Appendix 11: Blasting Impact Assessment

11.1 Independent Specialist Report

Blast Management and Consulting

Quality Service on Time

Report: Blast Impact Assessment Prepared For: Mthatha Quarry		
Report Date:	18 October 2025	
BMC Ref No:	Umhlaba_MthathaQuarry_BIAReport_251018_V01	
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ii. Independence Declaration

A declaration that the specialist is independent in a form as may be specified by the competent authority.

I, JD Zeeman, declare that -

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the relevant legislation and any guidelines that have relevance to the proposed activity;
- I will comply with the applicable legislation;
- I have not, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing - any decision to be taken with respect to the application by the competent authority; and - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct.

Signature of the Specialist

iii. Document Control:

Name & Company	Responsibility	Action	Date	Signature
H Eksteen Blast Management and Consulting	Document Preparation	Report Prepared	2025/10/18	
JD Zeeman Blast Management and Consulting	Consultant	Report Authorised	2025/10/20	

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List of Acronyms used in this Report.

a and b	Site Constant
APP	Air Pressure Pulse
B	Burden (m)
BH	Blast Hole
BMC	Blast Management and Consulting
D	Distance (m)
E	Explosive Mass (kg)
Freq.	Frequency
GRP	Gas Release Pulse
I&AP	Interested and Affected Parties
k	Factor value
M	Charge Height
m (SH)	Stemming height
Mc	Charge mass per metre column
POI	Points of Interest
PPV	Peak Particle Velocity
RPP	Rock Pressure Pulse
USBM	United States Bureau of Mine
WGS 84	Coordinates (South African)

List of Units used in this Report.

%	percentage
cm	centimetre
dB(L)	linear decibel
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
mm/s	millimetres per second
ms	milliseconds
Pa	Pascal
ppm	parts per million

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1. Executive Summary

Blast Management and Consulting (BMC) was appointed to conduct a blast impact assessment for the Mthatha Quarry on behalf of Umhlaba Environmental Consultants. The assessment evaluated the effects of ground vibration, air blast, and fly rock associated with current blasting operations, with specific focus on potential impacts to the nearby Ngolo community and surrounding infrastructure.

The review identified that the proximity of the community to the active pit area increases the potential for perceptible blast-related effects. Analysis of monitoring data indicated that several ground vibration and air blast events were greater than the recommended thresholds, particularly in relation to structures of varying construction quality, such as mud houses. While the risk of structural damage remains low, the likelihood of community disturbance and complaints is significant if exceedances persist.

Predicted outcomes correspond closely with the actual measurements, confirming that current blasting practices can influence the surrounding area. Effective blast design management—such as optimising charge mass per delay, controlling the number of holes fired per interval, and adjusting stemming lengths or deck charging—will be essential to reduce impacts and ensure compliance with vibration and air blast limits.

Although the results remain within general damage criteria, improved control measures and continuous monitoring are recommended to minimise potential effects on the Ngolo community and maintain adherence to regulatory and operational standards.

Furthermore, to assess the viability of the new pit extension, a series of blast designs were developed to determine the parameters required to remain within the applicable vibration, air blast, and fly rock limits. These designs were based on the current site practices but adjusted where necessary to suit the limiting factors of the new pit layout, particularly the 100 m boundary from the neighbouring community. A zone-based approach, defined by distance from the community, was implemented to provide clear guidance on permissible charge masses and associated parameters. This method provides a practical framework for ensuring compliance while allowing the new pit extension to be mined efficiently.

This concludes the investigation into the environmental impacts induced from the blasting operations at Mthatha Quarry.

2. Introduction

Mthatha Quarry is located on a certain portion of the Farm Zitatele No 39, in the Magisterial Division of Libode of the Eastern Cape Province, neighbouring the Ngolo community, at longitude 31° 33' 36" S and latitude 28° 50' 22" E, some five (5) kilometres north-east of the CBD of Mthatha. The quarry produces aggregate stone and sand for road pavement layering and general aggregates destined for the building and construction industry.

This report is a short report reviewing possible impacts from the current blasting operations on the Ngolo community.

Figure 1 shows the geographical locality plan of the Mthatha Quarry's current pit.

Figure 1: Locality Plan

3. Objectives

The objectives are to evaluate the associated environmental impacts from the current blasting operations. The receiving environment considered includes the Ngolo community, mine-owned infrastructure, and other public infrastructures. The impacts from ground vibration, air blast, and fly rock are considered in this assessment.

4. Assumptions and Limitations

The following assumptions have been made:

- The Mthatha Quarry pit layout data received only included the current pit layout and not the new layout proposed; therefore, all evaluations and assessments were done on the current pit layout.
- The designs provided by a third party to Mthatha Quarry were reviewed; however, only one (1) design done on 2025/05/08 was considered due to completeness.
- The seismograph reports are used in good faith that the monitoring was done correctly and all information provided on the seismograph event reports is true and accurate.
- Distances used for the monitoring are those indicated on the seismograph event reports.
- The anticipated levels of influence estimated in this report, other than the actual readings measured, are calculated using standard accepted methodology according to international and local regulations.
- The work done is based on the author's knowledge and information provided by the project applicant.
- This report concentrates on the current impact induced by the blasting operations at Mthatha Quarry on the neighbouring Ngolo community.

5. Influence from Blasting Operations

Blasting operations are required to break rock for excavation to access the targeted rock material. Explosives in the blast holes provide the essential energy needed to conduct the work required for the preferred outcome. Ground vibration, air blast, and fly rock are a result of the blasting process. Based on the regulations of the different acts consulted and internationally accepted standards, these effects are required to be within certain limits. The following sections provide guidelines on these limits.

5.1. 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 traditionally 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 higher frequency, and lower oscillation is synonymous with 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 damage.

The following limitations were used by BMC, that is inclusive of the Mine Health and Safety Act No. 29 of 1996, Guideline For A Mandatory Code Of Practice For Minimum Standards On Ground Vibrations, Noise, Air-Blast And Fly rock Near Surface Structures And Communities To Be Protected.

Table 1: Recommended Ground Vibration Levels

Structure Description	Peak Particle Velocity (mm/s)
National roads/tar roads	150
Electrical lines (pylons)	75
Railway	150
Transformers	25
Waters wells	50
Telecoms tower	50
General houses of proper construction	**USBM** criteria or 25 mm/s
Houses of lesser proper construction	12.5
Rural building – mud houses	6

Specific additional limitations applied by BMC are as follows:

- Steel pipelines: 50 mm/s (Rand Water Board).
- Sasol Pipelines: 25 mms/s (Sasol).
- Concrete less than 3 days old: 5 mm/s [1].
- Concrete after 10 days: 200 mm/s [2].
- 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.)[2].
- Waterwells or Boreholes: 50 mm/s [3].

[1] Chiapetta F., Van Vreden A., 2000. Vibration/Air blast Controls, Damage Criteria, Record Keeping and Dealing with Complaints. 9th Annual BME Conference on Explosives, Drilling and Blasting Technology, CSIR Conference Centre, Pretoria, 2000.

[2] Chiapetta F., Van Vreden A., 2000. Vibration/Air blast Controls, Damage Criteria, Record Keeping and Dealing with Complaints. 9th Annual BME Conference on Explosives, Drilling and Blasting Technology, CSIR Conference Centre, Pretoria, 2000.

[3] Berger P. R., & Associates Inc., Bradfordwoods, Pennsylvania, 15015, Nov 1980, Survey of Blasting Effects on Ground Water Supplies in Appalachia., Prepared for United States Department of Interior Bureau of Mines.

5.2. Ground Vibration Predictions

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. An acceptable standard set of constants is applied.

Equation 1:

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

Where:
PPV = Predicted ground vibration (mm/s)
a = Site constant
b = Site constant
D = Distance (m)
E = Explosive Mass (kg)

Applicable and accepted factors a and b for operations with site constants is as follows:
Factors:
a = 1143
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.

Review of the type of structures that are found within the influence zone of the current mining area and the limitations that may be applicable, different limiting levels of ground vibration will be required. This is due to the typical structures and installations observed surrounding the site and location of the mining area. Structure types and qualities vary greatly according to the Housing inspection report done, and this calls for limits to be considered as per Table 1.

5.3. Air blast limitations on Structures

Air blast or air-overpressure is a pressure wave generated from the blasting process. Air blast is measured as pressure in pascals (Pa) and reported as a decibel value (dB(L)). 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 such as 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 the 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).

Table 2 lists air blast limitations according to The Mine Health and Safety Act No. 29 of 1996 Guideline For A Mandatory Code Of Practice For Minimum Standards On Ground Vibrations, Noise, Air-Blast And Fly rock Near Surface Structures And Communities To Be Protected.

Table 2: Recommended Air Blast Levels

Decibels (dB(L))	Effect
100	Barely noticeable
110	Readily noticeable
120	Currently accepted by the South African authorities as being a reasonable level for public concern (not more than 10% of the measurement should exceed this value.)
134	Currently accepted by the South African authorities that damage will not occur below this level (no measurement should exceed this value outside of the mine boundaries)
164	Window break
176	Plaster cracks
180	Structural damage

Considering the above limitations, BMC's work is based on the following:

- The limits provided in the Mine Health and Safety Act
- The additional limits provided above.
- Consideration of private structures and infrastructure in the area of influence.

5.4. Air Blast Predictions

The prediction of air blast is difficult to define exactly, as there are many variables that influence the outcome of air blast. Air blast is the direct result of the blast process, although influenced by meteorological conditions, wind strength and direction, the final blast layout, timing, stemming, accessories used, covered or not covered, etc., all have an influence on the outcome of the blast. Air blast is also an aspect that can be controlled to a great degree by applying basic rules.

In most cases, mainly an indication of typical levels can be obtained. The indication of levels or the prediction of air blast in this report is used to predefine possible indicators of concern.

Standard accepted prediction equations are applied for the prediction of air blast. 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 millibars. This equation does not take temperature or any weather conditions into account.

Equation 2:

$$P = \mathrm{A}\ \mathrm{x}\ (\frac{\mathrm{D}}{\mathrm{E}^{\frac{1}{3}}})^{-B}$$

Where:

P = Air blast level (mB)

D = Distance from source (m)

E = Maximum charge mass per delay (kg)

A = Constant - (37.1)

B = Constant – (-0.97)

The constants for A and B were then selected according to the information as provided in Figure 2 below. Various types of mining operations are expected to yield different results. The information provided in Figure 2 is based on detailed research that was conducted for each of the different types of mining environments. In this report, the data for "Quarry face" was applied in the prediction of air blast.

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 2: 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:

$$\mathrm{p}_s = 20\ \mathrm{x}\ \log\frac{P}{P_o}$$

Where:

p_s = Air blast level (dB(L))

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.

5.5. 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. The movement should be in the direction of the free face, and therefore the orientation of the blast is important. Material or elements travelling outside of this expected range would be considered to be fly rock. Figure 3 shows schematic of 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.

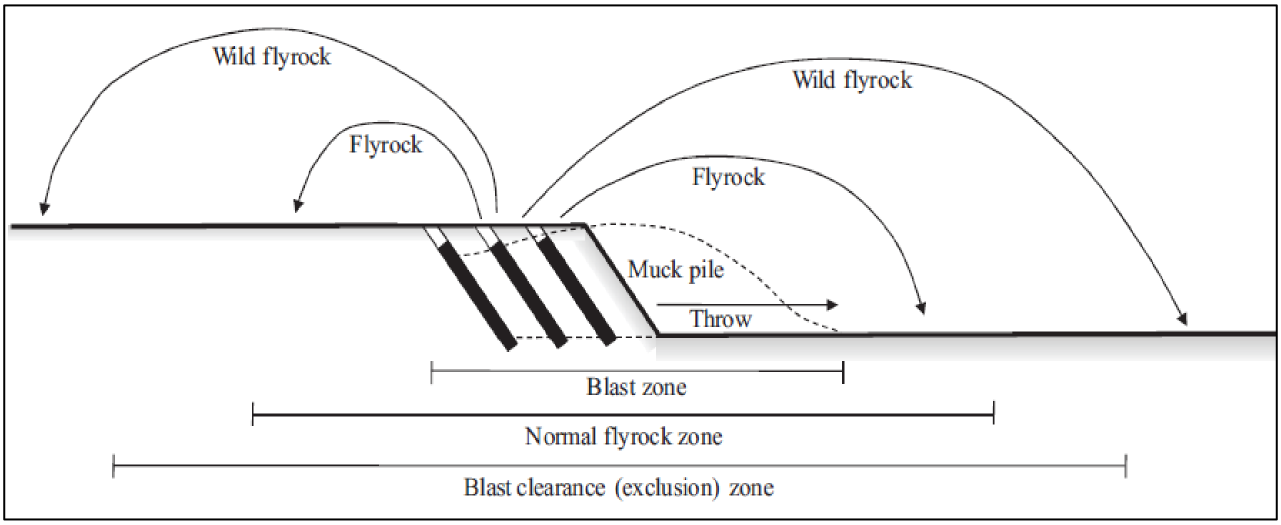

Figure 3: Schematic Of Fly Rock Terminology

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. BMC uses a prediction calculation defined by the International Society of Explosives Engineers (ISEE) to assist with determining minimum distance.

6. Site Review

The mining areas were reviewed for location and surrounding infrastructure. The location is such that various and private structures, public structures and mine owned infrastructure is found at varying distances from the current pit area. Site plans provided was used for review. Information sought during the review was to identify surface structures present in proximity of the mining area, which required consideration during the evaluation of blasting operations done i.e. houses, general structures, mining activity, etc.

7. Blasting Operations

Conventional drilling and blasting operations are done at Mthatha Quarry. Previously used blast designs were provided and used to determine the probable impact of ground vibration and air blast. JKSimblast software was used to replicate the design and simulate the blasting operation. The simulation of the blast was then used to obtain an average charge mass per delay used for all simulations.
The following tables and figures show the proposed designs and summarised information from the simulation.

Table 3: Blast Design Information Provided

Block 115 At TKQ Mthatha	
BCM	(B) 2.3m x (S) 2.7m x (Ave D) 8.6m x (H) 129 = 6 889.37m3
ROCK VOLUME	19 979.18 Tons
Pattern Staggered	
Number of Holes	129
Burden	2.3m
Spacing	2.7m
Diameter	102mm
Number of decks per hole	1
Explosives	INNOVEXTM 100
Total Explosives	7 964.46 kg
Hole Powder Factor	1.16
Hole Energy Factor	1.01
Stemming Length	2.3m
Rock Density	2.9
Booster Size	400G
CTP	216324
Summary	
Total Holes	129
Total Detonators	129
Average Hole Depth	8.6 m
Average Explosives per	61kg
Total Explosives	7 964.46 kg
Total Meters Drilled	1 109.4m
Average Hole Powder	1.16
Average Hole Energy	1.01
Average Block Powder Factor	1.15kg/m3

A detailed design in JKSimblast was done using the parameters above. Timing was used as per the parameters provided in the design. This blast was simulated, and the charge mass per delay was obtained, which was taken as an average charge mass per delay for the blasting operation.
The following Table 4 shows a summary of the simulated blast technical information.

Table 4: Simulated Blast Information

Blast Reference:	Mthatha Quarry_BIA_251016
Rock Type:	Bulk
AS DESIGNED PARAMETERS:	
Avg. Burden (m):	2.3
Avg. Spacing (m):	2.7
Drill Pattern:	Square
BLAST HOLES	
Diameter (mm)	102
Number of Holes	129
Total Length (m)	1135.2
Av. Length (m)	8.8
CHARGE DECKS	
Material Name	BME INNOVEX 100C
Total Number Charge Holes	129
Total Length (m)	838.5
Mean Length (m)	6.5
Total Mass (kg)	8222
Mean Mass (kg)	64
STEMMING DECKS	
Material Name	Stemming
Total Number	129
Mean Length (m)	2.3
Type of Stemming:	Crushed Aggregate
Accessories Type:	Axxis Titanium BME Electronic
Surface Timing - Inter hole (ms):	12 ms
Surface Timing - Inter row (ms):	38 ms
Booster / Primer (gr.):	400
Delay Pattern:	Full Chevron
Max Charge per delay (kg):	446.0
Max No of BH per delay:	7
Powder Factor (kg/m3):	1.17

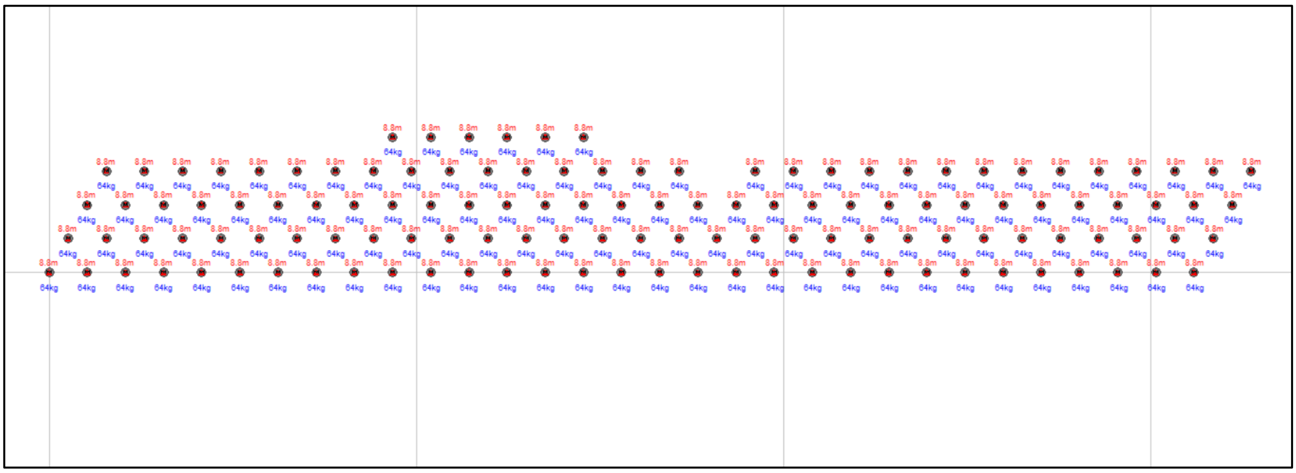

Figure 4: Blast layout with depths and charge

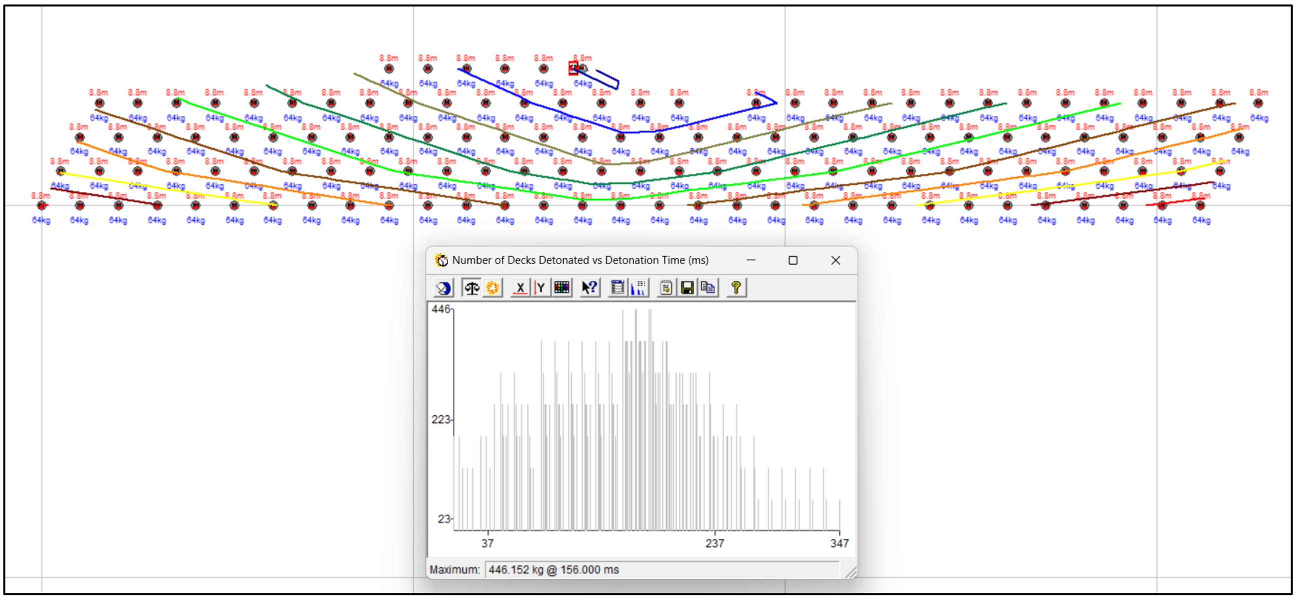

Figure 5: Simulation Charge Mass Per Delay

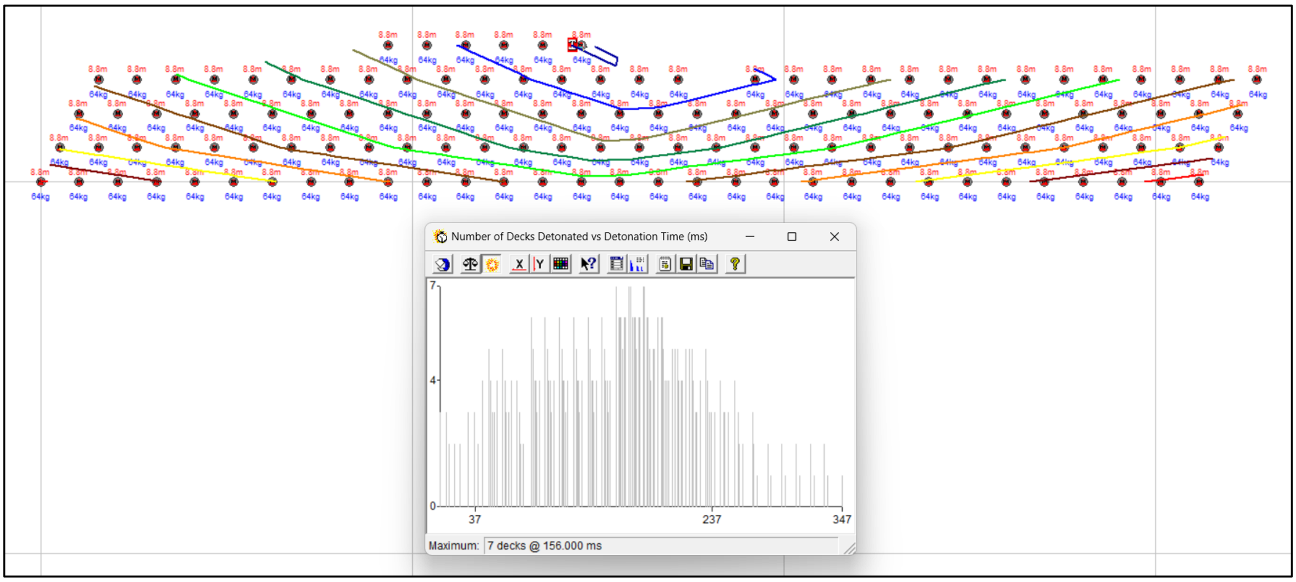

Figure 6: Simulation Blast Holes Per Delay

Based on the simulation work done, a maximum charge mass per delay of 446 kg can be expected. This value was used for the blasting impact evaluation.

8. Impact Assessment

The probable impact in relation to the Ngolo community was assessed. This section concentrates on the outcome of modelling the current and possible effects of ground vibration, air blast, and fly rock at specific distances. In the possible effects evaluation, the charge mass selected is as indicated in section 7, with regard to ground vibration and air blast.

Ground vibration and air blast were modelled from the edge of the pit outline and calculated accordingly, due to the unknown blast block locality, which resulted in the readings obtained. Blasting further away from the pit edge will certainly have less influence on the surrounding area. Reference is made to the community as a whole, surrounding the mine.

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

- Ground Vibration modelling results;
- Air blast modelling results;
- Impact of fly rock;

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

8.1. Ground Vibration Evaluation

Presented herewith are the actual measured ground vibration levels and expected level contours of relevant influences. Actual results and expected ground vibration levels were evaluated and calculated for the area surrounding the pit boundary and assessed with regard to possible structural concerns and human perception.

Tables are provided for each of the different evaluation models done with regard to:

Explanation of Column Headings in Table 5:

L, T & V-PPV:	Longitudinal, Transverse, and Vertical Peak Particle Velocities (mm/s)
L, T & V-Freq:	Longitudinal, Transverse, and Vertical Dominant Frequencies (Hz)
R-PPV:	Resultant Peak Particle Velocity (mm/s)
dB(L):	Peak Air Blast Recorded [dB(L)]

- "Description" indicates the monitor location.
- "Ground Vibration Limit" is the maximum limit for ground vibration.
- "Distance" is the distance between the monitor position and edge of the pit area.
- "PPV (mm/s)" is the ground vibration recorded at the monitor position.
- 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 "Problematic" or "Acceptable" is given for the possibility of damage to a structure. Levels below 0.76 mm/s could be considered to have negligible possibility of influence.
- Additional colour codes used in the tables are as follows:

Structure Evaluations:
Vibration levels higher than 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"

8.1.1. Review of Actual Ground Vibration

Ground vibrations induced by the blasting operations were monitored by Mthatha Quarry. These results were reviewed and plotted as seen in Figure 7. According to the MCOP, the mine has a 12.5 mm/s ground vibration limit to impose.

Reviewing of the house inspection report, describing the type of structures that are found within the influence zone of the mining area, strict limits of ground vibration will be required. This is due to the typical structures and installations observed surrounding the site and location of the blasting area, are different with regards to types of structures and qualities. The limit of 12.5 mm/s used is appropriate, although the mud houses identified by the house inspection report could be evaluated on a limit of 6 mm/s.

Simulations for ground vibration levels from the actual recordings are presented below.

Table 5: Results Obtained from Current Blasting

Serial No.	Date	Time	Seismograph Location	Long Peak (mm/s)	Tran Peak (mm/s)	Vert Peak (mm/s)	Long Freq (Hz)	Tran Freq (Hz)	Vert Freq (Hz)	Max PPV (mm/s)	Mic Peak (dB(L))	Distance
22274	2025/05/28	16:13:23	BLAST 01 - CLOSEST HOUSE	14.86	23.62	8.00	102.40	102.40	64.00	23.62	127.5	218.0
13099	2025/06/18	15:09:52	OFFICE MAIN GATE	2.16	2.16	1.91	51.20	64.00	51.20	2.16	115.7	651.0
22274	2025/06/18	15:10:02	VILLAGE GRAVEYARD	13.59	17.65	5.33	102.40	128.00	73.10	17.65	122.4	210.0
22274	2025/06/26	14:13:48	VILLAGE GRAVEYARD	10.41	11.05	10.16	128.00	128.00	102.40	11.05	124.2	210.0
13099	2025/06/26	14:13:56	OFFICE MAIN GATE	2.16	3.30	2.16	46.50	51.20	73.10	3.30	111.2	651.0
13099	2025/07/16	15:38:44	QUARRY ENTRANCE	3.43	2.79	2.67	64.00	46.50	85.30	3.43	116.9	661.0
22274	2025/07/16	15:39:07	VILLAGE GRAVEYARD	11.30	6.60	5.84	102.40	28.40	56.80	11.30	133.9	220.0
13099	2025/08/01	14:46:32	OFFICE GATE	3.56	4.19	4.45	34.10	39.30	73.10	4.45	111.5	661.0
22274	2025/08/01	14:47:06	VILLAGE GRAVEYARD	10.33	12.05	10.26	125.00	125.00	98.41	12.05	131.5	240.0
13099	2025/08/15	14:38:06	COMMUNITY HOUSE	15.01	12.94	11.68	56.80	51.20	46.50	15.01	132.3	243.0
22274	2025/08/15	14:38:26	QUARRY ENTRANCE	1.40	1.14	0.76	42.60	36.50	46.50	1.40	97.5	660.0
13099	2025/08/28	14:38:50	OFFICE GATE	2.29	3.05	1.78	102.40	128.00	102.40	3.05	118.7	690.0
22274	2025/08/28	14:41:25	COMMUNITY HOUSE	7.87	9.68	7.11	73.10	85.30	102.40	9.68	134.2	263.0
13099	2025/09/11	15:27:02	QUARRY ENTRANCE	2.41	4.19	3.30	56.80	73.10	102.40	4.19	129.9	658.0
22274	2025/09/11	15:28:11	COMMUNITY HOUSE	9.62	11.00	6.19	39.30	73.10	56.80	11.00	128.4	244.0

Table 6: Evaluation of Ground Vibration Results Obtained

Tag	Description	Date	Time	Ground Vibration Limit (mm/s)	Distance (m)	PPV (mm/s)	Max Charge Structure Response @ 10Hz	Max Charge Human Tolerance @ 30Hz
1	BLAST 01 - CLOSEST HOUSE	2025/05/28	16:13:23	12.5	218	23.6	Problematic	Intolerable
2	OFFICE MAIN GATE	2025/06/18	15:09:52	12.5	651	2.2	Acceptable	Perceptible
3	VILLAGE GRAVEYARD	2025/06/18	15:10:02	12.5	210	17.7	Problematic	Intolerable
4	VILLAGE GRAVEYARD	2025/06/26	14:13:48	12.5	210	11.0	Acceptable	Unpleasant
5	OFFICE MAIN GATE	2025/06/26	14:13:56	12.5	651	3.3	Acceptable	Perceptible
6	QUARRY ENTRANCE	2025/07/16	15:38:44	12.5	661	3.4	Acceptable	Perceptible
7	VILLAGE GRAVEYARD	2025/07/16	15:39:07	12.5	220	11.3	Acceptable	Unpleasant

Tag	Description	Date	Time	Ground Vibration Limit (mm/s)	Distance (m)	PPV (mm/s)	Max Charge Structure Response @ 10Hz	Max Charge Human Tolerance @ 30Hz
8	OFFICE GATE	2025/08/01	14:46:32	12.5	661	4.4	Acceptable	Perceptible
9	VILLAGE GRAVEYARD	2025/08/01	14:47:06	12.5	240	12.0	Acceptable	Unpleasant
10	COMMUNITY HOUSE	2025/08/15	14:38:06	12.5	243	15.0	Problematic	Unpleasant
11	QUARRY ENTRANCE	2025/08/15	14:38:26	12.5	660	1.4	Acceptable	Perceptible
12	OFFICE GATE	2025/08/28	14:38:50	12.5	690	3.0	Acceptable	Perceptible
13	COMMUNITY HOUSE	2025/08/28	14:41:25	12.5	263	9.7	Acceptable	Unpleasant
14	QUARRY ENTRANCE	2025/09/11	15:27:02	12.5	658	4.2	Acceptable	Perceptible
15	COMMUNITY HOUSE	2025/09/11	15:28:11	12.5	244	11.0	Acceptable	Unpleasant

Figure 7: Ground Vibration Influence from Current Blasting

8.1.2. Review of Expected Ground Vibration

Utilizing the equation in Section 5.2 and the said factors, allowable levels for specific limits and expected ground vibration levels for various distances can then be calculated.

Ground vibration can be calculated and modelled for the pit area at the charge mass per delay for specific distances from the mining area. The charge masses applied are according to the blast design discussed in the section 7. These levels are then plotted and overlaid with current mining plans to observe possible influences at certain distances. Ground vibration predictions were done considering distances ranging from 100 m to 1500 m around the 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 be applicable for the type of structures observed surrounding the pit area. These levels are: 3 mm/s, 6 mm/s, 12.5 mm/s, and 25 mm/s. This enables immediate review of possible concerns that may apply to any of the privately-owned structures, social gathering areas, or sensitive installations.

Based on the design presented, the following Table 7 shows expected ground vibration levels (PPV) for various distances calculated for the 446 kg maximum charge.

Table 7: Expected Ground Vibration at Various Distances

No.	Distance (m)	Expected PPV (mm/s) for 446 kg Charge
1	100.0	87.9
2	150.0	45.0
3	200.0	28.0
4	250.0	19.4
5	300.0	14.3
6	350.0	11.1
7	400.0	8.9
8	450.0	7.3
9	500.0	6.2
10	600.0	4.6
11	700.0	3.5
12	800.0	2.8
13	900.0	2.3
14	1000.0	2.0
15	1100.0	1.7
16	1200.0	1.5
17	1300.0	1.3
18	1400.0	1.1
19	1500.0	1.0

Based on the ground vibration limit of 12.5 mm/s, the following Table 8 shows the maximum charge allowed for various distances.

Table 8: Allowable Charge Mass Per Delay at Various Distances

No.	Distance (m)	Allowable charge mass per delay (kg) @ 12.5 mm/s PPV Limit
1	100.0	42
2	150.0	94
3	200.0	168
4	250.0	262
5	300.0	378
6	350.0	514
7	400.0	671
8	450.0	850
9	500.0	1049
10	600.0	1511
11	700.0	2056
12	800.0	2686
13	900.0	3399
14	1000.0	4196
15	1100.0	5078
16	1200.0	6043
17	1300.0	7092
18	1400.0	8225
19	1500.0	9442

Table 9: Ground Vibration Evaluation for Maximum Charge

Ground Vibration Limit (mm/s)	Distance (m)	Max Charge Mass/Delay (kg)	Max Charge Predicted PPV (mm/s)	Max Charge Structure Response @ 10Hz	Max Charge Human Tolerance @ 30Hz
12.5	100	446	87.9	Problematic	Intolerable
12.5	150	446	45.0	Problematic	Intolerable
12.5	214	446	25.0	Problematic	Intolerable
12.5	250	446	19.4	Problematic	Intolerable
12.5	300	446	14.3	Problematic	Unpleasant
12.5	327	446	12.4	Acceptable	Unpleasant
12.5	400	446	8.9	Acceptable	Unpleasant
12.5	450	446	7.3	Acceptable	Unpleasant
12.5	510	446	6.0	Acceptable	Unpleasant
12.5	550	446	5.3	Acceptable	Unpleasant
12.5	600	446	4.6	Acceptable	Perceptible
12.5	700	446	3.5	Acceptable	Perceptible
12.5	780	446	3.0	Acceptable	Perceptible
12.5	800	446	2.8	Acceptable	Perceptible
12.5	900	446	2.3	Acceptable	Perceptible
12.5	1000	446	2.0	Acceptable	Perceptible
12.5	1100	446	1.7	Acceptable	Perceptible
12.5	1200	446	1.5	Acceptable	Perceptible
12.5	1300	446	1.3	Acceptable	Perceptible
12.5	1400	446	1.1	Acceptable	Perceptible
12.5	1500	446	1.0	Acceptable	Perceptible

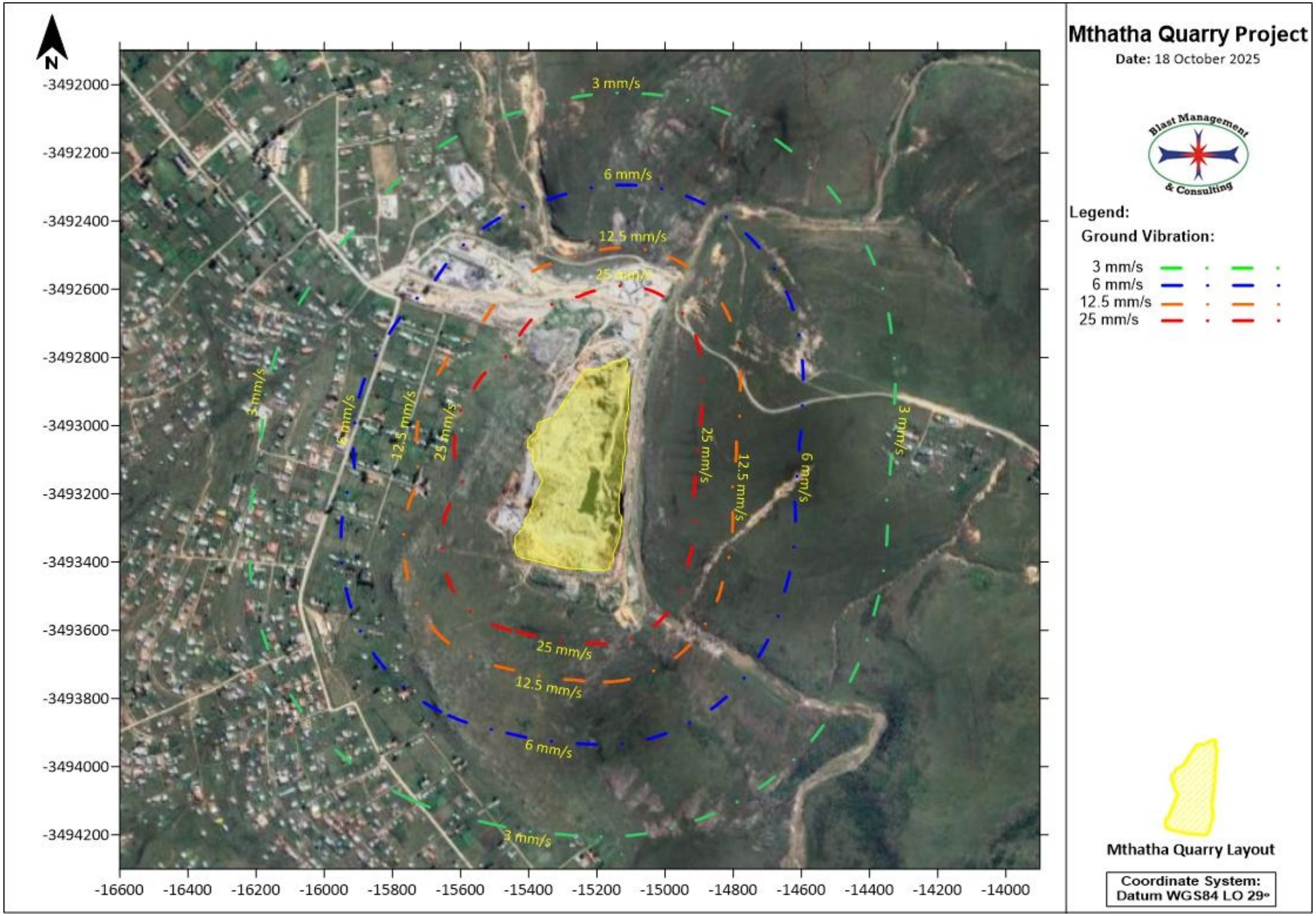

Figure 8: Ground Vibration Influence from Maximum Charge Per Delay

8.2. Air Blast Evaluation

Presented herewith are the actual and expected air blast level contours of relevant influences. Actual results and expected air blast levels were evaluated and calculated for the area surrounding the pit boundary and assessed with regards to possible concerns.

- "Description" indicates the monitor location.
- "Air Blast Limit (dB(L))" is the limit for Air Blast.
- "Distance" is the distance between the monitor position and edge of the pit area.
- "Air Blast (dB(L))" is the air blast level recorded at the monitor position;
- "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 dB(L);
  - "Complaint" where people will be complaining due to the experienced effect on structures at levels of 120 dB(L) and higher (not necessarily damaging);
  - "Acceptable" if levels are less than 120 dB(L);
  - Levels below 115 dB(L) could be considered to have low or negligible possibility of influence.
- Additional colour codes used in the tables are as follows:

Air blast levels higher than proposed limit is coloured "Red"
Air blast levels indicated as possible Complaint is coloured "Mustard"

8.2.1. Review of Actual Air Blast

There are many variables that have an influence on the outcome of air blast. Air blast is the direct result of the blast process, although influenced by meteorological conditions, wind strength and direction, the final blast layout, timing, stemming, accessories used, covered or not covered, etc., all have an influence on the outcome of the blast. Air blast is also an aspect that can be controlled to a great degree by applying basic rules.

The actual results recorded are evaluated and presented below. Stated in the MCOP, the blaster/mine would like to maintain the air blast level below 125 dB(L), although some complaints might still arise from levels in this region, it is well below the criteria of where damage can be expected.

Table 10: Evaluation of Air Blast Results Obtained

Tag	Description	Date	Time	Air Blast Limit (dB(L))	Distance (m)	Air blast (dB(L))	Max Charge Possible Concern?
1	BLAST 01 - CLOSEST HOUSE	2025/05/28	16:13:23	134	218	127.5	Complaint
2	OFFICE MAIN GATE	2025/06/18	15:09:52	134	651	115.7	Acceptable
3	VILLAGE GRAVEYARD	2025/06/18	15:10:02	134	210	122.4	Complaint
4	VILLAGE GRAVEYARD	2025/06/26	14:13:48	134	210	124.2	Complaint
5	OFFICE MAIN GATE	2025/06/26	14:13:56	134	651	111.2	Acceptable
6	QUARRY ENTRANCE	2025/07/16	15:38:44	134	661	116.9	Acceptable
7	VILLAGE GRAVEYARD	2025/07/16	15:39:07	134	220	133.9	Complaint
8	OFFICE GATE	2025/08/01	14:46:32	134	661	111.5	Acceptable
9	VILLAGE GRAVEYARD	2025/08/01	14:47:06	134	240	131.5	Complaint
10	COMMUNITY HOUSE	2025/08/15	14:38:06	134	243	132.3	Complaint
11	QUARRY ENTRANCE	2025/08/15	14:38:26	134	660	97.5	Acceptable
12	OFFICE GATE	2025/08/28	14:38:50	134	690	118.7	Acceptable
13	COMMUNITY HOUSE	2025/08/28	14:41:25	134	263	134.2	Problematic
14	QUARRY ENTRANCE	2025/09/11	15:27:02	134	658	129.9	Complaint
15	COMMUNITY HOUSE	2025/09/11	15:28:11	134	244	128.4	Complaint

8.2.2. Review of Expected Air Blast

The prediction of an air blast is very subjective. In most cases, mainly an indication of typical levels can be obtained. The indication of levels or the prediction of air blast in this report is used to predefine possible areas of concern.

Although the equation in Section 5.4 was applied for the prediction of air blast levels, additional measures are also recommended in Section 10 to ensure that air blast and associated fly-rock possibilities are minimized as best possible.

Table 11: Expected Air Blast at Various Distances

No.	Distance (m)	Expected Air blast (dB(L)) for 446 kg Charge
1	100.0	143.6
2	150.0	140.2
3	200.0	137.8
4	250.0	135.9
5	300.0	134.4
6	350.0	133.1
7	400.0	132.0
8	450.0	131.0
9	500.0	130.1
10	600.0	128.6
11	700.0	127.3
12	800.0	126.1
13	900.0	125.2
14	1000.0	124.3
15	1100.0	123.5
16	1200.0	122.7
17	1300.0	122.1
18	1400.0	121.4
19	1500.0	120.9

Table 12: Air Blast Evaluation for Maximum Charge

Air Blast Limit (dB(L))	Distance (m)	Max Charge Mass/Delay (kg)	Max Charge Air blast (dB(L))	Max Charge Possible Concern?
134	100	446	143.6	Problematic
134	150	446	140.2	Problematic
134	214	446	137.2	Problematic
134	250	446	135.9	Problematic
134	300	446	134.4	Problematic
134	326	446	133.7	Complaint
134	400	446	132.0	Complaint
134	450	446	131.0	Complaint
134	510	446	129.9	Complaint
134	550	446	129.3	Complaint
134	600	446	128.6	Complaint

Air Blast Limit (dB(L))	Distance (m)	Max Charge Mass/Delay (kg)	Max Charge Air blast (dB(L))	Max Charge Possible Concern?
134	700	446	127.3	Complaint
134	780	446	126.4	Complaint
134	800	446	126.1	Complaint
134	900	446	125.2	Complaint
134	1000	446	124.3	Complaint
134	1100	446	123.5	Complaint
134	1200	446	122.7	Complaint
134	1300	446	122.1	Complaint
134	1400	446	121.4	Complaint
134	1500	446	120.9	Complaint

Table 13: Ground Vibration and Air Blast Evaluation for Maximum Charge

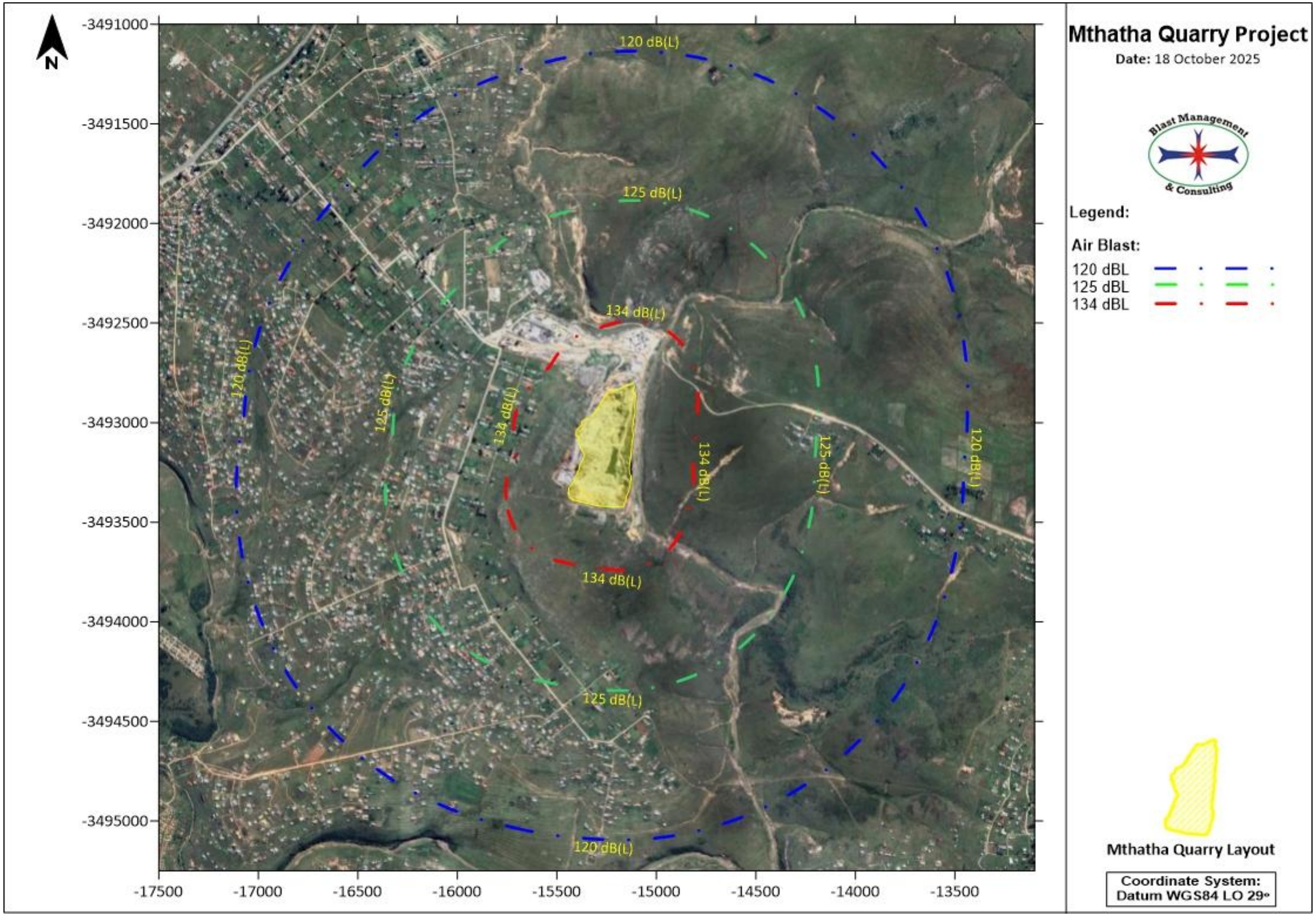

Figure 9: Air Blast Influence from Maximum Charge Per Delay

8.3. Summary of Ground Vibration and Air Blast Levels Evaluated

The mining operations were evaluated for their current and expected levels of ground vibration and air blast from blasting operations. Review of the site and the location of the Ngolo community showed that the distance between the pit and the Ngolo community is less than 500 m.

The distances between the community and the pit are a contributing factor to the levels of ground vibration and air blast expected and experienced, with subsequent possible influences.

Reviewing the ground vibration data in Table 6 three (3) levels recorded were greater than the 12.5 mm/s limit, with most of the other levels being close to this level and could be problematic, about the structure response as well as the human perception factor. If the data is reviewed according to a 6 mm/s limit, which is fit for mud houses, as described in the house inspection report, eight (8) events in total exceeded this limit. The recorded events will likely be noticeable to the nearby community and may lead to complaints. While the risk of actual damage is low, it cannot be completely ruled out if ground vibration levels continue to exceed the specified limits.

According to the house inspection survey done, there is a notable quantity of mud houses identified, however, without any locations of them. This should be investigated and the distances considered for how blasting operations are conducted, as the DMPR's recommended ground vibration limit for mud houses is 6 mm/s, which will change all dynamics for the blasting operation in order to stay within this limit to avoid the possibility of causing damage.

An evaluation of the recorded air blast events indicates that approximately 50% of the measured levels exceeded the ideal threshold specified in the MCOP, which the mine aims to remain below. Although these levels are still within the established damage criteria, they are likely to generate complaints from the neighbouring community due to the perceptible effects of air blast. Typical nuisance effects include the rattling of windows and corrugated roofing, as well as psychological disturbance or discomfort among residents.

Furthermore, a maximum charge mass per delay was derived from a blast design provided, which was utilized to do ground vibration and air blast predictions. This was taken as an average, as the charge mass might be more or less, depending on the block size.

Applying the maximum charge per delay as a guideline for probable impact, it is observed that ground vibration levels predicted would still, to some extent, have an impact on a portion of the neighbouring community, which is in line with what was actually recorded and observed. Essentially, mitigation measures on blast designs will be necessary.

As previously stated, the prediction of air blast does not account for the external environmental and physical factors and should be taken as a guideline of what is to be expected. The predicted levels do indicate that a majority of the community can experience levels between 120 – 125 dB(L), and a smaller portion closer to the mine can experience levels of between 125 – 134 dB(L), which is close to what is being recorded currently.

The possibility of effects from ground vibration and air blast is expected and should be managed accordingly. It is, however, maintained that if proper blast planning, designing, and stemming control is not implemented, the effects could be greater with a greater range of complaints or damage. The pit is located such that "free blasting" – meaning no controls on blast preparation – will not be possible. In many cases, the lack of proper control on blast design, timing, stemming length, and material contributes mostly to complaints from the neighbours.

8.4. 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. This unsafe zone may be anything between 10 m and 1000 m. A general unsafe zone applied by most mines is normally considered to be within a radius of 500 m from the blast but needs to be quantified and determined as best possible.

Calculations are also used to help, and assist determine 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 10 shows the results from the ISEE calculations for fly rock range based on a 102 mm diameter blast hole and 2.3 m stemming length as used in the designs provided. Based on these values, a possible fly rock range with a safety factor of 2 was calculated to be 264 m. The absolute minimum unsafe zone is then 264 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 its occurrence can never be eliminated. Figure 11 shows the area around the Pit that incorporates the 264 m unsafe zone.

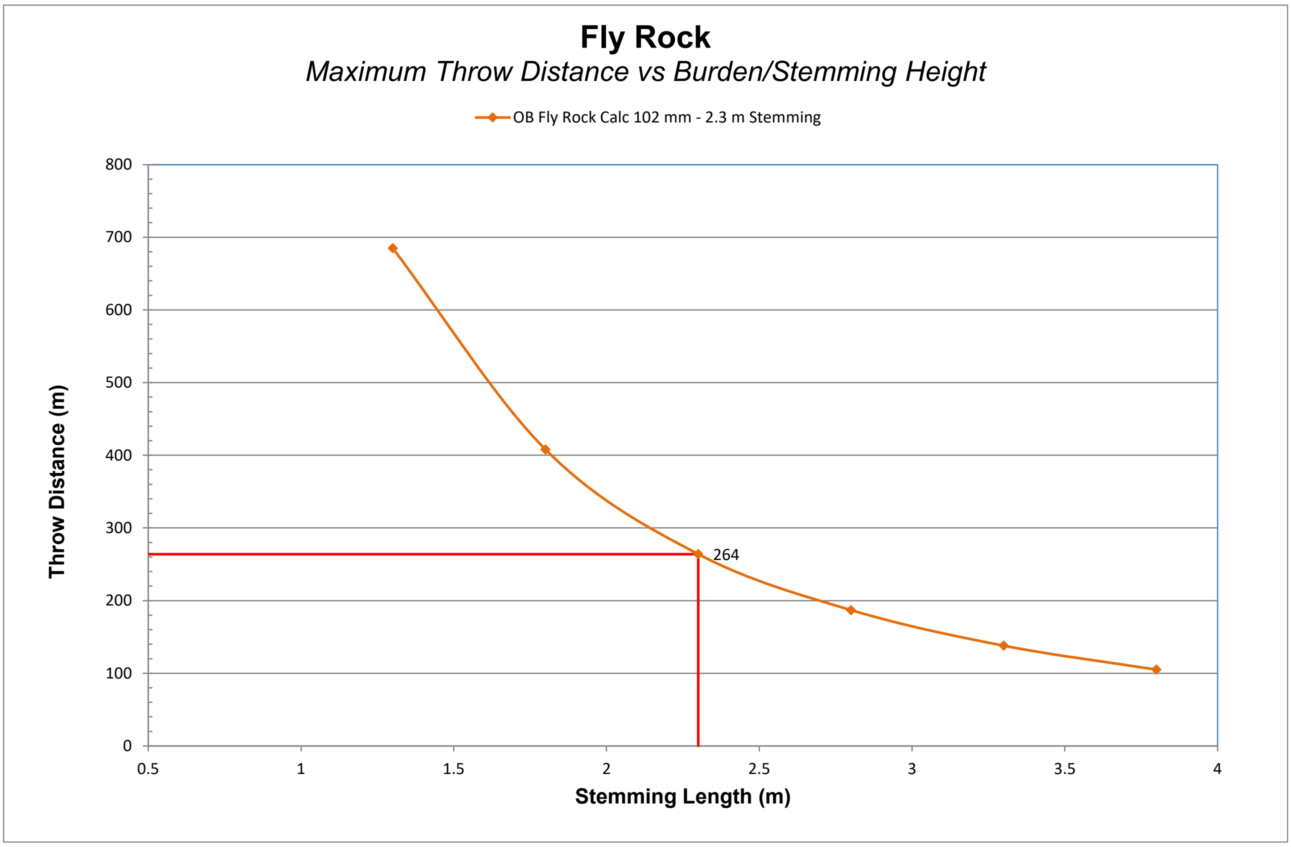

Figure 10: Fly Rock Prediction Calculation

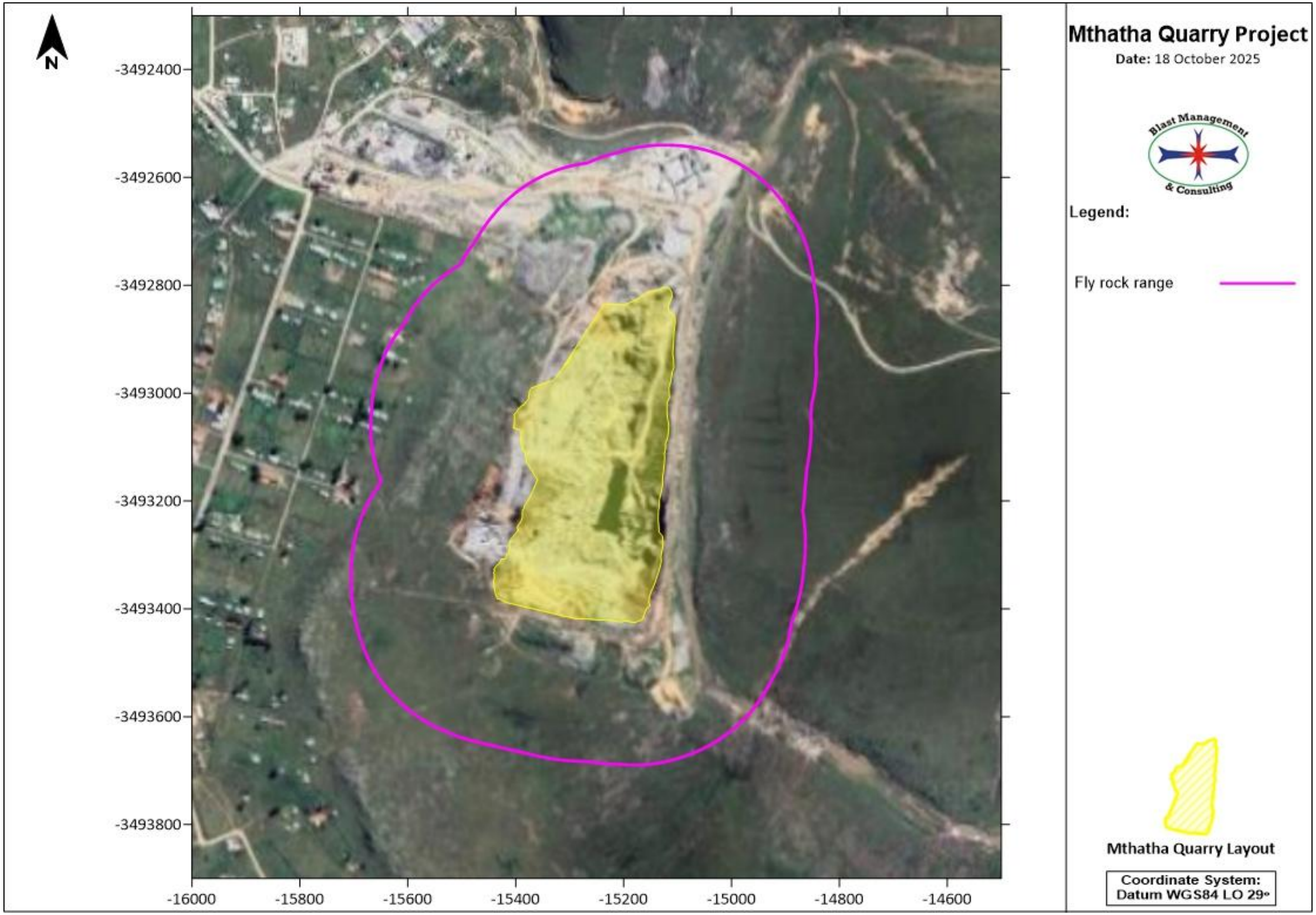

Figure 11: Predicted Fly Rock Exclusion Zone for all Areas

9. Recommendations

The following recommendations are proposed.

9.1. Blast Designs

Blast designs should be reviewed to ensure compliance with ground vibration limits for all infrastructure surrounding the pit area. To effectively manage ground vibrations, the charge mass per delay can be reduced by limiting the number of blast holes firing within a 9-ms time interval. Alternatively, vibration levels can be controlled by adjusting the charge distribution within the blast hole, such as increasing the stemming length or applying deck charging techniques.

9.2. Stemming Length

The current stemming length used provides for some control on air blast and fly rock. Consideration can be given to increase this length for better control. Specific designs where distances between blasts and points of concern are known should be considered. Recommended stemming length should range between 25 and 30 times the blast hole diameter. In cases for better fly rock control, this should range between 30 and 34 times the blast hole's diameter. There are, however, blast outcome challenges that arise from increasing the stemming length and should be closely looked at and evaluated in consideration of the neighbouring community.

9.3. Safe Blasting Distance and Evacuation

Calculated minimum safe distance is 264 m. The blast designs that will be used should determine the final decision on the safe distance to evacuate people and animals. This distance may be greater depending on the responsible blaster’s decision on safe distance. The blaster has a legal obligation concerning the safe distance, and he needs to determine this distance.

10. New Pit Extension – Permissible Blast Designs

This section outlines the new blast designs developed to identify what blasting parameters are permissible within the new pit layout. The aim was to determine safe and practical limits for blasting while staying within all relevant safety and environmental requirements. The designs were kept as close as possible to the current blasting practices used on site to maintain consistency and ease of application. However, some parameters such as burden, spacing, bench height, charge mass, stemming and timing were adjusted to suit the new pit layout limiting factors (100 m Boundary from the community). These changes were made to ensure that vibration, air blast, and fly rock levels remain within the acceptable limits, providing an effective balance between safe, efficient blasting and controlled environmental impact.

The following Figure 12 shows the current pit layout and the anticipated new pit boundary.

Figure 12: Current and New Pit Boundaries

10.1. Protocols, Assumptions, Limitations and Notes

The following to be noted:

Protocols applied:

1. Defining the maximum charge mass per delay at distances from the community according to the limits applicable.
2. Creation of a set of blast designs for each of the zones considering the distance between the blast zone and the community without exceeding the proposed limits.
3. All blasts closer than 250 m from community boundary has extra stemming length applied based on the diameter of the blasthole.
4. A critical factor is the charge mass per delay and thus it is critical that the number of blastholes per delay must be noted.
5. Powder factors as applied in the designs from third party was used as guideline for design to be similar.

Assumptions:

1. The new anticipated pit layout as provided were used as the boundaries of the blasting areas to the community.
2. All blast designs are done based on control for ground vibration, air blast and fly rock.

3. The work done is based on the author's knowledge and information provided by the project applicant.
4. Variable bench heights may need to be considered and were suggested to produce the best suitable solution.
5. Electronic initiation systems were considered for all designs, to control blast holes firing per delay.

Limitations:

1. The anticipated new pit layout is an estimation and not the actual layout and pit boundary.
2. The boundary taken at the community is based on what is located on google earth and its unknown if the structures are still applicable.

Notes:

1. Allowable holes firing within a 9 ms delay controlling the charge mass fired per delay will be crucial to control the ground vibrations.
2. Two air blast prediction methods were used, namely AEL and USBM calculations. The results from these methods can vary to some degree, giving a range from worst case to more likely outcomes. It is important to keep in mind the limitations of air blast predictions when looking at the results. Some predictions may suggest the limits could be exceeded, but it is maintained that if the stemming lengths in the proposed designs are applied correctly in practice, the actual air blast levels are expected to be lower than predicted.

10.2. Proposed Blast Designs

A review of the permitted charge mass indicates significant restrictions on the western side of the pit due to the proximity of the neighbouring community. Only a limited area, starting approximately 350 m from the community, allows the original blast designs provided by a third party to be applied. To address these restrictions, a set of zone-specific designs was developed to provide a reasonable approach for managing the impacts of ground vibration, air blast, and fly rock. All three factors were carefully considered to ensure safe and permissible blasting within the new pit layout.

These blast designs were developed based on zones defined by their distance from the neighbouring community. Zone 1 covers 100 – 150 m, Zone 2 is 150 – 200 m, Zone 3 is 200 – 250 m, Zone 4 is 250 – 300 m, and Zone 5 is 300 – 350 m. Specific blast parameters were assigned to each zone to effectively manage ground vibration, air blast, and fly rock. This zone-based approach provides a practical and safe framework for implementing the blast designs while maintaining compliance with all applicable limits within the restricted area.

The following Figure 13 and Table 15 present the proposed zones and blast designs for each zone, outlining the parameters that can be applied at the various distances from the neighbouring community as well as the predicted ground vibration and air blast values for the said parameters.

Table 14 shows explanatory notes for technical aspects as applied in the designs.

Table 14: Explanatory Notes

Design No.:	Provides the design number plus the distance range applicable
Critical Point Description:	**Description of the concern infrastructure**
Closest Distance to Critical Point:	Distance to critical point considered for the design
Proposed Ground Vibration Limits	Ground vibration limits applied
Proposed Air Blast Limits (Damage Criteria)	Air Blast limit applied
Blast Information:	
B/H Diameter (mm):	Applied blast hole diameter.
Min Depth (m):	Minimum depth of the blast holes. This will be variable for the different areas to be drilled.
Maximum Depth (m):	Maximum depth of the blast holes. This will be variable for the different areas to be drilled.
Pattern:	Staggered / square
Burden (m):	Burden to be drilled
Spacing (m):	Spacing to be drilled
Include Subdrill (Yes/No):	Sub drill to be drilled or not
Average Depth (m):	Average depth of the blast holes based on the minimum and maximum
Explosive Charge:	
Explosive Type:	Emulsion or cartridges
Explosive Description:	Specific product used
Explosive Density (1.0 - 1.25 g/cm^3):	Explosive density as per supplier's specifications
Explosive REE	Relative effective energy of explosive according to specifications
Explosive RBS	Relative bulk strength of explosive according to specifications
Charging Regime:	
Linear Charge Mass (kg):	Charge mass loaded per meter of column
Column Length:	Explosives column length in the blast hole
Stemming: BH Diameter Ratio:	Ratio of stemming vs blast hole diameter
Stemming Length (m):	Stemming length to be applied
Stemming Material Type	
Explosives Per B/H (kg):	Total charge per blast hole
P/F Blasthole (kg/m^3):	Charge mass for the volume drilled
Initiation Regime:	
Accessories Type:	Type of initiation System used
Booster / Primer (gr.):	Down the hole boosters size
Delay Pattern:	Firing pattern applied - V1, V2 etc.
SDOB:	SDOB
SD = D/W1/3 (Avg. Depth):	Scaled depth of burial refers to the expected fly rock and air blast levels. See figure below.
Fly Rock Control:	Adjudication of SDOB factor according to figure below
Vibration & Air Blast Predictions:	Distances from Critical Point/s
Distance to Ngolo Community	The distance considered for prediction of ground vibration and air blast

BH / Delay:	Estimated number of blastholes per delay
Distance to Ngolo Community	Distance to POI used
Multiple BH / Delay Charge (kg):	Charge mass per delay in kg
PPV Single Blasthole (mm/s):	Expected ground vibration at the distance selected for single hole firing
PPV Multiple Blastholes (mm/s):	Expected ground vibration from multiple blastholes at the distance selected
USBM Air blast (dB(L)):	USBM air blast prediction formula
AEL Air Blast (dB(L)):	AEL air blast prediction formula

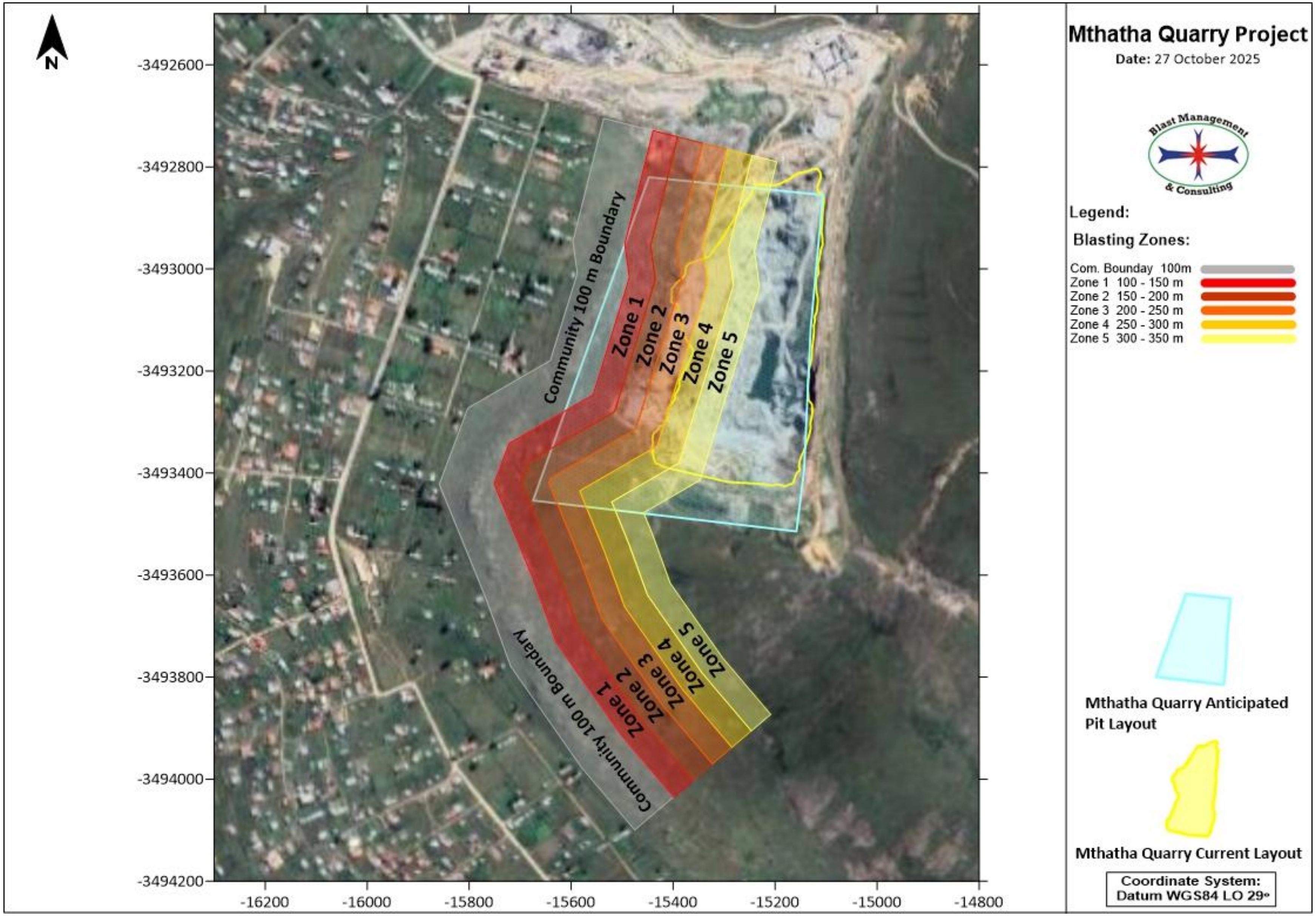

Figure 13: Blasting Zones

Table 15: Permissible Blast Designs

Design No.:	Zone 1_Design 100 - 150 m	Zone 2_Design 150 - 200 m	Zone 3_Design 200 - 250 m	Zone 4_Design 250 - 300 m	Zone 5_Design 300 - 350 m
Critical Point Description:	Ngolo Community	Ngolo Community	Ngolo Community	Ngolo Community	Ngolo Community
Closest Distance to Critical Point:	100	150	200	250	300
Proposed Ground Vibration Limits	12.5	12.5	12.5	12.5	12.5
Proposed Air Blast Limits (Damage Criteria)	134.0	134.0	134.0	134.0	134.0
Blast Information:					
B/H Diameter (mm):	89	89	89	89	89
Min Depth (m):	8.0	10.0	10.0	10.0	10.0
Maximum Depth (m):	8.0	10.0	10.0	10.0	10.0
Pattern:	Staggered	Staggered	Staggered	Staggered	Staggered
Burden (m):	2.1	2.2	2.2	2.2	2.2
Spacing (m):	2.4	2.5	2.5	2.5	2.5
Include Subdrill (Yes/No):	No	No	No	No	No
Average Depth (m):	8.0	10.0	10.0	10.0	10.0
Explosive Charge:					
Explosive Type:	Emulsion	Emulsion	Emulsion	Emulsion	Emulsion
Explosive Description:	Innovex 100	Innovex 101	Innovex 102	Innovex 103	Innovex 104
Explosive Density (1.0 - 1.25 g/cm^3):	1.15	1.15	1.15	1.15	1.15
Explosive REE	84	84	84	84	84
Explosive RBS	126	126	126	126	126
Charging Regime:					
Linear Charge Mass (kg):	7.15	7.15	7.15	7.15	7.15
Column Length	5.3	7.3	7.5	7.5	7.8
Stemming: BH Diameter Ratio:	30	30	28	28	25
Stemming Length (m):	2.7	2.7	2.5	2.5	2.2
Stemming Material Type	Crushed Aggregate	Crushed Aggregate	Crushed Aggregate	Crushed Aggregate	Crushed Aggregate
Explosives Per B/H (kg):	38	52	54	54	56
P/F Blasthole (kg/m^3):	0.96	0.97	0.99	0.99	1.02
Initiation Regime:					

Accessories Type:	Electronic	Electronic	Electronic	Electronic	Electronic
Booster / Primer (gr.):	400	400	400	400	400
Delay Pattern:	V3	V3	V3	V3	V3
SDOB:					
SD = D/W1/3 (Avg. Depth):	1.68	1.68	1.59	1.59	1.44
Fly Rock Control:	Well Controlled	Well Controlled	Well Controlled	Well Controlled	Well Controlled
Vibration & Air Blast Predictions:					
Distance to Ngolo Community	100.0				
Distance to Ngolo Community	150.0	150.0			
Distance to Ngolo Community	200.0	200.0	200.0		
Distance to Ngolo Community	250.0	250.0	250.0	250.0	
Distance to Ngolo Community	300.0	300.0	300.0	300.0	300.0
BH / Delay:	**1**	**1**	**2**	**3**	**5**
Distance to Ngolo Community	100.0				
Multiple BH / Delay Charge (kg):	38				
PPV Single Blasthole (mm/s):	11.6				
PPV Multiple Blastholes (mm/s):	11.6				
USBM Air blast (dB(L)):	136.8				
AEL Air Blast (dB(L)):	129.7				
Distance to Ngolo Community	150.0	150.0			
BH / Delay:	1.0	1.0			
Multiple BH / Delay Charge (kg):	38.1	52.4			
PPV Single Blasthole (mm/s):	5.9	7.7			
PPV Multiple Blastholes (mm/s):	5.9	7.7			
USBM Air blast (dB(L)):	133.4	134.3			
AEL Air Blast (dB(L)):	125.4	126.5			
Distance to Ngolo Community	200.0	200.0	200.0		
BH / Delay:	1.0	1.0	2.0		
Multiple BH / Delay Charge (kg):	38.1	52.4	107.3		
PPV Single Blasthole (mm/s):	3.7	4.8	4.9		
PPV Multiple Blastholes (mm/s):	3.7	4.8	8.6		

USBM Air blast (dB(L)):	131.0	131.9	133.9		
AEL Air Blast (dB(L)):	122.4	123.5	126.0		
Distance to Ngolo Community	250.0	250.0	250.0	250.0	
BH / Delay:	1.0	1.0	2.0	3.0	
Multiple BH / Delay Charge (kg):	38.1	52.4	107.3	161.0	
PPV Single Blasthole (mm/s):	2.5	3.3	3.4	3.4	
PPV Multiple Blastholes (mm/s):	2.5	3.3	6.0	8.4	
USBM Air blast (dB(L)):	129.1	130.0	132.0	133.1	
AEL Air Blast (dB(L)):	120.1	121.2	123.7	125.1	
Distance to Ngolo Community	300.0	300.0	300.0	300.0	300.0
BH / Delay:	1.0	1.0	2.0	3.0	5.0
Multiple BH / Delay Charge (kg):	38.1	52.4	107.3	161.0	277.9
PPV Single Blasthole (mm/s):	1.9	2.5	2.5	2.5	2.6
PPV Multiple Blastholes (mm/s):	1.9	2.5	4.4	6.2	9.7
USBM Air blast (dB(L)):	127.5	128.4	130.4	131.6	133.1
AEL Air Blast (dB(L)):	116.6	117.7	120.2	121.6	123.5

10.3. Fly Rock Estimates

Using the information from the proposed blast designs for each zone, the Scaled Depth of Burial (SDoB) and the expected fly rock ranges were calculated for the different areas in proximity to critical infrastructure. These calculations were conducted to assess the potential impact of blasting and to ensure that adequate controls are maintained in sensitive areas. This is not taken as a clearance distance but as the possible effect from the blast design parameters.

The following table provides a summary of the calculated SDoB values and the corresponding expected fly rock distances for the blasts located closest to each critical area.

Table 16: Fly Rock Estimates

Flyrock Assumptions		**Zone 1_Design 100 - 150 m**	**Zone 2_Design 150 - 200 m**	**Zone 3_Design 200 - 250 m**	**Zone 4_Design 250 - 300 m**	**Zone 5_Design 300 - 350 m**
Critical Distance		100	150	200	250	300
Rock density	g/cc	2.9	2.9	2.9	2.9	2.9
Hole diameter	mm	89	89	89	89	89
Stemming length	m	2.7	2.7	2.5	2.5	2.2
Charge length	m	5.3	7.3	7.5	7.5	7.8
Burden	m	2.1	2.2	2.2	2.2	2.2
Explosive density	g/cc	1.15	1.15	1.15	1.15	1.15
Flyrock constant		28	28	28	28	28
Factor of safety	FoS	1	1	1	1	1
Trajectory angle (Stemming ejection)	deg	50	50	50	50	15
Charge mass/m	kg/m	7.2	7.2	7.2	7.2	7.2
Gravity	m/s/s	9.81	9.81	9.81	9.81	9.81
Scaled Depth of Burial						
Contributing charge length factor		10	10	10	10	10
Scaled depth of burial	m/kg^ 1/3	1.68	1.68	1.59	1.59	1.44
Clearance Distance and Projectile Size						
Projectile size	mm	16	16	18	18	23
Projectile weight	kg	0.01	0.01	0.01	0.01	0.02
Clearance Distance	m	71	71	80	80	99
Maximum Horizontal Distance						
Face burst	m	139	125	125	125	125
Cratering	m	80	80	95	95	128
Stemming ejection	m	79	79	94	94	64

Flyrock Assumptions		**Zone 1_Design 100 - 150 m**	**Zone 2_Design 150 - 200 m**	**Zone 3_Design 200 - 250 m**	**Zone 4_Design 250 - 300 m**	**Zone 5_Design 300 - 350 m**
Maximum Vertical Distance						
Launch velocity (FB)	m/s	37	35	35	35	35
Launch velocity (C)	m/s	28	28	31	31	35
Launch velocity (SE)	m/s	28	28	30	30	25
Face burst	m	70	63	63	63	63
Cratering	m	40	40	48	48	64
Stemming ejection	m	40	40	47	47	32

10.4. Summary Notes on New Pit Extension and Blast Designs

In summary, the following key points are noted regarding the proposed blast designs:

- The blast design parameters were adjusted where required to remain within the applicable vibration, air blast, and fly rock limits, while still reflecting the practicality of the current blasting practices used on site.
- It is advisable that the proposed designs be used when conducting blasting in the new pit to ensure that all activities remain within the applicable limits.
- The new pit can be mined effectively, provided that the proposed blast designs and parameters for each zone are followed as recommended.

11. Conclusion

The assessment evaluated the effects of ground vibration, air blast, and fly rock associated with current blasting operations, with specific focus on potential impacts to the nearby Ngolo community and surrounding infrastructure.

The review identified that the proximity of the community to the active pit area increases the potential for perceptible blast-related effects. Analysis of monitoring data indicated that several ground vibration and air blast events were greater than the recommended thresholds, particularly in relation to structures of varying construction quality, such as mud houses. While the risk of structural damage remains low, the likelihood of community disturbance and complaints is significant if exceedances persist.

Predicted outcomes correspond closely with the actual measurements, confirming that current blasting practices can influence the surrounding area. Effective blast design management—such as optimising charge mass per delay, controlling the number of holes fired per interval, and adjusting stemming lengths or deck charging—will be essential to reduce impacts and ensure compliance with vibration and air blast limits.

Although the results remain within general damage criteria, improved control measures and continuous monitoring are recommended to minimise potential effects on the Ngolo community and maintain adherence to regulatory and operational standards.

Furthermore, to assess the viability of the new pit extension, a series of blast designs were developed to determine the parameters required to remain within the applicable vibration, air blast, and fly rock limits. These designs were based on the current site practices but adjusted where necessary to suit the limiting factors of the new pit layout, particularly the 100 m boundary from the neighbouring community. A zone-based approach, defined by distance from the community, was implemented to provide clear guidance on permissible charge masses and associated parameters. This method provides a practical framework for ensuring compliance while allowing the new pit extension to be mined efficiently.

This concludes the investigation into the environmental impacts induced from the blasting operations at Mthatha Quarry.

12. 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.

BMC 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 BMC.

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