**). **Figure 8-2** illustrates the distance from a potential blast (mass per charge) for various vibration limits.

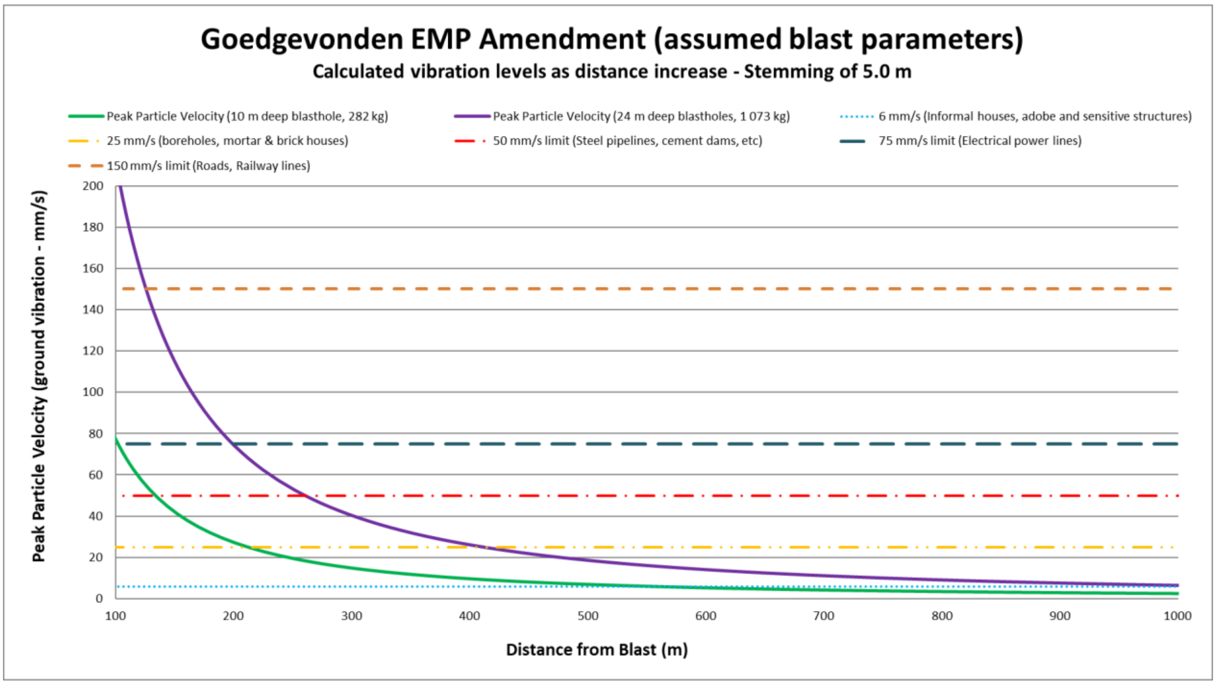

Figure 8-1: Ground vibration levels as the distance increase for assumed blast parameters

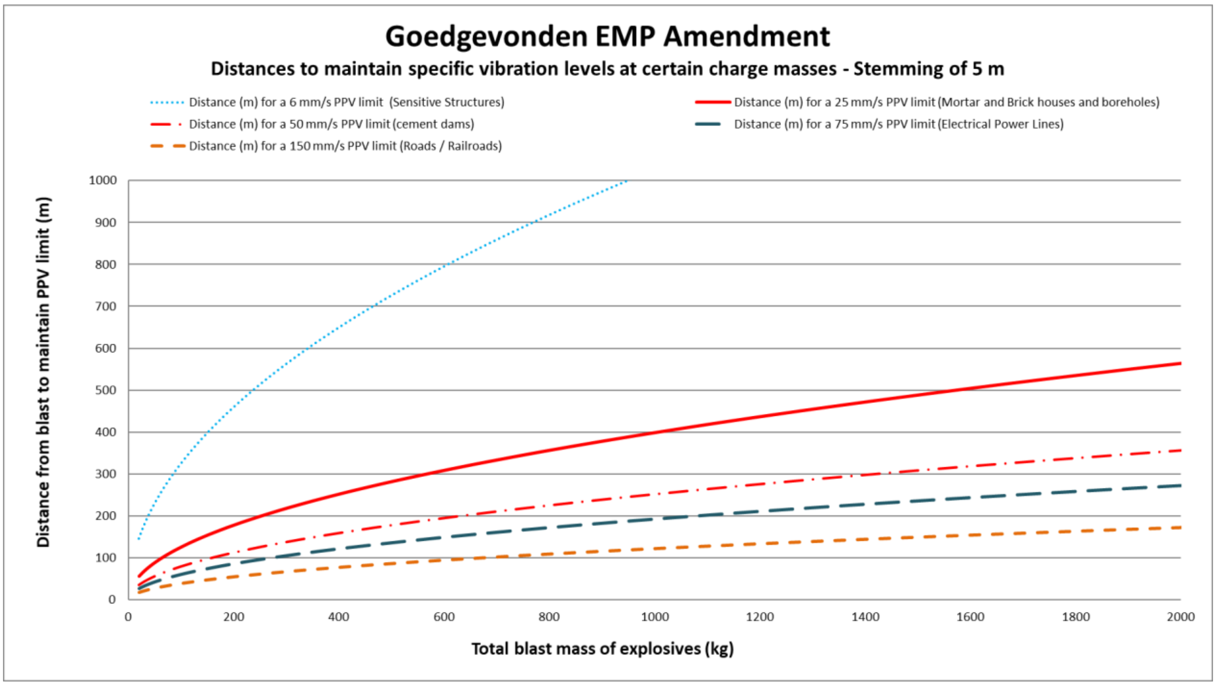

Figure 8-2: Required distances to maintain specific vibration levels at certain charge masses

Potential buffers are illustrated in: for the evaluated blast parameters, indicating the buffer areas:

- **Figure 8-5**, the buffer area where vibration levels of 2.54 mm/s may result in a response from receptors;
- **Figure 8-6**, the buffer area where vibration levels of 6.0 mm/s may result in potential damage to sensitive structures (buildings such as informal, mud or adobe houses – while not identified onsite it was included);
- **Figure 8-7**, the buffer area where vibration levels of 25.0 mm/s may result in potential damage to sensitive plant equipment, pipeline or brick houses;
- **Figure 8-8**, the buffer area where vibration levels of 150.0 mm/s may result in potential damage to tar roads or railway lines.

8.2 PROJECTED MAGNITUDE OF AIR BLAST LEVEL

As discussed in **section 5.3**, 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). Using Equation 2, the potential air blast level can be calculated for the options as indicated in:

- **Figure 8-3** for the assumed blast parameters using the USBM method; and
- **Figure 8-4** for the assumed blast parameters using the AS 2187.2 method.

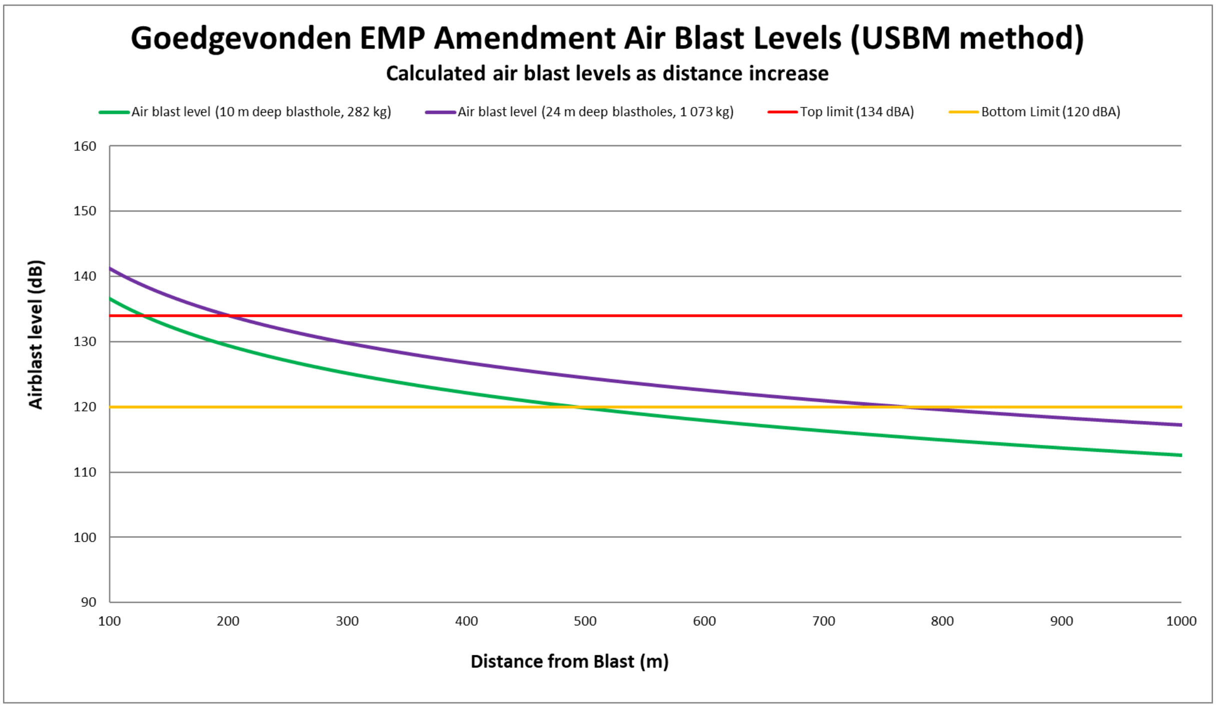

Figure 8-3: Air blast levels as the distance increase for assumed blast parameters using the USBM method

Using the more precautious USBM method, the potential extent of the impact (120 dBA noise limit) is illustrated on an aerial image in **Figure 8-9**. Blasting noises may exceed 120 dB at a distance of 768 m for a 1073 kg charge per delay.

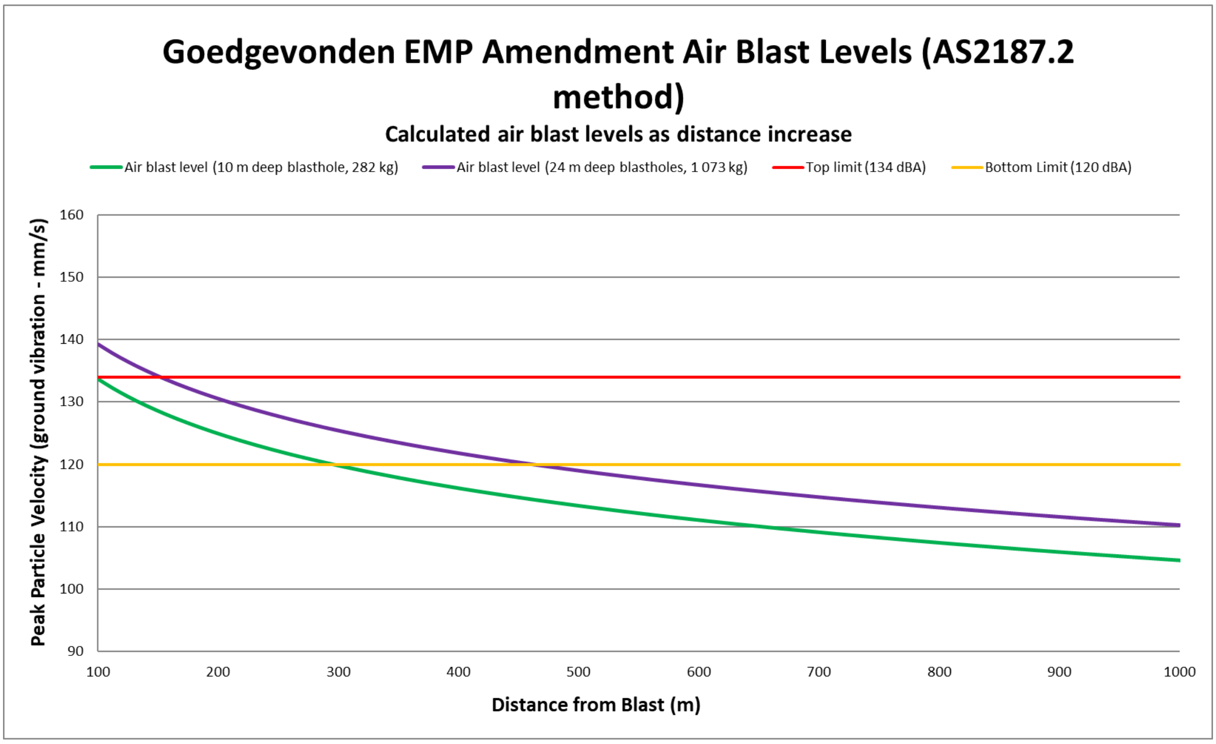

Figure 8-4: Air blast levels as the distance increase for assumed blast parameters using the AS2187.2 method

8.3 PROJECTED MAGNITUDE OF FLY ROCK RISKS

Section 5.4 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 for all three methods (Face bursting, Cratering, Rifling), 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. Using a minimum safety factor of 2 would set a minimum unsafe zone of 428 m from the active blasting area, although it is critical to note that the occurrence of fly rock can never be excluded. It is recommended that the mine at all times use a minimum exclusion zone of 500 m (equipment, people or livestock).

It must be highlighted that once blastholes are shallow, requiring a lower stemming height (less than 4 m), the potential dangers of fly rock increases, due to inadequately confined explosive bay increase dangers due to cratering. When shallow boreholes must be drilled and blasted, it is recommended that the borehole diameter, burden and spacing be reduced accordingly.

Table 8-2: Type of Fly rock and potential area of risk

Fly rock type	Blast Parameters considering 14 m bench height, 127 mm borehole diameter
Face bursting	133 m (for a 6 m burden)
Cratering	214 m (for a 5.0 m stemming depth)
Rifling	73 m (for a 5.0 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 highwalls of the incline portals isn't too steep and dangerous, but the impact will be less than a typical overburden or Interburden blast (associated with the construction of the incline portals). This risk is significantly lower than construction or operational (existing opencast mining activities) blasting and this will not be investigated further.

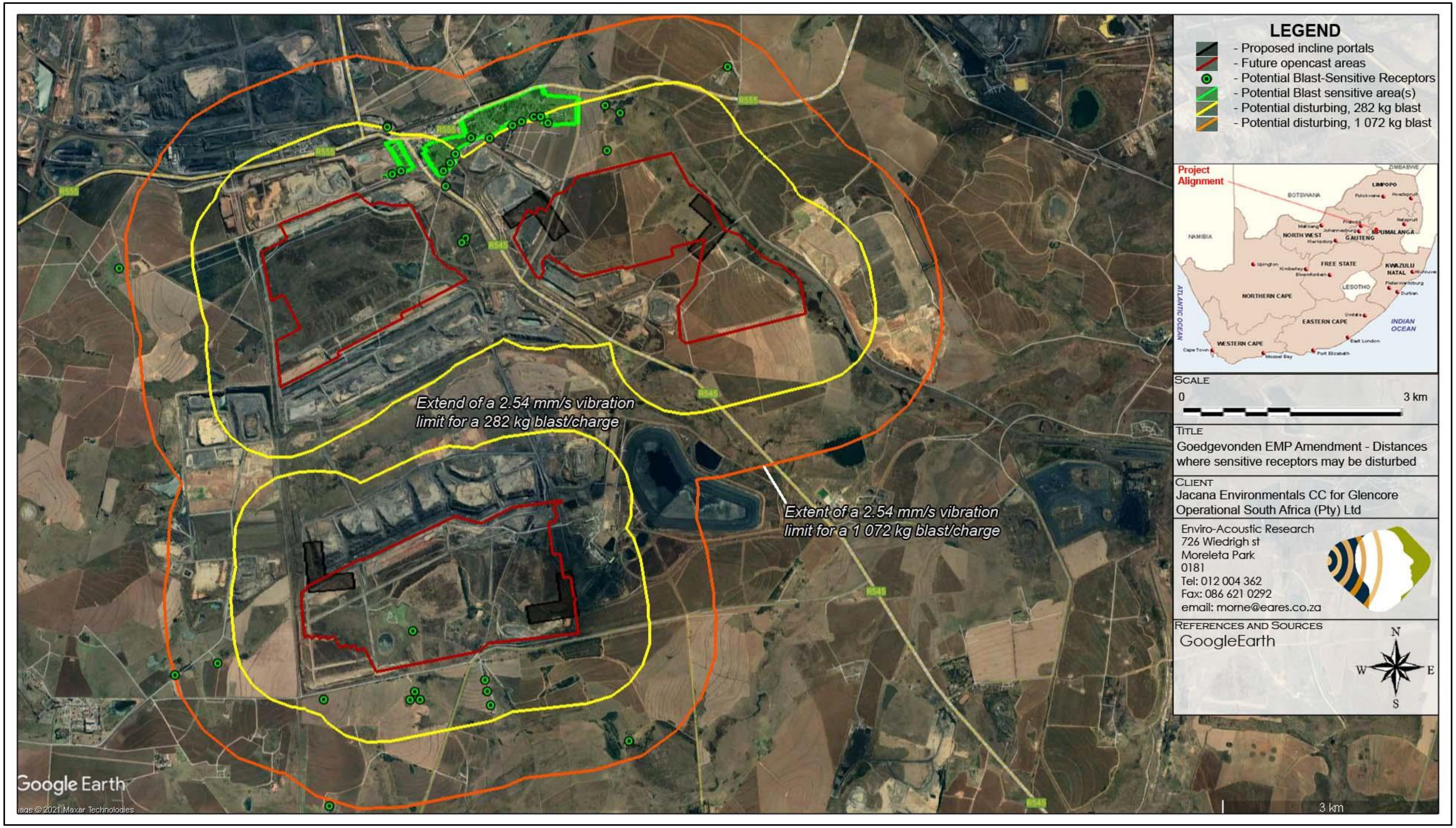

Figure 8-5: Projected Extent of Blasting Vibration Impacts – Potential area where people may respond to blasting vibration for the assessed blast parameters

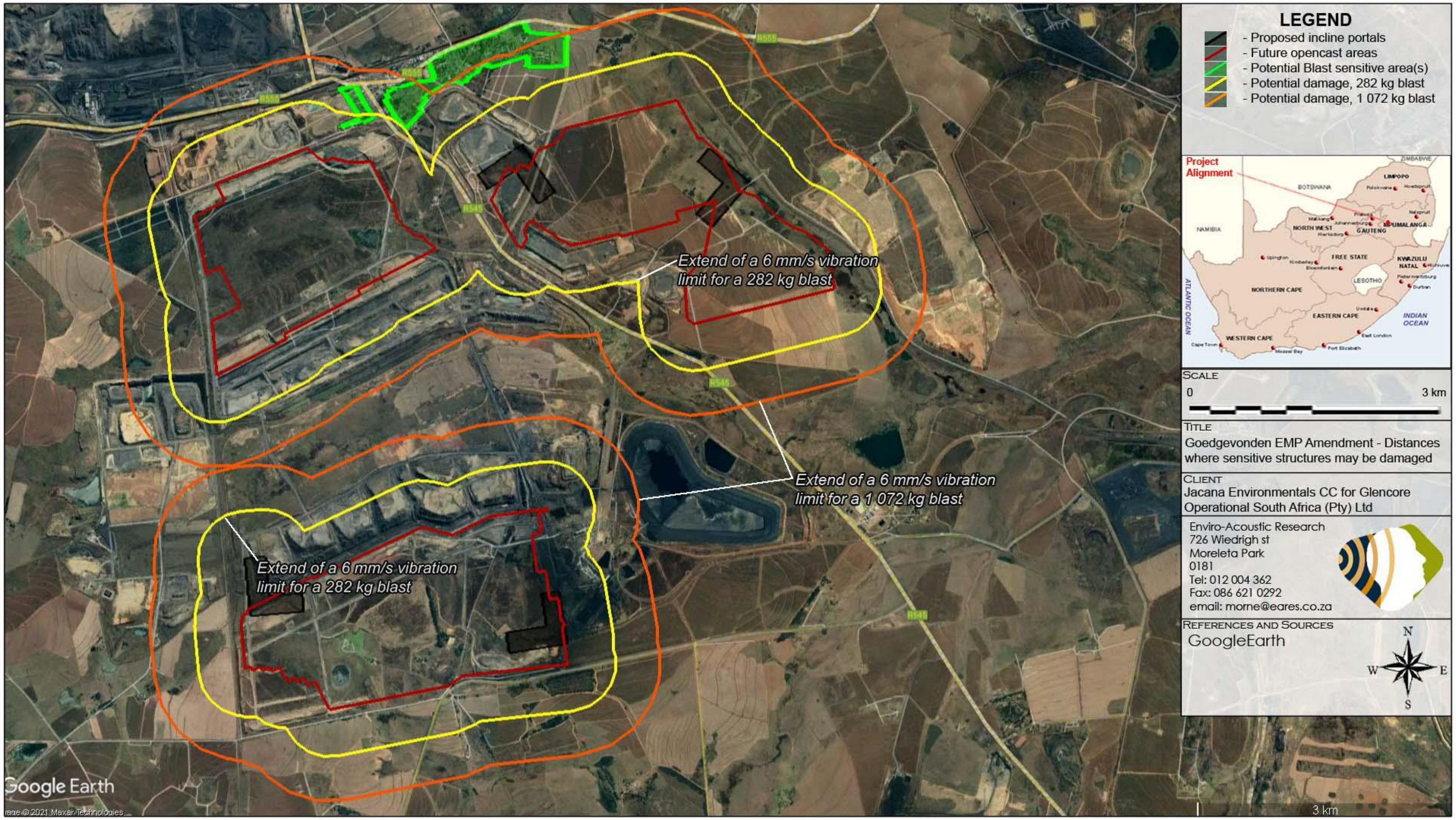

Figure 8-6: Projected Extent of Blasting Vibration Impacts – Potential area where sensitive structures (informal, mud or adobe) may be damaged

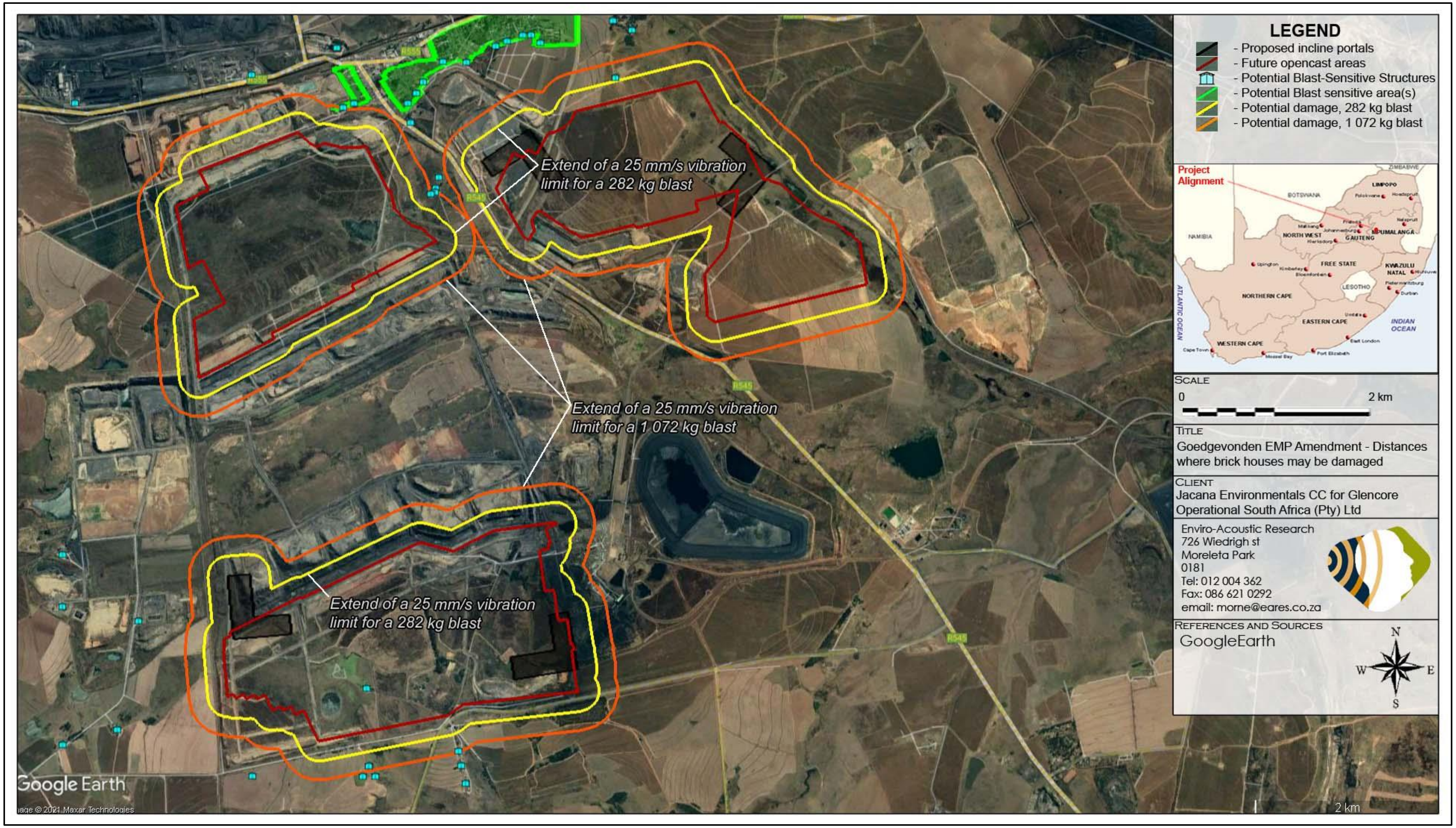

Figure 8-7: Projected Extent of Blasting Vibration Impacts – Potential area where brick houses may be damaged or sensitive plant equipment influenced

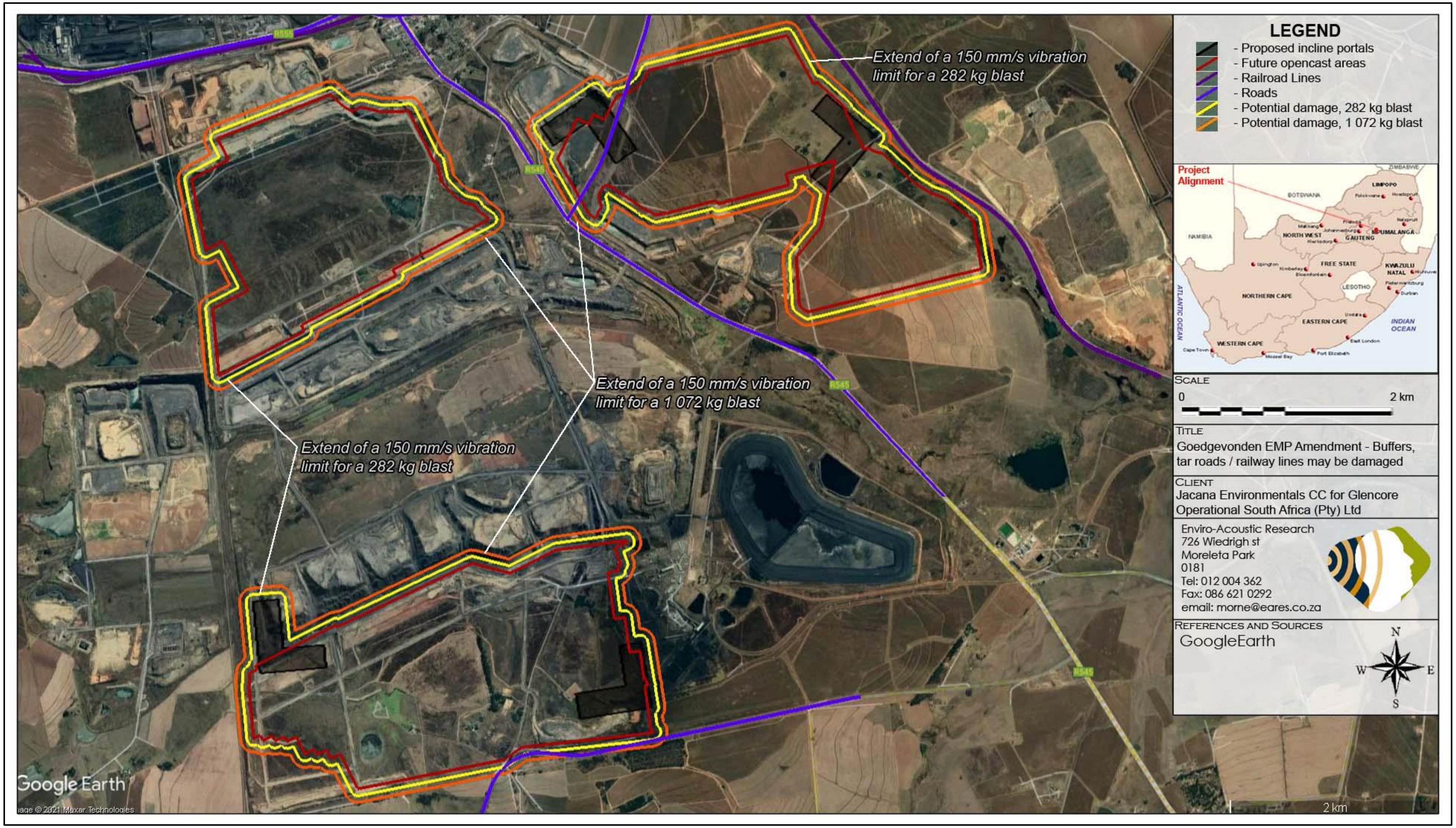

Figure 8-8: Projected Extent of Blasting Vibration Impacts – Potential area where roads and railway lines may be damaged

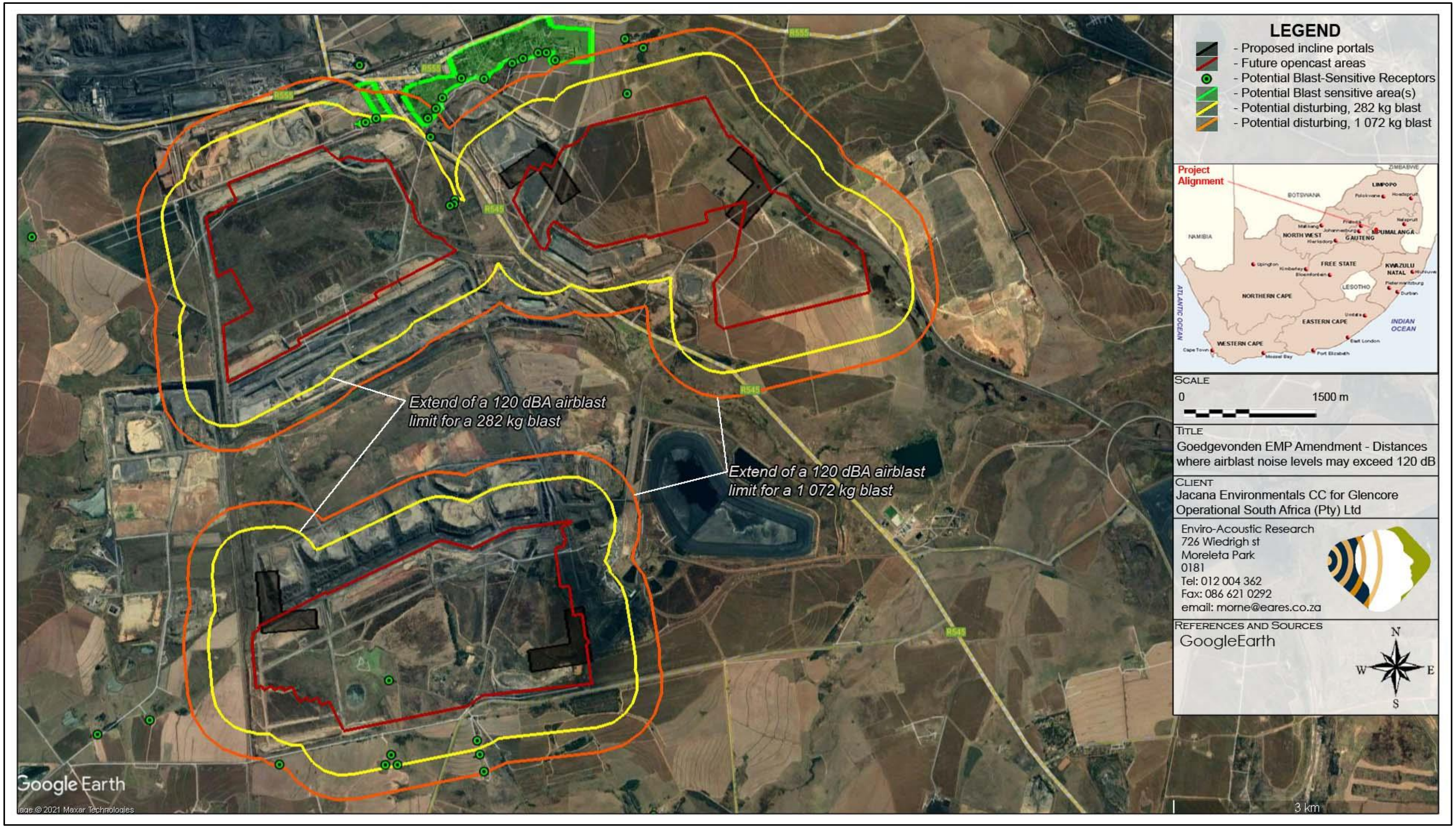

Figure 8-9: Projected Extent of Blasting Impacts – Air blast level for the selected blast parameters

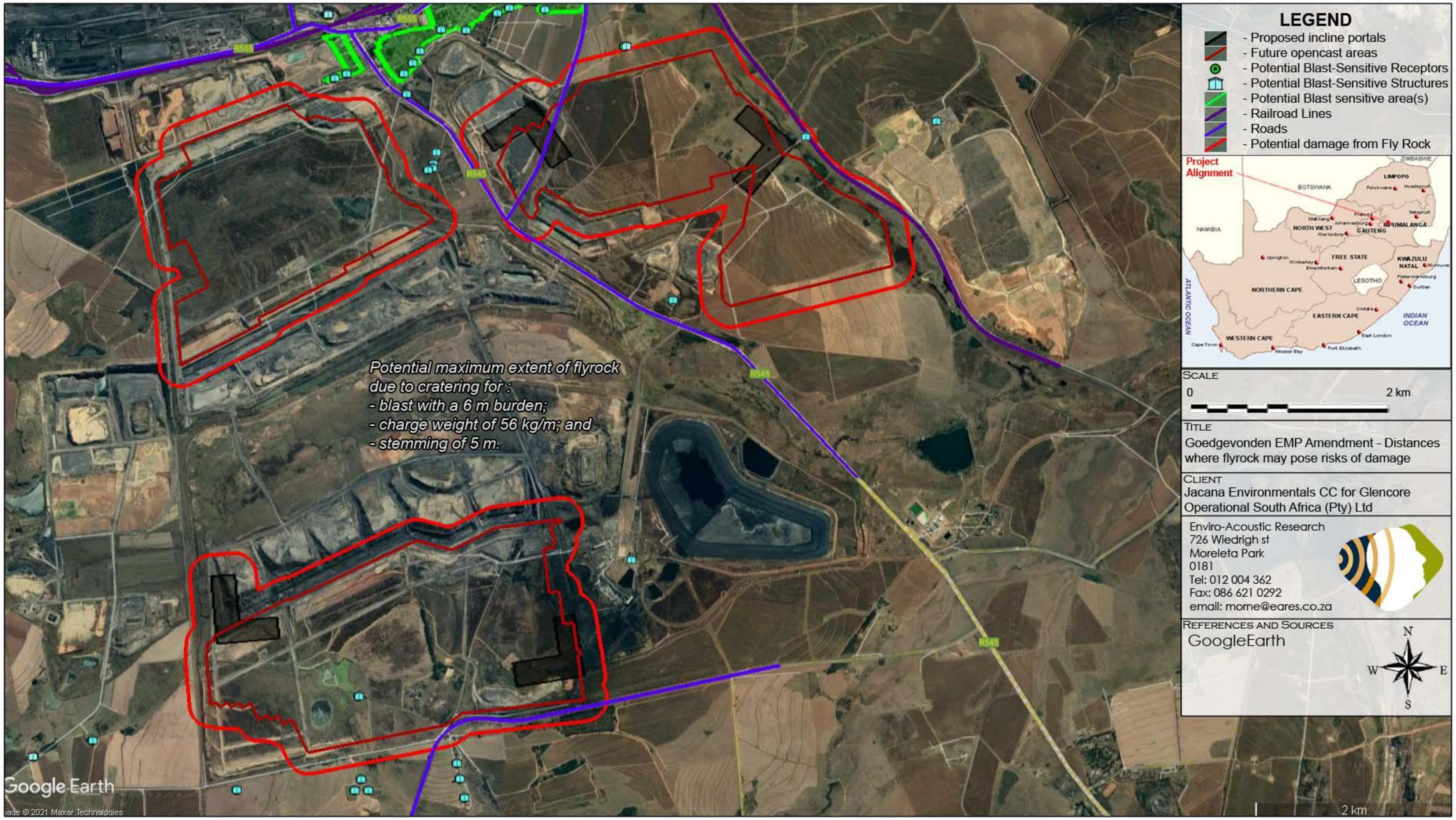

Figure 8-10: Projected Extent of Blasting Impacts – Fly rock risks on surrounding Blast Sensitive Structures

9 SIGNIFICANCE OF THE BLASTING IMPACTS

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

9.1 SIGNIFICANCE OF GROUND VIBRATION IMPACTS

The magnitude of the ground vibration levels was calculated in section **8.1**, defined in **Appendix Table C. 1** (per potential blast sensitive receptors) and **Appendix Table C. 2** (per potential blast sensitive structure) with the estimated significance summarised in **Table 9-1**. It should be noted that there are currently residential as well as livestock farming activities located within areas to be mined in the future. It is recommended that the mine relocate these NSRs when mining activities approach these NSRs (within 500 m), which was considered in the **Table 9-1**.

9.2 SIGNIFICANCE OF AIR BLAST IMPACTS

The magnitude of the air blast levels was calculated in **section 8.2**, defined in **Appendix Table C. 1** with the significance summarised in **Table 9-1**.

9.3 SIGNIFICANCE OF FLY ROCK IMPACTS

The magnitude of potential fly rock risk levels was calculated in section **8.3** and the significance is summarised in **Table 9-1**.

9.4 CLOSURE AND DECOMMISSIONING PHASE IMPACTS

No drilling and blasting are expected during the closure and decommissioning phase, excluding minimal blasting to ensure that any remaining highwalls are safe. These blasts will be much smaller than the blasts evaluated, and, the risks from such blasts are very low.

9.5 EVALUATION OF ALTERNATIVES

No alternatives were considered for this assessment.

Table 9-1: Impact Assessment: Significance of Impacts relating to blasting

Aspect	Risk Event & Cause	Likelihood	Potential Consequences	Consequence Category	Consequence	Current Risk Rating	Mitigation Action
Blasting Vibration	Human response due to the blasting vibration with a blast - 282 kg per delay	C	Complaints from land owner (NSR34)	Image & Reputation / Community	3	13 (M)	The mine can change the blast design when blasting the opencast closer to NSR34 (reduce borehole diameter, burden and spacing).
Blasting Vibration	Human response due to the blasting vibration with a large blast - 1 073 kg per delay	C	Complaints from surrounding sensitive receptors as well as users at the Mosque	Image & Reputation / Community	3	13 (M)	No blasting to occur during times the Mosque is being used (prayers/worship).
Blasting Vibration	Potential damage to sensitive buildings in the informal settlement located south of Ogies, close to the R545.	D	Low risk to structures that are not well constructed. Potential complaints from the community members.	Image & Reputation / Community	2	5 (L)	Photographic survey of the residences within 1,000 m from the blasting area. The mine can reduce the blast mass per delay when blasting within 1,000 m from an NSR (reduce borehole diameter, burden and spacing).
Blasting Vibration	Potential concern by receptors to damage to buildings located closer than 1,000 m from the mine when blast mass per delay exceed 500 kg (per blasthole).	C	While the risk remain low, people may still have concerns about vibration levels and potential damage to their buildings. Potential complaints from the community members.	Image & Reputation / Community	3	13 (M)	Photographic survey of the residences within 1,000 m from the blasting area. The mine can reduce the blast mass per delay when blasting within 1,000 m from an NSR (reduce borehole diameter, burden and spacing).
Blasting Vibration	Potential risk of cracks developing in the cement bridge close to Incline Portal 2 / the opencast mining area with a high blast mass per delay (exceeding 1,000 kg/blasthole).	C	Damage to the bridge	Health and Safety	2	8 (M)	Mine can reduce the blast quantity per delay (reduce borehole diameter, optimizing borehole depth, reducing burden and spacing). The mine can change the blast design when blasting closer than 150 m from this bridge.
Blasting Vibration	Houses and other brick structures within 1,000 m from blasting area with a high blast mass per delay (exceeding 1,000 kg/blasthole).	D	Damage to brick structures, including cracks developing.	Image & Reputation / Community	1	2 (L)	Photographic survey of the residences within 1,000 m from the blasting area. Potential relocation of all people staying within 500m from future areas where blasting may take place.
Blasting Vibration	Road R53 (RAMS naming) transecting the Incline Portal 2/Opencast mining area to be destroyed	A	The section of the road transecting the project area (Incline Portal 2 and Opencast) will be destroyed.	Legal & Compliance	5	25 (H)	Road must be closed or diverted around the Incline Portal 2 area / opencast mining area.
Blasting Vibration	Roads R52 (passing west of Incline Portal 1/Opencast mining area) may develop cracks	E	Potential damage (cracks) to road surface.	Image & Reputation / Community	1	1 (L)	No mitigation required.

Blasting Vibration	Roads R53 (passing south of Incline Portal / the opencast mining area) may develop cracks	C	Potential damage (cracks) to road surface.	Image & Reputation / Community	3	13 (M)	Mine can reduce the blast quantity per delay (reduce borehole diameter, optimizing borehole depth, reducing burden and spacing). The mine can change the blast design at Incline Portal 2 or at the Opencast mining area when mining closer than 150 m from this road.
Air Blast Noise Level	Human response due to air blast noise levels perceived to be "loud" with a high blast mass per delay (exceeding 300 kg/blasthole) when blasting within 1,000m from a NSR.	B	Complaints from surrounding sensitive receptors as well as users at the Mosque	Image & Reputation / Community	2	12 (M)	No blasting to occur during times the Mosque is being used (prayers/worship). The mine can change the blast design when mining within 1,000 m from the Mosque (reduce borehole diameter, burden and spacing). The mine can increase the stemming length when mining within 1,000m from a NSR. The mine should minimise the use of detonating cord, and, if detonating cord must be used when blasting within 1,000m from NSR, the detonating cord should be covered with drill cuttings, stemming material or sand/aggregate.
Damage due to fly Rock	Damage to Equipment and Structures, risks to people or livestock	D	While the risks of Fly Rock are low, damage to equipment or structures, or the loss of life or livestock will result in catastrophic repercussions.	Health and Safety	4	14 (M)	The mine can change the blast design when there are structures located within 500 m from a blast to ensure that the blast is sufficiently contained (reduce borehole diameter, burden and spacing with increased stemming).

10 MITIGATION OPTIONS

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 mine to consider and implement.

10.1 GENERAL MANAGEMENT AND OPERATIONAL MEASURES TO MANAGE BLASTING IMPACTS

The project is proposed in an area with a significant number of BSRs and BSSs such as residential houses, a cement bridge, a railway line and a few tar roads. As such blasting must be carefully planned and executed to ensure that people, livestock, structures and equipment are protected. The following should be noted and considered by the mine:

- A number of tar roads transects the project site, with the project plan indicating future mining activities over a portion of road R53 (RAMS naming system). The mine must remember that GNR.584 of 2015 does limit blasting within 500 m from certain structures unless certain conditions are met (also see **section 4.2**). The mine will have to discuss the project with the relevant authorities to authorize the closure and implement the agreed upon mitigation measures (which may include the rerouting of the road R53 around the mining areas);
- It is critical that the mine provide feedback to the surrounding community and identified BSR, highlighting that the blast impacts were calculated and potential mitigation measures proposed;
- 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 as well as a warning to residents that, when they are indoors during a blast, vibration of windows and ceilings may appear excessive;
- Any evidence of fly rock must be noted and the blast be analysed for possible improvements;
- Blast vibration levels to be calculated for each blast to take place within 1,000 m from any BSR.
- As the onsite conditions are not known, it is recommended that the mine carefully monitor blasting as recommended by Rorke (2005);
- Considering the recommendations set in Dyno (2017), the optimal blasthole diameter is 150 mm for the proposed 10 m bench height. A 250 mm blasthole diameter is large considering a 10 m bench height, resulting in the significant charge per blasthole. Due to the numerous BSRs and BSSs located within the potential area of influence the mine may consider a more optimal blast design.
- There are a number of roads (including the R53 (R545) and R52) located within the project site, and these roads must be closed once blasting is to take place closer than 500 m from these roads. The closure of these roads must be arranged and negotiated with local land owners and the relevant road authority;
- The mine must survey the proposed blasting area before the marking and drilling of blastholes. It is critical that:

  - The burden should be considered to prevent the confinement of blasts. If necessary, the blast design should be adjusted;
  - Blastholes should be accurately drilled and correctly charged with the selected explosives. The over- or undercharging of blastholes must be minimized;
  - Blastholes should always be correctly stemmed, ideally with gravel and not the cuttings from drillings. Too short stemming will result in "blowout" before blast pressure is developed, with too long stemming resulting in insufficient charge and excessive confinement. Both these will result in poor fragmentation, possibly increasing airblast levels and flyrock "unsafe zone".
- The mine must conduct a photographic (crack) survey at all houses, cement dams as well as define the status of water boreholes located within 1,000 m from areas where future blasting is to take place. Cracks will develop with time, which may be due to construction of the structures, standards of building, the age of the structure, the underlying geology and soils, maintenance etc., and not necessarily due to blasting.

10.2 SPECIFIC MITIGATION OPTIONS TO PROTECT BSRS AND BSSS

10.2.1 General Measures

It is recommended that:

- All BSRs working closer than 500 m (Business with reference 37 – MK Metals, see **Figure 3-2**) from active future mining areas must be evacuated before and during blasts;
- All livestock within 500 m from a blast should be moved before, and during a blast;
- The roads must be closed when blasting is to take place within 500 m from the roads;
- The mine must implement a blast monitoring programme, especially when blasting is to take place closer than 1,000 m from the Ogies community. This data should be processed to calculate and confirm the site-specific constants to allow more accurate calculation of the potential blast impacts;
- The mine should erect clear signs indicating blast dates and times along the R545 road as well as agreed locations within Ogies. A blast schedule should be available to interested BSRs;
- The mine should schedule blasting at the same time in the early afternoons, to minimise airblast levels. No blasting should take place early in the mornings, late in the afternoons, during overcast conditions, in the fog or when the wind is blowing towards the Ogies community;
- The mine should discuss the blasting schedule when blasting is to take place within 1,000 m from the Mosque with the Muslim Iman of the Mosque. The mine should agree on the most appropriate time to blast;
- The use of detonating cord should be minimised to control airblast levels. When used within 1 000 m from identified BSRs, the cord should be covered with cuttings or aggregate to minimise airblast levels from this source;

- The mine must undertake a Crack Survey before construction activities (with blasting activities) start at all structures located within 1,000 m from the active future blasting activities.

10.3 MITIGATION OPTIONS THAT SHOULD BE INCLUDED IN THE EMPR AND ENVIRONMENTAL AUTHORIZATION

Measures to be included in the EMPr and Environmental Authorization include:

- The mine must implement a blast monitoring programme, especially when blasting is to take place closer than 1,000 m from the Ogies community. This data should be processed to confirm the site-specific constants to allow more accurate calculation of the potential blast impacts;
- This report must be updated if the blast design is changed where more than 1,100 kg explosives are detonated per delay;
- All BSR staying closer than 500 m from active future mining areas must be evacuated before and during blasts;
- All receptors or livestock within 500 m from a blast should be moved before, and during a blast;
- The roads must be closed when blasting is to take place within 500 m from the roads;
- This report must be updated if the location of the Incline Portals or future opencast mining areas are to change, with potential blasting locations closer to people (as assessed in this report);
- 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 as well as a warning to residents that, when they are indoors during a blast, vibration of windows and ceilings may appear excessive. The local community members must be notified of times when blasts will be undertaken and the community must know that the potential impact of vibration was assessed.
- The mine should discuss the blasting schedule when blasting is to take place within 1,000 m from the Mosque with the Muslim Iman of the Mosque. The mine should agree on the most appropriate time to blast;
- The mine should erect clear signs indicating blast dates and times along the R545 road as well as agreed locations within Ogies. A blast schedule should be available to interested BSRs;
- Mine to prevent blasting in adverse meteorological conditions (overcast conditions, strong wind blowing in direction of local community, early in the mornings or late in the afternoon);
- All roads be closed, and trains on the railway line be stopped before and during a blast taking place within 500 m from such infrastructure;
- The mine must keep full records of each blast (blast design, timing, explosive mass per blast hole, stemming, subdrill, spacing, burden, meteorological conditions during the blast, etc.);
- Any evidence of fly rock is noted and the blast be analysed for possible improvements.

11 CONCLUSION AND RECOMMENDATIONS

This blasting impact assessment covers the proposed development of the Goedgevonden EMP Amendment Project south of Ogies, Mpumalanga Province, 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 blast design was provided by the mine and evaluated in this assessment. This assessment indicated that:

- That ground vibration levels may be unpleasant to BSRs when blasting take place within approximately 1,000 m from structures used for residential, worship or business activities. The impact is of a potential **Medium** significance and mitigation required and proposed that could reduce the vibration levels. However, due to the sensitivity to blast effects, it is possible that people may still complain about the perceived blast effects;
- That ground vibration levels could be of **Medium** significance to potential BSSs in the vicinity of the mining area. General measures are highlighted to ensure that risks due to vibration damage are minimized;
- Air blast levels will be clearly audible to all surrounding receptors and the significance may be **Medium** for the closest BSRs. Mitigation is required and measures are proposed that could reduce the airblast levels. Due to the sensitivity of people to the significant loud noise as well as secondary vibration of large surfaces (due to the change in air pressure), BSRs must be informed about the potential impacts;
- There are no risks of fly rock to BSRs or BSSs, but blasting close to the mine infrastructure may result in fly rock damage. Management measures are available to ensure the risks are minimised.

The significance of blasting risks is **Medium** (excluding the High significance of the impact on the R53 road transected by future mining areas [Incline Portal 2 and Opencast Area]) and blasting monitoring is recommended (as per Rorke, 2005).

In addition, community involvement throughout the project is of utmost importance. This is especially true for any 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 conducts a detailed photographic survey at selected structures (that does not belong to the applicant) located within 1,000 m from the mine (from the opencast boundary limit) before any mining activities start (before the construction phase start where blasting is to take place). This should include a survey (condition assessment with photographic records) of residential structures, water boreholes and cement dams to determine the status of these structures.

Opencast mining is proposed over a portion of road R53. The mine must remember that GNR.584 of 2015 does limit blasting within 500 m from certain structures unless certain conditions are met. The mine will have to discuss the project with the relevant authorities to authorize the closure and implement the agreed upon mitigation measures (which may include the rerouting of the road R53 around the future opencast mining area).

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 Goedgevonden EMP Amendment Project be authorized (from a blasting impact perspective) subject to compliance with the conditions of the EMP.

12 REFERENCES

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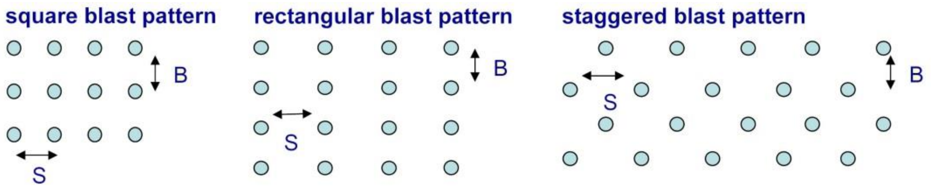
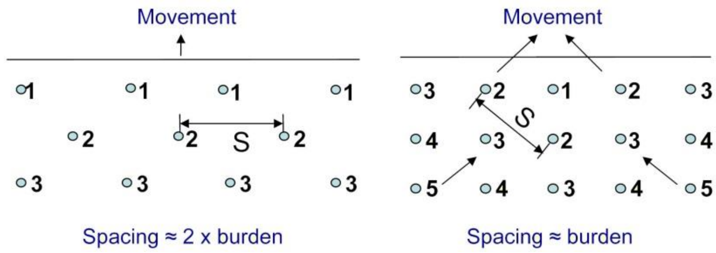
APPENDIX A

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 hole(s) 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

APPENDIX C

Effect of Blasting Impacts on Receptors and Structures

Table C. 1: Potential human response and significance of impact due to blasting vibration impacts

					Peak Particle Velocity (PPV)		Airblast Level (dB)		Potential Human Response, vibration		Potential Human Response, Air blast level	
Description	Longitude	Latitude	Reference	Distance from potential blast site	282 kg blast (per delay)	1 072 kg blast (per delay)	282 kg blast (per delay)	1 072 kg blast (per delay)	282 kg blast (per delay)	1 072 kg blast (per delay)	282 kg blast (per delay)	1 072 kg blast (per delay)
BSR	29.02201214	-26.116577	1	1237	**1.7**	**4.8**	**110.4**	**115.0**	Detectable	Unpleasant	No Response	No Response
BSR	29.04598164	-26.0564582	2	443	**8.2**	**22.5**	**121.1**	**125.7**	Unpleasant	Intolerable.	Complains.	Complains.
BSR	29.04717377	-26.0560532	3	492	**7.0**	**19.2**	**120.0**	**124.6**	Unpleasant	Intolerable.	No Response	Complains.
BSR	29.05297954	-26.0560429	4	712	**4.0**	**11.0**	**116.1**	**120.8**	Unpleasant	Unpleasant	No Response	Complains.
BSR	29.05549184	-26.0648619	5	403	**9.5**	**26.0**	**122.1**	**126.7**	Unpleasant	Intolerable.	Complains.	Complains.
BSR	*29.04877832*	*-26.1126156*	*6*	*4*	***10033.2***	***27490.2***	***170.2***	***174.8***	*Intolerable.*	*Intolerable.*	*Complains.*	*Complains.*
BSR	29.04903829	-26.1200675	7	353	**11.6**	**31.7**	**123.5**	**128.1**	Unpleasant	Intolerable.	Complains.	Complains.
BSR	29.05866178	-26.1186396	8	392	**9.9**	**27.1**	**122.4**	**127.0**	Unpleasant	Intolerable.	Complains.	Complains.
BSR	29.05388183	-26.0550643	9	852	**3.1**	**8.4**	**114.3**	**118.9**	Unpleasant	Unpleasant	No Response	No Response
BSR	29.05896603	-26.1200253	10	548	**6.0**	**16.3**	**118.9**	**123.5**	Unpleasant	Unpleasant	No Response	Complains.
BSR	29.05943592	-26.1217335	11	743	**3.8**	**10.3**	**115.7**	**120.3**	Unpleasant	Unpleasant	No Response	Complains.
BSR	29.06729619	-26.0501611	12	990	**2.4**	**6.7**	**112.7**	**117.3**	Detectable	Unpleasant	No Response	No Response
BSR	29.09190493	-26.0432628	13	1441	**1.4**	**3.8**	**108.8**	**113.4**	Detectable	Unpleasant	No Response	No Response
BSR	29.05462221	-26.0539706	14	991	**2.4**	**6.7**	**112.7**	**117.3**	Detectable	Unpleasant	No Response	No Response
BSR	29.05675608	-26.0519906	15	1166	**1.9**	**5.2**	**111.0**	**115.6**	Detectable	Unpleasant	No Response	No Response
BSR	29.05930547	-26.0520625	16	1089	**2.1**	**5.8**	**111.7**	**116.4**	Detectable	Unpleasant	No Response	No Response
BSR	29.06245548	-26.0504831	17	1141	**2.0**	**5.4**	**111.2**	**115.9**	Detectable	Unpleasant	No Response	No Response
BSR	29.06629341	-26.0493902	18	1094	**2.1**	**5.7**	**111.7**	**116.3**	Detectable	Unpleasant	No Response	No Response
BSR	29.0497555	-26.1210592	19	470	**7.5**	**20.6**	**120.5**	**125.1**	Unpleasant	Intolerable.	Complains.	Complains.
BSR	29.07840112	-26.1261367	20	1613	**1.2**	**3.2**	**107.6**	**112.3**	Detectable	Unpleasant	No Response	No Response
BSR	29.07513233	-26.0480088	21	868	**3.0**	**8.1**	**114.1**	**118.7**	Unpleasant	Unpleasant	No Response	No Response
BSR	29.0653745	-26.0494124	22	1117	**2.0**	**5.6**	**111.5**	**116.1**	Detectable	Unpleasant	No Response	No Response
BSR	29.06367603	-26.0499963	23	1124	**2.0**	**5.5**	**111.4**	**116.0**	Detectable	Unpleasant	No Response	No Response
BSR	29.00854455	-26.0680142	24	1965	**0.9**	**2.4**	**105.6**	**110.2**	Detectable	Detectable	No Response	No Response
BSR	29.03654685	-26.1210299	25	726	**3.9**	**10.7**	**115.9**	**120.6**	Unpleasant	Unpleasant	No Response	Complains.
BSR	29.04839587	-26.1210695	26	447	**8.1**	**22.2**	**121.0**	**125.6**	Unpleasant	Intolerable.	Complains.	Complains.
BSR	29.07718693	-26.048927	27	719	**4.0**	**10.8**	**116.0**	**120.7**	Unpleasant	Unpleasant	No Response	Complains.
Mosque	29.05595875	-26.0647018	28	432	**8.5**	**23.4**	**121.4**	**126.0**	Unpleasant	Intolerable.	Complains.	Complains.
BSR	29.04528128	-26.0506552	29	1021	**2.3**	**6.4**	**112.4**	**117.0**	Detectable	Unpleasant	No Response	No Response
BSR	29.05329216	-26.0579249	30	616	**5.0**	**13.7**	**117.7**	**122.3**	Unpleasant	Unpleasant	No Response	Complains.
BSR	29.05602175	-26.0643037	31	476	**7.4**	**20.2**	**120.3**	**125.0**	Unpleasant	Intolerable.	Complains.	Complains.
BSR	29.03731417	-26.1341341	32	1920	**0.9**	**2.5**	**105.8**	**110.4**	Detectable	Detectable	No Response	No Response
BSR	29.01616794	-26.1180218	33	1843	**1.0**	**2.6**	**106.2**	**110.9**	Detectable	Unpleasant	No Response	No Response
BSR	*29.07539009*	*-26.0535652*	*34*	*258*	***18.6***	***50.9***	***126.7***	***131.4***	*Intolerable.*	*Intolerable.*	*Complains.*	*Complains.*

* Recommended that NSRs located within 500m from future blasting areas to be relocated.

Description	Reference	Longitude	Latitude	Potential Human Response, vibration - 282 kg blast (per delay)			Potential Human Response, vibration - 1 072 kg blast (per delay)			Potential Human Response, airblast level - 282 kg blast (per delay)			Potential Human Response, airblast level - 1 072 kg blast (per delay)		
				Consequence	Probability	Significance	Consequence	Probability	Significance	Consequence	Probability	Significance	Consequence	Probability	Significance
BSR	1	29.022	-26.1166	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	2	29.046	-26.0565	2	D	Low	3	C	Medium	2	C	Low	2	C	Low
BSR	3	29.0472	-26.0561	2	D	Low	3	D	Low	2	C	Low	2	C	Low
BSR	4	29.053	-26.056	2	D	Low	2	D	Low	1	D	Low	2	C	Low
BSR	5	29.0555	-26.0649	2	D	Low	3	C	Medium	2	C	Low	2	C	Low
BSR	6	29.0488	-26.1126	5	A	High	5	A	High	5	A	High	5	A	High
BSR	7	29.049	-26.1201	2	D	Low	3	C	Medium	2	C	Low	2	C	Low
BSR	8	29.0587	-26.1186	2	D	Low	3	C	Medium	2	C	Low	2	C	Low
BSR	9	29.0539	-26.0551	2	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	10	29.059	-26.12	2	D	Low	2	D	Low	1	D	Low	2	C	Low
BSR	11	29.0594	-26.1217	2	D	Low	2	D	Low	1	D	Low	2	C	Low
BSR	12	29.0673	-26.0502	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	13	29.0919	-26.0433	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	14	29.0546	-26.054	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	15	29.0568	-26.052	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	16	29.0593	-26.0521	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	17	29.0625	-26.0505	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	18	29.0663	-26.0494	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	19	29.0498	-26.1211	2	D	Low	3	C	Medium	2	C	Low	2	C	Low
BSR	20	29.0784	-26.1261	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	21	29.0751	-26.048	2	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	22	29.0654	-26.0494	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	23	29.0637	-26.05	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	24	29.0085	-26.068	1	D	Low	1	D	Low	1	D	Low	1	D	Low
BSR	25	29.0365	-26.121	2	D	Low	2	D	Low	1	D	Low	2	C	Low
BSR	26	29.0484	-26.1211	2	D	Low	3	C	Medium	2	C	Low	2	C	Low
BSR	27	29.0772	-26.0489	2	D	Low	2	D	Low	1	D	Low	2	C	Low
Mosque	28	29.056	-26.0647	2	C	Low	3	C	Medium	2	C	Low	2	C	Low
BSR	29	29.0453	-26.0507	1	D	Low	2	D	Low	1	D	Low	1	D	Low
BSR	30	29.0533	-26.0579	2	D	Low	2	D	Low	1	D	Low	2	C	Low
BSR	31	29.056	-26.0643	2	C	Low	3	C	Medium	2	C	Low	2	C	Low
BSR	32	29.0373	-26.1341	1	D	Low	1	D	Low	1	D	Low	1	D	Low
BSR	33	29.0162	-26.118	1	2	Low	1	2	Low	1	2	Low	1	2	Low
BSR	34	29.0754	-26.0536	3	3	Medium	4	4	Medium	2	3	Low	2	4	Medium

Table C. 2: Potential response and significance of impact from blasting vibrations on various structures

Description	Longitude	Latitude	Reference	Distance from potential blast site	Peak Particle Velocity (PPV)		Potential structural damage.		Potential structural damage, vibration - 282 kg blast (per delay)			Potential structural damage, vibration - 1 072 kg blast (per delay)		
					282 kg blast (per delay)	1 072 kg blast (per delay)	282 kg blast (per delay)	1 072 kg blast (per delay)	Consequence	Probability	Significance	Consequence	Probability	Significance
House	29.02201214	-26.116577	1	1237	**1.7**	**4.8**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.04598164	-26.0564582	2	443	**8.2**	**22.5**	Very Low Risk	Very Low Risk	1	1	**1**	2	1	**2**
House	29.04717377	-26.0560532	3	492	**7.0**	**19.2**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
Informal Houses	29.05297954	-26.0560429	4	712	**4.0**	**11.0**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.05549184	-26.0648619	5	403	**9.5**	**26.0**	Very Low Risk	Risks	1	1	**1**	3	3	**9**
House	29.04877832	-26.1126156	6	4	**10033.2**	**27490.2**	Risks	Risks	5	5	**25**	5	5	**25**
House	29.04903829	-26.1200675	7	353	**11.6**	**31.7**	Very Low Risk	Risks	1	1	**1**	1	1	**1**
House	29.05866178	-26.1186396	8	392	**9.9**	**27.1**	Very Low Risk	Risks	1	1	**1**	3	3	**9**
Informal Houses	29.05388183	-26.0550643	9	852	**3.1**	**8.4**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.05896603	-26.1200253	10	548	**6.0**	**16.3**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.05943592	-26.1217335	11	743	**3.8**	**10.3**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.06729619	-26.0501611	12	990	**2.4**	**6.7**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.09190493	-26.0432628	13	1441	**1.4**	**3.8**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
Informal Houses	29.05462221	-26.0539706	14	991	**2.4**	**6.7**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.05675608	-26.0519906	15	1166	**1.9**	**5.2**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.05930547	-26.0520625	16	1089	**2.1**	**5.8**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.06245548	-26.0504831	17	1141	**2.0**	**5.4**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.06629341	-26.0493902	18	1094	**2.1**	**5.7**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.0497555	-26.1210592	19	470	**7.5**	**20.6**	Very Low Risk	Very Low Risk	1	1	**1**	2	2	**4**
House	29.07840112	-26.1261367	20	1613	**1.2**	**3.2**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.07513233	-26.0480088	21	868	**3.0**	**8.1**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.0653745	-26.0494124	22	1117	**2.0**	**5.6**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.06367603	-26.0499963	23	1124	**2.0**	**5.5**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.00854455	-26.0680142	24	1965	**0.9**	**2.4**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.03654685	-26.1210299	25	726	**3.9**	**10.7**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**

House	29.04839587	-26.1210695	26	447	**8.1**	**22.2**	Very Low Risk	Very Low Risk	1	1	**1**	2	2	**4**
House	29.07718693	-26.048927	27	719	**4.0**	**10.8**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.05595875	-26.0647018	28	432	**8.5**	**23.4**	Very Low Risk	Very Low Risk	1	1	**1**	2	2	**4**
House	29.04528128	-26.0506552	29	1021	**2.3**	**6.4**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.05329216	-26.0579249	30	616	**5.0**	**13.7**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.05602175	-26.0643037	31	476	**7.4**	**20.2**	Very Low Risk	Very Low Risk	1	1	**1**	2	2	**4**
House	29.03731417	-26.1341341	32	1920	**0.9**	**2.5**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.01616794	-26.1180218	33	1843	**1.0**	**2.6**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.01601415	-26.0997368	34	1800	**1.0**	**2.7**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.0160301	-26.1047461	35	1791	**1.0**	**2.7**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.02422187	-26.1061387	36	958	**2.6**	**7.0**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.05634317	-26.0632521	37	503	**6.8**	**18.6**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.07541039	-26.053583	38	255	**18.9**	**51.8**	Very Low Risk	Risks	1	2	**2**	3	3	**9**
House	29.01699384	-26.0560087	39	1589	**1.2**	**3.3**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
House	29.03607328	-26.0532676	40	772	**3.6**	**9.7**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
Cement Bridge	29.09375514	-26.0619109	Cement Bridge	130	**52.3**	**143.3**	Very Low Risk	Very Low Risk	1	1	**1**	3	2	**6**
Railway Line	29.09950648	-26.0666833	Railway Line	125	**55.5**	**152.0**	Very Low Risk	Risks	1	1	**1**	3	3	**9**
Road	29.06446187	-26.070312	Road	174	**33.7**	**92.3**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
Road	29.06454307	-26.070383	Road	175	**33.4**	**91.5**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
Road	29.06463426	-26.0704539	Road	177	**32.8**	**89.9**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
Road	29.06475543	-26.0705244	Road	176	**33.1**	**90.7**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
Road	29.06499792	-26.0706744	Road	177	**32.8**	**89.9**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
Road	29.06524025	-26.0708153	Road	177	**32.8**	**89.9**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**
Road	29.06465814	-26.067827	Road	10	**2515.1**	**6891.1**	Risks	Risks	5	5	**25**	5	5	**25**
Road	29.06890848	-26.0588934	Road	9	**2948.8**	**8079.5**	Risks	Risks	5	5	**25**	5	5	**25**
Road	29.05785071	-26.1157177	Road	61	**163.9**	**449.2**	Risks	Risks	3	3	**9**	4	3	**12**
Road	29.05827546	-26.1154228	Road	57	**181.6**	**497.6**	Risks	Risks	3	3	**9**	4	3	**12**
Road	29.07155179	-26.113662	Road	72	**127.6**	**349.7**	Very Low Risk	Risks	2	1	**2**	3	3	**9**
Road	29.05961543	-26.0640719	Road	270	**17.3**	**47.5**	Very Low Risk	Very Low Risk	1	1	**1**	1	1	**1**

End of Report