Blast Management & Consulting

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Report: Blast Impact Assessment Proposed Vlakvarkfontein Mine Extension Project	
Date:	10 November 2017
BM&C Ref No:	EIMS~Vlakvarkfontein Mine Extension Project~EIAReport~171110V01
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DMR Ref No:	n/a
Signed:	
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ii. Study Team Qualifications and Background

The study team comprises J D Zeeman (as the member of Blast Management & Consulting) and Blast Management & Consulting employees. Blast Management & Consulting's main areas of concern are pre-blast consultation and monitoring, insitu monitoring, post-blast monitoring and consulting as well as specialised projects. Blast Management & Consulting has been active in the mining industry since 1997 and work has been done at various levels for mining companies in South Africa, Botswana, Namibia, Mozambique, Democratic Republic of Congo, Sierra Leone and Côte d'Ivoire.

J D Zeeman holds the following qualifications:

1985 - 1987	Diploma: Explosives Technology, Technikon Pretoria
1990 - 1992	BA Degree, University of Pretoria
1994	National Higher Diploma: Explosives Technology, Technikon Pretoria
1997	Project Management Certificate, Damelin College
2000	Advanced Certificate in Blasting, Technikon SA

Member: International Society of Explosive Engineers

iii. Independence Declaration

Blast Management & Consulting is an independent company. The work done for the report was performed in an objective manner and according to national and international standards, which means that the results and findings may not all be positive for the client. Blast Management & Consulting has the required expertise to conduct such an investigation and draft the specialist report relevant to the study. Blast Management & Consulting did not engage in any behaviour that could be result in a conflict of interest in undertaking this study.

iv. Legal Requirements

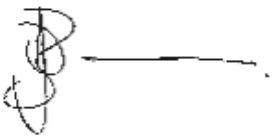
In terms of the NEMA 2014 EIA Regulations contained in GN R982 of 04 December 2014 all specialist studies must comply with Appendix 6 of the NEMA 2014 EIA Regulations (GN R982 of 04 December 2014). Table 1 show the requirements as indicated above.

Table 1: Legal Requirements for All Specialist Studies Conducted

Legal Requirement		**Relevant Section in 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	i
	(ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Section ii and 24
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority;	Section iii
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 4
(d)	the date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 7
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process	Section 6
(f)	the specific identified sensitivity of the site related to the activity and its associated structures and infrastructure;	Section 10
(g)	an identification of any areas to be avoided, including buffers;	Section 10
(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;	Section 10 & 15
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 8
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives on the environment;	Section 15
(k)	any mitigation measures for inclusion in the EMPr;	Section 17
(l)	any conditions/aspects for inclusion in the environmental authorisation;	Section 17
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 21.11
(n)	a reasoned opinion (Environmental Impact Statement)-	Section 23
	as to whether the proposed activity or portions thereof should be authorised; and	Section 23

Legal Requirement		Relevant Section in Specialist study
	if the opinion is that the proposed activity 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 23
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	Section 11
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	None
(q)	any other information requested by the competent authority.	None

v. Document Control:

Name & Company	Responsibility	Action	Date	Signature
C Zeeman Blast Management & Consulting	Document Preparation	Report Prepared	10/11/2017	
JD Zeeman Blast Management & Consulting	Consultant	Report Finalise	20/11/2017	

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List of Acronyms used in this Report

a and b	Site Constant
ANFO	Ammonium nitrate fuel oil
APP	Air Pressure Pulse
B	Burden (m)
BH	Blast Hole
BM&C	Blast Management & Consulting
Bs	Scaled Burden ($m^{3/2}kg^{-1/2}$)
D	Distance (m)
D	Duration (s)
E	East
E	Explosive Mass (kg)
EIA	Environmental Impact Assessment
Freq.	Frequency
GRP	Gas Release Pulse
I&AP	Interested and Affected Parties
k	Factor value
L	Maximum Throw (m)
Lat/Lon hddd°mm'ss.s"	Latitude/Longitude Hours/degrees/minutes/seconds
M	Charge Height
m (SH)	Stemming height
M/S	Magnitude/Severity
Mc	Charge mass per metre column
N	North
NE	North East
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxide
NOx's	Noxious Fumes
NW	North West
P	Probability
POI	Points of Interest
PPD	Peak particle displacement
PPV	Peak Particle Velocity
PVS	Peak vector sum
RPP	Rock Pressure Pulse
S	Scale
S	South
SE	South East
SH	Stemming height (m)

SW	South West
T	Blasted Tonnage
TNT	Explosives (Trinitrotoluene)
USBM	United States Bureau of Mine
W	West
WGS 84	Coordinates (South African)
WM	With Mitigation Measures
WOM	Without Mitigation Measures

List of Units used in this Report

%	percentage
cm	centimetre
dB	decibel
dBL	linear decibel
g	acceleration
g/cm^3	gram per cubic centimetre
Hz	frequency
kg	kilogram
kg/m^3	kilogram per cubic metre
kg/t	kilogram per tonne
km	kilometre
kPa	kilopascal
m	metre
m^2	metre squared
MJ	Mega Joules
MJ/m^3	Mega Joules per cubic meter
MJ/t	Mega Joules per tonne
mm/s	millimetres per second
mm/s^2	millimetres per second square
ms	milliseconds
Pa	Pascal
ppm	parts per million
psi	pounds per square inch
θ	theta or angle

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1 Executive Summary

Blast Management & Consulting (BM&C) was contracted as part of the Environmental Impact Assessment (EIA) to perform review of possible impacts with regards to blasting operations on the proposed Vlakvarkfontein Mine Extension Project located in the Mpumalanga Province of South Africa. Ground vibration, air blast, fly rock and fumes are some of the aspects resulting from blasting operations. The report concentrates on the possible influences of ground vibration, air blast and fly rock. It intends to provide information, calculations, predictions, possible influences and mitigation of blasting operations for the project.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as a 3500 m radius from where blasting will take place. The range of structures observed and considered in this evaluation ranged between industrial structures, community houses, power lines, railway lines and heritage sites.

The project area does have people and houses at very close distance to the project area. The nearest house or buildings is found 16 m away. Specific attention will be required for adjustments in the blasting operations to ensure expected levels of ground vibration and air blast are within the required limits. There are also regulations that will need to be followed for permission to conduct blasting operations as these installations area within 500 m from the blast operations. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage. There is a possibility that ground vibration may be intolerable at the closest community houses and the school. Considerations will have to be given to alternative placement or installation of the community houses specifically. The ground vibration levels predicted for all installations evaluated surrounding the pit area ranged between 0.3 mm/s and 3653.5 mm/s. Ground vibration levels at the nearest buildings where people may be present is very high.

Air blast predicted for the maximum charge ranges between 107.4 and 144.4 dB for all the POI's considered. Air blast observed and predicted showed the same concern than ground vibration. In view of the predicted levels the probability of damages exists if blasting operations does not take careful planning of stemming length and material into consideration. Damages are only expected to occur at levels greater than 134dB. On prediction it is expected that air blast will be greater than 134 dB at a distance of 75 m and closer to the pit boundary. Various private installations are within 500 m from the pit boundary. Air blast that could lead to complaints is expected to reach distances of 486 m from the pit area. The levels at other private houses or settlements are expected to be within limits and not damaging.

An exclusion zone for safe blasting was also calculated. The exclusion zone was established to be at least 266 m. Normal practice observed in mines is a 500 m exclusion zone. The minimum distance recommended is 266 m. This distance may be greater but not less.

Recommendations were made that should be considered, specifically for review of blast designs, monitoring of ground vibration and air blast, safe blasting zones, safe ground vibration and air blast limits, blast designs, blasting times and relocations of infrastructure to be considered.

Probably the most specific concern regarding the project is location of the Arbor village. The village is located directly adjacent to the mine and will require a detail management plan for the planned operation.

This concludes this investigation for the Vlakvarkfontein Mine Extension Project. Blast Management and Consulting is of opinion that specific detail management plan will be required with regards to the Arbor village area. Provided that such management addresses the aspects of concern there is no reason to believe that this operation cannot continue if attention is given to the recommendations made.

2 Introduction

Ntshovelo Mining Resources (Pty) Ltd (Ntshovelo) a subsidiary of Mbuyelo Coal (Pty) Ltd. has an approved Mining Right (MR) (Ref No: MP 30/5/1/2/2/300 MR) and Environmental Management Programme (EMPR), in terms of the Minerals and Petroleum Resources Development Act (Act 28 of 2002, as amended) (MPRDA), for the mining of coal at the Vlakvarkfontein Coal Mine. Ntshovelo wishes to extend the mining operations at the Vlakvarkfontein Coal Mine, located on Portions 5, 13, and 18 of the Farm Vlakvarkfontein 213 IR. The mining area is situated approximately 30 km north east of Delmas, and approximately 15 km south west of Ogies. The N12 highway passes to the north of the mining area. The project falls within the Nkangala District Municipality and the Delmas Local Municipality at coordinates (Lat/Lon WGS84) 26° 3'22.65"S, 28°53'33.39"E.

It is proposed to expand the open cast mining operations, using the roll-over mining method, onto Portion 5 of the farm Vlakvarkfontein 213IR. This area is within the existing approved mining right boundary but was not specifically included and assessed in the approved Environmental Management Programme Report (EMPR) and associated environmental permits and authorisations. The proposed new mining operations will necessitate the relocation and re-establishment of the existing ancillary infrastructure associated with the current mining operations, including the Pollution Control Dam (PCD) and the administrative structures. It is also proposed to establish a coal processing plant (wash plant) to decontaminate the Run of Mine (RoM) coal. An application for the amendment to the existing Mine Works Programme (MWP) and EMPR, through an MPRDA Section 102 Application, and a full Environmental Impact Assessment (EIA) for the proposed new mining area is, therefore, required to support an application for environmental authorisation (EA) / waste management licence (WML) as applicable. A new water use licence application (WULA) for the relevant water use triggers associated with the proposed project will also be undertaken.

As part of Environmental Impact Assessment (EIA), Blast Management & Consulting (BM&C) was contracted to perform a review of possible impacts from blasting operations for the proposed new open pit coal mining operation. Ground vibration, air blast and fly rock are some of the aspects that result from blasting operations and this study considers the possible influences that blasting may have on the surrounding area in this respect. The report concentrates on ground vibration and air blast and intends to provide information, calculations, predictions, possible influences and mitigating aspects of blasting operations for the project.

3 Objectives

The objectives of this document are to outline the expected environmental effects that blasting operations at the Vlakvarkfontein Mine Extension Project could have on the surrounding environment and to propose specific mitigation measures if required. This study investigates the related influences of expected ground vibration, air blast and fly rock. These effects are investigated in relation to the blast site area and surrounds and the possible influence on nearby private installations, houses and the owners or occupants.

The objectives were dealt with whilst taking specific protocols into consideration. The protocols applied in this document are based on the author's experience, guidelines taken from literature research, project applicant requirements and general indicators in the various appropriate pieces of South African legislation. There is no direct reference in the following acts regarding requirements and limits on the effect of ground vibration and air blast and some of the aspects addressed in this report:

- National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA)
- Mine Health and Safety Act, 1996 (Act No. 29 of 1996)
- Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA)
- Explosives Act, 2003 (Act No. 15 of 2003)

The guidelines and safe blasting criteria are based on internationally accepted standards and specifically criteria for safe blasting for ground vibration and recommendations on air blast published by the United States Bureau of Mines (USBM). There are no specific South African standards and the USBM is well accepted as a standard for South Africa. Additional restrictions are also considered where necessary. Specifically, where structures of lesser integrity are observed i.e. traditional built structures.

4 Scope of Blast Impact Study

The scope of the study is determined by the terms of reference to achieve the objectives. The terms of reference can be summarised according to the following steps taken as part of the EIA study with regards to ground vibration, air blast and fly rock due to blasting operations.

- Site specific evaluation of blasting operations according to the following:
  - Evaluation of expected ground vibration levels from blasting operations at specific distances and on structures in surrounding areas
  - Evaluation of expected ground vibration influence on neighbouring communities
  - Evaluation of expected blasting influence on national and provincial roads surrounding the blasting operations, if present

- Evaluation of expected ground vibration levels on water boreholes if present within 500 m from blasting operations
- Evaluation of expected air blast levels at specific distances from the operations and possible influence on structures
- Evaluation of fly rock unsafe zone
- Discussion on the occurrence of noxious fumes and dangers of fumes
- Evaluation of the location of blasting operations in relation to surrounding areas according to the regulations from the applicable Acts

- Undertake an impact assessment and identify suitable mitigation measures

5 Study Area

The proposed Vlakvarkfontein Mine Extension Project is located approximately 30 km north east of Delmas, and approximately 15 km south west of Ogies in the Mpumalanga province, South Africa at coordinates (Lat/Lon WGS84) 26° 3'22.65"S, 28°53'33.39"E.

Figure 1 shows an Aerial Imagery Locality Map of the proposed Project area. Figure 2 shows the Topographical Locality Map.

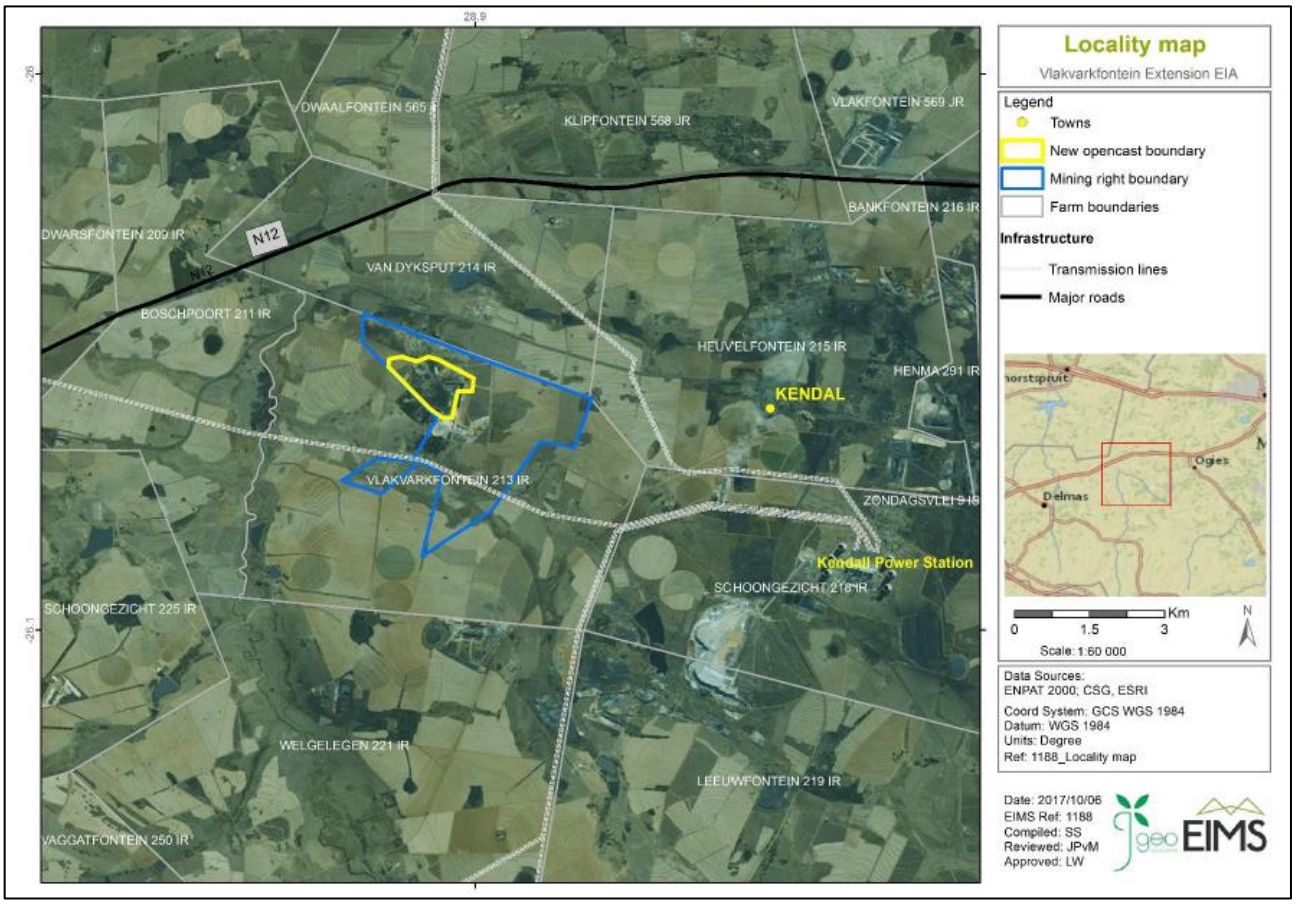

Figure 1: Aerial Imagery Locality Map indicating the mining right boundary and the proposed opencast extension area

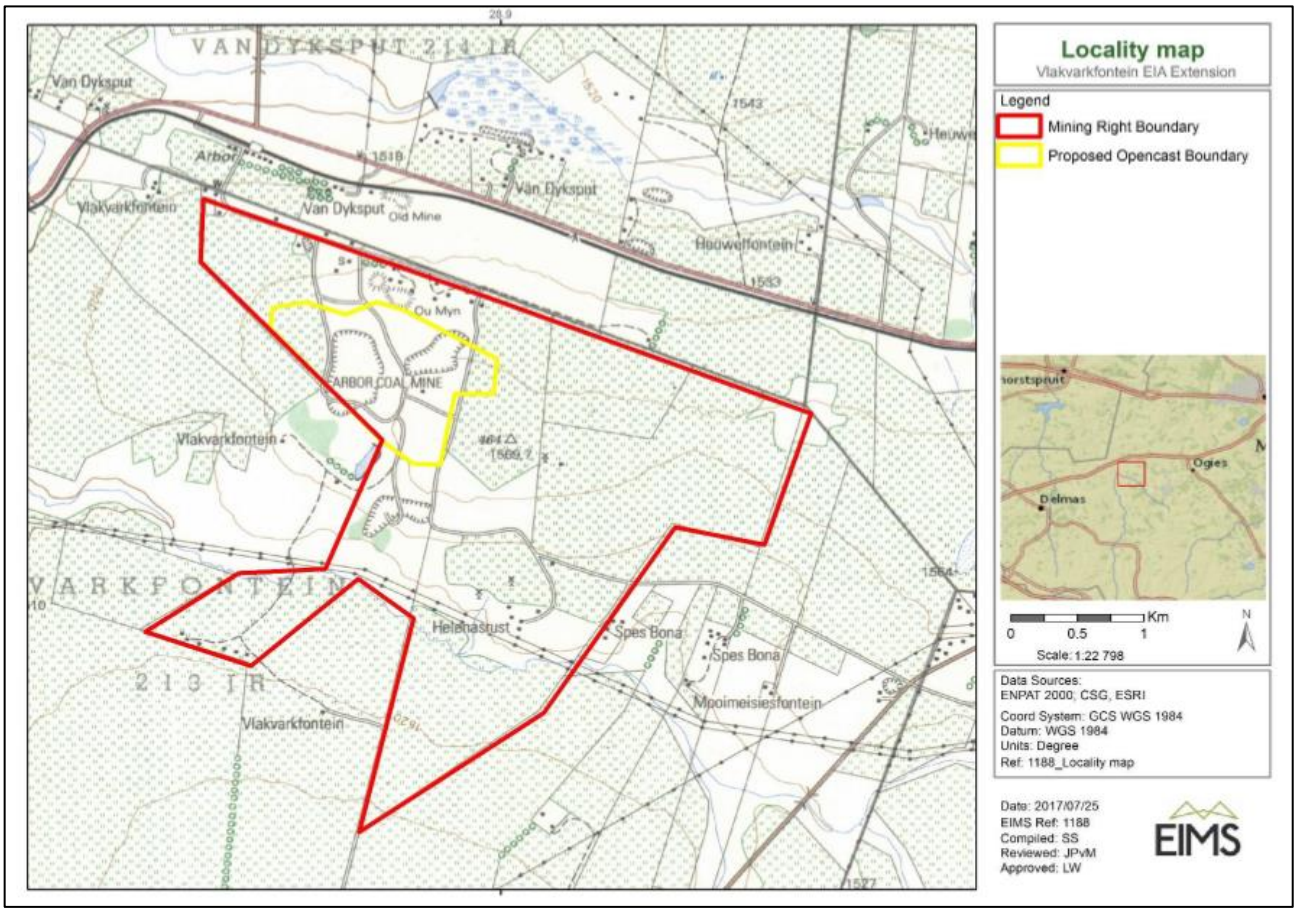

Figure 2: Topographical Locality Map indicating the mining right boundary and the proposed opencast extension area.

6 Methodology

The detailed plan of study consists of the following sections:

- Base line influence: Review of data from current ground vibration and air blast monitoring program.
- Identifying surface structures/ installations that are found within reason from the project site. A list of Point of Interests (POI's) were created that will be used for the evaluation.
- Site evaluation: This entails an evaluation of the planned mining, drilling and blasting operations and the possible influences from the blasting operations. The methodology includes the modelling of the expected impacts based on the expected drilling and blasting information provided for the project. Various accepted mathematical equations were applied to determine the attenuation of ground vibration, air blast and fly rock. These values were then calculated over the distance investigated from the site and shown

as amplitude level contours. Overlaying these contours on the location of the various receptors gave an indication of the possible impacts and the expected results of potential impacts. Evaluation of each receptor according to the predicted levels further gave an indication of the possible mitigation measures to be applied. The possible environmental or social impacts were addressed in the detailed EIA phase investigation.

7 Site Investigation

The site was visited and structure identification was done on 16th November 2017. This site visit was done specifically to get an understanding of the location of the open pit for the project and identifying the structures and installations surrounding the proposed open pit area.

The investigation and evaluation are not season specific. The operations are not season specific.

8 Assumptions and Limitations

The following assumptions have been made:

- The Vlakvarkfontein is an operational mine. The EIA process considers an extension of the current mining operations. A ground vibration and air blast monitoring program are currently active and data from this is reviewed as part of the evaluation.
- The anticipated levels of influence estimated in this report are calculated using standard accepted methodology according to international and local regulations.
- The assumption is made that the predictions are a good estimate with significant safety factors to ensure that expected levels are based on worst case scenarios. These will have to be confirmed with actual measurements observed from the baseline data.
- The limitation is that data available only show location of monitoring points and results for these monitoring points. No specific blast data is specific considered for each measurement done.
- Blast Management & Consulting was not involved in the blast design. The information on blast design applied was provided by the client.
- The work done is based on the author's knowledge and information provided by the project applicant.

9 Legal Requirements

The protocols applied in this document are based on the author's experience, guidelines elicited by the literature research, project applicant requirements and general indicators provided in the various applicable South African Acts. There is no direct reference in the consulted acts specifically with regard to limiting levels for ground vibration and air blast. There is however specific requirements and regulations with regard to blasting operations and the effect of ground vibration and air blast and some of the aspects addressed in this report. The acts consulted are:

- National Environmental Management Act, 1998 (Act No. 107 of 1998) (NEMA)
- Mine Health and Safety Act, 1996 (Act No. 29 of 1996)
- Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002) (MPRDA)
- Explosives Act, 2003 (Act No. 15 of 2003)

There are no specific South African standards providing limiting levels regarding ground vibration and air blast. The guidelines and safe blasting criteria applied in this study are as per internationally accepted standards, and specifically the United States Bureau of Mines (USBM) criteria for safe blasting for ground vibration and the recommendations on air blast. The USBM is well accepted as a standard for South Africa. Additional criteria required by various institutions in South Africa were also taken into consideration, i.e. Eskom, Telkom, Transnet, Rand Water Board, etc. as well as specific limitations regarding traditional built structures where applicable.

In view of the acts consulted the following guidelines and regulations are noted. Only parts of the acts were extracted:

- **Mine Health and Safety Act, 1996 (Act No. 29 of 1996)**

(Gazette No.17242, Notice No. 967 dated 14 June 1996. Commencement date: 15 January 1997 for all sections with the exception of sections 86(2) and (3), which came into operation on 15 January 1998, [Proc.No.4, Gazette No. 17725])

Mine Health and Safety Regulations
Precautionary measures before initiating explosive charges
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
4.16 The employer must take reasonable measures to ensure that:
4.16(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;
4.16(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.

- **Mineral and Petroleum Resources Development Act, 2002 (Act No. 28 of 2002)**

(Gazette No. 23922, Notice No. 1273 dated 10 October 2002. Commencement date: 1 May 2004 [Proc. No. R25, Gazette No. 26264])

Mineral and Petroleum Resources Development Regulations
67. Blasting, vibration and shock management and control
(1) A holder of a right or permit in terms of the Act must comply with the provisions of the Mine Health and Safety Act, 1996, (Act No. 29 of 1996), as well as other applicable law regarding blasting, vibration and shock management and control.
(2) An assessment of impacts relating to blasting, vibration and shock management and control, where applicable, must form part of the environmental impact assessment report and environmental management programme or the environmental management plan, as the case may be.

10 Sensitivity of the Project

A review of the project and the surrounding areas is done before any specific analysis is undertaken and sensitivity mapping is undertaken based on typical areas and distance from the proposed pit area. This sensitivity map uses distances at which possible influences may occur and where influence is expected to be very low or none. Two different areas were identified in this regard:

- A highly sensitive area of 500 m around the mining area. Normally, this 500 m area is considered an area that should be cleared of all people and animals prior to blasting. Levels of ground vibration and air blast are also expected to be higher closer to the decline shaft area.

- An area 500 m to 1500 m around the shaft area can be considered as being a medium sensitive area. In this area, the possibility of impact is still expected, but is lower. The expected level of influence may be low, but there may still be reason for concern, as levels could be low enough not to cause structural damage but still result in a reaction by surrounding landowners/occupiers.
- An area greater than 1500 m is considered a low sensitivity area. In this area it is relatively certain that influences will be low with low possibility of damages or a reaction by surrounding landowners/occupiers.

Figure 3 shows the sensitivity mapping with the identified POI in the surrounding areas for the Opencast for the proposed Vlakvarkfontein Mine Extension Project.

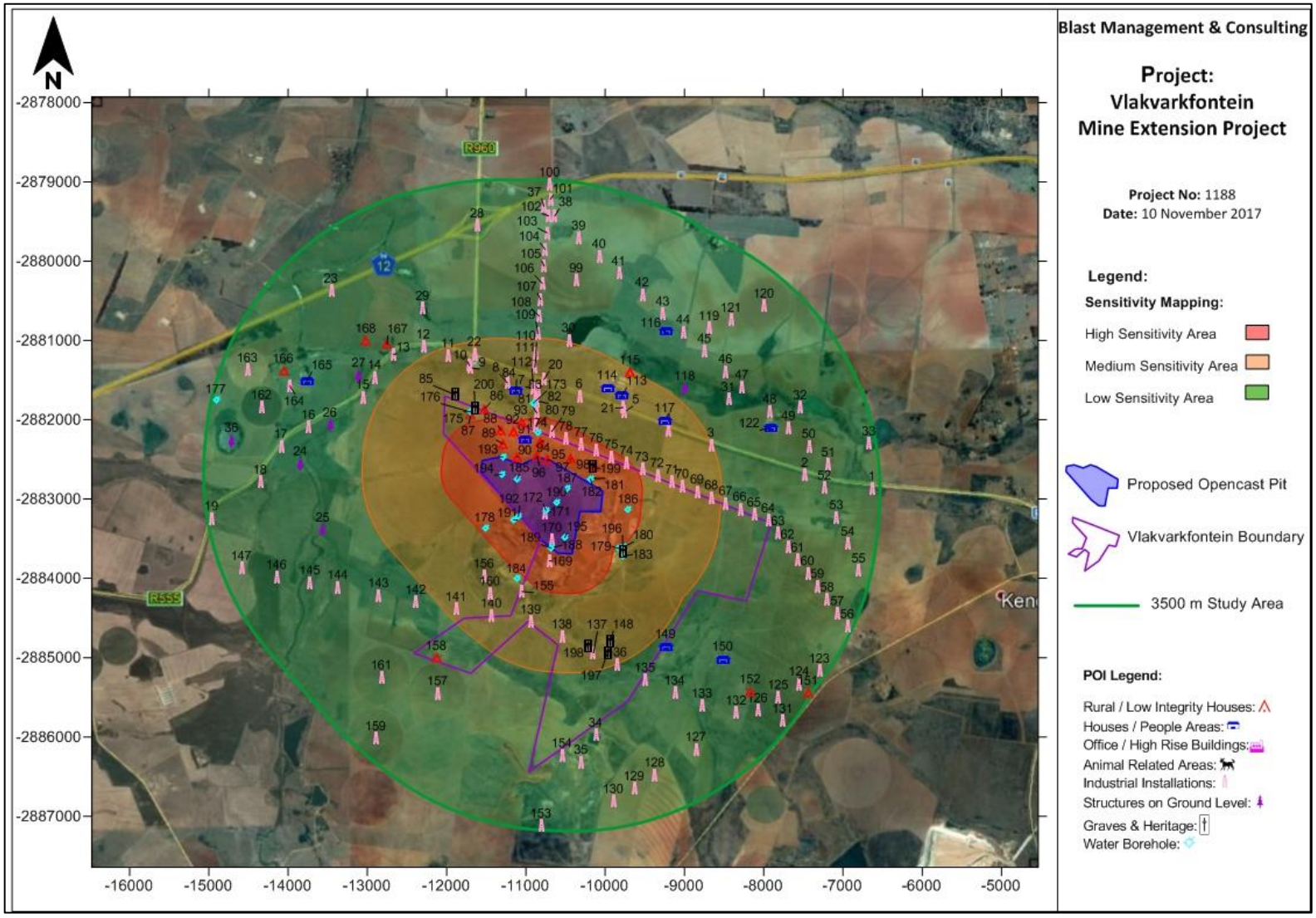

Figure 3: Identified sensitive areas

11 Consultation Process

EIMS Pty Ltd. as the lead consultant is responsible for the consultation process throughout the EIA. No specific consultation was done by the author with any external parties as part of the study.

12 Influence from Blasting Operations

Blasting operations are required to break rock for excavation to access the targeted ore material. Explosives in blast holes provide the required energy to conduct the work. Ground vibration, air blast and fly rock result from the blasting process. Based on the regulations of the different acts consulted and international accepted standards these effects are required to be within certain limits. The following sections provide guidelines on these limits. As indicated there are no specific South African ground vibration and air blast limit standards.

12.1 Ground Vibration Limitations on Structures

Ground vibration is measured in velocity with units of millimetres per second (mm/s). Ground vibration can also be reported in units of acceleration or displacement if required. Different types of structures have different tolerances to ground vibration. A steel structure or a concrete structure will have a higher resistance to vibrations than a well-built brick and mortar house. A brick and mortar house will be more resistant to vibrations than a poorly constructed or a traditional built mud house. Different limits are then applicable to the different types of structures. Limitations on ground vibration take the form of maximum allowable levels or intensity for different installations or structures. Ground vibration limits are also dependent on the frequency of the ground vibration. Frequency is the rate at which the vibration oscillates. Faster oscillation is synonymous with a higher frequency and lower oscillation is synonymous with a lower frequency. Lower frequencies are less acceptable than higher frequencies because structures have a low natural frequency. Significant ground vibration at low frequencies could cause increased structure vibrations due to the natural low frequency of the structure and this may lead to crack formation or damages to occur.

Currently, the USBM criteria for safe blasting are applied as the industry standard where private structures are of concern. Ground vibration amplitude and frequency is recorded and analysed. The data is then evaluated accordingly. The USBM graph is used for plotting of data and evaluating the data. Figure 4 below provides a graphic representation of the USBM analysis for safe ground vibration levels. The USBM graph is divided mainly into two parts. The red lines in the figure are the USBM criteria:

- Analysed data displayed in the bottom half of the graph shows safe ground vibration levels; and
- Analysed data displayed in the top half of the graph shows potentially unsafe ground vibration levels.

Added to the USBM graph is a blue line and green dotted line that represents 6 mm/s and 12.5 mm/s which are additional criteria that are used by BM&C. 6 mm/s is used for traditional built rural structures and 12.5 mm/s is used for structures that are considered being of lesser structural integrity than brick and mortar structures built according to building regulations.

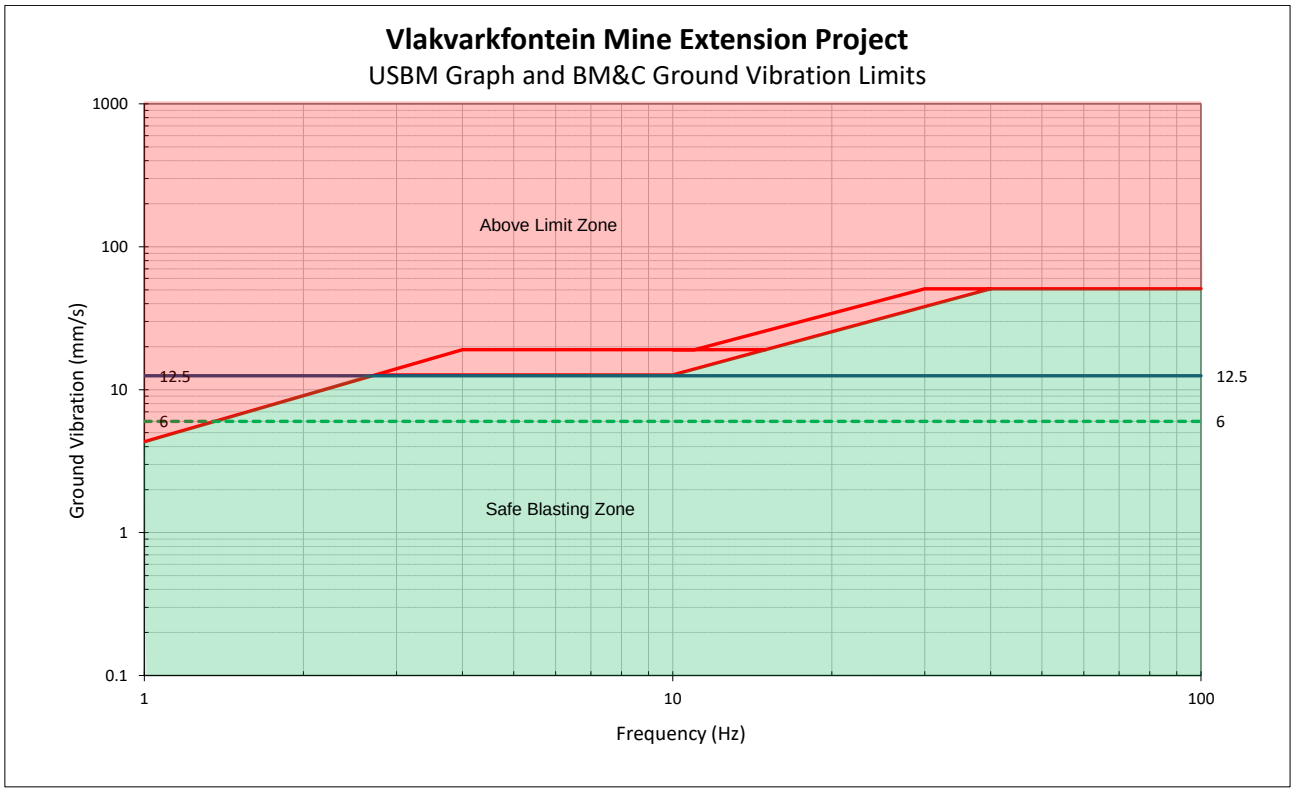

Figure 4: USBM Analysis Graph

Additional limitations that should be considered were determined through research and prescribed by the various institutions; these are as follows:

- National roads/tar roads: 150 mm/s
- Steel pipelines: 50 mm/s (Rand Water Board)
- Electrical lines: 75 mm/s (Eskom)
- Sasol Pipe Lines: 25 mms/s (Sasol)
- Railways: 150 mm/s
- Concrete less than 3 days old: 5 mm/s
- Concrete after 10 days: 200 mm/s
- Sensitive plant equipment: 12 mm/s or 25 mm/s, depending on type. (Some switches could trip at levels of less than 25 mm/s.)
- Water wells: 50 mm/s

Considering the above limitations, BM&C work is based on the following:

- USBM criteria for safe blasting.
- The additional limits provided above.
- Consideration of private structures in the area of influence.
- Should structures be in poor condition the basic limit of 25 mm/s is halved to 12.5 mm/s or when structures are in very poor condition limits will be restricted to 6 mm/s. It is a standard accepted method to reduce the limit allowed with poorer condition of structures.
- Traditional built mud houses are limited to 6 mm/s. The 6 mm/s limit is used due to unknowns on how these structures will react to blasting. There is also no specific scientific data available that would indicate otherwise.
- Input from other consultants in the field locally and internationally.

12.2 Ground Vibration Limitations and Human Perceptions

A further aspect of ground vibration and frequency of vibration that must be considered is human perceptions. It should be realized that the legal limit set for structures is significantly greater than the comfort zone of human beings. Humans and animals are sensitive to ground vibration and the vibration of structures. Research has shown that humans will respond to different levels of ground vibration at different frequencies.

Ground vibration is experienced at different levels; BM&C considers only the levels that are experienced as “Perceptible”, “Unpleasant” and “Intolerable”. This is indicative of the human being’s perceptions of ground vibration and clearly indicates that humans are sensitive to ground vibration and humans perceive ground vibration levels of 4.5 mm/s as unpleasant (See Figure 5). This guideline helps with managing ground vibration and the complaints that could be received due to blast induced ground vibration.

Indicated on Figure 5 is a blue solid line that indicates a ground vibration level of 12.5 mm/s and a green dotted line that indicates a ground vibration level of 6 mm/s. These are levels that are used in evaluation.

Generally, people also assume that any vibration of a structure - windows or roofs rattling - will cause damage to the structure. Air blast is one of the causes of vibration of a structure and is the cause of nine out of ten complaints.

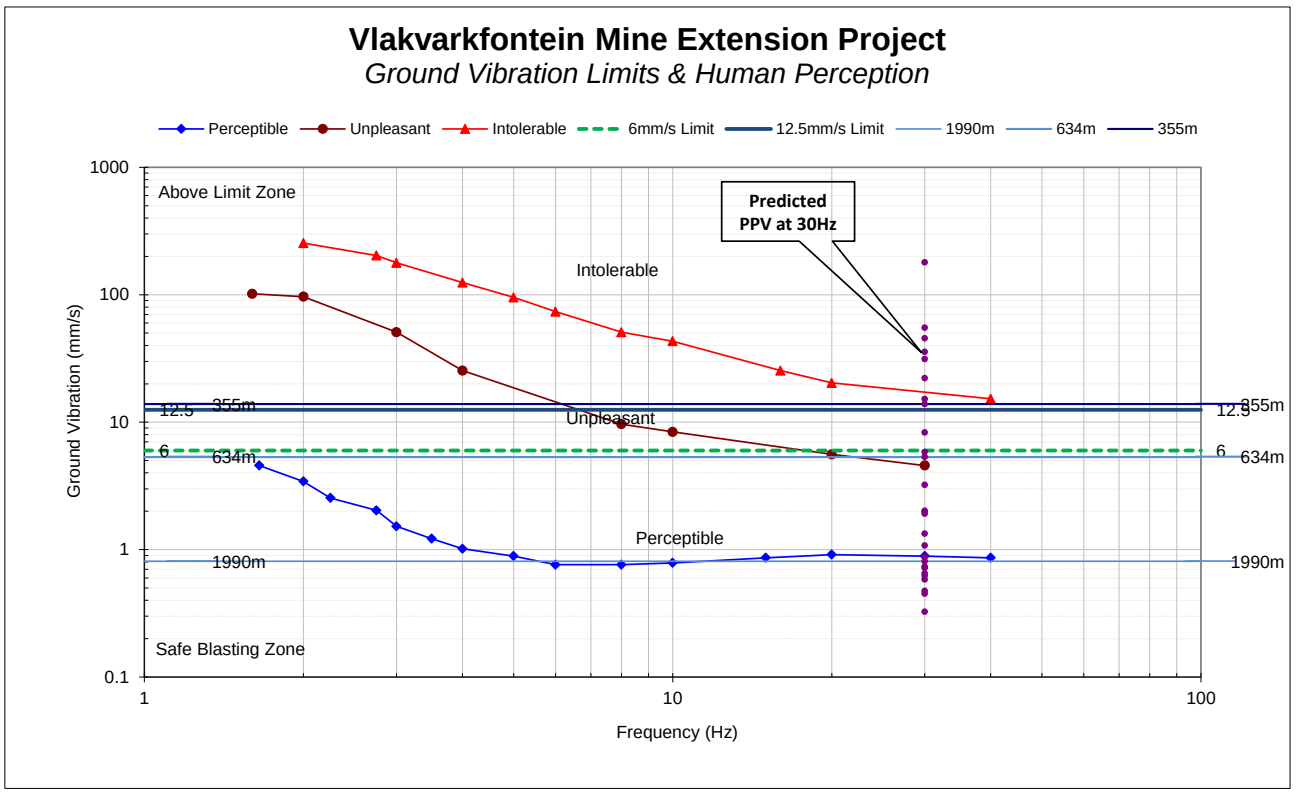

Figure 5: USBM Analysis with Human Perception

12.3 Air Blast Limitations on Structures

Air blast or air-overpressure is a pressure wave generated from the blasting process. Air blast is measured as a pressure in pascal (Pa) and reported as a decibel value (dBL). Air blast is normally associated with frequency levels less than 20 Hz, which is at the threshold for hearing. Air blast can be influenced by meteorological conditions, the final blast layout, timing, stemming, accessories used, blast covered by a layer of soil or not etc. Air blast should not be confused with sound that is within the audible range (detected by the human ear). A blast does generate sound as well but for the purpose of possible damage capability we are only concerned with air blast in this report. The three main causes of air blasts can be observed as:

- Direct rock displacement at the blast; the air pressure pulse (APP).
- Vibrating ground some distance away from the blast; rock pressure pulse (RPP).
- Venting of blast holes or blowouts; the gas release pulse (GRP).

The general recommended limit for air blast currently applied in South Africa is 134 dBL. This is based on work done by the USBM. The USBM also indicates that the level is reduced to 128 dB in proximity of hospitals, schools and sensitive areas where people congregate. Based on work carried out by Siskind *et al.* (1980), monitored air blast amplitudes up to 135 dB are safe for structures, provided the monitoring instrument is sensitive to low frequencies. Persson *et al.* (1994) have published

estimates of damage thresholds based on empirical data (Table 2). Levels given in Table 2 are at the point of measurement. The weakest points on a structure are the windows and ceilings.

Table 2: Damage Limits for Air Blast

Level	Description
>130 dB	Resonant response of large surfaces (roofs, ceilings). Complaints start.
150 dB	Some windows break
170 dB	Most windows break
180 dB	Structural Damage

All attempts should be made to keep air blast levels from blasting operations well below 120dB where the public is of concern.

12.4 Air Blast Limitations and Human Perceptions

Considering human perceptions and the misunderstanding about ground vibration and air blast, BM&C generally recommends that blasting be done in such a way that air blast levels are kept below 120dB. This will ensure fewer complaints regarding blasting operations. The effect on structures that startle people will also be reduced, which reduces the reasons for complaints. It is the effect on structures (like rattling windows, doors or a large roof surface) that startles people. These effects are sometimes erroneously identified as ground vibration and considered to be damaging to the structure.

In this report initial limits for evaluating conditions have been set at 120 dB, 120 dB to 134 dB and greater than 134 dBL. The USBM limits for nuisance is 134 dBL.

12.5 Fly Rock

Blasting practices require some movement of rock to facilitate the excavation process. The extent of movement is dependent on the scale and type of operation. For example, blasting activities at large coal mines are designed to cast the blasted material over a greater distance than in quarries or hard rock operations or a decline shaft as in this project. The movement should be in the direction of the free face. The orientation of the blast and expected movement direction is important. Material or elements travelling outside of a planned or expected range would be considered fly rock. Figure 6 shows a schematic representation of the following fly rock definitions.

Fly rock can be categorised as follows:

- Throw - the planned forward movement of rock fragments that form the muck pile within the blast zone.

- Fly rock - the undesired propulsion of rock fragments through the air or along the ground beyond the blast zone by the force of the explosion that is contained within the blast clearance (exclusion) zone. When using this definition, fly rock, while undesirable, is only a safety hazard if a breach of the blast clearance (exclusion) zone occurs.
- Wild fly rock - the unexpected propulsion of rock fragments that travels beyond the blast clearance (exclusion) zone when there is some abnormality in a blast or a rock mass.

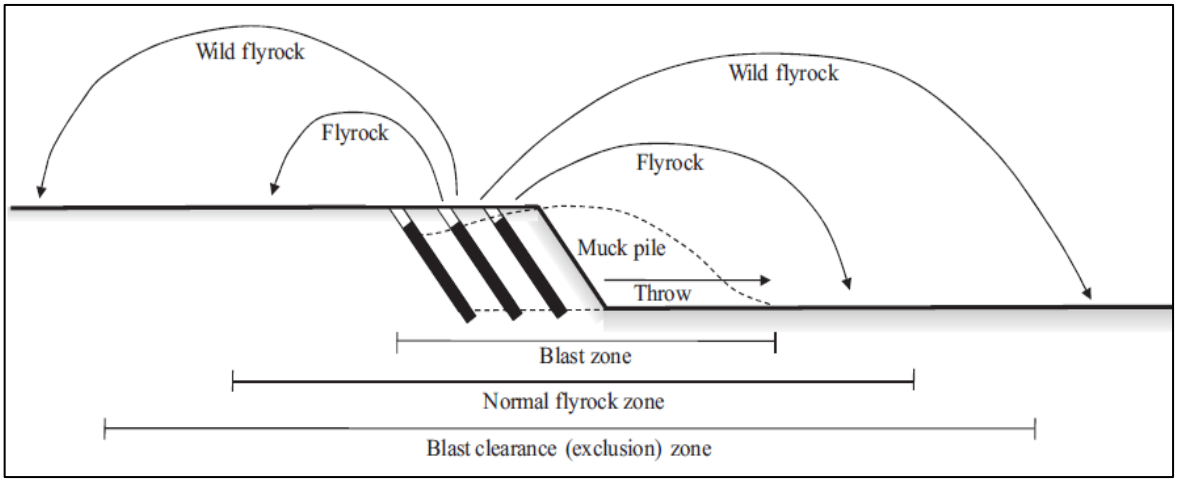

Figure 6: Schematic of fly rock terminology

Fly rock from blasting can result under the following conditions:

- When burdens are too small, rock elements can be propelled out of the free face area of the blast.
- When burdens are too large and movement of blast material is restricted and stemming length is not correct, rock elements can be forced upwards creating a crater forming fly rock.
- If the stemming material is of poor quality or too little stemming material is applied, the stemming is ejected out of the blast hole, which can result in fly rock.

Stemming of correct type and length is required to ensure that explosive energy is efficiently used to its maximum and to control fly rock.

The occurrence of fly rock in any form will have impact if found to travel outside the safe boundary. If a road or structure or people or animals are within the safe boundary of a blast, irrespective of the possibility of fly rock or not, precautions should be taken to stop the traffic, remove people or animals for the period of the blast. The fact is that fly rock will cause damage to the road, vehicles or even death to people or animals. This safe boundary is determined by the appointed blaster or as per mine code of practice. BM&C uses a prediction calculation defined by the International Society of Explosives Engineers (ISEE) to assist with determining minimum distance.

12.6 Noxious Fumes

Explosives used in the mining environment are required to be oxygen balanced. Oxygen balance refers to the stoichiometry of the chemical reaction and the nature of gases produced from the detonation of the explosives. The creation of poisonous fumes such as nitrous oxides and carbon monoxide are particularly undesirable. These fumes present themselves as red brown cloud after the blast has detonated. It has been reported that 10 ppm to 20 ppm can be mildly irritating. Exposure to 150 ppm or more (no time period given) has been reported to cause death from pulmonary edema. It has been predicted that there is a 50 % chance of death following exposure to 174 ppm for 1 hour. Anybody exposed must be taken to hospital for proper treatment.

Factors contributing to undesirable fumes are typically: poor quality control on explosive manufacture, damage to explosive, lack of confinement, insufficient charge diameter, excessive sleep time, water in blast holes incorrect product used or product not loaded properly and specific types of rock/geology can also contribute to fumes.

12.7 Vibration impact on provincial and national roads

The influence of ground vibration on tarred roads are expected when levels is in the order of 150 mm/s and greater. Or when there is actual movement of ground when blasting is done to close to the road or subsidence is caused due to blasting operations. Normally 100 blast hole diameters are a minimum distance between structure and blast hole to prevent any cracks being formed into the surrounds of a blast hole. Crack forming is not restricted to this distance. Improper timing arrangements may also cause excessive back break and cracks further than expected. Fact remain that blasting must be controlled in the vicinity of roads. Air blast from blasting does not have influence on road surfaces. There is no record of influence on gravel roads due to ground vibration. The only time damage can be induced is when blasting is done next to the road and there is movement of ground. Fly rock will have greater influence on the road as damage from falling debris may impact on the road surface if no control on fly rock is considered.

12.8 Vibration will upset adjacent communities

The effects of ground vibration and air blast will have influence on people. These effects tend to create noises on structures in various forms and people react to these occurrences even at low levels. As with human perception given above – people will experience ground vibration at very low levels. These levels are well below damage capability for most structures.

Much work has also been done in the field of public relations in the mining industry. Most probably one aspect that stands out is “Promote good neighbour ship”. This is achieved through communication and more communication with the neighbours. Consider their concerns and address in a proper manner.

The first level of good practice is to avoid unnecessary problems. One problem that can be reduced is the public's reaction to blasting. Concern for a person's home, particularly where they own it, could be reduced by a scheme of precautionary, compensatory and other measures which offer guaranteed remedies without undue argument or excuse.

In general, it is also in an operator's financial interests not to blast where there is a viable alternative. Where there is a possibility of avoiding blasting, perhaps through new technology, this should be carefully considered in the light of environmental pressures. Historical precedent may not be a helpful guide to an appropriate decision.

Independent structural surveys are one way of ensuring good neighbour ship. There is a part of inherent difficulty in using surveys as the interpretation of changes in crack patterns that occur may be misunderstood. Cracks open and close with the seasonal changes of temperature, humidity and drainage, and numbers increase as buildings age. Additional actions need to be done in order to supplement the surveys as well.

The means of controlling ground vibration, overpressure and fly rock have many features in common and are used by the better operators. It is said that many of the practices also aid cost-effective production. Together these introduce a tighter regime which should reduce the incidence of fly rock and unusually high levels of ground vibration and overpressure. The measures include the need for the following:

- Correct blast design is essential and should include a survey of the face profile prior to design, ensuring appropriate burden to avoid over-confinement of charges which may increase vibration by a factor of two,
- The setting-out and drilling of blasts should be as accurate as possible and the drilled holes should be surveyed for deviation along their lengths and, if necessary, the blast design adjusted,
- Correct charging is obviously vital, and if free poured bulk explosive is used, its rise during loading should be checked. This is especially important in fragmented ground to avoid accidental overcharging,
- Correct stemming will help control air blast and fly rock and will also aid the control of ground vibration. Controlling the length of the stemming column is important; too short and premature ejection occurs, too long and there can be excessive confinement and poor fragmentation. The length of the stemming column will depend on the diameter of the hole and the type of material being used,
- Monitoring of blasting and re-optimising the blasting design in the light of results, changing conditions and experience should be carried out as standard.

12.9 Cracking of houses and consequent devaluation

Houses in general have cracks. It is reported that a house could develop up to 15 cracks a year. Ground vibration will be mostly responsible for cracks in structures if high enough and at continued high levels. The influences of environmental forces such as temperature, water, wind etc. are more reason for cracks that have developed. Visual results of actual damage due to blasting operations are limited. There are cases where it did occur and a result is shown in Figure 7 below. A typical X crack formation is observed.

Figure 7: Example of blast induced damage.

Observing cracks of this form on a structure will certainly influence the value as structural damage has occurred. The presence of general vertical cracks or horizontal cracks that are found in all structures does not need to indicate devaluation due to blasting operations but rather devaluation due to construction, building material, age, standards of building applied. Proper building standards are not always applied or else stated was not always applied in the country side when houses were built. Thus, damage in the form of cracks will be present. Exact costing of devaluation for normal cracks observed is difficult to estimate. A property valuator will be required for this and I do believe that property value will include the total property and not just the house alone. Mining operations may not have influence to change the status quo of any property.

13 Baseline Results

Baseline work for this report normally consists of two parts. The first part is monitoring of blasting operations if the mine is operational. The second part of baseline work done is familiarising oneself with the surroundings and the typical structures that are found in the area of the project. The information for this is presented below.

13.1 Baseline influence

Vlakvarkfontein is an active operation. Monitoring is of ground vibration and air blast is conducted by external consultants. Three seismographs stations are strategically placed and blasting operations monitored for ground vibration and air blast. The data recorded is summarised according to blasts conducted at the mine.

Data recorded from this project is presented as baseline data for comparison. Table 4 below shows data recorded for the period of July 2017 to October 2017. The limits applied for the monitoring program is 12.5 mm/s for ground vibration and 134 dBL for air blast. Figure 9 to **Error! Reference source not found.** shows summarised data for ground vibration and air blast recorded.

Figure 8: View of mine and monitoring areas

Table 3: Baseline data recorded for Vlakvarkfontein Mine

Date	Time	Station							
		Station 1 Truter Vibr.* (mm/s)	Station 1 Truter Air blast (dB)	Station 2 Arbor Village Vibr.* (mm/s)	Station 2 Arbor Village Air blast(dB)	Station 3 School Vibr.* (mm/s)	Station 3 School Air blast (dB)	Vibr.* Limit (mm/s)	Air blast Limit (dB)
06/07/17	16:26			2.61	129			12.5	134
11/07/17	16:11			2.35	117			12.5	134
13/07/17	15:59			6.55	127			12.5	134

14/07/17	16:07					2.45	120	12.5	134
15/07/17	11:45	0.28	126					12.5	134
16/07/17	13:30			1.70	**134**			12.5	134
26/07/17	11:29			1.99	124			12.5	134
27/07/17	14:35	0.31	128			0.58	133	12.5	134
03/08/17	16:07			1.55	115			12.5	134
04/08/17	16:35					0.36	129	12.5	134
10/08/17	16:09					0.28	126	12.5	134
11/08/17	16:50					1.58	124	12.5	134
14/08/17	10:47			3.90	125			12.5	134
14/08/17	14:41	0.28	127					12.5	134
16/08/17	16:23			2.26	127			12.5	134
17/08/17	16:15			1.70	129			12.5	134
22/08/17	16:01			2.25	111			12.5	134
24/08/17	12:58					0.70	133	12.5	134
29/08/17	16:11					0.31	128	12.5	134
01/09/17	16:02					0.52	130	12.5	134
05/09/17	16:10	1.87	121			3.12	128	12.5	134
08/09/17	16:07			2.31	126			12.5	134
09/09/17	14:32					1.87	127	12.5	134
13/09/17	16:10	1.89	123			4.14	127	12.5	134
14/09/17	16:10	1.44	122	5.46	125			12.5	134
19/09/17	16:20	1.74	123			1.75	128	12.5	134
20/09/17	12:14	1.92	127	10.19	131			12.5	134
03/10/17	16:16			1.54	129			12.5	134
10/10/17	16:16					1.10	133	12.5	134
11/10/17	16:12	1.44	116	6.59	130			12.5	134
12/10/17	16:49			0.44	129			12.5	134
17/10/17	16:21	2.01	131			2.46	**141**	12.5	134
18/10/17	16:09			2.32	131			12.5	134
20/10/17	12:19			1.78	131			12.5	134
20/10/17	12:39	1.71	121	6.37	128			12.5	134
20/10/17	12:57			1.47	96			12.5	134
21/10/17	14:36	0.31	130			5.44	125	12.5	134
23/10/17	15:58			2.32	128			12.5	134
26/10/17	13:35					1.60	119	12.5	134
31/10/17	16:31					0.31	130	12.5	134

*Vibr. - Vibration

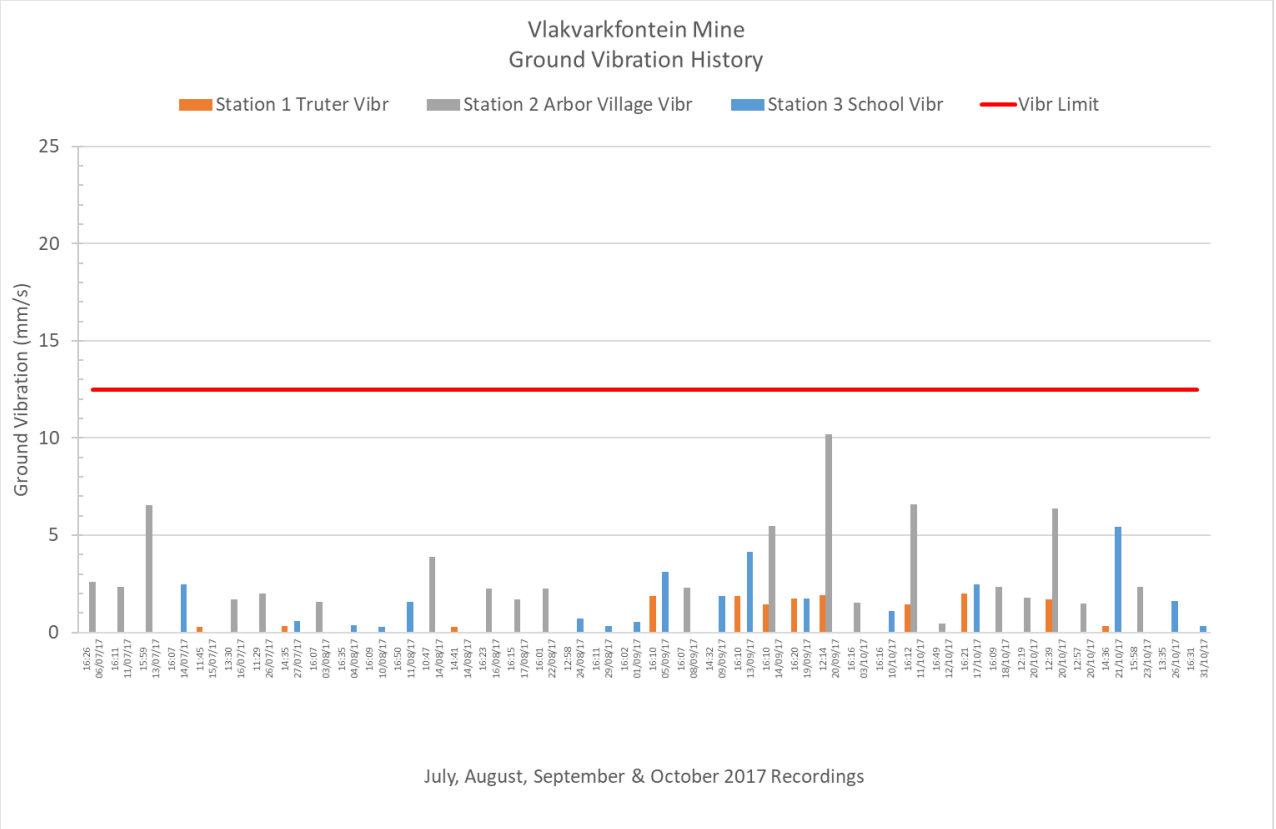

Figure 9: Four-month ground vibration summary data

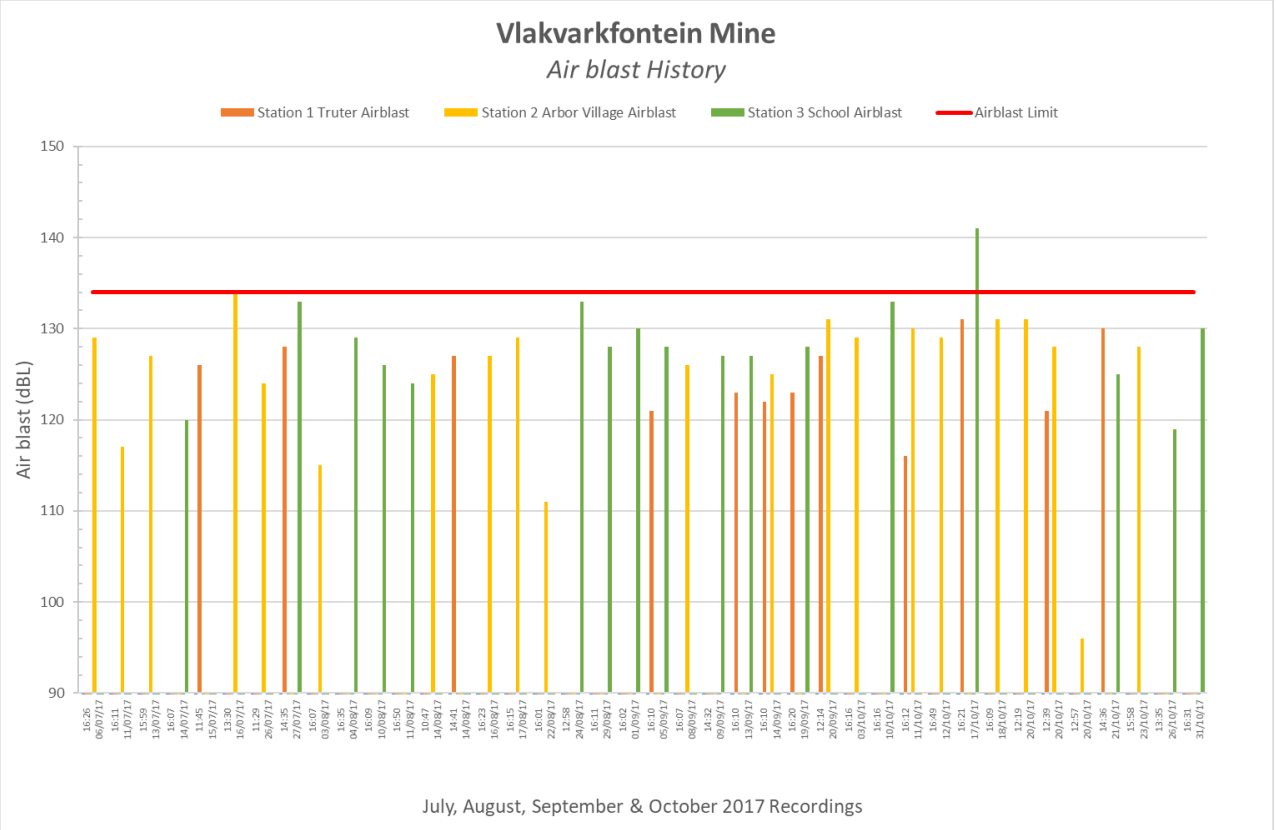

Figure 10: Four-month air blast summary data

The recorded data indicates more frequent recording of air blast than ground vibration. Ground vibration levels recorded for the four months show maximum vector sum of ground vibration less than 11 mm/s. In most cases if ground vibration is registered it is less than 5 mm/s. Generally, it seems good control on ground vibration levels at the three monitoring points. Air blast levels shows greater probable influence as levels is generally greater than 120 dB when measured. In one case a 134 dB was registered. 134 dB is on the limit currently applied in South Africa for air blast. Review of the recorded data do show more events registered for Station 2. Station is obviously closer to the blasting operations. In a few cases there were events registered from a blast and observed at more than one station. The trend seems to be that station 1 and 2 are more frequently triggered than station 3. The current operations are closer to these stations. Considering the levels of air blast observed greater than 120 dB it may be expected that complaints will be raised from blasting operations. Levels greater than 120 dB tends to give effect of rattling of roofs or windows which normally upsets people and give impression of damages done.

13.2 Structure Profile

As part of the baseline, all possible structures in a possible influence area are identified. The site was reviewed using Google Earth imagery. Information sought during the review was to identify surface structures present in a 3500 m radius from the proposed open pit area, which will require consideration during modelling of blasting operations, e.g. houses, general structures, power lines, pipelines, reservoirs, mining activity, roads, shops, schools, gathering places, possible historical sites, etc. A list was prepared of all structures in the vicinity of the open pit area. The list includes structures and POI within the 3500 m boundary – see Table 4 below. A list of structure locations was required to determine the allowable ground vibration limits and air blast limits. Figure 11 shows an aerial view of the open pit area and surroundings with POIs. The type of POIs identified is grouped into different classes. These classes are indicated as “Classification” in Table 5. The classification used is a BM&C classification and does not relate to any standard or national or international code or practice. Table 4 shows the descriptions for the classifications used.

Table 4: POI Classification used

Class	Description
1	Rural Building and structures of poor construction
2	Private Houses and people sensitive areas
3	Office and High-rise buildings
4	Animal related installations and animal sensitive areas
5	Industrial buildings and installations
6	Earth like structures – no surface structure
7	Graves & Heritage
8	Water Borehole

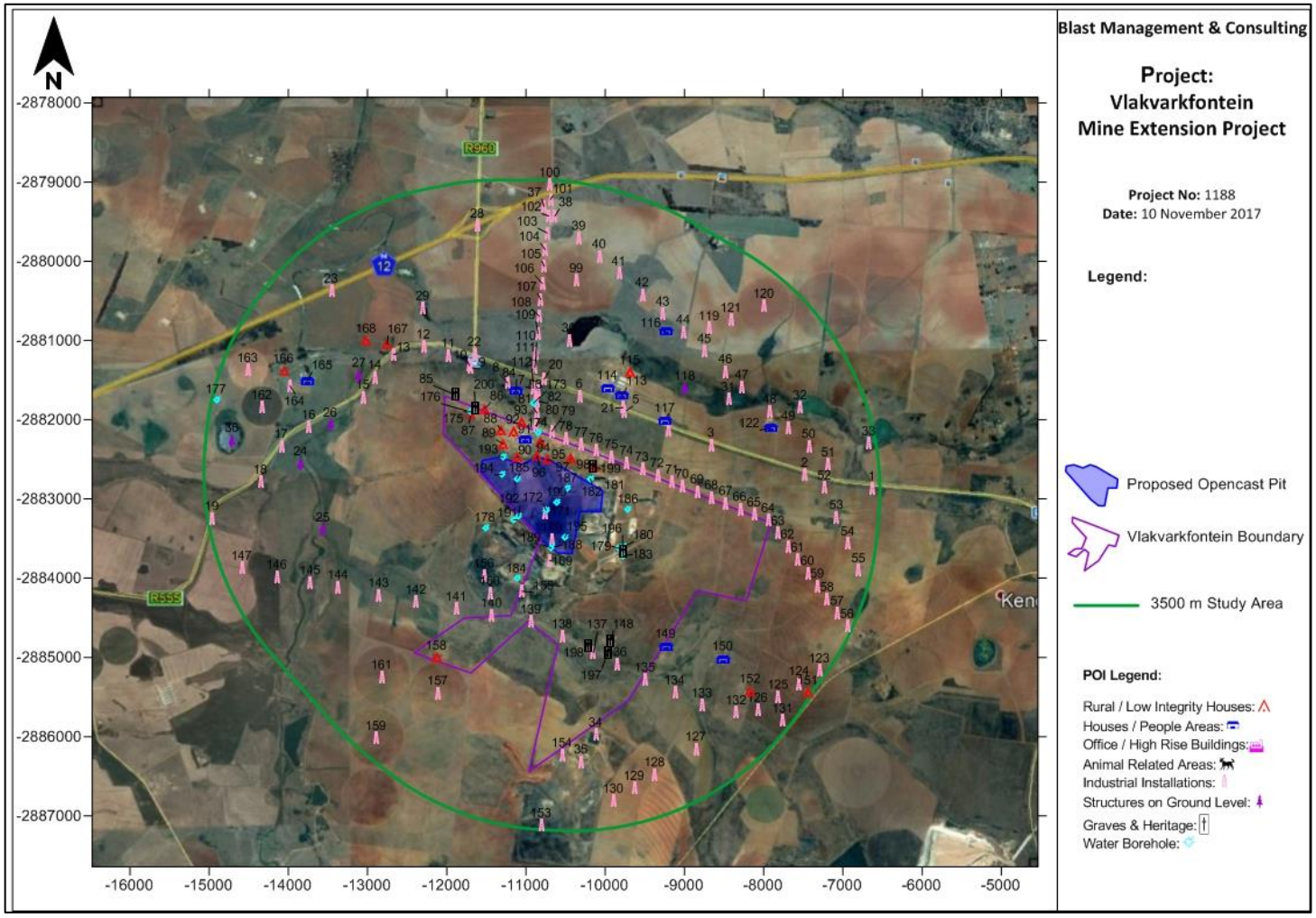

Figure 11: Aerial view and surface plan of the proposed mining area with points of interest identified

Table 5: List of POIs identified (WGS – LO 29°)

Tag	Description	Classification	Y	X
1	Railway Line	5	6628.94	2882868.67
2	Railway Line	5	7478.69	2882696.36
3	Railway Line	5	8659.74	2882320.49
4	Railway Line	5	9200.50	2882131.25
5	Railway Line	5	9751.92	2881898.52
6	Railway Line	5	10320.88	2881701.54
7	Railway Line	5	10852.00	2881632.64
8	Railway Line	5	11233.51	2881536.36
9	Arbor Railway Station	5	11693.74	2881343.79
10	Railway Line	5	11712.16	2881317.72
11	Railway Line	5	11974.89	2881191.43
12	Railway Line	5	12289.36	2881078.28
13	Railway Line	5	12673.49	2881173.27
14	Railway Line	5	12902.97	2881464.89
15	Railway Line	5	13055.76	2881714.98
16	Railway Line	5	13739.22	2882091.10
17	Railway Line	5	14085.39	2882333.98
18	Railway Line	5	14347.99	2882784.95
19	Railway Line	5	14962.02	2883244.68
20	R555 Road	5	10774.71	2881493.09
21	R555 Road	5	9773.20	2881845.97
22	R960 Road	5	11646.07	2881174.97
23	N12 Road	5	13455.07	2880370.73
24	Wilge River	6	13840.75	2882554.45
25	Wilge River	6	13558.77	2883389.56
26	Wilge River	6	13467.50	2882066.82
27	Wilge River	6	13103.99	2881439.23
28	N12 Road/Ramp	5	11611.07	2879551.42
29	Dam	5	12299.73	2880591.60
30	Dam	5	10454.10	2880995.50
31	Dam	5	8443.33	2881743.42
32	Dam	5	7535.36	2881846.66
33	Dam	5	6668.59	2882302.36
34	Dam	5	10114.26	2885975.44
35	Mine Activity	5	10301.35	2886318.60
36	Pan	6	14707.53	2882258.86
37	Power lines/Pylons	5	10774.77	2879306.11
38	Power lines/Pylons	5	10635.59	2879429.77
39	Power lines/Pylons	5	10328.36	2879707.85
40	Power lines/Pylons	5	10072.06	2879938.88
41	Power lines/Pylons	5	9824.42	2880156.21
42	Power lines/Pylons	5	9528.99	2880423.22
43	Power lines/Pylons	5	9268.71	2880662.95
44	Power lines/Pylons	5	9009.66	2880892.65
45	Power lines/Pylons	5	8742.91	2881133.31
46	Power lines/Pylons	5	8477.38	2881391.54
47	Power lines/Pylons	5	8268.96	2881590.05
48	Power lines/Pylons	5	7917.37	2881896.14
49	Power lines/Pylons	5	7683.66	2882105.71
50	Power lines/Pylons	5	7425.88	2882334.32
51	Power lines/Pylons	5	7179.74	2882565.06
52	Power lines/Pylons	5	7229.25	2882856.55
53	Power lines/Pylons	5	7077.42	2883231.24

Tag	Description	Classification	Y	X
54	Power lines/Pylons	5	6932.34	2883564.36
55	Power lines/Pylons	5	6797.47	2883902.31
56	Power lines/Pylons	5	6941.36	2884606.63
57	Power lines/Pylons	5	7064.63	2884438.67
58	Power lines/Pylons	5	7194.25	2884268.43
59	Power lines/Pylons	5	7318.12	2884096.60
60	Power lines/Pylons	5	7440.66	2883936.19
61	Power lines/Pylons	5	7566.52	2883767.32
62	Power lines/Pylons	5	7692.85	2883600.63
63	Power lines/Pylons	5	7815.50	2883433.86
64	Power lines/Pylons	5	7936.83	2883272.60
65	Power lines/Pylons	5	8116.61	2883198.85
66	Power lines/Pylons	5	8296.21	2883127.52
67	Power lines/Pylons	5	8473.50	2883055.00
68	Power lines/Pylons	5	8654.63	2882982.40
69	Power lines/Pylons	5	8834.79	2882907.41
70	Power lines/Pylons	5	9021.98	2882836.13
71	Power lines/Pylons	5	9150.98	2882783.86
72	Power lines/Pylons	5	9338.15	2882701.38
73	Power lines/Pylons	5	9531.20	2882625.32
74	Power lines/Pylons	5	9723.77	2882544.03
75	Power lines/Pylons	5	9916.40	2882465.77
76	Power lines/Pylons	5	10107.56	2882386.66
77	Power lines/Pylons	5	10296.68	2882313.02
78	Power lines/Pylons	5	10488.91	2882234.07
79	Power lines/Pylons	5	10674.90	2882147.47
80	Power lines/Pylons	5	10875.35	2882075.16
81	Power lines/Pylons	5	10860.51	2881917.33
82	Power lines/Pylons	5	10865.63	2881764.99
83	Sub Station	5	10874.98	2881709.74
84	Buildings/Structures	2	11125.95	2881634.79
85	Heritage Site (VVF08 - Historic Store)	7	11895.69	2881683.90
86	Community Houses	1	11523.34	2881862.81
87	Community Houses	1	11693.81	2881930.62
88	Community Houses	1	11313.65	2882137.98
89	Community Houses	1	11289.70	2882304.77
90	Community Houses	1	11114.27	2882466.35
91	School	2	11012.65	2882251.31
92	Community Houses	1	11161.03	2882154.07
93	Community Houses	1	11058.04	2882033.48
94	Community Houses	1	10812.02	2882275.39
95	Community Houses	1	10723.37	2882499.86
96	Community Houses	1	10860.95	2882455.19
97	Community Houses	1	10428.16	2882490.77
98	Community Houses	1	10134.85	2882587.55
99	Pivot Irrigation	5	10359.60	2880243.83
100	Power lines/Pylons	5	10695.19	2879035.41
101	Power lines/Pylons	5	10691.84	2879219.29
102	Power lines/Pylons	5	10715.05	2879428.51
103	Power lines/Pylons	5	10733.27	2879642.68
104	Power lines/Pylons	5	10755.21	2879852.98
105	Power lines/Pylons	5	10768.82	2880063.90
106	Power lines/Pylons	5	10793.43	2880279.45
107	Power lines/Pylons	5	10812.80	2880483.79

Tag	Description	Classification	Y	X
108	Power lines/Pylons	5	10831.29	2880694.78
109	Power lines/Pylons	5	10850.52	2880912.22
110	Power lines/Pylons	5	10873.51	2881168.10
111	Power lines/Pylons	5	10887.87	2881336.26
112	Power lines/Pylons	5	10909.28	2881601.95
113	Farm Buildings/Structures	2	9790.81	2881696.26
114	Buildings/Structures	2	9969.32	2881609.83
115	Informal Housing	1	9683.52	2881400.20
116	Farm Buildings/Structures	2	9235.39	2880888.13
117	Buildings/Structures	2	9242.33	2882021.65
118	Pan	6	8991.02	2881602.67
119	Pivot Irrigation	5	8683.75	2880845.49
120	Pivot Irrigation	5	7993.93	2880562.44
121	Cement Dam	5	8408.14	2880742.10
122	Farm Buildings/Structures	2	7910.64	2882101.30
123	Power lines/Pylons	5	7291.53	2885165.99
124	Power lines/Pylons	5	7547.69	2885330.69
125	Power lines/Pylons	5	7813.24	2885499.65
126	Power lines/Pylons	5	8073.85	2885662.67
127	Power lines/Pylons	5	8851.75	2886155.86
128	Power lines/Pylons	5	9371.75	2886480.41
129	Power lines/Pylons	5	9632.68	2886647.29
130	Power lines/Pylons	5	9893.37	2886810.03
131	Power lines/Pylons	5	7754.71	2885799.89
132	Power lines/Pylons	5	8342.93	2885695.87
133	Power lines/Pylons	5	8772.46	2885604.85
134	Power lines/Pylons	5	9118.58	2885443.53
135	Power lines/Pylons	5	9492.93	2885280.91
136	Power lines/Pylons	5	9848.67	2885085.28
137	Power lines/Pylons	5	10148.82	2884940.16
138	Power lines/Pylons	5	10539.59	2884732.75
139	Power lines/Pylons	5	10933.71	2884548.33
140	Power lines/Pylons	5	11430.05	2884468.25
141	Power lines/Pylons	5	11875.55	2884388.36
142	Power lines/Pylons	5	12384.53	2884299.87
143	Power lines/Pylons	5	12854.51	2884214.26
144	Power lines/Pylons	5	13368.63	2884112.11
145	Power lines/Pylons	5	13720.46	2884054.01
146	Power lines/Pylons	5	14140.98	2883983.16
147	Power lines/Pylons	5	14585.87	2883873.33
148	Heritage Site (VVF02 - Farmstead)	7	9939.84	2884799.04
149	Farm Buildings/Structures	2	9236.14	2884874.18
150	Farm Buildings/Structures	2	8512.77	2885026.00
151	Informal Housing	1	7439.22	2885446.36
152	Informal Housing	1	8167.49	2885423.25
153	Mine Buildings/Structures	5	10805.94	2887117.62
154	Dam	5	10538.86	2886233.03
155	Dam	5	11046.20	2884166.49
156	Mine Activity	5	11526.38	2883968.00
157	Pivot Irrigation	5	12108.59	2885449.11
158	Informal Housing	1	12129.13	2885004.29
159	Pivot Irrigation	5	12891.01	2886020.22
160	Dam	5	11450.01	2884191.71
161	Pivot Irrigation	5	12818.19	2885248.62

Tag	Description	Classification	Y	X
162	Pivot Irrigation	5	14330.95	2881841.03
163	Pivot Irrigation	5	14508.81	2881374.03
164	Cement Dam	5	13976.87	2881574.12
165	Farm Buildings/Structures	2	13763.68	2881512.79
166	Informal Housing	1	14057.40	2881381.49
167	Informal Housing	1	12751.11	2881051.12
168	Informal Housing	1	13015.68	2881004.03
169	Dam	5	10703.16	2883777.97
170	Dam (Inside Pit Area)	5	10668.57	2883513.66
171	Mine Buildings/Structures (Inside Pit Area)	5	10751.76	2883181.94
172	Domestic Borehole (Drinking Water - Office - Inside Pit Area)	8	10747.45	2883142.86
173	Domestic Borehole-VBH 06 (Tap Water)	8	10908.69	2881791.37
174	Domestic Borehole (Playground)	8	10848.33	2882168.00
175	Domestic Borehole (Arbor Community-2)	8	11699.22	2881902.84
176	Domestic Borehole (EUB-04B)	8	11699.22	2881902.84
177	Domestic Borehole (EUB-09)	8	14907.94	2881744.36
178	Domestic Borehole (EUB-10)	8	11514.79	2883365.09
179	Domestic Borehole (EUB-17)	8	9834.45	2883624.07
180	Domestic Borehole (EUB-18)	8	9769.43	2883605.19
181	Domestic Borehole (VBH-1M)	8	10183.37	2882743.57
182	Domestic Borehole (VBH-01S)	8	10185.37	2882743.57
183	Domestic Borehole (VBH-02M)	8	9767.34	2883718.19
184	Domestic Borehole (VBH-03M)	8	11116.97	2884007.32
185	Domestic Borehole (VBH-03S - Inside Pit Area)	8	11111.04	2882744.32
186	Domestic Borehole (VBH-04M)	8	9707.74	2883132.07
187	Domestic Borehole (VBH-05M - Inside Pit Area)	8	10473.48	2882866.77
188	Domestic Borehole (VBH-06M - Inside Pit Area)	8	10678.01	2883619.19
189	Domestic Borehole (VBH-06S)	8	10681.02	2883619.20
190	Domestic Borehole (VBH-07MS - Inside Pit Area)	8	10609.43	2883045.25
191	Domestic Borehole (VBH-08M)	8	11154.63	2883265.07
192	Domestic Borehole (VBH-08S)	8	11095.63	2883220.70
193	Domestic Borehole (VBH-9D)	8	11291.41	2882475.26
194	Domestic Borehole (VBH-10-M - Inside Pit Area)	8	11299.23	2882687.98
195	Domestic Borehole (VBH-11-M - Inside Pit Area)	8	10512.01	2883487.22
196	Heritage Site (VVF01 - Dilapidated house structures & reservoir)	7	9778.61	2883664.04
197	Heritage Site (VVF03 - Stone& mortar kraal)	7	9966.65	2884935.18
198	Heritage Site (VVF04 - Stone enclosure)	7	10208.52	2884855.35
199	Heritage Site (VVF06 - Cemetery 20 graves)	7	10149.13	2882593.36
200	Heritage Site (VVF07 - Cemetery 150 graves)	7	11642.55	2881856.01

During the site visit, the structures were observed and the initial POI list ground-truthed and finalised as represented. Structures ranged from well-built structures to informal building styles.

Table 6 shows photos of the structures found in the area.

Table 6: Structure Profile

Structure Photo	**Description**
	N12 Highway on the boundary of influence area
	Old brick house

Structure Photo	Description
	Arbor siding coal handling area
	Arbor siding
	House near siding

Structure Photo	Description
	Eskom Sunstation near siding
	Dam on Truter farms
	Truter Farm stead

Structure Photo	Description
	Trauter farm workers houses
	Thach roof builg on south east side
	Arbor Village houses

Structure Photo	Description
	Arbor village brick and plaster houses
	Arbor village primary school
	Corrugated iron structure
	Typical house in Arbor village

Structure Photo	Description
	Powerlines in the area

14 Construction Phase: Blast and Vibration Assessment

The mine is an active operation. The application is an extension of existing operations with no specific construction phase. No specific evaluation is required as part of the construction phase.

15 Operational Phase: Impact Assessment and Mitigation Measures

The area surrounding the proposed mining areas was reviewed for structures, traffic, roads, human interface, animals interface etc. Various installations and structures were observed. These are listed in Table 5. This section concentrates on the outcome of modelling the possible effects of ground vibration, air blast and fly rock specifically to these points of interest or possible interfaces.

15.1 Mining Method

Vlakvarkfontein Coal mine produced its first coal on 27 May 2010. Operations started approximately 50-100m east of the old underground workings with a north-south box-cut and advanced to the east. This portion or section of the mine was planned and indicated in the previous MWP and original Mining Right Application. Very little resources are left in this section of the mine and will be fully depleted in 2019. Rehabilitation of this area is concurrent and well up to date. The more challenging resources in the old underground mine and the little bit to the west was only explored and decided to be mined recently in 2016. The mining will start with a north-south box-cut in the west where the 2 seam sub-outcrop. Mining will progress in strips towards the east and eventually intersect the UG pillars. Mining will continue through the old underground pillars and eventually through the barrier pillar that was left between the old underground section and the original opencast workings. The new open-cast operation will be initiated by the stripping of topsoil to expose the overburden of the proposed box-cut. The topsoil, subsoil, hards and carbonaceous hards will be hauled to a designated area and act as a berm between the community and the mine. All material types to be used for

rehabilitation at a later stage and stockpiled separately to avoid mixing of material types. The anticipated strip ratio is estimated at 1.75:1.
Once the topsoil is removed and stored appropriately, the overburden of the proposed box-cut is then drilled, blasted and removed in order to mine benches approximately 40 m wide and down to the 2 seam. There is no 4 seam where the box-cut will start in the west. It is eroded away. The annual estimated production rate of the open-cast is estimated at 100-140ktpm. See the production schedules lower in the document.
A new coal processing facility will be built where the non-select coal as well as the coal mined in the old underground pillars will be washed to get rid of the contamination in order to produce a saleable ESKOM product.

15.2 Ground Vibration and Air Blast Predictions

Explosives are used to break rock through the shock waves and gasses yielded from the explosion. Ground vibration and air blast is a result from blasting activities. Factors influencing ground vibration are the charge mass per delay, distance from the blast, the delay period and the geometry of the blast. These factors are controlled by planned design and proper blast preparation.

An aspect that is not normally considered as pre-operation definable is the effect of air blast. This is mainly due to the fact that air blast is an aspect that can be controlled to a great degree by applying basic rules. Air blast is the direct result from the blast process, although influenced by meteorological conditions, the final blast layout, timing, stemming length, stemming material, accessories used, covered blast or not covered blast etc. all has an influence on the outcome of the result.

The following information was provided by the client as drilling and charging information applied for the operation. This information was applied to define expected ground vibration, air blast and fly rock influences and levels. The technical information for designs used is provided Table 7 below.

Table 7: Blast design technical information

Drill/ Blast parameters:	*Overburden*	*Overburden*	*Interburden*	*4 Seam*	*2 Seam*
Geology	Predominantly coarse sandstone, Increasing clay content downwards	Scenario 2 (Increased Hardness)	Interbedded Shale and siltstone with increasing carbonaceous content downwards	Coal	Coal
Average Thickness (m)	12	18	10	3	3.5
Average block width (m)	40	40	40	40	40
Average block length (m)	120	120	120	120	120
Burden (m)	4	4	5	5	5

Spacing (m)	5	4	5	5	5
Stemming (m)	3	3	2	*N/A*	*N/A*
Drill diameter (mm)	171	171	165	165	165
Charging Parameters:					
O/B					
Charging:					
· 125 – 130kg per hole					
· P/F = 0.7 – 0.8					
Timing:					
· 42ms used on the face and 100ms surface lines in the middle.					
· 500ms Down delay with 400mg boosters.					
Coal					
Charging:					
· 7 – 16kg per hole. 2 seam is harder so greater kg used.					
· P/F = 2 seam :0.14 – 0.16 4 seam: 0.08 – 0.1					
Timing:					
· 17ms surface timing – Ezdet					
· Downhole 350ms – Ezdet					
· Initiation line – 42ms					
· 150 g boosters used.					

The information provided was used and applied in simulation with summary of the simulation result provided in Figure 12 below.

Figure 12: Simulated blast design

The design reported in Table 7 is expected to be the possible options that can be done. In order to evaluate the possible influence, two charge masses that will span the range of possible charge mass per delay were selected. Considering the option of standard shock tube initiation products to be used for overburden blasts a minimum charge and maximum charge is calculated. Minimum consists of a single blasthole charge and maximum charge consists of the approximately six blastholes detonating simultaneously due to the shock tube initiation system indicated from the simulation. The selected charge masses selected for evaluation consist of a single blasthole at 150 kg and maximum charge of 602 kg. This range of minimum and maximum charge will span various alternatives can may be possible. These charge masses were used for baseline modelling in this report. Applying the above charge masses, various ground vibration calculations were done and considered in this report. Attention is given to limit levels of 6 mm/s, 12.5 mm/s and 25 mm/s.

Ground Vibration:
When predicting ground vibration and possible decay, a standard accepted mathematical process of scaled distance is used. The equation applied (Equation 1) uses the charge mass and distance with two site constants. In the absence of testing or monitoring standard constants are applied. These constants are applied in equation 1 below.

Equation 1:

$$PPV = a\left(\frac{D}{\sqrt{E}}\right)^{-b}$$

Where:
PPV = Predicted ground vibration (mm/s)
a = Site constant
b = Site constant
D = Distance (m)
E = Explosive Mass (kg)
General factors applied for the constants a & b are:
a = 1143 and
b = -1.65.

Utilizing the abovementioned equation and the given factors, allowable levels for specific limits and expected ground vibration levels can then be calculated for various distances. Based on the design information and simulation presented on expected drilling and charging design, Table 8 shows expected ground vibration levels (PPV) for various distances calculated at the two different charge masses. A low charge mass and a maximum charge mass as worst-case scenario. The charge masses are 150 kg and 602 kg.

Table 8: Expected Ground Vibration at Various Distances from Charges Applied in this Study

No.	Distance (m)	Expected PPV (mm/s) for 150 kg Charge	Expected PPV (mm/s) for 602 kg Charge
1	50.0	112.2	353.1
2	75.0	57.5	180.9
3	150.0	18.3	57.6
4	200.0	11.4	35.9
5	250.0	7.9	24.8
6	300.0	5.8	18.4
7	400.0	3.6	11.4
8	500.0	2.5	7.9
9	600.0	1.9	5.9
10	700.0	1.4	4.5
11	800.0	1.2	3.6
12	900.0	1.0	3.0
13	1000.0	0.8	2.5
14	1250.0	0.6	1.7
15	1500.0	0.4	1.3
16	1750.0	0.3	1.0
17	2000.0	0.3	0.8
18	2500.0	0.2	0.6
19	3000.0	0.1	0.4
20	3500.0	0.1	0.3

Air blast:

Predicting the outcome of air blast is considered difficult in most circumstances. There are many variables that have influence on the outcome of air blast. In most cases mainly an indication of typical levels can be obtained. A standard cube root scaling prediction formula is applied for air blast predictions. The following Equation 2 was used to calculate possible air blast values in millibar. This equation does not take temperature or any weather conditions into account.

Equation 2:

$$P = A \times \left(\frac{D}{E^{\frac{1}{3}}}\right)^{-B}$$

Where:

P = Air blast level (mB)

D = Distance from source (m)

E = Maximum charge mass per delay (kg)

A = Constant

-B = Constant

The constants for A and B were then selected according to the information as provided in Figure 13 below. Various types of mining operations are expected to yield different results. The information provided in Figure 13[1] is based on detailed research that was conducted for each of the different types of mining environments. In this report the data for "Coal Mines (high wall)" was applied in the prediction or air blast – constants of 5.37 (A) and -0.79 (B) was applied.

Air Overpressure Prediction Equations

Blasting	Metric Equations mb	U.S. Equations psi	Statistical Type	Source
Open air (no confinement)	$P = 3589 \times SD_3^{-1.38}$	$P = 187 \times SD_3^{-1.38}$	Best Fit	Perkins
Coal mines (parting)	$P = 2596 \times SD_3^{-1.62}$	$P = 169 \times SD_3^{-1.62}$	Best Fit	USBM RI 8485
Coal mines (highwall)	$P = 5.37 \times SD_3^{-0.79}$	$P = 0.162 \times SD_3^{-0.79}$	Best Fit	USBM RI 8485
Quarry face	$P = 37.1 \times SD_3^{-0.97}$	$P = 1.32 \times SD_3^{-0.97}$	Best Fit	USBM RI 8485
Metal Mine	$P = 14.3 \times SD_3^{-0.71}$	$P = 0.401 \times SD_3^{-0.71}$	Best Fit	USBM RI 8485
Construction (average)	$P = 24.8 \times SD_3^{-1.1}$	$P = 1 \times SD_3^{-1.1}$	Best Fit	Oriard (2005)
Construction (highly confined)	$P = 2.48 \times SD_3^{-1.1}$	$P = 0.1 \times SD_3^{-1.1}$	Best Fit	Oriard (2005)
Buried (total confinement)	$P = 1.73 \times SD_3^{-0.96}$	$P = 0.061 \times SD_3^{-0.96}$	Best Fit	USBM RI 8485

Table 26.7 - Air overpressure prediction equations.

Figure 13: Proposed prediction equations

The air pressure calculated in Equation 2 is converted to decibels in Equation 3. The reporting of air blast in the decibel scale is more readily accepted in the mining industry.

Equation 3:

$$p_s = 20 \text{ x } \log \frac{P}{P_o}$$

Where:

p_s = Air blast level (dB)

P = Air blast level (Pa (mB x 100))

P_o = Reference Pressure (2 x 10^{-5} Pa)

Although the above equation was applied for prediction of air blast levels, additional measures are also recommended to ensure that air blast and associated fly-rock possibilities are minimized as best possible.

[1] ISEE Blasters Handbook, 18th Edition, Little, January 2011, Ohio USA

Although above equations 2 & 3 was applied for prediction of air blast levels, additional measures are also recommended to ensure that air blast and associated fly-rock possibilities are minimised as best as possible. As discussed earlier the prediction of air blast is very subjective. Following in Table 9 below is a summary of values predicted according to Equation 2 and Equation 3.

Table 9: Air Blast Predicted Values

No.	Distance (m)	Air blast (dB) for 150 kg Charge	Air blast (dB) for 602 kg Charge
1	50.0	133.2	136.4
2	100.0	130.4	133.6
3	150.0	125.7	128.8
4	200.0	123.7	126.9
5	250.0	122.2	125.3
6	300.0	120.9	124.1
7	400.0	118.9	122.1
8	500.0	117.4	120.6
9	600.0	116.2	119.4
10	700.0	115.1	118.3
11	800.0	114.2	117.4
12	900.0	113.4	116.6
13	1000.0	112.7	115.8
14	1250.0	111.1	114.3
15	1500.0	110.0	113.1
16	1750.0	108.9	112.0
17	2000.0	108.0	111.1
18	2500.0	106.4	109.5
19	3000.0	105.1	108.3
20	3500.0	104.1	107.2

15.3 Review of Expected Ground Vibration

Ground vibration and air blast was calculated from the edge of the pit outline and modelled accordingly. Blasting further away from the pit edge will certainly have lesser influence on the surroundings. A worst case is then applicable with calculation from pit edge. As explained previously reference is only made to some structures and these references covers the extent of all structures surrounding the mine.

The following aspects with comments are addressed for each of the evaluations done:

- Ground Vibration Modelling Results
- Ground Vibration and human perception
- Vibration impact on national and provincial road
- Vibration will upset adjacent communities
- Cracking of houses and consequent devaluation

- Air blast Modelling Results
- Impact of fly rock
- Noxious fumes Influence Results

Please note that this analysis does not take geology, topography or actual final drill and blast pattern into account. The data is based on good practise applied internationally and considered very good estimates based on the information provided and supplied in this document.

Presented herewith are the expected ground vibration level contours and discussion of relevant influences. Expected ground vibration levels were calculated for each POI identified surrounding the mining area and evaluated with regards to possible structural concerns and human perception. Tables are provided for each of the different charge models done with regards to:

- "Tag" No. is the number corresponding to the POI figures.
- "Description" indicates the type of the structure.
- "Distance" is the distance between the structure and edge of the open pit area.
- "Specific Limit" is the maximum limit for ground vibration at the specific structure or installation.
- "Predicted PPV (mm/s)" is the calculated ground vibration at the structure.
- The "Structure Response @ 10Hz and Human Tolerance @ 30Hz" indicates the possible concern and if there is any concern for structural damage or potential negative human perception respectively. Indicators used are "perceptible", "unpleasant", "intolerable" which stems from the human perception information given and indicators such as "high" or "low" is given for the possibility of damage to a structure. Levels below 0.76 mm/s could be considered to have low or negligible possibility of influence.

In evaluation the two different charge mass scenarios are considered with regards to ground vibration and air blast. Review of the charge per blast hole and the possible timing of a blast the two-different charge masses of 150 and 602 kg were selected to ensure proper source coverage.

Ground vibration is calculated and modelled for the open pit area at the minimum and maximum charge mass at specific distances from the open pit area. The charge masses applied are according to blast designs discussed in Section 15.1. These levels are then plotted and overlaid with current mining plans to observe possible influences at structures identified. Structures or POI's for consideration are also plotted in this model. Ground vibration predictions were done considering distances ranging from 50 m to 3500 m around the open pit mining area.

The simulation provided shows ground vibration contours only for a limited number of levels. The levels used are considered the basic limits that will applicable for the type of structures observed

surrounding the open pit area. These levels are: 6 mm/s, 12.5 mm/s, 25 mm/s and 50 mm/s. This enables immediate review of possible concerns that may be applicable to any of the privately-owned structures, social gathering areas or sensitive installations.
Data is provided as follows: Vibration contours; a table with predicted ground vibration values and evaluation for each POI. Additional colour codes used in the tables are as follows:

Structure Evaluations:
Vibration levels higher than proposed limit applicable to Structures / Installations is coloured "Red"
People's Perception Evaluation:
Vibration levels indicated as Intolerable on human perception scale is coloured "Red"
Vibration levels indicated as Unpleasant on human perception scale is coloured "Mustard"
Vibration levels indicated as Perceptible on human perception scale is coloured "Light Green"
POI's that are found inside the pit area is coloured "Olive Green"

Simulations for expected ground vibration levels from minimum and maximum charge mass are presented.

- ***Minimum charge mass per delay – 150 kg***

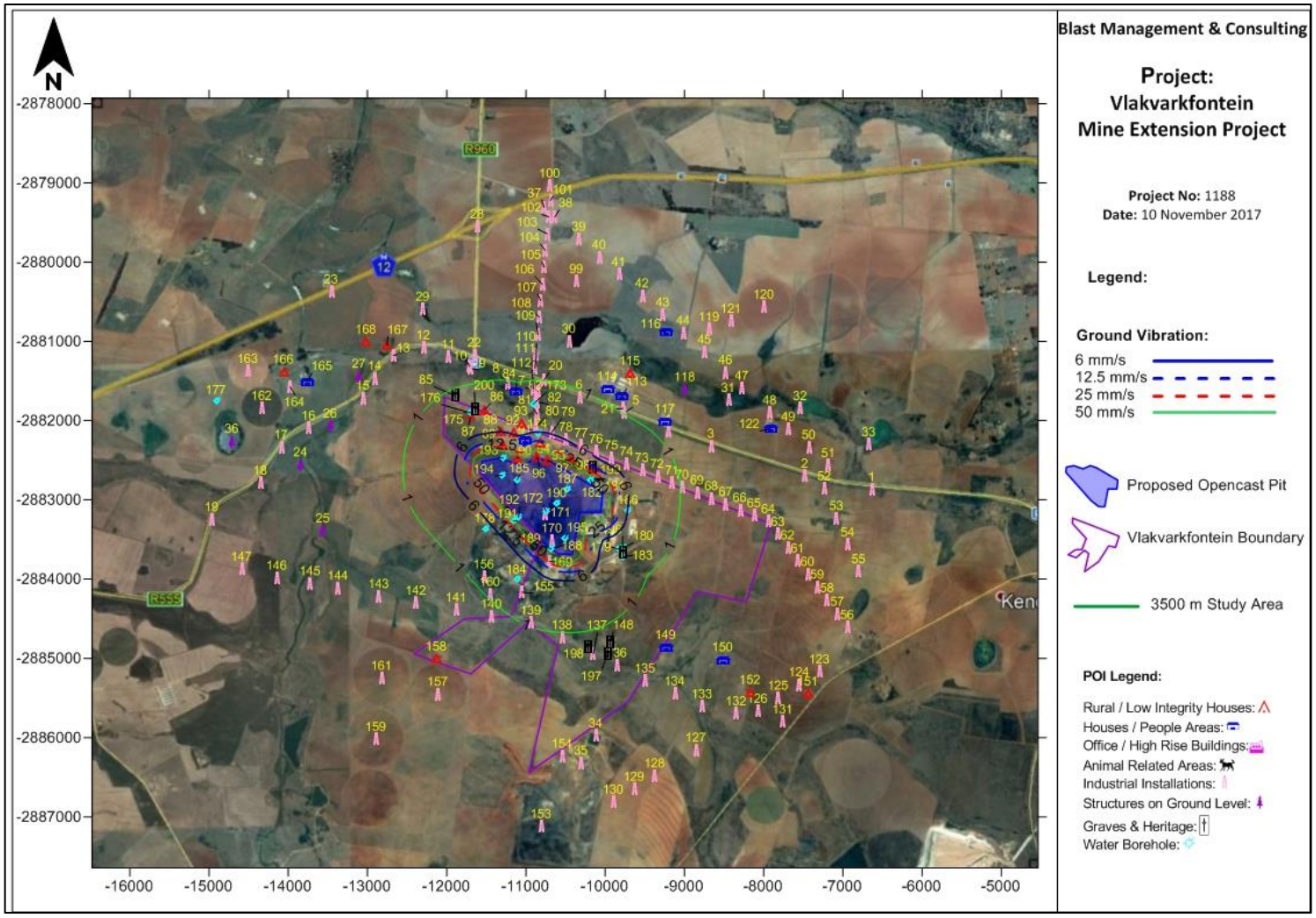

Figure 14: Ground vibration influence from minimum charge for Pit Area

Table 10: Ground vibration evaluation for minimum charge for Pit Area

Tag	Description	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Railway Line	3404	0.1	Acceptable	N/A
2	Railway Line	2563	0.2	Acceptable	N/A
3	Railway Line	1495	0.4	Acceptable	N/A
4	Railway Line	1135	0.6	Acceptable	N/A
5	Railway Line	1005	0.8	Acceptable	N/A
6	Railway Line	898	1.0	Acceptable	N/A
7	Railway Line	843	1.1	Acceptable	N/A
8	Railway Line	942	0.9	Acceptable	N/A
9	Arbor Railway Station	1177	0.6	Acceptable	N/A
10	Railway Line	1206	0.6	Acceptable	N/A
11	Railway Line	1391	0.5	Acceptable	N/A
12	Railway Line	1617	0.4	Acceptable	N/A
13	Railway Line	1752	0.3	Acceptable	N/A
14	Railway Line	1716	0.3	Acceptable	N/A
15	Railway Line	1709	0.3	Acceptable	N/A
16	Railway Line	2229	0.2	Acceptable	N/A
17	Railway Line	2538	0.2	Acceptable	N/A
18	Railway Line	2784	0.1	Acceptable	N/A
19	Railway Line	3445	0.1	Acceptable	N/A
20	R555 Road	984	0.8	Acceptable	N/A
21	R555 Road	1040	0.7	Acceptable	N/A
22	R960 Road	1333	0.5	Acceptable	N/A
23	N12 Road	2871	0.1	Acceptable	N/A
24	Wilge River	2276	0.2	Acceptable	N/A
25	Wilge River	2122	0.2	Acceptable	N/A
26	Wilge River	1969	0.3	Acceptable	N/A
27	Wilge River	1893	0.3	Acceptable	N/A
28	N12 Road/Ramp	2936	0.1	Acceptable	N/A
29	Dam	2065	0.2	Acceptable	N/A
30	Dam	1528	0.4	Acceptable	N/A
31	Dam	1969	0.3	Acceptable	N/A
32	Dam	2715	0.2	Acceptable	N/A
33	Dam	3419	0.1	Acceptable	N/A
34	Dam	2308	0.2	Acceptable	N/A
35	Mine Activity	2633	0.2	Acceptable	N/A
36	Pan	3164	0.1	Acceptable	N/A
37	Power lines/Pylons	3170	0.1	Acceptable	N/A
38	Power lines/Pylons	3052	0.1	Acceptable	N/A
39	Power lines/Pylons	2813	0.1	Acceptable	N/A
40	Power lines/Pylons	2649	0.2	Acceptable	N/A
41	Power lines/Pylons	2519	0.2	Acceptable	N/A
42	Power lines/Pylons	2395	0.2	Acceptable	N/A
43	Power lines/Pylons	2317	0.2	Acceptable	N/A
44	Power lines/Pylons	2248	0.2	Acceptable	N/A
45	Power lines/Pylons	2187	0.2	Acceptable	N/A
46	Power lines/Pylons	2168	0.2	Acceptable	N/A
47	Power lines/Pylons	2200	0.2	Acceptable	N/A
48	Power lines/Pylons	2346	0.2	Acceptable	N/A
49	Power lines/Pylons	2483	0.2	Acceptable	N/A
50	Power lines/Pylons	2670	0.2	Acceptable	N/A
51	Power lines/Pylons	2874	0.1	Acceptable	N/A
52	Power lines/Pylons	2804	0.1	Acceptable	N/A

Tag	Description	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
53	Power lines/Pylons	2973	0.1	Acceptable	N/A
54	Power lines/Pylons	3151	0.1	Acceptable	N/A
55	Power lines/Pylons	3344	0.1	Acceptable	N/A
56	Power lines/Pylons	3437	0.1	Acceptable	N/A
57	Power lines/Pylons	3256	0.1	Acceptable	N/A
58	Power lines/Pylons	3071	0.1	Acceptable	N/A
59	Power lines/Pylons	2896	0.1	Acceptable	N/A
60	Power lines/Pylons	2730	0.2	Acceptable	N/A
61	Power lines/Pylons	2565	0.2	Acceptable	N/A
62	Power lines/Pylons	2406	0.2	Acceptable	N/A
63	Power lines/Pylons	2259	0.2	Acceptable	N/A
64	Power lines/Pylons	2121	0.2	Acceptable	N/A
65	Power lines/Pylons	1935	0.3	Acceptable	N/A
66	Power lines/Pylons	1749	0.3	Acceptable	N/A
67	Power lines/Pylons	1566	0.4	Acceptable	N/A
68	Power lines/Pylons	1380	0.5	Acceptable	N/A
69	Power lines/Pylons	1198	0.6	Acceptable	N/A
70	Power lines/Pylons	1014	0.8	Acceptable	N/A
71	Power lines/Pylons	891	1.0	Acceptable	N/A
72	Power lines/Pylons	726	1.4	Acceptable	N/A
73	Power lines/Pylons	576	2.0	Acceptable	N/A
74	Power lines/Pylons	472	2.8	Acceptable	N/A
75	Power lines/Pylons	432	3.2	Acceptable	N/A
76	Power lines/Pylons	405	3.6	Acceptable	N/A
77	Power lines/Pylons	374	4.1	Acceptable	N/A
78	Power lines/Pylons	346	4.6	Acceptable	N/A
79	Power lines/Pylons	361	4.3	Acceptable	N/A
80	Power lines/Pylons	402	3.6	Acceptable	N/A
81	Power lines/Pylons	558	2.1	Acceptable	N/A
82	Power lines/Pylons	711	1.4	Acceptable	N/A
83	Sub Station	766	1.2	Acceptable	N/A
84	Buildings/Structures	863	1.0	Acceptable	Perceptible
85	Heritage Site (VVF08 - Historic Store)	901	1.0	Acceptable	N/A
86	Community Houses	635	1.7	Acceptable	Perceptible
87	Community Houses	602	1.8	Acceptable	Perceptible
88	Community Houses	336	4.8	Acceptable	Perceptible
89	Community Houses	173	14.5	Problematic	Unpleasant
90	Community Houses	75	57.0	Problematic	Intolerable
91	School	268	7.0	Acceptable	Unpleasant
92	Community Houses	356	4.4	Acceptable	Perceptible
93	Community Houses	486	2.6	Acceptable	Perceptible
94	Community Houses	201	11.3	Acceptable	Unpleasant
95	Community Houses	16	774.4	Problematic	Intolerable
96	Community Houses	21	458.6	Problematic	Intolerable
97	Community Houses	154	17.5	Problematic	Unpleasant
98	Community Houses	217	9.9	Acceptable	Unpleasant
99	Pivot Irrigation	2281	0.2	Acceptable	N/A
100	Power lines/Pylons	3443	0.1	Acceptable	N/A
101	Power lines/Pylons	3259	0.1	Acceptable	N/A
102	Power lines/Pylons	3049	0.1	Acceptable	N/A
103	Power lines/Pylons	2834	0.1	Acceptable	N/A
104	Power lines/Pylons	2623	0.2	Acceptable	N/A
105	Power lines/Pylons	2412	0.2	Acceptable	N/A

Tag	Description	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
106	Power lines/Pylons	2196	0.2	Acceptable	N/A
107	Power lines/Pylons	1991	0.3	Acceptable	N/A
108	Power lines/Pylons	1780	0.3	Acceptable	N/A
109	Power lines/Pylons	1563	0.4	Acceptable	N/A
110	Power lines/Pylons	1308	0.5	Acceptable	N/A
111	Power lines/Pylons	1140	0.6	Acceptable	N/A
112	Power lines/Pylons	876	1.0	Acceptable	N/A
113	Farm Buildings/Structures	1161	0.6	Acceptable	Too Low
114	Buildings/Structures	1146	0.6	Acceptable	Too Low
115	Informal Housing	1471	0.4	Acceptable	Too Low
116	Farm Buildings/Structures	2139	0.2	Acceptable	Too Low
117	Buildings/Structures	1182	0.6	Acceptable	Too Low
118	Pan	1664	0.3	Acceptable	N/A
119	Pivot Irrigation	2456	0.2	Acceptable	N/A
120	Pivot Irrigation	3102	0.1	Acceptable	N/A
121	Cement Dam	2701	0.2	Acceptable	N/A
122	Farm Buildings/Structures	2272	0.2	Acceptable	Too Low
123	Power lines/Pylons	3418	0.1	Acceptable	N/A
124	Power lines/Pylons	3307	0.1	Acceptable	N/A
125	Power lines/Pylons	3173	0.1	Acceptable	N/A
126	Power lines/Pylons	3065	0.1	Acceptable	N/A
127	Power lines/Pylons	2923	0.1	Acceptable	N/A
128	Power lines/Pylons	2982	0.1	Acceptable	N/A
129	Power lines/Pylons	3062	0.1	Acceptable	N/A
130	Power lines/Pylons	3166	0.1	Acceptable	N/A
131	Power lines/Pylons	3399	0.1	Acceptable	N/A
132	Power lines/Pylons	2888	0.1	Acceptable	N/A
133	Power lines/Pylons	2526	0.2	Acceptable	N/A
134	Power lines/Pylons	2184	0.2	Acceptable	N/A
135	Power lines/Pylons	1842	0.3	Acceptable	N/A
136	Power lines/Pylons	1509	0.4	Acceptable	N/A
137	Power lines/Pylons	1281	0.5	Acceptable	N/A
138	Power lines/Pylons	1047	0.7	Acceptable	N/A
139	Power lines/Pylons	933	0.9	Acceptable	N/A
140	Power lines/Pylons	1133	0.7	Acceptable	N/A
141	Power lines/Pylons	1375	0.5	Acceptable	N/A
142	Power lines/Pylons	1696	0.3	Acceptable	N/A
143	Power lines/Pylons	1990	0.3	Acceptable	N/A
144	Power lines/Pylons	2310	0.2	Acceptable	N/A
145	Power lines/Pylons	2563	0.2	Acceptable	N/A
146	Power lines/Pylons	2894	0.1	Acceptable	N/A
147	Power lines/Pylons	3255	0.1	Acceptable	N/A
148	Heritage Site (VVF02 - Farmstead)	1210	0.6	Acceptable	N/A
149	Farm Buildings/Structures	1675	0.3	Acceptable	Too Low
150	Farm Buildings/Structures	2328	0.2	Acceptable	Too Low
151	Informal Housing	3459	0.1	Acceptable	Too Low
152	Informal Housing	2842	0.1	Acceptable	Too Low
153	Mine Buildings/Structures	3443	0.1	Acceptable	N/A
154	Dam	2545	0.2	Acceptable	N/A
155	Dam	658	1.6	Acceptable	N/A
156	Mine Activity	835	1.1	Acceptable	N/A
157	Pivot Irrigation	2323	0.2	Acceptable	N/A
158	Informal Housing	1990	0.3	Acceptable	Too Low

Tag	Description	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
159	Pivot Irrigation	3257	0.1	Acceptable	N/A
160	Dam	932	0.9	Acceptable	N/A
161	Pivot Irrigation	2651	0.2	Acceptable	N/A
162	Pivot Irrigation	2861	0.1	Acceptable	N/A
163	Pivot Irrigation	3173	0.1	Acceptable	N/A
164	Cement Dam	2605	0.2	Acceptable	N/A
165	Farm Buildings/Structures	2433	0.2	Acceptable	Too Low
166	Informal Housing	2755	0.2	Acceptable	Too Low
167	Informal Housing	1896	0.3	Acceptable	Too Low
168	Informal Housing	2107	0.2	Acceptable	Too Low
169	Dam	140	20.4	Acceptable	N/A
170	Dam (Inside Pit Area)	-	-	-	-
171	Mine Buildings/Structures (Inside Pit Area)	-	-	-	-
172	Domestic Borehole (Drinking Water - Office - Inside Pit Area)	-	-	-	-
173	Domestic Borehole-VBH 06 (Tap Water)	687	1.5	Acceptable	N/A
174	Domestic Borehole (Playground)	307	5.6	Acceptable	N/A
175	Domestic Borehole (Arbor Community-2)	630	1.7	Acceptable	N/A
176	Domestic Borehole (EUB-04B)	630	1.7	Acceptable	N/A
177	Domestic Borehole (EUB-09)	3445	0.1	Acceptable	N/A
178	Domestic Borehole (EUB-10)	425	3.3	Acceptable	N/A
179	Domestic Borehole (EUB-17)	516	2.4	Acceptable	N/A
180	Domestic Borehole (EUB-18)	532	2.3	Acceptable	N/A
181	Domestic Borehole (VBH-1M)	58	87.8	Problematic	N/A
182	Domestic Borehole (VBH-01S)	57	90.6	Problematic	N/A
183	Domestic Borehole (VBH-02M)	630	1.7	Acceptable	N/A
184	Domestic Borehole (VBH-03M)	577	2.0	Acceptable	N/A
185	Domestic Borehole (VBH-03S - Inside Pit Area)	-	-	-	-
186	Domestic Borehole (VBH-04M)	345	4.6	Acceptable	N/A
187	Domestic Borehole (VBH-05M - Inside Pit Area)	-	-	-	-
188	Domestic Borehole (VBH-06M - Inside Pit Area)	-	-	-	-
189	Domestic Borehole (VBH-06S)	12	1161.0	Problematic	N/A
190	Domestic Borehole (VBH-07MS - Inside Pit Area)	-	-	-	-
191	Domestic Borehole (VBH-08M)	90	42.7	Acceptable	N/A
192	Domestic Borehole (VBH-08S)	20	496.8	Problematic	N/A
193	Domestic Borehole (VBH-9D)	12	1149.7	Problematic	N/A
194	Domestic Borehole (VBH-10-M - Inside Pit Area)	-	-	-	-
195	Domestic Borehole (VBH-11-M - Inside Pit Area)	-	-	-	-
196	Heritage Site (VVF01 - Dilapidated house structures& reservoir)	577	2.0	Acceptable	N/A
197	Heritage Site (VVF03 - Stone& mortar kraal)	1327	0.5	Acceptable	N/A
198	Heritage Site (VVF04 - Stone enclosure)	1186	0.6	Acceptable	N/A
199	Heritage Site (VVF06 - Cemetery 20 graves)	205	10.9	Acceptable	N/A
200	Heritage Site (VVF07 - Cemetery 150 graves)	664	1.6	Acceptable	N/A

- ***Maximum charge per delay – 602 kg***

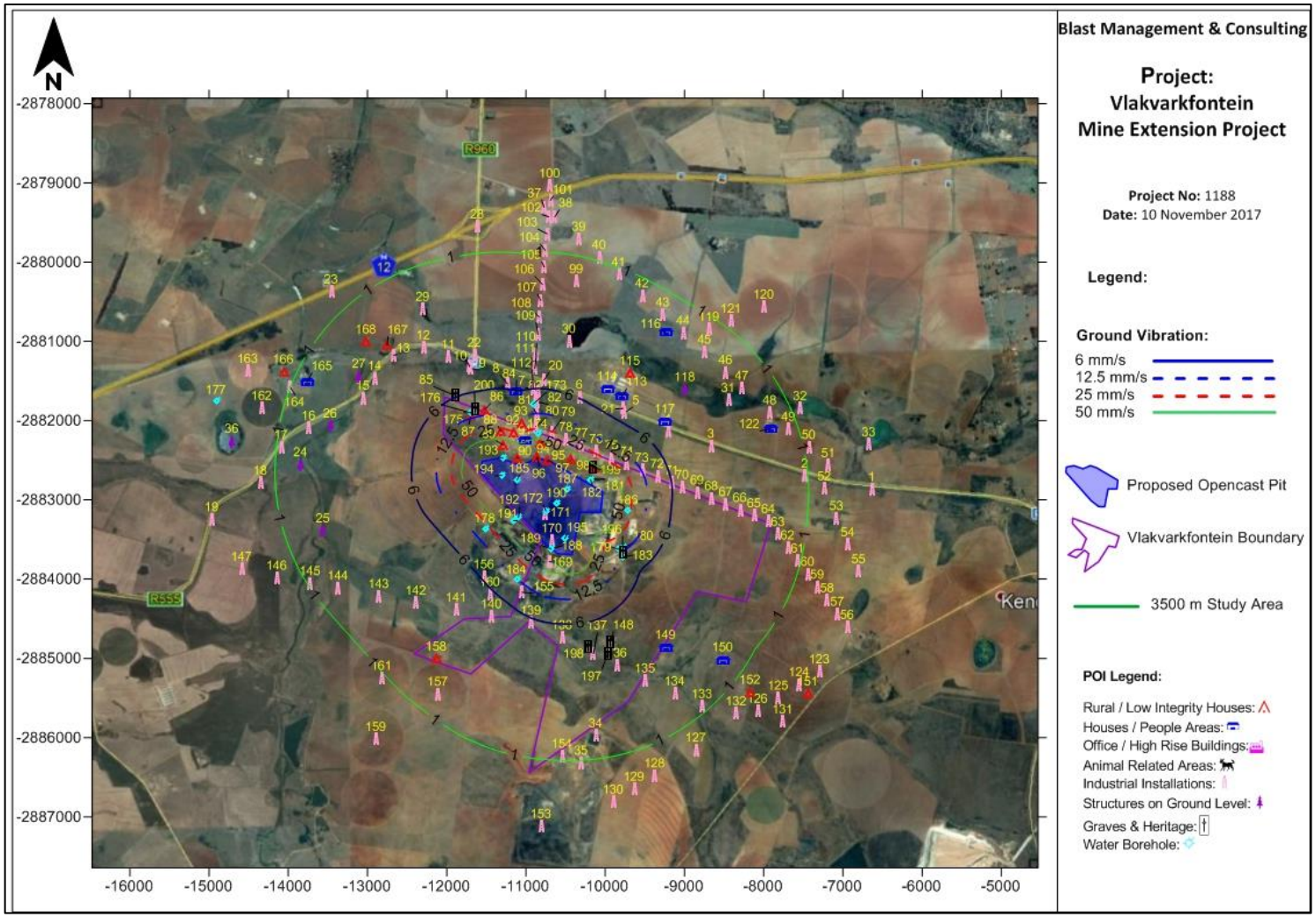

Figure 15: Ground vibration influence from maximum charge for Pit Area

Table 11: Ground vibration evaluation for maximum charge for Pit Area

Tag	Description	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Railway Line	3404	0.3	Acceptable	N/A
2	Railway Line	2563	0.5	Acceptable	N/A
3	Railway Line	1495	1.3	Acceptable	N/A
4	Railway Line	1135	2.0	Acceptable	N/A
5	Railway Line	1005	2.5	Acceptable	N/A
6	Railway Line	898	3.0	Acceptable	N/A
7	Railway Line	843	3.3	Acceptable	N/A
8	Railway Line	942	2.8	Acceptable	N/A
9	Arbor Railway Station	1177	1.9	Acceptable	N/A
10	Railway Line	1206	1.8	Acceptable	N/A
11	Railway Line	1391	1.5	Acceptable	N/A
12	Railway Line	1617	1.1	Acceptable	N/A
13	Railway Line	1752	1.0	Acceptable	N/A
14	Railway Line	1716	1.0	Acceptable	N/A
15	Railway Line	1709	1.0	Acceptable	N/A
16	Railway Line	2229	0.7	Acceptable	N/A
17	Railway Line	2538	0.5	Acceptable	N/A
18	Railway Line	2784	0.5	Acceptable	N/A
19	Railway Line	3445	0.3	Acceptable	N/A
20	R555 Road	984	2.6	Acceptable	N/A
21	R555 Road	1040	2.4	Acceptable	N/A
22	R960 Road	1333	1.6	Acceptable	N/A
23	N12 Road	2871	0.4	Acceptable	N/A
24	Wilge River	2276	0.6	Acceptable	N/A
25	Wilge River	2122	0.7	Acceptable	N/A
26	Wilge River	1969	0.8	Acceptable	N/A
27	Wilge River	1893	0.9	Acceptable	N/A
28	N12 Road/Ramp	2936	0.4	Acceptable	N/A
29	Dam	2065	0.8	Acceptable	N/A
30	Dam	1528	1.3	Acceptable	N/A
31	Dam	1969	0.8	Acceptable	N/A
32	Dam	2715	0.5	Acceptable	N/A
33	Dam	3419	0.3	Acceptable	N/A
34	Dam	2308	0.6	Acceptable	N/A
35	Mine Activity	2633	0.5	Acceptable	N/A
36	Pan	3164	0.4	Acceptable	N/A
37	Power lines/Pylons	3170	0.4	Acceptable	N/A
38	Power lines/Pylons	3052	0.4	Acceptable	N/A
39	Power lines/Pylons	2813	0.5	Acceptable	N/A
40	Power lines/Pylons	2649	0.5	Acceptable	N/A
41	Power lines/Pylons	2519	0.5	Acceptable	N/A
42	Power lines/Pylons	2395	0.6	Acceptable	N/A
43	Power lines/Pylons	2317	0.6	Acceptable	N/A
44	Power lines/Pylons	2248	0.7	Acceptable	N/A
45	Power lines/Pylons	2187	0.7	Acceptable	N/A
46	Power lines/Pylons	2168	0.7	Acceptable	N/A
47	Power lines/Pylons	2200	0.7	Acceptable	N/A
48	Power lines/Pylons	2346	0.6	Acceptable	N/A
49	Power lines/Pylons	2483	0.6	Acceptable	N/A
50	Power lines/Pylons	2670	0.5	Acceptable	N/A
51	Power lines/Pylons	2874	0.4	Acceptable	N/A
52	Power lines/Pylons	2804	0.5	Acceptable	N/A

Tag	Description	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
53	Power lines/Pylons	2973	0.4	Acceptable	N/A
54	Power lines/Pylons	3151	0.4	Acceptable	N/A
55	Power lines/Pylons	3344	0.3	Acceptable	N/A
56	Power lines/Pylons	3437	0.3	Acceptable	N/A
57	Power lines/Pylons	3256	0.4	Acceptable	N/A
58	Power lines/Pylons	3071	0.4	Acceptable	N/A
59	Power lines/Pylons	2896	0.4	Acceptable	N/A
60	Power lines/Pylons	2730	0.5	Acceptable	N/A
61	Power lines/Pylons	2565	0.5	Acceptable	N/A
62	Power lines/Pylons	2406	0.6	Acceptable	N/A
63	Power lines/Pylons	2259	0.7	Acceptable	N/A
64	Power lines/Pylons	2121	0.7	Acceptable	N/A
65	Power lines/Pylons	1935	0.8	Acceptable	N/A
66	Power lines/Pylons	1749	1.0	Acceptable	N/A
67	Power lines/Pylons	1566	1.2	Acceptable	N/A
68	Power lines/Pylons	1380	1.5	Acceptable	N/A
69	Power lines/Pylons	1198	1.9	Acceptable	N/A
70	Power lines/Pylons	1014	2.5	Acceptable	N/A
71	Power lines/Pylons	891	3.0	Acceptable	N/A
72	Power lines/Pylons	726	4.3	Acceptable	N/A
73	Power lines/Pylons	576	6.3	Acceptable	N/A
74	Power lines/Pylons	472	8.7	Acceptable	N/A
75	Power lines/Pylons	432	10.1	Acceptable	N/A
76	Power lines/Pylons	405	11.2	Acceptable	N/A
77	Power lines/Pylons	374	12.8	Acceptable	N/A
78	Power lines/Pylons	346	14.5	Acceptable	N/A
79	Power lines/Pylons	361	13.5	Acceptable	N/A
80	Power lines/Pylons	402	11.4	Acceptable	N/A
81	Power lines/Pylons	558	6.6	Acceptable	N/A
82	Power lines/Pylons	711	4.4	Acceptable	N/A
83	Sub Station	766	3.9	Acceptable	N/A
84	Buildings/Structures	863	3.2	Acceptable	Perceptible
85	Heritage Site (VVF08 - Historic Store)	901	3.0	Acceptable	N/A
86	Community Houses	635	5.3	Acceptable	Perceptible
87	Community Houses	602	5.8	Acceptable	Unpleasant
88	Community Houses	336	15.2	Problematic	Unpleasant
89	Community Houses	173	45.5	Problematic	Intolerable
90	Community Houses	75	179.4	Problematic	Intolerable
91	School	268	22.1	Acceptable	Intolerable
92	Community Houses	356	13.8	Problematic	Unpleasant
93	Community Houses	486	8.3	Acceptable	Unpleasant
94	Community Houses	201	35.5	Problematic	Intolerable
95	Community Houses	16	2437.1	Problematic	Intolerable
96	Community Houses	21	1443.3	Problematic	Intolerable
97	Community Houses	154	54.9	Problematic	Intolerable
98	Community Houses	217	31.2	Problematic	Intolerable
99	Pivot Irrigation	2281	0.6	Acceptable	N/A
100	Power lines/Pylons	3443	0.3	Acceptable	N/A
101	Power lines/Pylons	3259	0.4	Acceptable	N/A
102	Power lines/Pylons	3049	0.4	Acceptable	N/A
103	Power lines/Pylons	2834	0.5	Acceptable	N/A
104	Power lines/Pylons	2623	0.5	Acceptable	N/A
105	Power lines/Pylons	2412	0.6	Acceptable	N/A

Tag	Description	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
106	Power lines/Pylons	2196	0.7	Acceptable	N/A
107	Power lines/Pylons	1991	0.8	Acceptable	N/A
108	Power lines/Pylons	1780	1.0	Acceptable	N/A
109	Power lines/Pylons	1563	1.2	Acceptable	N/A
110	Power lines/Pylons	1308	1.6	Acceptable	N/A
111	Power lines/Pylons	1140	2.0	Acceptable	N/A
112	Power lines/Pylons	876	3.1	Acceptable	N/A
113	Farm Buildings/Structures	1161	2.0	Acceptable	Perceptible
114	Buildings/Structures	1146	2.0	Acceptable	Perceptible
115	Informal Housing	1471	1.3	Acceptable	Perceptible
116	Farm Buildings/Structures	2139	0.7	Acceptable	Too Low
117	Buildings/Structures	1182	1.9	Acceptable	Perceptible
118	Pan	1664	1.1	Acceptable	N/A
119	Pivot Irrigation	2456	0.6	Acceptable	N/A
120	Pivot Irrigation	3102	0.4	Acceptable	N/A
121	Cement Dam	2701	0.5	Acceptable	N/A
122	Farm Buildings/Structures	2272	0.7	Acceptable	Too Low
123	Power lines/Pylons	3418	0.3	Acceptable	N/A
124	Power lines/Pylons	3307	0.4	Acceptable	N/A
125	Power lines/Pylons	3173	0.4	Acceptable	N/A
126	Power lines/Pylons	3065	0.4	Acceptable	N/A
127	Power lines/Pylons	2923	0.4	Acceptable	N/A
128	Power lines/Pylons	2982	0.4	Acceptable	N/A
129	Power lines/Pylons	3062	0.4	Acceptable	N/A
130	Power lines/Pylons	3166	0.4	Acceptable	N/A
131	Power lines/Pylons	3399	0.3	Acceptable	N/A
132	Power lines/Pylons	2888	0.4	Acceptable	N/A
133	Power lines/Pylons	2526	0.5	Acceptable	N/A
134	Power lines/Pylons	2184	0.7	Acceptable	N/A
135	Power lines/Pylons	1842	0.9	Acceptable	N/A
136	Power lines/Pylons	1509	1.3	Acceptable	N/A
137	Power lines/Pylons	1281	1.7	Acceptable	N/A
138	Power lines/Pylons	1047	2.3	Acceptable	N/A
139	Power lines/Pylons	933	2.8	Acceptable	N/A
140	Power lines/Pylons	1133	2.1	Acceptable	N/A
141	Power lines/Pylons	1375	1.5	Acceptable	N/A
142	Power lines/Pylons	1696	1.1	Acceptable	N/A
143	Power lines/Pylons	1990	0.8	Acceptable	N/A
144	Power lines/Pylons	2310	0.6	Acceptable	N/A
145	Power lines/Pylons	2563	0.5	Acceptable	N/A
146	Power lines/Pylons	2894	0.4	Acceptable	N/A
147	Power lines/Pylons	3255	0.4	Acceptable	N/A
148	Heritage Site (VVF02 - Farmstead)	1210	1.8	Acceptable	N/A
149	Farm Buildings/Structures	1675	1.1	Acceptable	Perceptible
150	Farm Buildings/Structures	2328	0.6	Acceptable	Too Low
151	Informal Housing	3459	0.3	Acceptable	Too Low
152	Informal Housing	2842	0.4	Acceptable	Too Low
153	Mine Buildings/Structures	3443	0.3	Acceptable	N/A
154	Dam	2545	0.5	Acceptable	N/A
155	Dam	658	5.0	Acceptable	N/A
156	Mine Activity	835	3.4	Acceptable	N/A
157	Pivot Irrigation	2323	0.6	Acceptable	N/A
158	Informal Housing	1990	0.8	Acceptable	Perceptible

Tag	Description	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
159	Pivot Irrigation	3257	0.4	Acceptable	N/A
160	Dam	932	2.8	Acceptable	N/A
161	Pivot Irrigation	2651	0.5	Acceptable	N/A
162	Pivot Irrigation	2861	0.4	Acceptable	N/A
163	Pivot Irrigation	3173	0.4	Acceptable	N/A
164	Cement Dam	2605	0.5	Acceptable	N/A
165	Farm Buildings/Structures	2433	0.6	Acceptable	Too Low
166	Informal Housing	2755	0.5	Acceptable	Too Low
167	Informal Housing	1896	0.9	Acceptable	Perceptible
168	Informal Housing	2107	0.7	Acceptable	Too Low
169	Dam	140	-	-	-
170	Dam (Inside Pit Area)	-	-	-	-
171	Mine Buildings/Structures (Inside Pit Area)	-	-	-	-
172	Domestic Borehole (Drinking Water - Office - Inside Pit Area)	-	-	-	-
173	Domestic Borehole-VBH 06 (Tap Water)	687	4.7	Acceptable	N/A
174	Domestic Borehole (Playground)	307	17.6	Acceptable	N/A
175	Domestic Borehole (Arbor Community-2)	630	5.4	Acceptable	N/A
176	Domestic Borehole (EUB-04B)	630	5.4	Acceptable	N/A
177	Domestic Borehole (EUB-09)	3445	0.3	Acceptable	N/A
178	Domestic Borehole (EUB-10)	425	10.3	Acceptable	N/A
179	Domestic Borehole (EUB-17)	516	7.5	Acceptable	N/A
180	Domestic Borehole (EUB-18)	532	7.1	Acceptable	N/A
181	Domestic Borehole (VBH-1M)	58	276.4	Problematic	N/A
182	Domestic Borehole (VBH-01S)	57	285.1	Problematic	N/A
183	Domestic Borehole (VBH-02M)	630	5.4	Acceptable	N/A
184	Domestic Borehole (VBH-03M)	577	6.2	Acceptable	N/A
185	Domestic Borehole (VBH-03S - Inside Pit Area)	-	-	-	-
186	Domestic Borehole (VBH-04M)	345	14.6	Acceptable	N/A
187	Domestic Borehole (VBH-05M - Inside Pit Area)	-	-	-	-
188	Domestic Borehole (VBH-06M - Inside Pit Area)	-	-	-	-
189	Domestic Borehole (VBH-06S)	12	3653.5	Problematic	N/A
190	Domestic Borehole (VBH-07MS - Inside Pit Area)	-	-	-	-
191	Domestic Borehole (VBH-08M)	90	134.3	Problematic	N/A
192	Domestic Borehole (VBH-08S)	20	1563.5	Problematic	N/A
193	Domestic Borehole (VBH-9D)	12	3618.0	Problematic	N/A
194	Domestic Borehole (VBH-10-M - Inside Pit Area)	-	-	-	-
195	Domestic Borehole (VBH-11-M - Inside Pit Area)	-	-	-	-
196	Heritage Site (VVF01 - Dilapidated house structures& reservoir)	577	6.2	Problematic	N/A
197	Heritage Site (VVF03 - Stone& mortar kraal)	1327	1.6	Acceptable	N/A
198	Heritage Site (VVF04 - Stone enclosure)	1186	1.9	Acceptable	N/A
199	Heritage Site (VVF06 - Cemetery 20 graves)	205	34.4	Problematic	N/A
200	Heritage Site (VVF07 - Cemetery 150 graves)	664	4.9	Acceptable	N/A

15.4 Summary of Ground Vibration Levels

The Pit operations were evaluated for expected levels of ground vibration from future blasting operations. Review of the sites and the surrounding installations / houses / buildings / mine infrastructure showed that structures vary in distances from the pit area. The evaluation considered a distance up to 3500 m from the mining area.

The distances between structures and the pit area is the main contributing factor to the levels of ground vibration expected and the subsequent possible influences. It is observed that for the different charge masses evaluated that levels of ground vibration will change as well. In view of the maximum charge specific attention will need to be given to specific areas.

The closest structures to the open pit area are Community houses, Boreholes, Dam, School, Power Lines/Pylons, Heritage Site (VVF06 - Cemetery 20 graves) and Heritage Site (VVF01 - Dilapidated house structures & reservoir). The planned maximum charge evaluated showed that it could be problematic in terms of potential structural damage and human perception. A maximum of 3653.5 mm/s is expected for the maximum charge.

The nearest public houses are located 16 m from the pit boundary. The ground vibration levels predicted ranged between 0.3 mm/s and 2437 mm/s for house structures surrounding the open pit area. The nearest structures considered in the evaluation showed high levels of ground vibration and will certainly be experienced as problematic.

There are structures that are better built and some that are of lesser quality integrity. Only a detailed survey will pin point exactly what type of structure is found where.

In view of the above it is believed that specific mitigations will be required near POIs that have been identified as possible concerns such as possible relocation of relevant households and the Heritage Site where graves are present.

15.5 Ground Vibration and Human Perception

Considering the effect of ground vibration with regards to human perception, vibration levels calculated were applied to an average of 30Hz frequency and plotted with expected human perceptions on the safe blasting criteria graph (see Figure 16 below). Data applicable to human response only is plotted. The frequency range selected is the expected average range for frequencies that will be measured for ground vibration when blasting is done. Based on the maximum charge and ground vibration predicted over distance it can be seen from Figure 16 that up to a distance of 1990 m people may experience levels of ground vibration as perceptible. At 634 m and closer the perception of ground vibration could be unpleasant and at 355 m the levels would be Intolerable.

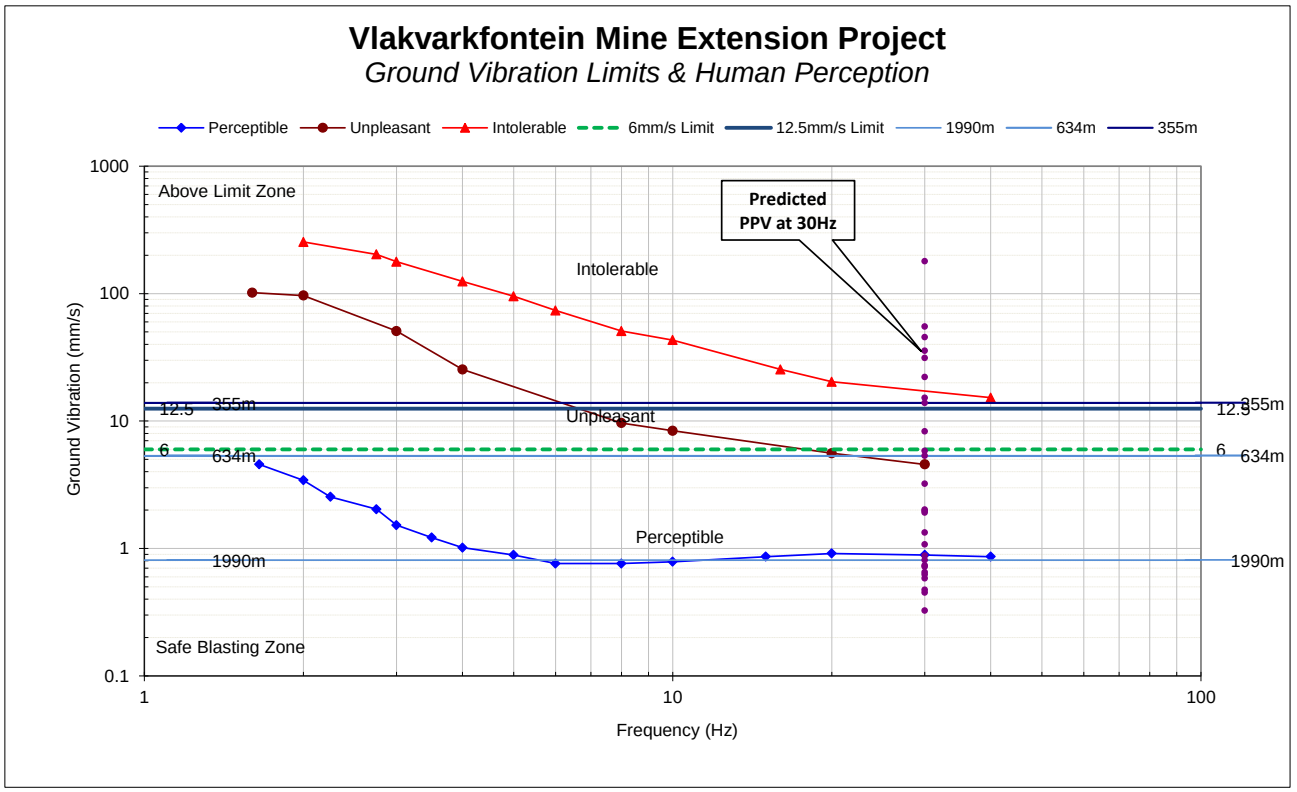

Figure 16: The effect of ground vibration with human perception and vibration limits

15.6 Potential that Vibration Will Upset Adjacent Communities

Ground vibration and air blast generally upset people living in the vicinity of mining operations. There are communities, heritage sites and a school that are within the evaluated area of influence. There are structures in close proximity of the pit area.

Ground vibration levels expected from maximum charge has possibility to be perceptible up to 1990 m. It is certain that lesser charges will reduce this distance for instance at minimum charge this distance is expected to be 863 m. Within these distance ranges there are a significant number of houses. The anticipated ground vibration levels are certain to have possibility of upsetting the adjacent communities. Intolerable levels are expected up to a distance of 355 m.

The importance of good public relations cannot be under stressed. People tend to react negatively on experiencing of effects from blasting such as ground vibration and air blast. Even at low levels when damage to structures is out of the question it may upset people. Proper and appropriate communication with neighbours about blasting, monitoring and actions done for proper control will be required.

15.7 Cracking of houses and consequent devaluation

The structures found in the areas of concern ranges from informal building style to brick and mortar structures, industrial structures and various types of roads. There are village / settlement areas, agricultural and rural community houses found within the 3500 m range from the mining area. Building style and materials will certainly contribute to additional cracking apart from influences such as blasting operations.

Some of the structures i.e. corrugated iron structures are relatively safe from ground vibrations but brick and mortar or traditional built houses or houses in poor state should be considered.

The presence of general vertical cracks, horizontal and diagonal cracks that are found in typical brick structures does not need to indicate devaluation due to blasting operations but rather devaluation due to construction, building material, age, standards of building applied. Thus, damage in the form of cracks will be present. Exact costing of devaluation for normal cracks observed is difficult to estimate. Mining operations may not have influence to change the status quo of any property if correct precautions are considered.

Review of structures, distance from pit area and the expected levels of ground vibration from maximum charge, the problematic indicators identified structures up to a distance of 577 m. The structures within this range could possibly be influenced. This distance is reduced to 500m for minimum charge applied.

The proposed limits as applied in this document i.e. 6 mm/s, 12.5 mm/s and 25 mm/s are considered sufficient to ensure that additional damage is not introduced to the different categories of structures. It is expected that, should levels of ground vibration be maintained within these limits, the possibility of inducing damage is limited. Mitigation measures will be required to manage the levels of ground vibration.

15.8 Vibration Impact on Roads

The R555, R960 and the N12 roads are in the vicinity of the project area and needs to be considered. The provincial roads are at closest point of 984 m for the R555 and 1333 m for the R960 in the vicinity of the project area. The N12 national road is at 2936 m from the project area. No specific actions are required for these roads. There are gravel roads in the vicinity of the project area that link the different communities. There is no concern for negative vibration influence for the R555, R960 and N12.

15.9 Review of Expected Air Blast

Presented herewith are the expected air blast level contours and discussion of relevant influences. Expected air blast levels were calculated for each POI identified surrounding the mining area and

evaluated with regards to possible structural concerns. Tables are provided for each of the different charge models done with regards to:

- "Tag" No. is number corresponding to the location indicated on POI figures.
- "Description" indicates the type of the structure.
- "Distance" is the distance between the structure and edge of the opencast area.
- "Air Blast (dB)" is the calculated air blast level at the structure.
- "Possible concern" indicates if there is any concern for structural damage or human perception. Indicators used are:
    - "Problematic" where there is real concern for possible damage – at levels greater than 134 dBL.
    - "Complaint" where people will be complaining due to the experienced effect on structures at levels of 120 dB and higher (not necessarily damaging).
    - "Acceptable" if levels are less than 120 dBL.
    - "Low" where there is very limited possibility that the levels will give rise to any influence on people or structures. Levels below 115 dB could be considered to have low or negligible possibility of influence.

Presented are simulations for expected air blast levels from two different charge masses at the shaft areas. Colour codes used in tables are as follows:

Air blast levels higher than proposed limit is coloured "Red"
Air blast levels indicated as possible Complaint is coloured "Mustard"
POI's that are found inside the pit area is coloured "Olive Green"

- ***Minimum charge per delay - 150 kg***

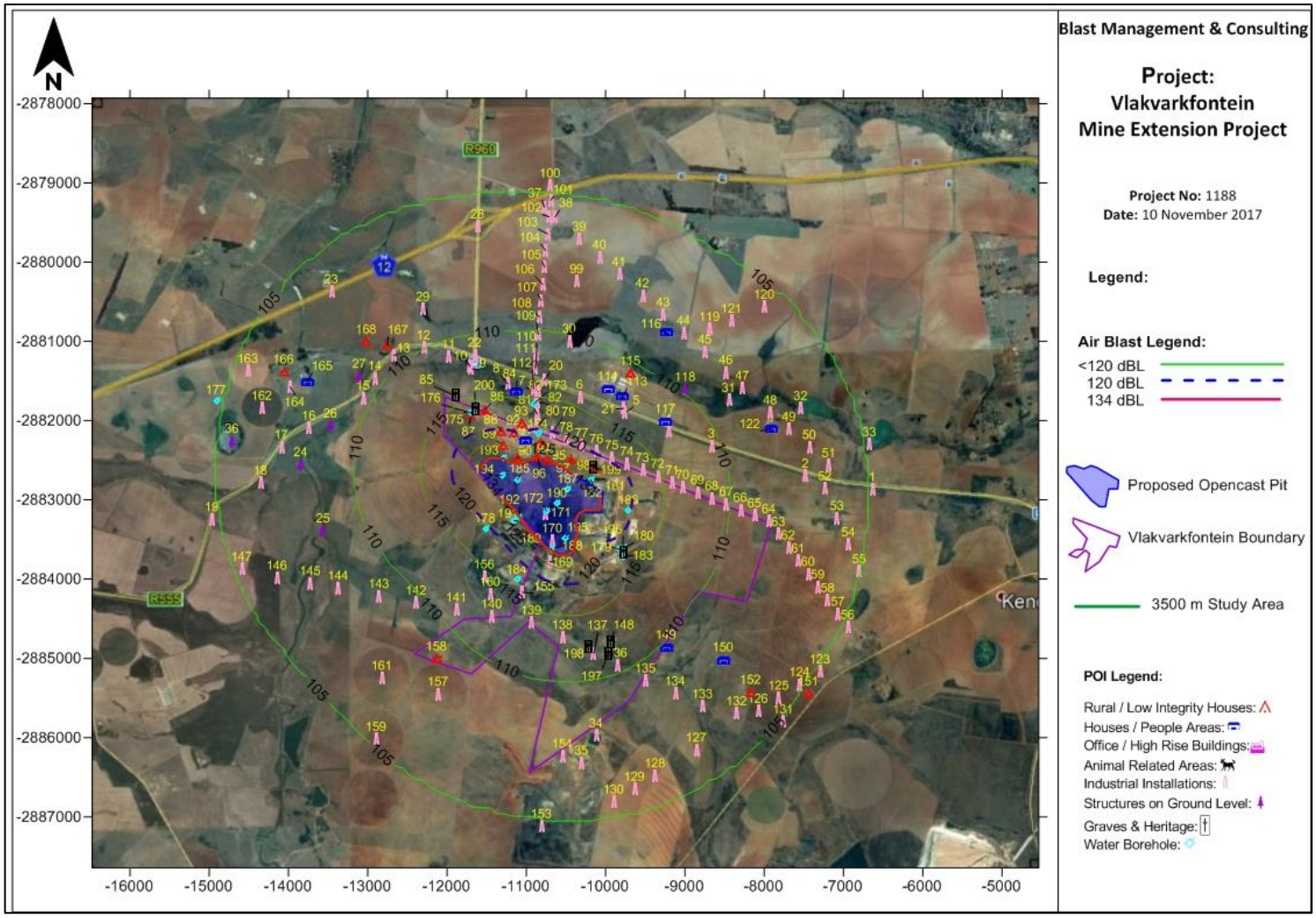

Figure 17: Air blast influence from minimum charge for Pit Area

Table 12: Air blast evaluation for minimum charge for Pit Area

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Railway Line	3404	104.3	N/A
2	Railway Line	2563	106.2	N/A
3	Railway Line	1495	110.0	N/A
4	Railway Line	1135	111.8	N/A
5	Railway Line	1005	112.7	N/A
6	Railway Line	898	113.4	N/A
7	Railway Line	843	113.9	N/A
8	Railway Line	942	113.1	N/A
9	Arbor Railway Station	1177	111.6	N/A
10	Railway Line	1206	111.4	N/A
11	Railway Line	1391	110.5	N/A
12	Railway Line	1617	109.4	N/A
13	Railway Line	1752	108.9	N/A
14	Railway Line	1716	108.9	N/A
15	Railway Line	1709	109.1	N/A
16	Railway Line	2229	107.2	N/A
17	Railway Line	2538	106.4	N/A
18	Railway Line	2784	105.8	N/A
19	Railway Line	3445	104.3	N/A
20	R555 Road	984	112.8	N/A
21	R555 Road	1040	112.5	N/A
22	R960 Road	1333	110.8	N/A
23	N12 Road	2871	105.6	N/A
24	Wilge River	2276	107.0	N/A
25	Wilge River	2122	107.6	N/A
26	Wilge River	1969	108.1	N/A
27	Wilge River	1893	108.3	N/A
28	N12 Road/Ramp	2936	105.3	N/A
29	Dam	2065	107.8	N/A
30	Dam	1528	109.8	N/A
31	Dam	1969	108.1	N/A
32	Dam	2715	105.8	N/A
33	Dam	3419	104.3	N/A
34	Dam	2308	107.0	N/A
35	Mine Activity	2633	106.0	N/A
36	Pan	3164	104.9	N/A
37	Power lines/Pylons	3170	104.9	N/A
38	Power lines/Pylons	3052	105.1	N/A
39	Power lines/Pylons	2813	105.6	N/A
40	Power lines/Pylons	2649	106.0	N/A
41	Power lines/Pylons	2519	106.4	N/A
42	Power lines/Pylons	2395	106.6	N/A
43	Power lines/Pylons	2317	107.0	N/A
44	Power lines/Pylons	2248	107.2	N/A
45	Power lines/Pylons	2187	107.4	N/A
46	Power lines/Pylons	2168	107.4	N/A
47	Power lines/Pylons	2200	107.2	N/A
48	Power lines/Pylons	2346	106.8	N/A
49	Power lines/Pylons	2483	106.4	N/A
50	Power lines/Pylons	2670	106.0	N/A
51	Power lines/Pylons	2874	105.6	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
52	Power lines/Pylons	2804	105.6	N/A
53	Power lines/Pylons	2973	105.3	N/A
54	Power lines/Pylons	3151	104.9	N/A
55	Power lines/Pylons	3344	104.6	N/A
56	Power lines/Pylons	3437	104.3	N/A
57	Power lines/Pylons	3256	104.6	N/A
58	Power lines/Pylons	3071	105.1	N/A
59	Power lines/Pylons	2896	105.3	N/A
60	Power lines/Pylons	2730	105.8	N/A
61	Power lines/Pylons	2565	106.2	N/A
62	Power lines/Pylons	2406	106.6	N/A
63	Power lines/Pylons	2259	107.2	N/A
64	Power lines/Pylons	2121	107.6	N/A
65	Power lines/Pylons	1935	108.1	N/A
66	Power lines/Pylons	1749	108.9	N/A
67	Power lines/Pylons	1566	109.7	N/A
68	Power lines/Pylons	1380	110.5	N/A
69	Power lines/Pylons	1198	111.5	N/A
70	Power lines/Pylons	1014	112.6	N/A
71	Power lines/Pylons	891	113.4	N/A
72	Power lines/Pylons	726	114.9	N/A
73	Power lines/Pylons	576	116.5	N/A
74	Power lines/Pylons	472	117.8	N/A
75	Power lines/Pylons	432	118.4	N/A
76	Power lines/Pylons	405	118.9	N/A
77	Power lines/Pylons	374	119.4	N/A
78	Power lines/Pylons	346	120.0	N/A
79	Power lines/Pylons	361	119.6	N/A
80	Power lines/Pylons	402	118.9	N/A
81	Power lines/Pylons	558	116.7	N/A
82	Power lines/Pylons	711	115.0	N/A
83	Sub Station	766	114.5	N/A
84	Buildings/Structures	863	113.7	Acceptable
85	Heritage Site (VVF08 - Historic Store)	901	113.4	N/A
86	Community Houses	635	115.8	Acceptable
87	Community Houses	602	116.1	Acceptable
88	Community Houses	336	120.1	Complaint
89	Community Houses	173	124.7	Complaint
90	Community Houses	75	130.4	Complaint
91	School	268	121.7	Complaint
92	Community Houses	356	119.7	Acceptable
93	Community Houses	486	117.6	Acceptable
94	Community Houses	201	123.7	Complaint
95	Community Houses	16	141.2	Problematic
96	Community Houses	21	139.1	Problematic
97	Community Houses	154	125.5	Complaint
98	Community Houses	217	123.1	Complaint
99	Pivot Irrigation	2281	107.0	N/A
100	Power lines/Pylons	3443	104.3	N/A
101	Power lines/Pylons	3259	104.6	N/A
102	Power lines/Pylons	3049	105.1	N/A
103	Power lines/Pylons	2834	105.6	N/A
104	Power lines/Pylons	2623	106.2	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
105	Power lines/Pylons	2412	106.6	N/A
106	Power lines/Pylons	2196	107.4	N/A
107	Power lines/Pylons	1991	108.0	N/A
108	Power lines/Pylons	1780	108.8	N/A
109	Power lines/Pylons	1563	109.7	N/A
110	Power lines/Pylons	1308	110.9	N/A
111	Power lines/Pylons	1140	111.8	N/A
112	Power lines/Pylons	876	113.6	N/A
113	Farm Buildings/Structures	1161	111.7	Acceptable
114	Buildings/Structures	1146	111.7	Acceptable
115	Informal Housing	1471	110.1	Acceptable
116	Farm Buildings/Structures	2139	107.6	Acceptable
117	Buildings/Structures	1182	111.6	Acceptable
118	Pan	1664	109.2	N/A
119	Pivot Irrigation	2456	106.6	N/A
120	Pivot Irrigation	3102	105.1	N/A
121	Cement Dam	2701	106.0	N/A
122	Farm Buildings/Structures	2272	107.0	Acceptable
123	Power lines/Pylons	3418	104.3	N/A
124	Power lines/Pylons	3307	104.6	N/A
125	Power lines/Pylons	3173	104.9	N/A
126	Power lines/Pylons	3065	105.1	N/A
127	Power lines/Pylons	2923	105.3	N/A
128	Power lines/Pylons	2982	105.3	N/A
129	Power lines/Pylons	3062	105.1	N/A
130	Power lines/Pylons	3166	104.9	N/A
131	Power lines/Pylons	3399	104.3	N/A
132	Power lines/Pylons	2888	105.6	N/A
133	Power lines/Pylons	2526	106.4	N/A
134	Power lines/Pylons	2184	107.4	N/A
135	Power lines/Pylons	1842	108.5	N/A
136	Power lines/Pylons	1509	109.8	N/A
137	Power lines/Pylons	1281	111.0	N/A
138	Power lines/Pylons	1047	112.4	N/A
139	Power lines/Pylons	933	113.2	N/A
140	Power lines/Pylons	1133	111.8	N/A
141	Power lines/Pylons	1375	110.5	N/A
142	Power lines/Pylons	1696	109.1	N/A
143	Power lines/Pylons	1990	108.0	N/A
144	Power lines/Pylons	2310	107.0	N/A
145	Power lines/Pylons	2563	106.2	N/A
146	Power lines/Pylons	2894	105.6	N/A
147	Power lines/Pylons	3255	104.6	N/A
148	Heritage Site (VVF02 - Farmstead)	1210	111.4	N/A
149	Farm Buildings/Structures	1675	109.2	Acceptable
150	Farm Buildings/Structures	2328	106.8	Acceptable
151	Informal Housing	3459	104.3	Acceptable
152	Informal Housing	2842	105.6	Acceptable
153	Mine Buildings/Structures	3443	104.3	N/A
154	Dam	2545	106.2	N/A
155	Dam	658	115.6	N/A
156	Mine Activity	835	113.9	N/A
157	Pivot Irrigation	2323	107.0	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
158	Informal Housing	1990	108.0	Acceptable
159	Pivot Irrigation	3257	104.6	N/A
160	Dam	932	113.2	N/A
161	Pivot Irrigation	2651	106.0	N/A
162	Pivot Irrigation	2861	105.6	N/A
163	Pivot Irrigation	3173	104.9	N/A
164	Cement Dam	2605	106.2	N/A
165	Farm Buildings/Structures	2433	106.6	Acceptable
166	Informal Housing	2755	105.8	Acceptable
167	Informal Housing	1896	108.3	Acceptable
168	Informal Housing	2107	107.6	Acceptable
169	Dam	140	126.1	N/A
170	Dam (Inside Pit Area)	-	-	-
171	Mine Buildings/Structures (Inside Pit Area)	-	-	-
172	Domestic Borehole (Drinking Water - Office - Inside Pit Area)	-	-	-
173	Domestic Borehole-VBH 06 (Tap Water)	687	115.3	N/A
174	Domestic Borehole (Playground)	307	120.7	N/A
175	Domestic Borehole (Arbor Community-2)	630	115.8	N/A
176	Domestic Borehole (EUB-04B)	630	115.8	N/A
177	Domestic Borehole (EUB-09)	3445	104.3	N/A
178	Domestic Borehole (EUB-10)	425	118.5	N/A
179	Domestic Borehole (EUB-17)	516	117.2	N/A
180	Domestic Borehole (EUB-18)	532	117.0	N/A
181	Domestic Borehole (VBH-1M)	58	132.2	N/A
182	Domestic Borehole (VBH-01S)	57	132.3	N/A
183	Domestic Borehole (VBH-02M)	630	115.8	N/A
184	Domestic Borehole (VBH-03M)	577	116.5	N/A
185	Domestic Borehole (VBH-03S - Inside Pit Area)	-	-	-
186	Domestic Borehole (VBH-04M)	345	120.0	N/A
187	Domestic Borehole (VBH-05M - Inside Pit Area)	-	-	-
188	Domestic Borehole (VBH-06M - Inside Pit Area)	-	-	-
189	Domestic Borehole (VBH-06S)	12	142.9	N/A
190	Domestic Borehole (VBH-07MS - Inside Pit Area)	-	-	-
191	Domestic Borehole (VBH-08M)	90	129.2	N/A
192	Domestic Borehole (VBH-08S)	20	139.4	N/A
193	Domestic Borehole (VBH-9D)	12	142.9	N/A
194	Domestic Borehole (VBH-10-M - Inside Pit Area)	-	-	-
195	Domestic Borehole (VBH-11-M - Inside Pit Area)	-	-	-
196	Heritage Site (VVF01 - Dilapidated house structures& reservoir)	577	116.5	N/A
197	Heritage Site (VVF03 - Stone& mortar kraal)	1327	110.8	N/A
198	Heritage Site (VVF04 - Stone enclosure)	1186	111.5	N/A
199	Heritage Site (VVF06 - Cemetery 20 graves)	205	123.5	N/A
200	Heritage Site (VVF07 - Cemetery 150 graves)	664	115.5	N/A

- ***Maximum charge per delay - 602 kg***

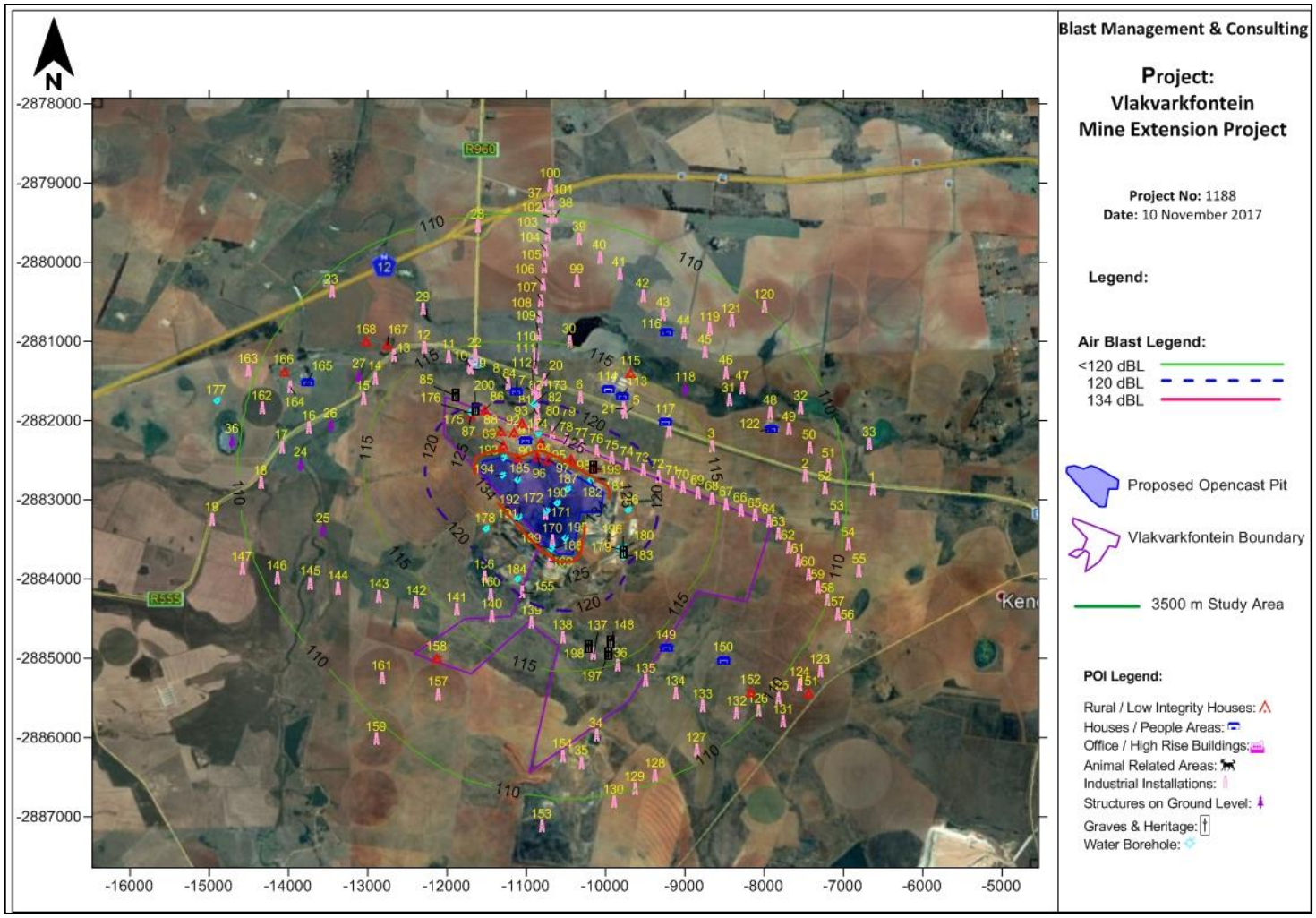

Figure 18: Air blast influence from maximum charge for Pit Area

Table 13: Air blast evaluation for maximum charge for Pit Area

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Railway Line	3404	107.4	N/A
2	Railway Line	2563	109.4	N/A
3	Railway Line	1495	113.1	N/A
4	Railway Line	1135	115.0	N/A
5	Railway Line	1005	115.8	N/A
6	Railway Line	898	116.6	N/A
7	Railway Line	843	117.0	N/A
8	Railway Line	942	116.3	N/A
9	Arbor Railway Station	1177	114.7	N/A
10	Railway Line	1206	114.6	N/A
11	Railway Line	1391	113.6	N/A
12	Railway Line	1617	112.6	N/A
13	Railway Line	1752	112.0	N/A
14	Railway Line	1716	112.1	N/A
15	Railway Line	1709	112.1	N/A
16	Railway Line	2229	110.4	N/A
17	Railway Line	2538	109.5	N/A
18	Railway Line	2784	108.9	N/A
19	Railway Line	3445	107.4	N/A
20	R555 Road	984	116.0	N/A
21	R555 Road	1040	115.6	N/A
22	R960 Road	1333	113.9	N/A
23	N12 Road	2871	108.6	N/A
24	Wilge River	2276	110.2	N/A
25	Wilge River	2122	110.8	N/A
26	Wilge River	1969	111.2	N/A
27	Wilge River	1893	111.5	N/A
28	N12 Road/Ramp	2936	108.5	N/A
29	Dam	2065	110.9	N/A
30	Dam	1528	113.0	N/A
31	Dam	1969	111.2	N/A
32	Dam	2715	109.1	N/A
33	Dam	3419	107.4	N/A
34	Dam	2308	110.1	N/A
35	Mine Activity	2633	109.2	N/A
36	Pan	3164	108.0	N/A
37	Power lines/Pylons	3170	108.0	N/A
38	Power lines/Pylons	3052	108.3	N/A
39	Power lines/Pylons	2813	108.8	N/A
40	Power lines/Pylons	2649	109.2	N/A
41	Power lines/Pylons	2519	109.5	N/A
42	Power lines/Pylons	2395	109.8	N/A
43	Power lines/Pylons	2317	110.1	N/A
44	Power lines/Pylons	2248	110.4	N/A
45	Power lines/Pylons	2187	110.5	N/A
46	Power lines/Pylons	2168	110.6	N/A
47	Power lines/Pylons	2200	110.5	N/A
48	Power lines/Pylons	2346	110.0	N/A
49	Power lines/Pylons	2483	109.7	N/A
50	Power lines/Pylons	2670	109.1	N/A
51	Power lines/Pylons	2874	108.6	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
52	Power lines/Pylons	2804	108.8	N/A
53	Power lines/Pylons	2973	108.5	N/A
54	Power lines/Pylons	3151	108.0	N/A
55	Power lines/Pylons	3344	107.6	N/A
56	Power lines/Pylons	3437	107.4	N/A
57	Power lines/Pylons	3256	107.8	N/A
58	Power lines/Pylons	3071	108.1	N/A
59	Power lines/Pylons	2896	108.6	N/A
60	Power lines/Pylons	2730	108.9	N/A
61	Power lines/Pylons	2565	109.4	N/A
62	Power lines/Pylons	2406	109.8	N/A
63	Power lines/Pylons	2259	110.2	N/A
64	Power lines/Pylons	2121	110.8	N/A
65	Power lines/Pylons	1935	111.4	N/A
66	Power lines/Pylons	1749	112.0	N/A
67	Power lines/Pylons	1566	112.8	N/A
68	Power lines/Pylons	1380	113.6	N/A
69	Power lines/Pylons	1198	114.6	N/A
70	Power lines/Pylons	1014	115.8	N/A
71	Power lines/Pylons	891	116.7	N/A
72	Power lines/Pylons	726	118.1	N/A
73	Power lines/Pylons	576	119.6	N/A
74	Power lines/Pylons	472	121.0	N/A
75	Power lines/Pylons	432	121.6	N/A
76	Power lines/Pylons	405	122.0	N/A
77	Power lines/Pylons	374	122.6	N/A
78	Power lines/Pylons	346	123.1	N/A
79	Power lines/Pylons	361	122.8	N/A
80	Power lines/Pylons	402	122.1	N/A
81	Power lines/Pylons	558	119.8	N/A
82	Power lines/Pylons	711	118.2	N/A
83	Sub Station	766	117.7	N/A
84	Buildings/Structures	863	116.8	Acceptable
85	Heritage Site (VVF08 - Historic Store)	901	116.6	N/A
86	Community Houses	635	118.9	Acceptable
87	Community Houses	602	119.3	Acceptable
88	Community Houses	336	123.3	Complaint
89	Community Houses	173	127.9	Complaint
90	Community Houses	75	133.6	Problematic
91	School	268	124.9	Complaint
92	Community Houses	356	122.9	Complaint
93	Community Houses	486	120.8	Complaint
94	Community Houses	201	126.8	Complaint
95	Community Houses	16	144.4	Problematic
96	Community Houses	21	142.2	Problematic
97	Community Houses	154	128.6	Complaint
98	Community Houses	217	126.3	Complaint
99	Pivot Irrigation	2281	110.2	N/A
100	Power lines/Pylons	3443	107.4	N/A
101	Power lines/Pylons	3259	107.8	N/A
102	Power lines/Pylons	3049	108.3	N/A
103	Power lines/Pylons	2834	108.8	N/A
104	Power lines/Pylons	2623	109.2	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
105	Power lines/Pylons	2412	109.8	N/A
106	Power lines/Pylons	2196	110.5	N/A
107	Power lines/Pylons	1991	111.1	N/A
108	Power lines/Pylons	1780	111.9	N/A
109	Power lines/Pylons	1563	112.8	N/A
110	Power lines/Pylons	1308	114.0	N/A
111	Power lines/Pylons	1140	115.0	N/A
112	Power lines/Pylons	876	116.8	N/A
113	Farm Buildings/Structures	1161	114.8	Acceptable
114	Buildings/Structures	1146	114.9	Acceptable
115	Informal Housing	1471	113.3	Acceptable
116	Farm Buildings/Structures	2139	110.6	Acceptable
117	Buildings/Structures	1182	114.7	Acceptable
118	Pan	1664	112.4	N/A
119	Pivot Irrigation	2456	109.7	N/A
120	Pivot Irrigation	3102	108.1	N/A
121	Cement Dam	2701	109.1	N/A
122	Farm Buildings/Structures	2272	110.2	Acceptable
123	Power lines/Pylons	3418	107.4	N/A
124	Power lines/Pylons	3307	107.8	N/A
125	Power lines/Pylons	3173	108.0	N/A
126	Power lines/Pylons	3065	108.3	N/A
127	Power lines/Pylons	2923	108.5	N/A
128	Power lines/Pylons	2982	108.5	N/A
129	Power lines/Pylons	3062	108.3	N/A
130	Power lines/Pylons	3166	108.0	N/A
131	Power lines/Pylons	3399	107.6	N/A
132	Power lines/Pylons	2888	108.6	N/A
133	Power lines/Pylons	2526	109.5	N/A
134	Power lines/Pylons	2184	110.5	N/A
135	Power lines/Pylons	1842	111.7	N/A
136	Power lines/Pylons	1509	113.1	N/A
137	Power lines/Pylons	1281	114.2	N/A
138	Power lines/Pylons	1047	115.6	N/A
139	Power lines/Pylons	933	116.3	N/A
140	Power lines/Pylons	1133	115.0	N/A
141	Power lines/Pylons	1375	113.7	N/A
142	Power lines/Pylons	1696	112.3	N/A
143	Power lines/Pylons	1990	111.1	N/A
144	Power lines/Pylons	2310	110.1	N/A
145	Power lines/Pylons	2563	109.4	N/A
146	Power lines/Pylons	2894	108.6	N/A
147	Power lines/Pylons	3255	107.8	N/A
148	Heritage Site (VVF02 - Farmstead)	1210	114.6	N/A
149	Farm Buildings/Structures	1675	112.4	Acceptable
150	Farm Buildings/Structures	2328	110.1	Acceptable
151	Informal Housing	3459	107.4	Acceptable
152	Informal Housing	2842	108.8	Acceptable
153	Mine Buildings/Structures	3443	107.4	N/A
154	Dam	2545	109.5	N/A
155	Dam	658	118.7	N/A
156	Mine Activity	835	117.1	N/A
157	Pivot Irrigation	2323	110.1	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
158	Informal Housing	1990	111.1	Acceptable
159	Pivot Irrigation	3257	107.8	N/A
160	Dam	932	116.3	N/A
161	Pivot Irrigation	2651	109.2	N/A
162	Pivot Irrigation	2861	108.6	N/A
163	Pivot Irrigation	3173	108.0	N/A
164	Cement Dam	2605	109.4	N/A
165	Farm Buildings/Structures	2433	109.8	Acceptable
166	Informal Housing	2755	108.9	Acceptable
167	Informal Housing	1896	111.5	Acceptable
168	Informal Housing	2107	110.8	Acceptable
169	Dam	140	129.3	N/A
170	Dam (Inside Pit Area)	-	-	-
171	Mine Buildings/Structures (Inside Pit Area)	-	-	-
172	Domestic Borehole (Drinking Water - Office - Inside Pit Area)	-	-	-
173	Domestic Borehole-VBH 06 (Tap Water)	687	118.4	N/A
174	Domestic Borehole (Playground)	307	123.9	N/A
175	Domestic Borehole (Arbor Community-2)	630	119.0	N/A
176	Domestic Borehole (EUB-04B)	630	119.0	N/A
177	Domestic Borehole (EUB-09)	3445	107.4	N/A
178	Domestic Borehole (EUB-10)	425	121.7	N/A
179	Domestic Borehole (EUB-17)	516	120.4	N/A
180	Domestic Borehole (EUB-18)	532	120.2	N/A
181	Domestic Borehole (VBH-1M)	58	135.4	N/A
182	Domestic Borehole (VBH-01S)	57	135.5	N/A
183	Domestic Borehole (VBH-02M)	630	119.0	N/A
184	Domestic Borehole (VBH-03M)	577	119.6	N/A
185	Domestic Borehole (VBH-03S - Inside Pit Area)	-	-	-
186	Domestic Borehole (VBH-04M)	345	123.1	N/A
187	Domestic Borehole (VBH-05M - Inside Pit Area)	-	-	-
188	Domestic Borehole (VBH-06M - Inside Pit Area)	-	-	-
189	Domestic Borehole (VBH-06S)	12	146.1	N/A
190	Domestic Borehole (VBH-07MS - Inside Pit Area)	-	-	-
191	Domestic Borehole (VBH-08M)	90	132.4	N/A
192	Domestic Borehole (VBH-08S)	20	142.6	N/A
193	Domestic Borehole (VBH-9D)	12	146.1	N/A
194	Domestic Borehole (VBH-10-M - Inside Pit Area)	-	-	-
195	Domestic Borehole (VBH-11-M - Inside Pit Area)	-	-	-
196	Heritage Site (VVF01 - Dilapidated house structures& reservoir)	577	119.6	N/A
197	Heritage Site (VVF03 - Stone& mortar kraal)	1327	113.9	N/A
198	Heritage Site (VVF04 - Stone enclosure)	1186	114.6	N/A
199	Heritage Site (VVF06 - Cemetery 20 graves)	205	126.7	N/A
200	Heritage Site (VVF07 - Cemetery 150 graves)	664	118.6	N/A

15.10 Summary of Findings for Air Blast

Review of the air blast levels indicates the same concerns than with ground vibration. Air blast predicted for the maximum charge ranges between 107.4 and 144.4 dB for all the POI's considered. This includes the nearest points such as the Community Houses. These levels may contribute to effects such as rattling of roofs or door or windows and is expected to be damaging. The current

accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134dB. On prediction it is expected that air blast will be greater than 134 dB at a distance of 75 m and closer from the pit boundary.

The Community Houses at POI's 90, 95 and 96 are POI's that were identified where air blast could be problematic and expected air blast is greater than 134 dBL. POI's up to 486 m, which include Community Houses and a School, could lead to complaints as air blast levels are higher than the acceptable 120dBL recommendations. The rest of the POI's showed levels lower than 134 dBL. Domestic Boreholes are closer but air blast does not have any influence on these installations.
A factor that should be considered is that areas where houses are old windows may not be to standard and being the weak part of the building be damaged at levels lower than normally expected.
Complaints from air blast are normally based on the actual effects that are experienced due to rattling of roof, windows, doors etc. These effects could startle people and raise concern of possible damage.

The calculations for air blast are based on the use of basic rules for stemming length and stemming material. It is maintained that if stemming control is not exercised this effect could be greater with greater range of complaints or damage. The project area is located such that "free blasting" – meaning no controls on blast preparation – will not be possible. Controls will be required.

15.11 Fly-rock Unsafe Zone

The occurrence of fly rock in any form will have a negative impact if found to travel outside the unsafe zone or within the safe boundary. The safe boundary may be anything between 10 m or 1000 m. A general safe boundary is normally considered to be a radius of 500 m or greater from the blast; but needs to be qualified and determined as best possible.

Calculations are used to help and assist determining safe distances. A safe distance from blasting is calculated following rules and guidelines from the International Society of Explosives Engineers (ISEE) Blasters Handbook. Using this calculation, the minimum safe distances can be determined that should be cleared of people, animals and equipment. Figure 19 shows the results from the ISEE calculations for fly rock range based on a 140 mm diameter blast hole and 3.5 m stemming length. Based on these values a possible fly rock range with a safety factor of 2 was calculated to be 266 m. The absolute minimum unsafe zone is then the 266 m. This calculation is a guideline and any distance cleared should not be less. The occurrence of fly rock can however never be 100 % excluded. Best practices should be implemented at all times. The occurrence of fly rock can be mitigated but the possibility of the occurrence thereof can never be eliminated. Figure 20 shows the area around the open pit that incorporates the 266 m unsafe zone.

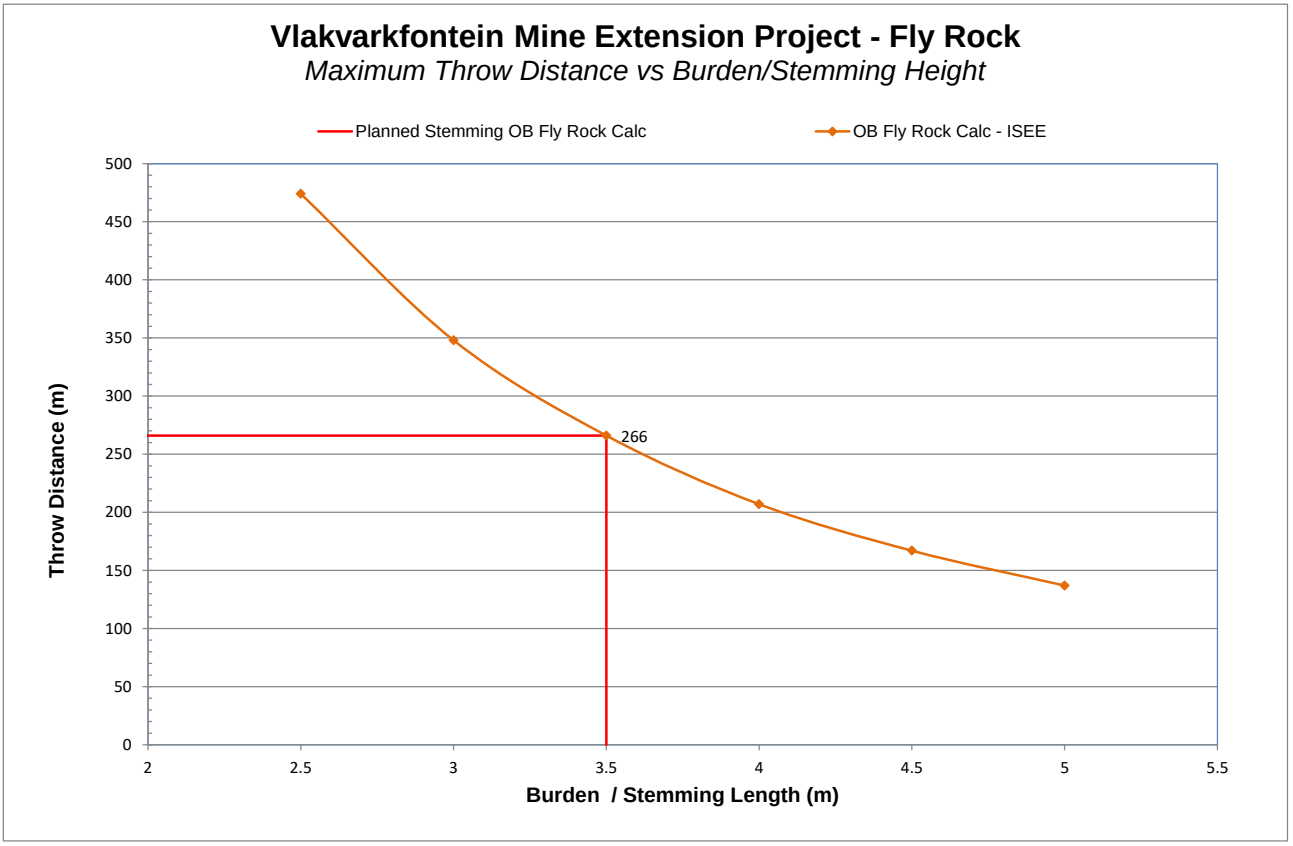

Figure 19: Fly rock prediction calculation

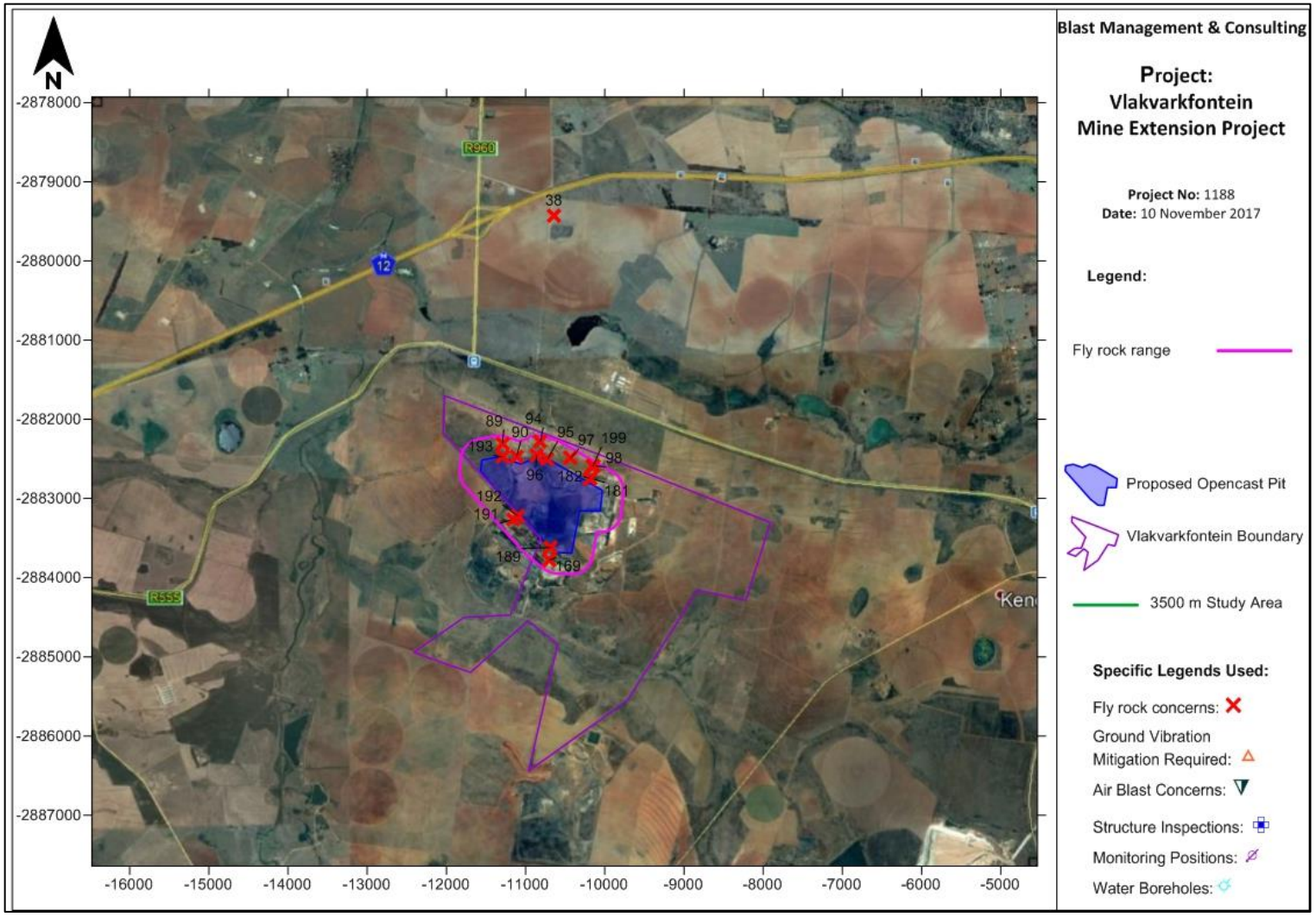

Figure 20: Predicted Fly Rock Exclusion Zone for Pit Area

Review of the calculated unsafe zone showed sixteen POI's (one POI may represent more than one structure) for the Open Pit are within the unsafe zone. This includes mainly the Domestic Boreholes, Power Lines/Pylons, Community Houses and Cemetery (Heritage Site VVF06). Table 14 below shows the POI's of concern and coordinates.

Table 14: Fly rock concern POI's

Tag	Description	Y	X
38	Power lines/Pylons	10635.59	2879429.77
89	Community Houses	11289.70	2882304.77
90	Community Houses	11114.27	2882466.35
94	Community Houses	10812.02	2882275.39
95	Community Houses	10723.37	2882499.86
96	Community Houses	10860.95	2882455.19
97	Community Houses	10428.16	2882490.77
98	Community Houses	10134.85	2882587.55
169	Dam	10703.16	2883777.97
181	Domestic Borehole (VBH-1M)	10183.37	2882743.57
182	Domestic Borehole (VBH-01S)	10185.37	2882743.57
189	Domestic Borehole (VBH-06S)	10681.02	2883619.20
191	Domestic Borehole (VBH-08M)	11154.63	2883265.07
192	Domestic Borehole (VBH-08S)	11095.63	2883220.70
193	Domestic Borehole (VBH-9D)	11291.41	2882475.26
199	Heritage Site (VVF06 - Cemetery 20 graves)	10149.13	2882593.36

15.12 Noxious Fumes

The occurrence of fumes in the form the NOx gas is not a given and very dependent on various factors as discussed in Section 11.6. However, the occurrence of fumes should be closely monitored. Furthermore, nothing can be stated as to fume dispersal to nearby farmsteads, but if anybody is present in the path of the fume cloud, it could be problematic.

15.13 Water Borehole Influence

Boreholes for water were evaluated for possible influence from blasting. Twenty-Four HydroSensus boreholes were provided that could possibly be influenced due to excessive ground vibration at minimum and maximum charge. The expected levels of ground vibration for eleven of these boreholes inside the area evaluated are well within the limit applied for water boreholes. There are six boreholes at POI 181 – 182, 189 and 191 - 193 that are in close proximity of the blasting areas. The calculation indicated that expected ground vibration levels are greater than the limits and could be problematic. These boreholes will have to be relocated. Seven boreholes are found within the open cast area. The ground water specialist will need to make recommendations regarding relocation of the boreholes. Table 15 shows all the identified boreholes. Figure 21 shows the location of the boreholes in the area. At all other identified boreholes, the expected levels of ground vibration were found to be within acceptable limits. The limit for boreholes of 50 mm/s is expected at a distance of 163 m from a blast.

Table 15: Identified Boreholes

Tag	Description	-Y	-X	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)
173	Domestic Borehole-VBH 06 (Tap Water)	10908.69	2881791.37	50	687	4.7
174	Domestic Borehole (Playground)	10848.33	2882168.00	50	307	17.6
175	Domestic Borehole (Arbor Community-2)	11699.22	2881902.84	50	630	5.4
176	Domestic Borehole (EUB-04B)	11699.22	2881902.84	50	630	5.4
177	Domestic Borehole (EUB-09)	14907.94	2881744.36	50	3445	0.3
178	Domestic Borehole (EUB-10)	11514.79	2883365.09	50	425	10.3
179	Domestic Borehole (EUB-17)	9834.45	2883624.07	50	516	7.5
180	Domestic Borehole (EUB-18)	9769.43	2883605.19	50	532	7.1
181	Domestic Borehole (VBH-1M)	10183.37	2882743.57	50	58	276.4
182	Domestic Borehole (VBH-01S)	10185.37	2882743.57	50	57	285.1
183	Domestic Borehole (VBH-02M)	9767.34	2883718.19	50	630	5.4
184	Domestic Borehole (VBH-03M)	11116.97	2884007.32	50	577	6.2
186	Domestic Borehole (VBH-04M)	9707.74	2883132.07	50	345	14.6
189	Domestic Borehole (VBH-06S)	10681.02	2883619.20	50	12	3653.5
191	Domestic Borehole (VBH-08M)	11154.63	2883265.07	50	90	134.3
192	Domestic Borehole (VBH-08S)	11095.63	2883220.70	50	20	1563.5
193	Domestic Borehole (VBH-9D)	11291.41	2882475.26	50	12	3618.0
172	Domestic Borehole (Drinking Water - Office - Inside Pit Area)	10747.45	2883142.86	50	-	-
185	Domestic Borehole (VBH-03S - Inside Pit Area)	11111.04	2882744.32	50	-	-
187	Domestic Borehole (VBH-05M - Inside Pit Area)	10473.48	2882866.77	50	-	-
188	Domestic Borehole (VBH-06M - Inside Pit Area)	10678.01	2883619.19	50	-	-
190	Domestic Borehole (VBH-07MS - Inside Pit Area)	10609.43	2883045.25	50	-	-
194	Domestic Borehole (VBH-10-M - Inside Pit Area)	11299.23	2882687.98	50	-	-
195	Domestic Borehole (VBH-11-M - Inside Pit Area)	10512.01	2883487.22	50	-	-

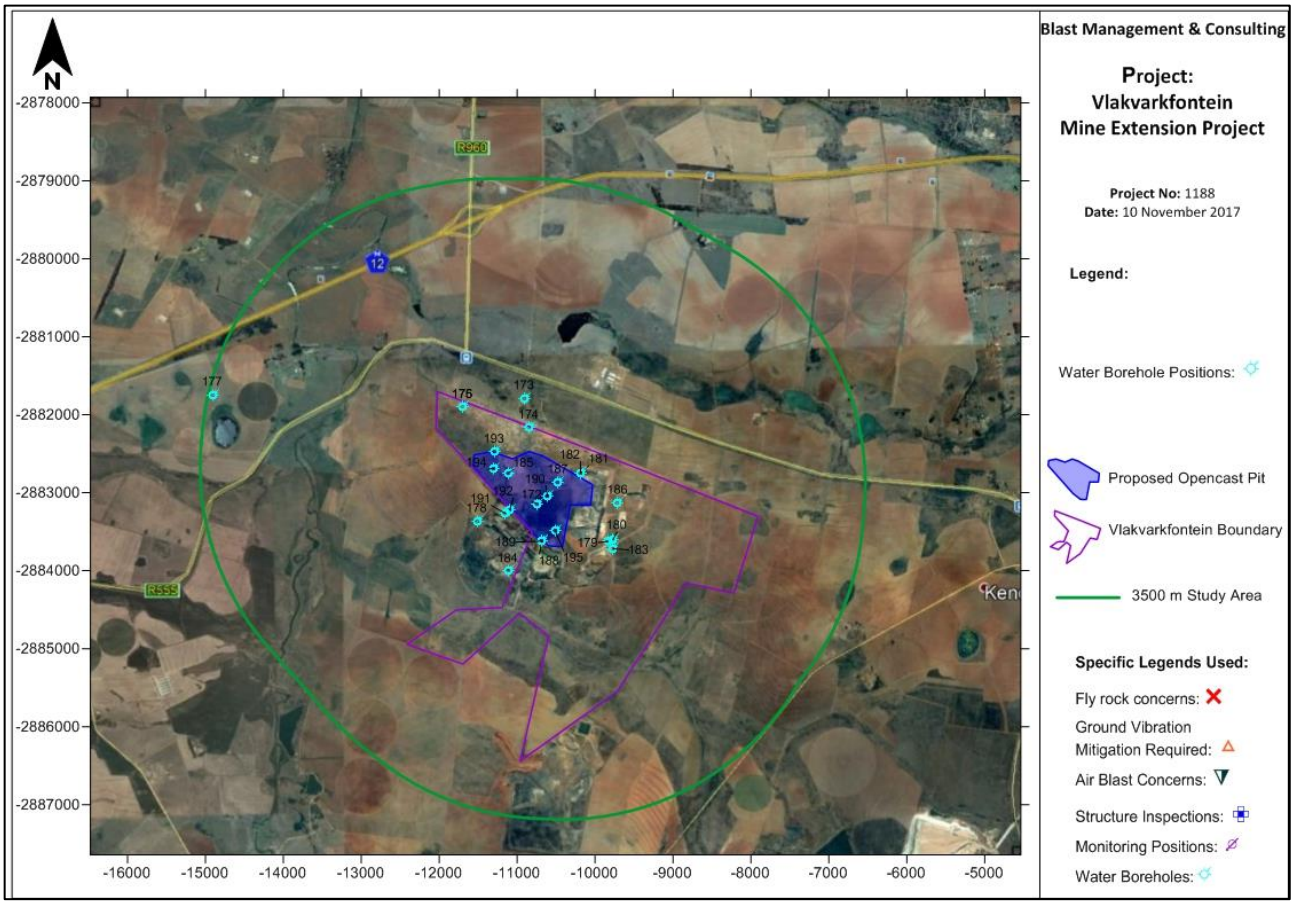

Figure 21: Location of the HydroSensus boreholes

16 Environmental Impact Assessment

The impact rating process is designed to provide a numerical rating of the various environmental impacts identified by use of the Input-Output model. As discussed above, it has to be stressed that the purpose of the EIA process is not to provide an incontrovertible rating of the significance of various aspects, but rather to provide a structured, traceable and defendable methodology of rating the relative significance of impacts in a specific context. This will give the project applicant a greater understanding of the impacts of his project and the issues which need to be addressed by mitigation. It will also give the regulators information on which to base their decisions.

Details of the impact assessment methodology used to determine the significance of physical, bio-physical and socio-economic impacts are provided below.

16.1 Method of Assessing Impacts

The impact assessment methodology is guided by the requirements of the NEMA EIA Regulations (2010). The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the

impact occurring. This determines the environmental risk. In addition other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S).

16.2 Determination of Environmental Risk

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER).

The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$\boldsymbol{C = \frac{E + D + M + R}{4} \times N}$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 16.

Table 16: Criteria for Determining Impact Consequence

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),

Aspect	Score	Definition
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated/scored as per Table 17.

Table 17: Probability Scoring

Probability	1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
	2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
	3	Medium probability (the impact may occur; >50% and <75%),
	4	High probability (it is most likely that the impact will occur- > 75% probability), or
	5	Definite (the impact will occur),

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

$$\boldsymbol{ER = C\ x\ P}$$

Table 18: Determination of Environmental Risk

Consequ						
	5	5	10	15	20	25
	4	4	8	12	16	20

	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
		Probability				

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 19.

Table 19: Significance Classes

Environmental Risk Score	
Value	**Description**
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk),
≥9; <17	Medium (i.e. where the impact could have a significant environmental risk),
≥ 17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

16.3 Impact Prioritisation:

In accordance with the requirements of Regulation 31 (2)(l) of the EIA Regulations (GNR 543), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

In addition it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision making process.

In an effort to ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher

priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

Table 20: Criteria for Determining Prioritisation

Public response (PR)	Low (1)	Issue not raised in public response.
	Medium (2)	Issue has received a meaningful and justifiable public response.
	High (3)	Issue has received an intense meaningful and justifiable public response.
Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable loss of resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 20. The impact priority is therefore determined as follows:

$$\boldsymbol{Priority = PR + CI + LR}$$

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (Refer to Table 21).

Table 21: Determination of Prioritisation Factor

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring. The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

Table 22: Final Environmental Significance Rating

Environmental Significance Rating	
Value	**Description**
< 10	Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
≥10 <20	Medium (i.e. where the impact could influence the decision to develop in the area),
≥ 20	High (i.e. where the impact must have an influence on the decision process to develop in the area).

16.4 Assessment Outcomes:

Impact Name	**Ground vibration Impact on houses**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**

Nature of Impact	-1	-1	Magnitude of Impact	5	3
Extent of Impact	3	3	Reversibility of Impact	4	2
Duration of Impact	4	4	Probability	5	2
Environmental Risk (Pre-mitigation)					-20.00
Mitigation Measures					
Reduce Charge Mass/Delay, Reconsider blast initiation system - electronics, Relocate POI's of concern at least 500 m, proper blast design.					
Environmental Risk (Post-mitigation)					-6.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					3
Issue has received an intense meaningful and justifiable public response					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					3
The impact may result in the irreplacable loss of resources of high value (services and/or functions).					
Prioritisation Factor					2.00
Final Significance					-12.00

Impact Name	**Ground vibration Impact on roads**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	1	1
Extent of Impact	3	3	Reversibility of Impact	1	1
Duration of Impact	4	4	Probability	1	1
Environmental Risk (Pre-mitigation)					-2.25
Mitigation Measures					
None Specific required					
Environmental Risk (Post-mitigation)					-2.25
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikley that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-2.25

Impact Name	Ground vibration Impact on boreholes				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	2
Extent of Impact	3	3	Reversibility of Impact	4	2
Duration of Impact	4	4	Probability	5	2
Environmental Risk (Pre-mitigation)					-20.00
Mitigation Measures					
Reduce Charge Mass/Delay, Reconsider blast initiation system – electronics, re-located boreholes.					
Environmental Risk (Post-mitigation)					-5.50
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					3
The impact may result in the irreplacable loss of resources of high value (services and/or functions).					
Prioritisation Factor					1.50
Final Significance					-8.25

Impact Name	Ground vibration Impact on heritage sites				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	4	1
Extent of Impact	3	3	Reversibility of Impact	5	2
Duration of Impact	4	4	Probability	4	2
Environmental Risk (Pre-mitigation)					-16.00
Mitigation Measures					
Reduce Charge Mass/Delay, Reconsider blast initiation system - electronics, Relocate of graves.					
Environmental Risk (Post-mitigation)					-5.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2

The impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.	
Prioritisation Factor	1.33
Final Significance	-6.67

Impact Name	**Air blast Impact on houses**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	3
Extent of Impact	3	3	Reversibility of Impact	4	2
Duration of Impact	4	4	Probability	5	2
Environmental Risk (Pre-mitigation)					-20.00
Mitigation Measures					
Reduce Charge Mass/Delay, increase stemming length, controls put in place for management of stemming lengths and quality stemming material, Relocate POI's of concern at least 500m, Proper blast design.					
Environmental Risk (Post-mitigation)					-6.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					3
Issue has received an intense meaningful and justifiable public response					
Cumulative Impacts					3
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					3
The impact may result in the irreplacable loss of resources of high value (services and/or functions).					
Prioritisation Factor					2.00
Final Significance					-12.00

Impact Name	**Air blast Impact on roads**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	1	1
Extent of Impact	3	3	Reversibility of Impact	1	1
Duration of Impact	4	4	Probability	1	1
Environmental Risk (Pre-mitigation)					-2.25
Mitigation Measures					
None required					
Environmental Risk (Post-mitigation)					-2.25
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1

Low: Issue not raised in public responses	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cummulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-2.25

Impact Name	**Air blast Impact on boreholes**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	1	1
Extent of Impact	3	3	Reversibility of Impact	1	1
Duration of Impact	4	4	Probability	1	1
Environmental Risk (Pre-mitigation)					-2.25
Mitigation Measures					
None required					
Environmental Risk (Post-mitigation)					-2.25
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-2.25

Impact Name	**Air blast Impact on heritage sites**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	2	2
Extent of Impact	3	3	Reversibility of Impact	1	1
Duration of Impact	4	4	Probability	2	2
Environmental Risk (Pre-mitigation)					-5.00
Mitigation Measures					

None required	
Environmental Risk (Post-mitigation)	-5.00
Degree of confidence in impact prediction:	High
Impact Prioritisation	
Public Response	1
Low: Issue not raised in public responses	
Cumulative Impacts	1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cummulative change.	
Degree of potential irreplaceable loss of resources	1
The impact is unlikely to result in irreplaceable loss of resources.	
Prioritisation Factor	1.00
Final Significance	-5.00

Impact Name	**Fly Rock Impact on houses**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	1	3
Extent of Impact	3	3	Reversibility of Impact	4	2
Duration of Impact	4	4	Probability	4	3
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
Reduce Charge Mass/Delay, Increased stemming length, controls put in place for management of stemming lengths and quality stemming material, Relocate POI's of concern at least 500m, Proper blast design.					
Environmental Risk (Post-mitigation)					-9.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					3
The impact may result in the irreplacable loss of resources of high value (services and/or functions).					
Prioritisation Factor					1.50
Final Significance					-13.50

Impact Name	**Fly Rock Impact on roads**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**

Nature of Impact	-1	-1	Magnitude of Impact	5	1
Extent of Impact	3	3	Reversibility of Impact	1	1
Duration of Impact	4	4	Probability	2	2
Environmental Risk (Pre-mitigation)					-6.50
Mitigation Measures					
None required					
Environmental Risk (Post-mitigation)					-4.50
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					1
The impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-4.50

Impact Name	**Fly Rock Impact on heritage sites**				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	5	2
Extent of Impact	3	3	Reversibility of Impact	4	2
Duration of Impact	4	4	Probability	4	1
Environmental Risk (Pre-mitigation)					-16.00
Mitigation Measures					
Reduce Charge Mass/Delay, Increased stemming length, controls put in place for management of stemming lengths and quality stemming material, Relocate POI's of concern at least 500m, Proper blast design.					
Environmental Risk (Post-mitigation)					-2.75
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.33
Final Significance					-3.67

Impact Name	Impact of Fumes - Houses				
Alternative	**0**				
Phase	**Operation**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature of Impact	-1	-1	Magnitude of Impact	2	3
Extent of Impact	3	3	Reversibility of Impact	4	3
Duration of Impact	4	4	Probability	3	2
Environmental Risk (Pre-mitigation)					-9.75
Mitigation Measures					
Use correct product, Control product quality, prevent sleep time for charged blast holes, same day charge and blast, Proper blast designs.					
Environmental Risk (Post-mitigation)					-6.50
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					2
Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cummulative change.					
Degree of potential irreplaceable loss of resources					2
The impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.					
Prioritisation Factor					1.33
Final Significance					-8.67

16.5 Cumulative Impact:

Review of possible impacts requires considerations of cumulative impacts as well. The cumulative impact from blasting operations is unfortunately not clearly defined. Blasting operations and the different effects from blasting have possible influence on multiple levels i.e. impact on structures, impact on infrastructure, impact on the livelihood of people surrounding the operations, impact on the livelihood of animals etc. In consideration of cumulative impact attention needs to be given to the possible effects from blasting operations i.e. ground vibration, air blast, fly rock and the logistics around the blasting operations.

Ground vibration, air blast and fly rock is effects that could cause damage or not. Over a long-term period, ground vibration could contribute to degrading of infrastructure pending the initial condition of the infrastructure such as houses, offices, buildings etc. Air blast is generally such that it will either cause damage or not. Fly rock is also an effect that either have influence or not.

16.5.1 Defining Cumulative Impact:

The cumulative impact of blasting operations is evaluated on the following basis:

1. Are the safe limits exceeded?

2. How frequent does this occur?
3. Is mitigation possible?
4. Is there only one source?
5. Is there logistical influence?
6. Does the blasting operation contribute to negative perceptions by neighbours?

The following table access the possible cumulative impact for the current project:
Table 23: Cumulative impact descriptions

Aspects:	Review
Are the safe limits exceeded?	The evaluation done in this report does indicate that levels can be exceeded. Mitigation measures were proposed to reduce the impacts. Baseline data indicates no exceedances regarding ground vibration but very limited occurrence high air blast levels. Possibility of fly rock was identified but baseline data had no specific indicators that fly rock did occur.
How frequent does this occur?	Blasting operations for the project occurs at frequency less than once a day – probably twice a week.
Is mitigation possible?	Mitigations are possible to ensure the all relevant effects are within the safe criteria.
Is there only one source?	Review of the project indicates that there is neighbouring operation in the vicinity. This operation was not evaluated as part of this project – it is a different company.
Is there logistical influence?	Indications from the evaluation done in this report is that an evacuation process will be required. This will have a logistical influence on the neighbouring community. The fact that there is a neighbouring mine it may also require such logistical influence.
Does the blasting operation contribute to negative perceptions by neighbours?	It is possible that the blasting operations will create effects that could be considered damaging by the neighbouring community. These effects may not necessarily be damaging but they tend to upset people.

16.5.2 Outcome:

Based on the evaluation a cumulative impact from blasting operations may be present. The neighbouring community will be influenced by more than one mining operation. The effects of blasting such as ground vibration, air blast and fly rock may be mitigated by the current project evaluated but not by the neighbouring mine. The logistical influence on the community is double as blasting operations from two mines will be present. Evacuations for blasting times from both mines

may not be required but effects from both will be experienced. Currently there is no control on the aspects of influence from the neighbouring mine.

In view from the neighbouring community perspective it is certain that a cumulative impact is possible. This impact is considered an impact on the livelihood rather than structural impact.

16.5.3 Cumulative Impact Mitigation:

Mitigation of cumulative impact will require a clear cooperation between the two mines specific. This cooperation needs to include the process of designing of blasts to manage the effects of blasting on the community to maintain levels and influence within the safe blasting criteria, monitoring blasting operations form both mines at similar locations, agreement on blasting times and frequency of blasting, communication with community and achieving an agreement with the community regarding blasting operations.

17 Mitigation Measures

There are two processes considered regarding the mitigation of the possible effects from blasting operations. Firstly, the considerations regarding the Mine Health and Safety Act regulations: MINE HEALTH AND SAFETY ACT 29 OF 1996: REGULATION 17. (7a;8a;9a and 10) and REGULATION 4.16(2). Consideration of the location of the various structures in relation to the mining area it may be worthwhile considering relocation. If this is probable and relocation can be done to outside 500 m it will mitigate most of the current concerns. Relocation will how ever be required for all structures within 100 m from the mining area and must be considered. Apart from relocation reduction of the mining area to facilitate the required distances may also be considered. In both situations it will have a financial impact on the operation.

Secondly a process changed drilling and blasting operations procedure. This mitigation provided here is on high level but give indications of what can be done. In some cases, the changes may not be feasible in the financial spectrum as drilling and blasting costs will be just too great to make some of these changes a viable option. It will require specific investigation into the possible drilling and blasting operations to facilitate a process blasting close to the existing structures.

Several POI's showed concerns with regards to ground vibration levels expected. This is for the Community Houses, Dam, Domestic Boreholes and Heritage Sites (VVF01 & VVF06).

On the basis if ground vibration needs to be mitigated then the following will be applicable. The following mitigations measures proposed are general mitigation measures. Any further detail

mitigations will require active involvement on the project at operational level. The current mitigation measures presented is considered sufficient at this stage of the project.

Though no specific mitigation detail for air blast and fly rock is provided it will require adjustments after considering the ground vibration levels. Mitigation for air blast and fly rock control is very similar and is based on the following. Air blast and fly rock can be controlled using proper charging methodology irrespective of the blast hole diameter and patterns used. The most effective way to mitigate air blast is the design of the stemming length and stemming material. This will require changed blast design to ensure energy levels remain as expected but with increased stemming lengths and the use of proper stemming material. The use of a crushed product with size of 10 % of the blasthole diameter is the recommended material.

Specific ground vibration impacts are expected at the following POI's identified.
Table 24 shows list of POI's that will need to be considered as defined above. Figure 22 shows the location of these POI's in relation to the open pit area.

Table 24: Structures at the Open Pit Area identified as problematic

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz
88	Community Houses	11313.65	2882137.98	12.5	336	15.2	Problematic
89	Community Houses	11289.70	2882304.77	12.5	173	45.5	Problematic
90	Community Houses	11114.27	2882466.35	12.5	75	179.4	Problematic
92	Community Houses	11161.03	2882154.07	12.5	356	13.8	Problematic
94	Community Houses	10812.02	2882275.39	12.5	201	35.5	Problematic
95	Community Houses	10723.37	2882499.86	12.5	16	2437.1	Problematic
96	Community Houses	10860.95	2882455.19	12.5	21	1443.3	Problematic
97	Community Houses	10428.16	2882490.77	12.5	154	54.9	Problematic
98	Community Houses	10134.85	2882587.55	12.5	217	31.2	Problematic
181	Domestic Borehole (VBH-1M)	10183.37	2882743.57	50	58	276.4	Problematic
182	Domestic Borehole (VBH-01S)	10185.37	2882743.57	50	57	285.1	Problematic
189	Domestic Borehole (VBH-06S)	10681.02	2883619.20	50	12	3653.5	Problematic
191	Domestic Borehole (VBH-08M)	11154.63	2883265.07	50	90	134.3	Problematic
192	Domestic Borehole (VBH-08S)	11095.63	2883220.70	50	20	1563.5	Problematic
193	Domestic Borehole (VBH-9D)	11291.41	2882475.26	50	12	3618.0	Problematic

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Predicted PPV (mm/s)	Structure Response @ 10Hz
196	Heritage Site (VVF01 - Dilapidated house structures& reservoir)	9778.61	2883664.04	6	577	6.2	Problematic
199	Heritage Site (VVF06 - Cemetery 20 graves)	10149.13	2882593.36	25	205	34.4	Problematic

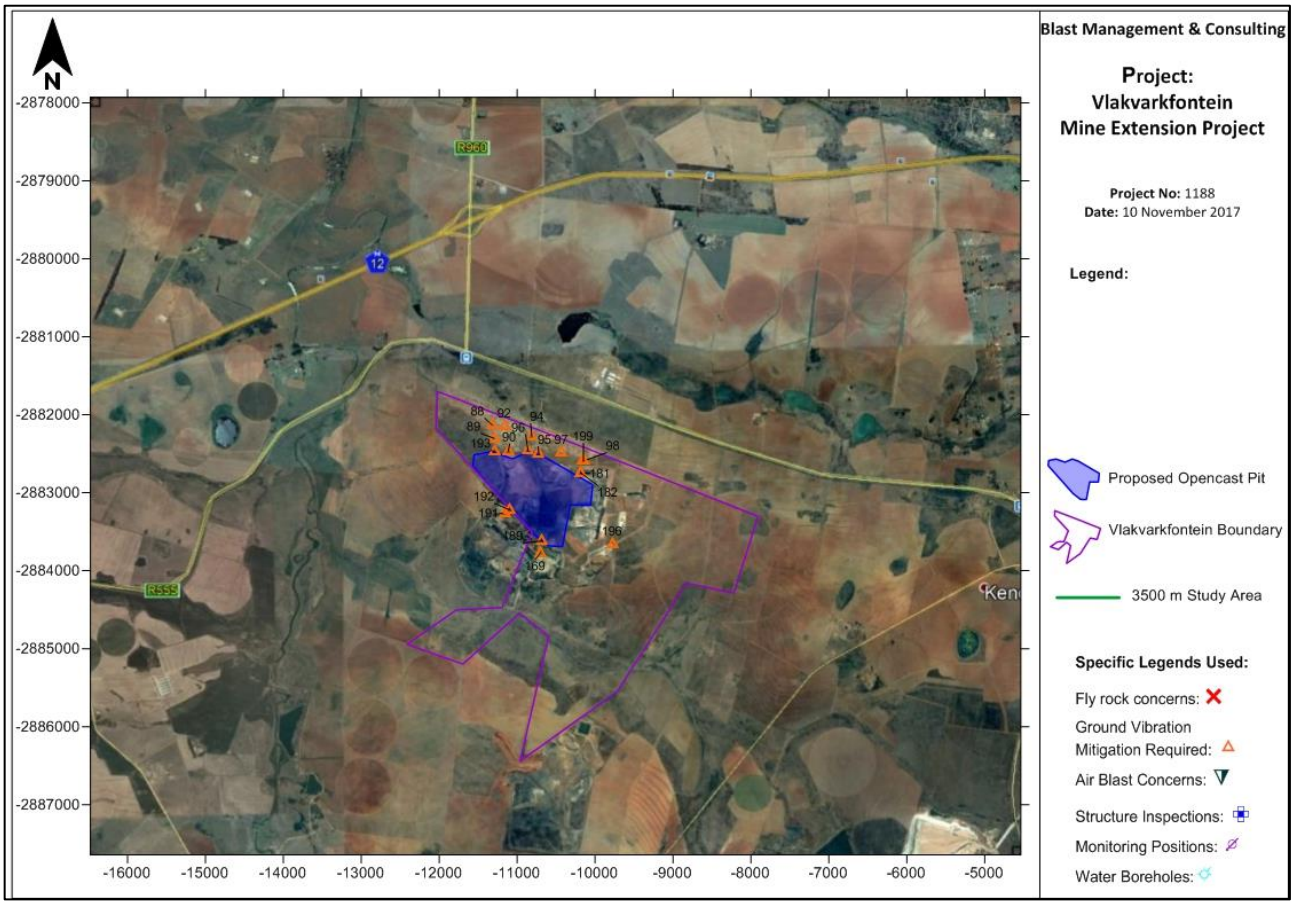

Figure 22: Structures identified where ground vibration mitigation will be required at Pit Area

Mitigation of ground vibration for this can be done applying the following methods:

- Do blast design that considers the actual blasting and the ground vibration levels to be adhered too.
- Change the initiating system to facilitate less blast holes detonating simultaneously making using of electronic initiation that allow for single hole firing.
- Do design for smaller diameter blast holes that will use fewer explosives per blasthole.

Considering the basic mitigation reduction of ground vibration is achieved by reducing the charge mass per delay and distance between source and receptor. These mitigations are guidelines that can

be used when doing a final detail blast design. Table 25 shows mitigation in the form of maximum charge mass allowed and minimum distance require for the maximum charge used in the evaluation. Firstly, the maximum charge mass per delay that will satisfy the required limits for the actual distance between blast area and point of concern is shown. Secondly the minimum distance required to satisfy limits for the maximum charge used in evaluation. These factors are highlighted yellow.

Table 25: Mitigation measures for ground vibration

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
Maximum Charge allowed at current distance								
88	Community Houses	11313.65	2882137.98	12.5	336	475	12.5	Acceptable
89	Community Houses	11289.70	2882304.77	12.5	173	126	12.5	Acceptable
90	Community Houses	11114.27	2882466.35	12.5	75	24	12.5	Acceptable
92	Community Houses	11161.03	2882154.07	12.5	356	532	12.5	Acceptable
94	Community Houses	10812.02	2882275.39	12.5	201	170	12.5	Acceptable
95	Community Houses	10723.37	2882499.86	12.5	16	1	12.5	Acceptable
96	Community Houses	10860.95	2882455.19	12.5	21	2	12.5	Acceptable
97	Community Houses	10428.16	2882490.77	12.5	154	100	12.5	Acceptable
98	Community Houses	10134.85	2882587.55	12.5	217	198	12.5	Acceptable
181	Domestic Borehole (VBH-1M)	10183.37	2882743.57	50	58	76	50.0	Acceptable
182	Domestic Borehole (VBH-01S)	10185.37	2882743.57	50	57	73	50.0	Acceptable
189	Domestic Borehole (VBH-06S)	10681.02	2883619.20	50	12	3	50.0	Acceptable
191	Domestic Borehole (VBH-08M)	11154.63	2883265.07	50	90	182	50.0	Acceptable
192	Domestic Borehole (VBH-08S)	11095.63	2883220.70	50	20	9	50.0	Acceptable
193	Domestic Borehole (VBH-9D)	11291.41	2882475.26	50	12	3	50.0	Acceptable
196	Heritage Site (VVF01 - Dilapidated house structures& reservoir)	9778.61	2883664.04	6	577	575	6.0	Acceptable
199	Heritage Site (VVF06 - Cemetery 20 graves)	10149.13	2882593.36	25	205	409	25.0	Acceptable
Minimum distance required for maximum charge								
Tag	**Description**	**Y**	**X**	**Specific Limit (mm/s)**	**Distance (m)**	**Total Mass/Delay (kg)**	**Predicted PPV (mm/s)**	**Structure Response @ 10Hz**
88	Community Houses	11313.65	2882137.98	12.5	379	602	12.5	Acceptable
89	Community Houses	11289.70	2882304.77	12.5	379	602	12.5	Acceptable
90	Community Houses	11114.27	2882466.35	12.5	379	602	12.5	Acceptable
92	Community Houses	11161.03	2882154.07	12.5	379	602	12.5	Acceptable

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
94	Community Houses	10812.02	2882275.39	12.5	379	602	12.5	Acceptable
95	Community Houses	10723.37	2882499.86	12.5	379	602	12.5	Acceptable
96	Community Houses	10860.95	2882455.19	12.5	379	602	12.5	Acceptable
97	Community Houses	10428.16	2882490.77	12.5	379	602	12.5	Acceptable
98	Community Houses	10134.85	2882587.55	12.5	379	602	12.5	Acceptable
181	Domestic Borehole (VBH-1M)	10183.37	2882743.57	50	163	602	50.0	Acceptable
182	Domestic Borehole (VBH-01S)	10185.37	2882743.57	50	163	602	50.0	Acceptable
189	Domestic Borehole (VBH-06S)	10681.02	2883619.20	50	163	602	50.0	Acceptable
191	Domestic Borehole (VBH-08M)	11154.63	2883265.07	50	163	602	50.0	Acceptable
192	Domestic Borehole (VBH-08S)	11095.63	2883220.70	50	163	602	50.0	Acceptable
193	Domestic Borehole (VBH-9D)	11291.41	2882475.26	50	163	602	50.0	Acceptable
196	Heritage Site (VVF01 - Dilapidated house structures& reservoir)	9778.61	2883664.04	6	591	602	6.0	Acceptable
199	Heritage Site (VVF06 - Cemetery 20 graves)	10149.13	2882593.36	25	249	602	25.0	Acceptable

The mitigation measures calculations clearly indicate that there are eight POI's of concern where the changes on charge mass per delay will not be a feasible financial and proper operational option. These POI's may represent a multiple number of structures and installations.
Consideration will have to be given to relocation or reducing of mining areas to facilitate distance between blasting and structures.

18 Closure Phase: Impact Assessment and Mitigation Measures

During the closure phase no mining, drilling and blasting operations are expected. It is uncertain if any blasting will be done for demolition. If any demolition blasting will be required it will be reviewed as civil blasting and addressed accordingly.

19 Alternatives (Comparison and Recommendation)

No specific alternative mining methods are currently under discussion or considered for drilling and blasting.

20 Public Response to operations

The current public response to the operation is negative. Complaints have been made about cracking of structures due to blasting operations. BM&C is in no position to confirm nor deny any

of the claims. A detail plan of action will be required by the mine to address any possible influences with the extension of operations. The extension will be significantly closer to Arbor village areas and without careful planning it is certain claims will grow. Blasting operations near public installations is not impossible but do require careful planning and detail communication to the community in the processes and methodology when conducting blasting operations. It will require detail discussions with the community and the community's acceptance of plans for future mining of the extension.

21 Recommendations

21.1 Regulatory requirements

Two specific regulatory requirements need to be considered for the project:

Firstly: MINE HEALTH AND SAFETY ACT 29 OF 1996: REGULATION 17. (7a;8a;9a and 10).

17(7) The employer must take reasonable measures to ensure that:

a) no mining operations are carried out within a horizontal distance of 100 (one hundred) metres from reserve land, buildings, roads, railways, dams, waste dumps, or any other structure whatsoever including such structures beyond the mining boundaries, or any surface, which it may be necessary to protect in order to prevent any significant risk, unless a lesser distance has been determined safe by risk assessment and all restrictions and conditions determined in terms of the risk assessment are complied with;

17(8) No person may erect, establish or construct any buildings, roads, railways, dams, waste dumps, reserve land, excavations or any other structures whatsoever within a horizontal distance of 100 (one hundred) metres from workings, unless a lesser distance has been determined safe:

a) in the case of the employer, by risk assessment and all restrictions and conditions determined in terms of the risk assessment are complied with; or

17(9) The person(s) responsible for activities in terms of regulations 17(7)(a) and 17(8) must:

a) in the case of an employer, provide the Chief Inspector of Mines with the distance and accompanying restrictions and conditions for comment, and;

17(10) No mining operations, erecting, establishment, or construction, as contemplated in regulations 17(7)(a) and 17(8) respectively, may take place until such written comment or approval, as referred to in 17(9)(a) and 17(9)(b), has been obtained.

Secondly: MINE HEALTH AND SAFETY ACT 29 OF 1996: REGULATION 4.16(2)

4.16(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.

The mine will have to apply for the necessary authorisations as prescribed in the various acts. Table 26 shows list of the installations as well as the POI's that falls within 500 m from the pit area. Figure 23 below shows the 500 m boundary around the pit area. The location of non-mining installations is clearly observed. Should these installations be relocated this requirement will not be applicable.

Table 26: List of possible installations within the regulatory 500 m

Tag	Description	Y	X
74	Power lines/Pylons	9723.77	2882544.03
75	Power lines/Pylons	9916.40	2882465.77
76	Power lines/Pylons	10107.56	2882386.66
77	Power lines/Pylons	10296.68	2882313.02
78	Power lines/Pylons	10488.91	2882234.07
79	Power lines/Pylons	10674.90	2882147.47
80	Power lines/Pylons	10875.35	2882075.16
88	Community Houses	11313.65	2882137.98
89	Community Houses	11289.70	2882304.77
90	Community Houses	11114.27	2882466.35
91	School	11012.65	2882251.31
92	Community Houses	11161.03	2882154.07
93	Community Houses	11058.04	2882033.48
94	Community Houses	10812.02	2882275.39
95	Community Houses	10723.37	2882499.86
96	Community Houses	10860.95	2882455.19
97	Community Houses	10428.16	2882490.77
98	Community Houses	10134.85	2882587.55
169	Dam	10703.16	2883777.97
170	Dam (Inside Pit Area)	10668.57	2883513.66
171	Mine Buildings/Structures (Inside Pit Area)	10751.76	2883181.94
172	Domestic Borehole (Drinking Water - Office - Inside Pit Area)	10747.45	2883142.86
174	Domestic Borehole (Playground)	10848.33	2882168.00
178	Domestic Borehole (EUB-10)	11514.79	2883365.09
181	Domestic Borehole (VBH-1M)	10183.37	2882743.57
182	Domestic Borehole (VBH-01S)	10185.37	2882743.57
185	Domestic Borehole (VBH-03S - Inside Pit Area)	11111.04	2882744.32
186	Domestic Borehole (VBH-04M)	9707.74	2883132.07
187	Domestic Borehole (VBH-05M - Inside Pit Area)	10473.48	2882866.77

Tag	Description	Y	X
188	Domestic Borehole (VBH-06M - Inside Pit Area)	10678.01	2883619.19
189	Domestic Borehole (VBH-06S)	10681.02	2883619.20
190	Domestic Borehole (VBH-07MS - Inside Pit Area)	10609.43	2883045.25
191	Domestic Borehole (VBH-08M)	11154.63	2883265.07
192	Domestic Borehole (VBH-08S)	11095.63	2883220.70
193	Domestic Borehole (VBH-9D)	11291.41	2882475.26
194	Domestic Borehole (VBH-10-M - Inside Pit Area)	11299.23	2882687.98
195	Domestic Borehole (VBH-11-M - Inside Pit Area)	10512.01	2883487.22
199	Heritage Site (VVF06 - Cemetery 20 graves)	10149.13	2882593.36

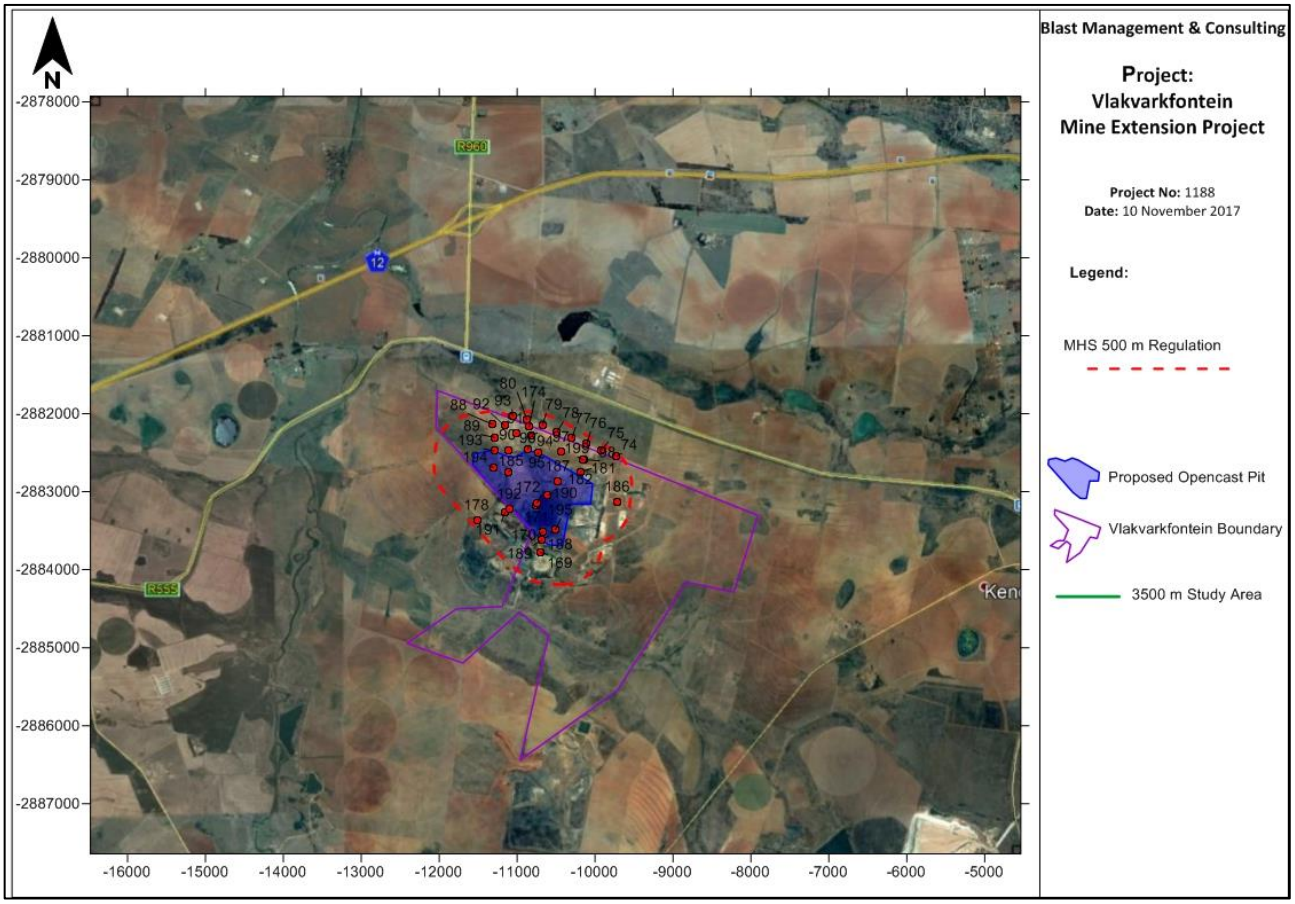

Figure 23: Regulatory 500 m range for Pit Area

21.2 Exclusion Zone for mining

Review of possible impacts and regulatory requirements an exclusion zone of 100 m is identified. This zone of 100m is identified from expected village boundary. Please note that this is not surveyed or statutory defined lines. Current information available (Google Earth imagery) was used for definition of the boundaries.

The following figure shows the village area with boundary defined and 100 m from village area that could be considered to be excluded from the operation.
It is recommended that the exact boundaries be defined as per mapping according to the state surveyor and 100 m exactly defined that should be considered for exclusion.

Figure 24: 100 m exclusion zone

21.3 Blast Designs

Blast designs can be reviewed prior to first blast planned and done. Specific attention can be given to the possible use of electronic initiation rather than conventional timing systems. This will allow for single blasthole firing instead of multiple blast holes resulting in less charge mass per delay. Consideration must also be given structures surrounding the blast intended. This may require changed drilling diameters, blasting patterns, charging configurations (single charge, decking etc.) or initiation system. A detail design cannot be done at this stage by the author as much more information is required than currently available.

21.4 Safe Blasting Distance and Evacuation

The calculated minimum safe distance is 266 m. This is the estimated area that must be cleared at least around a blast before firing. General evacuation used in the mining industry is at least 500 m from any blast. The final blast designs that may be used will determine the final decision on safe distance to evacuate people and animals. This distance may be greater pending the final code of

practice of the mine and responsible blaster's decision on safe distance. The blaster has a legal obligation concerning the safe distance and he needs to determine this distance.

21.5 Road Closure

The R555, R960 and the N12 roads are in the vicinity of the project area and needs to be considered. The provincial roads are at closest point of 984 m for the R555 and 1333 m for the R960 in the vicinity of the project area. The N12 national road is at 2936 m from the project area. No specific actions are required for these roads. There are gravel roads in the vicinity of the project area that link the different communities. These routes are specifically of concern when blasting is done. There may be people and animals on these routes and will require careful planning to main safe blasting radius.

21.6 Test Blasting

It is always good to conduct a first test blast to confirm levels and ground vibration and air blast. It is recommended that such a blast be done and detail monitoring done and used to help define blasting operations going forward. This test blast can be based on the existing design and data used to determine a way forward.

21.7 Stemming length

The current proposed stemming lengths at least must be maintained to ensure some form of fly rock control. Specific designs where distance between point of concern and blast is known should be considered with this. It may be required to increase stemming lengths for additional control.

21.8 Power lines

There are power lines that are 346 m from the pit area. No specific other recommendations are required.

21.9 Photographic Inspections

Pending decisions regarding relocation or reduction of operations it is recommended that photographic survey of all structures up to 1500 m from the pit areas is done. The mine will be operating for a significant number of years. This will give advantage on any negotiations with regards to complaints from neighbours. This process can however only succeed if done in conjunction with a proper monitoring program. At 1500 m at vibration level of 1.3 mm/s is expected for the maximum charge used. This level of ground vibration is already perceptible and people in structures could experience ground vibration negatively. Figure 25 shows the current structures within the 1500 m area for the pit area to be considered – this list basically includes the whole Arbor village. Table 27

shows list of structures identified for inspection. The list indicates a point used. This point may refer to a multiple number of structures in the area of the specific point.

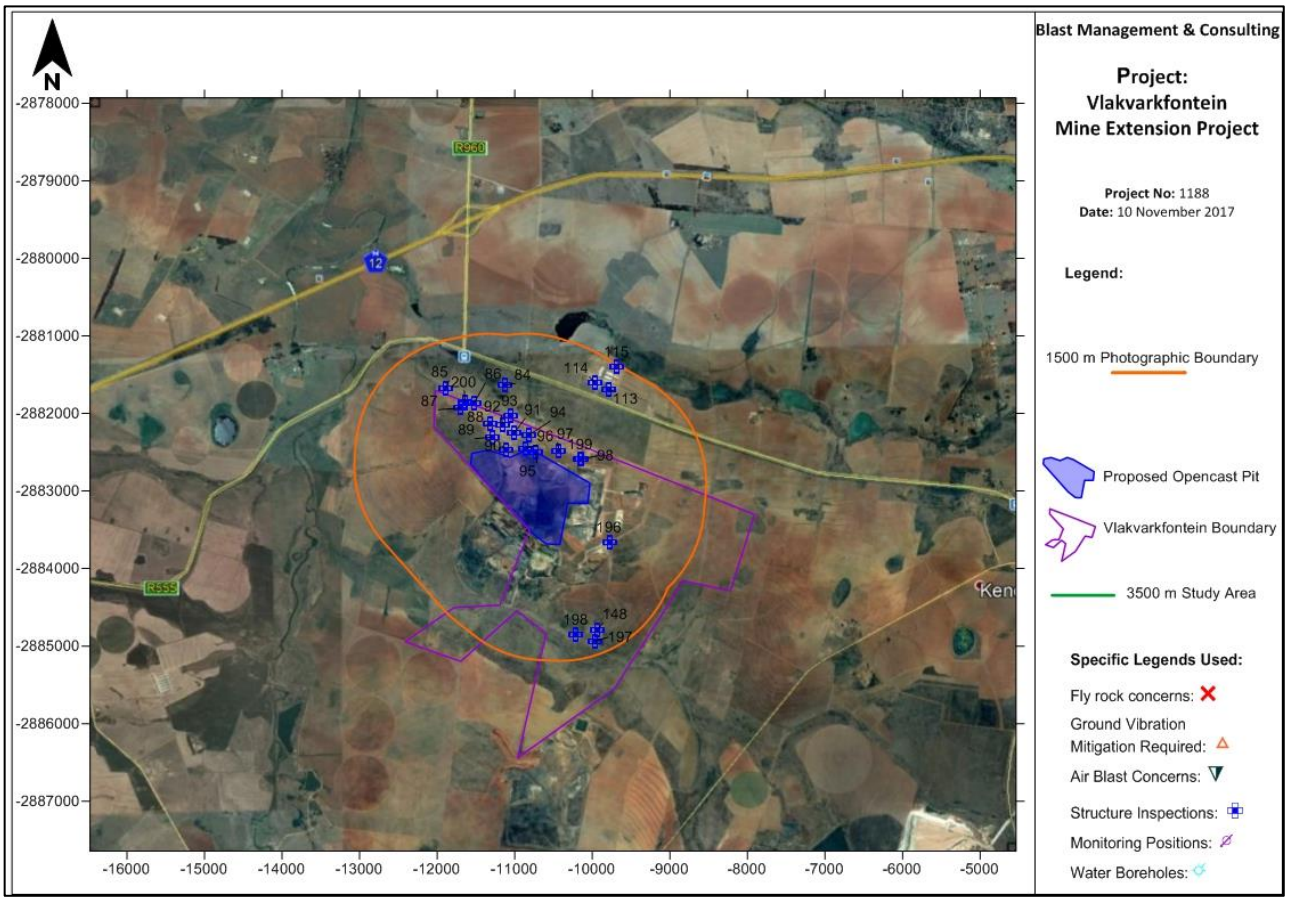

Figure 25: Structures within 1500 m area around pit area identified for structure inspections.

Table 27: List of structures identified for inspections

Tag	Description	Y	X
84	Buildings/Structures	11125.95	2881634.79
85	Heritage Site (VVF08 - Historic Store)	11895.69	2881683.90
86	Community Houses	11523.34	2881862.81
87	Community Houses	11693.81	2881930.62
88	Community Houses	11313.65	2882137.98
89	Community Houses	11289.70	2882304.77
90	Community Houses	11114.27	2882466.35
91	School	11012.65	2882251.31
92	Community Houses	11161.03	2882154.07
93	Community Houses	11058.04	2882033.48
94	Community Houses	10812.02	2882275.39
95	Community Houses	10723.37	2882499.86

96	Community Houses	10860.95	2882455.19
97	Community Houses	10428.16	2882490.77
98	Community Houses	10134.85	2882587.55
113	Farm Buildings/Structures	9790.81	2881696.26
114	Buildings/Structures	9969.32	2881609.83
115	Informal Housing	9683.52	2881400.20
148	Heritage Site (VVF02 - Farmstead)	9939.84	2884799.04
196	Heritage Site (VVF01 - Dilapidated house structures& reservoir)	9778.61	2883664.04
197	Heritage Site (VVF03 - Stone& mortar kraal)	9966.65	2884935.18
198	Heritage Site (VVF04 - Stone enclosure)	10208.52	2884855.35
199	Heritage Site (VVF06 - Cemetery 20 graves)	10149.13	2882593.36
200	Heritage Site (VVF07 - Cemetery 150 graves)	11642.55	2881856.01

21.10 Recommended Ground Vibration and Air Blast Levels

The ground vibration and air blast levels limits recommended for blasting operations in this area are provided in Table 28.

Table 28: Recommended ground vibration air blast limits

Structure Description	Ground Vibration Limit (mm/s)	Air Blast Limit (dBL)
National Roads/Tar Roads:	150	N/A
Electrical Lines:	75	N/A
Railway:	150	N/A
Transformers	25	N/A
Water Wells	50	N/A
Telecoms Tower	50	134
General Houses of proper construction	USBM Criteria or 25 mm/s	Shall not exceed 134dB at point of concern but 120 dB preferred
Houses of lesser proper construction	12.5	
Rural building – Mud houses	6	

21.11 Blasting Times

A further consideration of blasting times is when weather conditions could influence the effects yielded by blasting operations. It is recommended not to blast too early in the morning when it is still cool or when there is a possibility of an atmospheric inversion or too late in the afternoon in winter. Do not blast in fog or in the dark. Refrain from blasting when wind is blowing strongly in the direction of an outside receptor. Do not blast with low overcast clouds. These ‘do nots’ stem from the influence that weather has on air blast. The energy of air blast cannot be increased but it is distributed differently and therefore is difficult to mitigate.

It is recommended that a standard blasting time be adhered to and blasting notice boards setup at various routes around the project area that will inform the community of blasting dates and times.

21.12 Monitoring

The current monitoring program must be extended. At least one more monitoring point is required on the western side of the village. Thus, three monitors in the village and with the current one at Mr Truter to remain.

21.13 Third Party Monitoring

Third party consultation and monitoring should be considered for all ground vibration and air blast monitoring work. This will bring about unbiased evaluation of levels and influence from an independent group. Monitoring could be done using permanent installed stations. Audit functions may also be conducted to assist the mine in maintaining a high level of performance with regards to blast results and the effects related to blasting operations.

21.14 Video monitoring of each blast

Video of each blast will help to define if fly rock occurred and from where. Immediate mitigation measure can then be applied if necessary. The video will also be a record of blast conditions.

21.15 Relocation

There are various public houses and installations in close proximity of the pit area. The greatest concerns originate from domestic boreholes, community houses and a cemetery that are located up to 205 m from the pit area. Recommended that a clear plan of action is considered regarding the location of Arbor village in relation to the mine.

22 Knowledge Gaps

The data provided by the project applicant and information gathered was sufficient to conduct this study. Surface surroundings change continuously and this should be taken into account prior to initial blasting operations considered. This report may need to be reviewed and updated if necessary. This report is based on data provided and internationally accepted methods and methodology used for calculations and predictions.

23 Conclusion

Blast Management & Consulting (BM&C) was contracted as part of the Environmental Impact Assessment (EIA) to perform review of possible impacts with regards to blasting operations on the proposed Vlakvarkfontein Mine Extension Project located in the Mpumalanga Province of South Africa. Ground vibration, air blast, fly rock and fumes are some of the aspects resulting from blasting operations. The report concentrates on the possible influences of ground vibration, air blast and fly rock. It intends to provide information, calculations, predictions, possible influences and mitigation of blasting operations for the project.

Appendix I - Blasting and Vibration

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as a 3500 m radius from where blasting will take place. The range of structures observed and considered in this evaluation ranged between industrial structures, community houses, power lines, railway lines and heritage sites.

The project area does have people and houses at very close distance to the project area. The nearest house or buildings is found 16 m away. Specific attention will be required for adjustments in the blasting operations to ensure expected levels of ground vibration and air blast are within the required limits. There are also regulations that will need to be followed for permission to conduct blasting operations as these installations area within 500 m from the blast operations. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage. There is a possibility that ground vibration may be intolerable at the closest community houses and the school. Considerations will have to be given to alternative placement or installation of the community houses specifically. The ground vibration levels predicted for all installations evaluated surrounding the pit area ranged between 0.3 mm/s and 3653.5 mm/s. Ground vibration levels at the nearest buildings where people may be present is very high.

Air blast predicted for the maximum charge ranges between 107.4 and 144.4 dB for all the POI's considered. Air blast observed and predicted showed the same concern than ground vibration. In view of the predicted levels the probability of damages exists if blasting operations does not take careful planning of stemming length and material into consideration. Damages are only expected to occur at levels greater than 134dB. On prediction it is expected that air blast will be greater than 134 dB at a distance of 75 m and closer to the pit boundary. Various private installations are within 500 m from the pit boundary. Air blast that could lead to complaints is expected to reach distances of 486 m from the pit area. The levels at other private houses or settlements are expected to be within limits and not damaging.

An exclusion zone for safe blasting was also calculated. The exclusion zone was established to be at least 266 m. Normal practice observed in mines is a 500 m exclusion zone. The minimum distance recommended is 266 m. This distance may be greater but not less.

Recommendations were made that should be considered, specifically for review of blast designs, monitoring of ground vibration and air blast, safe blasting zones, safe ground vibration and air blast limits, blast designs, blasting times and relocations of infrastructure to be considered.

There is no reason to believe that this operation cannot continue if the recommendations made are adhered to.

This concludes this investigation for the Vlakvarkfontein Mine Extension Project. There is no reason to believe that this operation cannot continue if attention is given to the recommendations made.

24 Curriculum Vitae of Author

J D Zeeman was a member of the Permanent Force - SA Ammunition Core for period January 1983 to January 1990. During this period, work involved testing at SANDF Ammunition Depots and Proofing ranges. Work entailed munitions maintenance, proofing and lot acceptance of ammunition. From July 1992 to December 1995, Mr Zeeman worked at AECI Explosives Ltd. Initial work involved testing science on small scale laboratory work and large-scale field work. Later, work entailed managing various testing facilities and testing projects. Due to restructuring of the Technical Department, Mr Zeeman was retrenched but fortunately was able to take up an appointment with AECI Explosives Ltd.'s Pumpable Emulsion Explosives Group for underground applications.
From December 1995 to June 1997 Mr Zeeman provided technical support to the Underground Bulk Systems Technology business unit and performed project management on new products.
Mr Zeeman started Blast Management & Consulting in June 1997. The main areas of focus are Pre-blast monitoring, Insitu monitoring, Post-blast monitoring and specialized projects.

Mr Zeeman holds the following qualifications:

1985 - 1987	Diploma: Explosives Technology, Technikon Pretoria
1990 - 1992	BA Degree, University of Pretoria
1994	National Higher Diploma: Explosives Technology, Technikon Pretoria
1997	Project Management Certificate: Damelin College
2000	Advanced Certificate in Blasting, Technikon SA

Member: International Society of Explosives Engineers

Blast Management & Consulting has been active in the mining industry since 1997, with work being done at various levels for all the major mining companies in South Africa. Some of the projects in which BM&C has been involved include:
Iso-Seismic Surveys for Kriel Colliery in conjunction with Bauer & Crosby Pty Ltd.; Iso-Seismic surveys for Impala Platinum Limited; Iso-Seismic surveys for Kromdraai Opencast Mine; Photographic Surveys for Kriel Colliery; Photographic Surveys for Goedehoop Colliery; Photographic Surveys for Aquarius Kroondal Platinum – Klipfontein Village; Photographic Surveys for Aquarius – Everest South Project; Photographic Surveys for Kromdraai Opencast Mine; Photographic inspections for various other companies, including Landau Colliery, Platinum Joint Venture – three mini-pit areas; Continuous ground vibration and air blast monitoring for various coal mines; Full auditing and control with consultation on blast preparation, blasting and resultant effects for clients, e.g. Anglo Platinum Ltd, Kroondal Platinum Mine, Lonmin Platinum, Blast Monitoring Platinum Joint Venture – New Rustenburg N4 road; Monitoring of ground vibration induced on surface in underground mining environment; Monitoring and management of blasting in close relation to water pipelines in opencast mining environment; Specialized testing of explosives characteristics; Supply and service of seismographs and VOD measurement equipment and accessories; Assistance in protection of

ancient mining works for Rhino Minerals (Pty) Ltd.; Planning, design, auditing and monitoring of blasting in new quarry on new road project, Sterkspruit, with Africon, B&E International and Group 5 Roads; Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Pandora Joint Venture 180 houses – whole village; Structure Inspections and Reporting for Lonmin Platinum Mine Limpopo Section - 1000 houses / structures.

BM&C have installed a world class calibration facility for seismographs, which is accredited by Instantel, Ontario Canada as an accredited Instantel facility. The projects listed above are only part of the capability and professional work that is done by BM&C.

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17. Richards A.B., Aust F.I.E., Moore A.J., Blast Vibration Course Measurement - Assessment – Control, Terrock Consulting Engineers, A.B.N. 99 005 784 841 P O Box 829 Eltham Vic 3095 Phone: (03) 9431 0033 Fax: (03) 9431 1810 Email: Terrock@Terrock.Com