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Report: Blast Impact Assessment Stage II expansion at Afritin Mine, Uis on ML 134 Project		
Report Date:	23 February 2022	
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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
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1994	National Higher Diploma: Explosives Technology, Technikon Pretoria
1997	Project Management Certificate, Damelin College
2000	Advanced Certificate in Blasting, Technikon SA

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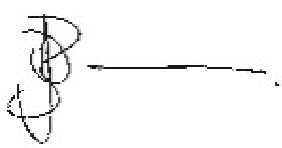
iii. Independence Declaration

i. 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

ii. Document Control:

Name & Company	Responsibility	Action	Date	Signature
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JD Zeeman Blast Management & Consulting	Consultant	Report Finalised	30/03/2022	

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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 & Consulting
D	Distance (m)
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
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NOx	Nitrogen Oxide
NOx's	Noxious Fumes
P	Probability
POI	Points of Interest
PPV	Peak Particle Velocity
RPP	Rock Pressure Pulse
SH	Stemming height (m)
USBM	United States Bureau of Mine
W	West
WM	With Mitigation Measures
WOM	Without Mitigation Measures

List of Units used in this Report

%	percentage
cm	centimetre
dB	decibel
dBL	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
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

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1 Executive Summary

Blast Management & Consulting (BMC) was contracted as part of Environmental Impact Assessment (EIA) to perform an initial review of possible impacts with regards to blasting operations in the proposed opencast mining operation.

Ground vibration, air blast, fly rock and fumes are some of the aspects as a result from blasting operations. The report evaluates the effects of ground vibration, air blast and fly rock and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 3500 m from the mining area considered. The range of structures observed is typical roads (tar and gravel), low cost houses, corrugated iron structures, brick and mortar houses, communication towers.

The location of structures around the Pit area is such that the charge evaluated showed possible influences due to ground vibration. The closest structures observed are the Power Lines, Boreholes and Mine Buildings/Structures. Ground vibrations predicted for the pit area ranged between low and very high. The expected levels of ground vibration for some of these structures are high and will require specific mitigations in the way of adjusting charge mass per delay to reduce the levels of ground vibration. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage.

Air blast predicted also showed more concerns for opencast blasting. The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134dB. It is maintained that if stemming control is not exercised this effect could be greater with greater range of complaints or damage. The pits are located such that “free blasting” – meaning no controls on blast preparation – will not be possible. The nearest private structures are located 1324 m from pit edge. Air blast levels from maximum charge is expected to be within the accepted limit but slightly greater than 120 dB. This may contribute to some complaints. All other private structures are further away and levels decrease over distance. Levels are expected to be less than 120 dB at distance of 2387 m from the pit edge.

The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134 dBL. Prediction shows that air blast will be greater than 134 dB at distance of 223 m and closer to pit boundary. Infrastructure at the pit areas such as roads, power lines/pylons are present, but air blast does not have any influence on these installations.

Fly rock remains a concern for blasting operations. Based on the drilling and blasting parameters values for a possible fly rock range with a safety factor of 2 was calculated to be 388 m. The absolute minimum unsafe zone is then the 388 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.

Specific actions will be required for the pit area such as Mine Health and Safety Act requirements when blasting is done within 500 m from structures and mining with 100 m for structures. The Power Lines, Stormwater Canal and Mine Buildings/Structures falls within the 500 m range from the pit area.

The pit areas are located such that specific concerns were identified and addressed in the report.

This concludes this investigation for the proposed Uis Tin Mining Project. There is no reason to believe that this operation cannot continue if attention is given to the recommendations made.

2 Introduction

AfriTin Mining Limited ("AfriTin") executed a Definitive Feasibility Study ("DFS") between October 2020 and December 2020 for the expansion of production at Uis Tin Mine in Namibia. This expansion is intended to fast-track opportunities and to exploit the financial benefit inherent in these opportunities.

The proposed expansion is in line with the Company's strategy for expansion of the Uis Phase 1 project, and forms part of the Phase 1 Stage II expansion, however it does not cover the full scope of the defined Stage II goals.

The aim is to fast-track some of the Stage II expansion objectives by leveraging certain capabilities. The expanded materials handling and concentrating plant ("MHCP") is designed to increase the average monthly production of 60 t of tin concentrate to 100 t. This will be achieved by increasing the feed rate of ore to the concentrating plant by 50% and improving the operation of the concentrating circuit to achieve consistent recovery of 64% of contained tin.

The Uis Tin Mine infrastructure development commenced in 2018 on the historical Uis Tin Mine located adjacent to the Uis mining village which was developed to support the historical mine.

Access to the project is obtained via an established road network that connects the project to larger towns and cities with modern infrastructure. The two main access routes to the project are via the C36 from the town of Omaruru and the C35 from the town of Henties Bay. Both these roads are two-way gravel roads that are maintained by the local road authorities. The condition of the roads is very good and allow for easy and efficient traveling and transport.

From the towns of Henties Bay and Omaruru access can be gained to larger towns and cities via tarred roads. The closest large town to the project is Swakopmund and is located 165 km by road from the project. Walvis Bay is a port city 40 km from Swakopmund by road, with an international airport, and import and export infrastructure. Swakopmund is also connected to the town of Omaruru via rail.

Uis is located approximately 270 km northwest of the Namibian capital Windhoek. Imports of industrial goods and equipment from South Africa are via Windhoek, while most imports from overseas come by sea through Walvis Bay. Concentrate export is also by sea via Walvis Bay.

The location of the project in relation to other towns and cities and access routes are illustrated in Figure 1.

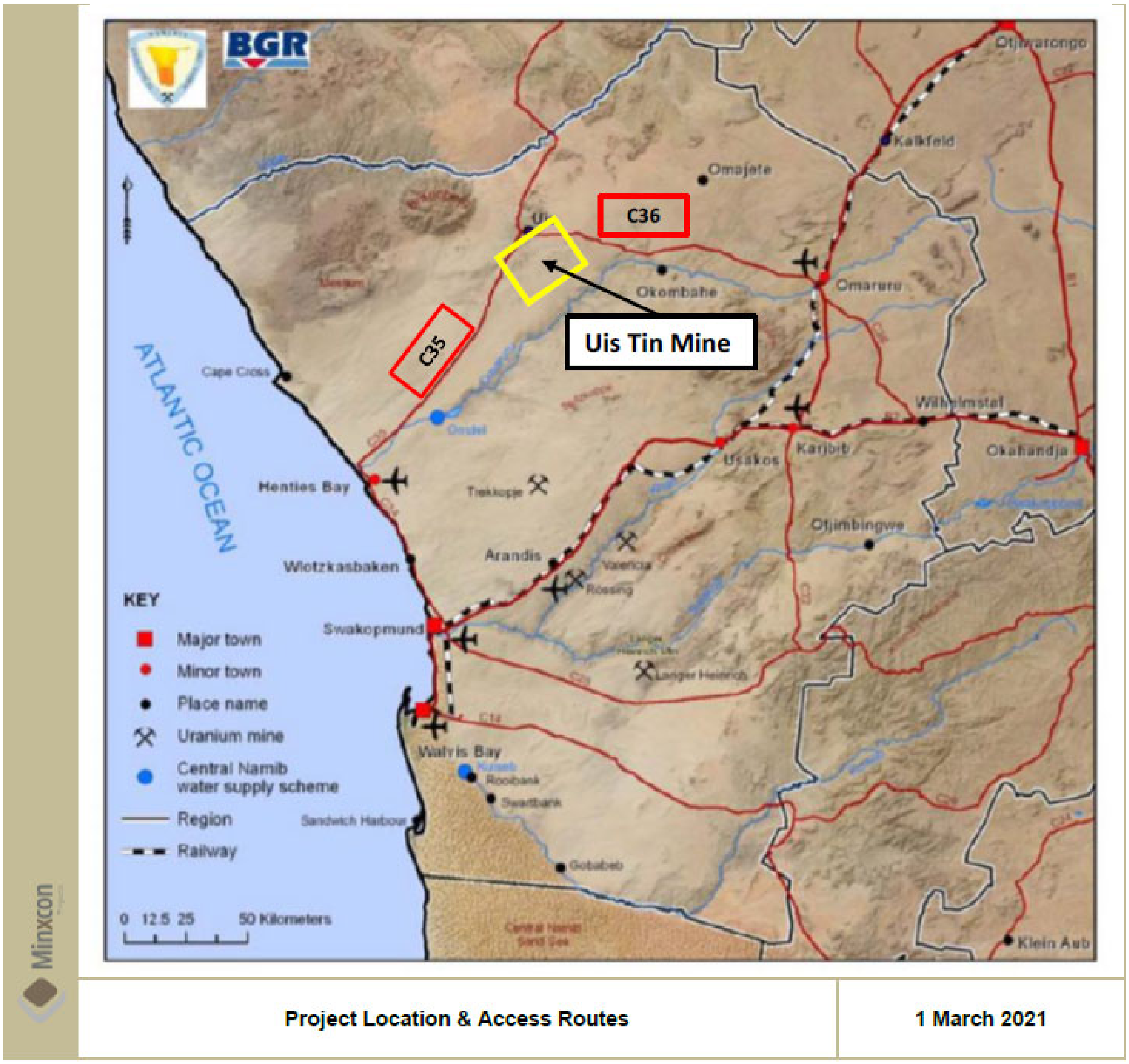

Figure 1: Project Location and Access Routes

Figure 2 indicates the relative position of the proposed open cast mining area (blue polygon).

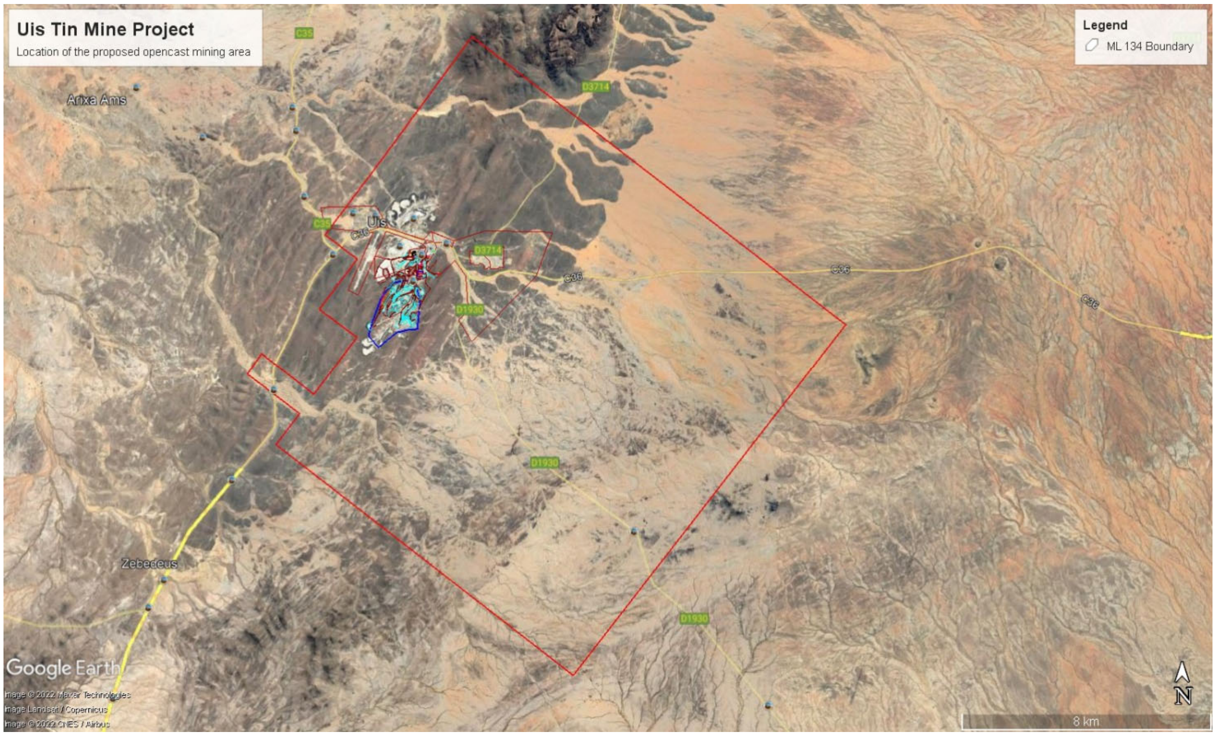

Figure 2: Location of the proposed opencast mining area

3 Objectives

The objectives of this document are outlining the expected environmental effects that blasting operations could have on the surrounding environment; and proposing the specific mitigation measures that will be 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, client requirements and general indicators in the various appropriate Namibian legislation. There is no direct reference in the following acts to requirements and limits on the effect of ground vibration and air blast and some of the aspects addressed in this report:

- Petroleum Products Regulations : Petroleum Products And Energy Act 13 of 1990
- Minerals (Prospecting And Mining) Act 33 of 1992
- Mine Health & Safety Regulations, 10th Draft
- Diamond Act 13 of 1999
- Mineral Act, 1992
- Annotated Statutes Explosives Act 26 of 1956.

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).

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.

- Background information of the proposed site.
- Blasting Operation Requirements.
- 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 1500 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 the location of blasting operations in relation to surrounding areas according to the regulations from the applicable Acts.
- Impact Assessment.
- Mitigations.
- Recommendations.
- Conclusion.

5 Study area

Uis Tin Mine is located to the south-east of the town of Uis, located in the Erongo Region of Namibia. Old infrastructure, open pits, and discarded waste dumps from previous mining in the area are still visible. The new mine is located to the south of the old plant area. The centre point of the Pit is 21°14'42.46"S and 14°52'34.90"E. Figure 3 shows the location map of the proposed opencast mining area (Blue Polygon).

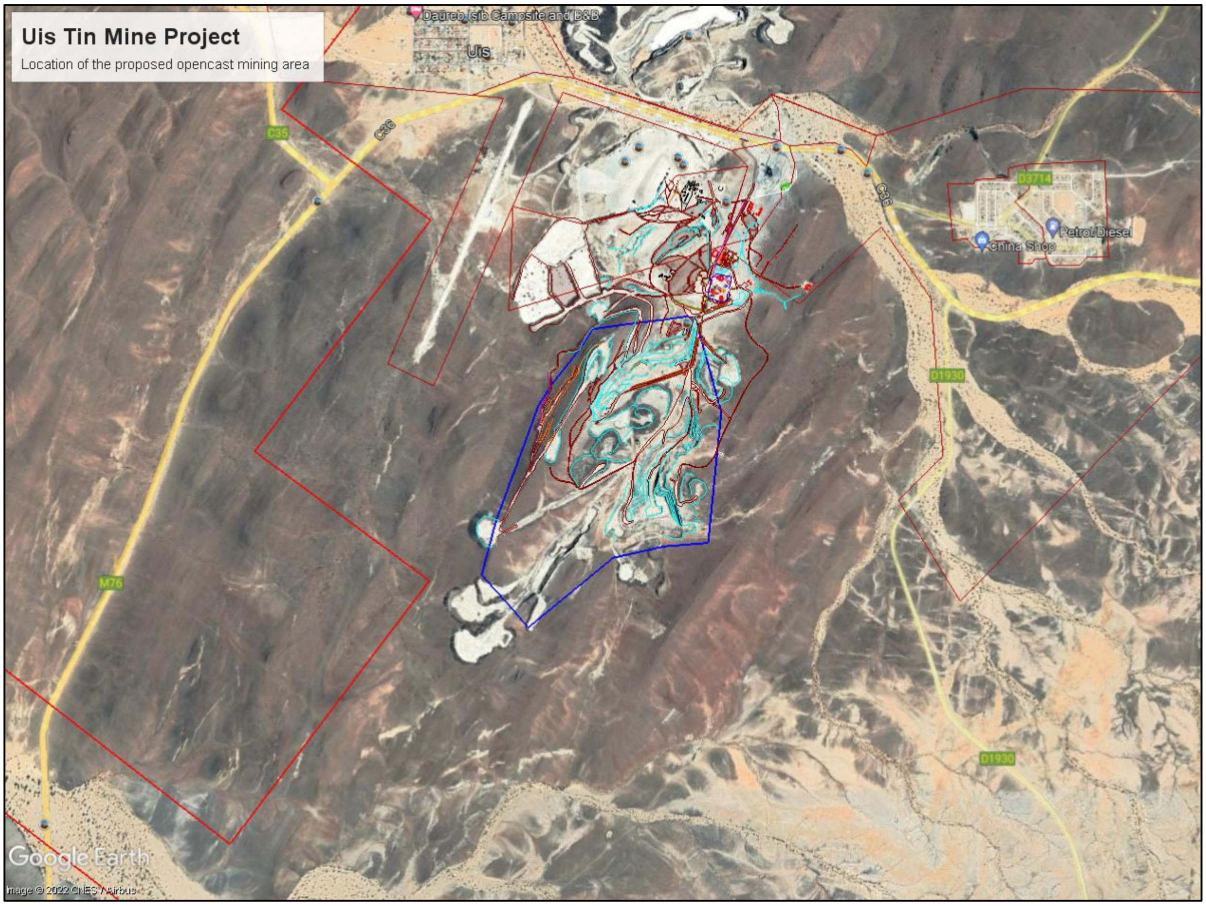

Figure 3: Location of the proposed opencast mining area

6 Methodology

The detailed plan of study consists of the following sections:

- Identifying surface structures / installations that are found within reason from project site. A list of Point of Interests (POI's) is created that will be used for evaluation. Google Earth imagery was used.
- Site evaluation: This consists of evaluation of the mining operations and the possible influences from blasting operations. The methodology is modelling the expected impact based on the expected drilling and blasting information provided for the project. Various accepted mathematical equations are applied to determine the attenuation of ground vibration, air blast and fly rock. These values are then calculated over the distance investigated from site and shown as amplitude level contours. Overlaying these contours on the location of the various receptors then gives an indication of the possible impacts and the expected results of potential impacts. Evaluation of each receptor according to the predicted levels then gives an indication of the possible mitigation measures to be applied. The possible environmental or social impacts are then addressed in the detailed EIA phase investigation.

- Reporting: All data is prepared in a single report and provided for review.

7 Season applicable to the investigation

The drilling and blasting operations are not season dependable. The investigation into the possible effects from blasting operations is not season bounded.

8 Assumptions and Limitations

The following assumptions have been made:

- 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 once the operation is active.
- The limitation is that limited data was available from this operation. No confirmation of the predicted values could be made.
- Blast designs applied currently was used for the evaluation inputs.
- The work done is based on the author's knowledge and information provided by the project applicant.

9 Legal Requirements

The Namibian legislation has been considered. There is no direct reference in the consulted acts specifically with regard to limiting levels for ground vibration and air blast. Impacts of mining are addressed but no specific reference to the blast impacts in relation to ground vibration and air blast. The following Namibian acts has been reviewed:

- Petroleum Products Regulations : Petroleum Products And Energy Act 13 of 1990
- Minerals (Prospecting And Mining) Act 33 of 1992
- Mine Health & Safety Regulations, 10th Draft
- Diamond Act 13 of 1999
- Mineral Act, 1992
- Annotated Statutes Explosives Act 26 of 1956.

The protocols applied in this document are based on the author's experience, guidelines elicited by the literature research, client requirements and international standards. Where applicable South African legislation has been consulted as well.

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.

10 Sensitivity of Project

A review of the project and the surrounding areas is done before any specific analysis is undertaken and sensitivity mapping is done, based on typical areas and distance from the proposed mining area. This sensitivity map uses distances normally associated where 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 pit area.
- An area 500 m to 1500 m around the pit area can be considered as being a medium sensitive area. In this area, the possibility of impact is still expected, but it 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 upset people.
- An area greater than 1500 m is considered low sensitivity area. In this area, it is relatively certain that influences will be low with low possibility of damages and limited possibility to upset people.

Figure 4 shows the sensitivity mapping with the identified points of interest (POI) in the surrounding areas for the proposed project area. The specific influences will be determined through the work done for this project in this report.

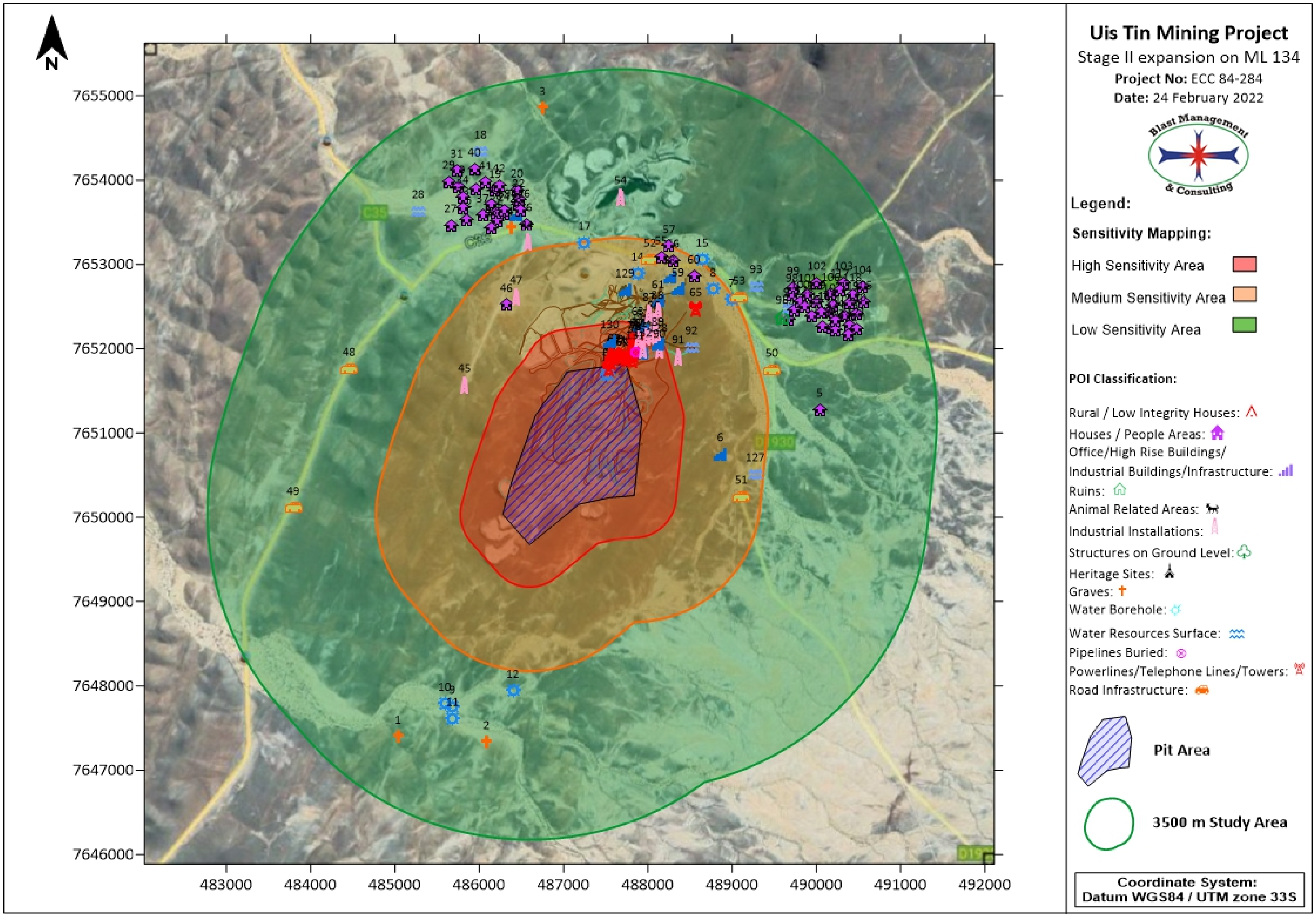

Figure 4: Identified sensitive areas

11 Consultation process

No specific consultation with external parties was utilised. The work done is based on the author's knowledge, information provided by the client and information captured during site visit.

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 are a result of 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 Namibian ground vibration and air blast limit standard.

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 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 damages.

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 5 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,
- 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 additional criteria that are applied by BM&C.

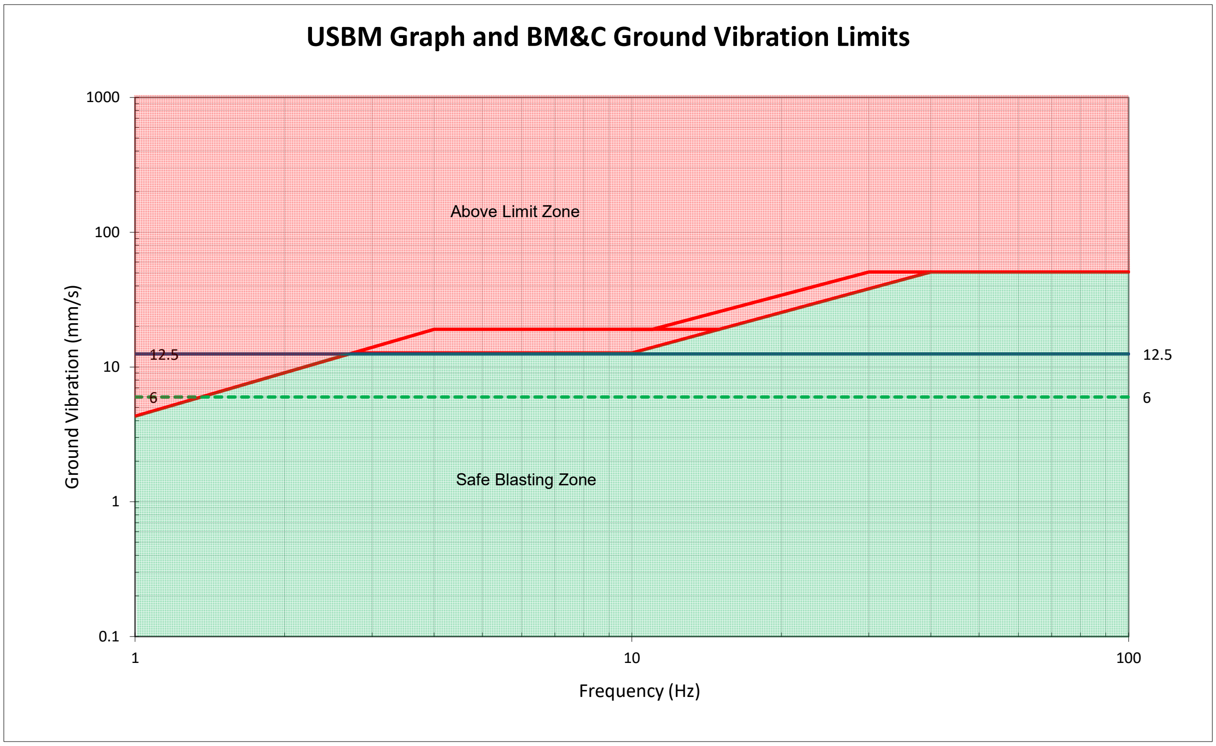

Figure 5: USBM Analysis Graph

The following additional limitations used by BMC in general and 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 (BMC).
- Steel pipelines: 50 mm/s (Rand Water Board).
- Electrical lines: 75 mm/s (Eskom).
- Sasol Pipelines: 25 mms/s (Sasol).
- Railways: 150 mm/s (BMC).
- Concrete less than 3 days old: 5 mm/s [1].

[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.

- 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].

Considering the above limitations, BMC 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.
- Traditionally 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; BMC 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 0.8 mm/s as perceptible (See Figure 6). This guideline helps with managing ground vibration and the complaints that could be received due to blast induced ground vibration.

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[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.

Indicated on Figure 6 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 the evaluation.

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

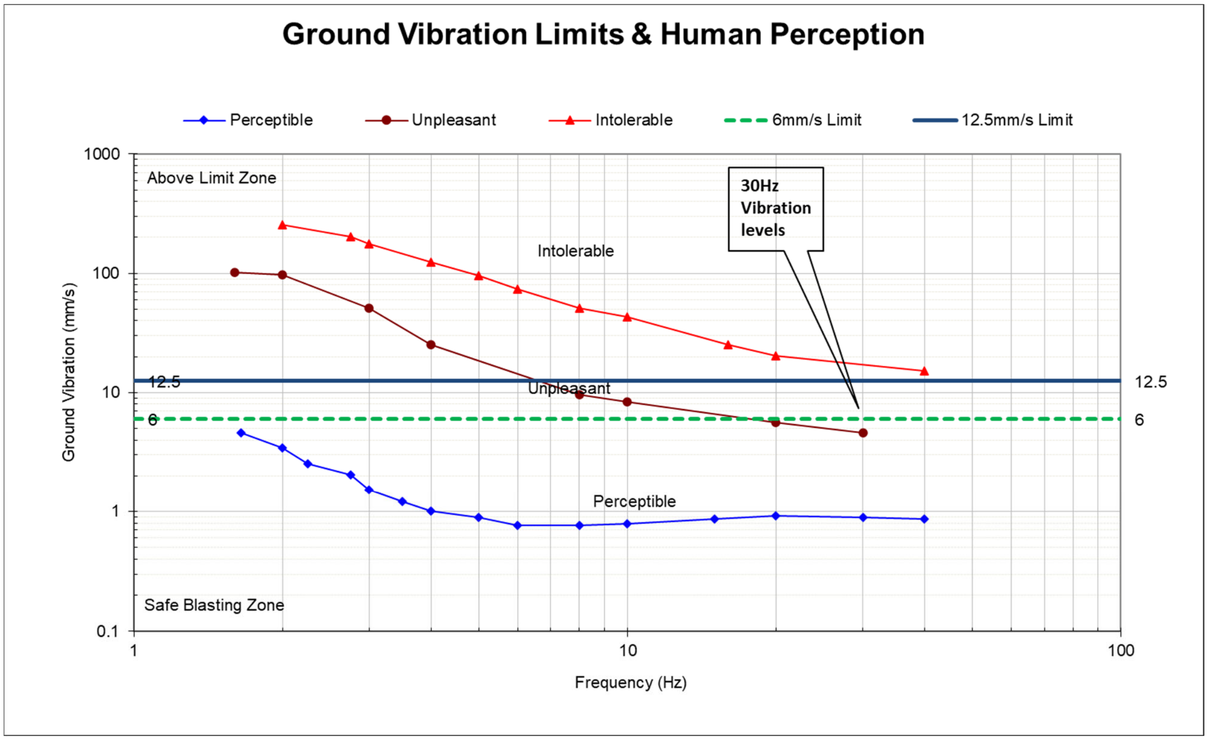


Figure 6: Ground Vibration and Human Perception

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 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 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 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 134dB. 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 135dB 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 1). Levels given in Table 1 are at the point of measurement. The weakest points on a structure are the windows and ceilings.

Table 1: Damage Causing Levels 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

The following table showing summary of air blast limits applied in this report applicable:

Table 2: Air Blast Limits

Level	Description
<120 dB	Preferred levels to avoid complaints
120 dB	Bottom limit applied for start of complains
128 dB	USBM Proposed Limit for Schools and Hospitals
134 dB	Current RSA Limit

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, BMC 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 of air blast on structures that startle people will also be reduced, which in turn 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 the structure.

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

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. 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 7 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.

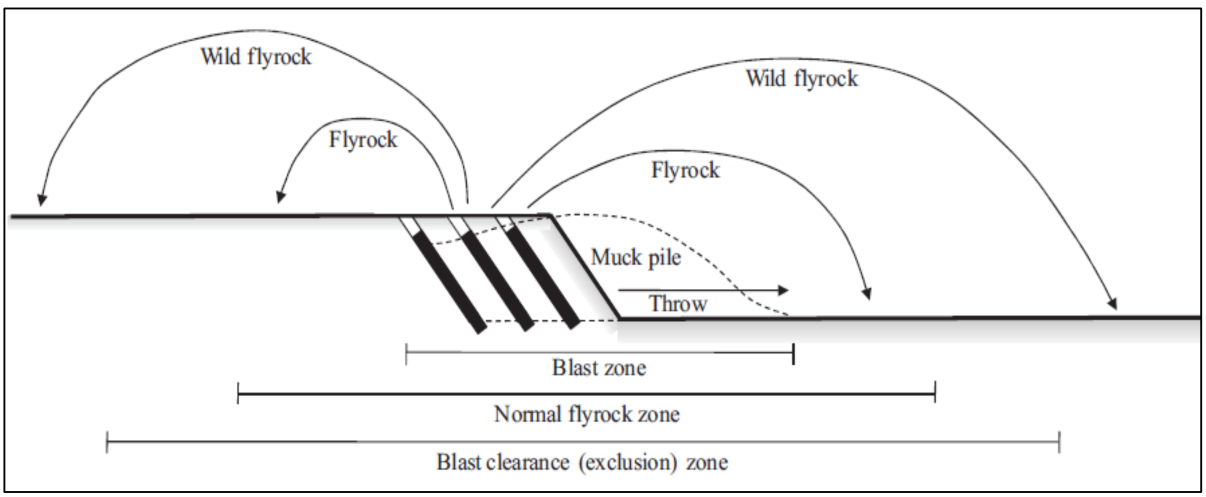


Figure 7: Schematic of fly rock terminology

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 particular undesirable. These fumes present themselves as red brown cloud after the blast has detonated. It has been reported that 10ppm to 20ppm can be mildly irritating. Exposure to 150 ppm or more (no time period given) has been reported to cause death from pulmonary oedema. It has been predicted that 50% lethality would occur following exposure to 174ppm 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 too 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.

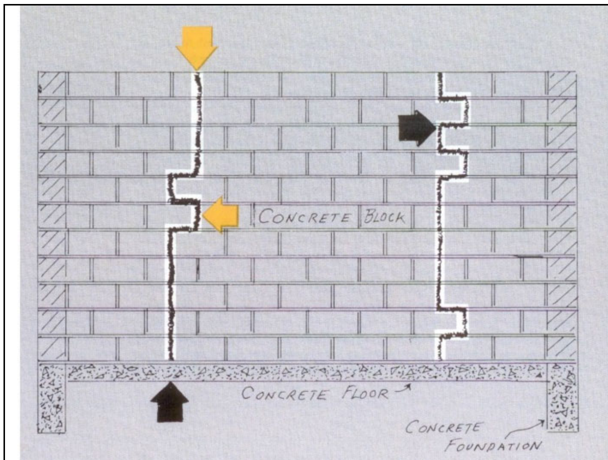
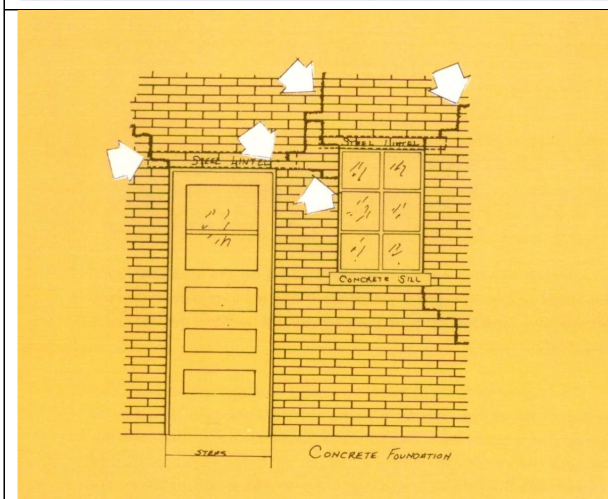
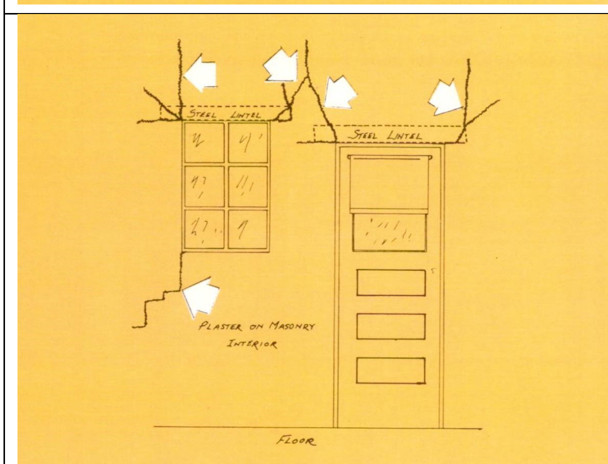
12.9 Cracking of houses and consequent devaluation

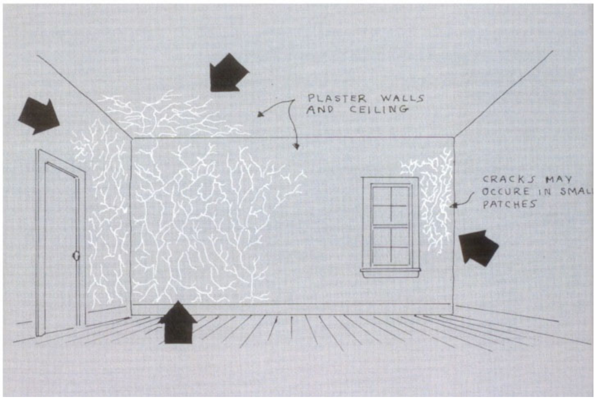
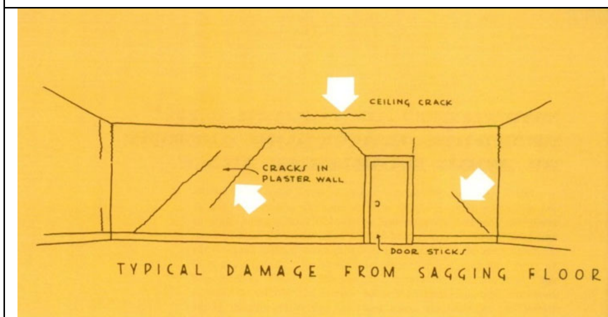
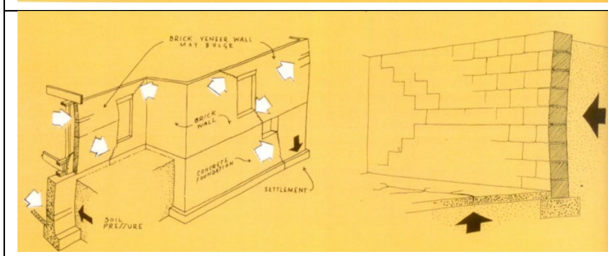
Houses in general have cracks. It is reported that a house could develop up to 15 non-blasting cracks a year. Ground vibration will be mostly responsible for cracks in structures if high enough and at continued high levels. The influences of environmental forces such as temperature, water, wind etc. 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 8 below. A typical X crack formation is observed.

Figure 8: Example of blast induced damage.

The table below with figures show illustrations of non-blasting damage that could be found.

Table 3: Examples of typical non-blasting cracks

	Cracks Resulting from Shrinkage of Concrete Blocks
	Typical Lintel Cracks
	Typical Lintel Cracks

	"Crazing" Cracks on Plaster
	Plaster Cracks Caused by Sagging Floors
	Cracks Resulting from Foundational Failure

Observing cracks in the form indicated in Figure 8 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, and the general existence of cracks may be due to materials used. 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.

12.10 Water well Influence from Blasting Activities

Domestic, agricultural and monitoring boreholes are present around the proposed site. The author has not had much experience on the effect of blasting on water wells, but specific research was done and results from this research work are presented.

Case 1 looked at 36 case histories. Vibration levels up 50 mm/s were measured. The well yield and aquifer storage improved as the mining neared the wells, because of the opening of the fractures from loss of lateral confinement, not blasting. This is similar to how stress-relief fractures form. At one site, the process was reversed after the mine was backfilled. It was more likely the fractures were recompressed. It was stated that blasting may cause some temporary (transient) turbidity similar to those events that cause turbidity without blasting.

Such as:

1. Natural sloughing off inside of the well bore due to inherent rock instability. This can be accelerated by frequent over pumping. This is common to wells completed through considerable thickness of poorly consolidated and/or highly fractured clay stones and shales.
2. Significant rainfall events. The apertures of the shallow fractures that are intersected by a domestic well are commonly highly transmissive, thus will transmit substantial amounts of shallow flowing and rapidly recharging water. This water will commonly be turbid and can enter the well in high volumes. The lack of grouting of the near surface casing commonly allows this to happen. Also, if the top of the well is not grouted properly surface water can enter along the side of the casing and flow down the annulus.

The Berger Study observed ground-water impacts from manmade stress-release caused the rock mass removal during mining, but nothing from the blasting. The water quality and water levels were unaffected by the blasting. The “opening up” of the fractures lowered the ground-water levels by increasing the storage or porosity.

A study tested wells 50 m from a blast. Wells exhibited no quality or quantity impacts. Blast pressure surges ranged from 3 cm to 10 cm. Blasting caused no noticeable water table fluctuations and the hydraulic conductivity was unchanged. The pumping of the pit and encroachment of the high wall toward the wells dewatered the water table aquifer.

It may then be concluded from the studies researched as follows: Depending on the well construction, litho logic units encountered, and proximity to the blasting, it is believed that large shots could act as a catalyst for some well sloughing or collapse. However, the well would have to be inherently weak to begin with. The small to moderate shots will not show to impact wells. The minor water fluctuations attributed to blasting may cause a short-term turbidity problem, but do not pose any long-term problems. This fluctuation would not cause well collapse, as fluctuations from recharge and pumping occurs frequently. Long term changes to the well yield are more likely due to the opening of fractures from loss of lateral confinement. Short term dewatering of wells is caused by the opening of the fractures creating additional storage. A longer-term dewatering is caused by encroachment of the high wall and pumping of the pit water. The pit acts like a large pumping well. It is not believed that long term water quality problems will be caused by blasting alone. The possible exception is the introduction of residual nitrates, from the blasting materials, into the ground water system. This is only possible through wells that are hydro logically connected to a blasting site. Most of the long-term impacts on water quality are due to the mining (the breakup of the rocks). The influence will also be dependent if wells are beneath the excavation. Stress relief effects occur at shorter distances in this instance.

The results observed and levels recorded during research done showed that levels up to 50 mm/s or even higher in certain cases did not have any noticeable effect. It seems that safe conditions will be in the order of the 50 mm/s. In addition to this there are certain aspects that will need to be addressed prior to blasting operations.

13 Baseline Structure Profile

The site was reviewed using Google Earth imagery. All possible structures in a possible influence area were identified. 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 5 below. A list of structure locations was required to determine the allowable ground vibration limits and air blast limits. Figure 4 shows an aerial view of the planned 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 4. 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, High-rise buildings and Industrial buildings / Infrastructure
4	Ruins
5	Animal related installations and animal sensitive areas
6	Industrial Installations
7	Earth like structures – no surface structure
8	Heritage sites (buildings, infrastructure, activity)
9	Graves
10	Water Borehole
11	Water Resources Surface
12	Pipelines Buried
13	Powerlines / Telephone Lines / Towers
14	Road Infrastructure

Table 5: List of points of interest identified (WGS84 / UTM zone 33S)

Tag	Description	Classification	Y	X
1	Grave (1) - Site 312/847	9	485040.16	7647396.53
2	Graves (22) - Site 312/849	9	486088.90	7647335.48
3	Graves (100) - Site 312/893	9	486751.93	7654853.93
4	Graves (26) - Site 312/901	9	486373.89	7653427.34
5	Mine village - Site 312/900	2	490040.02	7651277.55
6	Mine adit - Site 312/899	3	488864.03	7650750.97
7	Borehole (BH1)	10	488994.16	7652581.75
8	Borehole (BH2)	10	488777.20	7652703.34
9	Borehole (BH3)	10	485683.96	7647753.71
10	Borehole (BH4)	10	485593.68	7647786.83
11	Borehole (BH5)	10	485687.20	7647609.83
12	Borehole (BH6)	10	486400.64	7647942.47
13	Borehole (BH8) - Inside Pit Area	10	487520.26	7651695.29
14	Borehole (BH9)	10	487881.52	7652890.86
15	Borehole (BH10)	10	488647.24	7653057.42
16	Borehole (BH11)	10	487625.96	7651883.51
17	Borehole (BH12)	10	487250.30	7653255.61
18	Reservoir	11	486018.48	7654339.41
19	Buildings/Structures (Uis Elephant Guesthouse)	2	486190.76	7653872.39
20	Guesthouse/Lodge	2	486450.11	7653879.57
21	Church	2	486459.52	7653705.24
22	Houses	2	486471.35	7653765.35
23	Filling Station	3	486437.24	7653584.39
24	Buildings/Structures (Brandberg Rest Camp)	2	486295.14	7653602.24
25	Shopping Centre	2	486213.00	7653510.22
26	Public (Riemvasmaak Community Conservancy)	2	486557.13	7653480.08
27	Buildings/Structures	2	485663.14	7653465.37
28	Reservoir	11	485277.95	7653632.96
29	Building/Structure	2	485641.20	7653978.58
30	Public (Campsite and B&B)	2	485757.18	7653923.23
31	Buildings/Structures	2	485735.26	7654116.21
32	Houses	2	485843.19	7653525.89
33	Houses	2	485809.61	7653671.51
34	Houses	2	485804.84	7653801.51
35	Houses	2	485964.04	7653898.89
36	Houses	2	486145.14	7653715.86
37	Houses	2	486041.32	7653584.29
38	Shopping Centre	2	486199.99	7653613.28
39	Swimming Pool	2	486300.17	7653642.23
40	Buildings/Structures	2	485945.18	7654128.39
41	Houses	2	486076.26	7653969.24
42	Houses	2	486238.85	7653940.13
43	Structure	2	486145.00	7653429.67
44	Runway	6	486569.65	7653265.31
45	Runway	6	485829.08	7651568.60

Tag	Description	Classification	Y	X
46	Buildings/Structures	2	486326.81	7652522.29
47	Heli Pad	6	486440.81	7652615.86
48	C35 Road	14	484459.35	7651762.75
49	M76 Road	14	483795.58	7650112.33
50	D1930 Road	14	489474.56	7651751.92
51	D1930 Road	14	489111.77	7650246.93
52	C36 Road	14	488026.92	7653058.17
53	D3714 Road	14	489086.49	7652612.46
54	Tailings Dam	6	487678.79	7653797.60
55	Buildings/Structures	2	488160.68	7653083.55
56	Buildings/Structures	2	488304.53	7653047.64
57	Buildings/Structures	2	488253.51	7653218.90
58	Industrial Structures (Mine)	3	488255.24	7652852.05
59	Sub Station	3	488358.19	7652705.39
60	Buildings/Structures	2	488547.88	7652858.87
61	Mine Buildings/Structures	3	488125.00	7652562.77
62	Mine Buildings/Structures	3	487940.07	7652222.50
63	Mine Buildings/Structures	3	487882.90	7652244.55
64	Mine Buildings/Structures	3	487923.27	7651940.61
65	Communication Tower	13	488571.92	7652470.68
66	Power Lines/Pylons - Inside Pit Area	13	487542.63	7651761.39
67	Power Lines/Pylons	13	487564.50	7651824.76
68	Power Lines/Pylons	13	487586.39	7651887.09
69	Power Lines/Pylons	13	487600.88	7651929.21
70	Power Lines/Pylons	13	487638.52	7651916.64
71	Power Lines/Pylons	13	487680.28	7651903.04
72	Power Lines/Pylons	13	487724.69	7651888.20
73	Power Lines/Pylons	13	487765.92	7651873.84
74	Power Lines/Pylons	13	487815.39	7651857.83
75	Power Lines/Pylons	13	487825.12	7651915.85
76	Power Lines/Pylons	13	487832.86	7651955.23
77	Power Lines/Pylons	13	487845.02	7652011.67
78	Power Lines/Pylons	13	487855.36	7652063.02
79	Power Lines/Pylons	13	487832.24	7652076.86
80	Power Lines/Pylons	13	487865.32	7652114.09
81	Power Lines/Pylons	13	487919.46	7652105.13
82	Stormwater Canal	6	487887.43	7652112.82
83	Stormwater Canal	6	487983.94	7652141.49
84	Stormwater Canal	6	488033.59	7652154.15
85	Stormwater Canal	6	488065.98	7652271.48
86	Stormwater Canal	6	488076.10	7652313.88
87	Stormwater Canal	6	488016.17	7652414.62
88	Stormwater Canal	6	488117.51	7652437.75
89	Stormwater Canal	6	488121.19	7652120.07
90	Stormwater Canal	6	488140.85	7651979.31
91	Stormwater Canal	6	488363.51	7651907.33

Tag	Description	Classification	Y	X
92	Reservoir	11	488520.33	7652017.26
93	Dams	11	489288.02	7652742.73
94	Buildings/Structures (Clinic)	2	489674.60	7652342.61
95	Ruins	4	489595.34	7652377.87
96	Reservoir	11	489685.01	7652473.81
97	Houses	2	489736.20	7652452.66
98	Houses	2	489713.49	7652639.08
99	Houses	2	489727.72	7652722.27
100	Houses	2	489807.92	7652557.69
101	Buildings/Structures	2	489897.63	7652640.33
102	Houses	2	490008.79	7652780.66
103	Houses	2	490326.45	7652783.03
104	Houses	2	490547.14	7652735.85
105	Houses	2	490555.14	7652555.87
106	Houses	2	490173.77	7652651.24
107	Houses	2	490192.71	7652519.39
108	Houses	2	490336.26	7652384.07
109	Houses	2	490004.44	7652556.88
110	Houses	2	490136.55	7652426.87
111	Houses	2	490178.08	7652248.28
112	Houses	2	490389.49	7652276.35
113	Houses	2	490219.59	7652215.55
114	Houses	2	490071.94	7652265.12
115	Houses	2	489941.33	7652385.63
116	Houses	2	490052.27	7652423.08
117	Houses	2	490279.83	7652693.67
118	Houses	2	490429.64	7652645.20
119	Buildings/Structures	2	490398.44	7652540.57
120	Buildings/Structures	2	490481.42	7652410.93
121	Buildings/Structures	2	490472.72	7652238.21
122	Houses	2	490377.56	7652171.61
123	Buildings/Structures	2	489857.63	7652501.89
124	Buildings/Structures	2	490223.45	7652334.24
125	Graveyard	9	492151.44	7651242.60
126	School	2	486497.33	7653642.88
127	Reservoir	11	489276.37	7650509.74
128	Old Sub Station	3	488125.04	7652048.29
129	Old Abandoned Mine Structures	3	487731.64	7652696.61
130	Old Abandoned Mine Structures	3	487551.21	7652087.32
131	Fibre Optical Cable	12	487850.63	7651959.03
132	Primary Crusher	6	487940.90	7651990.57

14 Blasting Operations

In order to evaluate the possible influence from blasting operations with regards to ground vibration, air blast and fly rock a planned blast design is required to determine possible influences.

Blasting is required for the overburden material and ore reserves.

This report concentrates on the drilling and blasting of the overburden. The overburden blasts are then considered as a worst-case scenario and is used as indicator of possible influence.

Blast design information was provided for the project. Using the data provided JKSimblast blast design software was used to design and simulate the blast. This designed blast was applied for the evaluation done in this report. The simulation of the blast provided the best prediction possible. Table 6 shows summary technical information of the blast designed. Figure 9 to Figure 14 shows the simulation outcomes.

Table 6: Blast design technical information

Blast Type	OB
Design	Design 01
Bench Height (m)	11
Blast Depth Min. (m)	10
Blast Depth Max. (m)	10
Include Sub Drill (Yes/No)	Yes
Sub-drill (m)	1.00
Explosive Type	Emulsion
Explo. Density (gr/cm3)	1.165
Diameter (mm)	89
Burden (m):	2.7
Spacing (m):	2.7
Pattern	
Average Depth (m)	11
Explosives Per B/H (incl. Sub drill) (kg)	68.9
Average Column Length (incl. Sub drill.)	9.5
Linear Charge (kg/m)	7.25
Stemming Length (m):	1.5
Powder Factor (kg/m3)	0.86

Figure 9: Blast Area with blastholes and depths

Figure 10: Blast Area with blastholes and charge per blasthole

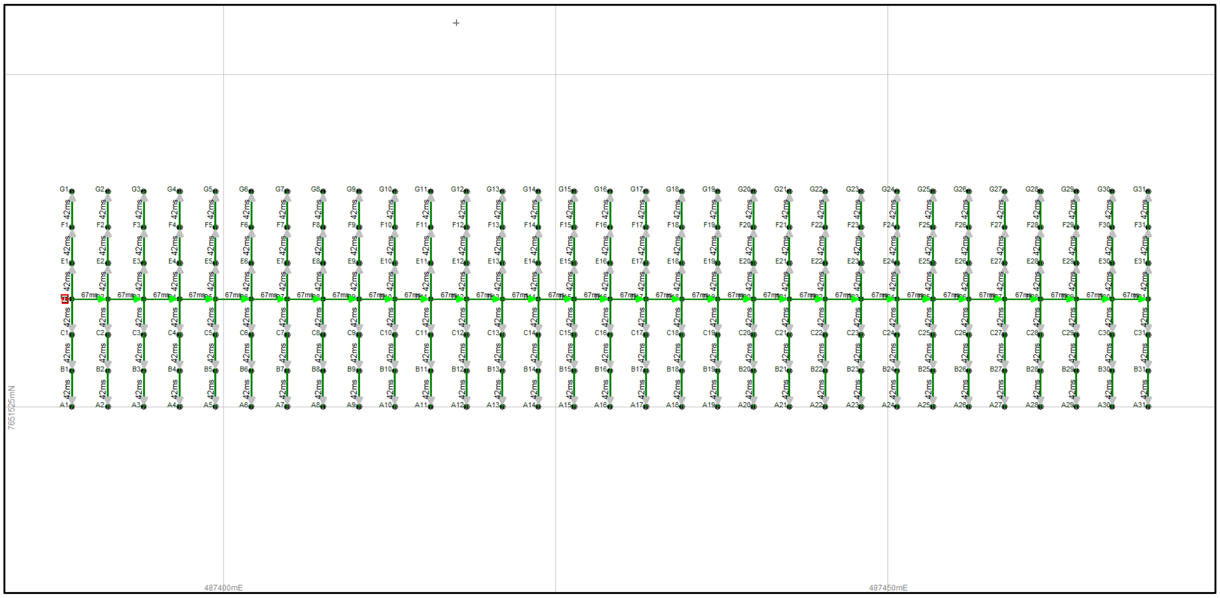


Figure 11: Blast Area with blastholes and blast timing

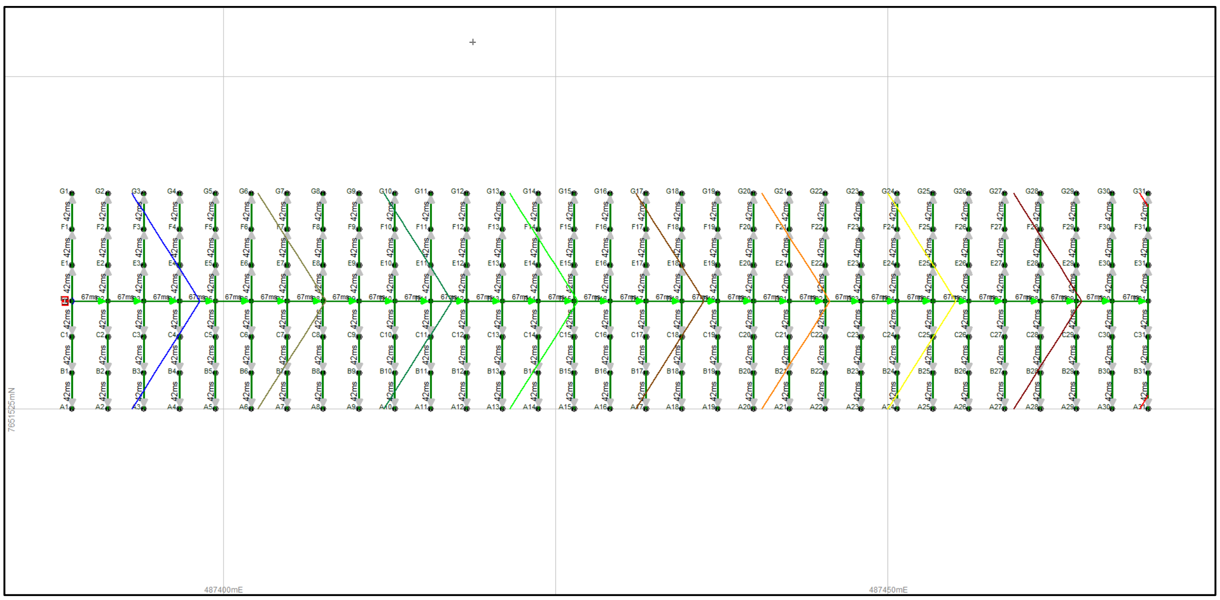


Figure 12: Blast simulated showing blast timing contours

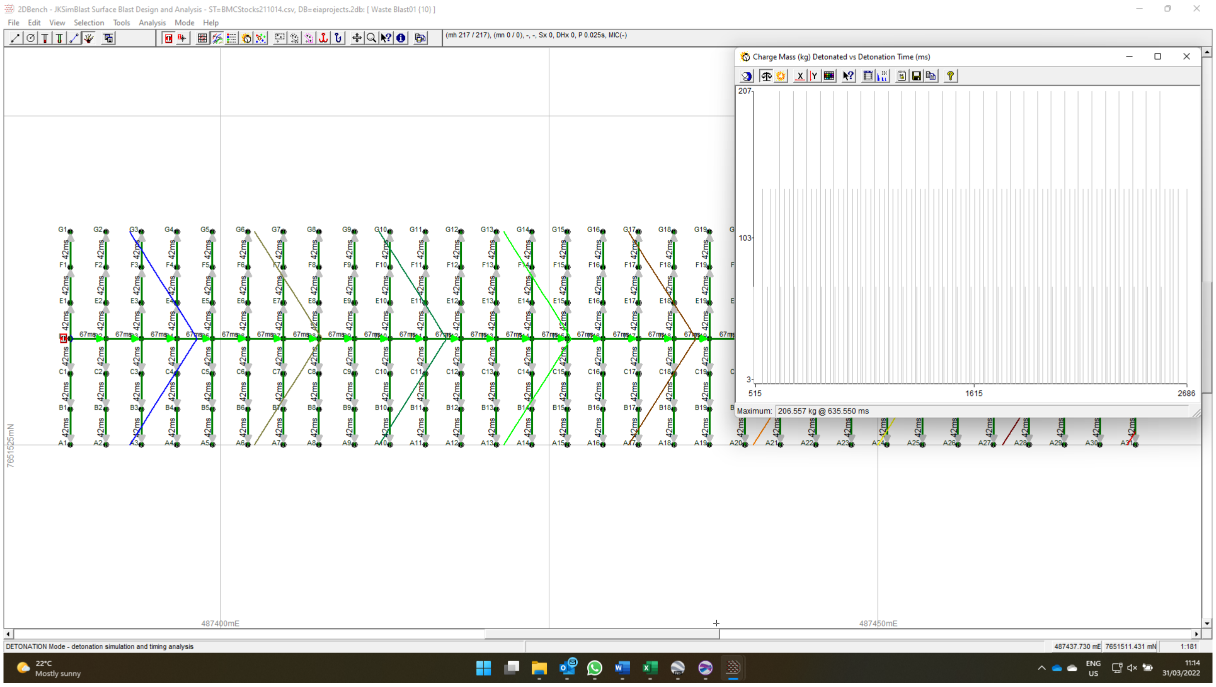


Figure 13: Blast simulated showing maximum charge mass per delay

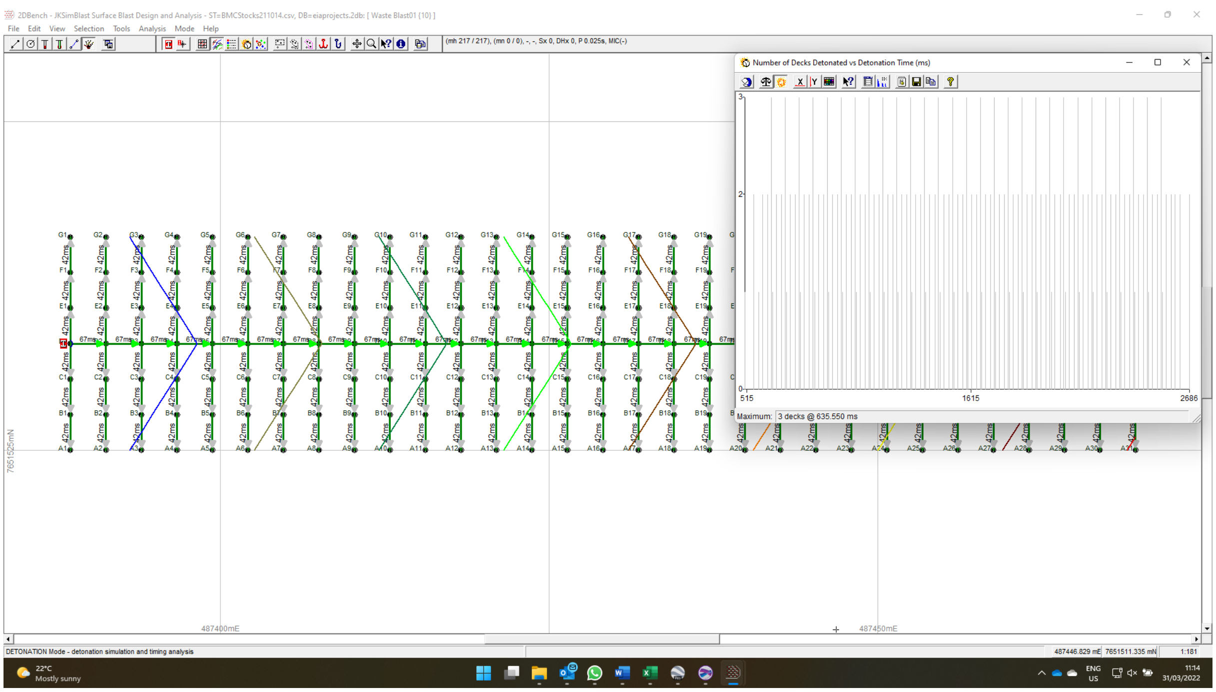


Figure 14: Blast simulated showing maximum number of blastholes per delay

The simulation work done provided information that is applied for predicting ground vibration and air blast. Evaluation of the blasting operations considered a minimum charge and a maximum charge. The minimum charge was derived from the 89 mm diameter single blast hole and the maximum charge was determined from a shock tube timing. The maximum charge relates to the total number of blast holes that detonates simultaneously based on the blast layout and initiation timing of the blast. Thus, the maximum mass of explosives detonating at once. The minimum charge relates to 69 kg and the maximum charge relates to 207 kg. These values were applied in all predictions for ground vibration and air blast.

14.1 Ground Vibration

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. The site constants are specific to a site where blasting is to be done. In the absence of measured values an acceptable standard set of constants is applied.

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)

Applicable and accepted factors a and b for new operations 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 possible influence zone of the proposed 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 project area. Structure types and qualities vary greatly and this calls for limits to be considered as follows: 6 mm/s, 12.5 mm/s levels and 25 mm/s at least.

Based on the designs presented on expected drilling and charging design, the following Table 7 shows expected ground vibration levels (PPV) for various distances calculated at the two different charge masses. The charge masses are 69 kg and 207 kg for the Pit area.

Table 7: Expected Ground Vibration at Various Distances from Charges Applied in this Study

No.	Distance (m)	Expected PPV (mm/s) for 69 kg Charge	Expected PPV (mm/s) for 207 kg Charge
1	50.0	59.1	146.4
2	100.0	30.3	75.0

No.	Distance (m)	Expected PPV (mm/s) for 69 kg Charge	Expected PPV (mm/s) for 207 kg Charge
3	150.0	9.7	23.9
4	200.0	6.0	14.9
5	250.0	4.2	10.3
6	300.0	3.1	7.6
7	400.0	1.9	4.7
8	500.0	1.3	3.3
9	600.0	1.0	2.4
10	700.0	0.8	1.9
11	800.0	0.6	1.5
12	900.0	0.5	1.2
13	1000.0	0.4	1.0
14	1250.0	0.3	0.7
15	1500.0	0.2	0.5
16	1750.0	0.2	0.4
17	2000.0	0.1	0.3
18	2500.0	0.1	0.2
19	3000.0	0.1	0.2
20	3500.0	0.1	0.0

14.2 Air blast

The prediction of air blast as a pre-operational effect is difficult to define exactly. There are many variables that have influence on the outcome of air blast. Air blast is the direct result from 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 has an influence on the outcome of the result. 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 millibar. This equation does not take temperature or any weather conditions into account.
Equation 2:

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

Where:

P = Air blast level (mB)

D = Distance from source (m)

E = Maximum charge mass per delay (kg)

A = Constant - (14.3)

B = Constant – (-0.71)

The constants for A and B were then selected according to the information as provided in Figure 15 below. Various types of mining operations are expected to yield different results. The information provided in Figure 15 is based on detailed research that was conducted for each of the different types of mining environments. In this report, the data for “Metal Mine” was applied in the prediction or 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 15: 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.

As discussed earlier the prediction of air blast is very subjective. Following in Table 8 below is a summary of values predicted according to Equation 2.

Table 8: Air Blast Predicted Values

No.	Distance (m)	Air blast (dB) for 69 kg Charge	Air blast (dB) for 207 kg Charge
1	50.0	141.6	143.9
2	100.0	139.1	141.4
3	150.0	134.8	137.1
4	200.0	133.1	135.3
5	250.0	131.7	134.0
6	300.0	130.6	132.8
7	400.0	128.8	131.1
8	500.0	127.4	129.7
9	600.0	126.3	128.6
10	700.0	125.3	127.6
11	800.0	124.5	126.8
12	900.0	123.8	126.1
13	1000.0	123.1	125.4
14	1250.0	121.8	124.0
15	1500.0	120.7	122.9
16	1750.0	119.7	122.0
17	2000.0	118.9	121.1
18	2500.0	117.5	119.8
19	3000.0	116.4	118.6
20	3500.0	115.4	111.9

15 Operational Phase: Impact Assessment and Mitigation Measures

The area surrounding the proposed mining area 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. In evaluation, the charge mass scenarios selected as indicated in section 0 is considered with regards to ground vibration and air blast.

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.

15.1 Review of expected ground vibration

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 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 negligible possibility of influence.

Ground vibration is calculated and modelled for the pit area at the minimum and maximum charge mass at specific distances from the opencast mining area. The charge masses applied are according to blast designs discussed in Section 15. 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 opencast 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: 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 below.

15.1.1 Ground vibration minimum charge mass per delay – 69 kg

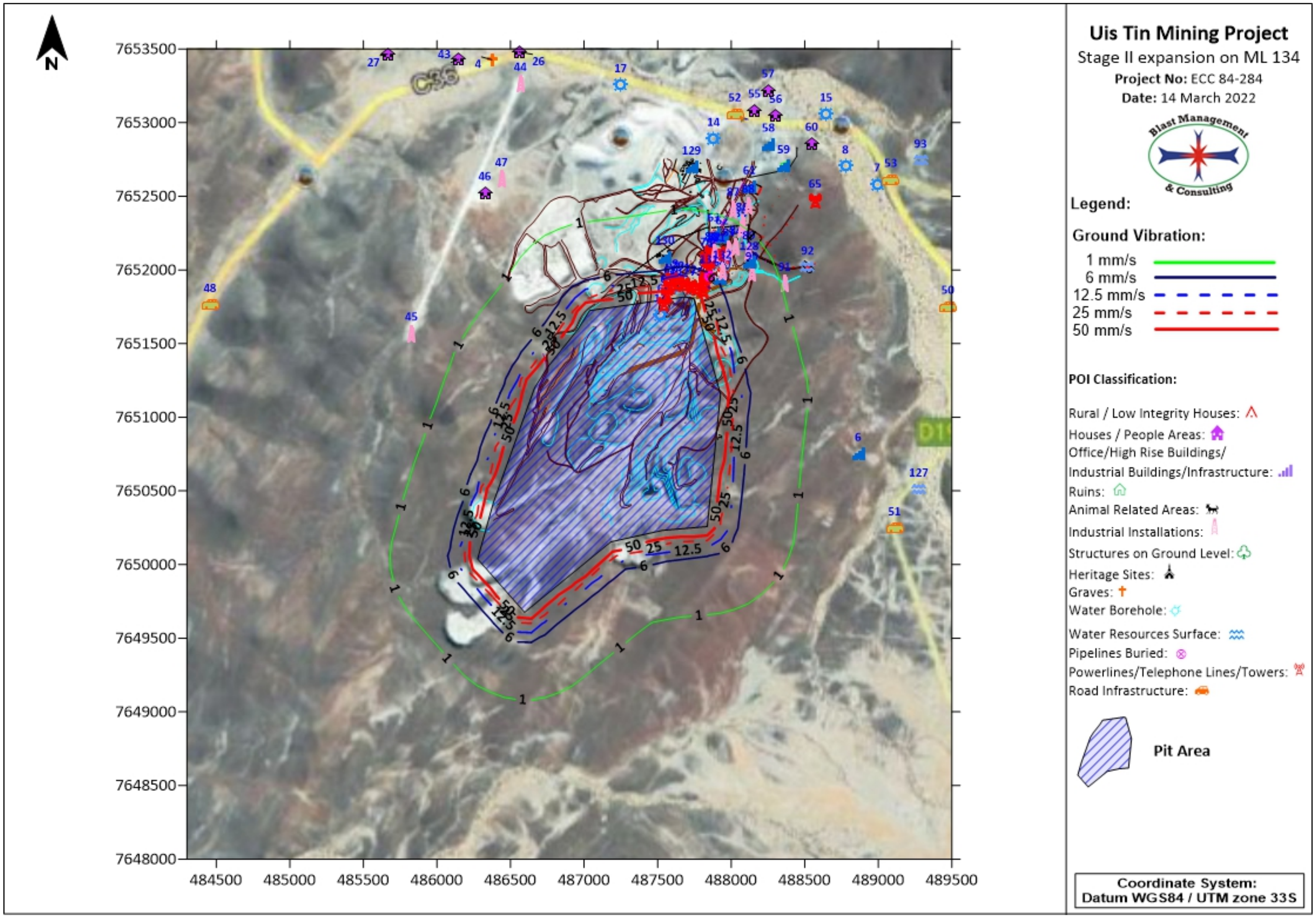


Figure 16: Ground vibration influence from minimum charge per delay

Table 9: Ground vibration evaluation for minimum charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Grave (1) - Site 312/847	50	2761	69	0.1	Acceptable	N/A
2	Graves (22) - Site 312/849	50	2397	69	0.1	Acceptable	N/A
3	Graves (100) - Site 312/893	50	3138	69	0.1	Acceptable	N/A
4	Graves (26) - Site 312/901	50	1830	69	0.2	Acceptable	N/A
5	Mine village - Site 312/900	12.5	2117	69	0.1	Acceptable	Too Low
6	Mine adit - Site 312/899	50	972	69	0.4	Acceptable	Too Low
7	Borehole (BH1)	50	1470	69	0.2	Acceptable	N/A
8	Borehole (BH2)	50	1367	69	0.3	Acceptable	N/A
9	Borehole (BH3)	50	2130	69	0.1	Acceptable	N/A
10	Borehole (BH4)	50	2141	69	0.1	Acceptable	N/A
11	Borehole (BH5)	50	2260	69	0.1	Acceptable	N/A
12	Borehole (BH6)	50	1747	69	0.2	Acceptable	N/A
13	Borehole (BH8) - Inside Pit Area	50	-	69	-	-	-
14	Borehole (BH9)	50	1092	69	0.4	Acceptable	N/A
15	Borehole (BH10)	50	1543	69	0.2	Acceptable	N/A
16	Borehole (BH11)	50	74	69	30.7	Acceptable	N/A
17	Borehole (BH12)	50	1486	69	0.2	Acceptable	N/A
18	Reservoir	50	2809	69	0.1	Acceptable	N/A
19	Buildings/Structures (Uis Elephant Guesthouse)	12.5	2311	69	0.1	Acceptable	Too Low
20	Guesthouse/Lodge	12.5	2235	69	0.1	Acceptable	Too Low
21	Church	12.5	2065	69	0.1	Acceptable	Too Low
22	Houses	12.5	2120	69	0.1	Acceptable	Too Low
23	Filling Station	12.5	1957	69	0.1	Acceptable	Too Low
24	Buildings/Structures (Brandberg Rest Camp)	12.5	2022	69	0.1	Acceptable	Too Low
25	Shopping Centre	50	1969	69	0.1	Acceptable	Too Low
26	Public (Riemvasmaak Community Conservancy)	25	1822	69	0.2	Acceptable	Too Low
27	Buildings/Structures	12.5	2220	69	0.1	Acceptable	Too Low
28	Reservoir	50	2597	69	0.1	Acceptable	N/A
29	Building/Structure	12.5	2654	69	0.1	Acceptable	Too Low
30	Public (Campsite and B&B)	25	2546	69	0.1	Acceptable	Too Low
31	Buildings/Structures	12.5	2725	69	0.1	Acceptable	Too Low
32	Houses	12.5	2163	69	0.1	Acceptable	Too Low
33	Houses	12.5	2304	69	0.1	Acceptable	Too Low
34	Houses	12.5	2417	69	0.1	Acceptable	Too Low
35	Houses	12.5	2427	69	0.1	Acceptable	Too Low
36	Houses	12.5	2185	69	0.1	Acceptable	Too Low
37	Houses	12.5	2112	69	0.1	Acceptable	Too Low
38	Shopping Centre	50	2069	69	0.1	Acceptable	Too Low
39	Swimming Pool	25	2057	69	0.1	Acceptable	Too Low
40	Buildings/Structures	12.5	2643	69	0.1	Acceptable	Too Low

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
41	Houses	12.5	2444	69	0.1	Acceptable	Too Low
42	Houses	12.5	2358	69	0.1	Acceptable	Too Low
43	Structure	12.5	1927	69	0.1	Acceptable	Too Low
44	Runway	150	1612	69	0.2	Acceptable	Too Low
45	Runway	150	912	69	0.5	Acceptable	Too Low
46	Buildings/Structures	12.5	1070	69	0.4	Acceptable	Too Low
47	Heli Pad	150	1075	69	0.4	Acceptable	Too Low
48	C35 Road	150	2265	69	0.1	Acceptable	N/A
49	M76 Road	150	2483	69	0.1	Acceptable	N/A
50	D1930 Road	150	1650	69	0.2	Acceptable	N/A
51	D1930 Road	150	1269	69	0.3	Acceptable	N/A
52	C36 Road	150	1284	69	0.3	Acceptable	N/A
53	D3714 Road	150	1565	69	0.2	Acceptable	N/A
54	Tailings Dam	25	1982	69	0.1	Acceptable	Too Low
55	Buildings/Structures	12.5	1344	69	0.3	Acceptable	Too Low
56	Buildings/Structures	12.5	1362	69	0.3	Acceptable	Too Low
57	Buildings/Structures	12.5	1502	69	0.2	Acceptable	Too Low
58	Industrial Structures (Mine)	25	1164	69	0.3	Acceptable	Too Low
59	Sub Station	25	1089	69	0.4	Acceptable	Too Low
60	Buildings/Structures	12.5	1324	69	0.3	Acceptable	Too Low
61	Mine Buildings/Structures	25	847	69	0.6	Acceptable	Too Low
62	Mine Buildings/Structures	25	460	69	1.5	Acceptable	Perceptible
63	Mine Buildings/Structures	25	461	69	1.5	Acceptable	Perceptible
64	Mine Buildings/Structures	25	223	69	5.0	Acceptable	Perceptible
65	Communication Tower	25	1061	69	0.4	Acceptable	N/A
66	Power Lines/Pylons - Inside Pit Area	75	-	69	-	-	-
67	Power Lines/Pylons	75	25	69	189.6	Problematic	N/A
68	Power Lines/Pylons	75	83	69	25.5	Acceptable	N/A
69	Power Lines/Pylons	75	123	69	13.4	Acceptable	N/A
70	Power Lines/Pylons	75	105	69	17.3	Acceptable	N/A
71	Power Lines/Pylons	75	87	69	23.5	Acceptable	N/A
72	Power Lines/Pylons	75	78	69	28.2	Acceptable	N/A
73	Power Lines/Pylons	75	72	69	32.5	Acceptable	N/A
74	Power Lines/Pylons	75	87	69	23.7	Acceptable	N/A
75	Power Lines/Pylons	75	136	69	11.3	Acceptable	N/A
76	Power Lines/Pylons	75	174	69	7.6	Acceptable	N/A
77	Power Lines/Pylons	75	229	69	4.8	Acceptable	N/A
78	Power Lines/Pylons	75	280	69	3.4	Acceptable	N/A
79	Power Lines/Pylons	75	285	69	3.3	Acceptable	N/A
80	Power Lines/Pylons	75	331	69	2.6	Acceptable	N/A
81	Power Lines/Pylons	75	347	69	2.4	Acceptable	N/A
82	Stormwater Canal	150	339	69	2.5	Acceptable	N/A
83	Stormwater Canal	150	412	69	1.8	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
84	Stormwater Canal	150	452	69	1.6	Acceptable	N/A
85	Stormwater Canal	150	566	69	1.1	Acceptable	N/A
86	Stormwater Canal	150	607	69	1.0	Acceptable	N/A
87	Stormwater Canal	150	667	69	0.8	Acceptable	N/A
88	Stormwater Canal	150	734	69	0.7	Acceptable	N/A
89	Stormwater Canal	150	490	69	1.4	Acceptable	N/A
90	Stormwater Canal	150	431	69	1.7	Acceptable	N/A
91	Stormwater Canal	150	622	69	0.9	Acceptable	N/A
92	Reservoir	50	803	69	0.6	Acceptable	N/A
93	Dams	50	1805	69	0.2	Acceptable	N/A
94	Buildings/Structures (Clinic)	12.5	2002	69	0.1	Acceptable	Too Low
95	Ruins	6	1936	69	0.1	Acceptable	N/A
96	Reservoir	50	2051	69	0.1	Acceptable	N/A
97	Houses	12.5	2093	69	0.1	Acceptable	Too Low
98	Houses	12.5	2137	69	0.1	Acceptable	Too Low
99	Houses	12.5	2183	69	0.1	Acceptable	Too Low
100	Houses	12.5	2195	69	0.1	Acceptable	Too Low
101	Buildings/Structures	12.5	2308	69	0.1	Acceptable	Too Low
102	Houses	12.5	2464	69	0.1	Acceptable	Too Low
103	Houses	12.5	2759	69	0.1	Acceptable	Too Low
104	Houses	12.5	2951	69	0.1	Acceptable	Too Low
105	Houses	12.5	2907	69	0.1	Acceptable	Too Low
106	Houses	12.5	2571	69	0.1	Acceptable	Too Low
107	Houses	12.5	2549	69	0.1	Acceptable	Too Low
108	Houses	12.5	2650	69	0.1	Acceptable	Too Low
109	Houses	12.5	2380	69	0.1	Acceptable	Too Low
110	Houses	12.5	2469	69	0.1	Acceptable	Too Low
111	Houses	12.5	2461	69	0.1	Acceptable	Too Low
112	Houses	12.5	2673	69	0.1	Acceptable	Too Low
113	Houses	12.5	2493	69	0.1	Acceptable	Too Low
114	Houses	12.5	2364	69	0.1	Acceptable	Too Low
115	Houses	12.5	2270	69	0.1	Acceptable	Too Low
116	Houses	12.5	2387	69	0.1	Acceptable	Too Low
117	Houses	12.5	2685	69	0.1	Acceptable	Too Low
118	Houses	12.5	2812	69	0.1	Acceptable	Too Low
119	Buildings/Structures	12.5	2752	69	0.1	Acceptable	Too Low
120	Buildings/Structures	12.5	2797	69	0.1	Acceptable	Too Low
121	Buildings/Structures	12.5	2742	69	0.1	Acceptable	Too Low
122	Houses	12.5	2633	69	0.1	Acceptable	Too Low
123	Buildings/Structures	12.5	2223	69	0.1	Acceptable	Too Low
124	Buildings/Structures	12.5	2528	69	0.1	Acceptable	Too Low
125	Graveyard	50	4226	69	0.0	Acceptable	N/A
126	School	25	1995	69	0.1	Acceptable	Too Low
127	Reservoir	50	1407	69	0.2	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
128	Old Sub Station	25	450	69	1.6	Acceptable	N/A
129	Old Abandoned Mine Structures	25	882	69	0.5	Acceptable	N/A
130	Old Abandoned Mine Structures	25	287	69	3.3	Acceptable	N/A
131	Fibre Optical Cable	50	186	69	6.8	Acceptable	N/A
132	Primary Crusher	200	269	69	3.7	Acceptable	N/A

15.1.2 Ground vibration maximum charge mass per delay – 207 kg

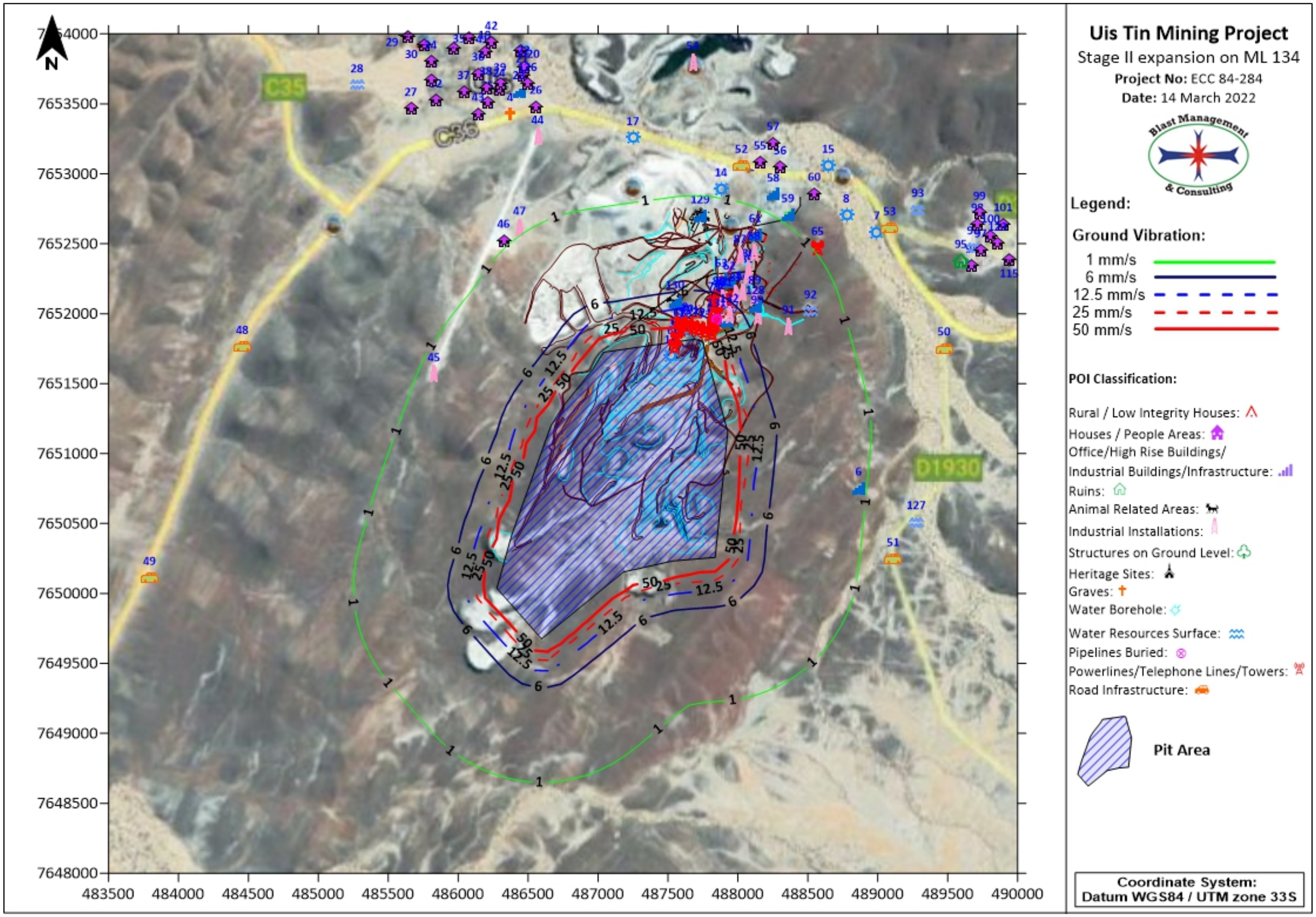


Figure 17: Ground vibration influence from maximum charge per delay

Table 10: Ground vibration evaluation for maximum charge

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
1	Grave (1) - Site 312/847	50	2761	207	0.2	Acceptable	N/A
2	Graves (22) - Site 312/849	50	2397	207	0.2	Acceptable	N/A
3	Graves (100) - Site 312/893	50	3138	207	0.2	Acceptable	N/A
4	Graves (26) - Site 312/901	50	1830	207	0.4	Acceptable	N/A
5	Mine village - Site 312/900	12.5	2117	207	0.3	Acceptable	Too Low
6	Mine adit - Site 312/899	50	972	207	1.1	Acceptable	Perceptible
7	Borehole (BH1)	50	1470	207	0.6	Acceptable	N/A
8	Borehole (BH2)	50	1367	207	0.6	Acceptable	N/A
9	Borehole (BH3)	50	2130	207	0.3	Acceptable	N/A
10	Borehole (BH4)	50	2141	207	0.3	Acceptable	N/A
11	Borehole (BH5)	50	2260	207	0.3	Acceptable	N/A
12	Borehole (BH6)	50	1747	207	0.4	Acceptable	N/A
13	Borehole (BH8) - Inside Pit Area	50	-	207	-	-	-
14	Borehole (BH9)	50	1092	207	0.9	Acceptable	N/A
15	Borehole (BH10)	50	1543	207	0.5	Acceptable	N/A
16	Borehole (BH11)	50	74	207	76.0	Problematic	N/A
17	Borehole (BH12)	50	1486	207	0.5	Acceptable	N/A
18	Reservoir	50	2809	207	0.2	Acceptable	N/A
19	Buildings/Structures (Uis Elephant Guesthouse)	12.5	2311	207	0.3	Acceptable	Too Low
20	Guesthouse/Lodge	12.5	2235	207	0.3	Acceptable	Too Low
21	Church	12.5	2065	207	0.3	Acceptable	Too Low
22	Houses	12.5	2120	207	0.3	Acceptable	Too Low
23	Filling Station	12.5	1957	207	0.3	Acceptable	Too Low
24	Buildings/Structures (Brandberg Rest Camp)	12.5	2022	207	0.3	Acceptable	Too Low
25	Shopping Centre	50	1969	207	0.3	Acceptable	Too Low
26	Public (Riemvasmaak Community Conservancy)	25	1822	207	0.4	Acceptable	Too Low
27	Buildings/Structures	12.5	2220	207	0.3	Acceptable	Too Low
28	Reservoir	50	2597	207	0.2	Acceptable	N/A
29	Building/Structure	12.5	2654	207	0.2	Acceptable	Too Low
30	Public (Campsite and B&B)	25	2546	207	0.2	Acceptable	Too Low
31	Buildings/Structures	12.5	2725	207	0.2	Acceptable	Too Low
32	Houses	12.5	2163	207	0.3	Acceptable	Too Low
33	Houses	12.5	2304	207	0.3	Acceptable	Too Low
34	Houses	12.5	2417	207	0.2	Acceptable	Too Low
35	Houses	12.5	2427	207	0.2	Acceptable	Too Low
36	Houses	12.5	2185	207	0.3	Acceptable	Too Low
37	Houses	12.5	2112	207	0.3	Acceptable	Too Low
38	Shopping Centre	50	2069	207	0.3	Acceptable	Too Low
39	Swimming Pool	25	2057	207	0.3	Acceptable	Too Low
40	Buildings/Structures	12.5	2643	207	0.2	Acceptable	Too Low

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
41	Houses	12.5	2444	207	0.2	Acceptable	Too Low
42	Houses	12.5	2358	207	0.3	Acceptable	Too Low
43	Structure	12.5	1927	207	0.4	Acceptable	Too Low
44	Runway	150	1612	207	0.5	Acceptable	Too Low
45	Runway	150	912	207	1.2	Acceptable	Perceptible
46	Buildings/Structures	12.5	1070	207	0.9	Acceptable	Perceptible
47	Heli Pad	150	1075	207	0.9	Acceptable	Perceptible
48	C35 Road	150	2265	207	0.3	Acceptable	N/A
49	M76 Road	150	2483	207	0.2	Acceptable	N/A
50	D1930 Road	150	1650	207	0.5	Acceptable	N/A
51	D1930 Road	150	1269	207	0.7	Acceptable	N/A
52	C36 Road	150	1284	207	0.7	Acceptable	N/A
53	D3714 Road	150	1565	207	0.5	Acceptable	N/A
54	Tailings Dam	25	1982	207	0.3	Acceptable	Too Low
55	Buildings/Structures	12.5	1344	207	0.6	Acceptable	Too Low
56	Buildings/Structures	12.5	1362	207	0.6	Acceptable	Too Low
57	Buildings/Structures	12.5	1502	207	0.5	Acceptable	Too Low
58	Industrial Structures (Mine)	25	1164	207	0.8	Acceptable	Perceptible
59	Sub Station	25	1089	207	0.9	Acceptable	Perceptible
60	Buildings/Structures	12.5	1324	207	0.7	Acceptable	Too Low
61	Mine Buildings/Structures	25	847	207	1.4	Acceptable	Perceptible
62	Mine Buildings/Structures	25	460	207	3.8	Acceptable	Perceptible
63	Mine Buildings/Structures	25	461	207	3.8	Acceptable	Perceptible
64	Mine Buildings/Structures	25	223	207	12.4	Acceptable	Unpleasant
65	Communication Tower	25	1061	207	0.9	Acceptable	N/A
66	Power Lines/Pylons - Inside Pit Area	75	-	207	-	-	-
67	Power Lines/Pylons	75	25	207	469.3	Problematic	N/A
68	Power Lines/Pylons	75	83	207	63.1	Acceptable	N/A
69	Power Lines/Pylons	75	123	207	33.1	Acceptable	N/A
70	Power Lines/Pylons	75	105	207	42.9	Acceptable	N/A
71	Power Lines/Pylons	75	87	207	58.3	Acceptable	N/A
72	Power Lines/Pylons	75	78	207	69.9	Acceptable	N/A
73	Power Lines/Pylons	75	72	207	80.5	Problematic	N/A
74	Power Lines/Pylons	75	87	207	58.6	Acceptable	N/A
75	Power Lines/Pylons	75	136	207	28.0	Acceptable	N/A
76	Power Lines/Pylons	75	174	207	18.8	Acceptable	N/A
77	Power Lines/Pylons	75	229	207	11.9	Acceptable	N/A
78	Power Lines/Pylons	75	280	207	8.5	Acceptable	N/A
79	Power Lines/Pylons	75	285	207	8.3	Acceptable	N/A
80	Power Lines/Pylons	75	331	207	6.5	Acceptable	N/A
81	Power Lines/Pylons	75	347	207	6.0	Acceptable	N/A
82	Stormwater Canal	150	339	207	6.2	Acceptable	N/A
83	Stormwater Canal	150	412	207	4.5	Acceptable	N/A
84	Stormwater Canal	150	452	207	3.9	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
85	Stormwater Canal	150	566	207	2.7	Acceptable	N/A
86	Stormwater Canal	150	607	207	2.4	Acceptable	N/A
87	Stormwater Canal	150	667	207	2.0	Acceptable	N/A
88	Stormwater Canal	150	734	207	1.7	Acceptable	N/A
89	Stormwater Canal	150	490	207	3.4	Acceptable	N/A
90	Stormwater Canal	150	431	207	4.2	Acceptable	N/A
91	Stormwater Canal	150	622	207	2.3	Acceptable	N/A
92	Reservoir	50	803	207	1.5	Acceptable	N/A
93	Dams	50	1805	207	0.4	Acceptable	N/A
94	Buildings/Structures (Clinic)	12.5	2002	207	0.3	Acceptable	Too Low
95	Ruins	6	1936	207	0.4	Acceptable	N/A
96	Reservoir	50	2051	207	0.3	Acceptable	N/A
97	Houses	12.5	2093	207	0.3	Acceptable	Too Low
98	Houses	12.5	2137	207	0.3	Acceptable	Too Low
99	Houses	12.5	2183	207	0.3	Acceptable	Too Low
100	Houses	12.5	2195	207	0.3	Acceptable	Too Low
101	Buildings/Structures	12.5	2308	207	0.3	Acceptable	Too Low
102	Houses	12.5	2464	207	0.2	Acceptable	Too Low
103	Houses	12.5	2759	207	0.2	Acceptable	Too Low
104	Houses	12.5	2951	207	0.2	Acceptable	Too Low
105	Houses	12.5	2907	207	0.2	Acceptable	Too Low
106	Houses	12.5	2571	207	0.2	Acceptable	Too Low
107	Houses	12.5	2549	207	0.2	Acceptable	Too Low
108	Houses	12.5	2650	207	0.2	Acceptable	Too Low
109	Houses	12.5	2380	207	0.2	Acceptable	Too Low
110	Houses	12.5	2469	207	0.2	Acceptable	Too Low
111	Houses	12.5	2461	207	0.2	Acceptable	Too Low
112	Houses	12.5	2673	207	0.2	Acceptable	Too Low
113	Houses	12.5	2493	207	0.2	Acceptable	Too Low
114	Houses	12.5	2364	207	0.3	Acceptable	Too Low
115	Houses	12.5	2270	207	0.3	Acceptable	Too Low
116	Houses	12.5	2387	207	0.2	Acceptable	Too Low
117	Houses	12.5	2685	207	0.2	Acceptable	Too Low
118	Houses	12.5	2812	207	0.2	Acceptable	Too Low
119	Buildings/Structures	12.5	2752	207	0.2	Acceptable	Too Low
120	Buildings/Structures	12.5	2797	207	0.2	Acceptable	Too Low
121	Buildings/Structures	12.5	2742	207	0.2	Acceptable	Too Low
122	Houses	12.5	2633	207	0.2	Acceptable	Too Low
123	Buildings/Structures	12.5	2223	207	0.3	Acceptable	Too Low
124	Buildings/Structures	12.5	2528	207	0.2	Acceptable	Too Low
125	Graveyard	50	4226	207	0.1	Acceptable	N/A
126	School	25	1995	207	0.3	Acceptable	Too Low
127	Reservoir	50	1407	207	0.6	Acceptable	N/A
128	Old Sub Station	25	450	207	3.9	Acceptable	N/A
129	Old Abandoned Mine Structures	25	882	207	1.3	Acceptable	N/A

Tag	Description	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz	Human Tolerance @ 30Hz
130	Old Abandoned Mine Structures	25	287	207	8.2	Acceptable	N/A
131	Fibre Optical Cable	50	186	207	16.7	Acceptable	N/A
132	Primary Crusher	200	269	207	9.1	Acceptable	N/A

15.2 Summary of ground vibration levels

The opencast operations were evaluated for expected levels of ground vibration from future blasting operations. Review of the site and the surrounding installations / houses / buildings showed that structures vary in distances from the pit area. The influences will also vary with distance from the pit area. The model used for evaluation does indicate significant levels. It will be imperative to ensure that a monitoring program is done to confirm levels of ground vibration to ensure that ground vibration levels are not exceeded.

The evaluation mainly considered a distance up to 3500 m from the pit area. The closest structures observed are the Power Lines, Boreholes, Fibre Optical Cable and Mine Buildings/Structures. The planned maximum charge evaluated showed that it could be problematic in terms of potential structural damage. The ground vibration levels predicted for these POI's ranged between 0.1 mm/s and 469.3 mm/s for structures surrounding the open pit area.

The distances between structures and the pit area are a contributing factor to the levels of ground vibration expected and the subsequent possible influences. It is observed that for the different charge masses evaluated those levels of ground vibration will change as well. In view of the minimum and maximum charge specific attention will need to be given to specific areas. The maximum charge indicated four POI's of concern in relation to possible structural damage.

The nearest public houses are located 1070 m from the Pit boundary. Ground vibration level predicted at this building where people may be present is 0.9 mm/s for the maximum charge. In view of this no specific mitigations will be required.

Structure conditions ranged from industrial construction to poor condition structures.

On a human perception scale three POI's were identified where vibration levels may be perceptible and lower for the minimum charge and nine POI's for the maximum charge. One POI was identified where vibration levels may be unpleasant for the maximum charge. Four POI's might be of concern to structural damage on maximum charge. Perceptible levels of vibration may be experienced up to 1000 m, unpleasant up to 300m and intolerable up to 150 m. Problematic levels of ground vibration – levels greater than the proposed limit – are expected up to 145 m from the pit edge for the maximum charge. Any blast operations further away from the boundary will have lesser influence on these points.

Mitigation of ground vibration was considered and discussed in Section 18.4. A detail inspection of the area and accurate identification of structures will also need to be done to ensure the levels of ground vibration allowable and limit to be applied.

15.3 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 18 below). 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 18 that up to a distance of 3485 m people may experience levels of ground vibration as perceptible. At 1225 m and closer the perception of ground vibration could be unpleasant. Closer than 620 m the levels will be intolerable and generally greater than limits applied for structures in the areas.

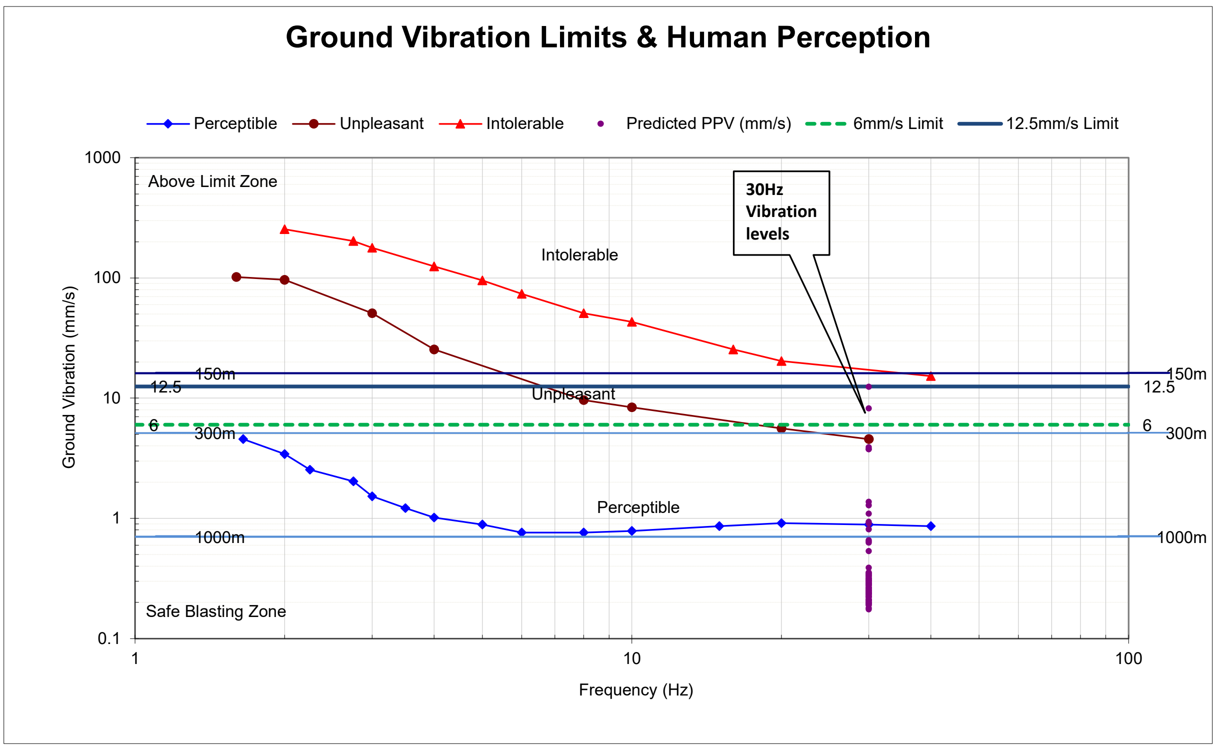


Figure 18: The effect of ground vibration with human perception and vibration limits

15.4 Vibration impact on roads

The C35, C36, D1930, D3714 and M76 roads, is at an approximate distance of 2265 m (C35), 1284 m (C36), 1269 m (D1930), 1565 m (D3714) and 2483 m (M76). No specific consideration regarding effects from blasting operations will be required for these roads.

15.5 Potential that vibration will upset adjacent communities

Ground vibration and air blast generally upset people living in the vicinity of mining operations. The nearest houses (POI 46) are approximately 1070 m from the planned operation. These buildings are located such that levels of ground vibration predicted are acceptable for structures but may be perceptible on a human perception level.

Ground vibration levels expected from maximum charge has possibility to be perceptible up to 1000 m. It is certain that lesser charges will reduce this distance for instance at minimum charge this distance is expected to be 699 m. Within these distance ranges there are no houses. The anticipated ground vibration levels are certain to have possibility of upsetting the house holds within these ranges. Intolerable levels are expected up to a distance of 150 m.

The importance of good public relations cannot be over emphasised. 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.

15.6 Cracking of houses and consequent devaluation

The structures found in the areas of concern ranges from informal building style to brick and mortar structures. There are various buildings 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.

The presence of general vertical cracks, horizontal and diagonal 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. 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.

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.

15.7 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 pit 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 dB;
    - "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 dB;
    - "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 each pit area. 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"

15.7.1 Air blast minimum charge mass per delay – 69 kg

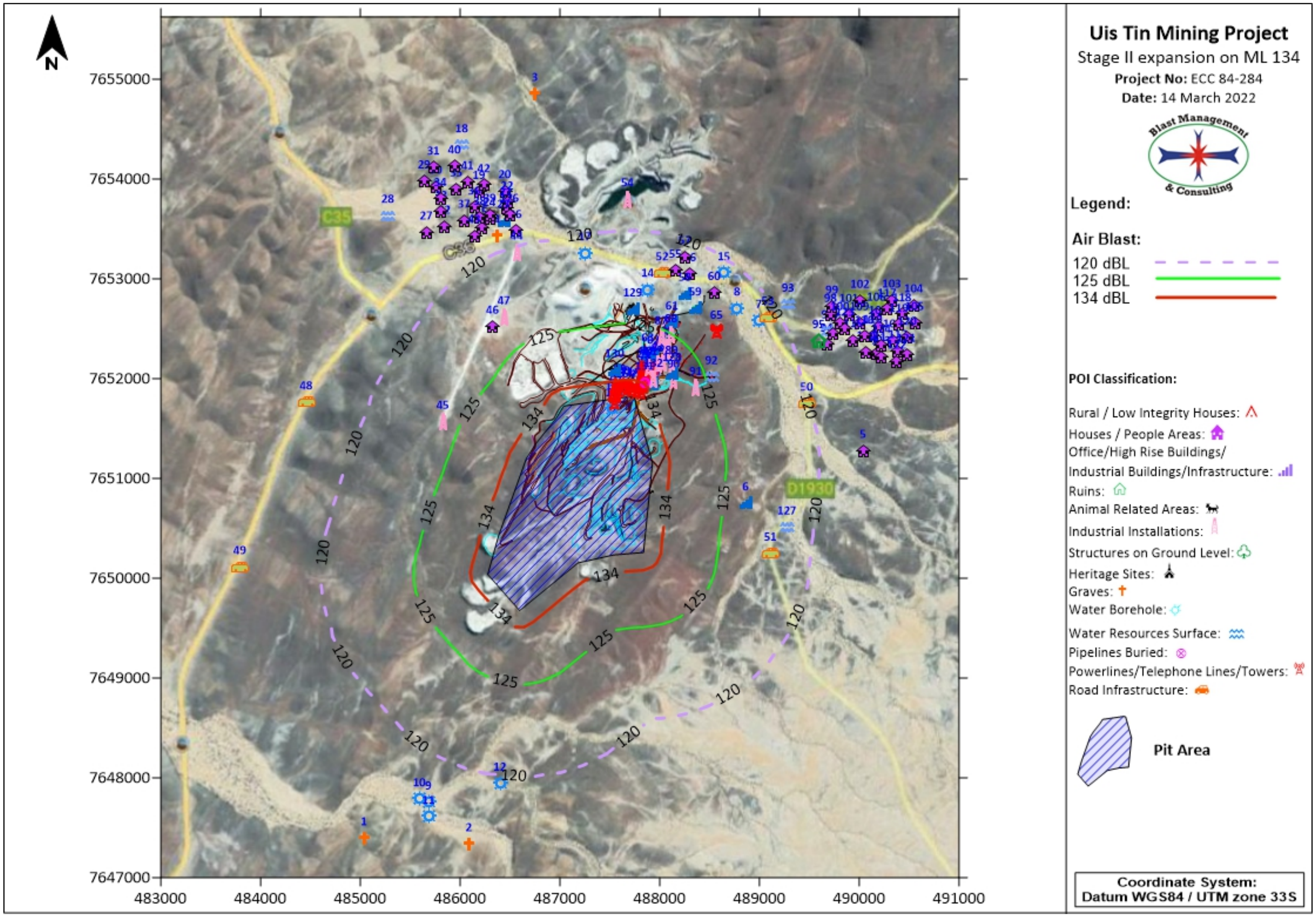


Figure 19: Air blast influence from minimum charge

Table 11: Air blast evaluation for minimum charge

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Grave (1) - Site 312/847	2761	116.9	N/A
2	Graves (22) - Site 312/849	2397	117.8	N/A
3	Graves (100) - Site 312/893	3138	116.1	N/A
4	Graves (26) - Site 312/901	1830	119.5	N/A
5	Mine village - Site 312/900	2117	118.5	N/A
6	Mine adit - Site 312/899	972	123.3	N/A
7	Borehole (BH1)	1470	120.8	N/A
8	Borehole (BH2)	1367	121.2	N/A
9	Borehole (BH3)	2130	118.5	N/A
10	Borehole (BH4)	2141	118.5	N/A
11	Borehole (BH5)	2260	118.1	N/A
12	Borehole (BH6)	1747	119.7	N/A
13	Borehole (BH8) - Inside Pit Area	-	-	-
14	Borehole (BH9)	1092	122.6	N/A
15	Borehole (BH10)	1543	120.5	N/A
16	Borehole (BH11)	74	139.2	N/A
17	Borehole (BH12)	1486	120.7	N/A
18	Reservoir	2809	116.8	N/A
19	Buildings/Structures (Uis Elephant Guesthouse)	2311	118.0	Acceptable
20	Guesthouse/Lodge	2235	118.2	Acceptable
21	Church	2065	118.7	Acceptable
22	Houses	2120	118.5	Acceptable
23	Filling Station	1957	119.0	Acceptable
24	Buildings/Structures (Brandberg Rest Camp)	2022	118.8	Acceptable
25	Shopping Centre	1969	119.0	Acceptable
26	Public (Riemvasmaak Community Conservancy)	1822	119.5	Acceptable
27	Buildings/Structures	2220	118.2	Acceptable
28	Reservoir	2597	117.3	N/A
29	Building/Structure	2654	117.2	Acceptable
30	Public (Campsite and B&B)	2546	117.4	Acceptable
31	Buildings/Structures	2725	117.0	Acceptable
32	Houses	2163	118.4	Acceptable
33	Houses	2304	118.0	Acceptable
34	Houses	2417	117.7	Acceptable
35	Houses	2427	117.7	Acceptable
36	Houses	2185	118.3	Acceptable
37	Houses	2112	118.5	Acceptable
38	Shopping Centre	2069	118.7	Acceptable
39	Swimming Pool	2057	118.7	N/A
40	Buildings/Structures	2643	117.2	Acceptable
41	Houses	2444	117.7	Acceptable
42	Houses	2358	117.9	Acceptable
43	Structure	1927	119.1	Acceptable
44	Runway	1612	120.2	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
45	Runway	912	123.7	N/A
46	Buildings/Structures	1070	122.7	Complaint
47	Heli Pad	1075	122.7	N/A
48	C35 Road	2265	118.1	N/A
49	M76 Road	2483	117.6	N/A
50	D1930 Road	1650	120.1	N/A
51	D1930 Road	1269	121.7	N/A
52	C36 Road	1284	121.6	N/A
53	D3714 Road	1565	120.4	N/A
54	Tailings Dam	1982	118.9	N/A
55	Buildings/Structures	1344	121.4	Complaint
56	Buildings/Structures	1362	121.2	Complaint
57	Buildings/Structures	1502	120.7	Complaint
58	Industrial Structures (Mine)	1164	122.2	Complaint
59	Sub Station	1089	122.6	N/A
60	Buildings/Structures	1324	121.4	Complaint
61	Mine Buildings/Structures	847	124.2	Complaint
62	Mine Buildings/Structures	460	127.9	Complaint
63	Mine Buildings/Structures	461	127.9	Complaint
64	Mine Buildings/Structures	223	132.4	Complaint
65	Communication Tower	1061	122.8	N/A
66	Power Lines/Pylons - Inside Pit Area	-	-	-
67	Power Lines/Pylons	25	146.0	N/A
68	Power Lines/Pylons	83	138.5	N/A
69	Power Lines/Pylons	123	136.1	N/A
70	Power Lines/Pylons	105	137.0	N/A
71	Power Lines/Pylons	87	138.2	N/A
72	Power Lines/Pylons	78	138.9	N/A
73	Power Lines/Pylons	72	139.4	N/A
74	Power Lines/Pylons	87	138.2	N/A
75	Power Lines/Pylons	136	135.4	N/A
76	Power Lines/Pylons	174	133.9	N/A
77	Power Lines/Pylons	229	132.2	N/A
78	Power Lines/Pylons	280	131.0	N/A
79	Power Lines/Pylons	285	130.9	N/A
80	Power Lines/Pylons	331	130.0	N/A
81	Power Lines/Pylons	347	129.7	N/A
82	Stormwater Canal	339	129.8	N/A
83	Stormwater Canal	412	128.6	N/A
84	Stormwater Canal	452	128.0	N/A
85	Stormwater Canal	566	126.7	N/A
86	Stormwater Canal	607	126.2	N/A
87	Stormwater Canal	667	125.6	N/A
88	Stormwater Canal	734	125.1	N/A
89	Stormwater Canal	490	127.6	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
90	Stormwater Canal	431	128.3	N/A
91	Stormwater Canal	622	126.1	N/A
92	Reservoir	803	124.5	N/A
93	Dams	1805	119.5	N/A
94	Buildings/Structures (Clinic)	2002	118.9	Acceptable
95	Ruins	1936	119.1	N/A
96	Reservoir	2051	118.7	N/A
97	Houses	2093	118.6	Acceptable
98	Houses	2137	118.5	Acceptable
99	Houses	2183	118.3	Acceptable
100	Houses	2195	118.3	Acceptable
101	Buildings/Structures	2308	118.0	Acceptable
102	Houses	2464	117.6	Acceptable
103	Houses	2759	116.9	Acceptable
104	Houses	2951	116.5	Acceptable
105	Houses	2907	116.6	Acceptable
106	Houses	2571	117.3	Acceptable
107	Houses	2549	117.4	Acceptable
108	Houses	2650	117.2	Acceptable
109	Houses	2380	117.8	Acceptable
110	Houses	2469	117.6	Acceptable
111	Houses	2461	117.6	Acceptable
112	Houses	2673	117.1	Acceptable
113	Houses	2493	117.5	Acceptable
114	Houses	2364	117.8	Acceptable
115	Houses	2270	118.1	Acceptable
116	Houses	2387	117.8	Acceptable
117	Houses	2685	117.1	Acceptable
118	Houses	2812	116.8	Acceptable
119	Buildings/Structures	2752	116.9	Acceptable
120	Buildings/Structures	2797	116.9	Acceptable
121	Buildings/Structures	2742	117.0	Acceptable
122	Houses	2633	117.2	Acceptable
123	Buildings/Structures	2223	118.2	Acceptable
124	Buildings/Structures	2528	117.5	Acceptable
125	Graveyard	4226	114.3	N/A
126	School	1995	118.9	Acceptable
127	Reservoir	1407	121.0	N/A
128	Old Sub Station	450	128.1	N/A
129	Old Abandoned Mine Structures	882	123.9	N/A
130	Old Abandoned Mine Structures	287	130.9	N/A
131	Fibre Optical Cable	186	133.5	N/A
132	Primary Crusher	269	131.2	N/A

15.7.2 Air blast maximum charge mass per delay – 207 kg

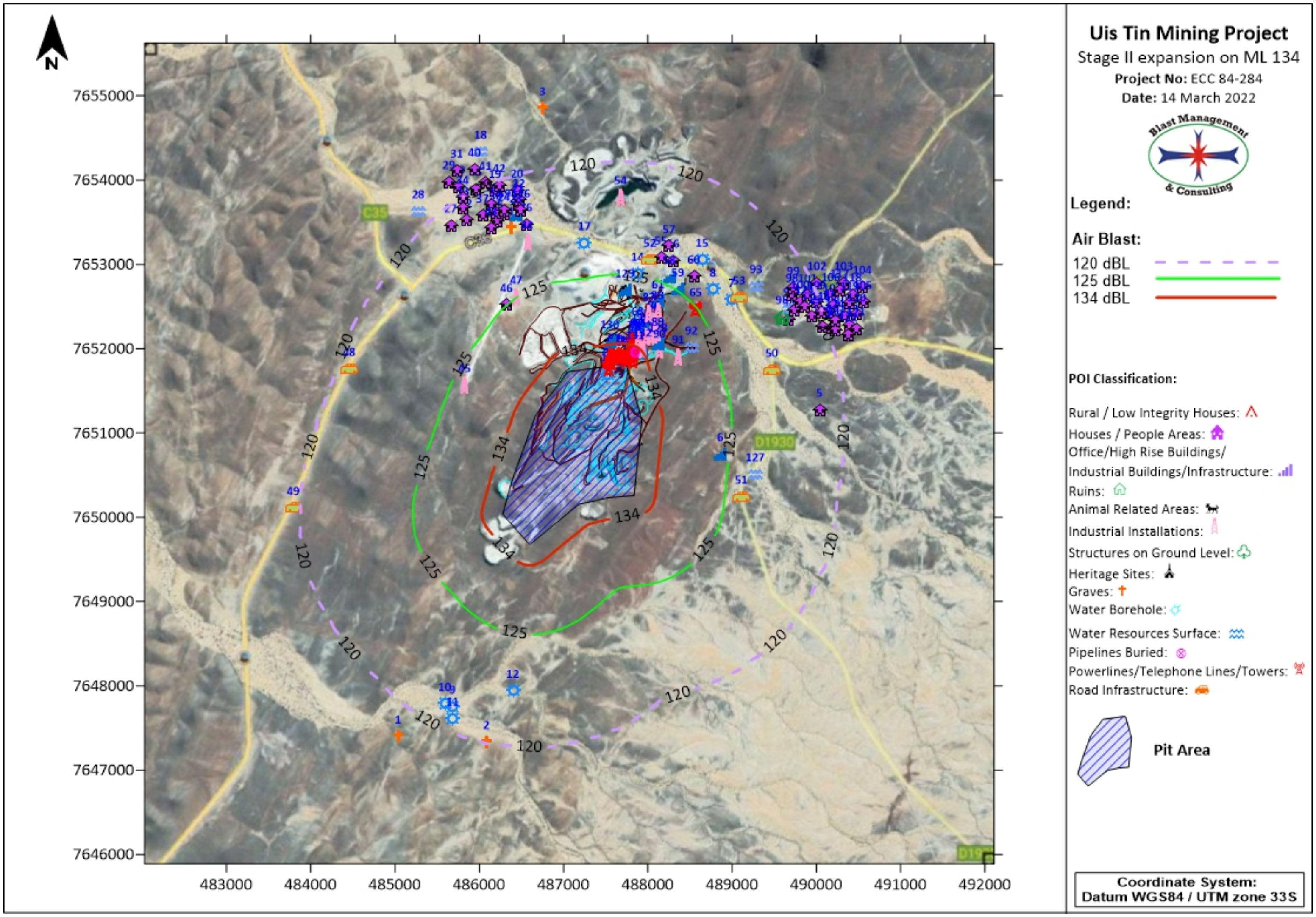


Figure 20: Air blast influence from maximum charge

Table 12: Air blast influence from maximum charge

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
1	Grave (1) - Site 312/847	2761	119.2	N/A
2	Graves (22) - Site 312/849	2397	120.0	N/A
3	Graves (100) - Site 312/893	3138	118.4	N/A
4	Graves (26) - Site 312/901	1830	121.7	N/A
5	Mine village - Site 312/900	2117	120.8	N/A
6	Mine adit - Site 312/899	972	125.6	N/A
7	Borehole (BH1)	1470	123.0	N/A
8	Borehole (BH2)	1367	123.5	N/A
9	Borehole (BH3)	2130	120.7	N/A
10	Borehole (BH4)	2141	120.7	N/A
11	Borehole (BH5)	2260	120.4	N/A
12	Borehole (BH6)	1747	122.0	N/A
13	Borehole (BH8) - Inside Pit Area	-	-	-
14	Borehole (BH9)	1092	124.9	N/A
15	Borehole (BH10)	1543	122.7	N/A
16	Borehole (BH11)	74	141.4	N/A
17	Borehole (BH12)	1486	123.0	N/A
18	Reservoir	2809	119.0	N/A
19	Buildings/Structures (Uis Elephant Guesthouse)	2311	120.2	Complaint
20	Guesthouse/Lodge	2235	120.5	Complaint
21	Church	2065	120.9	Complaint
22	Houses	2120	120.8	Complaint
23	Filling Station	1957	121.3	Complaint
24	Buildings/Structures (Brandberg Rest Camp)	2022	121.1	Complaint
25	Shopping Centre	1969	121.2	Complaint
26	Public (Riemvasmaak Community Conservancy)	1822	121.7	Complaint
27	Buildings/Structures	2220	120.5	Complaint
28	Reservoir	2597	119.6	N/A
29	Building/Structure	2654	119.4	Acceptable
30	Public (Campsite and B&B)	2546	119.6	Acceptable
31	Buildings/Structures	2725	119.2	Acceptable
32	Houses	2163	120.7	Complaint
33	Houses	2304	120.3	Complaint
34	Houses	2417	120.0	Acceptable
35	Houses	2427	120.0	Acceptable
36	Houses	2185	120.6	Complaint
37	Houses	2112	120.8	Complaint
38	Shopping Centre	2069	120.9	Complaint
39	Swimming Pool	2057	121.0	N/A
40	Buildings/Structures	2643	119.4	Acceptable
41	Houses	2444	119.9	Acceptable
42	Houses	2358	120.1	Complaint
43	Structure	1927	121.4	Complaint
44	Runway	1612	122.5	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
45	Runway	912	126.0	N/A
46	Buildings/Structures	1070	125.0	Complaint
47	Heli Pad	1075	125.0	N/A
48	C35 Road	2265	120.4	N/A
49	M76 Road	2483	119.8	N/A
50	D1930 Road	1650	122.3	N/A
51	D1930 Road	1269	124.0	N/A
52	C36 Road	1284	123.9	N/A
53	D3714 Road	1565	122.7	N/A
54	Tailings Dam	1982	121.2	N/A
55	Buildings/Structures	1344	123.6	Complaint
56	Buildings/Structures	1362	123.5	Complaint
57	Buildings/Structures	1502	122.9	Complaint
58	Industrial Structures (Mine)	1164	124.5	Complaint
59	Sub Station	1089	124.9	N/A
60	Buildings/Structures	1324	123.7	Complaint
61	Mine Buildings/Structures	847	126.4	Complaint
62	Mine Buildings/Structures	460	130.2	Complaint
63	Mine Buildings/Structures	461	130.2	Complaint
64	Mine Buildings/Structures	223	134.7	Problematic
65	Communication Tower	1061	125.1	N/A
66	Power Lines/Pylons - Inside Pit Area	-	-	-
67	Power Lines/Pylons	25	148.2	N/A
68	Power Lines/Pylons	83	140.7	N/A
69	Power Lines/Pylons	123	138.3	N/A
70	Power Lines/Pylons	105	139.3	N/A
71	Power Lines/Pylons	87	140.4	N/A
72	Power Lines/Pylons	78	141.1	N/A
73	Power Lines/Pylons	72	141.6	N/A
74	Power Lines/Pylons	87	140.5	N/A
75	Power Lines/Pylons	136	137.7	N/A
76	Power Lines/Pylons	174	136.2	N/A
77	Power Lines/Pylons	229	134.5	N/A
78	Power Lines/Pylons	280	133.2	N/A
79	Power Lines/Pylons	285	133.1	N/A
80	Power Lines/Pylons	331	132.2	N/A
81	Power Lines/Pylons	347	131.9	N/A
82	Stormwater Canal	339	132.1	N/A
83	Stormwater Canal	412	130.9	N/A
84	Stormwater Canal	452	130.3	N/A
85	Stormwater Canal	566	128.9	N/A
86	Stormwater Canal	607	128.5	N/A
87	Stormwater Canal	667	127.9	N/A
88	Stormwater Canal	734	127.3	N/A
89	Stormwater Canal	490	129.8	N/A
90	Stormwater Canal	431	130.6	N/A

Tag	Description	Distance (m)	Air blast (dB)	Possible Concern?
91	Stormwater Canal	622	128.3	N/A
92	Reservoir	803	126.8	N/A
93	Dams	1805	121.8	N/A
94	Buildings/Structures (Clinic)	2002	121.1	Complaint
95	Ruins	1936	121.4	N/A
96	Reservoir	2051	121.0	N/A
97	Houses	2093	120.9	Complaint
98	Houses	2137	120.7	Complaint
99	Houses	2183	120.6	Complaint
100	Houses	2195	120.6	Complaint
101	Buildings/Structures	2308	120.2	Complaint
102	Houses	2464	119.9	Acceptable
103	Houses	2759	119.2	Acceptable
104	Houses	2951	118.7	Acceptable
105	Houses	2907	118.8	Acceptable
106	Houses	2571	119.6	Acceptable
107	Houses	2549	119.6	Acceptable
108	Houses	2650	119.4	Acceptable
109	Houses	2380	120.1	Complaint
110	Houses	2469	119.9	Acceptable
111	Houses	2461	119.9	Acceptable
112	Houses	2673	119.4	Acceptable
113	Houses	2493	119.8	Acceptable
114	Houses	2364	120.1	Complaint
115	Houses	2270	120.4	Complaint
116	Houses	2387	120.0	Acceptable
117	Houses	2685	119.3	Acceptable
118	Houses	2812	119.0	Acceptable
119	Buildings/Structures	2752	119.2	Acceptable
120	Buildings/Structures	2797	119.1	Acceptable
121	Buildings/Structures	2742	119.2	Acceptable
122	Houses	2633	119.5	Acceptable
123	Buildings/Structures	2223	120.5	Complaint
124	Buildings/Structures	2528	119.7	Acceptable
125	Graveyard	4226	116.5	N/A
126	School	1995	121.2	Complaint
127	Reservoir	1407	123.3	N/A
128	Old Sub Station	450	130.3	N/A
129	Old Abandoned Mine Structures	882	126.2	N/A
130	Old Abandoned Mine Structures	287	133.1	N/A
131	Fibre Optical Cable	186	135.8	N/A
132	Primary Crusher	269	133.5	N/A

15.8 Summary of findings for air blast

Review of the air blast levels indicate more concerns. Air blast predicted for the maximum charge ranges between 116.5 and 134.7 dB for all the POI's considered. This includes the nearest points such as the Mine Buildings/Structures.

The general accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134 dBL. Prediction shows that air blast will be greater than 134 dB at distance of 223 m and closer to pit boundary. Infrastructure at the pit areas such as roads, power lines/pylons are present, but air blast does not have any influence on these installations.

The nearest private structures are located 1324 m from pit edge. Air blast levels from maximum charge is expected to be within the accepted limit but slightly greater than 120 dB. This may contribute to some complaints. All other private structures are further away and levels decrease over distance. Levels are expected to be less than 120 dB at distance of 2387 m from the pit edge.

The possible negative effects from air blast are expected to be the same than that of ground vibration. It is maintained that if stemming control is not exercised this effect could be greater with greater range of complaints or damage. The pit is located such that "free blasting" – meaning no controls on blast preparation – will not be possible. The effect of stemming control will need to be considered. In many cases the lack of proper control on stemming material and length contributes mostly to complaints from neighbours.

15.9 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 or 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 qualified and determined as best possible.

Calculations are also 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 21 shows the results from the ISEE calculations for fly rock range based on an 89 mm diameter blast hole and 1.5 m stemming length. Based on these values a possible fly rock range with a safety factor of 2 was calculated to be 388 m. The absolute minimum unsafe zone is then the 388 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 22 shows the area around the Pit area that incorporates the 388 m unsafe zone.

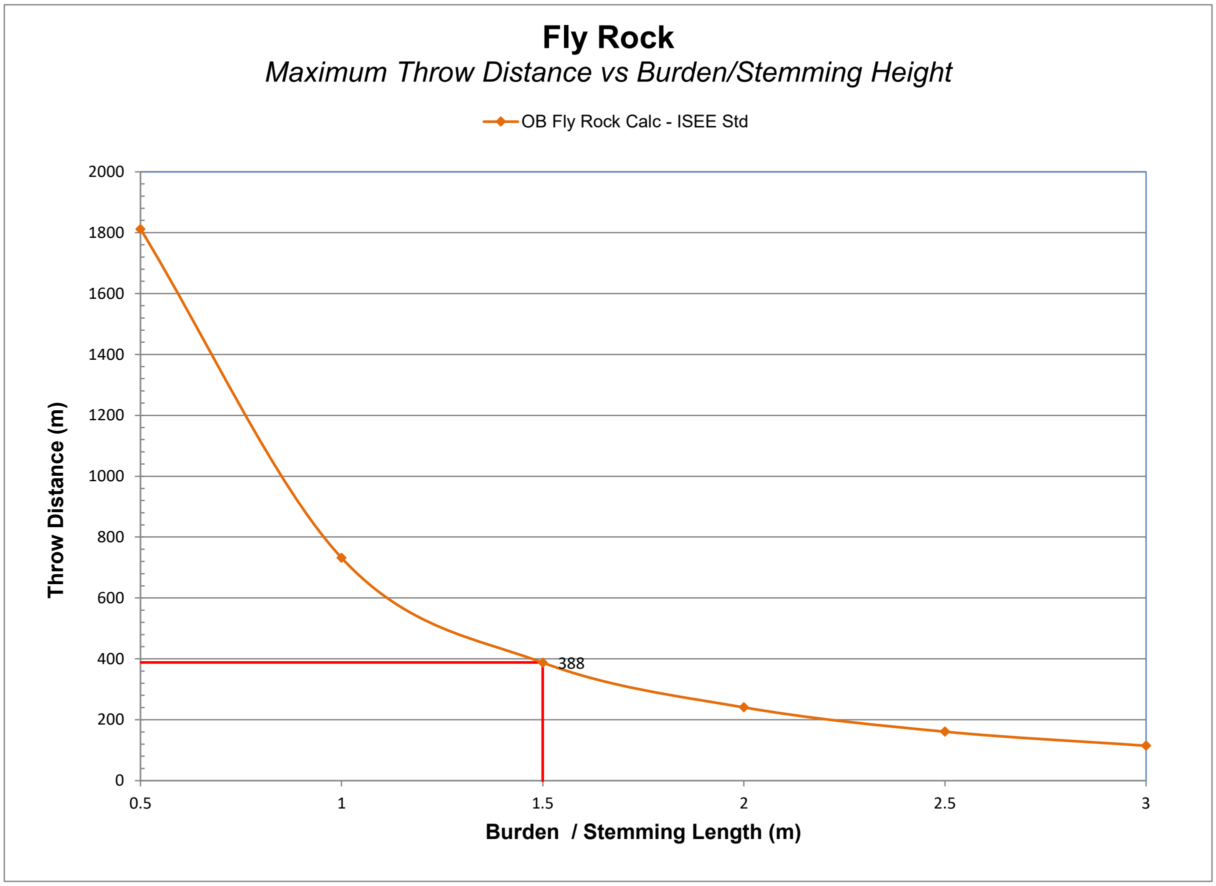


Figure 21: Fly rock prediction calculation

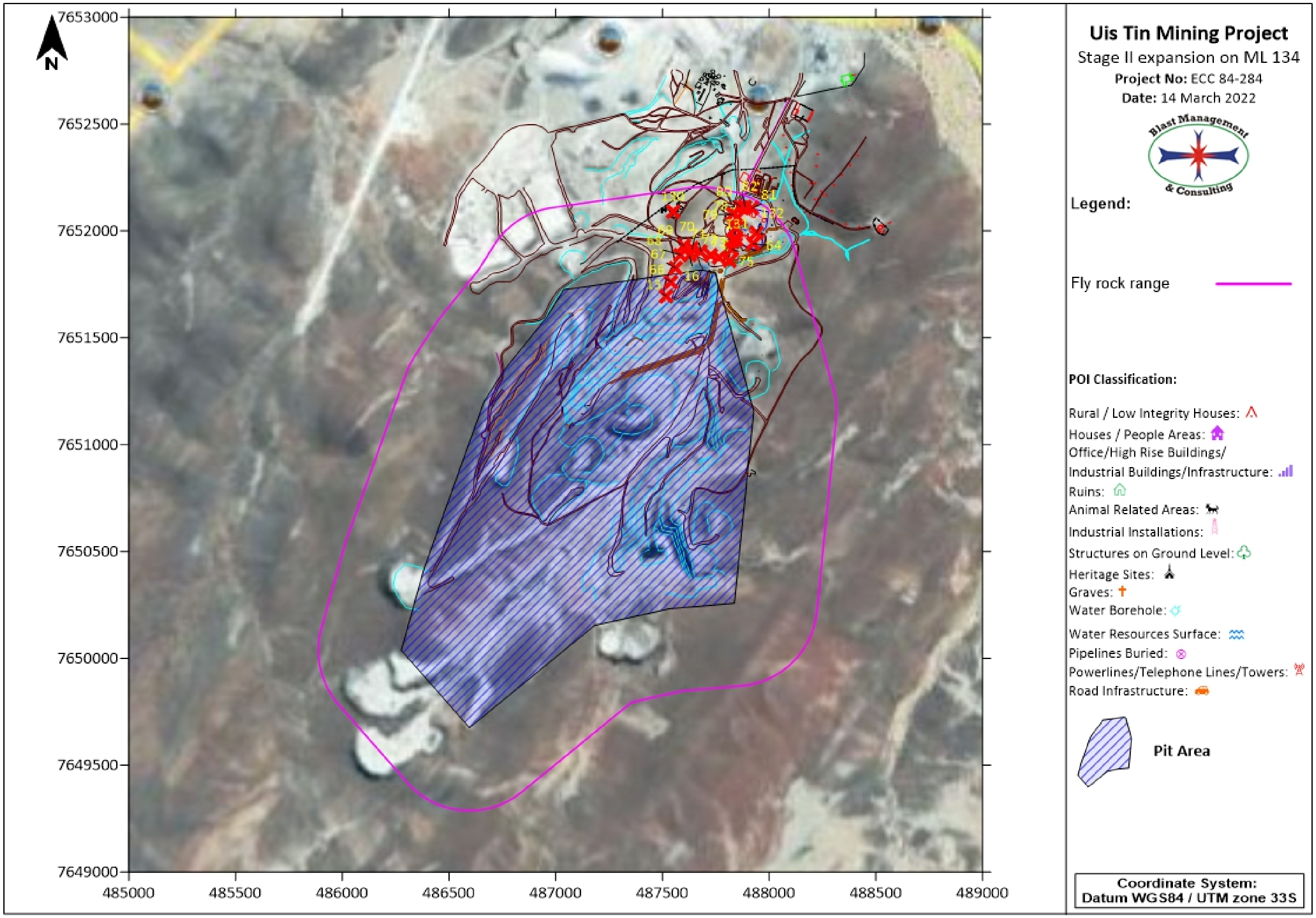


Figure 22: Predicted Fly Rock Exclusion Zone for the Pit area

Review of the calculated unsafe zone showed twenty-three POI's (included are two POI's that falls within the Pit Area) are within the unsafe zone. There are no private houses / structures within the range of the calculated unsafe zone. Table 13 below shows the POI's of concern and coordinates.

Table 13: Fly rock concern POI's

Tag	Description	Y	X
13	Borehole (BH8) - Inside Pit Area	487520.26	7651695.29
16	Borehole (BH11)	487625.96	7651883.51
64	Mine Buildings/Structures	487923.27	7651940.61
66	Power Lines/Pylons - Inside Pit Area	487542.63	7651761.39
67	Power Lines/Pylons	487564.50	7651824.76
68	Power Lines/Pylons	487586.39	7651887.09
69	Power Lines/Pylons	487600.88	7651929.21
70	Power Lines/Pylons	487638.52	7651916.64
71	Power Lines/Pylons	487680.28	7651903.04
72	Power Lines/Pylons	487724.69	7651888.20
73	Power Lines/Pylons	487765.92	7651873.84
74	Power Lines/Pylons	487815.39	7651857.83
75	Power Lines/Pylons	487825.12	7651915.85
76	Power Lines/Pylons	487832.86	7651955.23
77	Power Lines/Pylons	487845.02	7652011.67
78	Power Lines/Pylons	487855.36	7652063.02
79	Power Lines/Pylons	487832.24	7652076.86
80	Power Lines/Pylons	487865.32	7652114.09
81	Power Lines/Pylons	487919.46	7652105.13
82	Stormwater Canal	487887.43	7652112.82
130	Old Abandoned Mine Structures	487551.21	7652087.32
131	Fibre Optical Cable	487850.63	7651959.03
132	Primary Crusher	487940.90	7651990.57

15.10 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 13.6. 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.

15.11 Water borehole influence

Location of boreholes for water was evaluated for possible influence from blasting. Hydrocencus and Monitoring boreholes were identified within the influence area at the Pit area. There are boreholes that are in proximity of the blasting areas and could be problematic. Table 14 shows all the identified boreholes. Figure 23 shows the location of the boreholes in the area. The importance of these problematic boreholes must be defined by the client and if needed alternative boreholes provided.

Table 14: Identified water boreholes

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m) to Pit	Predicted PPV (mm/s)
7	Borehole (BH1)	488994.16	7652581.75	50	1470	0.6
8	Borehole (BH2)	488777.20	7652703.34	50	1367	0.6
9	Borehole (BH3)	485683.96	7647753.71	50	2130	0.3
10	Borehole (BH4)	485593.68	7647786.83	50	2141	0.3
11	Borehole (BH5)	485687.20	7647609.83	50	2260	0.3
12	Borehole (BH6)	486400.64	7647942.47	50	1747	0.4
13	Borehole (BH8) - Inside Pit Area	487520.26	7651695.29	50	-	-
14	Borehole (BH9)	487881.52	7652890.86	50	1092	0.9
15	Borehole (BH10)	488647.24	7653057.42	50	1543	0.5
16	Borehole (BH11)	487625.96	7651883.51	50	74	76.0
17	Borehole (BH12)	487250.30	7653255.61	50	1486	0.5

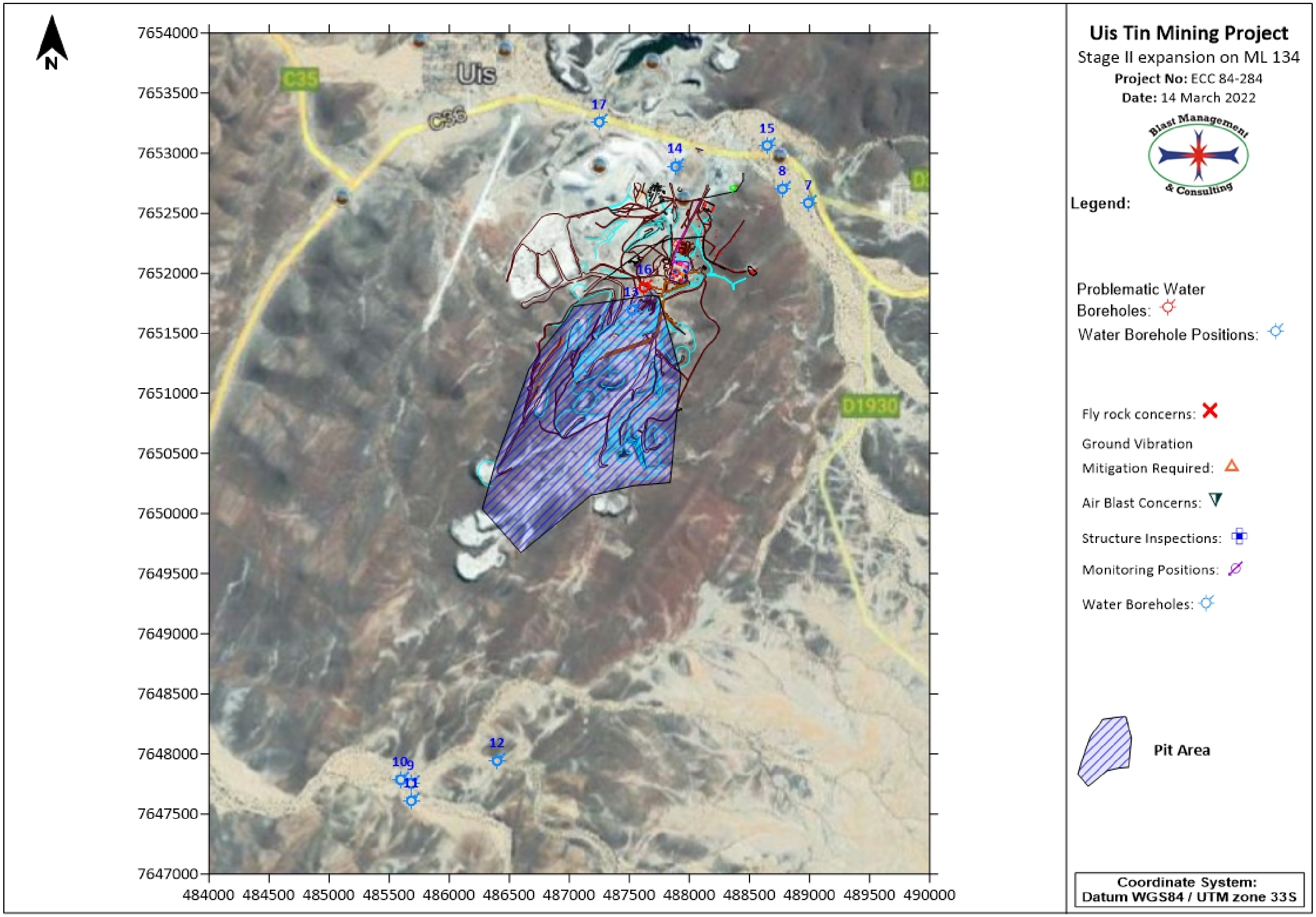


Figure 23: Location of the Boreholes for the Pit area

16 Potential Environmental Impact Assessment: Operational Phase

The following is the impact assessment of the various concerns covered by this report. The impact assessment and evaluation below were used for analysis and evaluation of aspects discussed in this report. The outcome of the analysis is provided in Table 19 with before mitigation and after mitigation. This risk assessment is a one-sided analysis and needs to be discussed with role players in order to obtain a proper outcome and mitigation.

16.1 Assessment Criteria

The criteria for the description and assessment of environmental impacts were drawn from the EIA Guidelines (DEAT, Environmental Impact Assessment Guidelines., 1998) and as amended from time to time (DEAT, Impact Significance, Integrated Environmental Management, Information series 5., 2002).

The level of detail as depicted in the EIA Guidelines (DEAT, Environmental Impact Assessment Guidelines., 1998) (DEAT, Impact Significance, Integrated Environmental Management, Information series 5., 2002)) was fine-tuned by assigning specific values to each impact. In order to establish a coherent framework within which all impacts could be objectively assessed, it was necessary to establish a rating system, which was applied consistently to all the criteria. For such purposes, each aspect was assigned a value, ranging from one (1) to five (5), depending on its definition. This assessment is a relative evaluation within the context of all the activities and the other impacts within the framework of the project. An explanation of the impact assessment criteria is defined below.

Table 15: Impact Assessment Criteria

EXTENT	
Classification of the physical and spatial scale of the impact	
Footprint	The impacted area extends only as far as the activity, such as footprint occurring within the total site area.
Site	The impact could affect the whole, or a significant portion of the site.
Regional	The impact could affect the area including the neighbouring farms, the transport routes and the adjoining towns.
National	The impact could have an effect that expands throughout the country (South Africa).
International	Where the impact has international ramifications that extend beyond the boundaries of South Africa.
DURATION	
The lifetime of the impact that is measured in relation to the lifetime of the proposed development.	
Short term	The impact will either disappear with mitigation or will be mitigated through a natural process in a period shorter than that of the construction phase.
Short to Medium term	The impact will be relevant through to the end of a construction phase (1.5 years).

EXTENT	
Classification of the physical and spatial scale of the impact	
Medium term	The impact will last up to the end of the development phases, where after it will be entirely negated.
Long term	The impact will continue or last for the entire operational lifetime i.e. exceed 30 years of the development, but will be mitigated by direct human action or by natural processes thereafter.
Permanent	This is the only class of impact, which will be non-transitory. Mitigation either by man or natural process will not occur in such a way or in such a time span that the impact can be considered transient.
INTENSITY	
The intensity of the impact is considered by examining whether the impact is destructive or benign, whether it destroys the impacted environment, alters its functioning, or slightly alters the environment itself. The intensity is rated as	
Low	The impact alters the affected environment in such a way that the natural processes or functions are not affected.
Medium	The affected environment is altered, but functions and processes continue, albeit in a modified way.
High	Function or process of the affected environment is disturbed to the extent where it temporarily or permanently ceases.
PROBABILITY	
This describes the likelihood of the impacts actually occurring. The impact may occur for any length of time during the life cycle of the activity, and not at any given time. The classes are rated as follows:	
Improbable	The possibility of the impact occurring is none, due either to the circumstances, design or experience. The chance of this impact occurring is zero (0 %).
Possible	The possibility of the impact occurring is very low, due either to the circumstances, design or experience. The chances of this impact occurring is defined as 25 %.
Likely	There is a possibility that the impact will occur to the extent that provisions must therefore be made. The chances of this impact occurring is defined as 50 %.
Highly Likely	It is most likely that the impacts will occur at some stage of the development. Plans must be drawn up before carrying out the activity. The chances of this impact occurring is defined as 75 %.
Definite	The impact will take place regardless of any prevention plans, and only mitigation actions or contingency plans to contain the effect can be relied on. The chance of this impact occurring is defined as 100 %.

The status of the impacts and degree of confidence with respect to the assessment of the significance must be stated as follows:

- **Status of the impact:** A description as to whether the impact would be positive (a benefit), negative (a cost), or neutral.
- **Degree of confidence in predictions:** The degree of confidence in the predictions, based on the availability of information and specialist knowledge.

Other aspects to take into consideration in the specialist studies are:

- Impacts should be described both before and after the proposed mitigation and management measures have been implemented.

- All impacts should be evaluated for the full lifecycle of the proposed development, including construction, operation and decommissioning.
- The impact evaluation should take into consideration the cumulative effects associated with this and other facilities which are either developed or in the process of being developed in the region.
- The specialist studies must attempt to quantify the magnitude of potential impacts (direct and cumulative effects) and outline the rationale used. Where appropriate, national standards are to be used as a measure of the level of impact.

16.2 Mitigation Assessment

The impacts that are generated by the development can be minimised if measures are implemented in order to reduce the impacts. The mitigation measures ensure that the development considers the environment and the predicted impacts in order to minimise impacts and achieve sustainable development.

16.2.1 Determination of Significance-Without Mitigation

Significance is determined through a synthesis of impact characteristics as described in the above paragraphs. It provides an indication of the importance of the impact in terms of both tangible and intangible characteristics. The significance of the impact "without mitigation" is the prime determinant of the nature and degree of mitigation required. Where the impact is positive, significance is noted as "positive". Significance is rated on the following scale:

Table 16: Significance Without Mitigation

NO SIGNIFICANCE	The impact is not substantial and does not require any mitigation action.
LOW	The impact is of little importance but may require limited mitigation.
MEDIUM	The impact is of importance and is therefore considered to have a negative impact. Mitigation is required to reduce the negative impacts to acceptable levels.
HIGH	The impact is of major importance. Failure to mitigate, with the objective of reducing the impact to acceptable levels, could render the entire development option or entire project proposal unacceptable. Mitigation is therefore essential.

16.2.2 Determination of Significance- With Mitigation

Determination of significance refers to the foreseeable significance of the impact after the successful implementation of the necessary mitigation measures. Significance with mitigation is rated on the following scale:

Table 17: Significance With Mitigation

NO SIGNIFICANCE	The impact will be mitigated to the point where it is regarded as insubstantial.
LOW	The impact will be mitigated to the point where it is of limited importance.

LOW TO MEDIUM	The impact is of importance, however, through the implementation of the correct mitigation measures such potential impacts can be reduced to acceptable levels.
MEDIUM	Notwithstanding the successful implementation of the mitigation measures, to reduce the negative impacts to acceptable levels, the negative impact will remain of significance. However, taken within the overall context of the project, the persistent impact does not constitute a fatal flaw.
MEDIUM TO HIGH	The impact is of major importance but through the implementation of the correct mitigation measures, the negative impacts will be reduced to acceptable levels.
HIGH	The impact is of major importance. Mitigation of the impact is not possible on a cost-effective basis. The impact is regarded as high importance and taken within the overall context of the project, is regarded as a fatal flaw. An impact regarded as high significance, after mitigation could render the entire development option or entire project proposal unacceptable.

16.2.3 Assessment Weighting

Each aspect within an impact description was assigned a series of quantitative criteria. Such criteria are likely to differ during the different stages of the project's life cycle. In order to establish a defined base upon which it becomes feasible to make an informed decision, it was necessary to weigh and rank all the criteria.

16.2.4 Ranking, Weighting and Scaling

For each impact under scrutiny, a scaled weighting factor is attached to each respective impact. The purpose of assigning weights serves to highlight those aspects considered the most critical to the various stakeholders and ensure that each specialist's element of bias is considered. The weighting factor also provides a means whereby the impact assessor can successfully deal with the complexities that exist between the different impacts and associated aspect criteria.

Simply, such a weighting factor is indicative of the importance of the impact in terms of the potential effect that it could have on the surrounding environment. Therefore, the aspects considered to have a relatively high value will score a relatively higher weighting than that which is of lower importance.

Table 18: Description of assessment parameters with its respective weighting

EXTENT		**DURATION**		**INTENSITY**		**PROBABILITY**		**WEIGHTING FACTOR (WF)**		**SIGNIFICANCE RATING (SR)**	
Footprint	1	Short term	1	Low	1	Probable	1	Low	1	Low	0-19
Site	2	Short to Medium	2			Possible	2	Low to Medium	2	Low to Medium	20-39
Regional	3	Medium term	3	Medium	3	Likely	3	Medium	3	Medium	40-59
National	4	Long term	4			Highly Likely	4	Medium to High	4	Medium to High	60-79
International	5	Permanent	5	High	5	Definite	5	High	5	High	80-100

MITIGATION EFFICIENCY (ME)		**SIGNIFICANCE FOLLOWING MITIGATION (SFM)**	
High	0.2	Low	0 - 19
Medium to High	0.4	Low to Medium	20 - 39

Medium	0.6	Medium	40 - 59
Low to Medium	0.8	Medium to High	60 - 79
Low	1.0	High	- 100

Following the assignment of the necessary weights to the respective aspects, criteria are summed and multiplied by their assigned weightings, resulting in a value for each impact (prior to the implementation of mitigation measures).

Equation 1:

Significance Rating (WOM) = (Extent + Intensity + Duration + Probability) x Weighting Factor

16.2.5 Identifying the Potential Impacts With Mitigation Measures (WM)

In order to gain a comprehensive understanding of the overall significance of the impact, after implementation of the mitigation measures, it was necessary to re-evaluate the impact.

16.2.6 Mitigation Efficiency (ME)

The most effective means of deriving a quantitative value of mitigated impacts is to assign each significance rating value (WOM) a mitigation efficiency (ME) rating (**Error! Reference source not found.**). The allocation of such a rating is a measure of the efficiency and effectiveness, as identified through professional experience and empirical evidence of how effectively the proposed mitigation measures will manage the impact.

Thus, the lower the assigned value the greater the effectiveness of the proposed mitigation measures and subsequently, the lower the impacts with mitigation.

Equation 2:

Significance Rating (WM) = Significance Rating (WOM) x Mitigation Efficiency

or WM = WOM x ME

16.2.7 Significance Following Mitigation (SFM)

The significance of the impact after the mitigation measures are taken into consideration. The efficiency of the mitigation measure determines the significance of the impact. The level of impact is therefore seen in its entirety with all considerations considered.

16.3 Assessment

The assessment done was based on evaluating the points of interested that showed expected levels greater than limits. This is however based on the worst-case scenario where blasting is done at the shortest distance from pit area to the point of interest. In after mitigation consideration was given to the fact that blasting will not be constantly at the short distance and the period of time that the influence may be present is significantly reduced due to that only areas or blocks will be blasted at a time.

Table 19: Potential Impacts Without And With Mitigation Measures Mitigation

No.	Receptor / Resource	Process / Activity	Environmental Impact	Extent	Duration	Intensity	Probability	Weighting Factor	Significance		Mitigation and Management Measures	Mitigation Efficiency	Significance Following Mitigation	
									Value	Rating			Value	Rating
1	Graves	Blasting	Ground Vibration	3	4	1	1	1	9	Low	Specific blast design to be done, shorter blast holes, smaller diameter blast hole, using electronic initiation instead of shock tube systems to obtain single hole firing.	0.2	1.8	Low
2	Mine Buildings/Structures	Blasting	Ground Vibration	3	4	1	2	2	20	Low to Medium		0.2	4	Low
3	Old Abandoned Mine Structures	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
4	Borehole	Blasting	Ground Vibration	3	4	5	5	5	85	High		0.2	17	Low
5	Reservoir	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
6	Old Sub Station	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
7	Buildings/Structures	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
8	Sub Station	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
9	Public (Riemvasmaak Community Conservancy)	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
10	Structure	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
11	Ruins	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
12	Filling Station	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
13	Shopping Centre	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
14	School	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
15	Buildings/Structures (Clinic)	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
16	Buildings/Structures (Brandberg Rest Camp)	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
17	Swimming Pool	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
18	Church	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
19	Runway	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
20	Houses	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low

No.	Receptor / Resource	Process / Activity	Environmental Impact	Extent	Duration	Intensity	Probability	Weighting Factor	Significance		Mitigation and Management Measures	Mitigation Efficiency	Significance Following Mitigation	
									Value	Rating			Value	Rating
21	Heli Pad	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
22	Main Roads	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
23	Tailings Dam	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
24	Communication Tower	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
25	Power Lines/Pylons	Blasting	Ground Vibration	3	4	5	5	5	85	High		0.2	17	Low
26	Guesthouse/Lodge	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
27	Graveyard	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
28	Fibre Optical Cable	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
29	Primary Crusher	Blasting	Ground Vibration	3	4	1	1	1	9	Low		0.2	1.8	Low
31	Mine Buildings/Structures	Blasting	Air Blast	3	4	3	3	3	39	Low to Medium	Specific blast design to be done, shorter blast holes, smaller diameter blast hole, use of specific stemming materials to manage air blast, increased stemming lengths to reduce air blast effect. Used of specific stemming to manage fly rock - crushed aggregate of specific size. Re-design with increased	0.6	23.4	Low to Medium
35	Old Sub Station	Blasting	Air Blast	3	4	1	1	1	9	Low		0.6	5.4	Low
36	Buildings/Structures	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium		0.6	21.6	Low to Medium
37	Sub Station	Blasting	Air Blast	3	4	1	1	1	9	Low		0.6	5.4	Low
38	Public (Riemvasmaak Community Conservancy)	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium		0.6	21.6	Low to Medium
39	Structure	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium		0.6	21.6	Low to Medium
40	Ruins	Blasting	Air Blast	3	4	1	1	1	9	Low		0.6	5.4	Low
41	Filling Station	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium		0.6	21.6	Low to Medium
42	Shopping Centre	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium		0.6	21.6	Low to Medium
43	School	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium		0.6	21.6	Low to Medium
44	Buildings/Structures (Clinic)	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium		0.6	21.6	Low to Medium
45	Buildings/Structures (Brandberg Rest Camp)	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium		0.6	21.6	Low to Medium

No.	Receptor / Resource	Process / Activity	Environmental Impact	Extent	Duration	Intensity	Probability	Weighting Factor	Significance		Mitigation and Management Measures	Mitigation Efficiency	Significance Following Mitigation	
									Value	Rating			Value	Rating
47	Church	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium	stemming lengths.	0.6	21.6	Low to Medium
49	Houses	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium		0.6	21.6	Low to Medium
53	Communication Tower	Blasting	Air Blast	3	4	3	1	2	22	Low to Medium		0.6	13.2	Low
55	Guesthouse/Lodge	Blasting	Air Blast	3	4	3	2	3	36	Low to Medium		0.6	21.6	Low to Medium
59	Graves	Blasting	Fly Rock	3	4	1	1	1	9	Low	Specific blast design to be done, shorter blast holes, smaller diameter blast hole, use of specific stemming materials to manage air blast, increased stemming lengths to reduce air blast effect. Used of specific stemming to manage fly rock - crushed aggregate of specific size. Re-design with increased stemming lengths.	0.6	5.4	Low
60	Mine Buildings/Structures	Blasting	Fly Rock	3	4	3	4	4	56	Medium		0.6	33.6	Low to Medium
61	Old Abandoned Mine Structures	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
62	Borehole	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
63	Reservoir	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
64	Old Sub Station	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
65	Buildings/Structures	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
66	Sub Station	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
67	Public (Riemvasmaak Community Conservancy)	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
68	Structure	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
69	Ruins	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
70	Filling Station	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
71	Shopping Centre	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
72	School	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
73	Buildings/Structures (Clinic)	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
74	Buildings/Structures (Brandberg Rest Camp)	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
75	Swimming Pool	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
76	Church	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
77	Runway	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
78	Houses	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
79	Heli Pad	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low

No.	Receptor / Resource	Process / Activity	Environmental Impact	Extent	Duration	Intensity	Probability	Weighting Factor	Significance		Mitigation and Management Measures	Mitigation Efficiency	Significance Following Mitigation	
									Value	Rating			Value	Rating
80	Main Roads	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
81	Tailings Dam	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
82	Communication Tower	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
83	Power Lines/Pylons	Blasting	Fly Rock	3	4	5	5	5	85	High		0.6	51	Medium
84	Guesthouse/Lodge	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
85	Graveyard	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
86	Fibre Optical Cable	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low
87	Primary Crusher	Blasting	Fly Rock	3	4	1	1	1	9	Low		0.6	5.4	Low

16.4 Mitigations

In review of the evaluations made in this report it is certain that specific mitigation will be required with regards to ground vibration. Ground vibration is the primary possible cause of structural damage and requires more detailed planning in preventing damage and maintaining levels within accepted norms. Air blast and fly rock can be controlled using proper charging methodology irrespective of the blast hole diameter and patterns used. Ground vibration requires more detailed planning and forms the focus for mitigation measures.

Specific impacts are expected at the following POI's identified. Table 20 shows list of POI's that will need to be considered and Table 21 the POI's that needs specific attention due to location within the pit area. Figure 24 shows the location of these POI's in relation to the pit area.

Table 20: Structures identified as problematic in and around the project area

Tag	Description	Classification	Y	X
16	Borehole (BH11)	10	487625.96	7651883.51
67	Power Lines/Pylons	13	487564.50	7651824.76
73	Power Lines/Pylons	13	487765.92	7651873.84

Table 21: Structures identified inside the planned pit area

Tag	Description	Classification	Y	X
13	Borehole (BH8) - Inside Pit Area	10	487520.26	7651695.29
66	Power Lines/Pylons - Inside Pit Area	13	487542.63	7651761.39

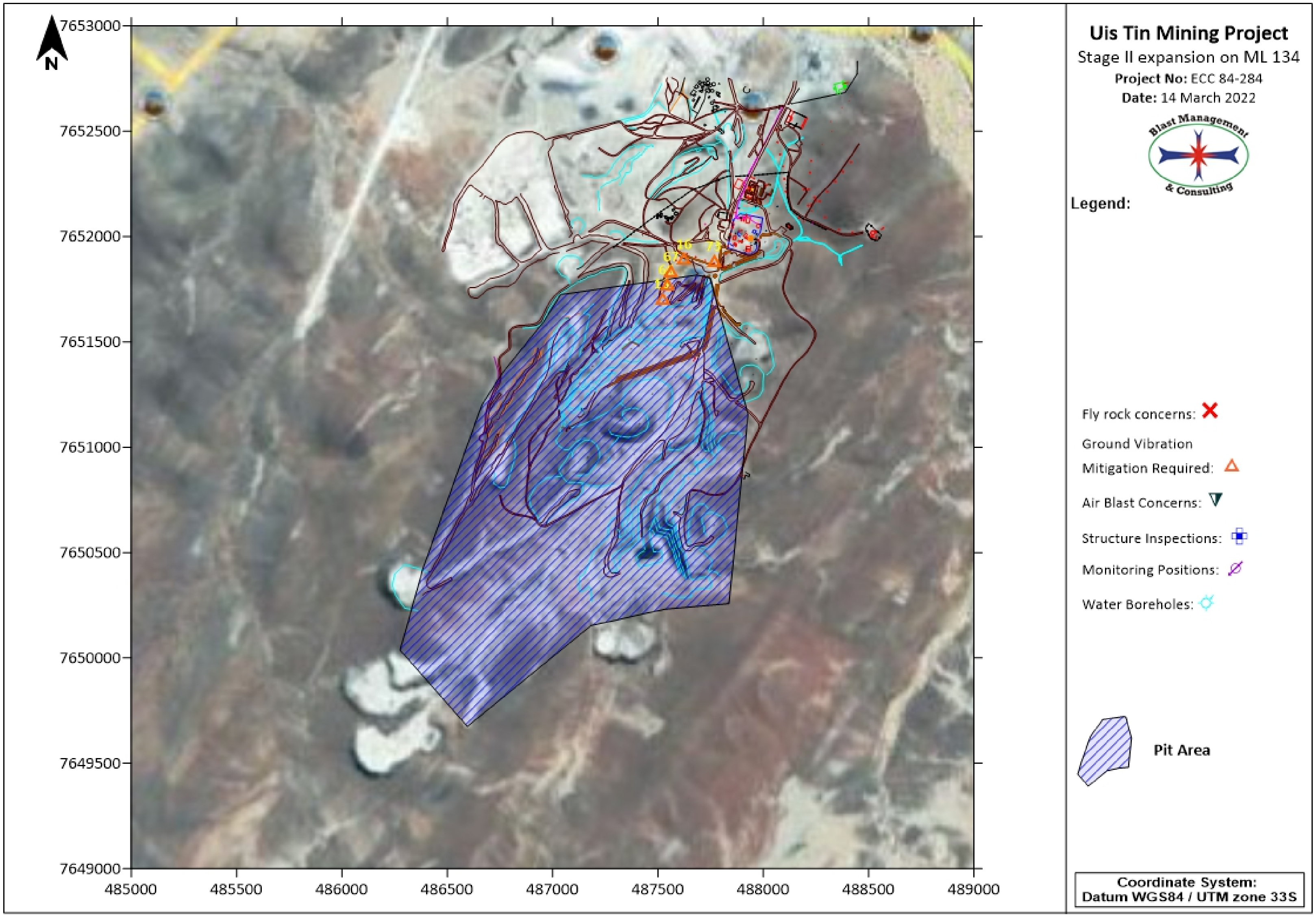


Figure 24: Structures identified where ground vibration mitigation will be required.

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.
- Only apply electronic initiation systems to facilitate single hole firing.
- Do design for smaller diameter blast holes that will use fewer explosives per blast hole.
- Relocate the POI / acquire the POI of concern – mined owned.

The identified POI's of concern is found in close proximity of the actual operations. In order to give indication of the possibilities of mitigation to consider two basic indicators are presented. Firstly, the maximum charge per delay that can be allowed for the shortest distance between blast and POI. Secondly the minimum distance between blast and POI to maintain ground vibration limits for minimum and maximum charge per delay. These table gives indication for planning of blasts when blasts at shortest distance to the POI's.

Table 22 do show mitigation in the form of maximum charge mass that will be allowed to maintain safe levels of ground vibration. Table 23 shows minimum distance between blast and POI to maintain ground vibration limits for minimum and maximum charge per delay.

Table 22: Mitigation measures: Maximum charge per delay for distance to POI

Tag	Description	Y	X	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)	Predicted PPV (mm/s)	Structure Response @ 10Hz
16	Borehole (BH11)	487625.96	7651883.51	50	74	125	50	Acceptable
67	Power Lines/Pylons	487564.50	7651824.76	75	25	22	75	Acceptable
73	Power Lines/Pylons	487765.92	7651873.84	75	72	190	75	Acceptable

Table 23: Mitigation measures: Minimum distances required

Tag	Example POI	Specific Limit (mm/s)	Distance (m)	Total Mass/Delay (kg)
16	Borehole (BH11)	50	96	207
67	Power Lines/Pylons	75	75	207

Based on evaluation done for the planned charge masses mitigation will be required for the Borehole and Power Lines. These POI's vary in distance and it will be required that each be evaluated in relation to a blast to be done. The distance should be checked, the charge mass allowed be calculated and then a design of charging or timing applied to ensure that the limits are not exceed. In most cases basic planned design does not need to change but timing can be adjusted as well electronic timing can used to reduce the charge mass per delay. This must be confirmed with monitoring of ground vibration at the POI.

17 Monitoring

A monitoring programme for recording blasting operations is recommended. The following elements should be part of such a monitoring program:

- Ground vibration and air blast results;
- Blast Information summary;
- Meteorological information at time of the blast;
- Video Recording of the blast;
- Fly rock observations.

Most of the above aspects do not require specific locations of monitoring. Ground vibration and air blast monitoring requires identified locations for monitoring. Monitoring of ground vibration and air blast is done to ensure that the generated levels of ground vibration and air blast comply with recommendations. Proposed positions were selected to indicate the nearest points of interest at which levels of ground vibration and air blast should be within the accepted norms and standards as proposed in this report. The monitoring of ground vibration will also qualify the expected ground vibration and air blast levels and assist in mitigating these aspects properly. This will also contribute to proper relationships with the neighbours.

Three monitoring points were identified as possible locations that will need to be considered. Monitoring positions are indicated in Figure 25 and Table 24 lists the positions with coordinates. These points will need to be re-defined after the first blasts done and the monitoring programme defined.

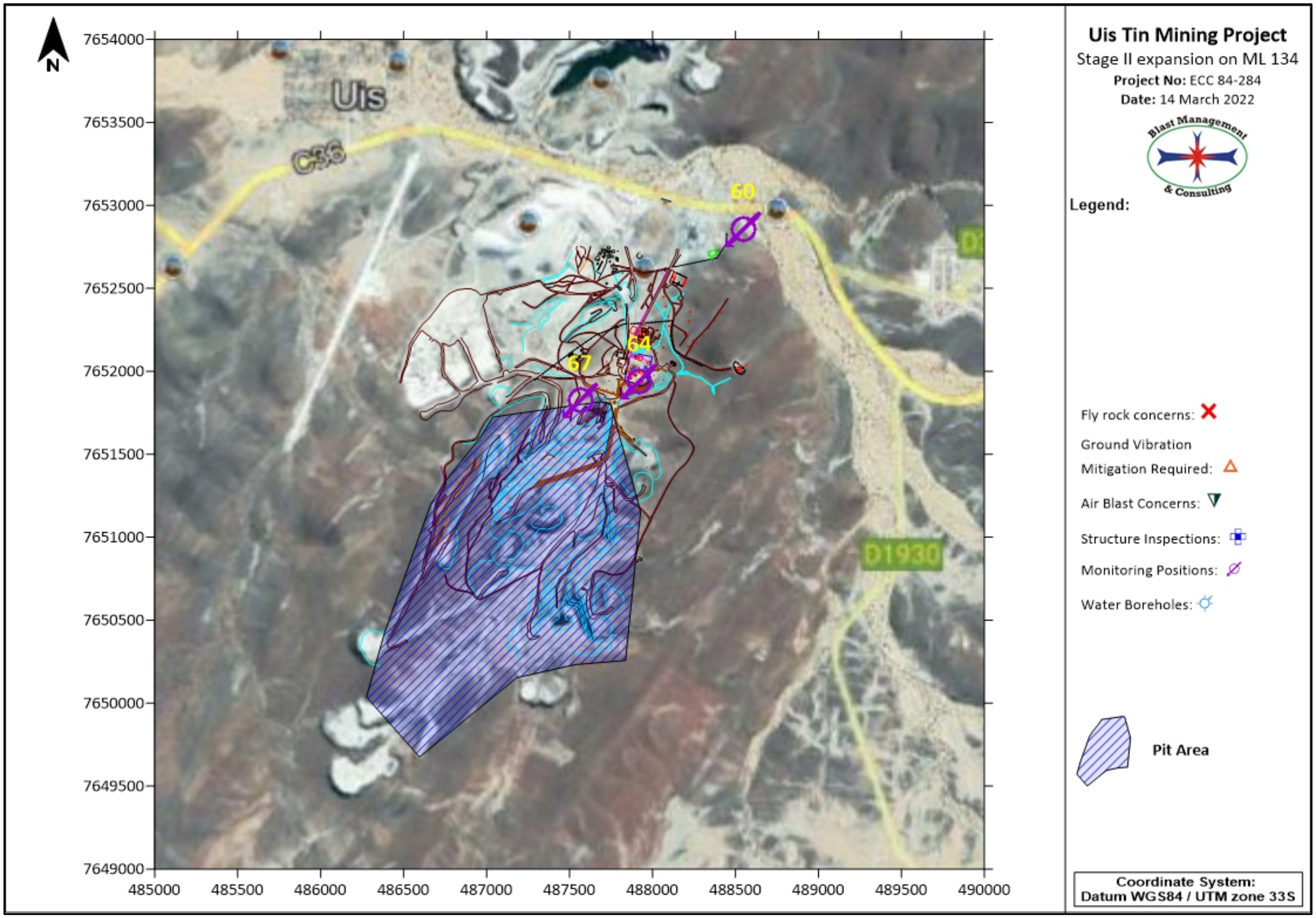


Figure 25: Suggested monitoring positions

Table 24: List of possible monitoring positions

Tag	Description	Y	X
67	Power Lines/Pylons	487564.50	7651824.76
64	Mine Buildings/Structures	487923.27	7651940.61
60	Buildings/Structures	488547.88	7652858.87

18 Recommendations

The following recommendations are proposed.

18.1 500 m general unsafe blasting area

Considering a general accepted rule of 500 m for the unsafe area POI's were identified. Various POI's are observed within the pit that needs consideration as well within 500 m from the mining area. Table 25 shows list of these installations. Figure 26 below shows the 500 m boundary around the opencast pit area. The location of non-mining installations is clearly observed.

Table 25: List of possible installations within the regulatory 500 m

Tag	Description	Y	X
13	Borehole (BH8) - Inside Pit Area	487520.26	7651695.29
16	Borehole (BH11)	487625.96	7651883.51
62	Mine Buildings/Structures	487940.07	7652222.50
63	Mine Buildings/Structures	487882.90	7652244.55
64	Mine Buildings/Structures	487923.27	7651940.61
66	Power Lines/Pylons - Inside Pit Area	487542.63	7651761.39
67	Power Lines/Pylons	487564.50	7651824.76
68	Power Lines/Pylons	487586.39	7651887.09
69	Power Lines/Pylons	487600.88	7651929.21
70	Power Lines/Pylons	487638.52	7651916.64
71	Power Lines/Pylons	487680.28	7651903.04
72	Power Lines/Pylons	487724.69	7651888.20
73	Power Lines/Pylons	487765.92	7651873.84
74	Power Lines/Pylons	487815.39	7651857.83
75	Power Lines/Pylons	487825.12	7651915.85
76	Power Lines/Pylons	487832.86	7651955.23
77	Power Lines/Pylons	487845.02	7652011.67
78	Power Lines/Pylons	487855.36	7652063.02
79	Power Lines/Pylons	487832.24	7652076.86
80	Power Lines/Pylons	487865.32	7652114.09
81	Power Lines/Pylons	487919.46	7652105.13
82	Stormwater Canal	487887.43	7652112.82
83	Stormwater Canal	487983.94	7652141.49
84	Stormwater Canal	488033.59	7652154.15
89	Stormwater Canal	488121.19	7652120.07
90	Stormwater Canal	488140.85	7651979.31
128	Old Sub Station	488125.04	7652048.29
130	Old Abandoned Mine Structures	487551.21	7652087.32
131	Fibre Optical Cable	487850.63	7651959.03
132	Primary Crusher	487940.90	7651990.57

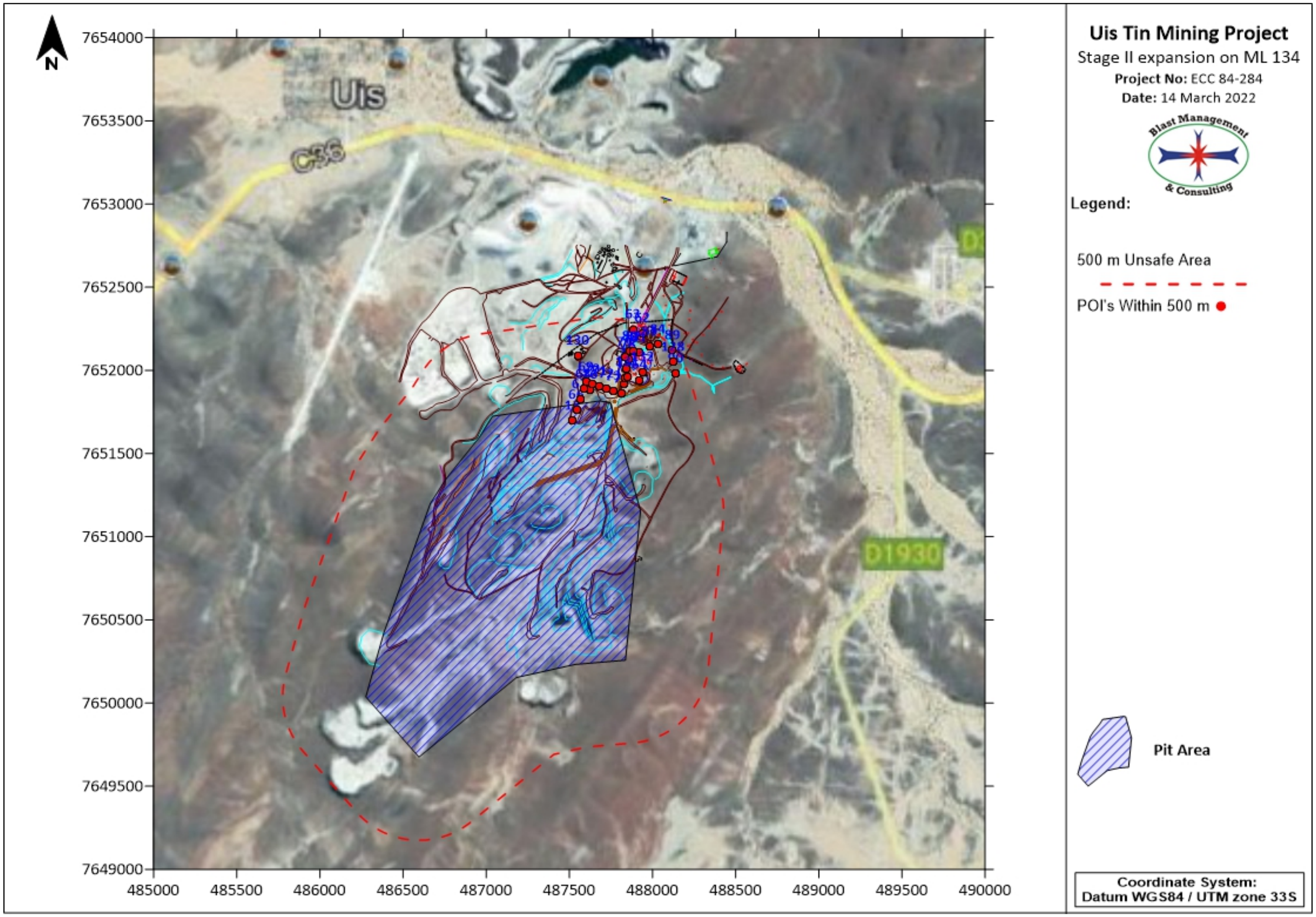


Figure 26: Regulatory 500 m range for the opencast area

18.2 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 blast hole firing instead of multiple blast holes. Single blast hole firing will provide single hole firing – thus less charge mass per delay and less influence.

18.3 Stemming length

The current proposed stemming lengths used provides for some control on fly rock. Consideration can be given to increase this length for better control. Specific designs where distances between blast and point of concern are known should be considered. Recommended stemming length should range between 20 and 30 times the blast hole diameter. In cases for better fly control this should range between 30 and 34 times the blast holes diameter. Increased stemming lengths will also contribute to more acceptable air blast levels.

18.4 Safe blasting distance and evacuation

Calculated minimum safe distance is 388 m. 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.

Further it must be confirmed with the respective authorities for the road and the powerlines what the minimum distance between pit and these infrastructure must be. The current distances are very small, and it is certain that the minimum requirements from the authorities will indicate distances further than current.

18.5 Road management

The C35, C36, D1930, D3714 and M76 roads, is at an approximate distance of 2265 m (C35), 1284 m (C36), 1269 m (D1930), 1565 m (D3714) and 2483 m (M76). No specific consideration regarding effects from blasting operations will be required for these roads.

18.6 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 26.

Table 26: 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 (preferred)	12.5	
Rural building – Mud houses	6	

18.7 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 atmospheric inversion or too late in the afternoon in winter. Do not blast in fog. Do not blast 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 is fixed and blasting notice boards setup at various routes around the project area that will inform the community of blasting dates and times.

18.8 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.

18.9 Video monitoring of each blast

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

19 Knowledge Gaps

The data provided from client and information gathered was sufficient to conduct this study. Surface surroundings change continuously, and this should be considered 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.

20 Project Result

Specific problems were identified, and recommendations made. The successful resolving of these concerns will allow that the project can be executed successfully with proper management and control on the aspects of ground vibration, air blast and fly rock.

21 Conclusion

Ground vibration, air blast, fly rock and fumes are some of the aspects as a result from blasting operations. The report evaluates the effects of ground vibration, air blast and fly rock and intends to provide information, calculations, predictions, possible influences and mitigations of blasting operations for this project.

The evaluation of effects yielded by blasting operations was evaluated over an area as wide as 3500 m from the mining area considered. The range of structures observed is typical roads (tar and gravel), low cost houses, corrugated iron structures, brick and mortar houses, communication towers.

The location of structures around the Pit area is such that the charge evaluated showed possible influences due to ground vibration. The closest structures observed are the Power Lines, Boreholes and Mine Buildings/Structures. Ground vibrations predicted for the pit area ranged between low and very high. The expected levels of ground vibration for some of these structures are high and will require specific mitigations in the way of adjusting charge mass per delay to reduce the levels of ground vibration. Ground vibration at structures and installations other than the identified problematic structures is well below any specific concern for inducing damage.

Air blast predicted also showed more concerns for opencast blasting. The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134dB. It is maintained that if stemming control is not exercised this effect could be greater with greater range of complaints or damage. The pits are located such that “free blasting” – meaning no controls on blast preparation – will not be possible. The nearest private structures are located 1324 m from pit edge. Air blast levels from maximum charge is expected to be within the accepted limit but slightly greater than 120 dB. This may contribute to some complaints. All other private structures are further away and levels decrease over distance. Levels are expected to be less than 120 dB at distance of 2387 m from the pit edge.

The current accepted limit on air blast is 134 dBL. Damages are only expected to occur at levels greater than 134 dBL. Prediction shows that air blast will be greater than 134 dB at distance of 223 m and closer to pit boundary. Infrastructure at the pit areas such as roads, power lines/pylons are present, but air blast does not have any influence on these installations.

Fly rock remains a concern for blasting operations. Based on the drilling and blasting parameters values for a possible fly rock range with a safety factor of 2 was calculated to be 388 m. The absolute minimum unsafe zone is then the 388 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.

Specific actions will be required for the pit area such as Mine Health and Safety Act requirements when blasting is done within 500 m from structures and mining with 100 m for structures. The Power Lines, Stormwater Canal and Mine Buildings/Structures falls within the 500 m range from the pit area.

The pit areas are located such that specific concerns were identified and addressed in the report.

This concludes this investigation for the proposed Uis Tin Mining Project. There is no reason to believe that this operation cannot continue if attention is given to the recommendations made.

22 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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